TEXTILE KNITTING

Textile Technology knowledge series Volume III

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Chapter 1 Introduction to Knitting

1.1 Introduction:

The human beings, were looking for a better kind of material to wrap around themselves than barks or leaves of trees and hides of animals to protect their bodies from the variable weather as well as to protect their modesty, which resulted in both the invention and development of the technology of manufacturing textile fabric/clothing. The available documentary evidences of human civilization from the different parts of the world confirmed that invention of the textile fabric manufacturing technology (clothing) must have happened about 7000 years ago. Textile fabric can be defined as a two dimensional (2D) plane-like structure (may be woven, knitted, nonwoven, braided, etc.) made of textile materials (fibre or yarn or their combination) having reasonable strength, elongation, flexibility, etc., used for different applications, particularly for apparels. Recently, fabrics are also made in three dimensions (3D) and widely used in technical applications including medical textiles in the form of artificial cardiovascular tube as well as different joints and tissues of the human body. Weaving, is the first technology developed for producing fabric by interlacing two sets of threads (warp and weft) and is the oldest technique of fabric formation, and its contribution forms the major share in total fabric production which is about 70%. Knitting is the second old technology of fabric formation which is very much popular to people. It is the technique of fabric formation from single set of yarn (may be one or any higher number) by inter-looping, and it has a share of 20% in the total fabric production.

The other methods of fabric formation are nonwoven, netting, crocheting, braiding, etc., are also used in the textile industry throughout the world for producing variety of fabrics. When the fabric is cut and sewn to give the shape according to the contour of the human body, it is called clothing or garment.

It is interesting that the latest development in knitting technology has the technique to produce clothing without cutting and sewing.

Knitting is the second most widely used technique of fabric or garment formation by inter-looping one or one set of yarns. Continuous length of yarn is converted into vertically/horizontally intermeshed loops either by using hand or by machine. The term “Knitting” has been evolved from the Saxon word ‘Cnyttan’ which in turn was derived from the ancient Sanskrit word ‘Nahyat’. According to the direction of movement of yarn during loop formation, knitting can be classified as weft knitting or warp knitting.

Out of two major types of knitting, weft knitting is widely used in India and abroad. The technique of knitting by using two sticks was invented about 3000 years ago and the same was mainly practiced by the women of royal families for making gloves, stockings and caps. Knitting became a profession only when male got involved around 1500 AD, and gradually the teaching on knitting started. The knitting process was first mechanized (hand driven flatbed machine) by Rev. William Lee in 1589. Circular knitting machine came in the market around 1850 and knitting industry started in India at Kolkata in 1892.

The concept of knitting for converting yarn in to fabric/garment was visualized long back (may be about 3000 years ago) and the same was implemented by some curious and innovative human minds using two sticks or needles. Such technique is of course known as hand knitting, but there is no record of the name of the inventor of hand knitting. Hand knitting is a very slow process and is still in practice. Rev. William Lee started to develop a frame around 1561 for continuing knitting process at a faster rate using a large number of needles. At the end of 3 years' persistent and consistent efforts, the frame could make a course or knit upon the frame and that too at a speed of 600 loops per minute using worsted yarns. The frame was further perfected and speed of loop formation was increased before its commercial appearance in 1589. Since then, modifications on the knitting frame have been continued for making better to better machine for producing quality knitted fabrics at much higher speeds. As collected from the different sources, the history of chronological developments in knitting technology may be summed as detailed in the Table 1.1.

Table 1.1 History of Development of Knitting Technology

Period/Year	**Nature of development**
1000 BC	Technique of knitting invented by using fingers only (hand knitting) 11th Century Knitted gloves in rituals of church service
12th Century	Knitted caps, gloves and socks from wool and silk
15th Century	Male got involved in knitting and knitting became a profession
1580 AD	Teaching of knitting started
1589 AD	Knitting frame with bearded needle was invented by Rev. William Lee; Lee's frame remained unaltered for about 150 years
1750 AD	Knitting industry established in UK
1758 AD	Introduction of double knit in derby rib frame by J. Strutt 1769 AD Rotary drive in knitting machine

1847 AD Invention of latch needle by Matthew Townsend

1850 AD Power-driven circular knitting frame with vertical bed 1863 AD V-bed flat knitting machine

1892 AD Hosiery industry in India at Kolkata 1900 AD Automatic foot-wear (socks) machine

1915 AD Tricot warp knitting machine built in Germany 1947 AD Commercial tricot warp knitting machine 1953 AD Raschel warp knitting machine

1963 AD Electronic needle selection

1970 AD Double needle bar warp knitting machine for producing seamless panties, brassieres and pocketings.

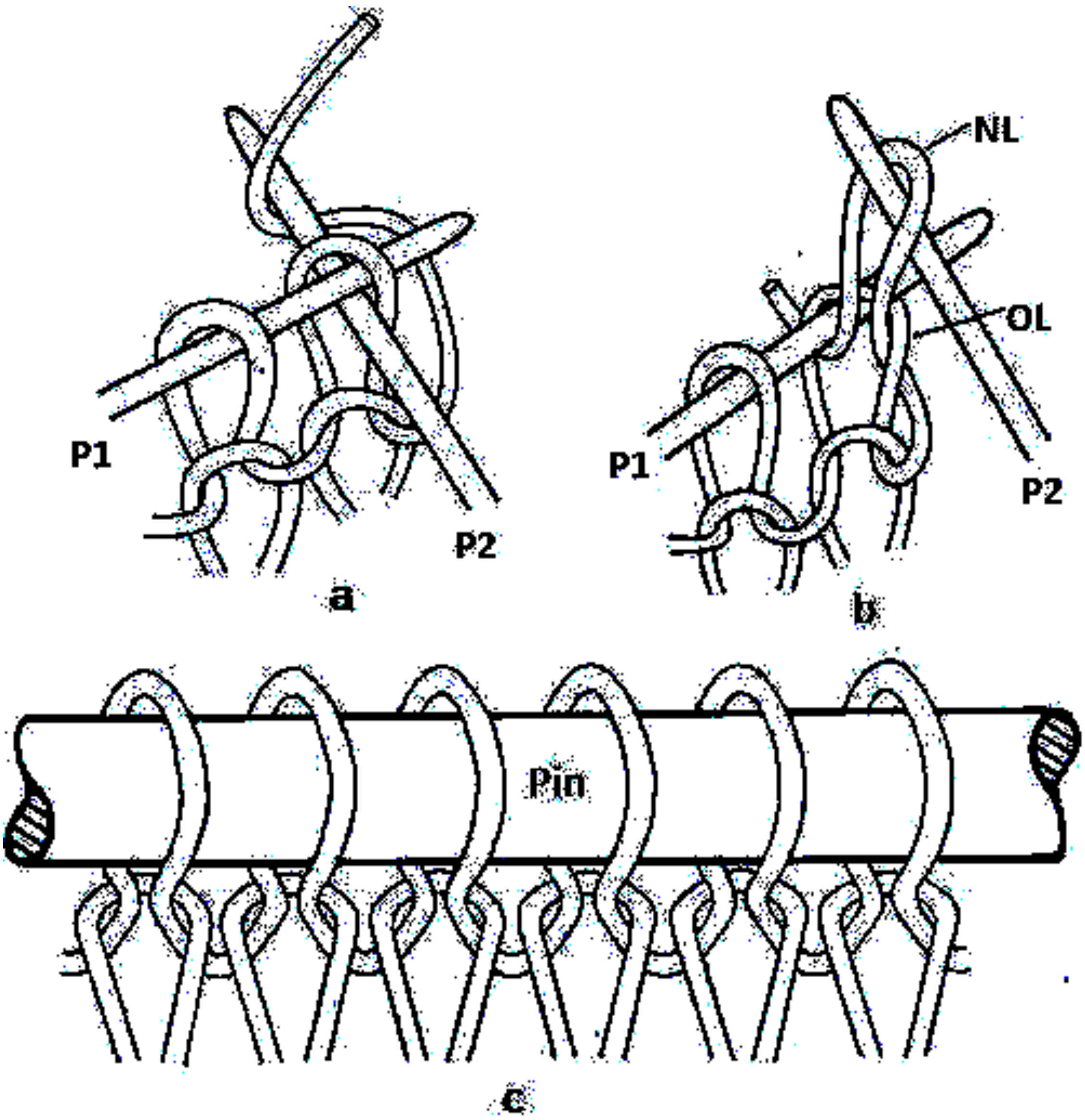
1987 AD Relanit Technology

1999 AD Double needle bar warp knitting machine with electronic (Piezo) jacquard

2003 AD MBI technology of intarsia knitting with maximum 42 colour change in single course

1.2 Principle of Hand Knitting

Since the inception of knitting, hand knitting technology is in existence till date and will continue its journey for years together. Basically two pins (needles) are used for making loops as well as inter-looping. As shown in Fig. 1.1(a), the pin 'P1' gripped by left hand of the knitter is retaining the previously formed loop and the pin 'P2' gripped by the right hand of the knitter is about to form the next loop. Figure 1.1(b) shows that the newly formed loop (NL) has been drawn through previously formed loop (OL). The resultant fabric, a matrix of rows and columns of loops, is formed by creating a single element in each knitting cycle. Hence, if a fabric needs to have 100 loops in each row, then 100 cycles of knitting operation would be needed to produce one course. All these 100 loops are to be held by one pin/needle as shown in Fig. 1.1(c) and subsequently the loops are to be transferred to the other pin/needle for making the next row. Although the principle is very simple, skill is required to prevent slipping off of the loops at the tip of the straight and pointed pins. Moreover, the nature of structure of the knitted fabric completely depends on the skill and artistic mind of the knitter.



1.1 Principle of hand knitting

1.3 Types of Knitting

For knitting a fabric, only one or one set of yarns is to be supplied to the knitting machine. Depending upon the direction of movement of yarn during loop formation with relation to the direction of fabric formation, knitting technique is classified as warp knitting or weft knitting. The position of yarn(s) with respect to the length of the resultant fabric is shown in Fig. 1.2.

Weft knitting machines produce four basic knitted structures such as plain, rib, interlock and purl. Plain structure is produced in single jersey machine whereas the other three are produced in double jersey machines.

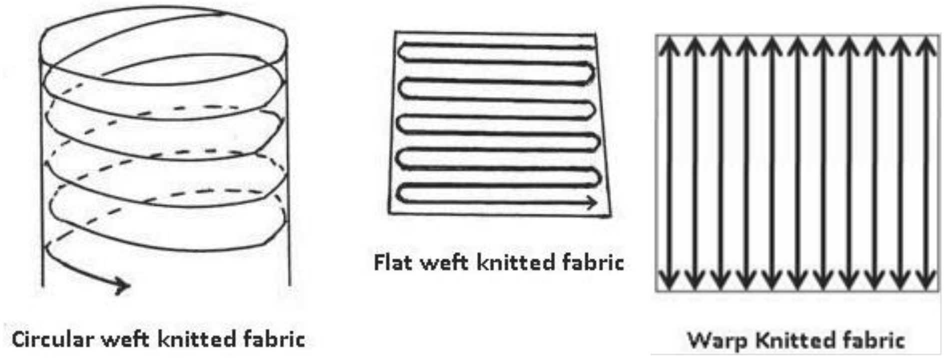


Figure 1.2 Direction of yarn flow in knit fabric production

These basic structures are composed of face loops and back loops. In addition, different derivatives of those basic structures are also produced by introducing tucking and floating. Such tucking and floating are possible due to individual needle selection. Pattern wheel, multiple cam track, jacquard, etc., are generally used for needle selection.

The main element required for loop formation is needle. Latch needles are used in weft knitting and bearded needles are mainly used in warp knitting. The other important element required in loop formation is sinker. The needles are given upward and downward movement along its axis for loop formation by means of a cam system. For proper axial movement of the needles without lateral displacement, needles are arranged in the grooves/cuts of a platform or bed. The grooves are called tricks and are placed at regular interval. The number of such tricks per inch is called gauge of a machine. The number of needle bed in a machine may be one or two, and accordingly they are called single jersey machine and double jersey machine. Similarly, shape of the needle bed may be also of two types – flat and circular; and according to shape of the needle bed machines are classified as flatbed machine and circular bed machine.

The most important parameter of a knitted fabric is its loop length which can be varied during knitting by changing machine parameters, process parameters and yarn parameters. The other important quality parameters of a knitted fabric are courses per inch, wales per inch, stitch density, GSM and tightness factor.

In general, the rate of production in knitting is much higher with less preparatory processes than weaving. Circular weft knitting machines offer the greatest potential for high speed production, because knitting can take place continuously in the same direction of yarn feed, and the rotary motion minimizes problems of vibration and wear and tear at high speed. In most latch-needled circular machines, knitting of yarn at a single feeder occupies a relatively small part of the circumference of the needle circle and the simplest way of increasing production is therefore to incorporate additional feeder around the circumference, so that for each revolution of the machine more than one course is knitted at a time. The number of feeder that can be accommodated depends on the gauge and diameter of the machine and the number of needle spaces taken by the cam system at each feeder. With the present machines, each feeder may occupy one inch of circumference, the limit being imposed by the cam angles. The flat bed weft knitting machines are very simple in construction and are less productive. The design capacity of these machines has also passed through revolutionary changes. With the help of CAD and CAM, seamless garments can be manufactured in flatbed weft knitting machines. The warp knitting machines are more versatile and are much more complicated and expensive.

1.4 Advantages of Knitting

The technique of inter-looping for making knitted fabrics has the following advantages:

1. Fabric can be produced from minimum set of yarns, even only one yarn.
2. Loop size can be varied to a great extent and very easily.
3. During knitting, loops can be transferred from one needle to other.
4. The extensibility and stability of the knitted fabric can be controlled and engineered.
5. The desired porosity or compactness of the fabric can be achieved.
6. Shaping can be done at the time of knitting itself on the resultant fabric.
7. Any type of yarns can be introduced in the fabric as in-lay.
8. Loop structures are easily distorted under tension in application, this property gives more freedom of movement and comfort of the wearer.
9. Fabric with single face, double face, open-work and surface interest can be knitted according to requirement.
10. The number of yarns to be knitted in the same fabric can be varied by selection for the designing purposes.
11. The total number of needles for loop formation can be controlled and varied from knitting cycle to cycle.
12. Yarns can easily flow from one loop to another under tension.
13. Wastage of yarns during conversion of yarn in to fabric by knitting is negligible.
14. Knitting can produce fabrics that are very much suitable for a wide range of applications from intimate wears to technical textiles.

1.5 Factors Responsible for the Growth of Knitting

1. Capital investment required for starting a new knitting unit is less than that is required for other fabric-producing methods.
2. No yarn preparation is required in weft knitting and only warping is needed for warp knitting.
3. Machine productivity is high and the time required to get an order executed is less than weaving.
4. Knitting is more flexible than weaving, i.e. styles and designs can be changed rapidly.
5. Textured and many other fancy yarns can easily be knitted and converted to light weight fashion garments.
6. Knitted fabrics are wrinkle-free and can be made into ease-of-care garments with better form fitting and comfort.
7. Labour component requirement is less in knitting; hence problems related to labour are less.
8. Modern knitting machines, particularly warp knitting machines can produce various types of technical textiles (medical textiles, automobile textiles, geo-textiles, etc.).
9. Seamless garments can directly be produced in knitting.
10. Knitted garments have very good demand in export market.
11. Computer-aided designing and manufacturing in knitting have made it possible to manufacture any desired design and structure within a short time at reasonable price.

Knitting industry is an important sector of the textile industry of India. Hosiery goods are mostly manufactured in small sector. However, there is a number of fairly big size organized units for manufacturing both woollen and cotton hosiery. The hosiery units are situated throughout the country but mostly concentrated as clusters at Kolkata, Ludhiana, Tirupur, Mumbai and Delhi. Each of these centres specializes in a particular type of hosiery. The knitting industry not only meets the domestic demand of the country but also earns valuable foreign exchange.

Knitting industry in India was established well after the industrial revolution in Europe. It was first set-up only in 1892 at Kolkata. Knitting industry has passed through many challenges and now has reached a stage for competing with other developed countries. Till 1980s knitting industry was predominantly organized as either cottage industry or small scale industry, units being run mostly as family enterprises. Knitting industry in Kolkata started as hosiery industry with imported machines for producing underwear and socks and the hand knitting industry started in Ludhiana for manufacturing woollen sweaters. Then, the industry gradually spread throughout the country with the inclusion of many other items (garments) in knitting. Though knitting units are located throughout the country, a few places have emerged as prime knitting centres. These are Tirupur in south, Ludhiana, Delhi and Kanpur in the north, Kolkata in the east and Mumbai and Ahmedabad in the west. Tirupur and Kolkata have specialized in cotton underwear knitwear using circular single jersey and double jersey machines, whereas Ludhiana and Kanpur are exclusive centres for woollen and acrylic outerwear knitwear items using single and double flatbed machines. The machineries used in both the sectors are mostly old type. Moreover the small units of this sector lack in adequate facilities for dyeing, processing and finishing. Recently, the knitting of Tirupur (Tamil Nadu) had tremendous growth. Tirupur produces 60% of India's total knitwear exports. Knitted garments account for almost 32% of all exported garments from India.

Post liberalization, privatization and globalization after 1990, Government policies have been favouring the growth of knitting for capturing export market and at the same time, large industrial houses have come forward to invest and explore the potential of knitting industry for their own growth. On account of the above-mentioned facts, the reputed small knitting houses have also started investing money for modernization. As a result, circular machines of larger diameter, with higher number of feeders, multiple cam track arrangement, etc., have been installed in circular weft knitting industry, and flatbed machines with power drive and computer-aided designing facility have become very much popular in sweater and outerwear knitwear industry. As quality garments need good wet processing, sophisticated wet processing and finishing, industry for knitted fabrics and garments have already been established. Already a good number of warp knitting units have been set up for producing mainly apparel and furnishing fabrics. A few new units are going to be established for producing technical textiles using very sophisticated warp knitting machines with weft insertion system.

Knitted garments are very popular in the modern fashion scene. Knitted garments are no longer confined to lingerie, underwear and stockings only. There has been a revolution in knitwear production and consumption. The range of styles that can be designed and manufactured is constantly expanding. It is a known fact that knitted garments are very much popular with kids since time immemorial. Children have always enjoyed wearing knitted garments more than adults. But, both times and fashions have changed today. Knitwear has become popular for all men, women and kids. The Indian knitting industry is one of the most innovative global producers of knitwear products. Today, there has been a tremendous change in technology. A large number of sophisticated computerized knitting, embroidery machines, dyeing machines, state-of-the-art sewing lines, CAD/CAM systems, large scale processing machines, and other machinery required in the knitwear manufacturing have been mostly imported are installed and functioning for fulfilling the export orders. The major technological developments of the CAD/CAM provide an essential service to the knitting industry. The considerable investment in capital equipment made by all companies of all sizes has ensured that the Indian knitting industry has not been left behind. The investment in this sector has seen the industry becoming one of the most creative users of many of the new types of machinery, which is re-enforcing our position in producing different varieties of knitwear and increasing our competitiveness within the global market. This is indeed a significant contribution to the Indian economy by the knitwear industry which has a bright future.

Today, knitting is a complex industry of four main types, each of which has its own subdivisions of specializations. The four main types of the knitting industry are as follows:

1. The first type produces knitted fabrics by weft (flat or circular) or warp knitting technique for apparel manufacturers, sewing centres, consumers and others.
2. The second type manufactures knitted garments by cutting and assembling from knitted fabrics.
3. The third type manufactures shaped knitted garments (panel knitting and assembling or integral garments).
4. The other one is engaged in both fabric knitting and garment manufacturing in the same factory premises.

Indian knitting industry is a growing industry. It has emerged as a premier supplier of value-added items. Some of the allied industries to knitting are as follows:

1. Yarn making (spinning industry)
2. Yarn dyeing
3. Fabrics dyeing and finishing
4. Fabric printing
5. Garment washings (stone, acid, enzyme washes, milling, shrink resist, etc.)

1.6 Comparison between Weaving and Knitting

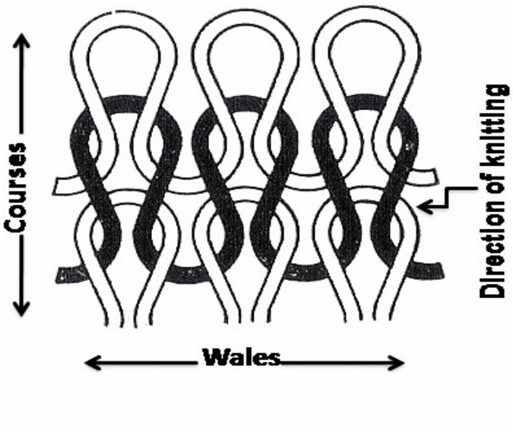
The comparison of the features of the techniques, machines and products of weaving and knitting is given in Table 1.2.

Table 1.2 Comparison between weaving and knitting

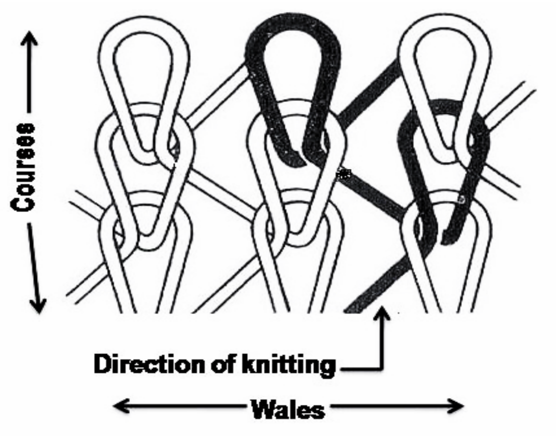
Weaving	Knitting
1. Fabric is made by interlacement of yarns	1. Fabric is made by inter-looping of yarn.
2. Two sets of yarns - warp and weft - used	2. One or one set of yarn(s) - either warp or for making the fabrics
3. Weaving requires more number of preparatory processes	3. Knitting requires less number of preparatory processes
4. Machines are mostly flat	4. Machines are flat as well as circular
5. Fabric is comparatively more rigid	5. Fabric is comparatively less rigid
6. Fabric is less stretchable	6. Fabric is more stretchable
7. Fabric does not bend easily and less comfort and form fitting property	7. Fabric bends easily and results in good Comfort and results in form fitting
8. It is easy to tear the fabric	8. It is difficult to tear the fabric
9. For same GSM the fabric is less thicker	9. For same GSM the fabric is more thicker
10. Fabric has low wrinkle resistance	10. Fabric has high wrinkle (crease) resistance
11. Fabric is stiffer and has a harsh feel	11. Fabric is less stiffer and has soft feel
12. Fabric is less porous and less air permeable	12. Fabric is more porous and air permeable
13. Fabric is stronger and durable	13. Fabric is comparatively weaker and less durable
14. Lesser inherent tensions cause minimum shrinkage	14. During conversion of yarn into loop, tension and shrinkage development
15. Moisture absorption is less due to compact structure.	15. Moisture absorption is more because of bulky structure.
16. Fabrics are more dimensionally stable due to tighter construction and the warp and of weft intersecting in right angle.	16. Because of loop structure and inability of yarn to return to original position dimensional stability is poor.

1.7 Classification of Knitting

Knitting is primarily classified as weft knitting and warp knitting. This classification is based on the direction of movement of yarn with respect to the direction of fabric formation. If the yarns run in the width or cross- wise direction with reference to the direction of fabric formation during knitting, then this process of knitting is called weft knitting. The yarns in the knitted structure are just like weft yarns in woven fabrics. Such structures are called weft-knitted fabrics or jersey fabrics, and the machines in which such structures are produced are called weft knitting machines. In case the yarns run in length wise direction, i.e. the direction of fabric formation during knitting, the process is called warp knitting. The yarns inside the knitted fabrics are just like the warp yarns in woven fabrics. Such knitted fabrics are called warp knitted fabrics, and the machine which produces such fabric is known as warp knitting machine. Direction of movement of yarn in weft and warp knitting is shown in Figs. 1.3a and 1.3b. Till date, most of the fabrics we use in our daily life as apparel belong to weft knitting; and hence to knitting learners, knitting means weft knitting if not otherwise mentioned. The terms weft and warp have been borrowed from the weaving developed much earlier than knitting.



1.3a Weft-Knitting



1.3b Warp knitting

1.7.1 Classification of Weft Knitting Machines

Weft knitting machines are classified in various ways. The main basis of classification is based on the basis of the needle bed. Needle bed is the bed or frame on which needles are arranged at regular pattern. There are grooves or cuts at regular interval to accommodate the individual needles so that those can move up and down or to and fro along the needle axis for loop formation but restricted to move laterally. The number of needle bed in a machine may be one or two and accordingly, the machines are called either single bed (single jersey) or double bed (double jersey in UK and double knit in USA) machines. Further, the shape of the bed may be flat or circular. So, according to the shape of the bed, knitting machine may be either flatbed machine or circular bed machine. Thus, combining the number and shape of the bed, a total combination of four types of machines is possible. Flat single bed machines are generally horizontal or slightly angled. But, the two beds in flat machines are generally inclined making an angle of about 90° at the meeting point. The single circular bed is cylindrical and vertical. But circular double beds are of two types – (a) two cylinders facing each other, or (b) dial and cylinder type, i.e. cylinder at the bottom and dial (a circular plate) at the top. The dial and cylinder type machines are more common in commercial uses. The same machines may be classified as hand-driven machine and power-driven machine according to the nature of drive (mainly applicable to flatbed machine).

The types of structure produced in different machines are different. So, machines may be classified according to the basic knitted structures they produce. The four basic weft-knitted structures are (a) plain, (b) rib, (c) interlock and (d) purl. The plain structure is made in single jersey / bed machine whereas the other three are made in double jersey / bed machine.

Sometimes different design elements/devices are fitted in knitting machine and then those machines are given names according to the element/ device attached to the machine. For example such machines are:

a. Knitting machine with pattern wheel
b. Knitting machine with jacquard
c. Knitting machine with multiple cam track arrangement
d. Knitting machine with intarsia facility
e. Knitting machine with CAD and CAM.

Sometimes, some machine is developed and used to produce some special end product, and accordingly some specific name is given to that machine, i.e. socks knitting machine, terry knitting machine, sliver knitting machine, etc.

Knitting machine can produce continuous fabric like weaving or can make garment with proper shaping. On the basis of the product, machines may be classified as fabric length machine or garment length machine. Garment length machines are more complicated and less productive.

There is another type of weft knitting machine according to shape of the needle bed equipped with bearded needles called straight bar frame. It has much similarity in appearance with Lee's original hand frame knitting machine. This machine is mainly used for fashioning. As neither the machines are popular in India and neighbouring countries nor manufactured in good number, so the details of the same is not included in the next chapters. The brief classification of weft knitting machine is given in Fig. 1.4.

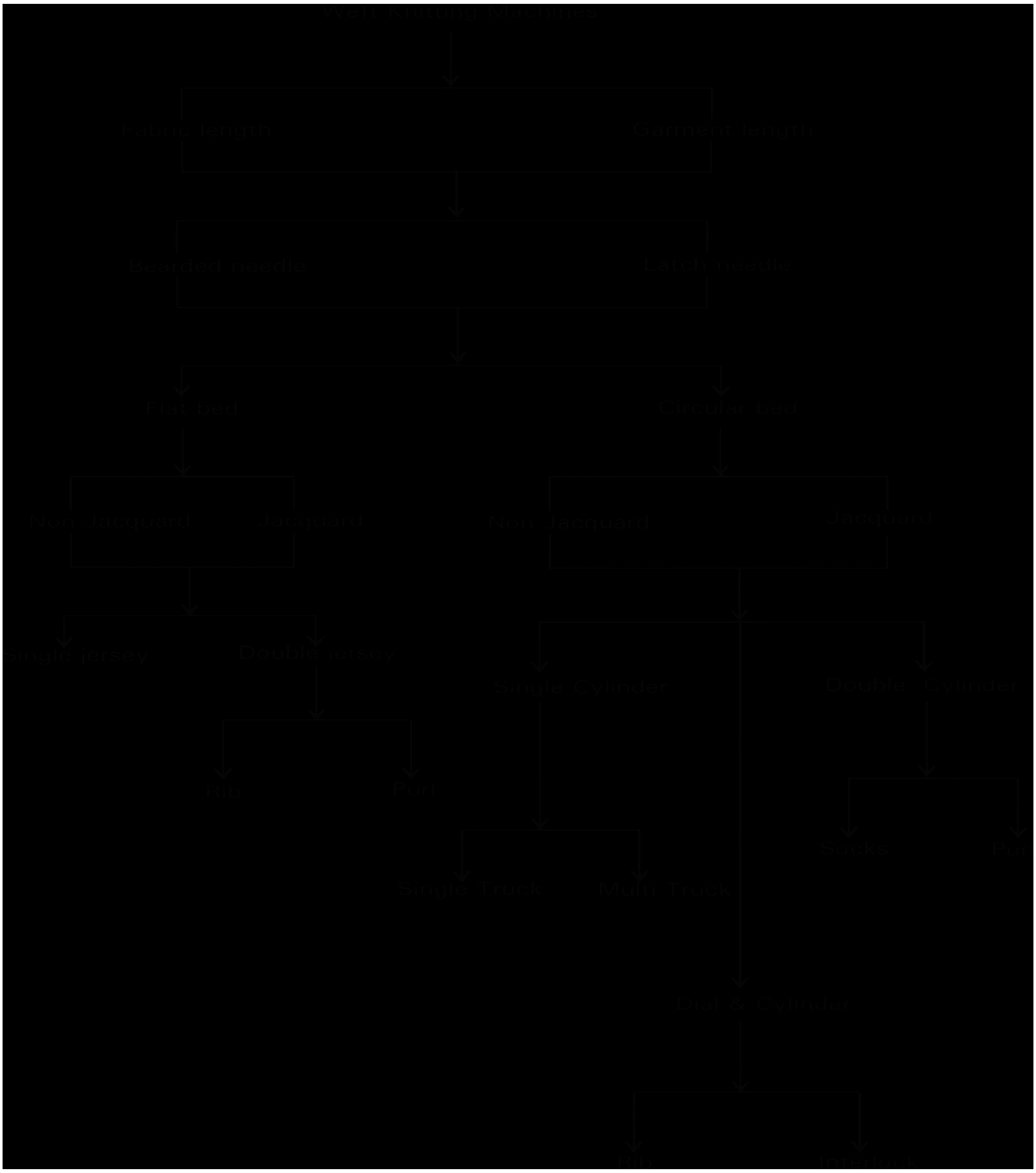


Figure 1.4 Weft knitting classification

1.7.2 Classification of Warp Knitting Machines

Based on the features of warp knitting, the machines available are classified into two categories: Tricot and Raschel. Both Tricot and Raschel may be made with either single needle bar or double needle bar. A brief classification of warp knitting machine is given in Fig. 1.5.

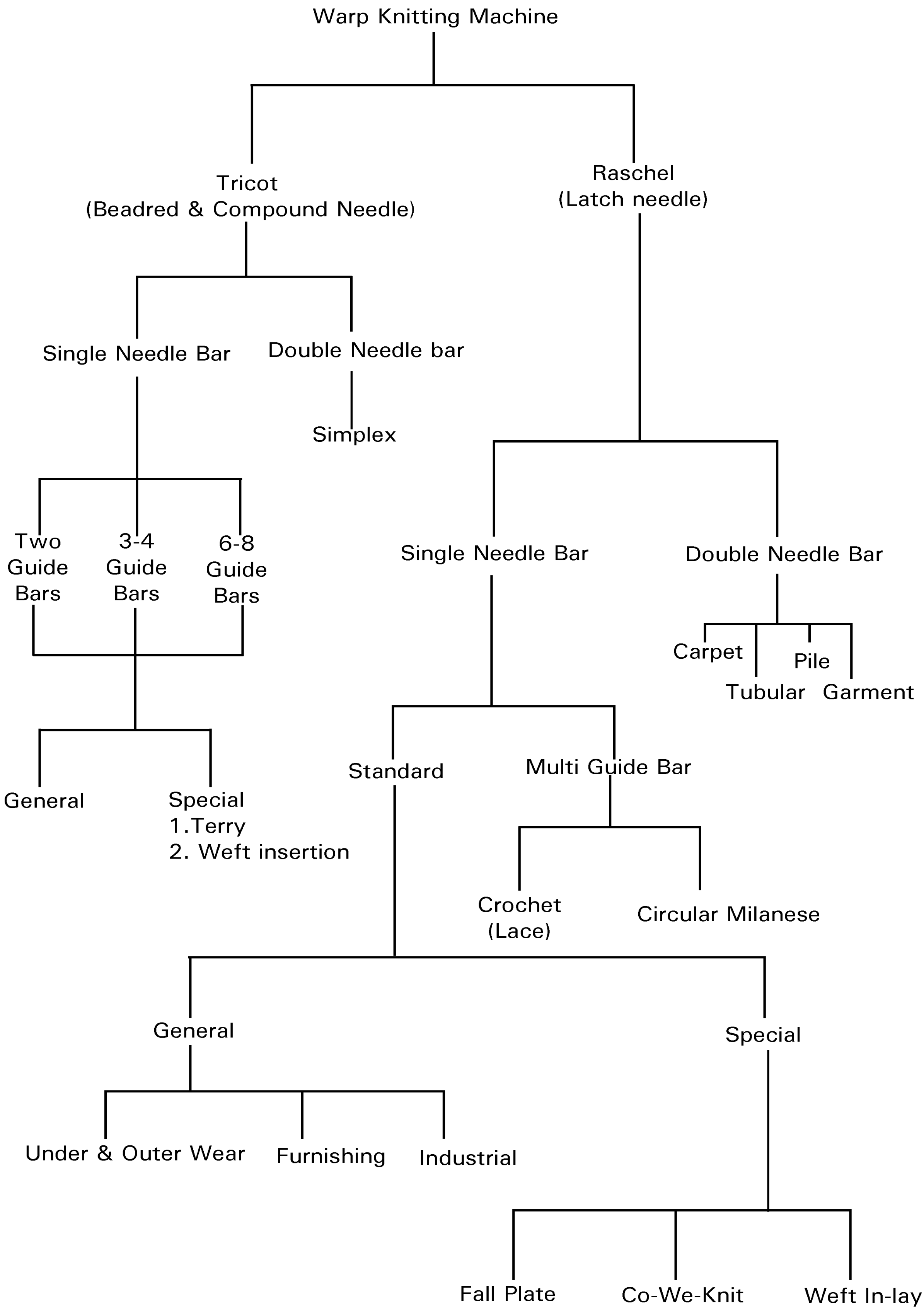


Figure 1.5 Warp knitting classification.

1.8 Comparison between Weft knitting and warp knitting

The relative comparison between weft knitting and warp knitting (process, machine and structure) is shown in Table 1.3.

Table 1.3 Comparison between Weft Knitting and Warp Knitting

	Weft knitting	**Warp knitting**
1.	Loop formation takes place course wise in horizontal direction	Loop formation takes place wale wise in vertical direction
2.	Yarn runs in horizontal or course direction during knitting	Yarn runs in vertical or wale direction during knitting
3.	Needles knit sequentially in a knitting cycle	Needles knit altogether in a knitting cycle
4.	Yarn is supplied generally in the form of cone hold in a creel	Yarn is supplied generally in the form of warp beam (number of beams may be 2 or more)
5.	Only one or a few yarn(s) (152 maximum) is/are needed during knitting a fabric	Large number of yarns are needed for knitting a fabric
6.	Staple yarns are preferably used but filament yarns are more suitable	Filament yarns are mostly used but staple yarns are nowadays used in some cases
7.	Less preparatory processes are required before knitting	More preparatory processes are required before knitting
8.	Latch needles are used in all machines	Bearded needles are mostly used but latch needles can also be used in some cases
9.	Less variety of structures can be made in a machine	Wide variety of structures can be made in machine
10	Change in pattern reduces the machine speed	Change in pattern does not reduce the machine speed
11	Fabrics have less aesthetic value	Fabrics have more aesthetic value
12	Fabrics are more resilient and suitable for inner garments and ladies garments	Fabrics are less resilient and not suitable for inner garments
13	Fabrics have some uses as outer garments as well as furnishing material	Fabrics have much uses as outer garments as well as furnishing material
14	Fabrics have good stretchability in both direction, comparatively higher width direction	Fabrics have low stretchability in both direction, comparatively higher in width direction

15	Dimensional stability of the fabrics are lower	Dimensional stability of the fabrics are higher
16	Wide range of semi or full garment length machines are available	Limited range of garment length machine is available
17	Machine may be flat or circular	Machines are generally flat
18	Circular machine produces circular fabrics but both flat or tubular fabric may be produced in flat machine	Mainly flat fabrics are produced but limited range of circular fabrics can also be produced.
19	Weft insertion during loop formation is not possible for producing highly dimensional stable technical textiles	Weft insertion during loop formation is possible for producing highly dimensional stable technical textiles
20	Tailoring is difficult	Tailoring is not difficult
21	Machines as well as the fabrics produced are comparatively cheaper	Machines as well as the fabrics comparatively are costlier

Chapter 2 Weft Knitting

2.1 Introduction

Knitting is the technique of fabric formation by inter-looping of yarns. The straight continuous length of yarn is bent into loops and those loops are inter- looped with each other for fabric formation. The main element used for such loop formation and subsequent inter-looping is the needle. The needle takes the help of sinker for the loop formation, which applies necessary support to the yarn for loop formation. Moreover, needle has to move along its axis for performing the loop formation. So, one more element (cam) is also required to impart the motion to the needle during loop formation. The designing of these elements with proper dimensions should be done precisely as well as those should be placed accurately in the machine in order to continue knitting effectively and smoothly.

2.2 Types of needles

The main element used in knitting is the needle which actually forms the loop. There are three types of needles commonly used in knitting machines namely

(a) Latch needle, (b) bearded needle and (c) compound or bi-partite needle.

Irrespective of the needle type, needles are may be arranged on the needle bed at regular interval in such a way so that needles may move freely along the axis without any lateral tilting. For this purpose cuts or groves, technically known as tricks, are provided on the needle bed. As discussed below, the latch needle is the best and most widely used in the knitting industry. The position of the latch needle inside the trick of the cylinder bed of circular weft knitting machine is shown in Fig. 2.1.

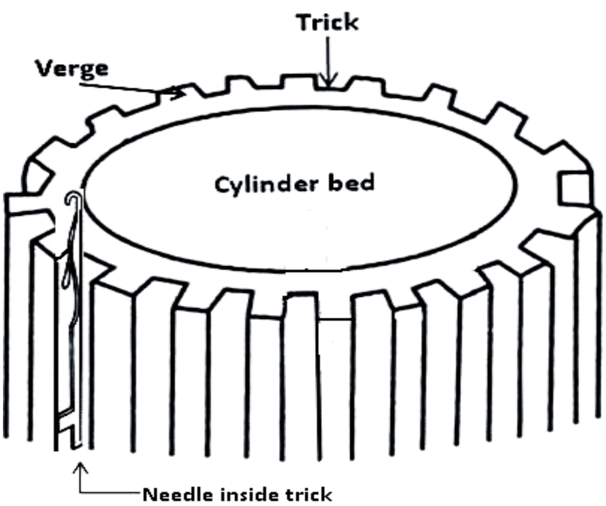


Figure 2.1 The schematic arrangement of the cylinder bed, trick and the needle.

All the varieties of knitting needles used in different types of knitting machines (warp and weft) are mainly manufactured and supplied by M/s Groz- Beckert established in 1852.

2.3 Latch needle

The different parts of a latch needle as shown in Fig. 2.2 are as follows:

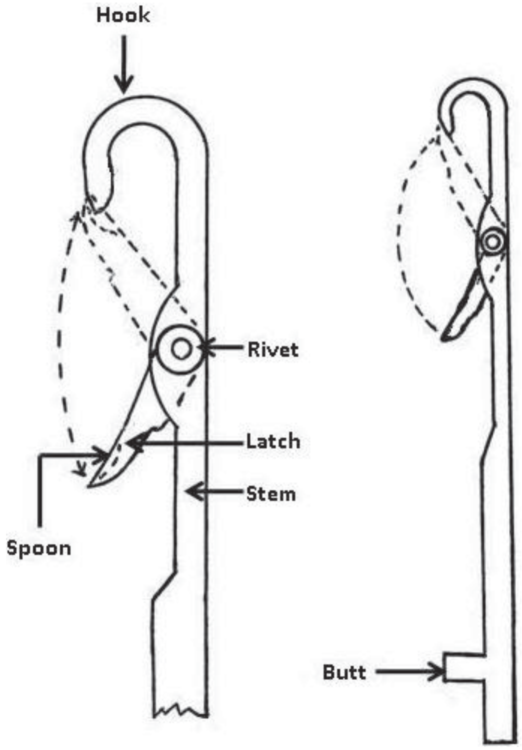


Figure 2.2 Parts of the latch needle

(a) Hook, which draws the yarn, makes the loop and retains the same. The top of the hook is called crown.

(b) Slot or saw cut on the stem which receives the latch blade.

(c) Cheek or slot walls where the latch is riveted.

(d) Rivet which fixes the latch on the slot of the needle stem.

(e) Latch which moves around its fulcrum for opening and closing of the hook.

(f) Latch has a spoon or cup at the end which imparts better closing of the hook.

(g) Stem – the main body of the needle.

(h) Butt which receives the motion from cam system needed for loop formation.

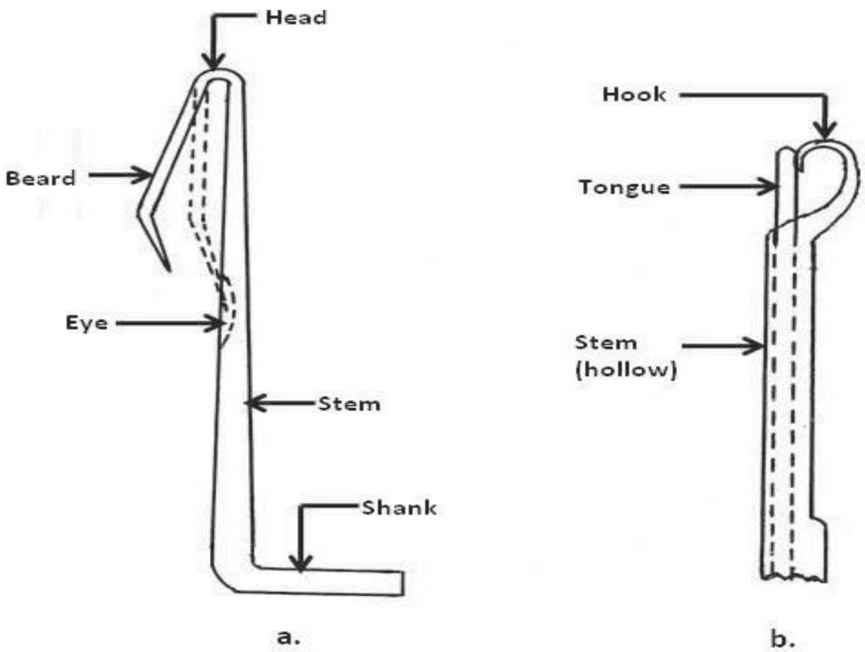
(i) Tail, which is an extension of the stem below the butt, is used for giving support to the needle inside the trick.

Latch needles are mostly used in weft knitting as well as now-a-days in warp knitting on account of the following advantages.

1. Needles are robust.
2. Needles are self-sufficient, i.e. no extra element is required for hook closure. Latch moves up and down due to yarn tension.
3. The newly developed spring-loaded latch needles guarantee high process reliability and precise stitch formation. The only demerit of latch needles is that very finer gauge is not possible.

2.4 Bearded needle

The different parts of a bearded needle as shown in Fig. 2.3(a) are as follows:



2.3 a) Parts of the bearded needle and b) parts of the compound needle

(a) Stem the body of the needle.

(b) Head where the stem has been bent to make the hook.

(c) Beard, the flexible hook which can be pushed to the stem for hook closure.

(d) Groove or eye cut into the stem to accommodate the tip of the beard.

(e) Shank, the bent bottom portion of the needle for connecting with a separate machine part.

Bearded needles are mainly used in tricot-type warp knitting machine. These needles are available in very finer gauge. An additional part called pusher is needed to close the hook during loop formation.

2.5 Compound or Bi-Partite Needle

Compound needles are more versatile and suitable for both weft and warp knitting. Out of various types of compound needles, one has been shown in Fig. 2.3(b). It is a modified latch needle. The main parts of this needle are as follows:

(a) Hook

(b) Stem

(c) Slot or hole inside the stem

(d) Sliding latch or hook closer

(e) Butt of the needle

(f) Butt or driving attachment of the hook closer

These needles are very robust and durable but cannot be made of finer variety. Moreover, motions are to be given separately on the needle and the hook closer; and hence compound needles have very limited applications.

2.6 Manufacturing and Specifications of Latch Needle

From a manufacturing point of view, latch needles may be of two types:

Wire needle

Die-cut needle

Wire needle are made from a steel wire shaped through various machining steps to create a desired (flat/circular) profile and a hook, the section accommodating the latch, and an end butt with tail; sometimes the butt is not obtained with a bending process but by a pressing one.

Die-cut needles are made from a steel plate of the desired thickness, which is die cut so as to create the shape of a butt with or without a tail; the hook and latch fitting are created with a special process.

The manufacturing process with the wire needle is the simplest and most cost-effective one, while the die-cutting process gives better technical results and imparts greater stiffness to certain sections of the needle.

A critical feature of all needles is the gauge; it is directly connected to the strength of the needle which must bear the stress and strain generated during the various technical cycles of the knitting process. The gauge of the needle is directly proportional to the gauge of the machine; the needle must be neither too thick (if so there would not be enough space between a needle and the next one for looping the yarn) nor too fine since in this case the needle, besides being too weak, could compromise the resistance of the binding pattern which would result poorly balanced.

2.7 Sinker

The second primary knitting element next to needle is the sinker. It is a thin metal plate positioned in between the needles. The sinkers generally move to and fro in horizontal, i.e. at 90° to the direction of movement of needles and maintain a fixed height. The old loops or the cloth rests on the sinkers. Both the construction and the function of the sinker varies from machine to machine. Sinker is used in both weft and warp knitting in combination with latch needle as well bearded needle. Sinkers may be unnecessary when knitting (circular weft) with two needle beds as the second bed restrain the fabric loops whilst the other set needles move. Sinker may perform one or more of the following functions depending upon its shape and movement as well as the type of the machine:

(a) Loop formation, (b) holding down (c) knocking over.

The typical shapes of sinker commonly found in knitting machine are shown in Fig. 2.4. The main parts are as follows:

(a) Throat which holds the yarn during loop formation.

(b) Belly is the projected portion on which the old loops or fabric rests.

(c) Butt which receives motion from a cam system.

(d) Neb which prevents the yarns and fabric from moving up.

The type of sinker used in circular weft knitting machine is known as holding down sinker, and it performs the following functions.

(a) It helps in loop formation by holding or restricting the yarn.

(b) It helps in take-down of the fabric by pushing the same after loop formation.

The phases of operation of sinker in weft knitting can be viewed as –

1. The held loop is positioned in the throat of the sinker when the sinker moves forward and the needle moves upward for clearing. The held loop is retained by the throat and hence its movement along the needle is restricted.
2. The sinker remains at its forward position when the needle attains its clearing position.
3. The sinker retracts when the needle comes down after feeding. At this stage, due to sinker retraction, fabric or held loop is eased out. Also the sinker belly supported the fabric or held loop and hence its movements along the needle is prevented.

4. Sinker remains in backward position and the needle descends to its down most position drawing the new loop through the old loop.
5. Before the needle ascends, the sinker moves forward to push the knitted fabric a little and to hold the old loop away from the head of the needle and to be in a position to control the fabric.

Further the holding down sinkers enable tighter construction with improved appearance to be obtained, the minimum draw-off tension is reduced, higher knitting speeds are possible and knitting can be commenced on empty needles.

In some modern weft knitting machines (Make: Mayer and Cie and Jumberca), the sinkers also move in vertical direction in addition to its horizontal movement in order to get higher knitting speed which is technically known as CONTRA or RELANIT system.

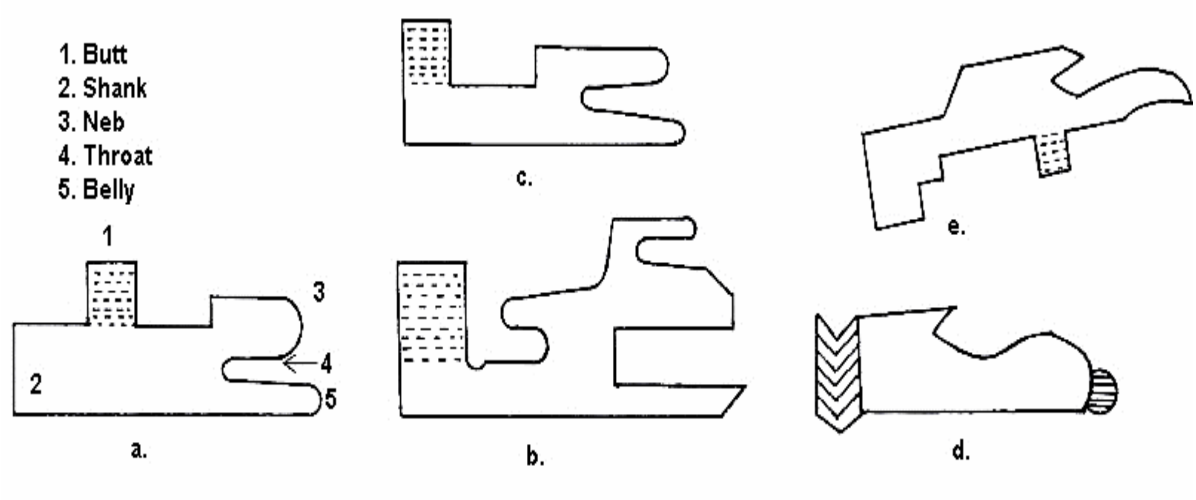


Figure 2.4 Shapes of sinkers

2.8 Knitting cam system

For the purpose of loop formation, needles are to move along the needle axis inside the trick. This axial movement of the needles is produced by means a cam system with a cam profile. Generally, a few pieces of cams (metallic plates) make a groove or channel. The butts of the needles are placed inside the channel and the relative displacement of the two forces the needles to follow the profile of the cam system. According to the cam profile, the needles either move up or down or remain idle as required for the loop formation. There different types of knitting machines produce different types of structures. So, the profiles of knitting cam systems found in different machines have to be different. The line diagram of the typical shape or profile of a knitting cam system found in circular single jersey weft knitting machine is shown in Fig. 2.5. The clearing cam (C) forces the needle to rise up for clearing of the old loop and the corresponding guard cam (G) controls its rising motion and prevents it from jumping etc. After clearing, the needle starts moving downwards under the control of the stitch cam (S). The downward movement of the needle is guided by the up-throw cam (U). As soon as the loop formation is completed by stitch cam the needle slightly moves up to reach the level from where it started rising. The motion of the needle at this zone is controlled by up-throw cam or by the yarn tension the needle is subjected to. The level of the needle is maintained by the running cams or guard cams (R) and (R) until the needle is raised again for the next knitting cycle. The position of the stitch cam with reference to the running height of the needles governed by the sinker or verge level determines the stitch or loop length. So for varying the position of the stitch cam as well as to maintain uniform gap between stitch cam and up-throw cam, these two cam pieces are fitted on a common platform the position of which can be adjusted by means of a spring loaded setting knob. The clearing cam is sometimes made in such a way so that it can provide two or three different positions or levels during raising the needles. These positions are clearing, tucking and floating needed for normal loop formation, tuck loop formation and float or miss loop formation respectively.

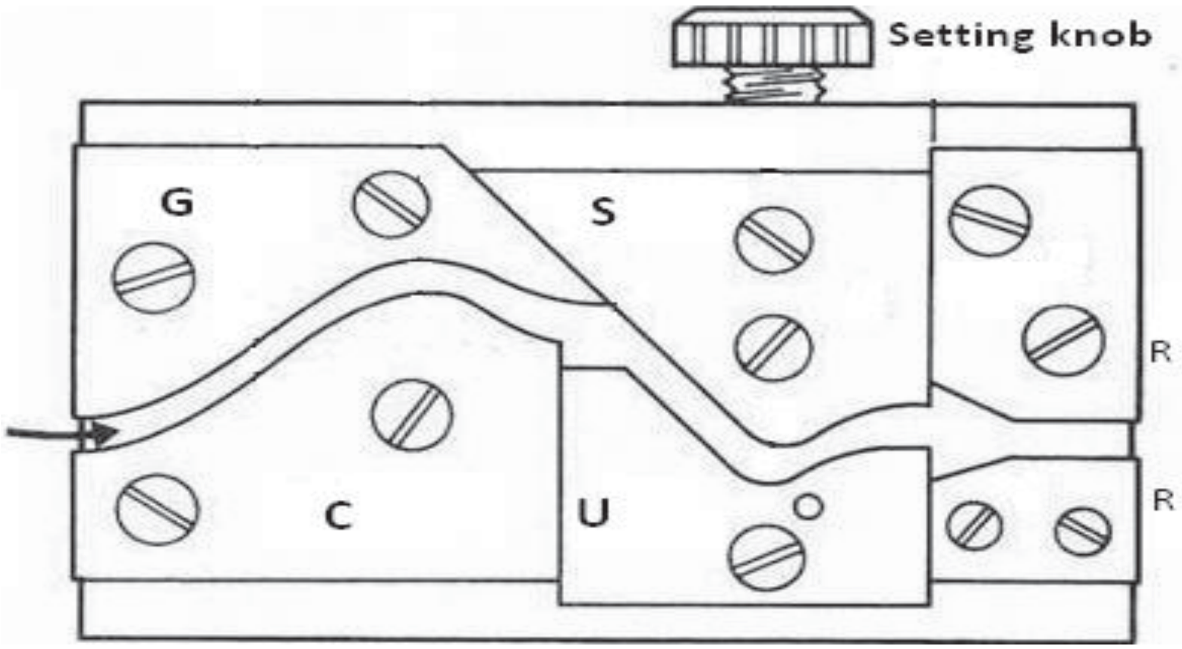


Figure 2.5 Cam system of a single jersey knitting machine

The cam system found in circular double jersey (cylinder and dial) interlock knitting machine is shown in Fig. 2.6. There are two cam tracks in both the cam jackets. The butts of short and long needles pass through the upper and lower cam tracks respectively during interlock knitting. However during rib knitting either short or long needles are to be taken out from both dial and cylinder and the working needles will pass through one track only in each bed. In addition the relative positions of the two cam jackets are adjustable for varying knitting timing.

The cam systems used in old machines are generally linear in nature position of the stitch cam as well as to maintain uniform gap between stitch cam and up-throw cam, these two cam pieces are fitted on a common platform the position of which can be adjusted by means of a spring loaded setting knob. The clearing cam is sometimes made in such a way so that it can provide two or three different positions or levels during raising the needles. These positions are clearing, tucking and floating needed for normal loop formation, tuck loop formation and float or miss loop formation respectively.

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The cam systems used in old machines are generally linear in nature.

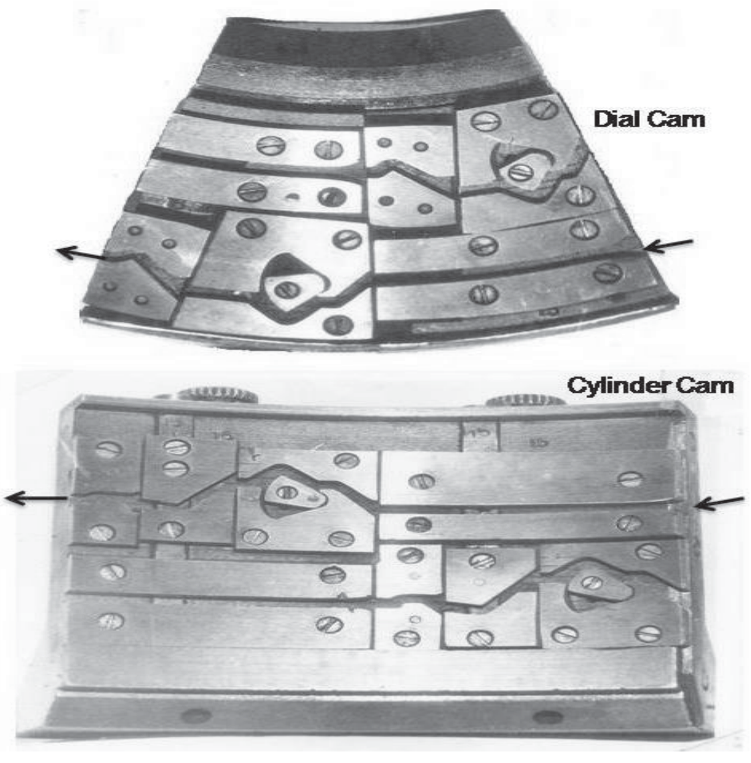


Figure 2.6 Knitting cam of a circular interlock machine

An inherent limitation of the linear cams is the sudden change in needle velocity as the needle but moves from one cam section to another. At higher circumferential speed of the needle, the acceleration of needle movement is so high that the movement of the needle butt becomes uncontrollable, needle but tends to fatigue and break off. Replacement of conventional linear cams by mathematically designed non-linear cams (Fig. 2.7) is the much needed solution. The properly designed non-linear cam permits smoother accelerations and gives longer life to the essential components. An eight (8) inch diameter commercial single jersey machine fitted with non-linear cam can run at a speed of 200 rpm which is about two times of the achievable speed with conventional linear cam. The profile of a typical non-linear cam has been shown along with the same of traditional linear cam in order to visualize the difference between the two. However, the actual design of the profile of the non-linear cam depends upon the boundary conditions of the polynomial equation chosen for the purpose.

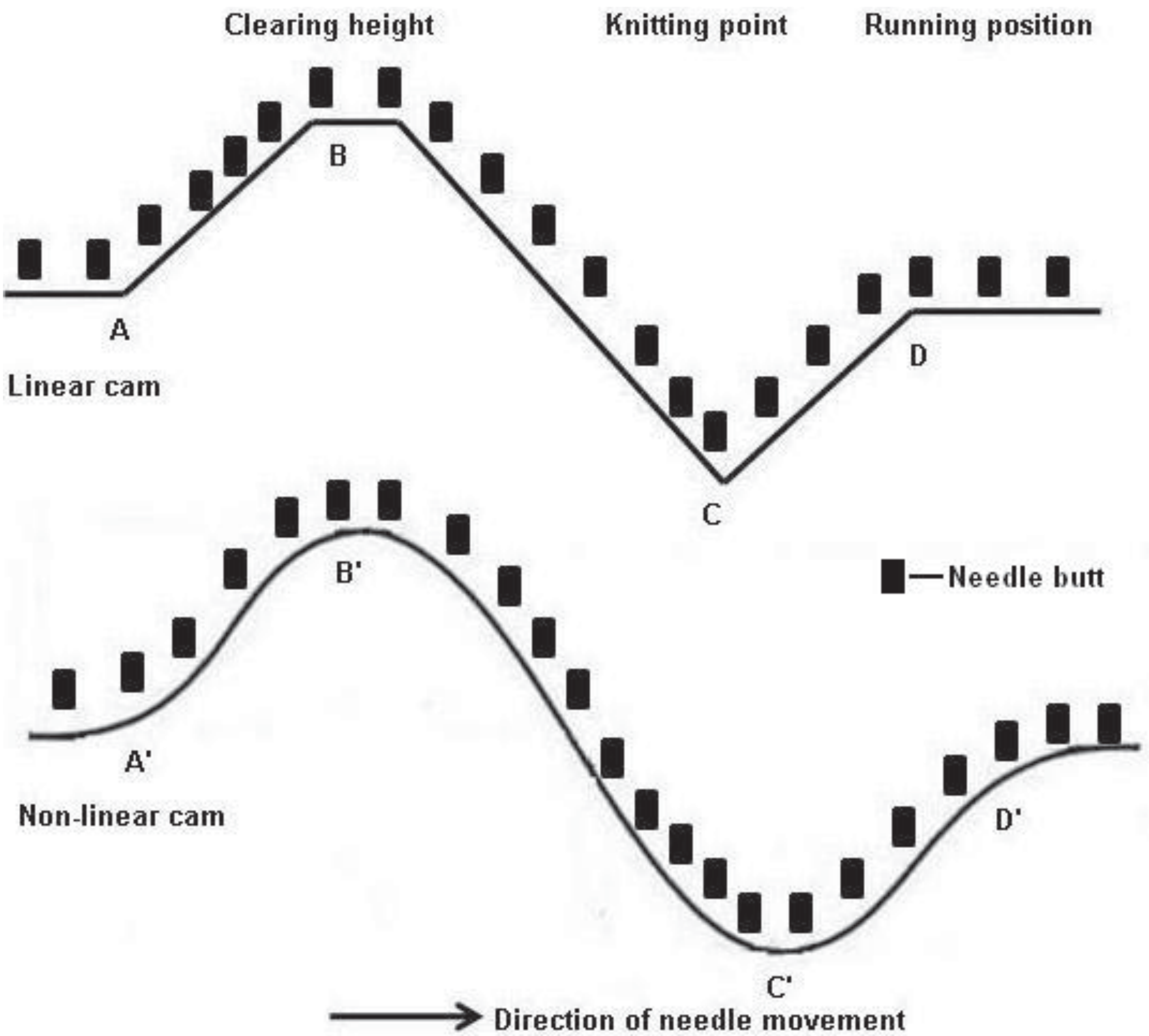


Figure 2.7 Schematic diagrams of cam profiles

2.9 Knitting Action of the Latch Needle

The knitting action of the latch needle, i.e., the position of a latch needle as it passes through the cam system and moves up and down in its trick with reference to the sinker level for completing one knitting cycle, is shown in Fig. 2.8. The knitting cycle passes through a large number of stages as described in the undergoing.

i. Rest position of the needle (a). The head or crown of the needle is at a slightly higher level of the top of the verge or sinker. The loop formed at the previous feeder or knitting cycle is in the closed hook.

Latch opening (b). As the needle follows the cam profile, needle is forced to gradually move up by the clearing cam. The old loop which is held down by the sinker as well as pulled by the take-down load, slides inside the hook, comes in contact with the latch and opens the latch.

iii. Clearing height (c). As the needle reaches the top of the clearing cam, the old loop is cleared from the latch and the latch is hanging down.

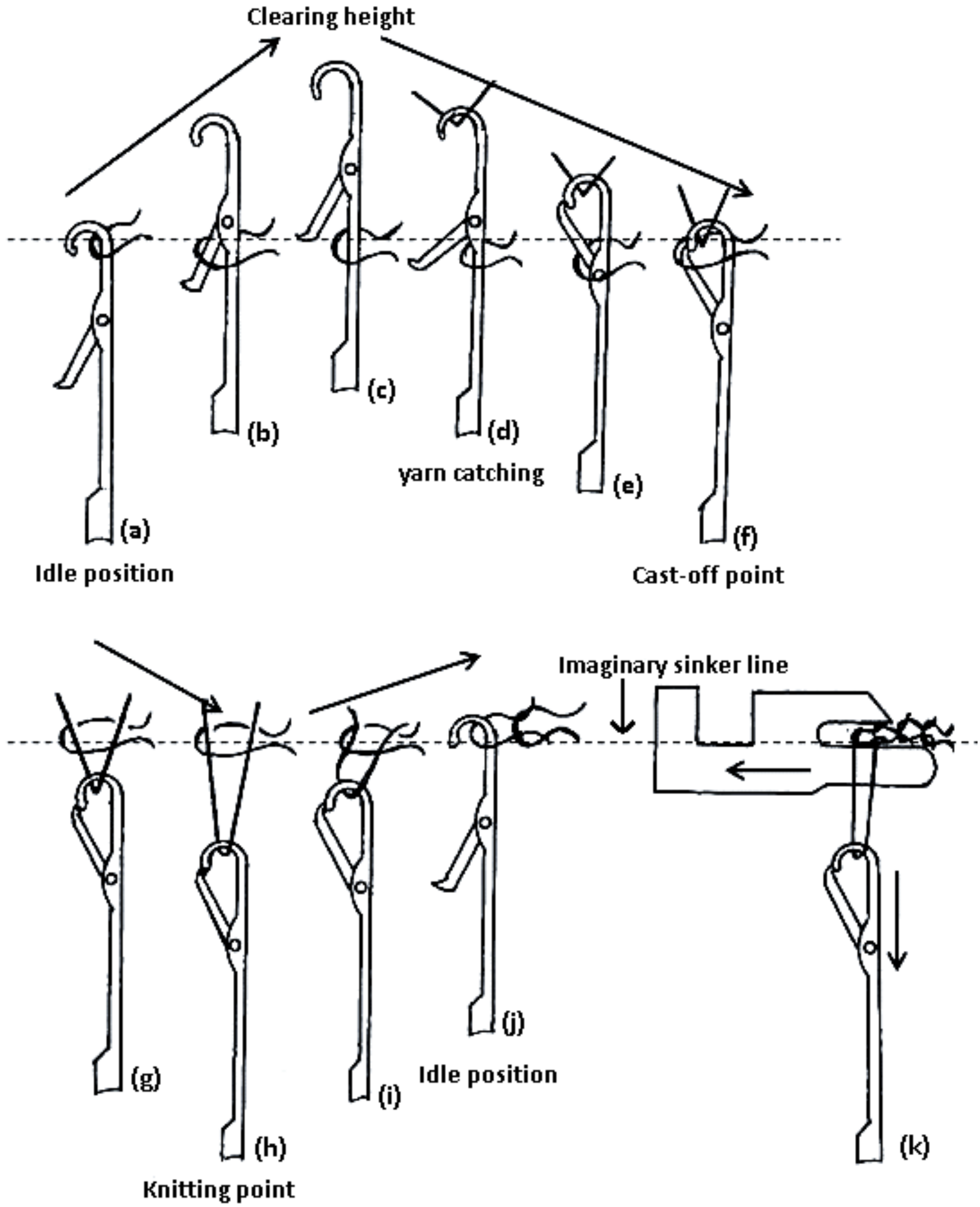
iv. Yarn feeding and latch closing (d and e). The needle starts to descend under the control of the stitch cam. The old loop which slides on the needle stem comes under the latch. At this height new yarn is fed to the needle and the needle continues downward movement. The loop closes the latch on the hook and rides over the latch. The sinker starts to move outward

v. Casting-off (f). As the needle head approaches the verge or sinker level, the old loop slides off the needle and the new loop is drawn through it. The sliding off of the old loop from the needle is called casting-off and the old loop is called cast-off loop. The sinker continues outward movement and allows the old loop to lie on the throat.

vi. Loop formation (g and h). The needle with the new loop in its hook descends further inside the trick and the loop size gradually increases. The needle ultimately reaches the bottom of the stitch cam, i.e., the down most position and maximum length of yarn is drawn mainly from the package and partly from the previous loop to complete the formation of the new loop. The down most point is termed as knitting point. The sinker starts inward movement.

vii. Attaining idle position (i and j). The needle with the new loop inside the hook moves up. The Sinker completes the inward movement and pushes the old loops or fabric to assist take-down. The needle reaches the idle position again.

During loop formation the sinkers also move to and fro maintaining same height or level. However for the sake of simplicity, the different positions of the sinker with respect to the needle are not shown in the figures. Only to have an idea of the same the position of the sinker at knitting point been shown in Fig. 3.8(k).



2.8 Latch needle loop formation cycle.

2.10 Knitting Action of the Bearded Needle

Like latch needle bearded needle also passes through different stages during a knitting cycle. The different stages of loop formation are shown in Fig. No. 2.9.

Idle position of the needle (a). The head or tip of the needle is at a slightly higher level of the top of the verge or sinker. The loop formed at the previous feeder or knitting cycle is inside the hook.

Clearing height (b). As the needle follows the cam profile, needle is forced to gradually move up by the clearing cam. The old loop which is held down by the sinker as well as pulled by the take-down load slides inside the hook. As the needle reaches the top of the clearing cam, the old loop is cleared from the hook, i.e., it reaches beyond the control of the beard.

Yarn feeding (c). The needle starts to descend under the control of the stitch cam. The old loop slides on the needle in upward direction. At this height new yarn is fed to the needle and the needle continues downward movement.

Hook closing (d and e). The pusher or presser bar comes in contact with the beard and closes the hook so that the old loop sliding on the needle stem now can ride over the beard.

Casting-off (f). As the needle head approaches the sinker or verge level, the old loop slides off the needle and the new loop is drawn through it. The pressure bar is withdrawn. The sliding off of the old loop from the needle is called casting-off and the old loop is called cast-off loop.

Loop formation (g). The needle with the new loop in its hook descends further inside the trick and the loop size gradually increases. The needle ultimately reaches the bottom of the stitch cam, i.e., the down most position and maximum length of yarn is drawn to form the loop. This is termed as knitting point.

Idle position (h). The needle with the new loop inside the hook moves up. Sinker pushes the old loops or fabric to assist take-down. The needle attains the idle position again.

2.11 General Terms in Weft Knitting

2.11.1 Machine Pitch and Gauge

Both these terms are related to the density of needles in each bed of the machine. Machine pitch (needle pitch) is defined as the distance between the centres of two neighbouring needles in one needle set measured on the nominal machine diameter or width. Although both English and Metric units can be used, generally metric unit, millimetre, is preferably used to indicate the pitch of any knitting machine. Machine gauge is also defined in various units (systems) in various countries. Definition of gauge also depends on the types of knitting machines. Most popularly, it is defined in English system as the number of needles per inch. So the relationship between these two parameters can be expressed as follows:

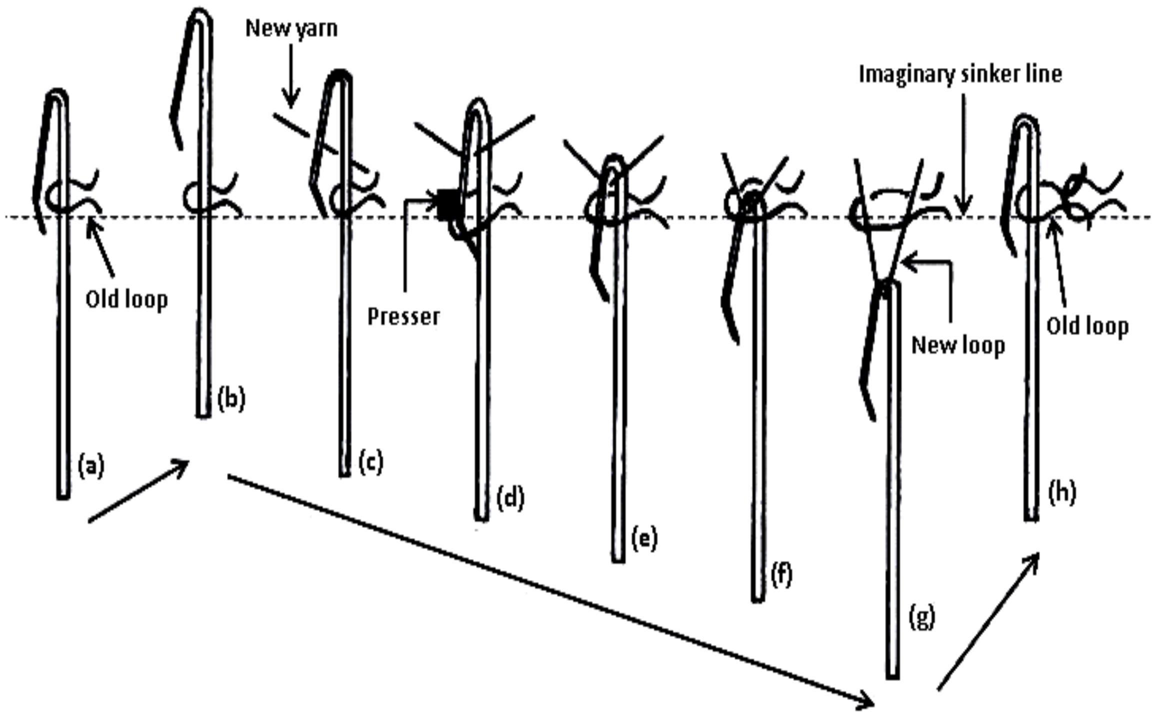
[Nominal machine circumference (diameter × 3.14) or width × 25.4

No. of needles in the machine

= (25.4 / Machine gauge in English system) or

Pitch in mm × Machine gauge in English system = 25.4

The selection of yarn (count and type) for knitting mainly depends on the gauge of the machine.



2.9 Bearded Needle Loop Formation Cycle.

2.11.2 Loop

Loop means a curve shape produced that bends round and crosses itself. In knitting, it is the basic unit of a knitted structure. It is produced by bending yarn with the help of some knitting elements, namely needle and sinker. Based on the knitting element, which is forcing the yarn to bend, loops may be termed as needle loop and sinker loop. Needle loop is a portion of the whole loop in the fabric formed initially by the needle hook. It consists of a head and two side limbs or legs (Figure 2.10 a). The sinker loop is the piece of yarn which joins one needle loop to the next, i.e. it is obtained when the legs of two adjoining needle loops are joined together. As the legs of the needle loop are formed by the support of the sinker, the joining of the legs is called sinker loop. The base portion of each leg is called foot. The other name of a loop is stitch.

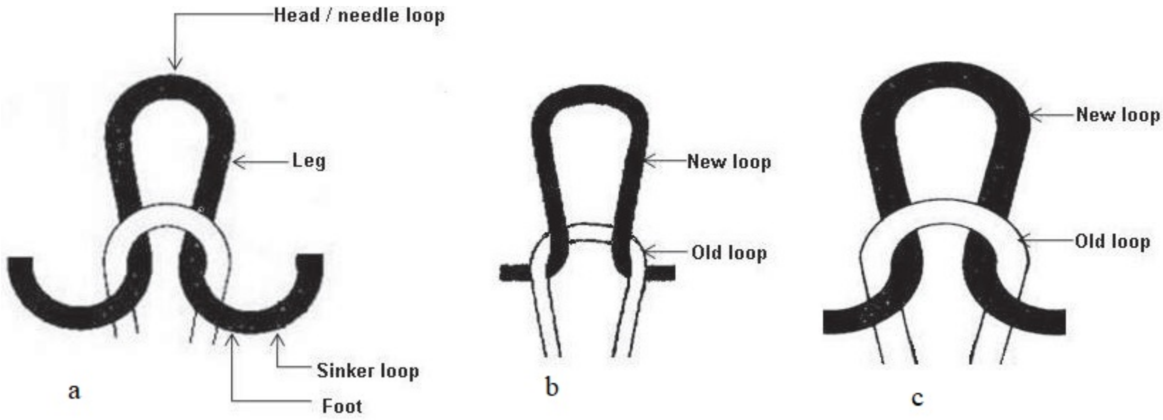


Figure 2.10 Diagrammatic representation of loops a) loop parts b) face loop c) back loop

2.11.3 Face Loop and Back (Reverse) Loop

A loop is called face loop or back (reverse) loop according to the direction of passing of one loop through another one during inter-looping (Figures 2.10 b and 2.10 c). If the new loop passes from the back to the front of the previous loop (towards the viewer) made by the same needle during inter- looping, the loop is called face loop (also known as knit stitch). Face loops tend to show the side limbs of the needle loops as a series of inter-fitting ‘V’s. When the new loop passes to the back from the front of the previous loop during inter-looping, the loop is called back loop (also known as purl stitch). Further the back loops are also known as reverse loops. Whether face loop or back loop, due to inter-looping or intermeshing each loop has four intermeshing points – two at the head with the loop above (next) and two at the base with the loop at the bottom (previous).

2.11.4 Single-Faced Structures and Double-Faced Structures

Single-faced structures are produced in both warp and weft knitting by needles operating as a single set. All the needles in the bed/bar face the same direction and draw the new loops downward through the old loops in the same direction, so that the intermeshing points at the head are identical with the intermeshing points at the base. As a result there will be all face loops on one side or surface of the fabric and the other side will have all back or reverse loops. The front (flatbed) or outer side (circular bed) of the fabric with all face loops which face the knitter is called ‘technical face’ of the fabric, and the back (flatbed) or inner side (circular bed) of the fabric with all back loops is called ‘technical back’ of the fabric.

Double-faced structures are produced in both warp and weft knitting when two sets of independently controlled needles are employed for loop formation. The hooks of the two sets of needles in two beds/bars face in opposite direction and thus draw their new loops from the same yarn in opposite direction. The fabric formed in the gap between the two sets of needles will have face loops made by one set of needles on one side and the face loops made by other set of needles on the opposite side. The reverse sides of the face loops made by two sets of needles generally remain hidden or become partly visible on both the surfaces. A double-faced structure which has an identical number of each type of stitch produced on each needle bed and therefore showing on each fabric surface usually in the same sequence is called a balanced structure.

2.11.5 Single Jersey and Double Jersey Fabrics

The weft knitted fabrics made with one set of needles arranged in the tricks (grooves) on one needle bed are called single jersey fabrics or plain knitted fabrics; whereas the knitted fabrics produced with two sets of needles arranged in the tricks of two different beds are called double jersey fabric. These two types of fabrics differ widely in their structure as well as their properties as detailed in the next chapter.

2.11.6 Courses, Wales and Stitch Density

A course is a horizontal row of loops produced by all the adjacent needles during the same knitting cycle. It is equivalent to a pick or weft yarn in a woven fabric. It is expressed as courses per inch (c.p.i.) or courses per centimetre (c.p.cm.). Fabric is produced by making courses in consecutive order. Number of loops in a course is equal to the number of needles in operation.

A wale is a vertical column of loops made by the same needle in successive knitting cycles. It is equivalent to warp end in a woven fabric. It is expressed as wales per inch (w.p.i.) or wales per centimetre (w.p.cm.). The total number of wales in a fabric is obtained from the total number of needles in operation. The direction of course and wale in weft knitted fabric is shown in Fig. 2.11.

Stitch density is the total number of loops in a unit area such as a square inch or a square centimeter. It is obtained by multiplying the number of courses and wales per inch or centimetre together. Courses per inch, wales per inch and stitch density are the most important parameters of a knitted fabric and are set before and calculated later very accurately for determining the quality of the knitted fabric.

2.11.7 Loop Length and Course Length

Length of yarn contained in a loop is called loop length or stitch length. Course length is length of yarn required in the production of a course. Course length is obtained by multiplying the stitch length with the number of needles involved in the production of the course. It can be measured at a yarn feed during knitting or by unravelling the yarn from the knitted fabric.

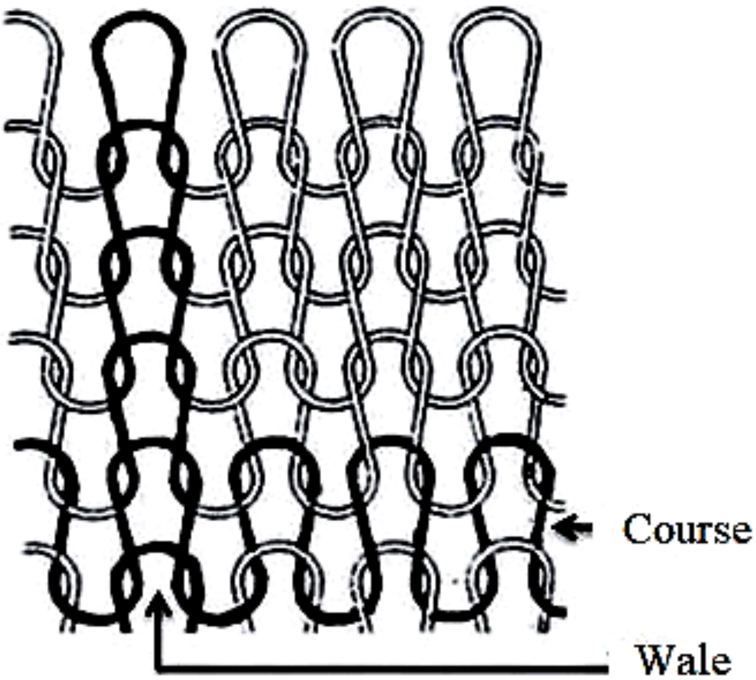


Figure 2.11 Course and Wale in knitted structure.

2.11.8 Different Situations in Loop Formation

As discussed in the previous chapter, normal loops are produced as a result of clearing, catching, casting-off and knocking-over. Moreover, the loop produced may be face loop or back loop. The normal loops – face or back – ultimately produce four basic weft knitted structures (plain, rib, interlock and purl). However to get diversity of structures, some modification is to be done in the loop forming cycle. The modification is done based on the possibility of clearing of old loop and catching of new yarn. The different possibilities of loop formation are shown in Table 2.1.

These possibilities indicate that in addition to formation of normal loops, loops such as drop stitch, tuck stitch and float stitch can be formed for design diversification. Moreover during formation of tuck and float loops, another new type of loop called held loop comes into reality.

2.11.9 Stitch Notation

The weft knitted structural units can be represented using the following methods:

(a) Line diagram

(b) Symbolic notation on graph paper

(c) Schematic or diagrammatic notation

Table 2.1 Different possibilities of loop formation

S. No.	Clearing	Catching	Situation I Remark
1.	Yes	Yes	Normal loop formation
2.	Yes	No	No knitting, fabric falls down
3.	No	Yes	Tucking or tuck loop formation
4.	No	No	Floating or float miss loop formation

Line diagram representation is easily understood by the beginner but it is comparatively difficult to produce particularly for complex designs. Generally, symbolic notation on graph paper is widely used for the representation of knitted structures. Any type of loop or knitted structure can be represented on graph paper with the help of some symbol. There are a large number of horizontal and vertical lines at equal distance which divide the paper into a large number of squares. Each square is used to represent one loop. The horizontal rows are used as courses whereas the vertical columns are used to indicate the wales in the knitted structure. The presence or absence of some particular symbol in a square indicates the various types of loops or stitches (Fig. 2.12 (a)).

(a) A cross mark (x) inside a square represents face loop.

(b) A blank circle (o) inside a square represents back loop.

(c) A dot (•) inside a square represents tuck loop.

(d) A blank square represents float or miss loop.

In addition to graphical representation, the knitted structure can be shown with the help of schematic diagram on point paper. The schematic diagram in Fig. 2.12 (b) describes the movement of the yarn across the cross- section of the needle (point) during loop formation. The techniques of representation of knitted loops as shown in Fig. 2.12 are internationally accepted and widely used in different countries. However, the symbols used in German system (DIN 62050) [1] of graphical representation knitted loops are different and are shown in Fig. 2.13.

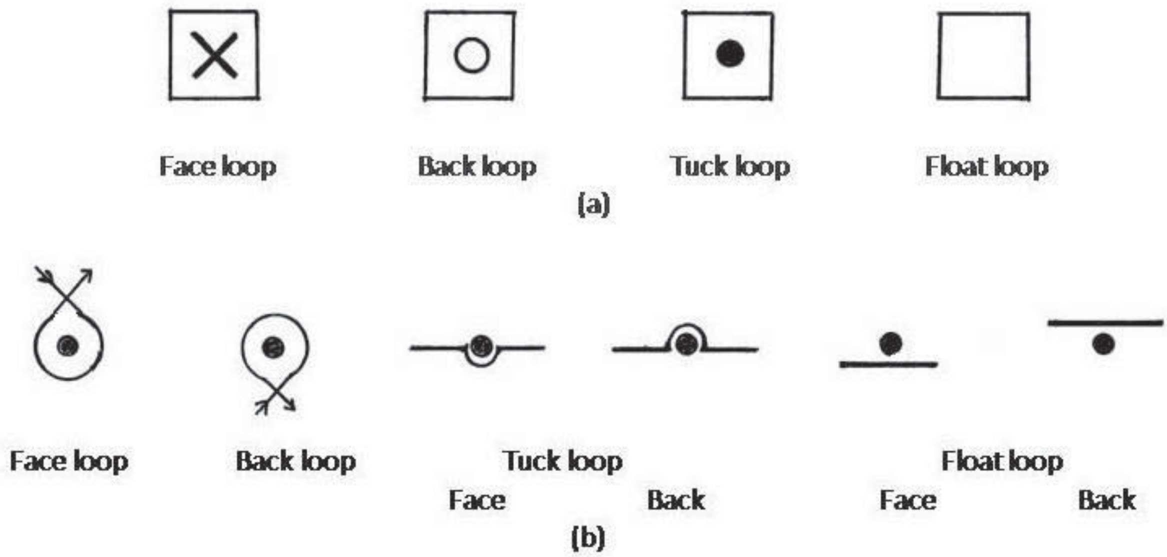


Figure 2.12 Graphical loop notation.

Figure 2.13 German notation of loop.

2.11.10 Held Loop

When an old loop is not released in due time but retained in the hook for two or more knitting cycles, then the old loop is called held loop. A held loop can only be retained by a needle for a limited number of knitting cycles before it is cast-off and a new loop is drawn through, otherwise the tension on the loop arms becomes excessive and yarn may break.

2.11.11 Tucking and Tuck Loop

If during rising, needle reaches to such a height that the old loop is not cleared but needle hook can catch new yarn during downward movement, then the old loop is not cast-off but retained in the hook as well as a new loop is formed. This situation is called tucking and the new loop is called tuck loop. The tuck loop is not intermeshed with the old (held) loop (Figure 2.14). The tuck loop along with the held loop may cast-off after one or more (generally up to 4) knitting cycles.

Since tuck loop tends to be wider than equivalent plain loop, it can be used to increase the width of the fabric but during tucking the held loop is stretched as a result when the same is cast-off and allowed to relax; it shrinks more causing more shrinkage of the fabric in the length direction.

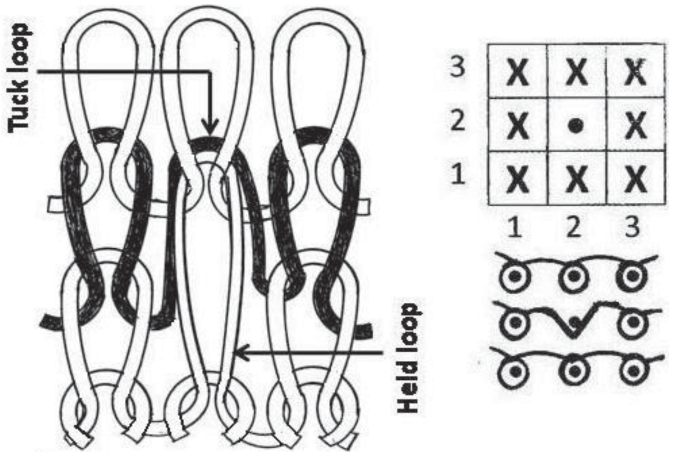


Figure 2.14 Tucked loop formation

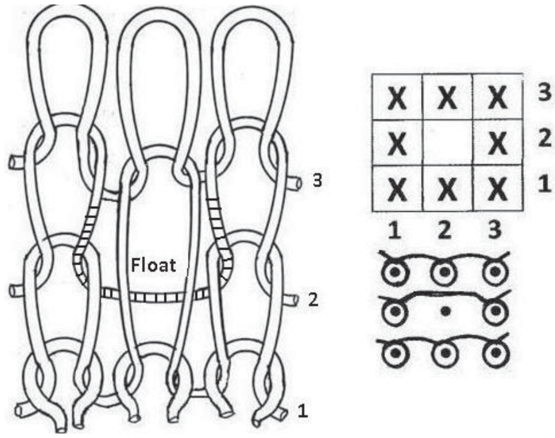


Figure 2.15 Tucked loop formation

It makes the fabric more compact and offers better dimensional stability and shape retention. Sometimes it also improves the bulk of the fabric (cardigan is an example), i.e. thickness of the fabric increases. Tuck stitch structure is generally less extensible and porous in nature. The tuck stitch can also be used for one or more of the followings:

1. Patterning and fancy effects by using coloured yarns
2. Making heavier fabric
3. Introducing special type of yarn (inflexible, thick, etc.)
4. Reducing laddering tendency in single knit structures
5. Marking the panels of garments for size or the cutting lines of armhole, neck, etc.

2.11.12 Floating and Float Loop (Or Missing and Miss Loop)

If during rising, needle reaches to such a height that neither the old loop is cleared nor the needle hook can catch new yarn during downward movement, then the old loop is not cast-off but retained in the hook as well as no new loop is formed. This situation is called floating. The yarn passes under the needle and remains straight between the neighbouring loops. The straight yarn connecting two nearest loops knitted from is called float or miss loop (Figure 2.15). The missed yarn floats freely on the reverse side of the held loop which is the technical back of the single jersey structures but is the middle of the rib and interlock structures. The held loop is extended in wale direction until a knitted loop is formed. Structures incorporating float stitches tend to exhibit faint horizontal lines, they are narrower because the wales are drawn closer together. Float stitches also reduce the width wise elasticity and improves the dimensional stability. Continuous float for maximum six adjacent needles is generally practiced. Float stitch provides a convenient way of hiding coloured yarns at the back of the fabric when they do not knit at the face. Combination of knitted and short float produces a fabric that does not ravel from the edge and for this reason they are used in welts of stockings. Fabrics made with float stitches are as follows:

1. Thinner and lighter than tuck stitched or normally knitted one
2. Narrower and less extensible
3. Flimsy or less rigid

2.11.13 Drop or Press-Off Stitch

If a needle releases the old loop but does not catch new yarn during knitting for loop formation, then knitting does not take place. As a result the needle becomes empty and loses contact with the fabric. Generally it's a fault and fabric falls down. Such a situation is termed as dropping or pressing- off. Sometimes this technique is used to achieve press-off on all needles in a set between garment length sequences. A drop stitch or press-off stitch is used very occasionally in flatbed knitting for design diversification.

2.11.14 Timing of Knitting in Circular Double Jersey Machine

The relative position of the two beds (say dial and cylinder) in a double jersey machine is changeable. This can be achieved by rotating the dial in clockwise or anti-clockwise direction. The relative position of the two beds determines the relative position of the knitting cams in the beds. According to the relative position of the knitting cams in the two beds, the adjacent dial and cylinder needles may form loops simultaneously or with a time gap. This possibility leads to two types of knitting timing – (a) synchronized timing and (b) delayed timing.

Under synchronized timing, the neighbouring dial and cylinder needles start forming loops simultaneously and reach the respective knitting points or loop forming points at the same time. In this situation, yarn is pulled out from the package simultaneously by both the needles, and knitting takes place under comparatively lower yarn tension.

When neighbouring dial and cylinder needles reach the respective knitting points with a time gap, generally the cylinder needle first makes the loop and reaches the cylinder knitting point and the neighbouring dial needle does the same job with a time gap or phase difference, the situation is called delayed timing (the reverse situation, i.e. the advanced timing generally does not occur mainly on account of mechanical designing of the machine). The time gap of loop formation by the dial and cylinder needles is expressed or measured by the number of needles or needle spaces between the two knitting points (say one needle delay, two needles delay, etc.). As the dial needle forms loop later, it finds difficult to pull yarn from the package and instead it pulls the yarn partly or fully from the cylinder loop already formed. Knitting tension is higher in this situation.

Synchronized timing results larger loop length than delayed timing. As amount of delay is adjustable, a wide range of loop length can be produced under delayed timing and that too at variable knitting tension to suit the requirement of the end products.

2.12 Basic Weft-Knitted Structures

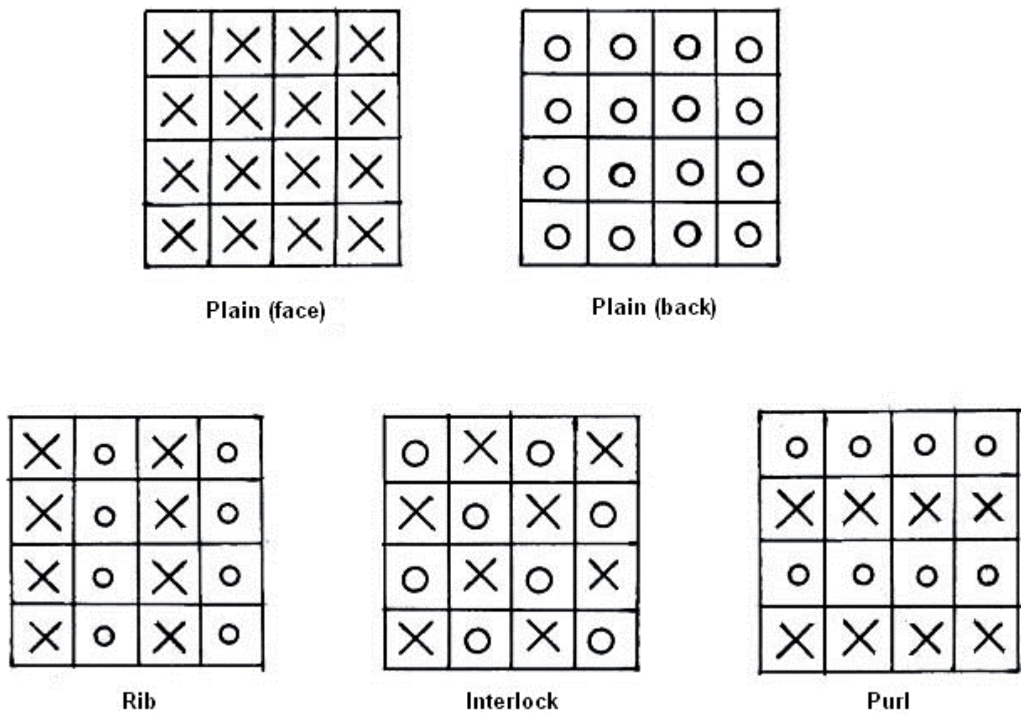
2.12.1 Introduction to Basic Weft-Knitted Structures

Plain, rib, interlock and purl are the four basic weft-knitted structures from which all other weft-knitted structures can be derived. The graphical and the schematic representations of the four basic weft-knitted structures are shown in Figs. 2.16 (a) and (b), respectively.

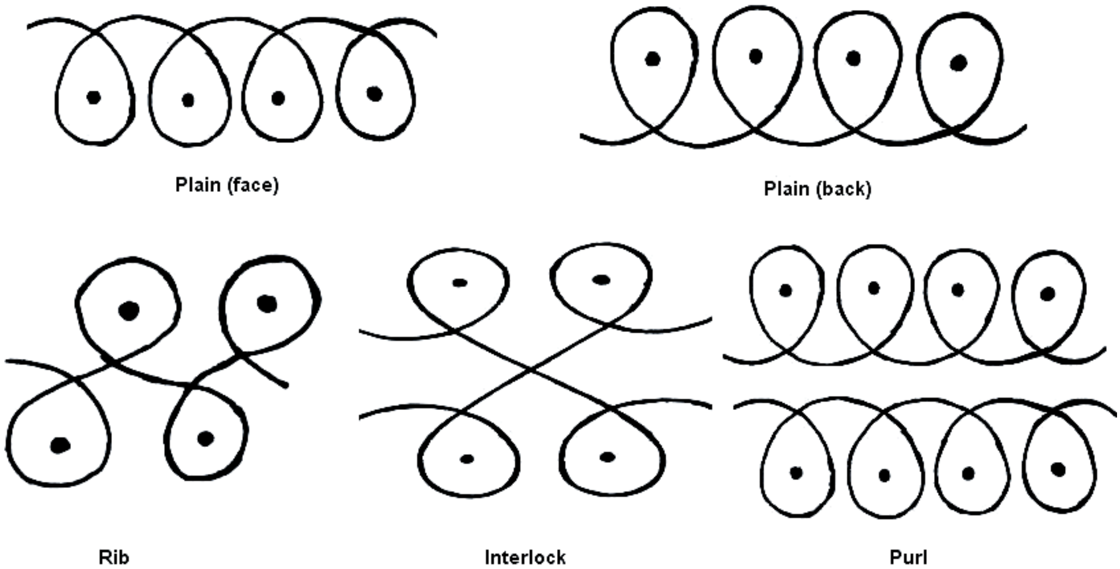
Plain structure is made on a single bed machine whereas the other three are made on double bed machines. But the arrangements of needles in the two beds are different for obtaining rib, interlock and purl structures. Further plain is made of only face loops or back/reverse loops whereas rib, interlock and purl are made of both face loops and back loops.

2.12.2 Single Jersey and Double Jersey Knitting

Single jersey horizontal knitting frame was first made in 1589 by William Lee. Single jersey machine can only produce plain. Plain is the simplest type of structure practiced since the inception of knitting technology. It can be done in hand knitting as well as machine knitting (flat and circular). Although stockings, gloves and caps were the main uses of plain hand-knitted structures in the past, now it has wide application in the manufacture of inner and outer garments.



2.16 A Graphical notation of four basic weft knitted structures.



2.16 b Schematic notation of four basic weft knitted structures.

The double jersey machine is made with two sets of needles. The second set of needles were first incorporated in the knitting frame by Jedediah Strutt in 1755 for producing a knitted structure with both face loops and back loops. The first such structure was 1 × 1 rib. Subsequently, double jersey machines were developed with modified needle gating for knitting interlock and purl structures. Double jersey machine with rib gating produces rib structures only. But, double jersey machine with interlock gating can be converted to rib gating. Double jersey purl knitting machines are capable of producing plain or rib if needed. On account of presence of two needle beds, the knitting process is complicated but offers higher possibility of manufacturing wide variety of structures required in various end uses.

2.12.3 Features of Plain (Single Jersey) Knitting (Machine, Process and Structure)

(a) Machine has only one bed which may be flat or circular.

(b) There is only one set of needles and one cam system in the machine.

(c) Minimum one yarn is needed to produce a fabric.

(d) Single-faced structure, i.e. only one type of loops – Face or Back – are visible on the surface (Fig. 2.17).

(e) Loops are V-shaped on technical face and semi-circular on technical back of the fabric.

(f) Because of side limbs of the loops on the face side, it feels smoother on face side than back side.

(g) Knitted loops tend to distort easily under tension which help to give form fitting and comfort.

(h) Fabric shortens in width if the same is extended in length by tension and vice-versa.

(i) Fabric has good extensibility in both length and width direction but width-wise extensibility is generally much higher than length-wise extensibility.

(j) Yarn /course can be unravelled from starting and ending end of knitting.

(k) Fabric curls at the free edges on flat surface – toward the front at the upper and lower edges and toward the back at left and right edges. This curling is mainly due to the unbalanced yarn bending moment existing in the three dimensional nature of the structure. Yarn bending rigidity property is responsible for curling.

(l) Because of stitch simplicity, production rate is high and machine is simple and cheap.

(m) Stitch length can be varied with stitch cam setting.

(n) Fabric shrinks in width/circumference and the extent of shrinkage is about in the range of 25–40%.

(o) Courses per inch and wales per inch in the fabric inversely vary with loop length.

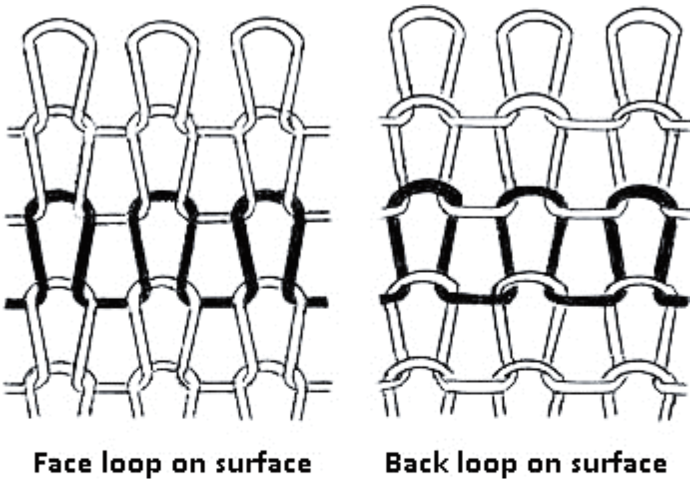
(p) Properties like rigidity, air permeability, bursting strength, etc. and GSM of the fabric change with change in loop length.

(q) Laddering (Fig. 2.18) takes place; laddering means disintegration of loops due to breakage of yarn as the intermeshed loops are held by each other at the cross-over points. The needle loops preferably unmesh down the wale.

(r) Fabric thickness is approximately two times the diameter of the yarn used.

(s) Sinker top machine is very common.

(t) Common gauge is 16–28 for circular machines and 5–12 for flat machines



2.17 Single Jersey Structure

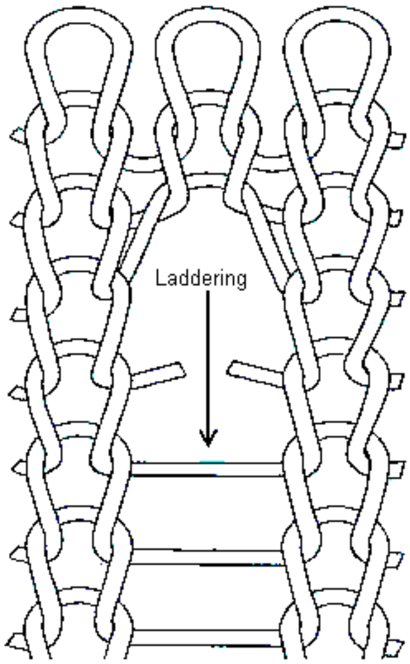


Figure 2.18 Laddering effect.

2.12.4 Features of Rib Knitting (Machine, Process and Structure)

(a) Machine has two beds – may be flat or circular.

(b) There are two sets of needles – one in each bed.

(c) There are two cam systems – one in each bed.

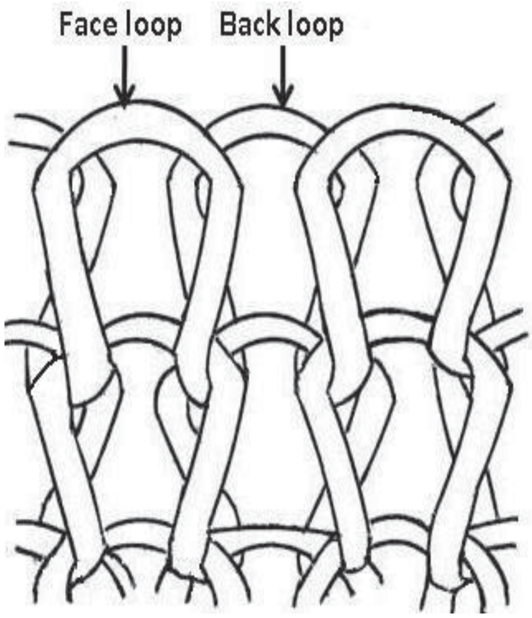
(d) Needles in the two beds are not face to face but needles in one bed are in between the needles of the other bed so that they do not touch while raised for clearing.

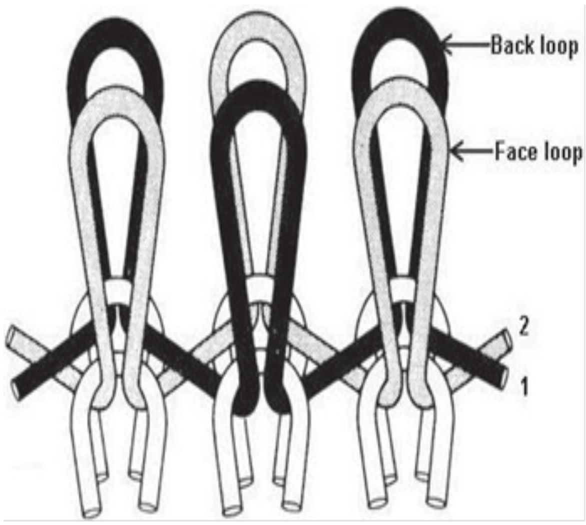
(e) Rib fabrics are double-faced structures as well as balanced structures.

(f) Both face loops and back loops are visible on both the sides of the fabric, and fabric has identical appearance in face and back.

(g) Each course is made of face loop and back loop in alternative order, the order may be 1×1, 2×2, 3×3, 6×3, etc. (Fig. 2.19).

(h) Face loops are made by the needles in front or bottom bed and back loops are made by needles in the back or top bed.





2.19 1 x 1 Rib structure 2.20 Interlock structure

(i) Fabric surface is vertically corrugated or ribbed.

(j) Fabric is much thicker, generally double, than single jersey fabric.

(k) Fabric has good extensibility in length direction, but the width-wise extensibility and the recovery are much higher than single jersey fabric which makes it suitable for neck collar, hand cuff, waist band, etc.

(l) Fabric surface is rough or harsh in feel.

(m)Fabric does not curl at the free edges.

(n) Fabric can easily be unravelled from the end last knitted.

(o) Loop length can be changed by varying dial height or vertical gap between two beds and timing of knitting in addition to stitch cam setting in both the beds.

(p) Rib machine requires finer yarn and results in comparatively costly fabric.

(q) Simplest needle gaiting is 1×1 but other combinations like 2×2, 3×3, 6×3, etc., are also possible.

(r) Minimum one yarn is needed to produce a fabric.

2.12.5 Features of Interlock Knitting (Machine, Process and Structure)

(a) Machine has two beds. Machines may be flat or circular, but generally circular.

(b) There are two sub sets of needles in each bed, the sub sets are known as short needles and long needles, respectively.

(c) Two sets of cam system, i.e. cam path in each bed accommodate short and long needles of the corresponding beds.

(d) Needles in two beds face each other – short needles in one bed face the long needles in the other bed and vice versa.

(e) Short needles in one bed make loops in conjunction with short needles in the other bed, similarly long needles in one bed make loops in conjunction with long needles in the other bed.

(f) Separate yarns are to be supplied to the short needles and long needles for loop formation through separate feeders.

(g) Short needles and long needles don't make loop simultaneously but with a time gap.

(h) Loops made by one set of needles are locked by the loops made by the other set of needles.

(i) Each interlock course is composed of two rib courses (Fig. 2.20).

(j) Minimum two yarns are needed to produce a fabric.

(k) Fabric has double faced as well as very stable structure.

(l) Fabric surface is smooth.

(m)Fabric is equally thicker to rib but much more compact.

(n) Fabric neither curls nor ladder.

(o) Like rib, interlock can be made of different combination of needle gaiting.

(p) Interlock fabric made from 2×2 needle gaiting or 2×2 rib is known as eight lock fabric, as there are total eight loops in a unit of interlock loop.

(q) Machine is complicated and costly.

(r) Fabrics are dimensional stable, heavy and costly.

2.12.6 Features of Purl Knitting (Machine, Process and Structure)

(a) Machine has two beds. Machines may be flat or circular.

(b) There is only one set of needles which change the bed in alternative knitting cycle.

(c) Needles are of special type; generally double hooked latch needles are used.

(d) Needles are shifted from one bed to another bed with the help of sliders (Fig. 2.21b). Two sliders are needed for each needle.

(e) Same needle makes face loop in one bed and back loop in other bed.

(f) Alternative courses are made of all face loops and all back loops. As a result each wale is made of face loop and back loop in alternative order (Fig. 2.22 a).

(g) Fabric has horizontal corrugation or rib appearance on the surfaces, i.e. opposite to rib fabric.

(h) Fabric is reversible in appearance and has soft handle.

(i) Fabric has very high extensibility in length direction, making it suitable for kids wear.

(j) Fabric does not curl at the edges because of alternate face and back loop courses.

(k) The knitting sequence or needle gating can be changed to produce rib and plain structures on one hand, and derivatives like moss purl, basket purl, etc., on the other.

(l) Machines are very rare.

The shapes of double hooked latch needle and slider are also shown in Fig. 2.22.

2.12.7 Comparison between Rib and Interlock Knitting

From the features mentioned in sections 2.12.4 and 2.12.5, it is observed that there are many differences between rib and interlock knitting, although both are double jersey knitting. The comparison between rib and interlock knitting is shown in Table 2.2.

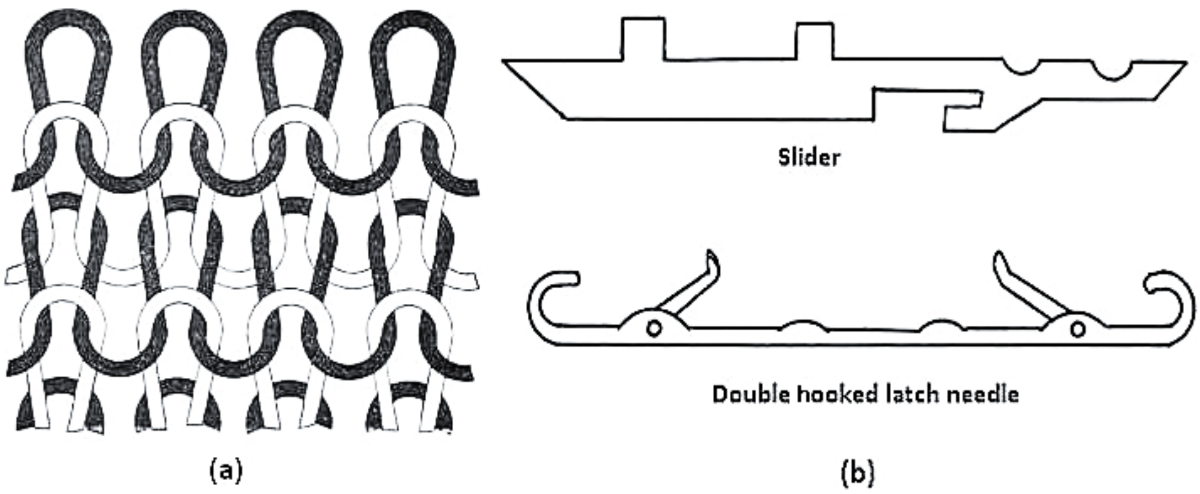


Figure 2.22 (a) Purl structure (b) double hooked latch needle and slider

Table 2.2 Comparison of Rib and Interlock Knitting

	Rib Knitting	**Interlock Knitting**
1.	Knitting takes place in double bed machine	Knitting takes place in double bed machine
2.	One set of needles in each bed	Two sets of needles in each bed - short needles and long needles
3.	One cam track in each bed	Two cam tracks in each bed
4.	Needles in two opposite beds are not face to face but in between	Needles in two beds face each other - short needles in one bed face the long needles in the other bed and vice versa
5.	Each rib course is made of one yarn	Each interlock course is made of two yarns
6.	Fabric has corrugation or rib appearance in length direction	No rib effect on fabric surface

7.	Fabric surface is rough	Fabric surface is smooth
8.	Fabric is highly extensible particularly in the width wise direction	Fabric extensibility is less
9.	Fabric is less compact and less dimensional stable	Fabric is more compact and more dimensional stable
10.	Machine is comparatively simpler and less costly	Machine is comparatively complicated and more costly
11.	Interlock knitting is not possible in rib machine	Rib knitting is possible in interlock machine

2.12.8 Comparison between Rib and Purl Knitting

It is observed from the features mentioned in sections 2.12.4 and 2.12.6 that there are many differences between rib and purl knitting, although both are double jersey knitting. Table 2.3 shows the comparison between rib and purl knitting.

Table 2.3 Comparison of Rib and Purl Knitting

Rib Knitting	Purl Knitting
1. Knitting takes place in double bed machine	Knitting takes place in double bed machine
2. Two sets of needles - one in each bed makes loop	Only one set of needles which makes loop in both the beds
3. Needles do not change the bed	Needles change the bed in alternative knitting cycle
4. Ordinary latch needles are used	Special type double hooked latch needles are used
5. No sliders are needed for loop formation	Sliders are needed for shifting of the needles from one bed to the other
6. Each course is made of face loop and back loop in alternative order	Alternative courses are made of all face loops and all back loops
7. Fabric has corrugation or rib appearance in lengthwise direction	Fabric has corrugation or rib appearance in appearance in width wise direction
8. Fabric has very high width wise extensibility which makes it suitable for for collar neck, hand cuff, waist band etc.	Fabric has very high lengthwise extensibility which makes it suitable for manufacturing garments for kids.
9. Only face loops are visible on the surface	Both face and back loops are visible on the surface
10. One of the typical derivative of pure rib is cardigan structure	One of the typical derivative of pure purl is basket purl

2.12.9 Comparison of Basic Weft-Knitted Structures

The appearance, properties and end applications of plain, 1×1 rib, 1×1 purl and interlock structures are summarized in Table 2.4.

These basic stitches are often combined together in one fabric to produce an enormous range of single- and double-jersey fabrics or garments. The weft-knitted fabrics are produced commercially for apparel, household and technical products and are used for an extremely large array of products and tights to imitation furs and rugs. Very recently, the knitted fabrics are being increasingly designed and developed for technical products ranging from scouring pads to fully fashioned nose cones for super-sonic aircrafts.

Table 2.4 Comparison of Basic Weft-Knitted Structures

Property	Plain	1x1 Rib	1x1 Purl	Interlock
Appearance	Different in face & back, V-shapes in face & arcs on back	Same on both sides, like face of plain	Same on both sides, like face of plain	Same on both sides, like face of plain
Extensibility - Lengthwise	Moderate (10-20%)	Moderate	Very high	Moderate
Width wise Area	High (30-50%)	Very high (>50%)	High	Moderate
Thickness and Warmth	Thicker and warmer than plain woven made from same yarn	Much thicker and warmer than plain	Much thicker and warmer than plain	Very much thicker and warmer than plain
Unravelling	Either ends	Only from end knitted last	Either ends	Only from end knitted last
Curling	Tendency to curl	No tendency to curl	No tendency to curl	No tendency to curl
End-uses	Inner garments, stockings, T-shirts and dresses, base fabric for coating	Outerwear, Socks, knitwear, under-wear, Collar, cuffs & waist bands in different garments	Children's clothing, knitwear, heavy outerwear	Underwear, trouser suits, shirts, dresses, sportswear,

2.13 Weft Knitted Structures

Four primary structures – plain, rib, interlock and purl – are the base structures from which all weft knitted fabrics and garments are derived. Each is composed of a different combination of face and reverse meshed stitches, knitted on a particular arrangement of needle beds. Each primary structure may exist alone, in a modified form with stitches other than normal cleared loops, or in combination with another primary structure in a garment-length sequence. All weft knitted fabric is liable to unravel (unravel), or ladder, from the course knitted last, unless special 'locking courses' are knitted, or unless it is specially seamed or finished.

Plain is produced by the needles knitting as a single set, drawing the loops away from the technical back and towards the technical face side of the fabric. Rib requires two sets of needles operating in between each other so that wales of face stitches and wales of reverse stitches are knitted on each side of the fabric.

Interlock was originally derived from rib but requires a special arrangement of needles knitting back-to-back in an alternate sequence of two sets, so that the two courses of loops show wales of face loops on each side of the fabric exactly in line with each other, thus hiding the appearance of the reverse loops.

Purl is the only structure having certain wales containing both face and reverse meshed loops. A garment-length sequence, such as a ribbed half-hose, is defined as purl, whereas smaller sections of its length may consist of plain and rib sections.

Although in the past structures of this type were knitted only on flat bed and double cylinder purl machines employing double-ended latch needles, electronically controlled V-bed flat machines with rib loop transfer and racking facilities are now used.

• Single-jersey machines can only produce one type of base structure.

• Rib machines, particularly of the garment-making type, can produce sequences of plain knitting by using only one bed of needles.

• Interlock machines can sometimes be changed to rib knitting.

• Purl machines are capable of producing rib or plain knitting sequences by retaining certain needle arrangements during the production of a garment or other knitted article.

2.13.1 Plain Structure:

Plain (the stocking stitch of hand knitting) is the base structure of ladies' hosiery, fully fashioned knitwear and single-jersey fabrics. Its use in ladies' suiting was popularized by Lily Langtry (1852–1929), known as the 'Jersey Lily' after her island birthplace. Other names for plain include stockinette, whilst in the USA the term 'shaker stitch' is applied to it when knitted in a coarse gauge of about 31–2 needles per inch (25mm). The term 'plain knit' may be used instead of just 'plain', particularly when the structure has a surface design. Its technical face (Fig. 2.23) is smooth, with the side limbs of the needle loops having the appearance of columns of V's in the wales. These are useful as basic units of design when knitting with different coloured yarns. On the technical back, the heads of the needle loops and the bases of the sinker loops form columns of interlocking semi-circles (Fig. 2.23), whose appearance is sometimes emphasized by knitting alternate courses in different coloured yarns. Plain can be unravelled from the course knitted last by pulling the needle loops through from the technical back, or from the course knitted first by pulling the sinker loops through from the technical face side. Loops can be prevented from unravelling by binding-off. If the yarn breaks, needle loops successively unmesh down a wale and sinker loops unmesh up a wale; this structural breakdown is termed laddering after 'Jacob's Ladder'. Laddering is particularly prevalent in ladies' hosiery, where loops of fine smooth filaments are in a tensioned state; to reduce this tendency, certain ladder-resist structures have been devised. The tendency of the cut edges of plain fabric to unravel and fray when not in tubular or flat selvedge form can be overcome by securing them during seaming.

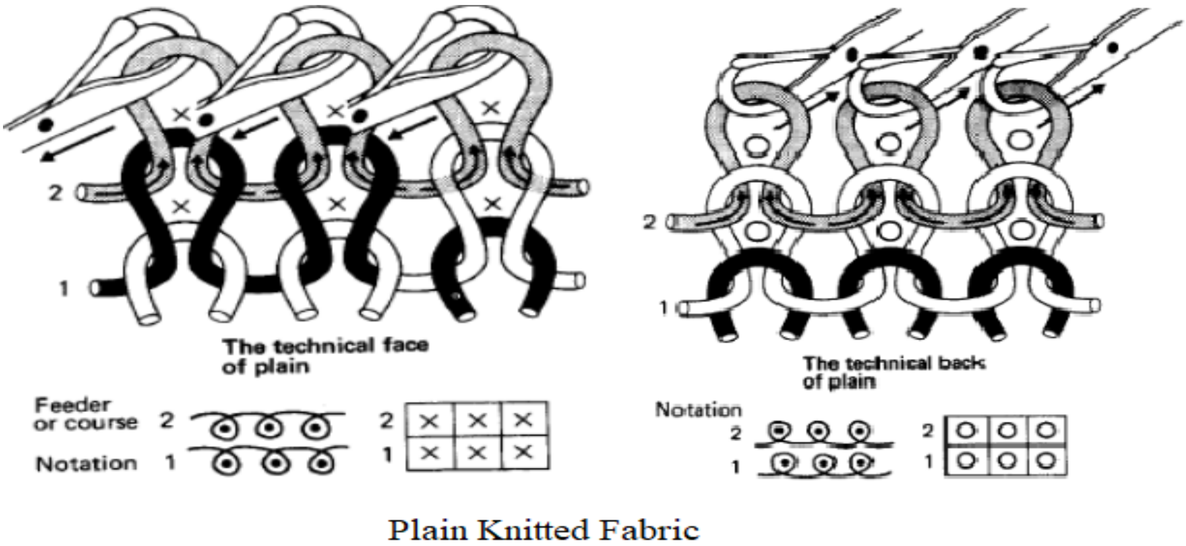


Figure 2.23 Plain Knitted Fabric

2.13.2 Rib Structure

The simplest rib fabric is 1 X 1 rib. The first rib frame was invented by Jedediah Strutt of Derby in 1755, who used a second set of needles to pick up and knit the sinker loops of the first set. It is now normally knitted with two sets of latch needles Rib has a vertical cord appearance because the face loop wales tend to move over and in front of the reverse loop wales. As the face loops show a reverse loop intermeshing on the other side, 1 X 1 rib has the appearance of the technical face of plain fabric on both sides until stretched to reveal the reverse loop wales in between. Please refer Fig. 2.24

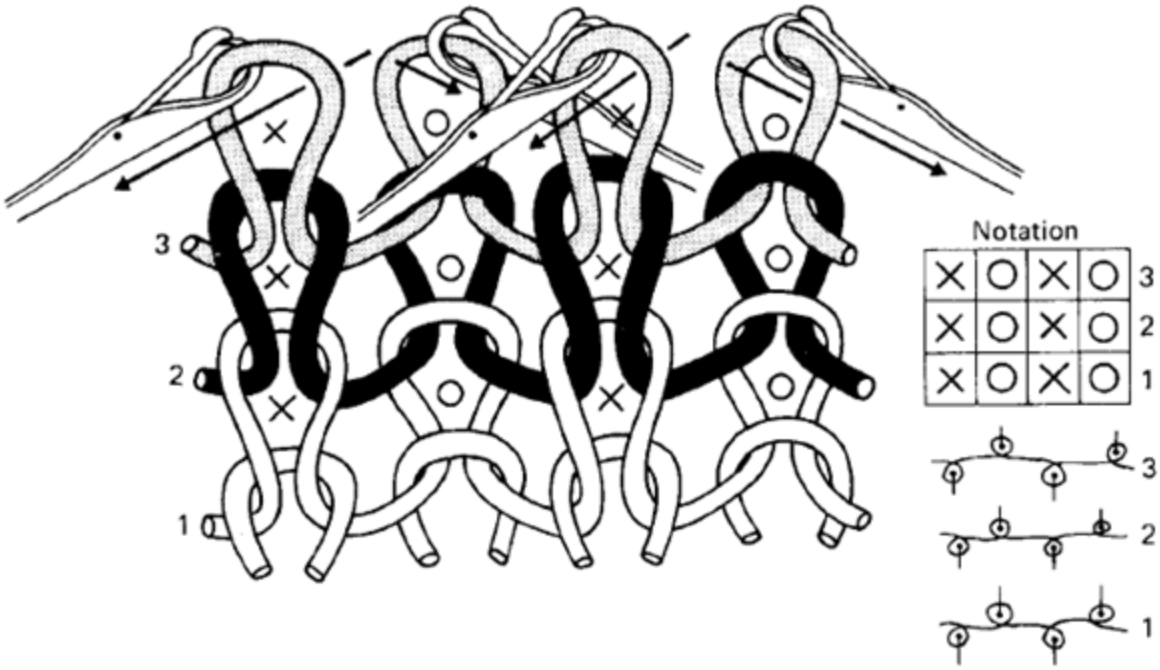


Fig. 2.24 Face and reverse loop wales in 1 × 1 rib.

1 X 1 rib is production of by two sets of needles being alternately set or gated between each other. Relaxed 1 X 1 rib is theoretically twice the thickness and half the width of an equivalent plain fabric, but it has twice as much width-wise recoverable stretch. In practice, 1 X 1 rib normally relaxes by approximately 30 per cent compared with its knitting width.

1 X 1 rib is balanced by alternate wales of face loops on each side; it therefore lies flat without curl when cut. It is a more expensive fabric to produce than plain and is a heavier structure; the rib machine also requires finer yarn than a similar gauge plain machine. Like all weft-knitted fabrics, it can be unravelled from the end knitted last by drawing the free loop heads through to the back of each stitch. It can be distinguished from plain by the fact that the loops of certain wales are withdrawn in one direction and the others in the opposite direction, whereas the loops of plain are always withdrawn in the same direction, from the technical face to the technical back.

Mock Rib is plain fabric knitted on one set of needles, with an elastic yarn inlaid by tucking and missing so that the fabric concertinas and has the appearance of 1 X 1 rib. It is knitted at the tops of plain knit socks and gloves.

Rib cannot be unravelled from the end knitted first because the sinker loops are securely anchored by the cross-meshing between face and reverse loop wales. This characteristic, together with its elasticity, makes rib particularly suitable for the extremities of articles such as tops of socks, cuffs of sleeves, rib borders of garments, and stolling and strapping for cardigans. Rib structures are elastic, form-fitting, and retain warmth better than plain structures.

There is a range of rib set-outs apart from 1 X 1 rib. The first figure in the designation indicates the number of adjacent plain wales and the second figure, the number of adjacent rib wales. Single or simple ribs have more than one plain wale but only one rib wale, such as 2/1, 3/1, etc. Broad ribs have a number of adjacent rib as well as plain wales, for example, 6/3 Derby Rib. Adjacent wales of the same type are produced by adjacent needles in the same bed, without needles from the other bed knitting in between them at that point.

The standard procedure for rib set-outs is to take out of action in one bed, one less needle than the number of adjacent needles required to be working in the other bed.

In the case of purl machines, the needles knit either in one bed or the other, so there are theoretically the same number of needles out of action in the opposite bed as are knitting in the first. In the case of 2/2 rib, Swiss rib, this is produced on a rib machine by taking one needle out of action opposite the two needles knitting.

Swiss rib is sometimes confusingly termed 2/3 rib because 2 out of 3 needles in each bed are knitting. It is not possible to commence knitting on empty needles with the normal 2 X 2 arrangement because the two needles in each bed will not form individual loops – they will make one loop across the two hooks. One needle bed must be racked by one needle space so that the 2 X 2 needle set-out is arranged for 1 X 1 rib; this is termed 'skeleton 1 X 1'; after knitting the set-up course, the bed is racked back so that 2 X 2 rib knitting can commence.

English rib is produced on a purl machine (or rib machine) with two empty tricks opposite to the two needles knitting; this type of rib is less elastic than Swiss rib. In garment-length knitting, a direct change of knitting from 2 X 2 to 1 X 1 rib brings every third needle into action. At the first course, the limbs of the loops knitted on these formerly empty needles open out, producing apertures between every two wales that spoil the appearance of the structure. This problem is overcome by knitting a tubular cover course of plain on all needles in one bed, then on all needles in the other bed. On each side, the sinker loops draw the wales together and prevent the loops on the newly-introduced needles from forcing the wales apart.

2.13.3 Interlock Structure

Although the American Scott and Williams Patent of 1908 for interlock was extended for 20 years, underwear manufacturers found the needles expensive, especially on the larger 20 inch (51 cm) diameter model. Suitable hosiery twist cotton yarn only became available in 1925, and the first stationary cam-box machine appeared in 1930.Originally, interlock was knitted almost solely in cotton on 20 gauge (needles per inch) machines for underwear, a typical weight being 5 oz per square yard (170 g per square metre) using 1/40’s s cotton, but from the 1950s onwards, 18 gauge machines were developed for knitting double-jersey for semi-tailored suiting because the open-width fabric could be finished on existing equipment. As the machines became more versatile in their capabilities, the range of structures became greater. Interlock has the technical face of plain fabric on both sides, but its smooth surface cannot be stretched out to reveal the reverse meshed loop wales because the wales on each side are exactly opposite to each other and are locked together (Fig. 2.25). Each interlock pattern row (often termed an ‘interlock course’) requires two feeder courses, each with a separate yarn that knits on separate alternate needles, producing two half-gauge 1 X 1 rib courses whose sinker loops cross over each other. Thus, odd feeders will produce alternate wales of loops on each side and even feeders will produce the other wales.

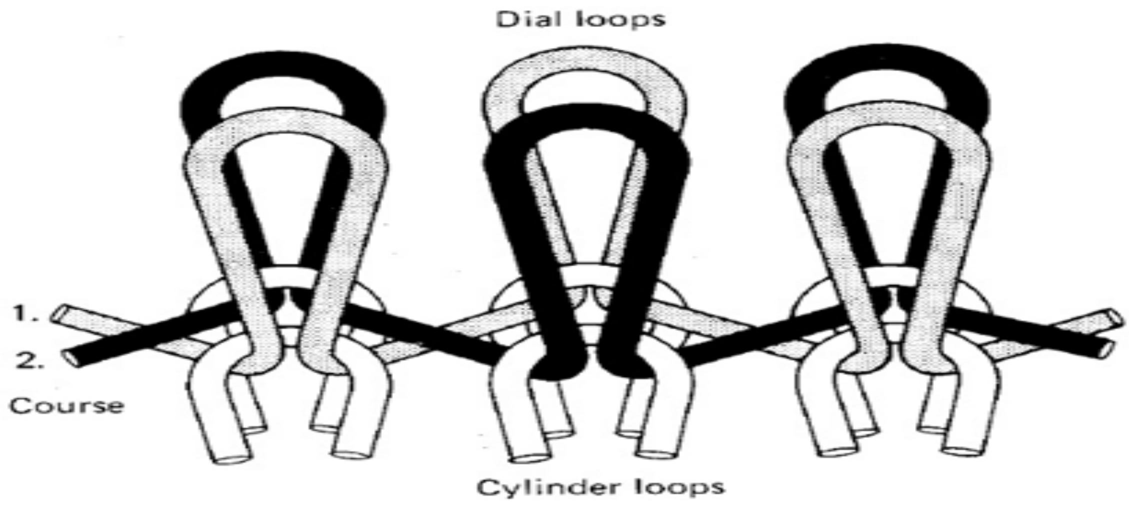


Fig. 2.25 Interlock fabric structure.

Interlock relaxes by about 30–40 per cent or more, compared with its knitted width, so that a 30-inch (76 cm) diameter machine will produce a tube of 94-inch (2.4 m) open width which finishes at 60–66 inches (1.5–1.7m) wide. It is a balanced, smooth, stable structure that lies flat without curl. Like 1 X 1 rib, it will not unravel from the end knitted first, but it is thicker, heavier and narrower than rib of equivalent gauge, and requires a finer, better, more expensive yarn.

As only alternate needles knit at a feeder, interlock machines can be produced in finer gauges than rib, with less danger of press-offs. Interlock knitting is, however, more of a problem than rib knitting, because productivity is half, less feeders can be accommodated, and there are finer tolerances. When two different-coloured yarns are used, horizontal stripes are produced if the same colour is knitted at two consecutive feeders, and vertical stripes if odd feeders knit one colour and even feeders knit the other colour. The number of interlock pattern rows per inch is often double the machine gauge in needles per inch. The interlock structure is the only weft knitted base not normally used for individual needle selection designs, because of the problems of cylinder and dial needle collision. However, selection has, in the past, been achieved by using four feeder courses for each pattern row of interlock, long and short cylinder needles not selected at the first two feeder courses for colour A being selected at the second two feeders for colour B. This knitting sequence is not cost effective.

Eight lock is a 2 X 2 version of interlock that may be produced using an arrangement of two long and two short needles, provided all the tricks are fully cut through to accommodate them and knock-over bits are fitted to the verges to assist with loop formation on adjacent needles in the same bed.

It was first produced on double-system V-bed flat machines having needles with two butt positions, each having its own cam system. This involved a total of eight locks, four for each needle bed, making one complete row per traverse. Set-outs for 4 X 4 and 3 X 3 can also be produced.

It is a well-balanced, uniform structure with a softer, fuller handle, greater width wise relaxation, and more elasticity than interlock. Simple geometric designs with a four wale wide repeat composed of every two loops of identical colour, can be achieved with careful arrangement of yarns.

Production of Interlock Fabric

Interlock is produced mainly on special cylinder and dial circular machines and on some double-system V-bed flat machines. An interlock machine must have the following:

1 Interlock gating, the needles in two beds being exactly opposite each other so that only one of the two can knit at any feeder.

2 Two separate cam systems in each bed, each controlling half the needles in an alternate sequence, one cam system controlling knitting at one feeder, and the other at the next feeder.

3 Needles set out alternately, one controlled from one cam system, the next from the other; diagonal and not opposite needles in each bed knit together.

Originally, the interlock machine had needles of two different lengths, long needles knitting in one cam-track and short needles knitting in a track nearer to the needle heads. Long needle cams were arranged for knitting at the first feeder and short needle cams at the second feeder. The needles were set out alternately in each bed, with long needles opposite to short needles. At the first feeder, long needles in cylinder and dial knit, and at the second feeder short needles knit together; needles not knitting at a feeder follow a run-through track. On modern machines the needles are of the same length. Please refer Fig.2.26.

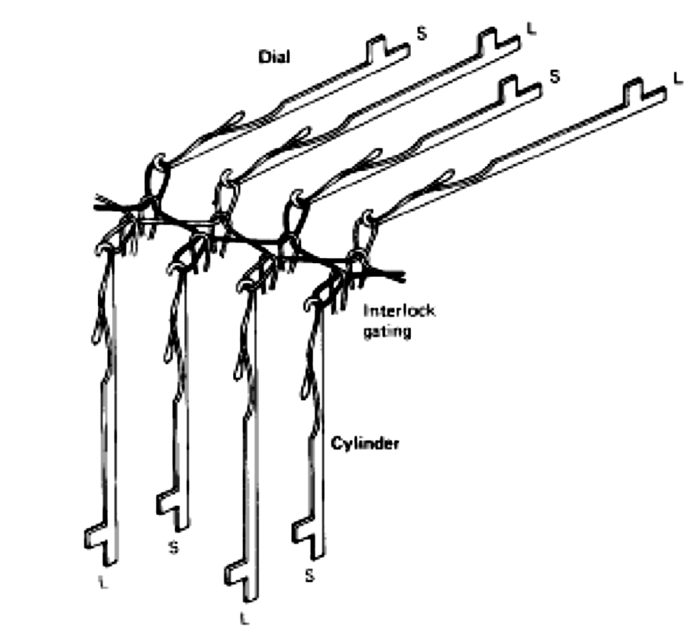


Figure 2.26 Interlock Knitting

Figure 2.27 shows the cylinder and dial needle camming to produce one course of ordinary interlock fabric, which is actually the work of two knitting feeders. In this example, the dial has a swing tuck cam that will produce tucking if swung out of the cam-track and knitting if in action.

The Cylinder Cam System

A Clearing cam which lifts the needle to clear the old loop.

B, C Stitch and guard cams respectively, both vertically adjustable for varying stitch length.

D Upthrow cam, to raise the cylinder needle whilst dial needle knocks-over.

E, F Guard cams, to complete the track.

G, H Guide cams that provide the track for the idling needles.

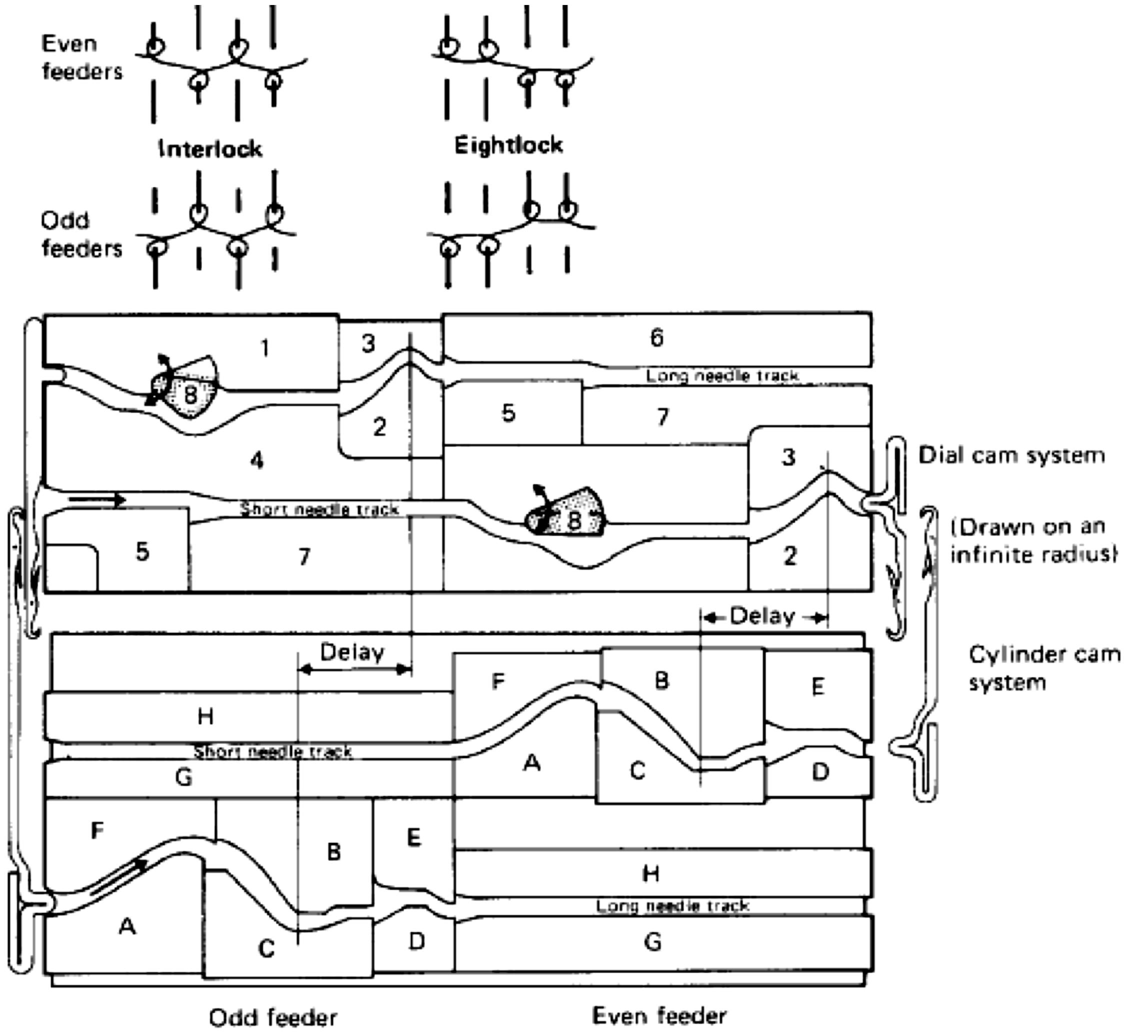


Fig. 2.27 Interlock cam system.

The Dial Cam System

1 Raising cam to tuck position only.

2, 3 Dial knock-over cams (adjustable).

4 Guard cam to complete the track.

5 Auxiliary knock-over cam to prevent the dial needle re-entering the old loop.

6, 7 Guide cams that provide the track for the idling needles.

8 Swing type clearing cam, which may occupy the knitting position as shown at feeder 1 or the tuck position as shown at feeder 2.

Interlock thus requires eight cam systems or locks in order to produce one complete course, two cam systems for each feeder in each needle bed. Basic cylinder and dial machines and flat-machines having this arrangement are often referred to as eight lock machines.

2.13.4 Purl structure:

Purl was originally spelt 'pearl' and was so named because of its similar appearance to pearl droplets. Purl structures have one or more wales which contain both face and reverse loops. This can be achieved with double-ended latch needles or by rib loop transfer from one bed to the other, combined with needle bed racking. The semi-circles of the needle and sinker loops produced by the reverse loop intermeshing tend to be prominent on both sides of the structure and this has led to the term 'links-links' being generally applied to purl fabrics and machines. Links is the German word for left and it indicates that there are left or reverse loops visible on each side of the fabric. In a similar manner, the German term for rib is rechtsrechts (right-right).The tricks of the two needle beds in purl machines are exactly opposite to each other and in the same plane, so that the single set of purl needles, each of which has a hook at either end, can be transferred across to knit outwards from either bed (Fig. 2.28). Knitting outwards from one bed, the needle will produce a face meshed needle loop with the newly-fed yarn whilst the same needle knitting outwards with its other hook from the opposite bed will produce a reverse meshed needle loop. As the needle moves across between the two needle beds, the old loop slides off the latch of the hook that produced it and moves along the needle towards the other hook. It cannot enter because it will pivot the latch closed (an action that must not occur until the new yarn has been fed to that hook).

The needle hook that protrudes from the bed knits with the yarn whilst the hook in the needle trick acts as a butt and is controlled by an element termed a slider. There is a complete set of sliders with their noses facing outwards from each bed. It is the sliders whose butts are controlled by the knitting and needle transfer cam systems in each bed and they, in turn, control the needles.

Each slider is normally provided with two butts – a knitting butt (K) near to its head and the needle hook that is connected to it, and a transfer butt (T) near to its tail. Each butt has its own cam system and track.

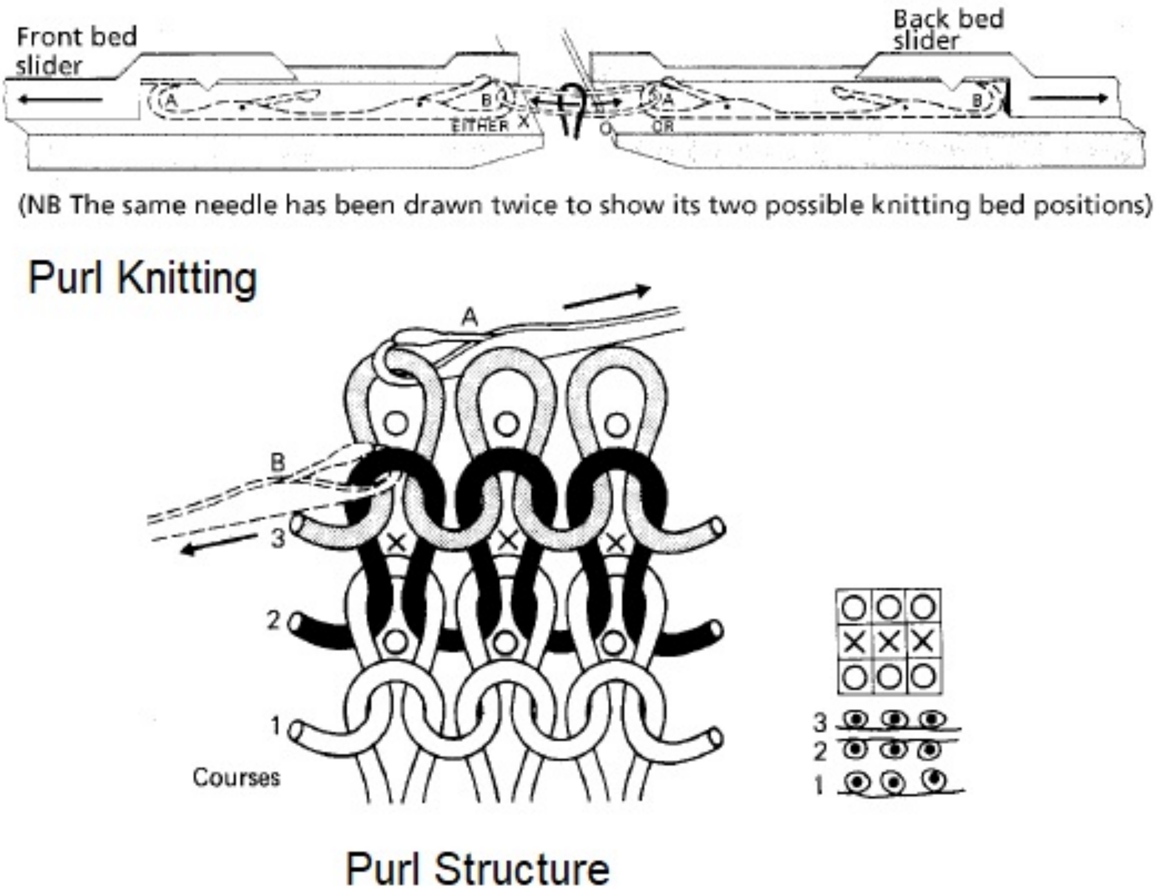


Figure 2.28 Purl Knitting

There are two types of purl needle bed machine – flat bed purls, which have two horizontally opposed needle beds and circular purls (double cylinder machines), which have two superimposed cylinders one above the other. Both types of machine generally produce garment lengths.

Flatbed purls are no longer built because electronically-controlled V-bed flat machines can now knit types of links-links designs. Small diameter (6 inch/15cm or less) double cylinder machines are used to knit broad rib socks, whereas larger diameter machines produce knitwear. V-bed rib machines will knit purl stitch designs if rib loops are transferred across to empty needles in the opposing bed, which then begin to knit in the same wales.

The simplest purl is 1 X 1 purl, which is the garter stitch of hand knitters and consists of alternate courses of all face and all reverse loops and is produced by the needles knitting in one bed and then transferring over to the other bed to knit the next course. Its lateral stretch is equal to plain, but its length-wise elasticity is almost double. When relaxed, the face loop courses cover the reverse loop courses, making it twice as thick as plain. It can be unravelled from both ends because the free sinker loops can be pulled through at the bottom of the fabric. In the USA,

1 X 1 purl is sometimes made up at right angles to the knitting sequence and is then termed ‘Alpaca stitch’.

Another simple purl is moss stitch, which consists of face and reverse loops in alternate courses and wales. Basket purls consist of rectangular areas of all X or all O loops, which alternate with each other. Examples include 5 X 3 (Fig. 7.21), 7 X 3, 4 X 4. On some of the older machines, a collecting row with all needles knitting in one bed making a plain course is necessary before needles change over beds.

The reverse stitches of purl give it the appearance of hand knitting and this is enhanced by using softly spun yarns. It is particularly suitable for baby wear, where width and length stretch is required, and also for adult knitwear.

The double-cylinder half-hose machine is actually a small diameter purl machine that produces ribs by retaining needles in the same set-out for a large number of successive courses.

2.13.5 Some Popular Extended Basic Double Jersey Structures

The simplest type of rib, interlock and purl structures are shown and discussed in the foregoing. As the ultimate properties of the fabric depend on structure, these structures are sometimes extended to achieve some properties like thickness, extensibility, form fitting, etc., including aesthetic value required for specific end uses. Graphical representation of a few of such basic double jersey structures are shown in Fig. 2.29.

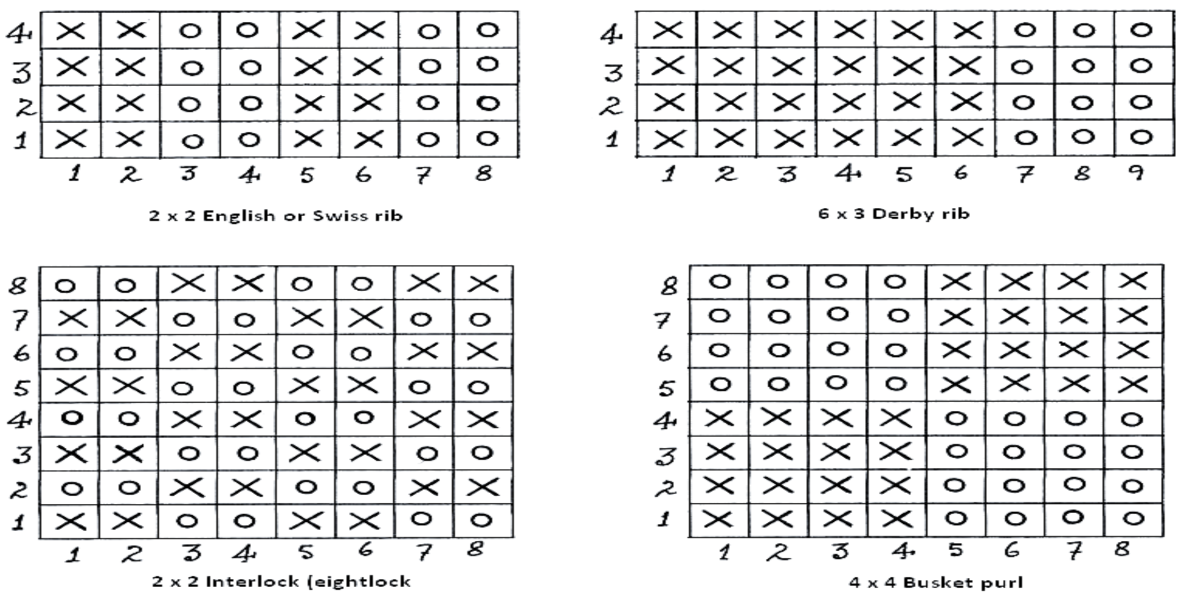


Figure 2.29 Double Jersey structures

2.13.6 Some Special Knitted Designs/Structures

The incorporation of tuck and float stitches with the help of any needle selection device may produce a lot of new structures with special characteristics and physical appearances making them suitable for various diversified applications. Such diversification may be associated with both single jersey and double jersey (rib and interlock) structures. The graphical representations of a few of such diversified structures have been show in Fig. 2.30, 2.31 and 2.32.

Further two or more coloured yarns may be used during knitting for value addition i.e., aesthetic value in one hand and better marketability on the other. Addition of more than one colours results horizontal stripe, vertical stripe, check or some special effect depending upon the combination of coloured yarns and the order of selection of needles making the loops using different colours. Production of stripe in width direction (course wise) is very simple. It does not require any specific order of needle selection but arrangement of coloured yarns in regular order (interval) during feeding will produce the desired effect. However to produce special effect or motif, selection of needle is essential along with feeding two or more coloured yarns. Generally two or more colours are used in the same course (resultant) to produce the desired effect and accordingly two or more neighbouring feeders make one complete course with proper needle selection. A few multi-coloured weft knitted structures are shown in Fig. 2.33. However, in order to make black and white representation of the coloured effect the presence of different colours on the surface of the knitted structures have been shown by the characters R, G, B etc. where R, G, B etc. stands for different colours.

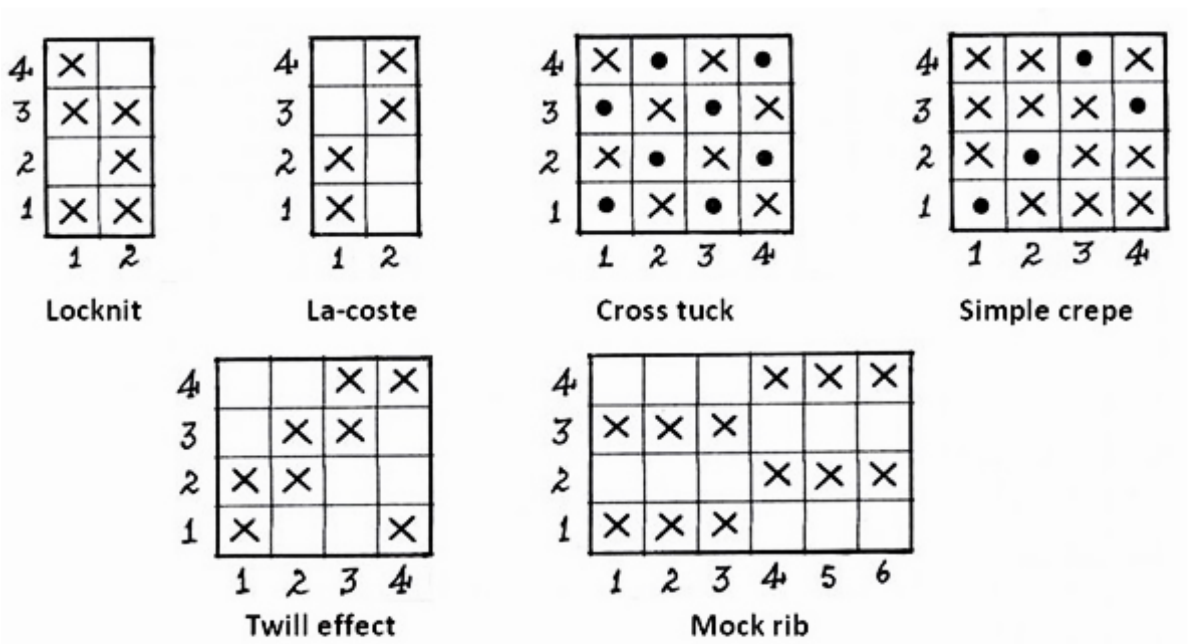
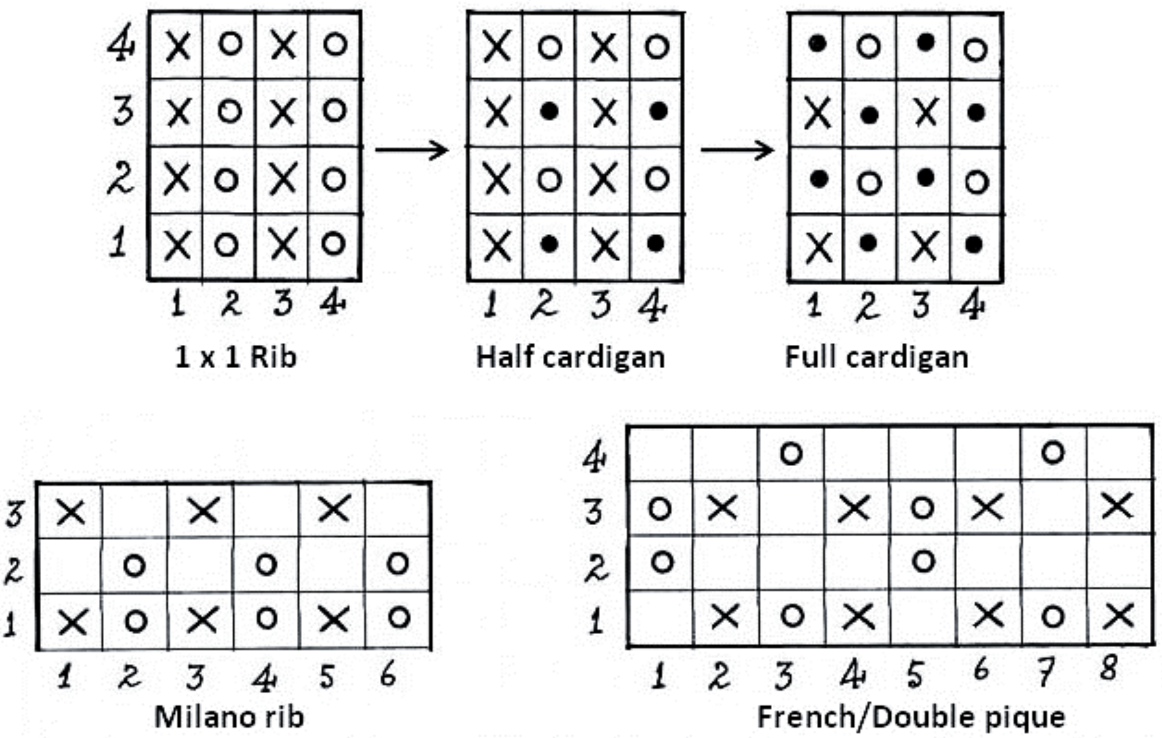


Figure 2.30 Diversified single jersey structures.



2.31 Diversified rib structures.

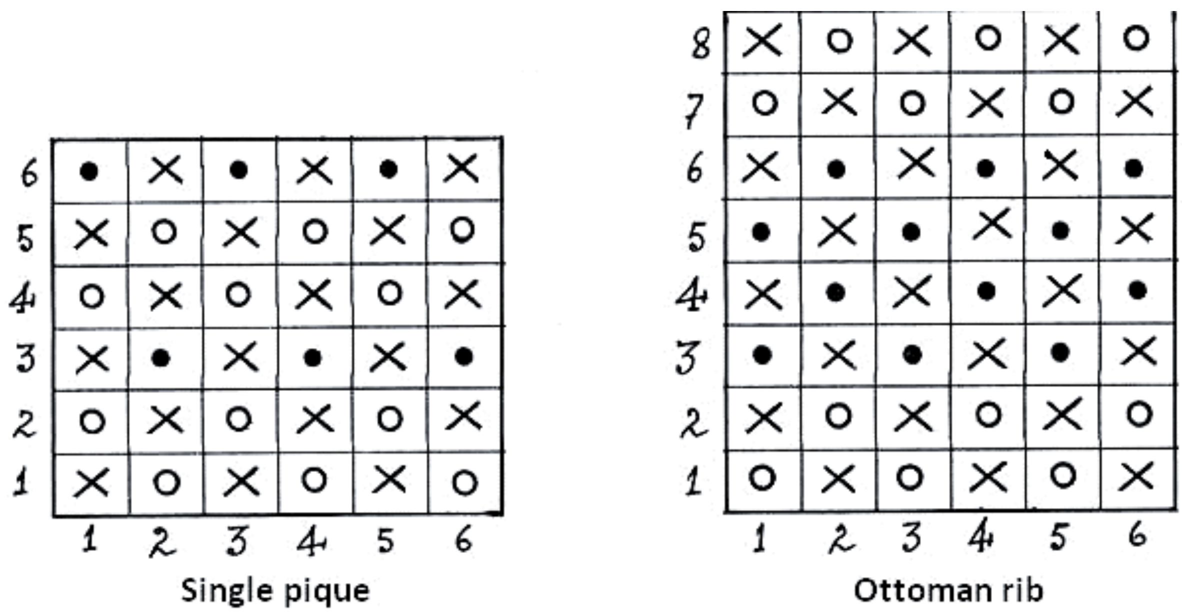


Figure 2.32 Diversified plain structures.

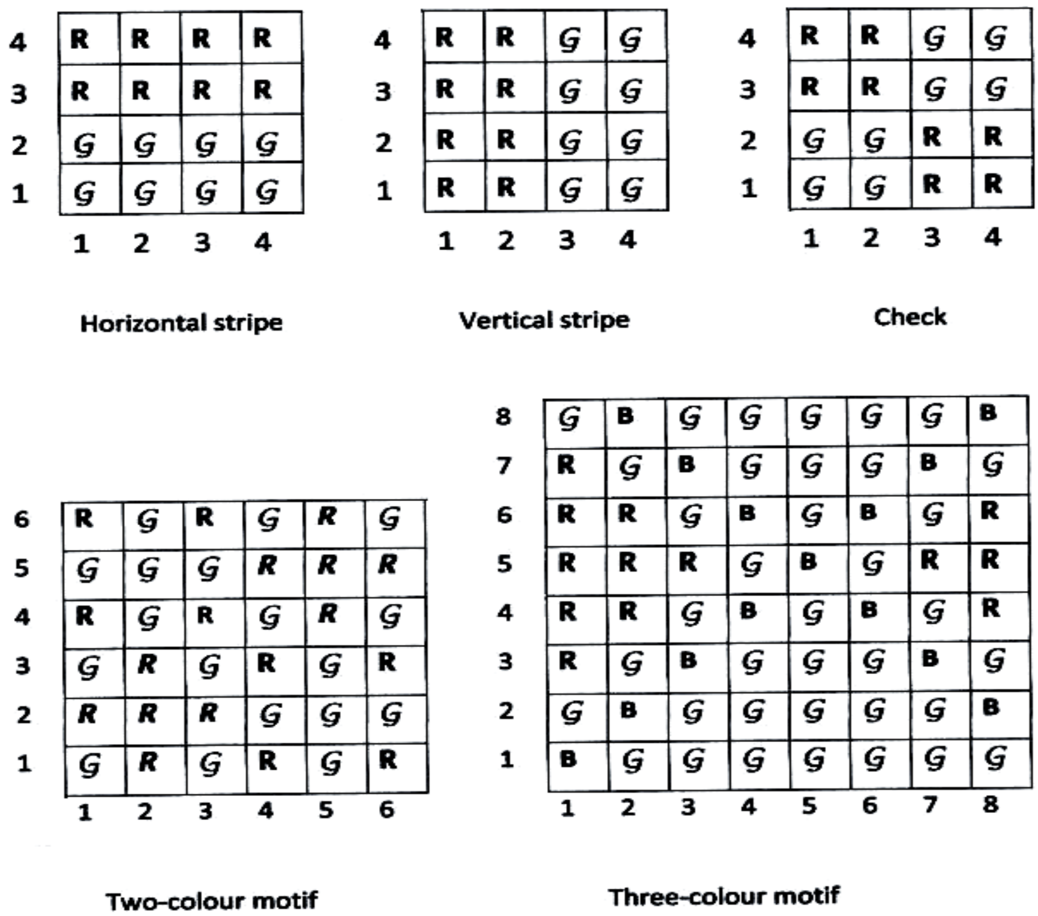


Figure 2.33 Effect of coloured yarns on knitted structures

Two more simple motifs produced on two colours – black and white – are shown in Fig. 2.34. The first one (a) repeats on 24 × 24 courses and wales whereas the second one (b) repeats on 20 × 28 courses and wales.

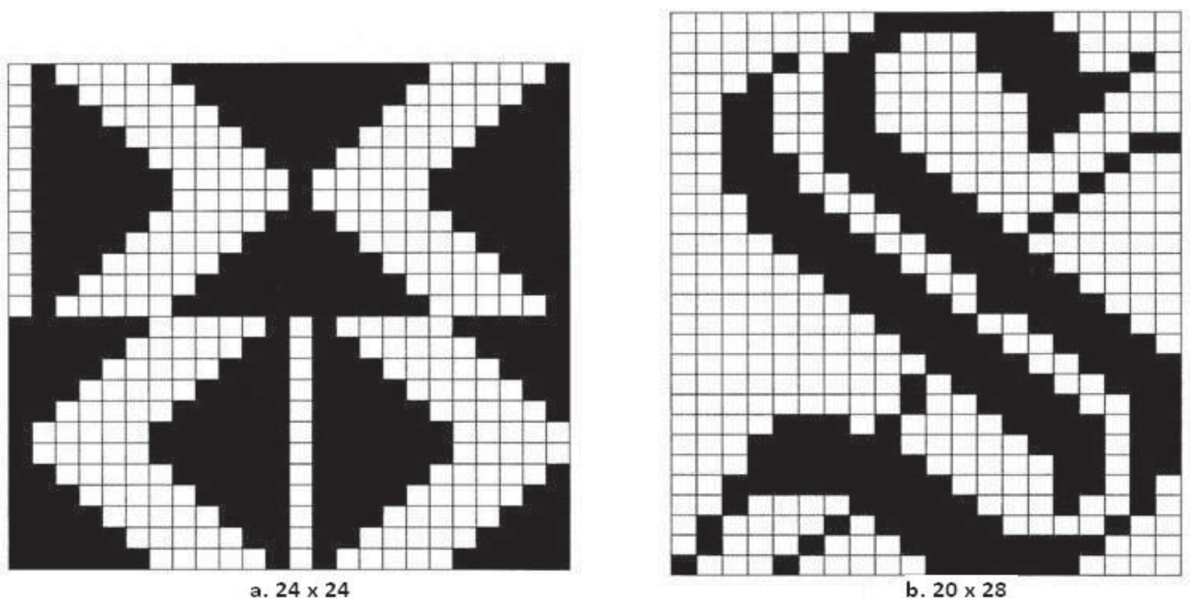


Figure 2.34 Motifs in black and white.

2.14 Special Techniques of Weft Knitting

2.14.1 Relative Technology with Latch Needle

Relative or relanit technology in circular knitting machine means that there is a contrary movement between the needle and the sinker during loop formation. It is also known as the "Contra" knitting technique. The relative technology is based on the division of the vertical movement of the needle with reference to the sinker, necessary for drawing-in the yarn for loop formation, into two individual movements for the needle and sinker. These movements enhance one another but are contrary or opposite in direction. Their total movement is equal to the movement needed for loop formation. So, sinkers are subjected to two types of motions – horizontal (inward and outward) and vertical (up and down). Within the knitting cycle the nature of movement of sinker passes through a large number of stages, however only two positions of sinker are shown in Fig. 2.35 (a) to explain the vertical movement. The path of sinkers and needles during the loop forming cycle are shown in Fig. 2.35 (b). Generally, sinker goes downward when needle is raised upward for clearing and the sinker moves upward after casting-off while the needle goes downward for loop formation. As observed in the figure, A is the rest position of the needle i.e. the point where both needle and sinker are at the same level, B is the knitting point and C is the level of the sinkers at the knitting point. Under both conventional and relanit technology the distance (BC) between needle and sinker is same. The needles cover the whole distance for reaching the knitting point under conventional technology but needles move BD distance and sinkers move CD distance at the same time to cover the BC distance required for loop formation under relanit technology.

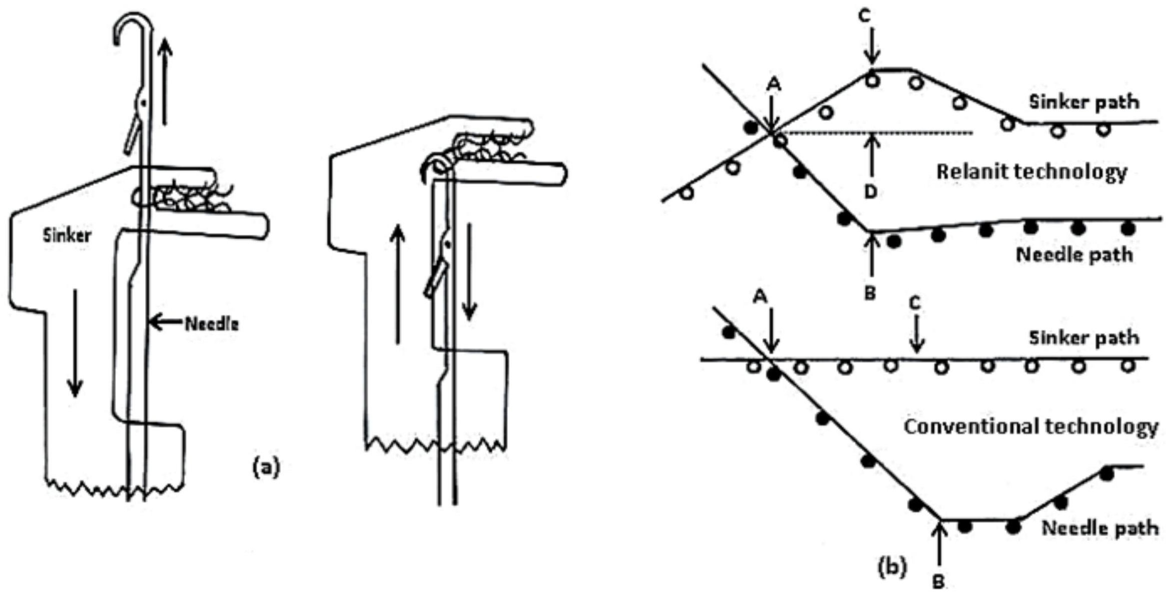


Figure 2.35 Relanit Technology

Naturally the time taken by the needles for loop formation under relanit technology is lesser than conventional technology and hence the former technology is faster. Although, the first patent on this relative technology was obtained by Solis in 1977, such technique was first exhibited in ITMA 1983 as RELANIT by Mayer and Cie. M/s. Jumberca also contemporarily developed this technology of positively cammed rocking sinkers on their four cam track model SYN-3 machine. On RELANIT machines, the vertical needle motion is always constant and stitch length is determined by adjusting the vertical movement of the sinker. This technique results in the following:

1. Less yarn metal contact points reducing the tendency of robbing back
2. Low yarn tension and less yarn breakage
3. Gentle handling of yarn enables weaker and lower quality yarns to be knitted
4. Smaller needle movement enables flatter or lower cam angles
5. Lower cam angle permits higher needle speed and ultimately high machine speed

2.14.2 Plating

Plating is a technique of simultaneous knitting with two or more yarns differing in colour, material, properties etc. to produce some special effect on fabric surface. A plated structure contains loops composed of two or more yarns, often with differing physical properties (Fig. 2.36). All the yarns are supplied separately to the same needle hook through their own guides in order to influence their respective position relative to the technical face surface of the fabric. Some yarn becomes more prominent in some zones in one surface and the other yarn becomes more prominent in certain zones or in other face. Plating is done to obtain –

a) Surface interest
b) Colour pattern
c) Openwork lace
d) Modification in wearing property

The basic rules governing the plating are –

The yarn positioned nearest to the needle hook shows on the reverse side of the fabric.

Position of the yarn is also determined by the tension developed on the yarn inside knitting zone. Tension development depends on the elastic property i.e. modulus of the yarn.

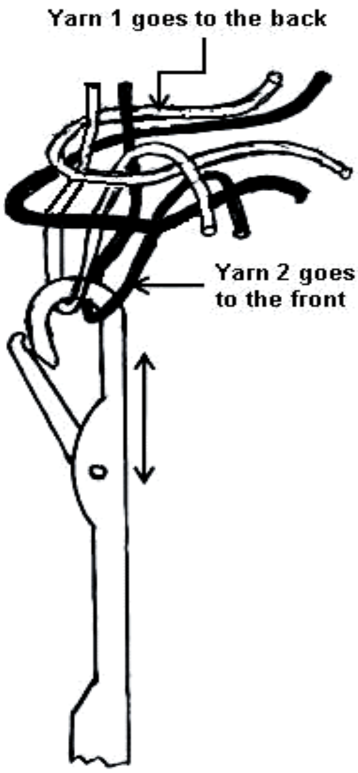


Figure 2.36 Plating.

Generally high modulus yarn is subjected to higher tension and goes to the back of the fabric. In Nylon-Cotton socks, cotton goes inside and nylon remains on the outer surface, as a result both comfort and durability are achieved.

Openwork mesh structure can be produced by float plating in single jersey knitting. It involves feeding two yarns in a plating relationship to needles. Generally a coarser yarn is fed at a high level and is only received by needles to that height whereas the finer yarn is fed at a lower level and is received by all the needles.

Plating requires special curvature on the needle hook, tansley plating angle hooks are preferred. The resultant count of two or more yarns is to be considered in Count-Gauge relationship. In spite of every effort, it may be difficult to achieve perfect plating.

2.14.3 Laying-In and Inlaid Structure

An inlaid fabric consists of a ground structure of knitted threads which hold in position other non-knitted threads which are incorporated (laid in) into the structure during some knitting cycle. An inlaid yarn is never formed into knitted loops in warp knitting although in single jersey weft knitting it is necessary to form it into tuck loops in order to hold within the structure. During weft knitting with two sets of needles it is possible to introduce the inlaid yarn into the structure merely by supplying the yarn across the back of the needles in order to trap it inside the fabric. Inlaid yarns are trapped inside the double needle bed fabrics by the loops of the two beds and towards the back of single bed fabric by the sinker loops. Laying-in is done to modify one or more of the following properties of the knitted structures –

a. Stability b. Handle

c. Surface Interest d. Weight

e. Visual Appearance f. Elastic Stretch and Recovery

Laying-in offers the possibility of introducing fancy yarn, unusual yarn (Rigid yarn, Rubber yarn, Fleecy yarn etc.), inferior or superior yarns which are difficult to knit at normal manner. An inlaid yarn generally assumes a relatively straight configuration and therefore requires less length of per course. The yarn carrier or feeder for laying-in may be of the following types –

a. Separate Conventional Feeder in Single Jersey Machine
b. Tunnel Feeder in Double Jersey Machine
c. Fane Knit Device

Hopsack is a typical example of single jersey inlaid structure (Fig. 2.37). In this case, after every normal course, an inlaid yarn is introduced which is tucked in alternative needles. It is a stable knitted structure suitable for ladies' suiting fabric.

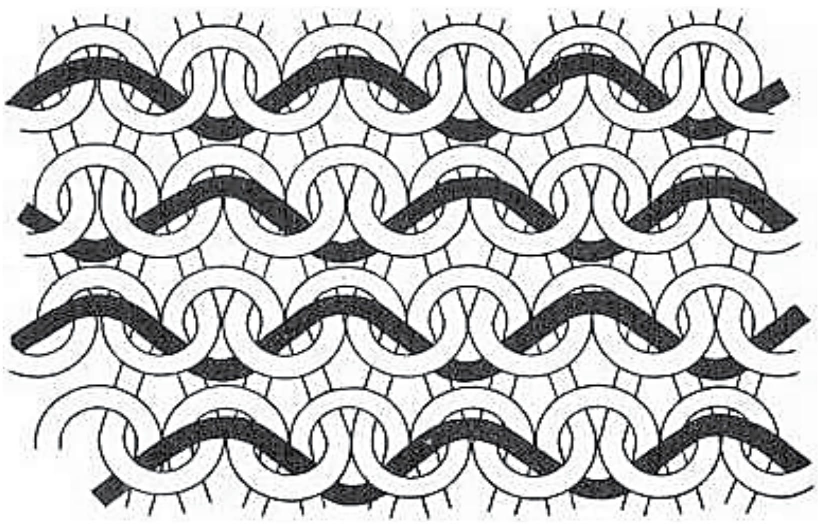


Figure 2.37 Laid-in Structure

2.14.4 Fair Isle Technique

Fair Isle is a traditional knitting technique used to create patterns with multiple colours. It is named after Fair Isle, a tiny island in the north of Scotland. Fair Isle knitting gained a considerable popularity when the Prince of Wales (later to become Edward VIII) wore Fair Isle

Tank tops in public in 1921. Traditional Fair Isle patterns have a limited palette of five or so colours, use only two colours per row, are worked in the round, and limit the length of a run of any particular colour. Some people use the term “Fair Isle” to refer to any colour work knitting where stitches are knit alternately in various colours, with the unused colours stranded across the back of the work. Basic two-colour Fair Isle requires no new techniques beyond the basic knit stitch. At each knit stitch, there are two available “active” colours of yarn; one is drawn through to make the knit stitch, and the other is simply held behind the piece, carried as a loose strand of yarn behind the just-made stitch. If you started with an even number of stitches, you will end up with a vertically striped tube of fabric, and if you started with an odd number of stitches, it will be a diagonal grid that appears to mix the two colours. Traditional Fair Isle patterns normally had no more than two or three consecutive stitches of any given colour, because they were stranded, and too many consecutive stitches of one colour means a very long strand of the other, quite easy to catch with a finger or button.

2.14.5 Fleecy Fabric Knitting

Generally two types of fleecy fabrics – simple fleece (two threads) and invisible fleece (three threads) – are produced on single jersey circular knitting machines. The fleecy or backing yarns are tucked into the base fabric at regular intervals on the back (inner) side of the fabric. Commonly points for inlay tucking are at each second needle (1:1 fleece) or at each fourth needle (3:1 fleece). If the interlacing points are staggered in successive rows, the structures are called 1:1 and 3:1 staggered fleecy. As the fleecy yarns do not lie as stitches, relative thick and soft yarns can be used for the purpose. Simple fleecy structure is made up of a main or base yarn and a fleecy yarn which are guided by normal holding down sinkers on successive feeders of a circular knitting machine. Since the base yarn is relatively finer, the fleecy yarn may become visible on the technical right or face side of the fabric at the inlaid points. The three thread fleecy structure is composed of fleecy yarn, binding yarn and face yarn and is produced with the help of some special attachment fitted on plain circular knitting machine. One repeat of the structure is produced on three successive knitting feeders. Specially shaped holding down sinkers with two throats are used in the machine. The fleecy yarn is generally invisible on the face side although there is difference in diameter between fleecy yarn and face yarn. The fleecy yarns and face yarns are supplied to the needle at different levels through different feed holes/points.

2.14.6 High Pile or Sliver Knitted Fabric Production

The production of sliver knitted or high pile furry fabrics on circular knitting machine is based on plain technique using latch needle and holding down / knocking over sinkers. Special equipment, a so called carding device, is employed to feed-in fibres into the latch needles at each knitting feeder. Normally each carding unit consists of two feed rollers, a carding or opening roller and a doffer (Fig. 2.38). The feed rollers draw-in the sliver and present it to the carding roller which has much higher surface speed in relation to the feed rollers. As a result, fibres are opened, stretched and paralleled. The doffer takes over the fibres from the carding roller and combs them into the needles with specially shaped wires.For the production of coloured or structure patterned high pile fabrics or combinations containing colour and structure, the needles of each combing points are selected according to the pattern in order to obtain fibres of the corresponding colour. The combed in fibres are processed together with the ground yarn during loop formation and the fibres protrude from the fabric base on the technical left (back or inner) side. By varying the speeds of the feed rollers, carding roller and doffer the amount of fibres and fibre density on the carding and doffer rollers and thus the number of fibres presented to each needle can be controlled. Depending upon the machine gauge, type of fibre, staple length of fibre and fibre fineness, fabrics of GSM in the range of 250 to 1500 can be obtained. M/s. Mayer Wildman Industries has recently introduced electronic needle selection for producing such fabrics on their model HP-18EII.

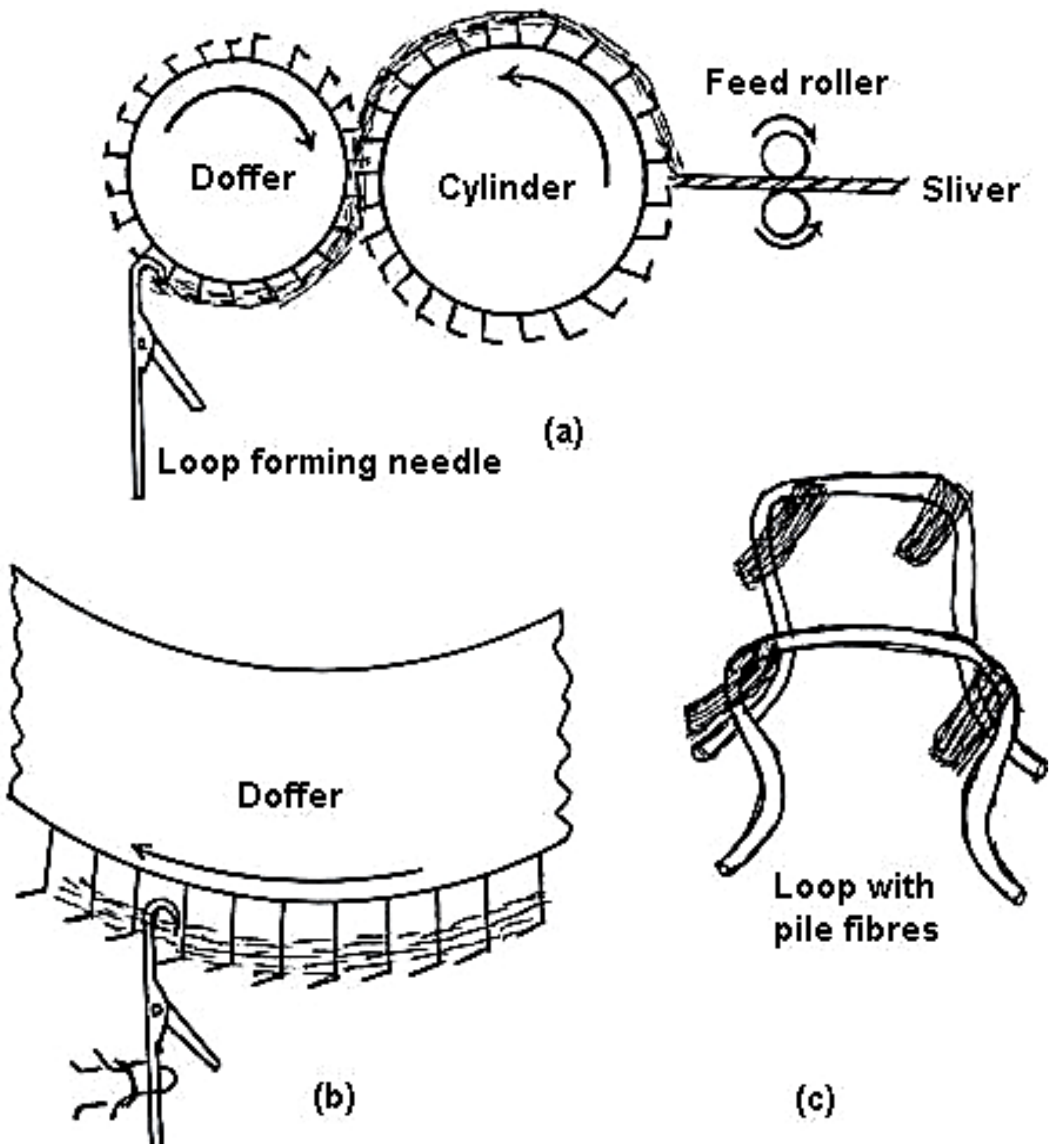


Figure 2.38 Sliver knitting.

2.14.7 Plush or Terry Fabric Production

Circular knitted plush or terry is a fabric with yarn loops protruding from the fabric base on one or both sides of the fabric. Most of plush fabrics produced have one-sided loops. Plush fabrics can be produced on both plain and rib type knitting machines. The most common method of production uses the plain circular knitting technique with combined holding down/knocking over sinkers for making one sided plush fabrics. The loops are actually enlarged sinker loops and they protrude from the fabric base to the technical left side.

The important demands are a firm fixing of the plush loops in the fabric base and a very uniform loop length. The loops may remain as it is in end use or may be cut or sheared to produce cut pile fabrics.

The un-patterned plush can be produced with different plain or rib knitting techniques. But jacquard is needed for producing patterned plush fabrics. The plain technique works with latch needles in the cylinder and holding down/knocking-over plush sinkers in the horizontally arranged sinker ring. In one groove of the sinker ring one or two sinkers (double sinker technique) can be set in. Double sinker technique is more modern process and produces uniform loops. With this technique, one sinker takes over the holding-down/plush function and the other sinker the knocking- over/plating function. The type of holding-down/knocking-over plush sinker and formation of loops on such sinker of M/s. Jumberca are shown in Fig. 2.33 (actual plush forming technique is very much complicated, not explained here).

2.14.8 Yarn Changer Device or Striper

Yarn changer device or striper becomes essential for producing vertical coloured stripes during knitting in circular knitting machine. Stripers are available with different capacity (yarn change finger), maximum up-to 5 colours at each knitting feeder. The selection of colour or the control of the striper may be either mechanical or electronic. In case of mechanical control, generally the striper is centrally controlled by a chain switch apparatus and rotating switch cams. The yarn change occurs in different switching stages of the yarn finger for laying-in and laying-out. But in case of electronic control, the striper unit works in conjunction with an electronic device. The electronic control unit contains the programmed pattern information of a striped pattern. This is recalled from the unit through a rotary code transmitter synchronous to the machine movement and passed on to the magnets of the yarn change fingers in the stripers. Whether mechanically or electronically controlled, the stripper unit is consisted of yarn change fingers and clamps and cutters (clamping cutters). The desired yarn change finger is brought into the yarn feeding-in position by the control mechanism. The concerned clamping cutters open and close according to need. The clamping cutter cuts and holds the yarn when closed and allows the yarn to pass when opened.

2.14.9 Linking

Linking is a process of joining two parts of a knitted garment. Out of these two parts, one is plain knitted body or panel and the other one is the rib border. The sewing operation can take place in many different procedures depending upon the required quality of the garment and determining the cost of the process. In fact linking is the most costly process that produces the highest quality garment. Linking is carried out under the following circumstances –

a) Where there is no facility to produce rib and plain knitted structures in the same machine/place

b) Where designs produced in horizontal direction on the main part or panel are to be used in turned position i.e., in vertical direction

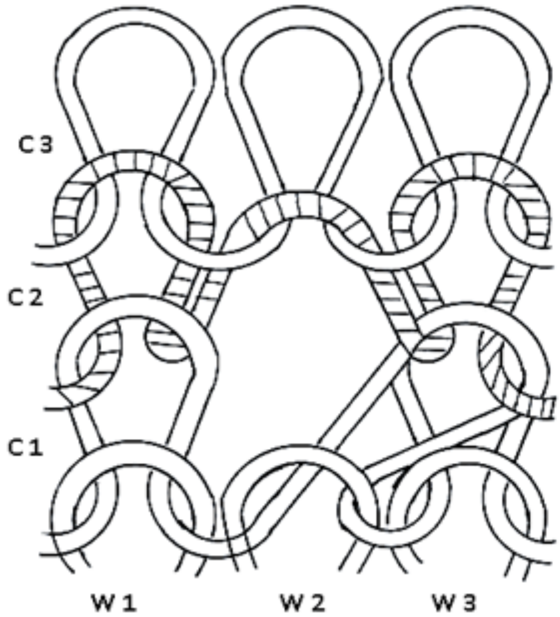
For the purpose the last few courses of the rib border are knitted separately as two plain fabrics (lips) some on the front and some on the rear needle bed. The lips of the border can then be made to encapsulate and cover the lower part of the turned knitted panel. The linking machine includes a series of horizontal pins corresponding in gauge to the wale density of the knitted parts to be linked. Across a single course, loops of one lip of the border are placed onto the pins in the linking machine. Keeping to the correct width of the panel, the bottom edge of the panel body is hooked onto the pins of the linking machine. The second lip of the border is placed on the pins of the linking machine. The linking machine now sews through the pins, and using a similar yarn to that used in the knitting operation, combines the three layers. The linking yarn passes through the loops of the border and produces a bond which is very flat and similar in appearance to the result produced when the border and the body are knitted together.

2.14.10 Loop Transfer

There is a wide scope of transferring of a full loop or a part of needle loop or sinker loop on the adjacent needle of the needle bed – same or opposite. The idea behind such transfer is to produce diversified structure and shaping. Loop transferring is done either manually or automatically according to the facility available in the machine. The commonly used transfer stitches are as follows:

1. Plain loop transfer stitch
2. Rib loop transfer stitch
3. Sinker loop transfer stitch
4. Fancy lacing stitch

Out of these the first two are widely used for achieving the target of loop transfer and the schematic structures of such transferred loops are shown in Fig. 2.39 and Fig.2.40 respectively. Some more discussion on technique of loop transfer is given in Flat Bed Knitting.



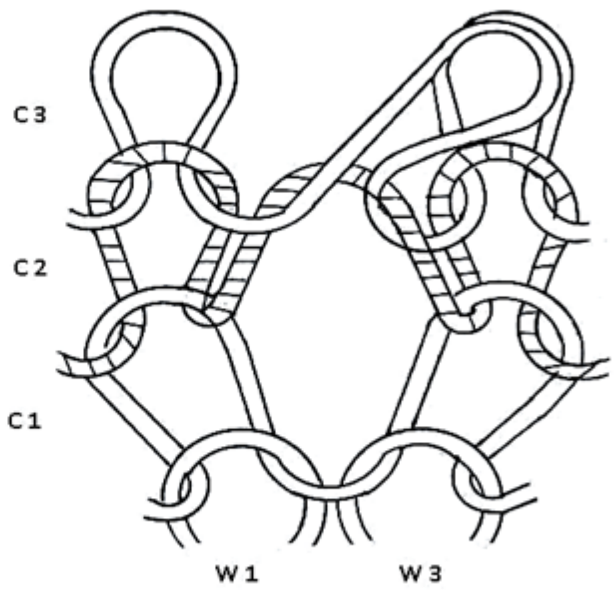


Figure 2.39 Plain loop transfer switch

Figure 2.40 Rib loop transfer stitch

2.14.11 Welt Formation

A welt is an attractive and secure edge of a knitted article which helps to prevent laddering or unravelling of a structure. It is either formed during the knitting sequence or as a later seaming operation during making-up. On machines with no facilities for welt sequences the plain fabric is formed in to a turned over welt or a mock rib welt. The ability to produce a knitted welt sequence usually distinguishes a socks (garment) producing machine from a fabric producing machine. Some machines commence at the closed toe end or finger-tip and terminate with the welt end of the fabric. The in- turned welt is used particularly for manufacturing ladies' hose on circular machines. Jacks or hooks collect the sinker loops of the third course or the set-up course and hold them, drawing the fabric away until sufficient has been knitted for the double thickness welt. The welt is then turned by transferring the held course back onto the needles, which knit it into the structure. A picot edge at the turn of the welt is achieved either by an alternate needle tuck sequence or by alternate needle loop transfer (Fig. 2.41).

Most fully fashioned and stitch shaped underwear and outerwear garments and half hose and socks have ribbed borders containing a welt sequence, which is produced by causing the sets of needles to act independently of each other after the 1x1 rib set-up course. Types of popular welts are:

a. Tubular or French welt
b. Roll or English welt

c. Racked welt

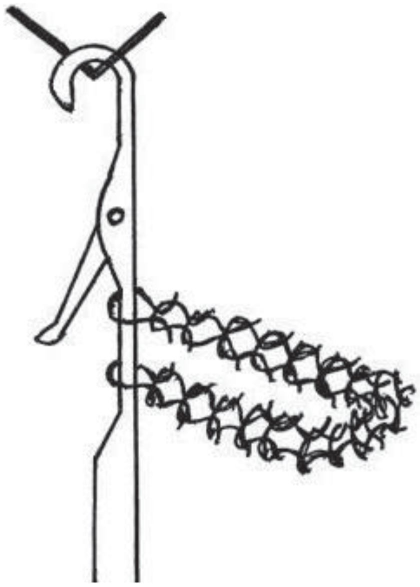


Figure 2.41 Welt formation

2.14.12 Shaping During Knitting

The weft knitting technique provides the unique opportunities for width- wise shaping during knitting with the garment length knitting sequence being initiated and coordinated from the same control mechanism. Shaping offers appreciable economies in raw material by the elimination of cutting waste as well as minimizing garment make-up times. The three methods of shaping garments without cutting are:

By varying the number of needles in action in the knitting width

By changing the knitting construction (design)

By altering the stitch length

The techniques of shaping have been dealt during garment manufacturing in knitting

2.15 Coloured Stitch Designs In Weft Knitting

Colour is one of the five ingredients of fashion, the other four being style, silhouette, texture and pattern .Ornamentation for design purposes may be introduced at the fibre, yarn, or dyeing and finishing stage, as well as at the knitting stage. Apart from different colours, it may take the form of sculptured or surface interest. In fibre form it may include a variation of fibre diameter, length, cross-section, dye uptake, shrinkage, or elastic properties. In yarn form it can include fancy twist and novelty yarns, as well as the combined use of yarns produced by different spinning or texturing processes. The dyeing process, which provides the possibility of differential and cross-dyeing of fabrics composed of more than one type of fibre, may occur at any point in manufacturing from fibre to finished article.

The finishing process may also utilise heat or chemically-derived shaping. Finally, printing and particularly transfer printing can introduce colour designs onto plain colour surfaces, whilst embroidery stitching may provide relief designs in one or more colours (usually onto garment panels or socks).

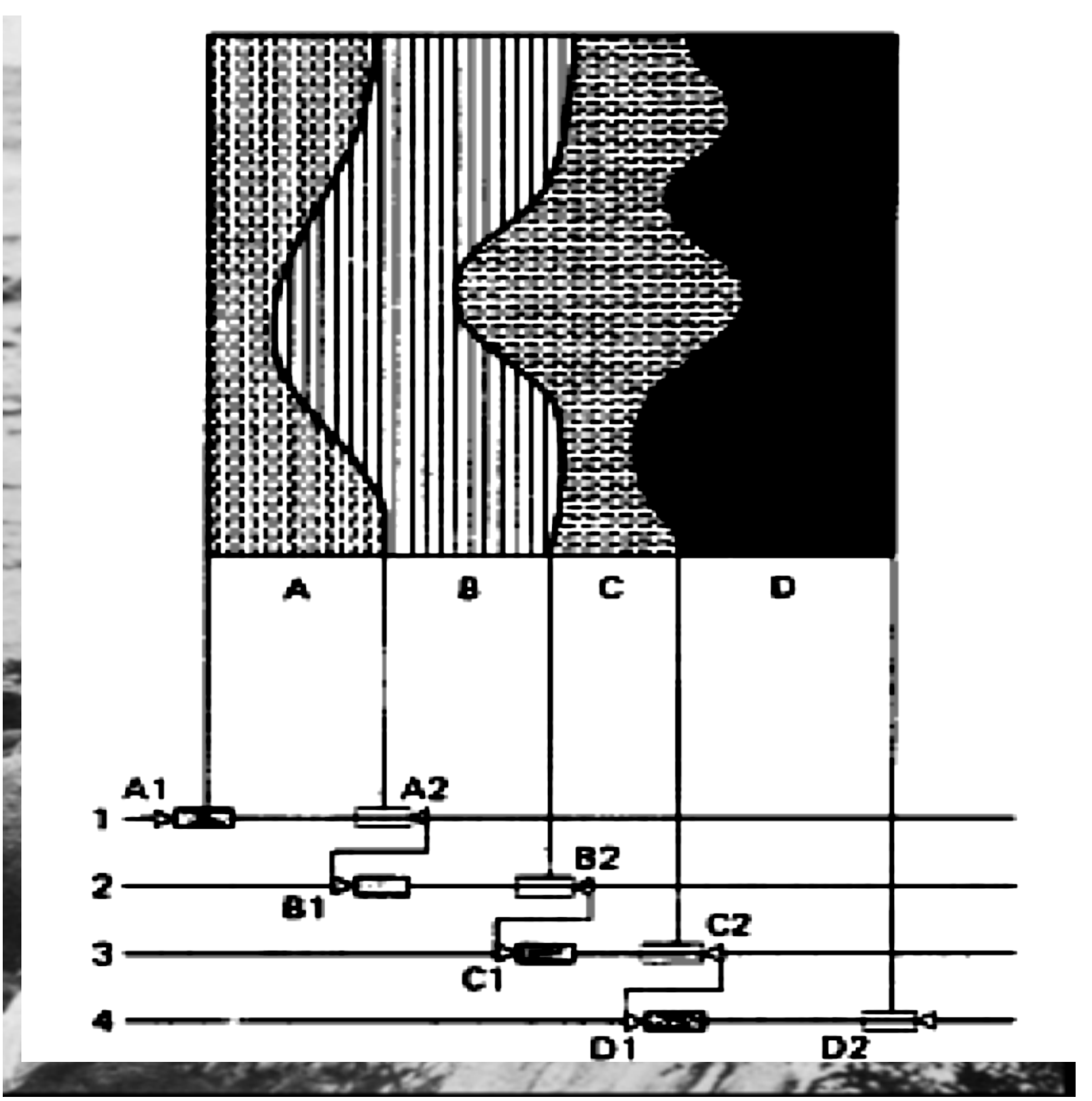
The finishing process can completely transform the appearance of a relatively uninteresting structure, either as an overall effect or on a selective basis. The knitting of stitch designs always involves a loss of productivity compared with the knitting of plain, non-patterned structures. Machine speeds are lower, less feeds can generally be accommodated, efficiency is less, design changes are time-consuming and dependent upon technique and machine type, and, in many cases, more than one feeder course is required to knit each pattern row. At the knitting stage, apart from stitches for surface interest and other functional purposes, four techniques may, if required, be employed to produce designs in coloured stitches. These are horizontal striping, intarsia, plating, and individual jacquard stitch selection.

2.15.1 Horizontal Striping

Horizontal striping provides the facility to select one from a choice of several coloured yarns at a machine feed position (Fig. 2.41). Even without striping selection facilities, by careful arrangement of the packages of coloured yarns on a large diameter, multi-feeder machine, an elaborate sequence of stripes having a depth that is repeated at each machine revolution, is obtained.

However, machines with few feeds (particularly garment length and hosiery machines) would have severely restricted capabilities without the facility of yarn changing by striping finger selection, which can provide a choice of one from four or five yarns at a particular feed point during each machine revolution. The choice of yarns may include elastic yarn and separation yarn as well as a choice of colour. On flat and straight bar frames, yarn carrier changes can take place during the pause in knitting on completion of each traverse. On circular machines, striping finger changes must occur whilst the needle cylinders or cam boxes rotate. A slight overlap of the two interchanging yarns is essential to maintain a continuous yarn flow at the knitting point.

Fig. 2.41 Yarn carrier positioning for intarsia



On flat and straight bar frames, yarn carrier changes can take place during the pause in knitting on completion of each traverse. On circular machines, striping finger changes must occur whilst the needle cylinders or cam boxes rotate. A slight overlap of the two interchanging yarns is essential to maintain a continuous yarn flow at the knitting point.

As the yarn finger is withdrawn from the needle circle with its yarn cut free and securely trapped and held for later re-selection, the newly-selected finger in the same unit or box is simultaneously introduced into the needle line. Its trapper releases the held cut end of yarn, allowing it to flow from its package to the needles. The facility of an individual cutter and trapper for each yarn in the unit is mechanically more complex but it enables a yarn as thin as 30 denier nylon to be trapped alongside a yarn as thick as 5/1's (Ne) cotton.

Figure.2.42 An attractive use of horizontal striping [International Institute for Cotton.

Although striping is useful for the introduction of a draw-thread in a full-course and splicing reinforcement on a part-course basis, the mechanism is not precise enough for individual stitch patterning. Its speed of operation and versatility has, however, been improved by employing electronic control so that the engineered placing of stripes of specific widths in the length of a garment is now possible.

Fig. 2.43 Examples of intarsia designs knitted on an electronic V-bed machine [Shima Seiki].

A design row of intarsia is divided into adjoining blocks of contiguous wales. Each block of needles knits a separate coloured area (field), for which it is exclusively supplied with its own particular yarn (Fig.2.41). The yarn then passes to the course above and does not float across the backs of needle loops. If there are further blocks of needles in the design row requiring the same colour, each will be supplied by a separate yarn.

2.15.2 Intarsia

Intarsia (Figures 2.42 and 2.43) is a special method of producing designs in knitted loops that form self-contained areas of pure colours. Unequalled colour definition is achieved, with a large number of colours and no adverse effect on the physical properties of the structure such as reduction of extensibility. Four zones are illustrated. Each colour (A, B, C and D) is supplied by its own yarn carrier, which travels only between its own carrier stops (which are capable of being repositioned). All carriers traverse in the same direction at a particular course. The stop blocks of adjoining colour zones (e.g. A2 and B1) are linked together so that when one yarn carrier traverse is decreased (for example, towards the left) the adjoining carrier traverse is correspondingly increased. Careful positioning of the yarn carriers and control of the extent of traverse of each from course to course determines the design and integration of the coloured areas into a cohesively-knitted structure. Such a cohesive structure is achieved by slight overlap of adjoining areas and the intermeshing of loops in each wale. As well as plain and 1 X 1 rib, other stitches such as purl or cable may be utilised.

The knitting action and supply of yarn for intarsia is from left-to-right at one course, and right-to-left at the next. This is the normal reciprocating movement found on all V-bed flat machines and straight bar frames. On circular, single cylinder sock machines, it is necessary to oscillate the cylinder (similarly to heel knitting) instead of continuously revolving it.

Traditionally, intarsia was skilfully knitted by hand, laying the yarns into the hooks of each block of adjacent needles as they are cammed outwards, on hand operated stationary needle bed machines such as the circular Griswold type sock machine or the flat bed model machine.

High-quality woollen Argyle tartan socks and sweaters can be knitted, consisting of diamond-shaped designs crossed diagonally by one wale wide stripes termed over checks.

Only on a hand-manipulated flat machine with hand-feeding of the yarn can a pure join of adjoining areas be achieved. As the edge yarn of an area rises to the next course, it crosses over and links to the edge yarn of the adjacent colour area.

Most automatic methods of knitting intarsia entail some way of overlapping (encroachment) of adjoining areas into each other, towards the right at one course and towards the left at the next. A slight saw-tooth effect across one, two, or more wales is thus produced at the join, which should be kept to a minimum, and the plating of knitted or tuck loops can be employed. Argyle socks can be knitted automatically with plated over checks.

Intarsia designs for full-fashioned sweaters have generally been balanced geometrical shapes because of the screw spindle control of the carrier stops. However, intarsia patterning as an optional extra on electronic V-bed flat machines is becoming increasingly sophisticated with precise yarn positioning, needle selection and carrier traversing that may be controlled electronically.

Although intarsia ensures that expensive yarns are fully utilised on the surface of the design, it is only generally suitable for geometric type designs (although they no longer need to be symmetrical) and not for figure designs in small areas. It is a comparatively slow, expensive, specialised technique that is subject to the whims of fashion.

2.15.3 Plating

Plating is widely used for single jersey, plush, open-work, float and interlock fleecy. However, with the exception of embroidery motif plating, the use of coloured yarns to produce plated designs has diminished in weft knitting. Plating requires great precision and offers limited colour choice with poor definition compared with the improved facilities offered by jacquard knit and miss needle selection of coloured stitches.

In reverse plating, two yarns (usually of contrasting colour) are caused to change over positions at the needle head by controlled movement of specially-shaped sinkers or yarn feed guides. In sectional plating (straight bar frames), the ground yarn knits continuously across the full width whilst the plating carrier tubes, set lower into the needles, supply yarn in a reciprocating movement to a particular group of needles, so that the colour shows on the face.

The one major advance in pattern plating coloured yarns has occurred in weft embroidery motif plating on electronically-controlled, single-cylinder hosiery machines knitting so-called ‘computer socks’. The main yarn is a fine, undyed filament nylon, which is continuously knitted throughout the sock. At each feed there is a group of coloured bulked yarns. A selected yarn is fed, in a plating relationship with the main yarn, to one or a group of adjacent needles according to the required design. The next adjacent needle(s) will receive a different coloured yarn, selected from the same group of yarns.

All the needles will thus receive a plated bulked yarn of some colour, whether they are knitting the motif or the ground colour. The designs appear to be pure colour intarsia because the main yarn is fine and is hidden by the plated, coloured bulked yarns. There are no floating threads on the inside of the sock because the yarn is cut and trapped when not in use. Care must be taken to ensure that the pattern threads are securely retained in the fabric.

Simple motif embroidery designs using warp threads have, for many years, been wrap-knitted on the side panels of double-cylinder half-hose. The technique is slow and less popular than weft embroidery patterning.

2.15.4 Individual Stitch Selection

Individual stitch selection is the most versatile and widely-employed method of knitting designs in colour, or different types of stitches in self-colour. It is based on the relative positioning of an element during a knitting cycle determining which stitch, from a choice of two or more, is produced in its corresponding wale at a particular feeder course of a machine revolution or traverse.

Latch needle weft knitting machines are especially suitable because their individually tricked and butted elements offer the possibility of independent movement. Depending upon machine and element design, and cam arrangement, one or more of the following stitches may be produced – knit, tuck, miss, plated, plush, inlay, loop transfer and purl needle transfer.

The following rules apply to individual element selection of stitches:

1. If each set of elements has butts of identical length and position, and the cam track is fixed, each element will follow the same path and produce an identical stitch in its corresponding wale at that feeder course.

2. If each feed in the machine has the same arrangement of fixed cams, identical stitches will be knitted in each wale at every feeder course.

3. When the butts of adjacent elements are caused to follow different paths through the same cam system, different stitches may be knitted in adjacent wales of the same feeder course.

4. When butts of the same element are caused to follow a different path through successive cam systems in the same machine, more than one type of stitch may be produced in the same wale.

5. Unless the device is of the variable type that can present a different selection commencing in the first wale of each traverse or machine revolution, the design depth in feeder courses will be the number of operative feeds on the machine.

If the device is variable, the design depth will be increased by a multiple of the number of different selections available per device.

2.15.5 Weft Knitted Jacquard

Weft knitted jacquard designs are built up from face loops in selected colours on a base fabric of either single jersey, 1 X 1 rib, or links-links (purl). The face loop needles are individually selected, usually each only once per pattern row, to rise and take one yarn from a sequence of different coloured yarn feeds on a knit or miss basis.

In two-colour jacquard, certain needles will be selected to knit colour A from the first feed and, at the next feed, there will be a negative selection with the remaining needles being selected to knit colour B. The face loops of two feed courses thus combine to produce one complete row of face pattern loops.

In three-colour jacquard, each needle will be selected to knit once and miss twice at a sequence of feeds, so that three feeder courses will produce one design row.

The greater the number of colours in a design row, the lower the rate of productivity in design rows per machine revolution or traverse, assuming striping is not employed.

If striping is employed with jacquard selection, different colours can be selected at different design rows so that there are more colours in the total design than in one design row. For example, a four-feed machine with four-colour striping at each feed could knit 4 colours per design row but have a total of 16 colours in the design depth.

2.15.6 Single-Jersey Jacquard

Single-jersey jacquard (Fig. 2.44) in knit and miss stitches produces clear stitch definition, exemplified by the Fair Isle designs used in woollen cardigans and pullovers. The floats to some extent reduce the lateral extensibility of the garments and, when continuous filament yarns are used in gauges of E 18 or less, the floats on the technical back can create problems of snagging. Single-cylinder sock machines may knit 1 X 1 float stitch jacquard. Odd needles are selected to knit and miss whilst even needles knit at every feed, thus reducing the coloured yarn floats on the technical back to a single wale. The clarity of the coloured pattern area is only slightly impaired.

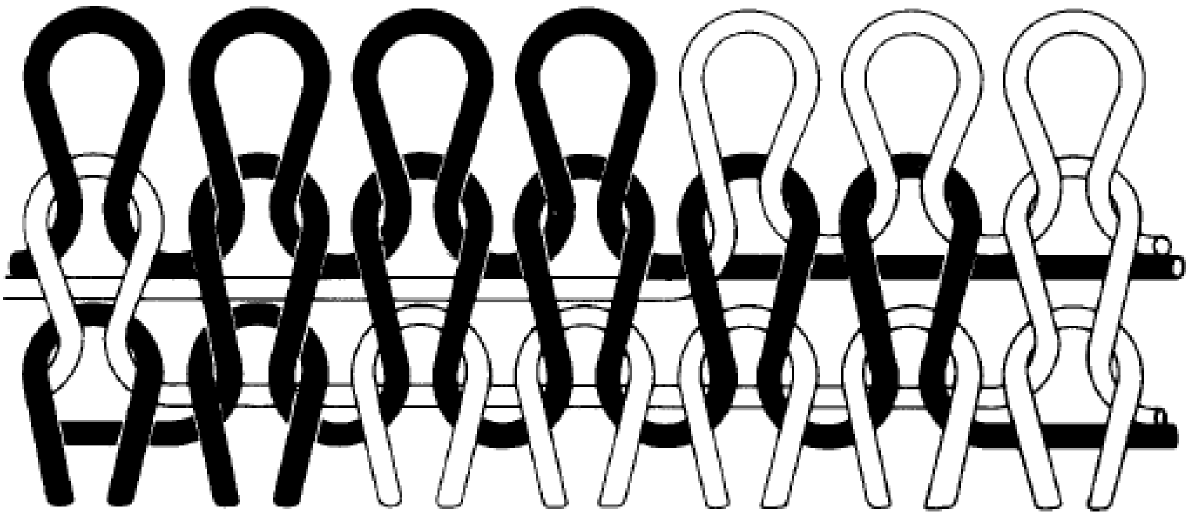


Fig. 2.44 Single jersey jacquard.

2.15.6 Accordion fabric

Accordion fabric (Fig. 2.45) is single jersey with the long floats held in place on the technical back by tuck stitches. It was originally developed using knit and miss pattern wheel selection. Needles required to tuck (if not selected to knit) were provided with an extra butt, in line with a tuck cam placed immediately after the pattern wheel selection.

In straight accordion, every odd needle was of this type, so every odd needle tucked when not selected to knit.

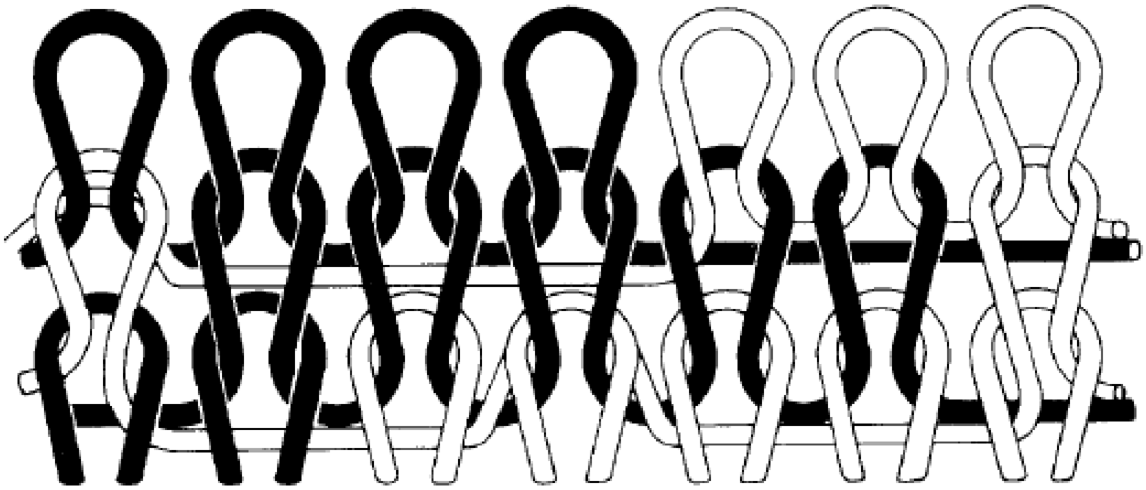


Figure 2.45 Accordion fabric.

Alternative accordion provides a better distribution of tuck stitches; odd needles had a tuck butt position in line with cams placed at odd feeders, and even needles had another butt position for cams at even feeders. With both these types of accordion, tuck stitches occur close together, causing distortion of face loops and allowing unselected colours to ‘grin’ through between adjacent wales onto the face.

The third type of accordion – selective accordion – is most widely used, but it requires a three-step pattern wheel or other selection device that can select the tuck loops so that they are carefully distributed to create the minimum of stitch distortion on the face of the design.

2.15.7 Rib jacquard

Rib jacquard designs are achieved by cylinder needle selection. The dial needles knit the backing and eliminate floats that occur when cylinder needles only are selected to miss (Fig. 2.46).Tuck stitches are therefore unnecessary. There are two groups of these fabrics – flat jacquards and relief designs.

Flat jacquards are described by the size of the design area followed by the number of colours in one complete pattern row of loops and the type of backing.

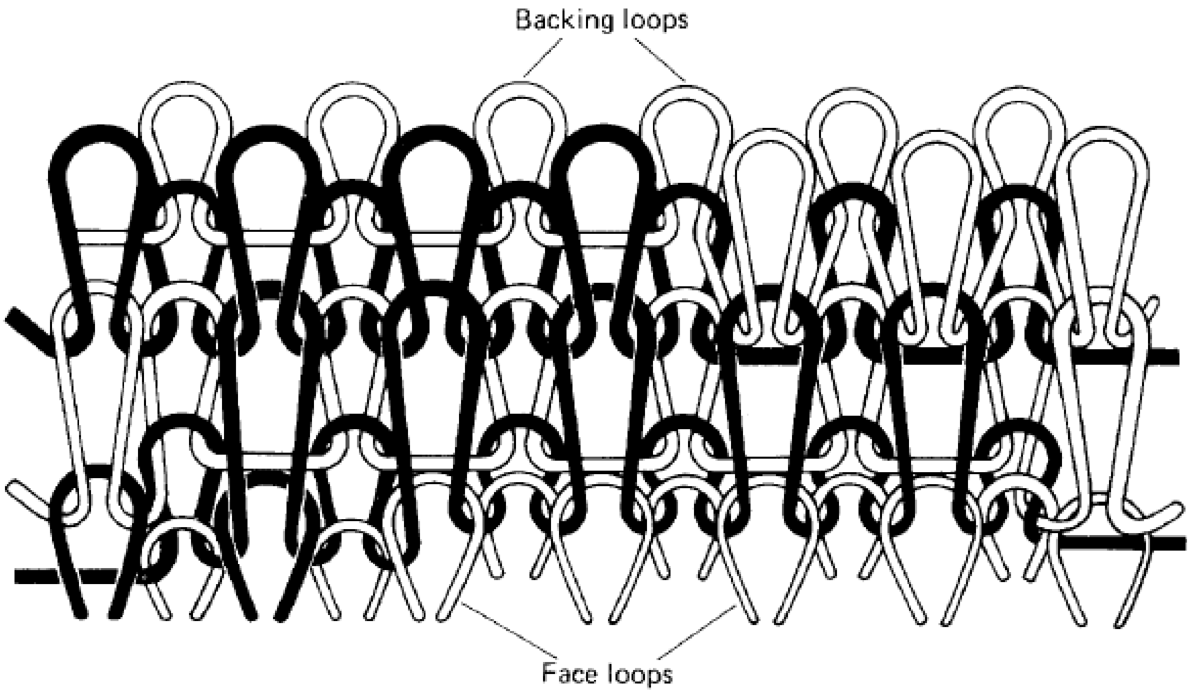


Figure 2.46 Rib jacquard

On circular machines, the selection is on the cylinder needles only and the dial needles knit the backing loops, whereas on flat machines both beds may have selection facilities.

With horizontally striped backing, all dial needles will knit at every feeder, thus producing an unbalanced structure with more backing rows of stitches than design rows. In the case of three-colour jacquard, there will be three times as many backing rows as design rows. This type of backing ensures that the maximum yarn floats are only across one needle space and there is thus little loss of lateral extensibility – a prerequisite for garment-length and hosiery structures.

For double jersey fabrics, bird's eye or twill backing (Fig. 2.47) is preferred as this is a more stable structure which is better balanced and has a pleasing, scrambled colour appearance on the backing side. It is achieved by knitting the backing on alternate needles only and arranging for each colour to be knitted by odd backing needles at one feed and even needles at the next. The optimum number of colours is usually three. On flat machines, it is possible to select only certain needles to remain in action to knit the backing; for example, 1 in 3 or 1 in 5. This is termed ladder backing. The backing needles virtually chain knit the floating threads in the back of the fabric. This produces a lighter fabric but there is less connection between the design and the backing sides of the fabric.

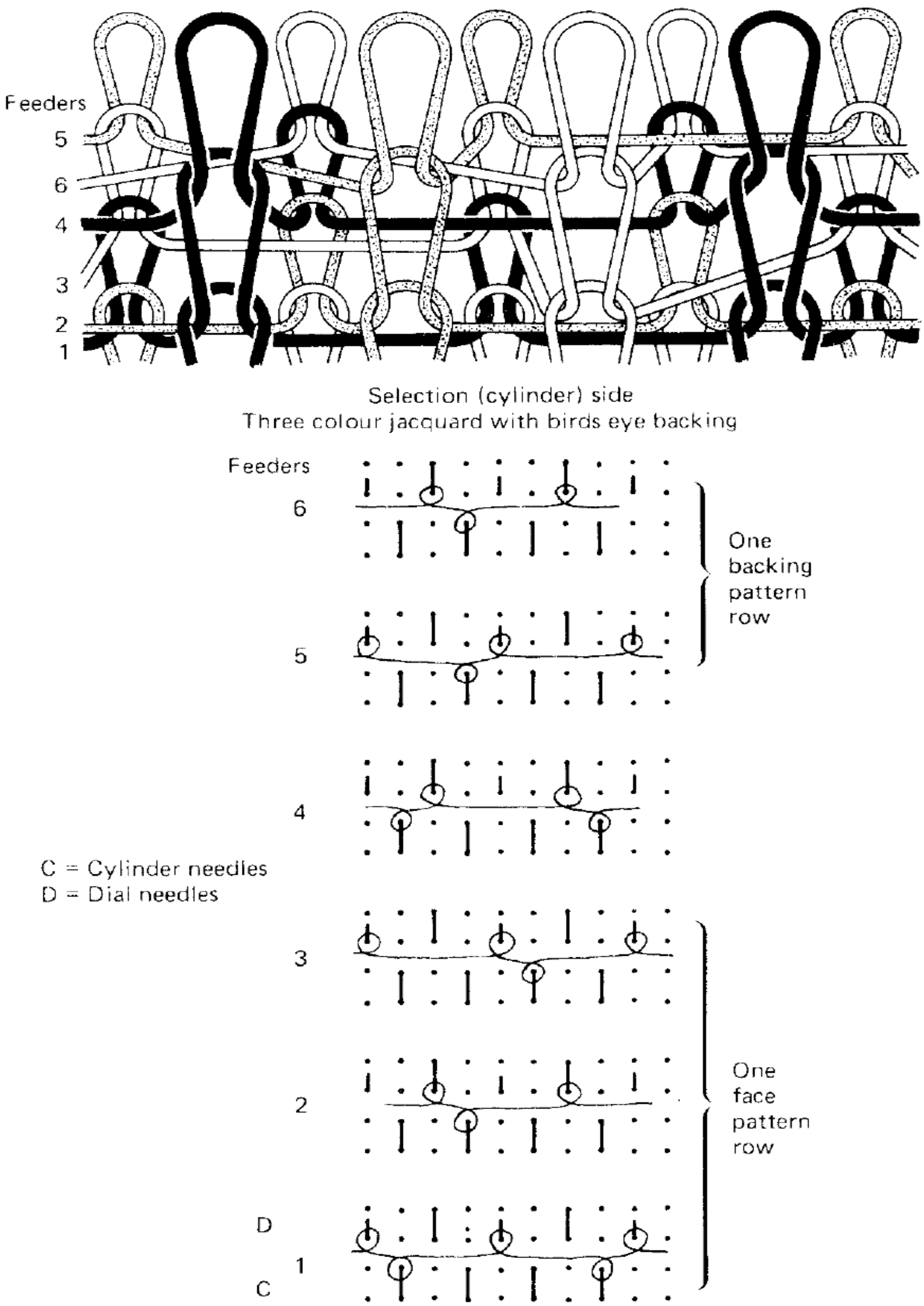


Fig. 2.47 Three colour jacquard with bird's eye backing

Whereas flat jacquard patterns have equal numbers of loops in each wale of the pattern repeat, blister and relief patterned fabrics do not. Links-links purl machines (particularly hosiery machines) may have facilities for knitting combined colour and stitch effects. Usually, the needles in one bed knit continuously so that the lateral extensibility of the structure is not too adversely affected. Float bolt patterning is more restricted. At the first feed, needles selectively transferred to the bottom cylinder knit together with those remaining in the top cylinder. At the second feed, the latter knit alone with the miss stitches floating at the back of the plain loops of the previous course. In combined links-links and three colour float jacquard, needles may be selected to knit in the bottom cylinder at any one of the three feeds. The needles which remain in the top cylinder knit at each of the three feeds, producing floats behind held plain loops (Fig. 2.48).

2.15.8 Jacquard Design Areas

The design area is controlled by the selection system of the machine: Full jacquard implies unrestricted pattern depth in pattern rows and a width that may be the total number of needles in the machine.

Large area jacquard designs have a pattern depth that requires more than one machine revolution to be developed and therefore each feeder contributes two or more courses; the pattern width is usually more than 48 wales.

Small area jacquard has a pattern depth which is developed in one machine revolution so that each feeder contributes only one course from a fixed selection, and the pattern width is 48 wales or less.

2.15.9 Worked Example

The squared diagram illustrates part of a three-colour jacquard design, each face stitch being represented by a square.

Using the running thread notation, provide:

(a) A representation of the design for single jersey knit/miss jacquard. (Please refer Fig.2.48)

(b) A repeat of the representation of the first two pattern rows for: (Please refer Fig.2.49, 2.50, 2.51 and 2.52)

(i) Straight accordion,

(ii) Alternate accordion, and

(iii) Selected accordion.

(c) A representation of the first two pattern rows as rib jacquard with:

(i) horizontally-striped backing,

(ii) vertically-striped backing, and

(iii) Birds eye backing.

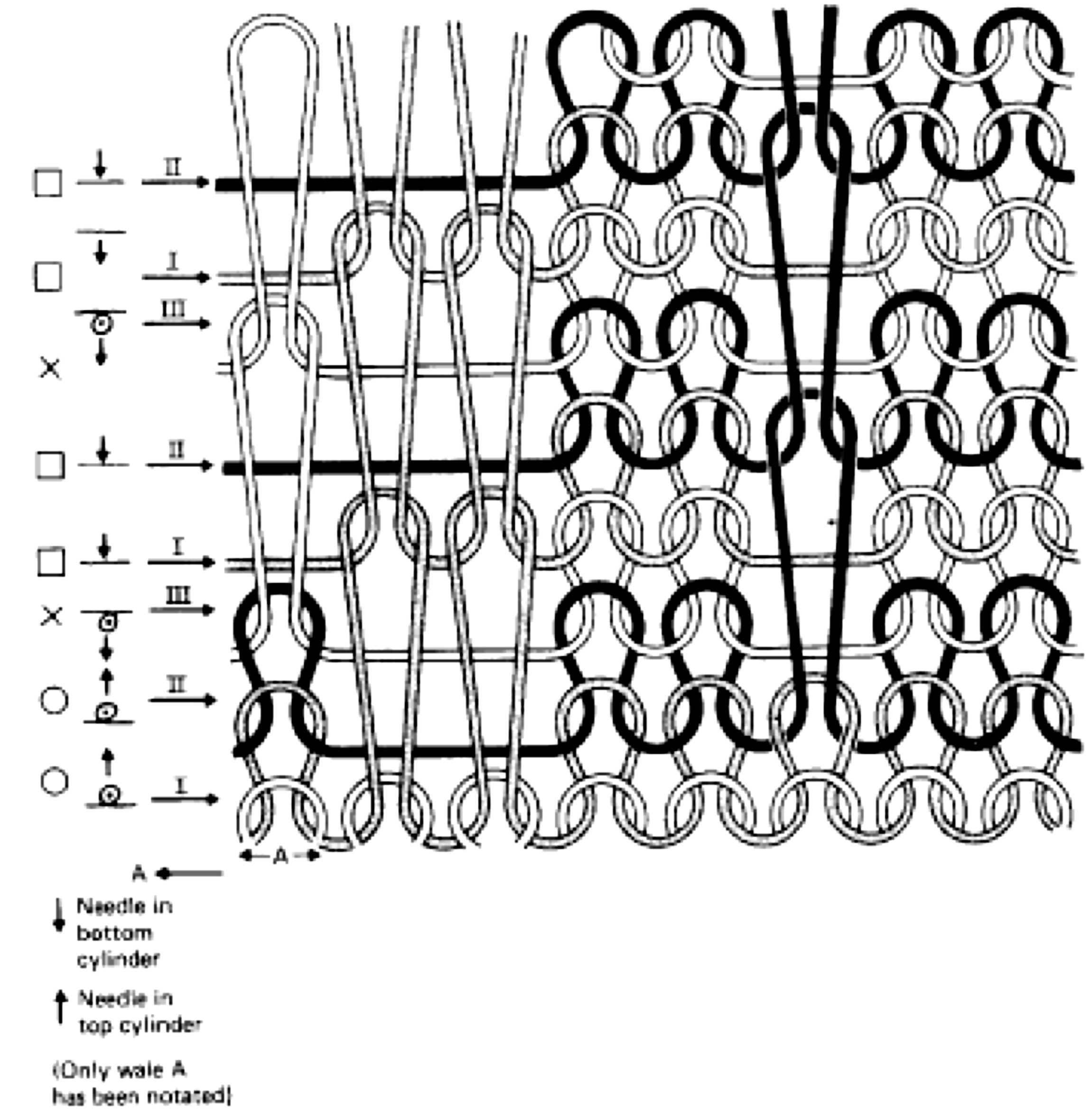


Fig. 2.48 Combined links-links and three colour float jacquard.

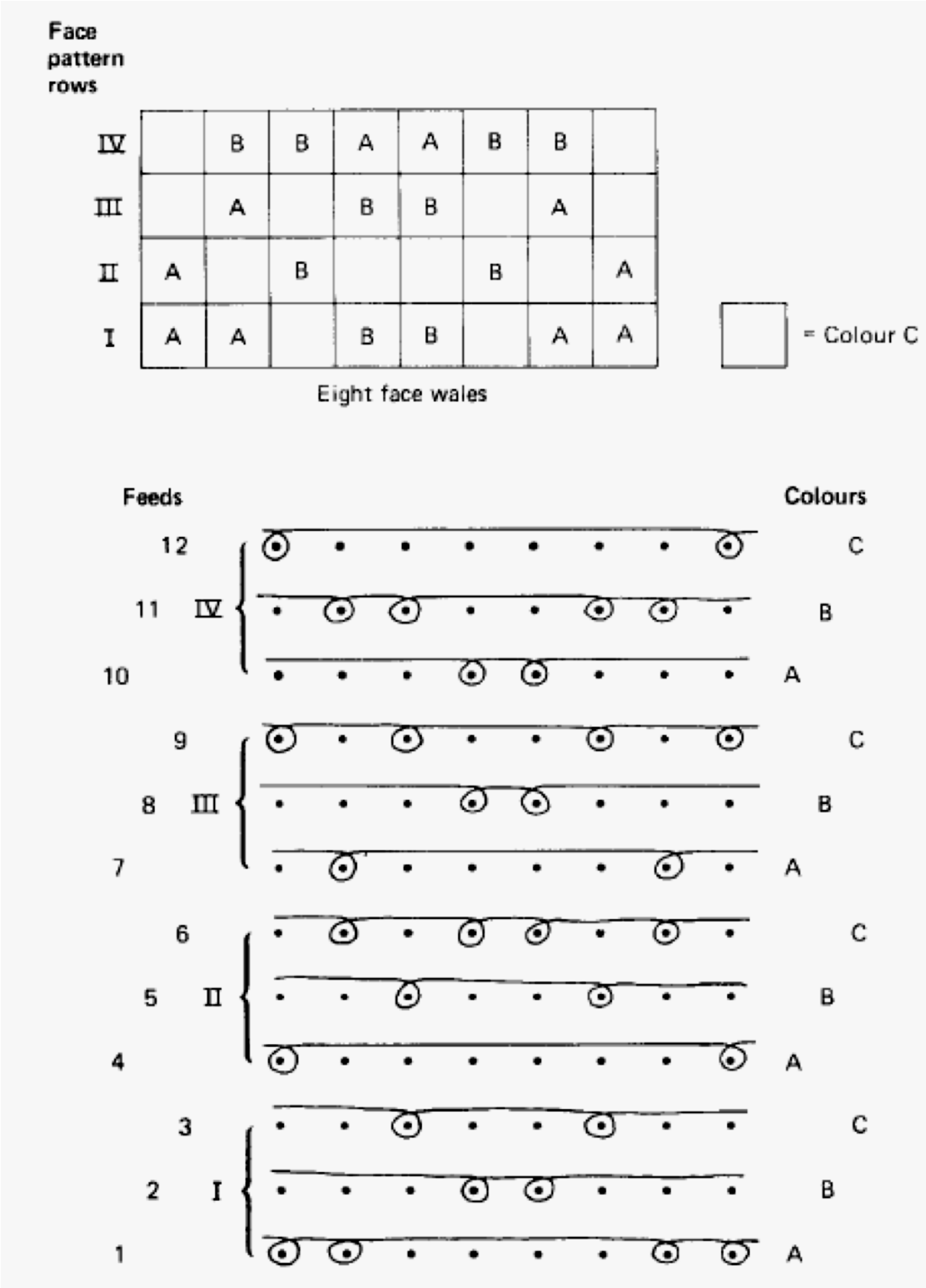


Figure 2.49 Single Jersey Knit Jacquard

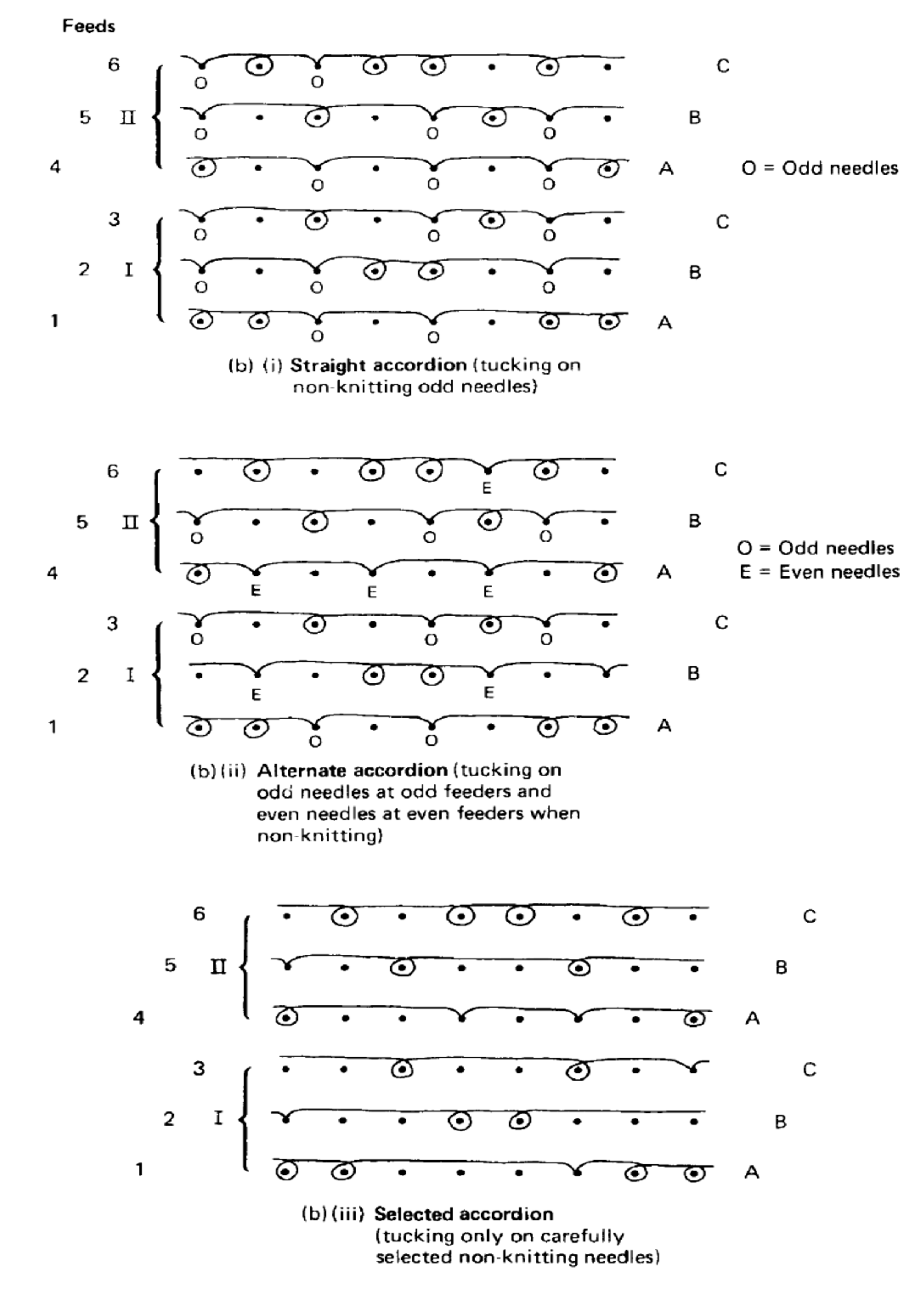
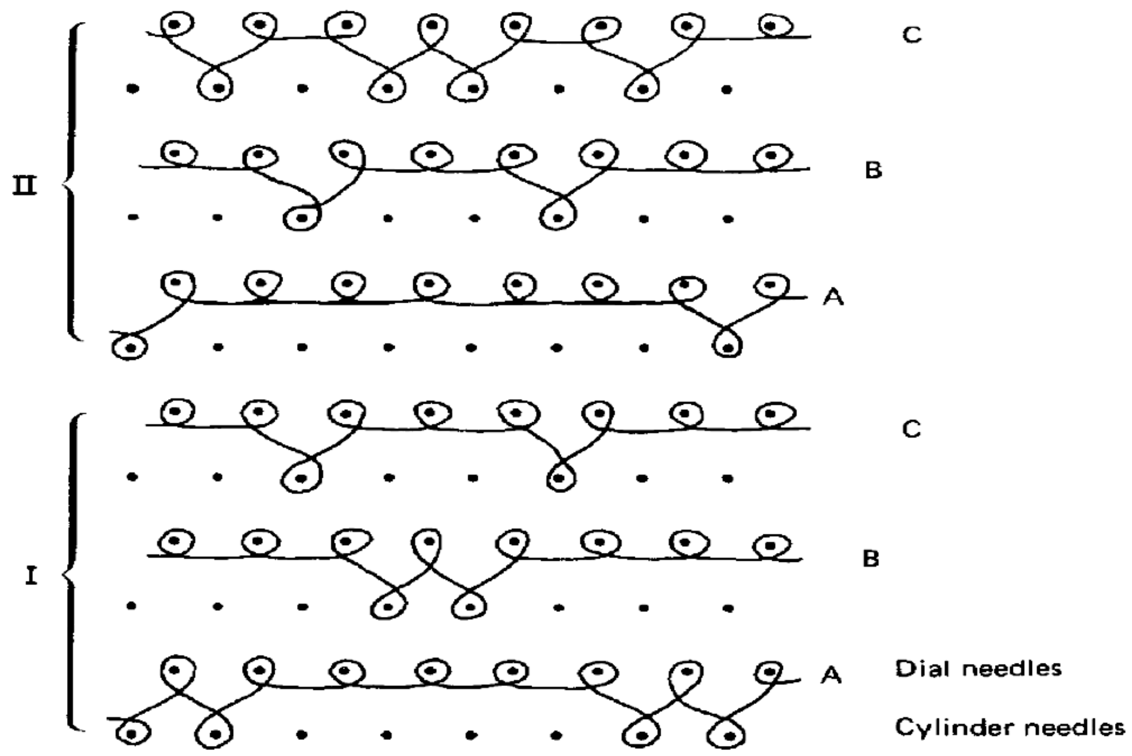
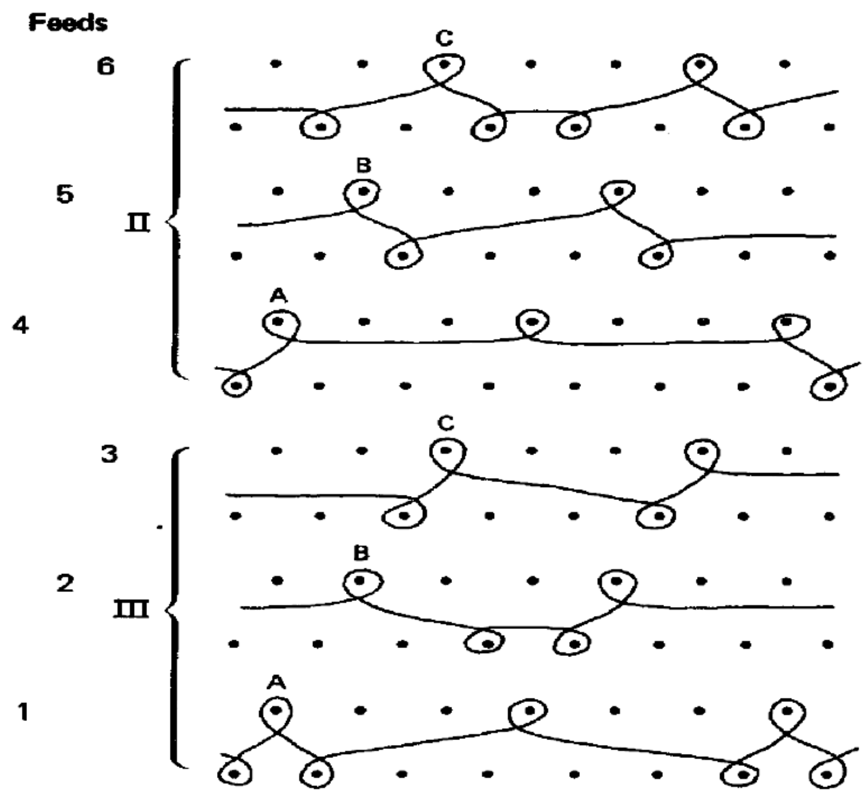


Figure 2.50 Single Jersey Knit Jacquard



(c) (i) Rib Jacquard with horizontally striped backing



(c)(ii) Rib Jacquard with vertically striped backing

Figure 2.51 Single Jersey Knit Jacquard

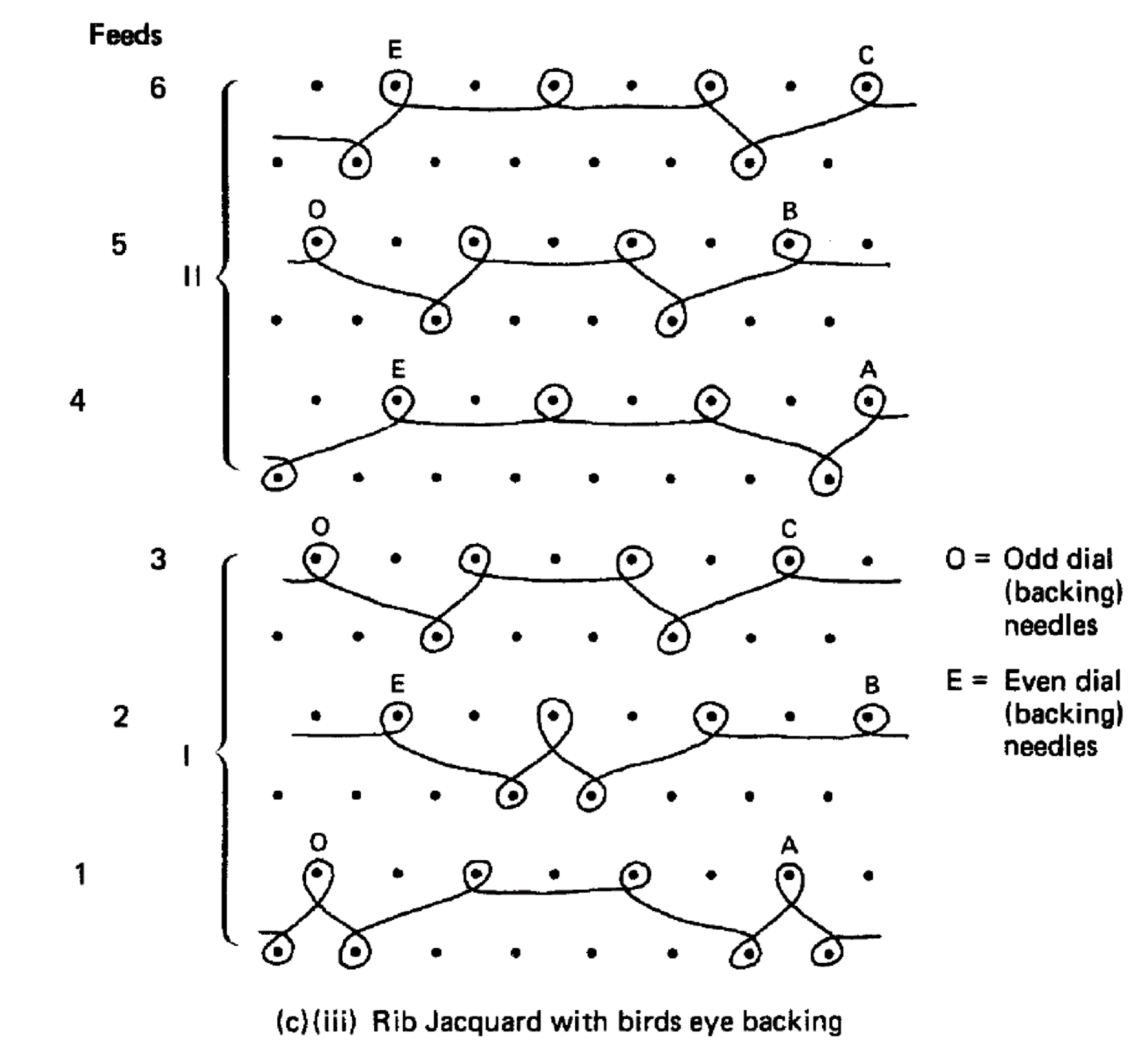


Figure 2.52 Single Jersey Knit Jacquard

Chapter 3 Weft Knitting Machines

3.1 Fabric Machines And Garment-Length Machines

Weft knitting machines may be broadly classified according to end product as either:

a. circular machines, knitting tubular fabric in a continuous uninterrupted length of constant width, or
b. flat and circular machines, knitting garment-length sequences, which have a timing or counting device to initiate an additional garment-length programming ('machine control') mechanism. This co-ordinates the knitting action to produce a garment-length structural repeat sequence in a wale-wise direction. The garment width may or may not vary within the garment length.

The difference between fabric and garment-length knitting is best understood in terms of hand flat knitting. If the knitter merely traverses the cam carriage backwards and forwards across the needle bed, a continuous fabric length will be knitted. However, if the knitter counts the traverses and alters the cam box settings at predetermined traverses, a garment-length sequence can be knitted.

Underwear may be knitted either in garment-length or fabric form, whereas knitwear is normally in garment-length form, usually knitted in machine gauges coarser than E 14. Jersey wear is cut and made-up from fabric usually knitted on large circular machines (26-inch or 30-inch diameter), although there are larger and smaller diameter machines used. Generally, gauges are finer than E 14.

3.1.1 Fabric Machines

Large diameter, circular, latch needle machines (also known as yard goods or piece goods, machines) knit fabric, at high speed, that is manually cut away from the machine (usually in roll form) after a convenient length has been knitted. Most fabric is knitted on circular machines, either single-cylinder (single jersey) or cylinder and dial (double jersey), of the revolving needle cylinder type, because of their high speed and productive efficiency.

Circular machines employing bearded needles are not in use anymore. Although sinker wheel and loop wheel frames could knit high quality speciality fabrics, their production rates are not competitive.

Unless used in tubular body-width, the fabric tube requires splitting into open width. It is finished on continuous finishing equipment and is cut-and-sewn into garments, or it is used for household and technical fabrics. The productivity, versatility and patterning facilities of fabric machines vary considerably. Generally, cam settings and needle set-outs are not altered during the knitting of the fabric.

3.1.2 Garment-Length Machines

Garment-length machines include straight bar frames, most flats, hosiery, legwear and glove machines, and circular garment machines including sweater strip machines, producing knitwear, outerwear and underwear. On these machines, the garment sequence control with the timing/counting device, collectively termed 'the machine control', automatically initiates any alteration to the other facilities on the machine needed to knit a garment-length construction sequence instead of a continuous fabric.

This machine control may have to initiate correctly-timed changes in some or all of the following: cam-settings, needle set-outs, feeders and machine speeds. It must be able to override and cancel the effect of the patterning mechanism in rib borders and be easily adjustable for different garment sizes.

Also the fabric take down mechanism must be more sophisticated than for continuous fabric knitting. It has to adapt to varying rates of production during the knitting of the sequence and, on some machines, be able to assist both in the setting-up on empty needles and the take away of separate garments or pieces on completion of the sequence.

Garments may be knitted to size either in tubular or open-width; in the latter case more than one garment panel may be knitted simultaneously across the knitting bed. Large-diameter circular machines and wide V-bed flat machines can knit garment blanks that are later split into two or more garment widths (blanket-width knitting)

3.2 Knitting Welts and Rib Borders

Garment-length knitting sequences vary considerably. The simplest circular garment machines knit repeat sequences of rib borders and body panels in a continuous structure at high speed. This structure requires cutting into garment lengths and seaming to produce a secure welt edge. Most garment machines knit some form of secure welt edge at the start of the garment sequence and either a 'knitted-in' separation course (draw-thread or dissolving thread) or 'press-off' separation between each garment piece. In the latter case, the machine must be capable of commencing knitting of the next garment length on empty needles. Shaping of flat garment panels is either in the form of cut edges or in the form of knitted selvedges (in the case of reciprocating knitting on a flat machine). The amount of shape introduced into the garment also varies; in some cases this is achieved entirely by the cutting and making-up operation, in others it is by stitch shaping, stitch length variation, loop transfer and fashioning, held stitches or reciprocation.

3.3 Integral Knitting

Whereas garments cut from fabric are completely assembled during seaming, others require varying amounts of making-up. Integrally knitted articles or 'whole garments' are completely assembled on the knitting machine and require no further making up operations off the machine.

Some V-bed glove knitting machines are of this type, as are some hosiery machines with integral toe-closing facilities. Some V-bed flat machines can knit complete garments in tubular form.

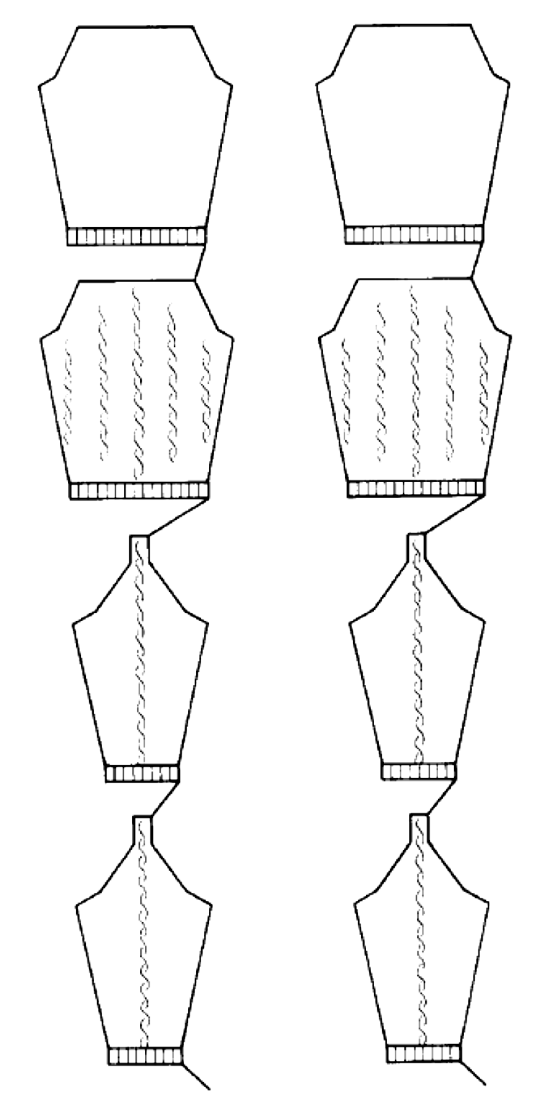


Fig. 3.1 Sequential knitting.

The advantages of this technique include savings in making-up machinery, space and labour, and reductions in the production sequence. Disadvantages include increased costs and complexity of the knitting machine and a possible reduction in its versatility and flexibility.

Certain electronically-controlled straight bar and V-bed flat machines can now be programmed to carry out a sequence of knitting a front, a back and two sleeves in turn thus using the same yarn and stitch lengths. Programming sequential knitting requires adequate computer memory and gives the advantages of quick response, less work in progress and better matching of component panels (Fig. 3.1).

3.4 The Three Classes of Weft Knitting Machines

The three main classes of weft knitting machinery may broadly be grouped as either straight bar frames, flats, or circulars, according to their frame design and needle bed arrangement.

3.4.1 Straight Bar Frame Machines

Straight bar frames are a specific type of machine having a vertical bar of bearded needles whose movement is controlled by circular engineering cams attached to a revolving cam-shaft in the base of the machine. The length of the machine is divided into a number of knitting heads ('sections' or 'divisions') and each head is capable of knitting a separate but identically-dimensioned fashion-shaped garment panel.

The needles press their beards against a fixed pressing edge; loop formation prior to intermeshing is achieved by individually horizontally-moving loop-forming sinkers, and knock-over occurs when the needles descend below the knock-over bits.

At either edge of each knitting head, a group of rack ably-controlled points transfer loops to fashion shape the garment panel at the selvedges by widening or narrowing the knitting width. On completion of the garment panel, it is pressed-off the needles.

As straight bar frames have a single needle bar, they are unable to knit rib welts. A few rib frames (with a horizontal as well as a vertical needle bar) were built, but they were too slow and complex to become accepted. The same situation arose with the rib-to-plain frame, which had an auxiliary needle bed and was designed to knit a rib border after which only the vertical needle bar continued knitting for the plain knit body panel.

The welt and border sequence at the beginning of the panel was achieved by one of the two following methods:

1. Knitting a rib border fabric and welt on a separate V-bed flat machine, running it onto the empty needles of the frame and then commencing to knit the body panel onto the rib.

2. Employing a welt-turning device on the frame to produce a double thickness plain fabric. This method is more popular in the USA. It is the only method of knitting welts on fully-fashioned stockings.

Straight bar frames are long, capital-expensive machines that, because of their multi-sections and in spite of their intermittent knitting action, are highly productive in a very narrow sphere of garment manufacture. The knitting width is rather restricted and fashion tends not to encourage full exploitation of the fashion shaping and stitch-transfer patterning potential of the machines.

The machines are noted for their production of high-quality garments as a result of the gentle knitting action, low fabric tension and fashion shaping, which reduces the waste of expensive yarn during cutting and is emphasised on the garments by carefully-positioned fashion marks. The straight bar frame is the only bearded needle weft knitting machine that is still commercially viable, although it now faces serious competition from electronically-controlled V-bed flat machines.

3.4.2 Flat Machines

The typical flat machine has two stationary beds arranged in an inverted V formation. Latch needles and other elements slide in the tricks during the knitting action. Their butts project and are controlled as they pass through the tracks formed by the angular cams of a bi-directional cam system. It is attached to the underside of a carriage that, with its selected yarn carriers, traverses in a reciprocating manner across the machine width (Fig. 3.2).

The machines range from hand-propelled and -manipulated models to automated, electronically-controlled, power-driven machines. The classes of flat machines are:

1. The V-bed flat machines, which form by far the largest class;

2. The flat-bed purl machines, which employ double-headed needles;

3 machines having a single bed of needles, which include domestic models and a few hand-manipulated intarsia machines; and 4 the unidirectional, multi-carriage ('Diamant') machines, which are no longer built.

As with all knitting machines, there is a separate cam system for each bed; the two systems are linked together by a bow, or bridge, that passes across from one needle bed to the other. The systems for each needle bed are symmetrically arranged so that knitting, and in some cases loop transfer, may be achieved in either direction of carriage traverse.

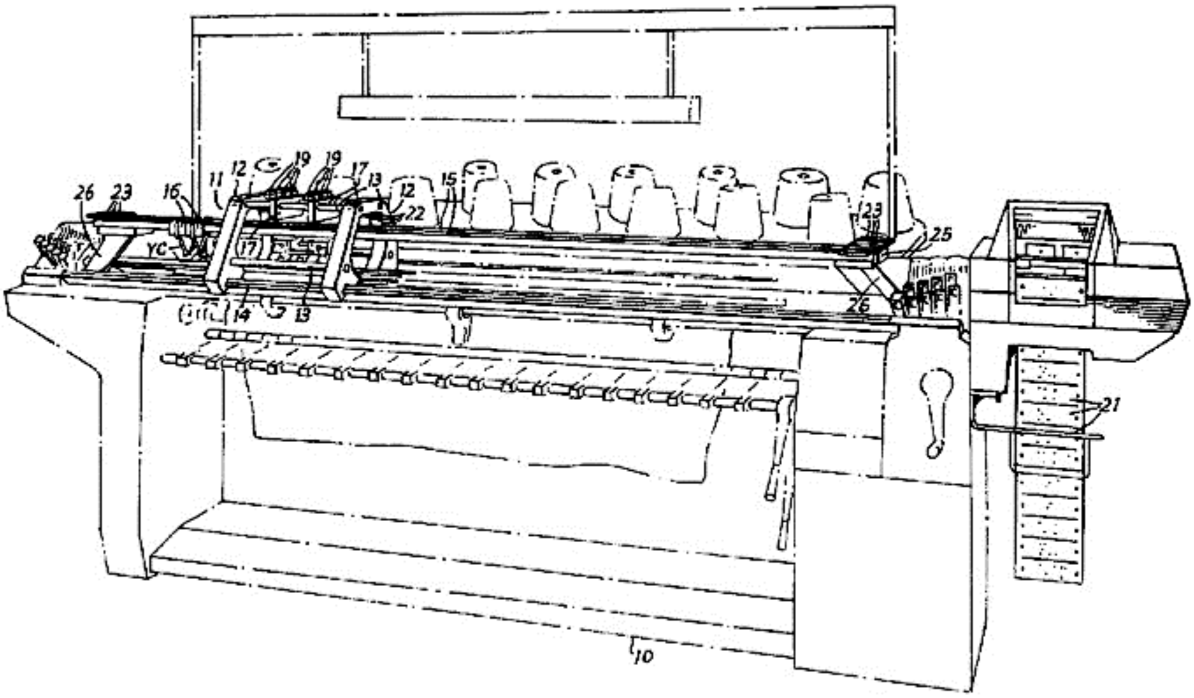


Fig. 3.2 Mechanically controlled flat knitting machines.

The intermittent action of the carriage traverse and its low number of knitting heads (one to four) and cam systems (often only two to six, with a maximum of eight) reduces productivity but enables major cam changes to occur when the carriage is clear of the active needles.

The flat machine is the most versatile of the weft knitting machines; its stitch potential includes needle selection on one or both beds, racked stitches, needle-out designs, striping, tubular knitting, changes of knitting width, and loop transfer; a wide range of yarn counts may be knitted for each machine gauge, including a number of ends of yarn at each knitting system; the stitch length range is also wide; and there is the possibility of changing the machine gauge. The operation and supervision of the machines of the simpler type are less arduous than for other weft knitting machines. The number of garments or panels knitted across the machine depends upon the knitting width, yarn carrier arrangement, yarn path and yarn package accommodation. Articles knitted on flat machines range from trimmings, edgings and collars, to shaped panels, integrally-knitted garment pieces, integrally-knitted complete garments and other articles.

3.4.3 Circular Machines

There are many types of circular knitting machine that produce long lengths of tubular fabric manufactured for specific end uses. Single jersey machines are equipped with a single 'cylinder' of needles that produces plain fabrics, about 30 inches in diameter. Wool production on single jersey machines tends to be limited to 20 gauge or coarser, as these gauges can use two-fold wool yarns. The cylinder system of single jersey machines is demonstrated in Fig. 3.3. Another inherent feature of woollen single jersey fabrics is that the fabric edges tend to curl inwards. This is not a problem whilst the fabric is in tubular form but once cut open can create difficulties if the fabric is not finished correctly. Terry loop machines are the basis for fleece fabrics that are produced by knitting two yarns into the same stitch, one ground yarn and one loop yarn. These protruding loops are then brushed or raised during finishing, creating a fleece fabric. Sliver knitting machines are single jersey machines that have been adapted to trap a sliver of staple fibre into the knit structure.

Double jersey machines are single jersey machines with a 'dial' that houses an extra set of needles positioned horizontally adjacent to the vertical cylinder needles. This extra set of needles allows the production of fabrics that are twice as thick as single jersey fabrics. Typical examples include interlock-based structures for underwear/base layer garments and 1 × 1 rib fabrics for leggings and outerwear products. Much finer yarns can be used, as single yarns do not present a problem for double jersey knitted fabrics.

The technical parameter is fundamental to the classification of knitting machines. The gauge is the spacing of the needles, and refers to the number of needles per inch. This unit of measure is indicated with a capital E. The circular machines now available from different manufacturers are offered in a vast range of gauge sizes. For example, flatbed machines are available in gauge sizes from E3 to E18, and large-diameter circular machines from E4 toE36. The vast range of gauges meets all knitting needs. Obviously, the most common models are those with middle gauge sizes.

This parameter describes the size of the working area. On circular machines, the width is the operating length of beds as measured from the first to the last groove, and is normally expressed in centimetres. On circular machines, the width is the bed diameter measured in inches. The diameter is measured on two opposite needles. Large-diameter circular machines can have a width of 60 inches; however, the most common width is 30 inches. Medium-diameter circular machines feature a width of about 15 inches, and the small-diameter models are about 3 inches in width.

The term 'circular' covers all those weft knitting machines whose needle beds are arranged in circular cylinders and/or dials, including latch, bearded, or (very occasionally) compound needle machinery, knitting a wide range of fabric structures, garments, hosiery and other articles in a variety of diameters. Circular garment length machines are either of body size or larger (Fig. 3.3), having a cylinder and dial arrangement, single cylinder or double cylinder, as is also the case with small diameter machines for hosiery (Fig. 3.4).

During the last 200 years, numerous inventors have assisted the development of circular weft knitting technology towards its present state of sophistication and diversity. Whilst Decroix's patent of 1798 has been considered to be the first for a circular frame, Marc Brunel's 'tricoteur' of 1816 is probably the first practical working example of such a frame. Efforts were concentrated during the subsequent 30 years on improving the knitting action of this frame, with its revolving dial of fixed bearded needles radiating horizontally outwards and having their beards uppermost.

In 1845, Fouquet applied his 'Stuttgarter Mailleuse' wheels to the frame and their individually moving, loop-forming sinkers provided the sinker frame with the capability of knitting high-quality fabric, a possibility later exploited by Terrot who improved the frame's patterning facilities and marketed it throughout the world.

In 1849, Moses Mellor produced a revolving circular frame with vertically arranged bearded needles facing outwards from the needle circle; this later developed to become the loop wheel frame. In the same year, Matthew Townsend patented uses for the latch needle and by 1855, Pepper had produced a commercial machine with a single set of movable latch needles and two feed points. This was soon followed by Aiken's circular latch needle rib machine of 1859, which also contained movable needles. Henry Griswold took latch needle knitting a stage further by moving the needles individually and directly via their bent shanks in his world-famous, hand-operated, revolving cam-box, small-diameter sock machine of 1878 (Fig. 3.4).

The first small-diameter, revolving-cylinder machine appeared about 1907 but there was still much strenuous effort required by machine builders and needle manufacturers before circular latch needle machines could seriously begin to challenge bearded needle straight and circular machines in the production of consistently high-quality knitted articles.

Circular machines rotate in a single direction, and the various systems are distributed along the bed circumference. By increasing the diameter of the machine, it is then possible to increase the number of systems and therefore the number of courses inserted per each revolution. Today, large-diameter circular machines are available with a number of diameters and systems per inch. For example, simple constructions such as the jersey stitch can have up to 180 systems; however, the number of systems incorporated on large-diameter circular machines normally ranges from 42 to 84.

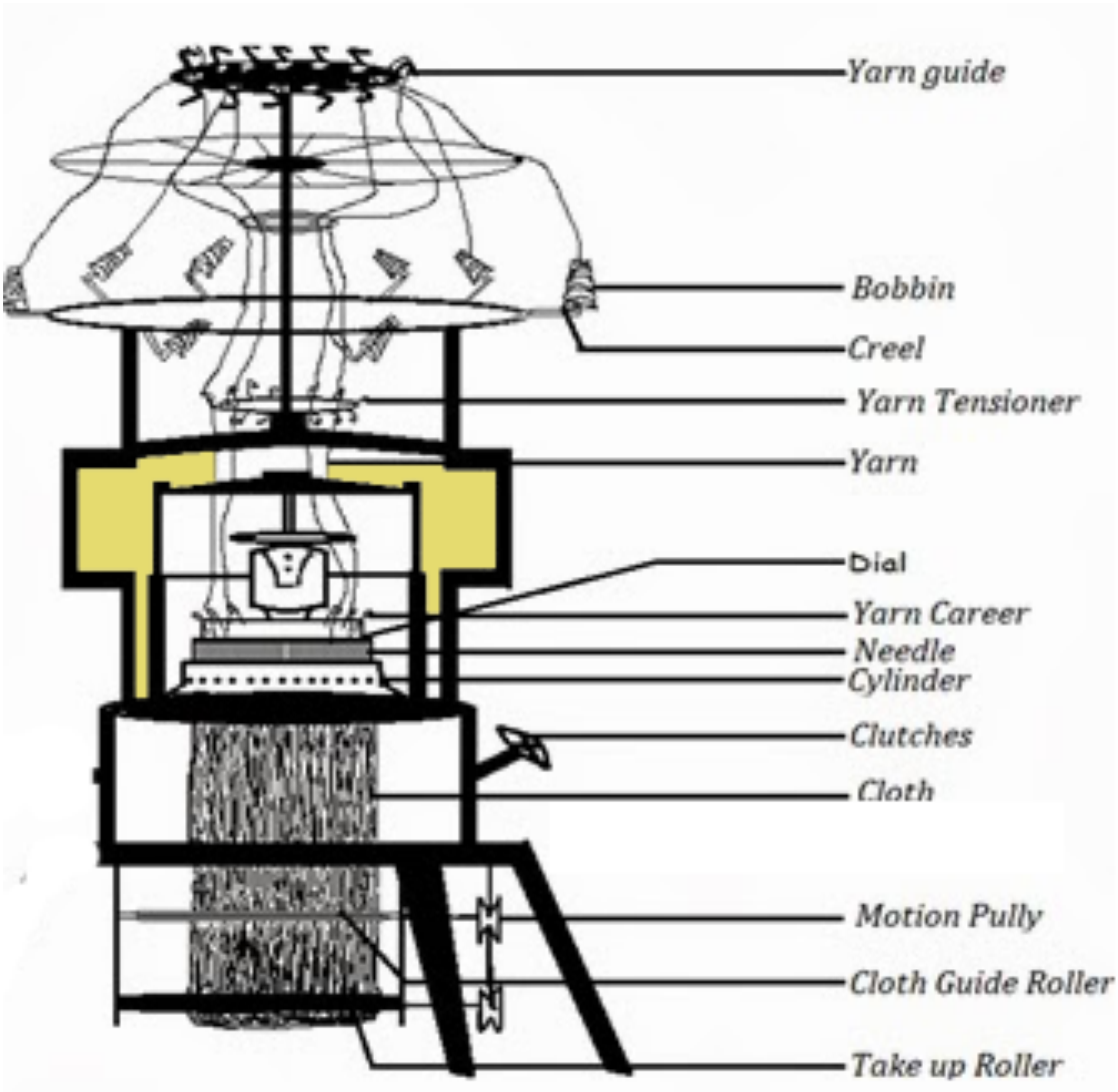


Fig. 3.3 Mechanically controlled circular knitting machines.

Fig. 3.4 Mechanically controlled hosiery machines.

Chapter 4 Circular Weft Knitting Machine and Mechanism

4.1 Knitting Machine

Circular knitting machines have been designed and manufactured for mass production of knitted fabrics. The special properties of knitted fabrics, especially fine fabrics made by the circular knitting process, makes these types of fabric suitable for application in clothing, industrial textiles, medical and orthopedic garments, automotive textiles, hosiery, agro and geo textiles, etc. The most important areas for discussion in circular knitting technology are increasing production efficiency and improving fabric quality as well as new trends in quality clothing, medical applications, electronic garments, fine fabrics, etc.

Famous manufacturing companies have pursued developments in circular knitting machines in order to extend into new markets. Textile specialists in the knitting industry should be aware that tubular and seamless fabrics are highly suitable for various applications not only in textiles but also in medical, electronic, agriculture, civil and other fields.

In knitting machine technology, the basic system is the set of mechanical components that move the needles and allow the formation of the loop. The output rate of a machine is determined by the number of systems it incorporates, as every system corresponds to a lifting or lowering movement of the needles, and therefore, to the formation of a course. The system motions are caused by cams or triangles (lifting or lowering according to the resulting movement of the needles).A knitting machine is an apparatus for applying mechanical movement by means of hand or other power to primary knitting elements in order to produce knitted structures from yarn. The machine incorporates and coordinates the action of a number of mechanisms and devices each performing specific function which contributes towards the efficiency of the knitting action. The main features of a typical circular weft knitting machine (Figure 4.1) are listed below:

(a) The frame or body either circular or rectilinear according to needle bed shape supports the majority of the mechanisms of the machine.

(b) The machine driving system which coordinates the power for the drive of various devices and mechanisms.

(c) The yarn supply system or creel for holding the yarn packages, yarn tensioning devices, yarn feed control and yarn feed carriers or guides.

(d) The knitting system which includes the housing and driving of knitting elements as well as the selection devices of the needles and garment length control devices.

(e) The fabric take-down mechanism.

(f) The attachments like stop motions, automatic lubricator, etc., for better running as well as quality of the products.

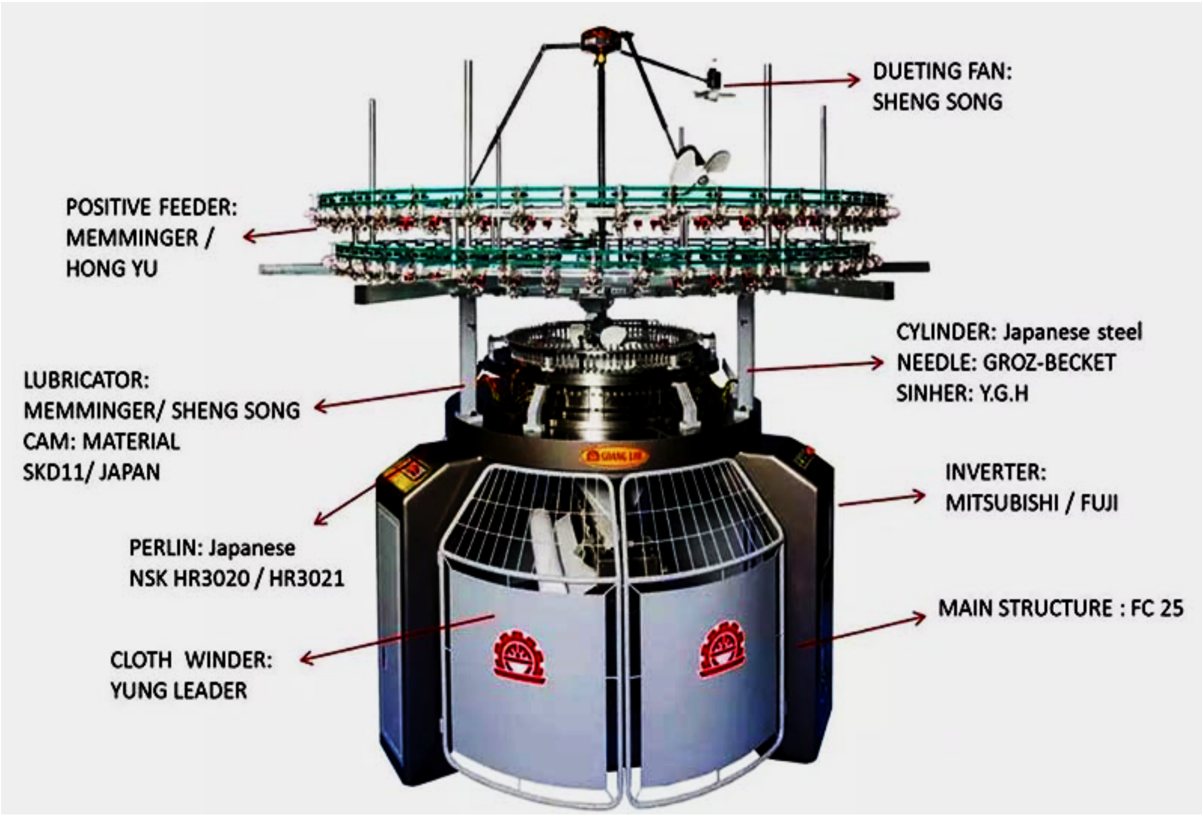


Figure 4.1 Circular knitting machine

As observed in Fig. 4.1 (photographic view of a circular weft knitting machine), the yarn from the package is withdrawn upward and ultimately comes downward for being supplied to the needles through guides, tensioner, stop motion, feed plate, etc. The knitted fabric is taken down inside the cylinder and ultimately rolled on the cloth roller. The whole machine stands on three legs or supports. The yarn fed to the needles in order to form the fabric must be conveyed along a predetermined path from the spool to the knitting zone. The various motions along this path guide the yarn (thread guides), adjust the yarn tension (yarn tensing devices), and check for eventual yarn breaks.

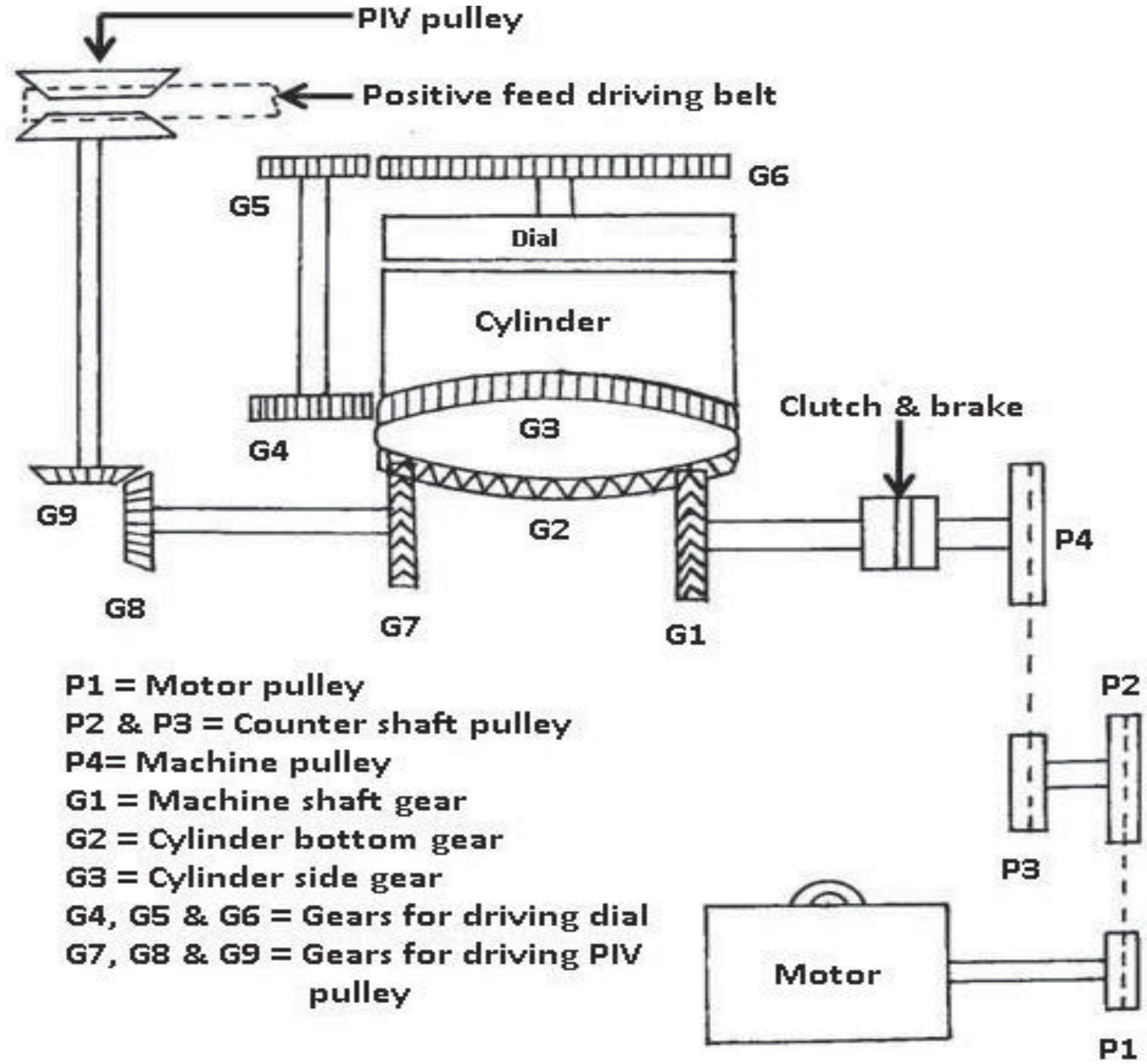
The yarn is taken down from the spool arranged on a special holder, called a creel (if placed beside the machine), or a rack (if placed above it). The yarn is then guided into the knitting zone through the thread guide, which is typically a small plate with a steel eyelet for holding the yarn. In order to obtain particular designs such as intarsia and vanisé effects, the machines are equipped with special thread guides.

4.2 Frame

The construction of the frame of knitting machines varies from make to make but it mostly depends on the type of knitting machine. The machine frame of a circular knitting machine is composed of (i) lower frame with base crossbeams, feet (generally 3) and supports for the fabric take-down device and (ii) upper frame with carrier plate, cylinder needle bed with cylinder bearing, columns and dial needle bed housing with dial bearing. The quality of the machine frame is a very important pre-requisite for the operational reliability of the machine and the product quality. The frame must be absolutely distortion free and should absorb the acceleration and braking forces the machine is subjected to during starting, running and stopping of the machine.

4.3 Drive

The machine drive has a significant influence on the operational reliability of the knitting machine and the quality of the fabric produced. As a result of an increase in the production speed and the number of feeders in recent years, the demand placed on the drive has also gone up.Method of driving depends on the type of machine. The power required in driving the machine is either man power or electrical (motor) power.Excepting a few small diameter machines, circular weft knitting machines are generally power driven. A motor of desired horse power is fitted with the machine. The motor pulley is connected with the machine pulley through brake and clutch arrangement. The machine pulley shaft ultimately transfers the motion to the cylinder through gearing arrangement. In case of double cylinder or dial and cylinder type machine, the second cylinder or dial gets motion from the bottom cylinder through gears. Moreover the PIV pulley of the positive feed arrangement also gets from the cylinder through gears. As the cylinder rotates, the stretcher board assembly fitted with it also rotates. The rotation of the stretcher board assembly transmits motion to the take-down rollers and cloth rollers through eccentric or cam mechanism. Sometimes a separate motor is used for the drive of the fabric take-down and cloth winding mechanisms. In addition to the power driving arrangement, a few handles are connected to the cylinder for manual drive of the machine. A typical driving arrangement in dial and cylinder type weft knitting is shown in Fig. 4.2.



4.2 Circular double jersey machine drive.

4.4 Creel

Creel means the assembly on which all the yarn packages are held in working position with necessary guides. There are two types of creels – top or umbrella creel (Fig. 4.3) and side or free standing creel (Fig. 4.4). The creel, positioned at the top of the machine, is called top creel. Top creel looks like an umbrella – so it is also named as umbrella creel. When the creel is positioned at one side of the machine instead positioning at the top of the machine, the creel is called side creel. The side creel can be covered to eliminate deposition of dirt, fluffs etc. such covered creel is called Filter Creel. In modern side creels pneumatic or suction tubes are used for passing of the yarn from the creel to the knitting zone.

Figure 4.3 Top or umbrella creel

Figure 4.4 Side creel

4.5 Tensioner

Any element or machine part on which the yarn passes applies some tension and acts as a tensioner. But technically an attachment which is used intentionally to apply and maintain desired tension to the yarn is called yarn tensioner. Some desired yarn tension is essential for smooth flow of yarn from the package to the needle as well as for loop formation. Without tension, yarn does not flow properly, it is difficult to bend the yarn for giving the shape of loop, old loop may not cast-off etc. Again at very high input tension, tension developed inside knitting zone is extremely high, as a result yarn and other knitting element may break. The loop length and compactness of the fabric largely depend on the yarn tension. Generally loop length is inversely proportional to yarn tension. So applying as well as maintaining of desired (optimum) tension is very much important.

There are different types of tensioners (mechanical, pneumatic, electro-magnetic etc.) available in the market as well as used in the knitting machine. But according to the working principle they are either additive or multiplicative in nature.

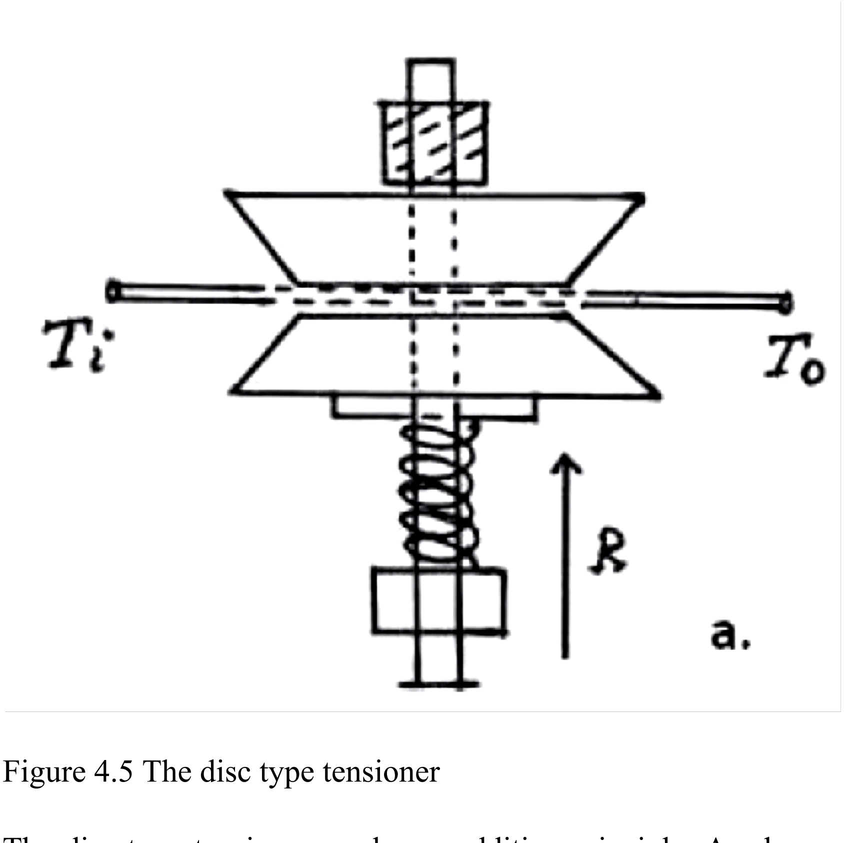


Figure 4.5 The disc type tensioner

The disc type tensioner works on additive principle. As shown in Fig. 4.5, the yarn passes through the gap between two washers or plates. The weight (R) of the upper washer or some additional dead weight or spring load applies resistance to the movement of the yarn, as a result the tension on the yarn increases. The final tension (T_o) is obtained by adding the tension applied by the tensioner to the initial tension (Ti) of the yarn.

= $T_i + 2\mu R$, where μ is the coefficient of friction between disc and yarn.

The gate or pulley type tensioners work on multiplicative principle. The yarn passes over a guide rod or pulley surface. The increase in tension

4.6 Guides

Guides are there mainly to give and maintain proper path and alignment of yarn so that yarn can flow smoothly from the package to the knitting zone for fabric formation. Guides are generally metallic or ceramic rings fitted at different parts of the machines. The inner or working surface of the guides should be smooth enough so that neither yarn is damaged nor much tension is developed due to friction. As fluffs may deposit and choke the opening of the guides, guides should be cleaned regularly. Moreover the number and position of the guides should not deflect much of the yarn as well should not allow the adjacent yarns to entangle.

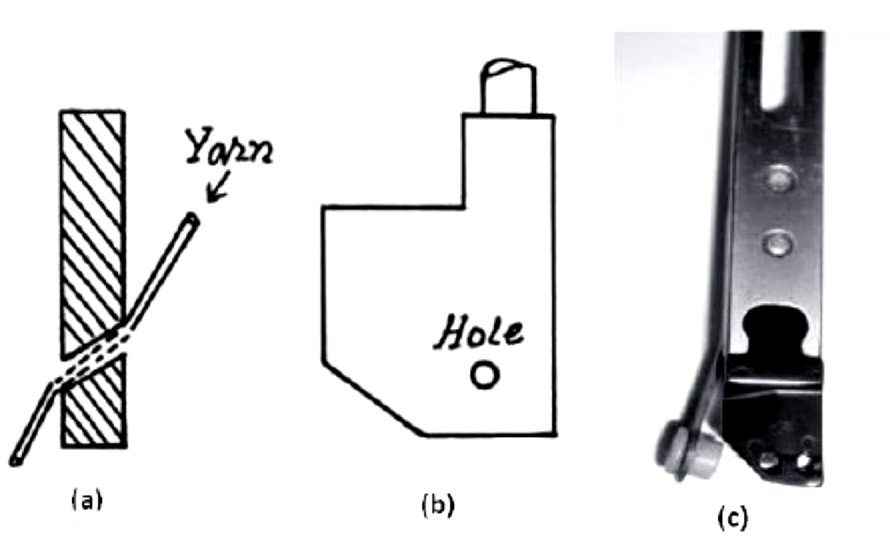


Figure 4.6 Feed plate

4.7 Feed Plate

Feed plate or feeder is a small metallic plate with a hole at the centre. Passing of yarn through the feed hole, shape of feed plate along with hole and the actual feed plate of recent machines are shown in a, b and c parts respectively of the Fig. 4.6. It is fitted near the knitting zone, on the carriage itself in case of flatbed machine and on the frame near the cam jacket on the circular machine. The yarn passes through the hole just before being caught by the needle. The main purpose of using the feed plate is to maintain a proper path and alignment of the yarn so that needles after getting cleared can catch the new yarn at tuck height level for loop formation without fail. While doing this job it causes deflection of the yarn and adds tension on the same depending upon the angle of deflection. The feed plate is curved to the corresponding curvature of the needle bed (cylinder). The bevelled edge of the plate guards the latch of the needle going to catch the yarn. The position of the feed plate is adjustable for proper catching of the yarn to suit variation of quality, count and type of yarn as well as yarn input tension. Sometimes two holes are provided on the feed plate for plating purposes.

4.8 Methods of Yarn Feeding

In a knitting cycle, yarn is generally fed when the needle is raised for clearing and the hook is open. During downward movement, needle hook can catch yarn for forming the loop. Such feeding of yarn to the needle hook can be done by two ways. In first case the yarn is moved from needle to needle whereas in the second case the needles move over a stationary yarn feed position. As the yarn feeding is related to the up and down movement of the needles given by the cam system, the yarn feeding point is connected with the cam system. Based on the method of yarn feeding, machines may be of two types – a) stationary needle bed with moving cam and b) stationary cam with moving needle bed. The flat bed machines belong to first category. In flatbed machines the cam system called carriage along with the yarn traverses over the needles during knitting operation.

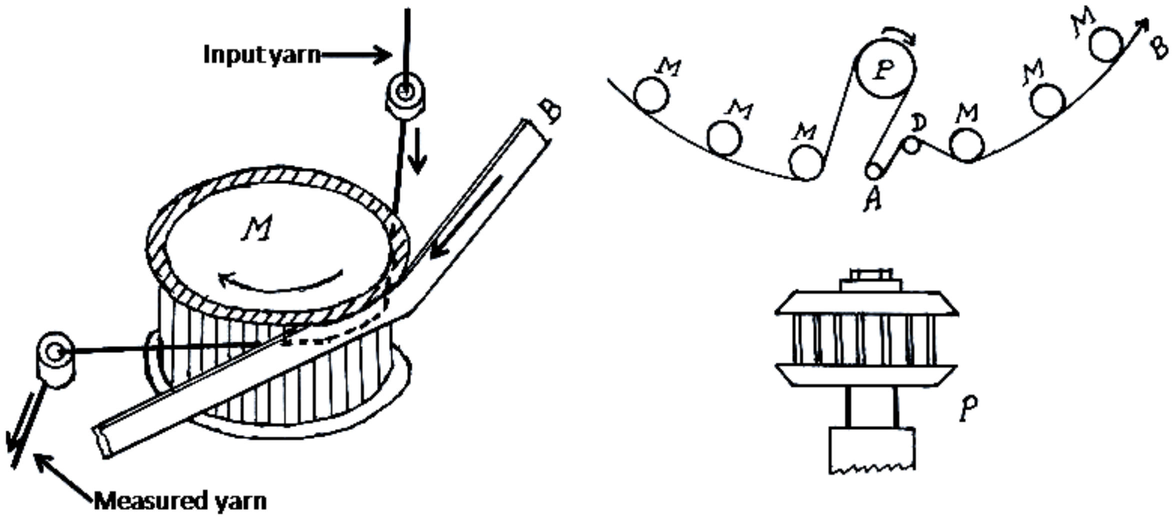
The moving or rotating cam system may be found in a few small diameter circular weft knitting machines with single feed. When needle bed is stationary, the fabric formed during knitting is also stationary. Circular weft knitting machines with multiple feed are generally made with stationary cam system. The needle bed rotates along with the fabric under it. If circular machines are made with stationary needle bed the yarn supply packages are to rotate otherwise they will entangle and resist knitting.

4.9 Principles of Yarn Feeding

For continuous knitting, yarn is to be supplied or fed to the needles or to the knitting zone continuously. In weft knitting, yarn is generally supplied or fed from cones or other suitable yarn packages positioned in a creel. The principles involved in supplying or feeding of yarn may be summed as follows:

Negative feeding – Yarn is pulled by the needles directly from the package through guides, tensioners etc. This is a very simple technique of yarn feeding. It does not require any extra attachment as yarn is drawn automatically due to the knitting process. This technique does not maintain uniform yarn tension. But it can easily adjust and take care of difference in stitch cam setting in different feeds.

Positive Feeding – In case of positive feeding, yarn is first measured according to requirement and then supplied to the needle or knitting zone. This technique makes it possible to supply equal length of yarn in all the feeds and maintain uniform tension of the input yarn. As a result uniform loop length and better quality of fabric are obtained. But this technique requires a special attachment in the machine. The Fig. 4.7 shows the construction of a typical positive feeder. For measuring the yarn before entering the knitting zone, measuring drum or cylinder (M) is provided in every feeding zone. In order to make equal loop length in every course, all the measuring drums are rotated at same surface speed by means of a common belt (B). The belt generally gets motion from a P.I.V. pulley (P) which is also sometimes called control drive wheel. The effective diameter of this pulley can be varied in infinite steps according to requirement. The yarn passes through the nip formed by the measuring drum and the belt and advances to the knitting zone at the rate of the surface speed of the measuring drum. When cam setting is changed to vary loop length, the surface speed of the measuring drum is changed by varying the effective diameter of the driving pulley. The adjustment of the position of the pulley (A and D) maintains the required tension on the belt. As the yarn passes between a rotating drum and the driving tape/belt, the yarn may be partly damaged.



4.7 Positive feeder.

Moreover, the yarn tension offers by this system depends on the

– a) count and evenness of the yarn, b) running behaviour of the yarn, particularly the mean value and coefficient of friction and c) type of yarn, particularly spun yarn or filament yarn. So the positive feed is unsuitable when either yarns of different quality or variable yarn length is to be fed at different feeders. In order to partially overcome this problem tape delivery devices have been developed with 2, 3 and 4 tapes.

Storage Feeding – As measurement of exact requirement of yarn is to some extent difficult and needs very accurate and adjustable attachment, a storage device may be used for feeding the yarn instead of positive feeder. Storage feeder supply yarn at a uniform tension rather than at a uniform rate of feed and is thus suitable for wide range of yarn feed. In this case yarn is first withdrawn from the package and wound tangentially as equally spaced coils on a store (drum) and then the needles draw the yarn from the store which allows the yarn to be delivered at a uniform tension. The working principle of the IRO storage feeder, the most popular in this field, is shown in Fig. 4.8 (a). The yarn coming from the yarn package is first wound on a specially shaped rotating drum or cylinder coil by coil. As soon as the drum is filled with yarn coils, a photo-electric or capacitance type sensor stops the drum. When certain amount of yarn is delivered to the knitting zone from the, the drum automatically starts rotating for winding further length of yarn. The yarn from the drum surface is withdrawn gently coil by coil by the needles through a floating nip formed by the bottom edge of the drum and nylon bristled ring (called tension ring) in a constant low tension. The yarn is prevented from slipping off the drum by the tension ring. The nylon bristled rings of different colours are generally used to vary the yarn tension.

Combined positive and storage feeding – A further development is the combination of positive feed and storage feed with a choice of mode available by means of a clutch. In this case yarn path is not guided by the tape or belt but directly wound on a drum. The working principle of combined positive and storage feeder is shown in Fig. 4.8 (b). In this case the drum is provided with a grooved pulley at the top which can be detached from the drum if needed. The drum gets the motion from the P.I.V. drive through tape or belt which passes over the pulley and the yarn is deposited or wound on the drum surface at a constant rate. The yarn is withdrawn from the drum by the needles according to their requirement. A slight variation between surface speed of the drum and rate of yarn withdrawal from the drum may permit knitting at almost uniform yarn tension. However, surface speed of the drum should be so adjusted that the number of coils deposited on the drum surface will always be same. The drum may be de-clutched from the positive drive and used as negative feeder.

4.10 Number of Feeders And Feeder Density

In small diameter circular knitting machine as well as flatbed knitting machine, generally one yarn is fed at a time to the needle for loop formation through the desired feeding system or feeder. However, in medium to larger diameter circular knitting machines, more number of feeders are arranged/ accommodated at regular intervals for supplying more number of yarns to the needles simultaneously for achieving higher production.

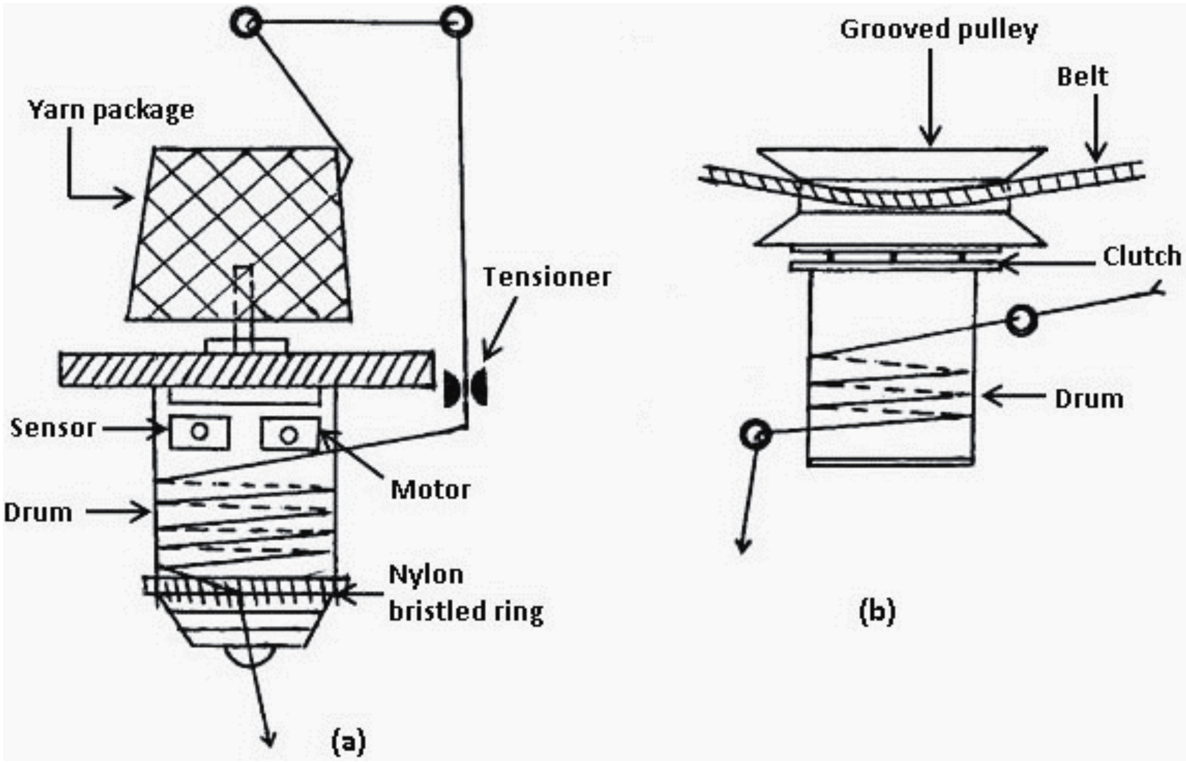


Figure 4.8 Storage feeder.

Each feeder produces separate course in each revolution of the machine. Production can also be increased by increasing the machine speed. But there is a limitation in increasing the machine speed as vibration, jerk, noise, yarn breakage and ultimately power consumption increase to a great extent at higher speed. So instead of increasing the machine speed, attempts are being made to increase the number of feeders in the machine. Machines are available with up-to 152 feeders for 42 inch diameter. Number of feeders on a circular machine depends on machine diameter, type of machine (plain, rib etc.), patterning facility and machine gauge. Number of feeder is mostly even number. Feeder density (D) is defined as number of feeders per inch diameter. D = (number of feeders / machine diameter in inch)

For example, a 20 inch diameter circular machine with 40 feeders has a feeder density of 2.

Higher density (D = 2.5 and above) is preferred for getting higher production but it requires a major modification in the machine including redesigning of stitch cam.

Electronic Feeders

The use of electronic feeders enables quick and efficient regulation of yarn tensile stress. These systems are often based on the principle of storage feeders with control of reel rotation according to output yarn stress F, Fig. 4.9 Yarn (1) is wound on the reel (2), which is designed as a lightweight cage with self-cleaning abilities. Input yarn tension F0 is controlled by the disc tensioner (4). Output force F is measured by the sensor (3), which controls the motor drive (5). The motor reaction is so quick that the feeder allows knitting of patterned fabric and can be combined with a striper (yarn guide or finger exchange), which is standard equipment on hosiery machines.

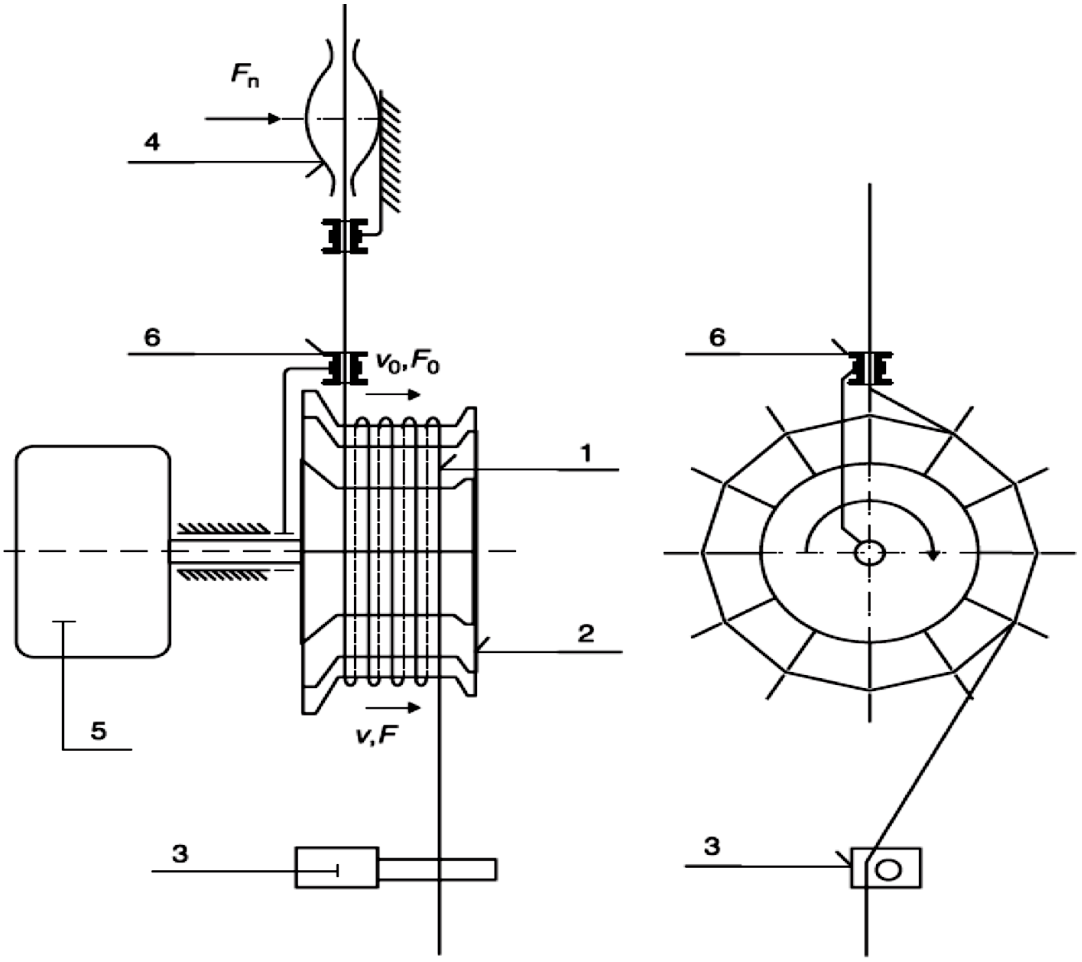


Figure 4.9 Electronic yarn feeder

Some electronic feeders can be used on circular machines with reciprocated movement (for example in hosiery and body technologies). In this case, the feeder must allow backward yarn movement to compensate for shortening the length of the yarn path on the machine. In Fig. 4.7 this is achieved by the thread eye (6) mounted on a separately controlled arm. When the reel (2) moves backwards, the eye (6) turns in the same direction and keeps the input section of the yarn extended.

The specific features influencing yarn delivery on large-diameter circular knitting machines are high productivity, continuous knitting and a great number of simultaneously processed yarns. Some of these machines are equipped with a striper (yarn guide exchange), but only a few enable reciprocated knitting. Small diameter hosiery machines have up to four (or occasionally eight) knitting systems (feeders) and an important feature is the combination of rotary and reciprocal movement of the needle bed (beds). Between these extremes are the middle diameter machines for 'body' technologies.

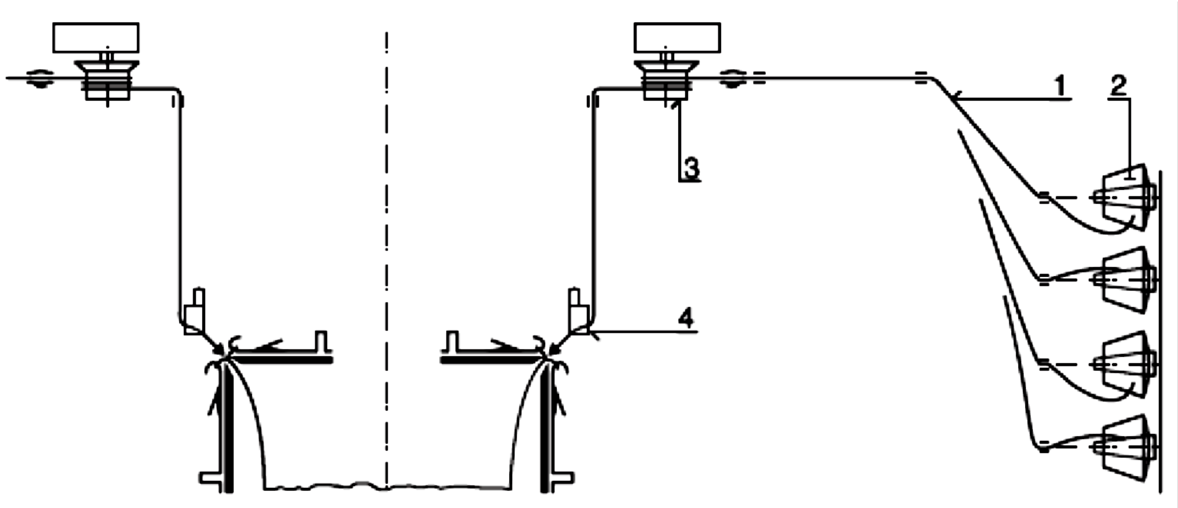


Figure 4.10 Simplified yarn supply system

Figure 4.10 shows the simplified yarn supply system on a large-diameter circular knitting machine. Yarns (1) are brought from the bobbins (2), passed through the side creel to the feeder (3) and finally to the yarn guide (4). Usually the feeder (3) is equipped with stop-motion sensors for yarn checking.

The creel of the knitting machine controls the placement of yarn packages (bobbins) on all machines. Modern large-diameter circular machines use separate side creels, which are able to hold a large number of packages in a vertical position. Floor projection of these creels may differ (oblong, circular, etc.). If there is a long distance between the bobbin and the yarn guide, the yarns may be threaded pneumatically into tubes. The modular design facilitates the changing of the number of bobbins where required. Small-diameter machines with a smaller number of cam systems use either side creels or creels designed as integral to the machine.

Modern creels make it possible to use double bobbins. Each pair of creel pins is centred on one thread eye (Fig. 4.11). The yarn of a new bobbin (3) may be linked to the end of the previous length of yarn (1) on bobbin (2) without stopping the machine. Some of the creels are equipped with systems for blowing off dust (fan creel), or with air circulation and filtration (filter creel). The example in Fig. 4.12 shows the bobbins (2) in six rows, closed in a box with internal air circulation, provided by fans (4) and tubes (3). A filter (5) clears dust from the air.

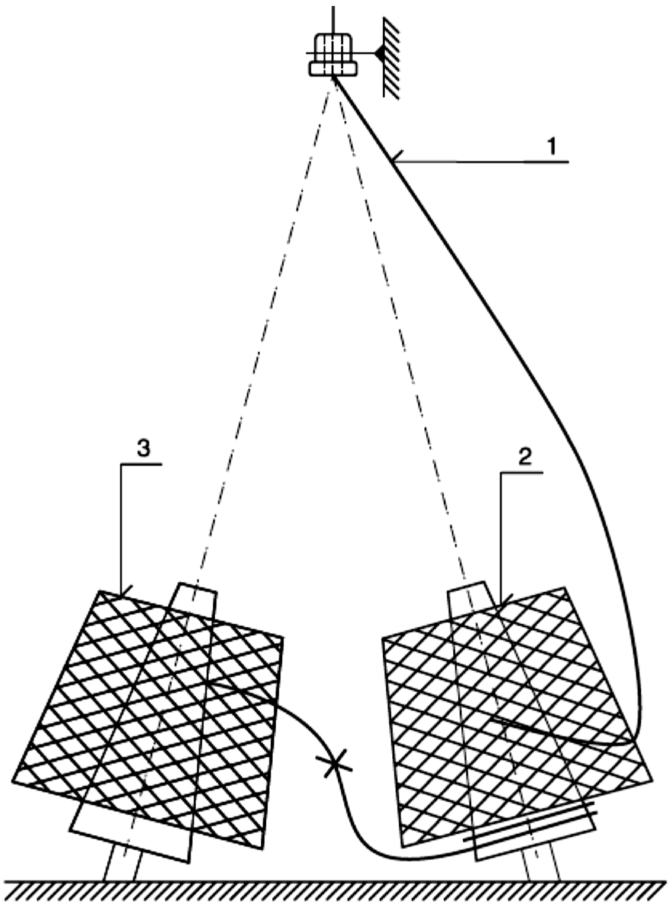


Figure 4.11 Double bobbin creel

The creel can be air-conditioned. When the machine is not equipped with a striper, this can be supplied by yarn exchange on the creel; some systems enable the knots to be positioned in the optimal area of the fabric.

Yarn length control (positive feeding), when not used for patterned fabric knitting, must enable different yarn lengths to be fed into courses in different structures. As an example, in Milano-rib knit there is one double-faced course (1) and two single-faced (2), (3) courses in the repeated pattern. As a double-faced course contains twice as many stitches, the yarns must be fed at approximately twice the length per machine revolution. This is the reason why these feeders use several belts, individually adjusted for speed, whilst feeders using yarns of the same length are controlled by one belt. The feeders are usually mounted onto two or three rings around the machine. If a configuration with two belts on each ring is used (Fig. 4.7), yarns can be fed simultaneously at four or six speeds.

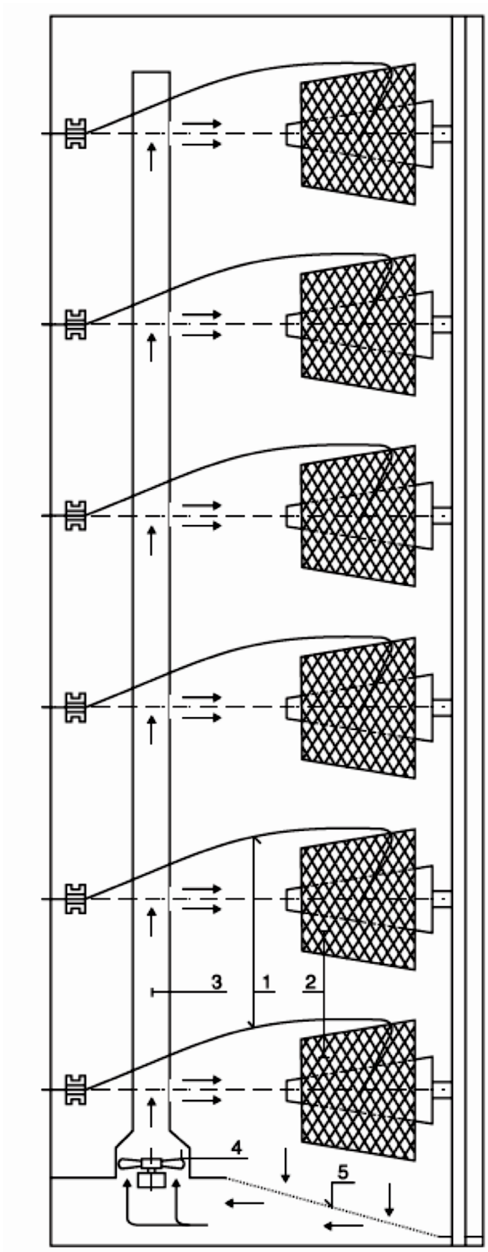


Figure 4.12 A modern creel

4.11 Stop Motions

Stop motions are there to stop the machine in the event of occurrence some unwanted situations which may cause fabric defects and some break- down of knitting elements. Generally stop motions are used for the following purposes –

I. To stop the machine when any yarn breaks – The number of such stop motions in a machine is equal to the number of feeders, i.e., the presence of every feed yarn is individually detected and action is taken to stop the machine when the same is either broken or subjected to very high tension variation. The principle of operation of such stop motion may be mechanical, electrical or capacitance type. In standard circular weft knitting each yarn passes through two stop motion assembly – one at the top of the creel which mainly senses the tension variation and the other fitted above the feed plate to detect the presence of yarn and ultimately stops the machine accordingly to the signal generated by them. The actual construction of these stop motions varies from make to make as well on the location of fitting on the machine.

II. To stop the machine when loops of a needle are not cleared for a few consecutive knitting cycles due to some other faults in the machine– This type of stop motion is fitted over the needles maintaining a slight gap with the cloth fell at a regular interval on the circular knitting machines. A pointed knife just placed over the cloth forming zone acts as a sensor. The knife also opens and closes an electrical circuit according to its position. During normal running of the machine, the knife keeps the relevant electrical circuit open. When due to some fault in the machine, a particular needle does not clear loops for a few consecutive cycles, that zone of the fabric is raised and pushes the knife above it. This up position of the knife closes the relevant electrical circuit and stops the machine.

4.12 Take-Down Mechanism

After formation of every course, the cloth is withdrawn from the knitting zone, generally in downward direction, and wound on the cloth roller. The mechanism used for this purpose is called take-down mechanism. The take- down mechanism works on any of the following three principles.

Dead weight principle – Some dead weight is clamped with cloth for withdrawing the cloth from the knitting zone. The dead weight applies necessary tension for casting-off of the old loops and pulls the cloth downward. It's a simple technique but it does not result continuous knitting as the dead weight touches the ground after some time. Moreover it is difficult to apply uniform take-down load on every wale. It is mainly used in flatbed knitting and sometimes in small diameter circular machines for experimental works.

Eccentric principle – In this the cloth is withdrawn in downward direction from the knitting zone at a constant rate by means of a pair of fluted take-down rollers. The motion to the pair of take-down rollers is transferred from the main driving of the machine through an eccentric arrangement. A typical take-down motion found widely in circular weft knitting machine is shown in Fig. 4.13. As the machine runs, the stretcher board frame rotates over the eccentric ring fitted on the machine stand. The stretcher board lever fitted at the stretcher board bottom is raised up intermittently when passing over the cam profile or high portion of the eccentric ring. The pawl connected with this lever is also raised and causes partial rotation of the ratchet. This motion rotates the take-down rollers through wheels. Another pawl connected with stretcher board lever causes rotation of the cloth roller through wheels. In order to maintain constant surface speed of the cloth roller, a friction clutch type drive is incorporated into the cloth winding motion (not shown in the figure).

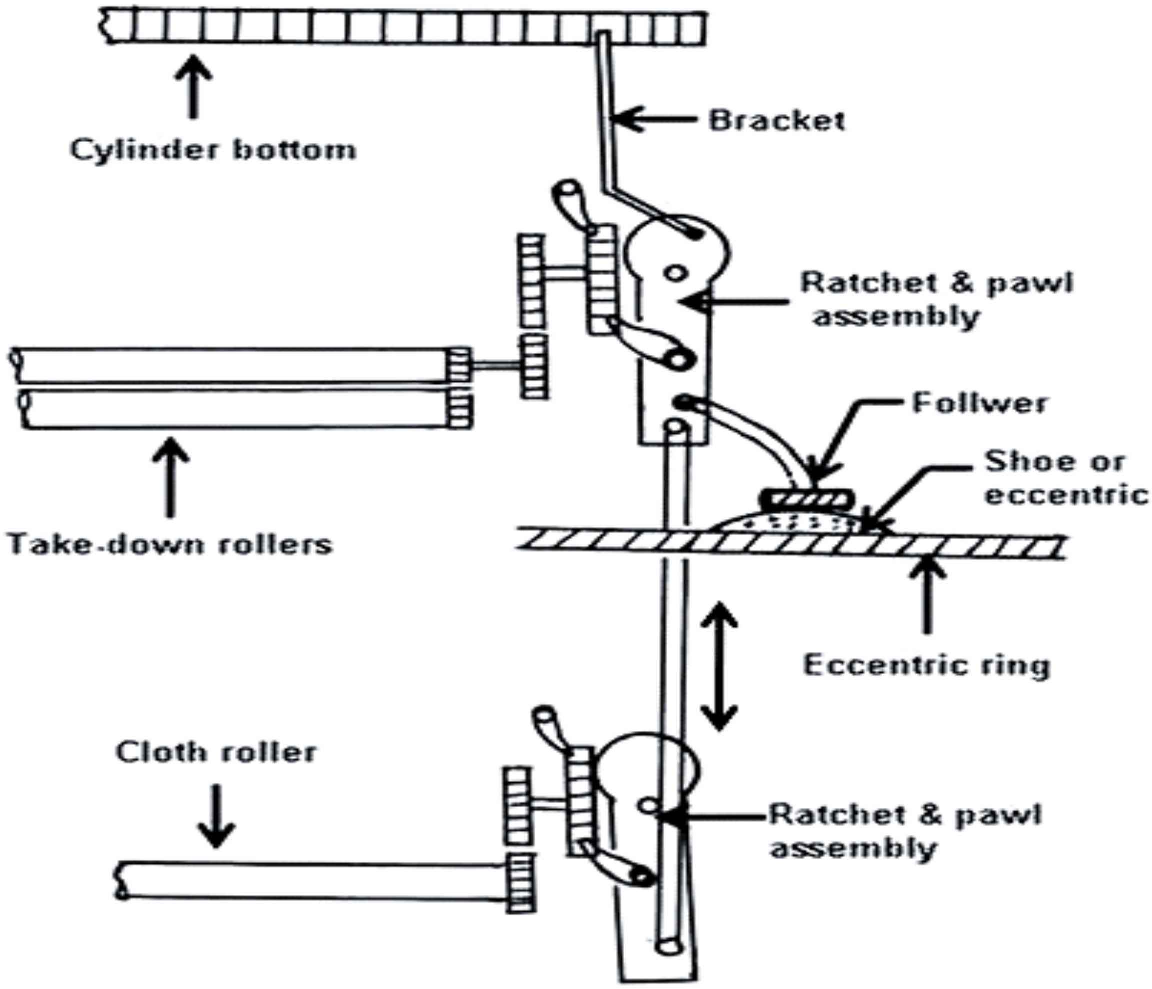


Figure 4.13 Eccentric type fabric take-down

Electrical Principle – In a typical electrical type take-down motion the take-down rollers and cloth winder are driven separately by an electric motor (Fig. 4.14.(a)) fitted on a hanging platform under the cylinder. The hanging platform rotates along with the cylinder. The cloth passing through the nip of the take-down rollers is wound on the cloth roller. The cloth roller is driven by the take-down rollers through gear arrangement. The take down tension or the surface speed of the take down rollers can be sensed and adjusted with the help of facility available in the control panel. The electrical type take-down motion found in Krenzler TK-83 type single feed machine is shown in Fig. 4.14(b) where the cloth roller (drum) is driven in surface contact with the take-down roller. Take-down mechanism based on electrical principle is getting popularity day by day.

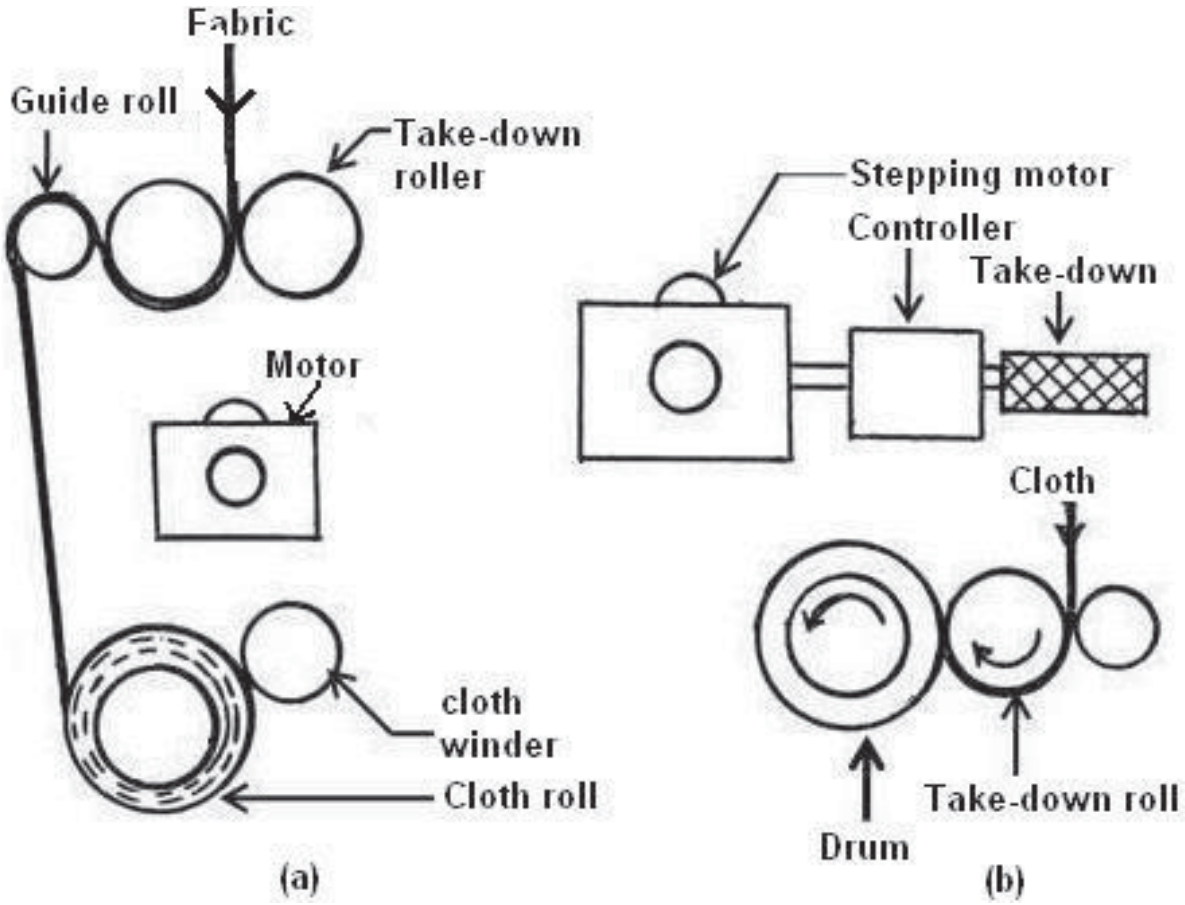


Figure 4.14 Electrical type fabric take-down.

4.13 Fabric Spreader Or Stretcher Board

After knitting, the circular fabric in tubular form goes downward for rolling into a roller as flattened double layered fabric. During such conversion, tension variation takes place across the width of the fabric due to distance variation which leads to unwanted wrinkles, crease mark and stitch deformations. To overcome this problem, knitting machines are provided with spreader or stretcher board (Fig. 4.15) for applying almost uniform tension to the fabric.

Stretcher board (Fig. 4.15(a)) is a flat wooden body placed inside the fabric tube. It floats inside the fabric tube above the take-down rollers i.e., in the zone where the tubular fabric is converted to flattened or two fold state. It is used to partly stretch the fabric while shrinking after coming down from the knitting zone. The stretcher board is generally made of two pieces of wood in order get variable dimension according to requirement of the fabric width produced. Sometimes the wooden board is replaced with a new type of spreader (Fig. 4.15(b)) consisting of two curved metal bars with adjustment for their sizes. It is important that stretcher board or spreader should not bend the courses and increase the takedown tension.

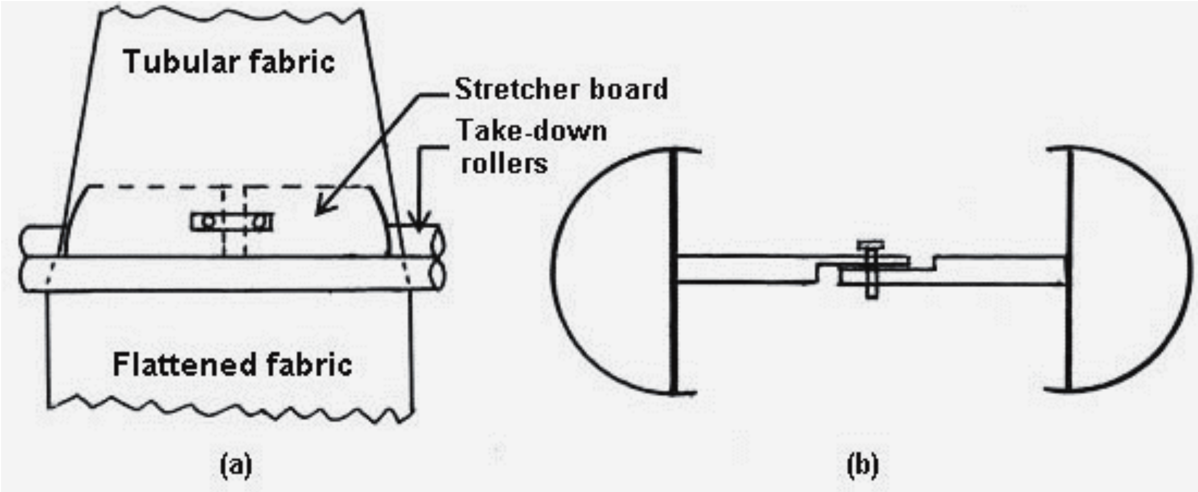


Figure 4.15 Stretcher board.

Fabric distortion and variation in take-down tension across the width of the fabric is unavoidable in case of conventional type take-down mechanisms. The occurring of such unwanted situation can be overcome by using the Cadratex unit developed by ITF Maille of France.

It replaces the conventional spreader with two complementary elements one inside and the other outside the fabric tube which cause the tube to adopt a square cross-section and then gradually flatter configuration but of constant circumference right into the nip of the take-down rollers. The distance from any needle to the take-down rollers is the same so that wale and course density remains constant around the fabric tube.

4.14 Open Width Cloth Winding

As early as 1999 in ITME, Paris, M/s. Terrot was first to introduce a single jersey circular knitting machine where the tubular fabric was cut and wound up in open width directly on the machine. The idea behind was to eliminate the fold mark in the fabric (particularly made with lycra and alike yarns) and at the same time to reduce the rate of change in diameter of the cloth roller i.e. to roll same length of cloth with comparatively lower final diameter of the cloth roller. The improved S296-1 machine is now available with a more compact open width frame (Fig. 5.12) which offers easy handling by the operator. Some of the advantages of such system are:

- Higher Productivity
- Excellent fabric quality with wider GSM range
- Easy Lycra plaiting and excellent Lycra plaiting quality – lower rejection
- Lower power consumption and space requirement
- Easy access to knitting head – higher efficiency

Quick Conversion from open width to tubular frame

4.15 Sinkerless Knitting Machine

As mentioned in the earlier, sinker is an important element in loop formation, particularly in single jersey knitting. There is no sinker in double jersey knitting machines. The needles in the top cylinder or dial perform the function of sinker for the bottom cylinder needles and vice versa during knitting. Recently commercial single jersey machine are available without sinker. Italian machine manufacturer M/s. Pilotelli has exhibited in June, 2010 their true sinker less single jersey machine in ITMA ASIA + CITME in Shanghai. The patented 'sinker less' technology is believed to incorporate a ring which holds down stitches, replacing sinkers which consumes less oil and energy due to lesser moving parts. Absence of sinker eliminates the vertical line (mark) along the length and results better quality fabric in fine gauges (gauge up-to 54).

4.16 Speed Factor

The speed factor is a bench marking measurement used to assess the machine performance. It is obtained by multiplying the machine speed by nominal machine diameter. It helps in deciding the machine speed if the diameter of the same is known. The recommended value of speed factor is about 1200 and 1000 for modern high speed single jersey and interlock machines respectively. The value of speed factor depends on the –

1. quality of yarn used
2. construction of knitting system
3. design of the fabric
4. environmental or climatic conditions
5. cleanliness of the machine
6. type of machine lubrication

4.17 Individual Needle Selection

Individual needle selection is the most versatile and widely used technique of knitting designs in colour or self-colour. It is based on relative positioning of needle hooks during clearing. Needles may attain one of the three positions – clearing height, tuck height and float height. Weft knitting machines employing latch needles are especially suitable for this purpose as the individually tricked and butted needles offer the possibility of independent movement. Depending upon type of machine, design element and cam arrangement, needles may be selected for one or more of the followings – knit, tuck, float or miss, plated, plush, loop transfer and purl needle transfer. The design elements or selection devices used for patterning by individual needle selection are –

1. Pattern Wheel
2. Pegged drum
3. Needles with Different Length of Butt
5. Needles with Different Butt Positions (Multiple Cam Track)
5. Jacquard (Mechanical and Electrical)

The selection device takes the position of the clearing cam and performs the function of the same and the other cam units remain unchanged.

4.17.1 Pattern Wheel

The pattern wheel (Fig. 4.16) is cheap and simple device for needle selection. It occupies less space and is unique in employing separate raising or clearing cam in the form of pattern bits. The pattern bits of two different sizes are placed in the tricks (gaps between the teeth) of the wheel as per pattern requirement. The pattern bits select the needles and move them individually in their tricks. The high or clearing bit raises the needle to the clearing height for forming normal loop. The low or tucking bit raises the needle to the tuck height for making tuck loop. If no pattern bit is placed in the trick of the wheel, then the needle is neither selected nor raised and the corresponding needle makes float loop. The pattern wheel is very popular in circular single jersey machines. It is fitted in inclined position (20 to 40 degrees to the ground) in front of the needle bed and rotates in opposite direction to the direction of rotation of needle bed. The wheels are tricked to the same gauge of the needle bed. The inclined pattern wheel, like other selection devices, is normally fitted at each feeder.

4.17.2 Pegged Drum

The pegged drum method is a simple and effective mechanism of needle selection. The replaceable pegs fitted on the pattern drum surface work directly on the jacks, like the pegs acting on a feeler in a dobby shedding mechanism of loom. The drum can be racked clockwise or anti-clockwise or can be kept stationary in a pre-determined manner.

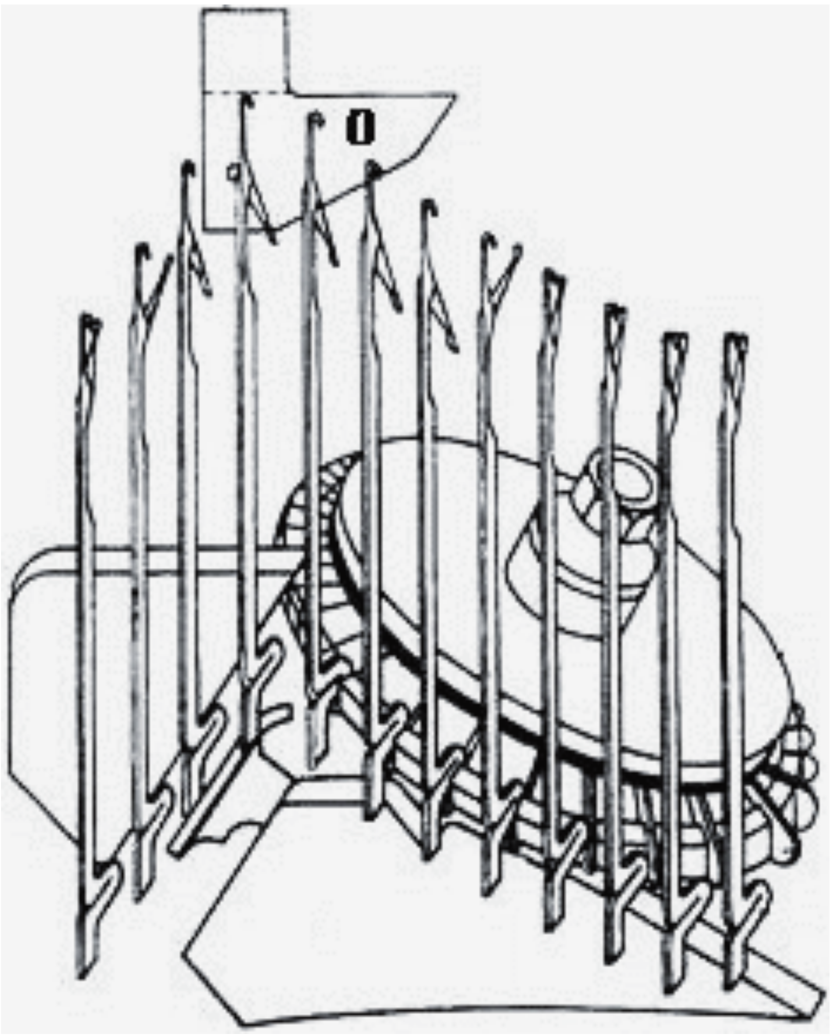


Figure 4.16 Pattern wheel

The drum is mounted outside the needle cylinder. It has vertical columns of holes in which metal pegs are inserted according to the pattern. Each column corresponds to a course. The jacks in the cylinder have butts at height corresponding with each horizontal row of pegs in the drum. If there is a peg in the drum at the height of the butt, the jack is pushed into the machine trick so that the needle supported by the jack is not raised to knit by auxiliary jack which moves up by a cam. If, however, there is no peg present, the needle along with the corresponding jack is raised up by the auxiliary jack and will knit. The design width is equal to the number of different levels of jack butts in the machine. New knitting machines are not coming in the market with such facility.

4.17.3 Needles with Different Lengths of Butt

In this case needles having different lengths of butt are used for needle selection. Generally butts of three different lengths – long, medium and short – are used to get clearing, tuck and miss heights of the corresponding needles. As the needle butt remains inside the cam groove/ profile, the edge of the clearing cam should have different profiles. The long length butts extend into the track formed by the cams and are guided by contact with the profiled edges, whereas a butt of shorter length may not reach into the cam track and will pass across the face of the cam and be unaffected by its profile. As a result needle with long length butt will reach clearing height and make normal loop whereas a needle with short butt will be raised up to miss or float height and make miss loop. Similarly a needle with medium butt length will be guided up to tuck height and make tuck loop. This type of needle selection is not popular in knitting industry.

4.17.4 Needles with Different Butt Positions (Multiple Cam Track}

Needles with different butt positions are used for needle selection in a machine having multiple cam tracks. Generally one cam track is sufficient for one set of needles in a bed, but in this case, multiple cam tracks (up to 5) are made in the bed to accommodate needles having up to five different butt positions. Fig. 416 shows an arrangement of needles with four different butt positions (a, b, c and d) in four different cam tracks. For a particular feed position, the clearing cam profiles in the different cam tracks may be same or different for achieving heights like clearing, tuck or float of the needles in the corresponding cam tracks. The number or proportion of needles in various tracks depends on the pattern to be knitted. The placing of needles to various tracks according to butt positions is technically known as “needle butt – cam set out”. The types of needle butt – cam set out and the corresponding knitted designs or structures using four cam tracks and four feeders are also shown in Fig. 4.17. The needle butt set-out pattern varies from design to design. The set-out repeat is the number of needles used to make a particular design. As shown in the Fig. 4.17, the set-out repeats are 4 and 6 respectively. Multiple cam track system is gradually getting popularity in the market.

4.17.5 Jacquard (Mechanical and Electrical)

Jacquard is generally used for producing elaborative designs and motifs. According to the principle of needle selection jacquards may of either mechanical or electrical (electronic) type. The principle of punched paper for needle selection is utilized in mechanical type jacquards as used in weaving. This method provides the possibility of independent selection over the full width of the stationary needle bed of flatbed machines or onto blocks of adjacent needles on revolving circular beds. According to the capacity i.e., the number of needles they can control, jacquards are classified as follows:

a) Intermediate Jacquard – up to 24 wales
b) Medium Jacquard – up to 48 wales

c) Full Jacquard – up to 144 wales

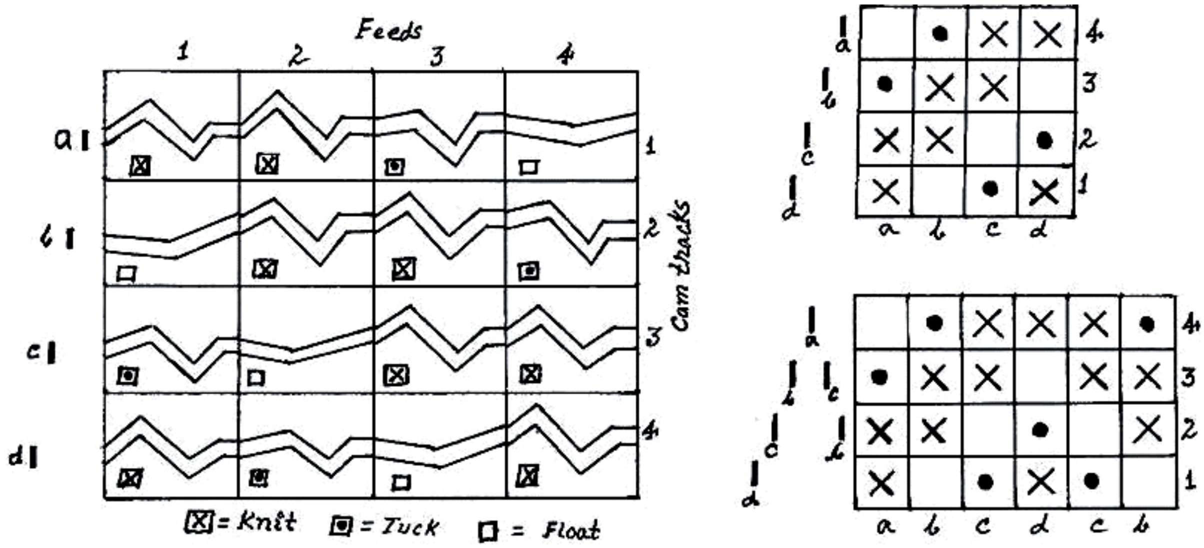


Figure 4.17 Needle butt set-out in multiple cam track.

As a circular knitting machine is generally equipped with multiple feeders, the number of jacquard units should also be more than one. In fact one jacquard unit is to be placed near each feeder. The repeat size of a jacquard design is expressed by the number of wales and courses involved in the production of the repeating unit of the design. The number of wales is decided by the capacity of the jacquard. The number of courses required to produce a repeat of the design can be varied according to requirement but it mainly depends upon the number feeders in the machine. The design paper or film is provided with number of tracks equal to the capacity of the jacquard and the number of rows of holes to be punched is equal to the number of courses in the repeat of the design. Although the number of repeats of the design in the whole circumference of the fabric is same as the number of feeders or jacquard units, the design units are not horizontal along the circumference of the fabric but at an angle depending upon the number of feeders and the course density.

The design effect can be enhanced by using more colours in the pattern in addition to the capacity of the jacquard. In the punched paper, each column of holes is allocated to a particular needle with a new selection being presented by each part turn of the prism or roller. The arrangement has been widely applied to flatbed machine but can be used successfully in circular beds too. The machines working with jacquard are generally coarser in gauge and slower in speed. The pattern preparation is also tedious and time consuming.

Mechanical Jacquard

The arrangement of various elements of a full jacquard suitable for circular machines is illustrated in Fig. 4.18. The selectors and lifters are arranged in groups of 48, termed an automat, are controlled by a 48 track film (F) or paper and roller. On a 30 inch diameter 14 gauge machines there will be 28 automats arranged around the periphery of the needle cylinder. Beneath each cylinder needle there is a jack (J) whose tail is supported by the inner end of a pivoted lifter lever (B). Resting on the outer end of lever B is the inner end of a pivoted automat lever (A). The outer end of lever A holds a spring-loaded pin (P) which rest on top of the film roll as it passes over a grooved roller (G). The roller G gets part turn intermittently by the driving mechanism of the machine.

A punched hole in the film or paper causes the corresponding needle to knit normal loop. If there is a hole, the corresponding automat pin passes through the hole in to the roller groove. After the selection, the roller G turns and advances the film. As a result all the automat levers whose pins have entered the holes on the film as well as the grooves of the roller G are moved forward and the inner ends of the pivoted automat levers A reach at the top of the outer ends of the pivoted lifter levers B.

A cam revolving with the cam-box presses down advanced inner ends of the automat levers A which in turn press down the outer end of the pivoted lifter levers B. This motion causes the inner end of the lifter levers L to raise their jacks into the alignment with a raising or clearing cam so that the needles above them are raised or cleared to knit. During downward movement of the automat levers at the inner end by the cam mechanism, the outer ends of the automat levers are raised and the pins are withdrawn from the holes of film and grooved roller whilst the return spring brings the automat levers to the rest position so that their pins are in line with the next row of selection holes.

When there is no hole on the film, the corresponding pin just rests on the film and the corresponding automat lever is not advanced. The depressing action of the cam is not transmitted to the lifting lever and the needle remains in miss position.

Electronic Jacquard

Electro-magnetic needle selection has now been introduced in some of the jacquards which are called electrical or electronic type jacquards. An electronic impulse is used to energize an electro-magnet which ultimately selects and determines the position of the needle during loop formation. The minute selection movement generated by the electro-magnet is magnified by mechanical movements of other elements. The input to the electro-magnets may be supplied in various forms including latest CD drive.

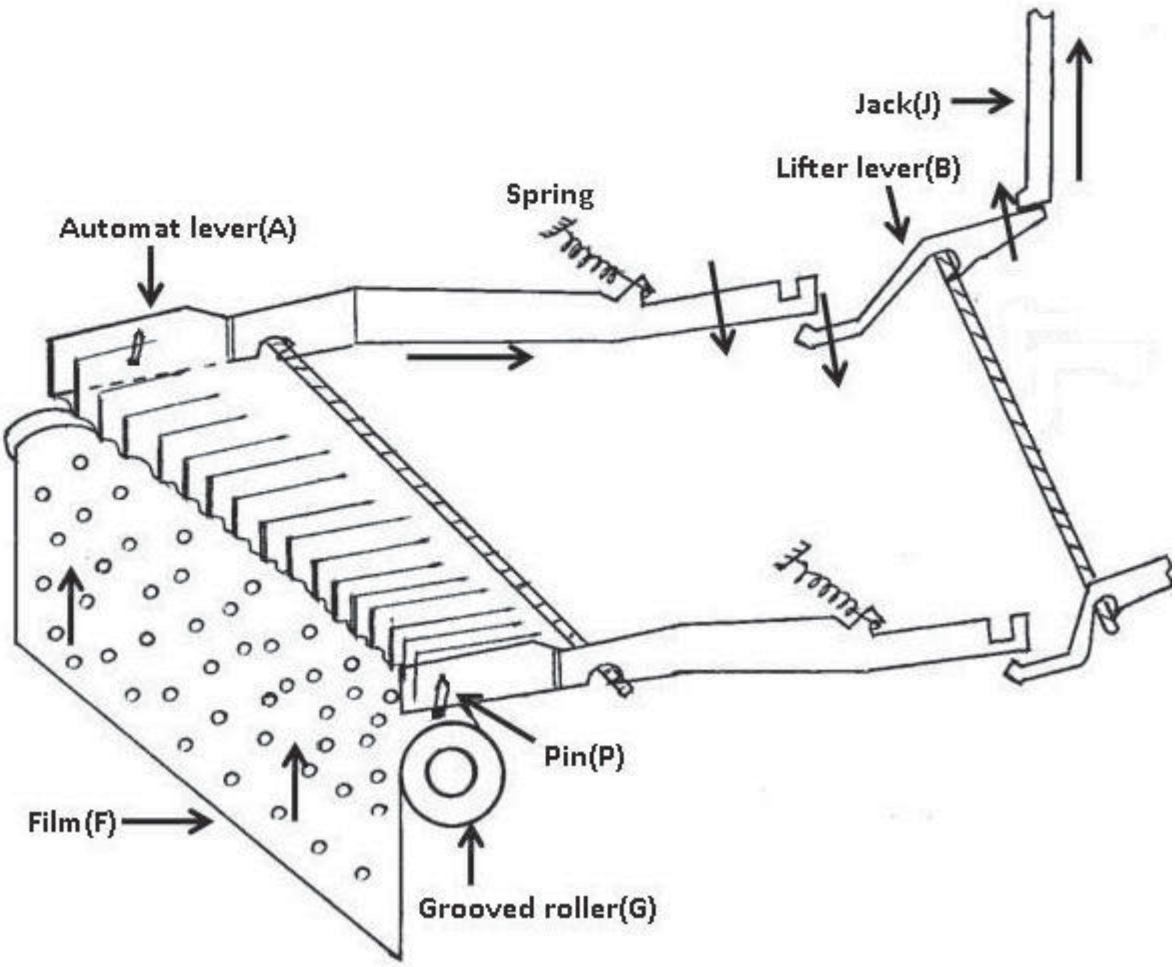


Figure 4.18 Mechanical jacquard with punched paper.

Photo-films are generally used for giving the input to the first generation electronic jacquards. In Moratronic Jacquard (first generation machine), a photo-transistor in each feeder scans the tracks of a 35 mm film giving a selection for each jack control spring as it passes the control position of the feeder. If the position of the film has a transparent spot, light is transmitted to generate an impulse. If the position of the film is opaque no impulse is generated for that control spring. The transparent or opaque spots are made on the film according to the design, generally prepared on point paper. But for the new generation electronic jacquards, the design to be produced on the fabric is first prepared on the computer using suitable CAD software. The ultimate fabric can also be viewed on the monitor. The software then converts the design into the fabric manufacturing details which are either directly sent to the electronic jacquard or copied and stored on Pen drive/CD or as EPROM for using the same as input to the electronic jacquard as and when needed. The Capacity of the electronic jacquards are much higher and they are much faster (selection time is less than 0.5 milliseconds) than conventional mechanical jacquards, but of course the electronic jacquards are very expensive. The principle of needle selection in a typical electronic jacquard is shown in Fig. 4.19. Below the needles in the tricks there are jacks or sliders. These jacks actually perform the function of clearing cam which is not included in the needle cam track. The jacks are provided with butts. The butt of any jack may be either under the control or beyond the control of the jack cam track decided by its position in the trick. These two positions of the jack are controlled by the combined action of two flat springs. One flat spring (may be called retaining spring) is positioned at the back of the jack which always pushes the jack outward to bring the butt of the jack under the control of the jack cam track. To accommodate the retaining spring, this portion of the trick is comparatively deeper. Another flat spring, called control spring, is positioned in front of the jack. The control spring when not attracted by the electro-magnet (control pole) or solenoid, can push the jack inside the trick against the retaining spring. When the same is attracted by the electro-magnet, the jack is pushed forward by the retaining spring. Whatever may the type of input (photo-film, magnetic film, floppy, CD or EPROM), the design information is scanned/read course wise by appropriate device and the corresponding signal is sent to the electro-magnet. The electro-magnet may be energized or not according to the nature of signal. In case, an electro-magnet is energized it will attract the corresponding control spring to bring the jack under its jurisdiction to the control of the jack cam track. Subsequently the jack moves up by the jack cam track and causes the needle above it to move up to the clearing height for resulting normal loop formation. But if the electro-magnet is not energized by the input signal, the control spring pushes the jack inside the trick and jack is not lifted up by the jack cam track. As a result, the needle above it is also not moved up but allowed to remain in lower position for resulting float or miss formation by the same. Nowadays piezo elements are being used more and more in number for smoother selection of the needles and operation of the electronic jacquard.

4.17.6 Selection of Pattern Mechanism

The selection of pattern mechanism mainly depends on the end product i.e., the structure to be produced. But sometimes similar structures can be produced by more than one type of selection mechanisms. In that case, the following factors may be considered for the selection of pattern mechanism.

a) Scope of patterning or flexibility of the mechanism

b) Extent of need of patterning

c) Complications in the process of patterning

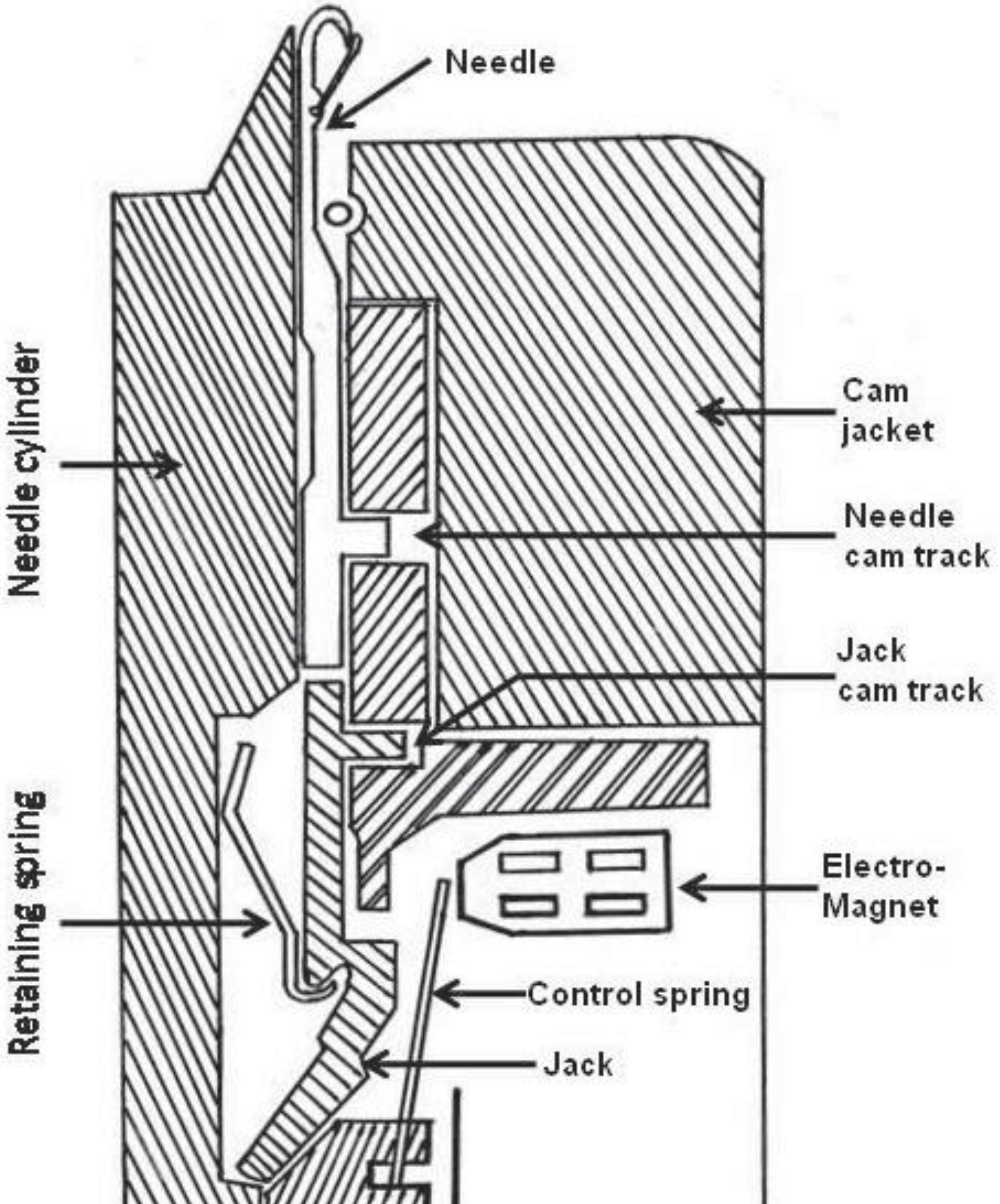


Figure 4.19 Principle of needle selection in electronic jacquard.

d) Investment for the mechanism

e) Techno-economic aspects of the mechanism

f) Rate of production

g) Time loss in changing the pattern and setting up the pattern device

4.18 Hosiery Knitting Technology

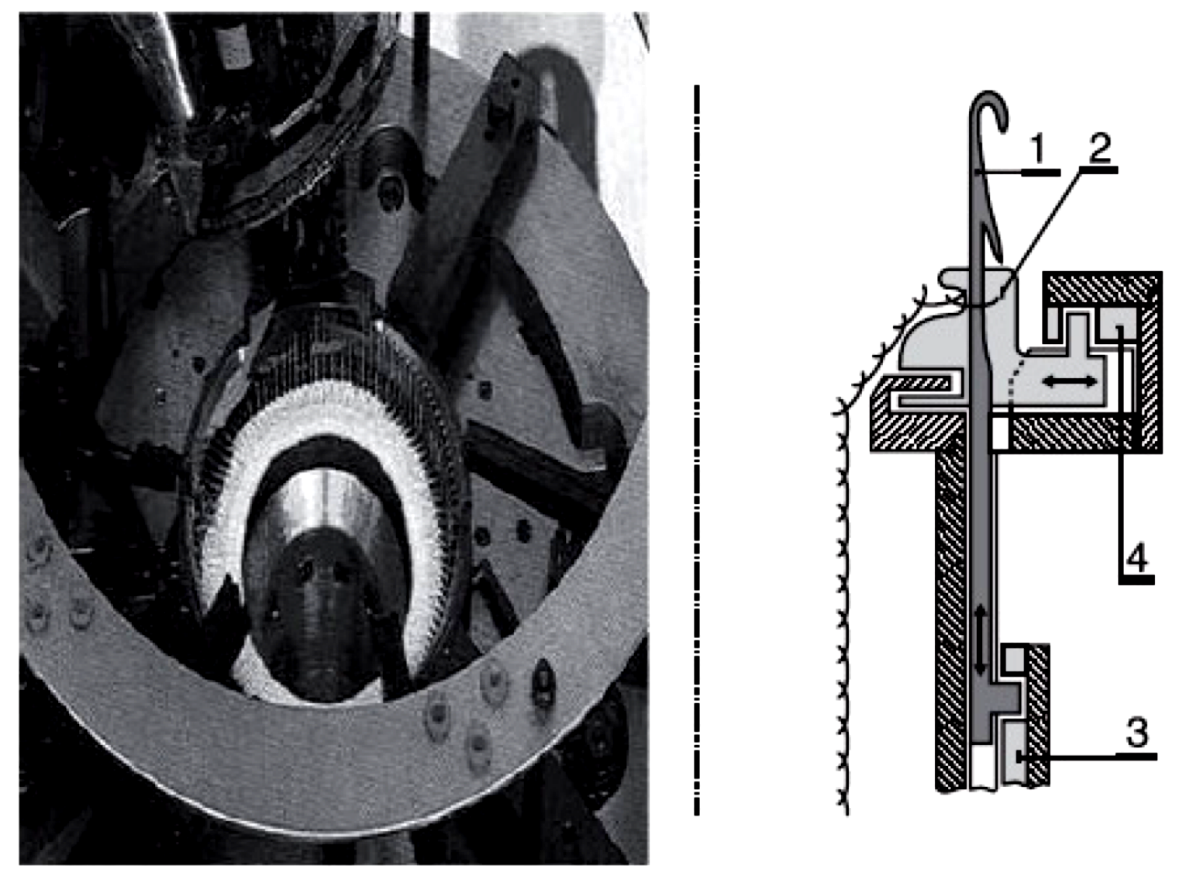
For centuries, the production of hosiery was the main concern of the knitting industry. The prototype machines for warp, circular, flat and fully-fashioned knitting were conceived for knitting hosiery; however, hosiery production is centred almost exclusively on the use of small-diameter circular machines. The term ‘hosiery’ is used for clothes that mainly cover the lower extremities: legs and feet. There are fine products made of multifilament yarns on knitting machines with 24 to 40 needles per 25.4 mm, such as fine women’s stockings and tights, and coarse products made of spun yarns on knitting machines with 5 to 24 needles per 25.4 mm, such as socks, knee socks and coarse pantyhose.

Ladies’ fine-gauge seamless fabrics are knitted in a plain structure on single cylinder machines with holding-down sinkers. Men’s, ladies’ and children’s socks with a rib or purl structure are knitted on double-cylinder machines with a reciprocated heel and toe that are closed by linking. Either an anklet or an over the-calf length stocking can be produced on a typical machine specification with 4-inch diameter and 168 needles. Currently, most seamless hosiery products are manufactured on circular knitting machines of small diameter, mostly between E3.5 and E5.0 or needle pitches between 76.2 and 147 mm.

Sports and casual socks in a plain base structure are now usually knitted on single-cylinder machines with holding-down sinkers. More formal simple rib socks may be knitted on cylinder and dual rib machines termed ‘true-rib’ machines. Figure 4.20 presents the dial system and knitting elements of true-rib machines.

Problems in High-Speed Circular Knitting Machines

The most important problems in high-speed knitting machines are classified as the limitation of friction occurrence in knitting elements and tension control in the yarn feeding system. Some research has been done about the influence of different parameters and factors among yarn, needles and knitting elements during the knitting operations. Important factors in the contact between yarn and knitting elements during the knitting process are friction, flexural rigidity, the mechanical properties of the yarn and the velocity of knitting elements and yarn in the knitting zone. Amoton’s law for friction occurrence in the dynamic conditions of loop formation during the knitting process states that the yarn tension increases on the yarn supply side of the stitch cam and the lowest tension occurs on the yarn on the other side of the knitting cam.



4.20 The true-rib machine in hosiery technology: 1 – needle, 2 – fabric, 3 – needle cam and 4 – sinker cam.

This matters because it is easier to 'rob back' yarn from already-formed loops than to pull new yarn from the yarn package, owing to the fact that the tension is higher on this side. The tension on the yarn during knitting is influenced by the number and the angles of yarn wrap between yarn and machine elements, and the fact that robbing back can reduce tension in the yarn. Robbing back is the term for the yarn that comes from the already-formed loops back into the knitting zone, because the yarn tension is lower on this side and higher on the yarn package side.

An increase of input tension makes the position of maximum knitting tension move towards the yarn supply side, and with lower input tension the point of maximum knitting tension lies closer to the knitting point. These factors and the fact that many parameters cooperate and influence each other between yarn and machine elements make knitting a rather complex process. When it comes to producing knitted structures of yarns or monofilament fibres with high stiffness such as carbon, aramid or polyester mono-filament, parameters such as friction and the flexural rigidity of the yarn are of considerable importance for the knit-ability of the structure.

However, a significant problem is that some of these stiff yarns are almost inextensible, which causes tension peaks with breakage of the yarn or single filament in the yarn bundle, especially in high speed knitting operations.

4.19 Limitation of Pattern in Jacquard Circular Machines

The creation of patterns in jacquard machines is limited to a number of knit elements: the yarn feeder system, the needle selection system and the dial needle bar gauge. Mini-jack circular knitting machines are suited to the production of jacquard fabrics. Some models are equipped with selection systems that have 39 levels, 37 of which are for jacquard selection and two for set selections, but more selection elements are limited by the diameter of the dial. The selection is accomplished through a plug-in cartridge or PVC cards, which can be easily changed and programmed separately. Some firms also offer single-bed full jacquard models with electronic needle-by-needle selection to carry out jacquard and operated motifs with virtually unlimited pattern repeats. Some manufacturers have developed a single-bed circular machine for the production of striped jersey fabrics, in versions with 44 four-colour electronic stripe pattern motions, a model for open-worked jacquard fabrics with a diameter of 36 inches and gauge 20–22, as well as a vast range of fully electronic single-bed models for plain or striped three- or four-colour jersey fabrics. These manufacturers also offer a special single-bed machine for jacquard samples, introduced at the ‘ITMA‘99’ fair, with a diameter of 4 inches, two systems and two six-colour electronic stripe pattern motions, with needle-by-needle selection to produce the prototypes of jacquard patterns with enormous time and yarn savings, as it avoids the repeated setting up of a full-size production machine for the various samples. Developed models can be improved by adding the needle-by-needle selection system for the jacquard pattern application if the selection system can work with high-speed machines.

4.20 Production Limits Of Seamless Knitting Machines

The most important limitation of seamless knitting machines in circular form is the poor flexibility of these types of machine for producing fabrics in different diameters. In the commonly used method of apparel making in flat fabrics the cutting operation is important. In seamless technology the fabric cannot be cut, and therefore the various diameters should be prepared in the knitting process.

This applies to different types of seamless machine of varying cylinder diameters. The short, thin fabrics are knitted in small diameter cylinders and therefore the production rate is lower. This leads to increasing costs and may be a serious problem for seamless, circular knitting technology.

Seamless fabric is knitted in simple structures and there is no advanced jacquard machine to prepare a mixed pattern fabric for this purpose. Seamless circular knitting machines have lately been manufactured to apply a fine gauge as well. These machines are suitable if the benefit of selling price of fabric is justified by the cost of production at a limited rate of production.

Chapter 5 Flatbed Knitting Machine

5.1 Introduction

The basic principles of loop formation as well as the meaning of various terms in flatbed machines are same as discussed earlier under the general headings. However, the path of yarn during knitting, the knitting cam system and some special features related to flatbed knitting which are not covered earlier have been discussed in this chapter.

5.2 Types of Flat Bed Machines

The flatbed machines are available as single bed for producing plain or single jersey structures and double bed for producing rib and purl structures. Flatb ed machine with interlock gating is not available on account of difficulty in knitting using two sets of needles in each bed by traversing of cam carriages. A double bed flat knitting machine can easily be converted to single jersey knitting machine by detaching one bed along with its cam carriage from the combined one and hence most of the commercial flatbed machines are supplied with two beds.

V-bed machines have two rib gated, diagonally approaching needle beds set at between 90 and 105 degrees to each other and have inverted V-shape appearance. Flatbed purls or links-links machines are mainly employed to knit some speciality items using double hooked latch needles. The one set of needles are transferred to knit in either of two directly opposed needle beds by means of a set of sliders in each bed.

Intarsia machines are available as both single and double bed. In case of double bed intarsia machines, one bed is used for knitting plain solid colour designs and other bed is utilized to produce rib border for garment. Intarsia garments are generally expensive and their demand is subject to the vagaries of fashion.

Power V-bed flat machines are used mainly for the production of knitwear for children, women and men. They range from simple machines through mechanical jacquard machines to fully electronic and computerized flat machines, even equipped with presser foot. The developments in the automation of fabric designing, pattern preparation, and electronic needle selection, as well as in the range of structures and effects which can be produced, have been tremendous. In fact, flat machines and their products are now regarded as extremely sophisticated. High quality garments can now be produced at competitive prices owing to revolutionary garment production systems feasible with presser foot. Two- and three-dimensional structures as well as complete garments without any seams or joins can be produced on the latest electronic flat knitting machines and the associated design systems.

Whatever may be the type, the needle bed must be precision made to ensure the uniformity of the fabric. The tricks must be uniformly spaced and very smooth to allow the free sliding movement of the needles. Moreover, the tricks of the two beds should not be face to face but the tricks of one bed should be in between the tricks of the other bed to ensure that the needles will not collide while ascending to knit at the same time on both beds.

5.3 Range of Machine Gauge And Width

Flatbed machines are gauged in both English and Metric systems. In English system, gauge is the number of needles per inch (npi). In finer gauge machine the space between two needles is lesser and hence there is requirement of finer yarns. This system is more popular. In case of Metric system, gauge is ten times of distance between two adjacent needles in millimetre. It's a direct system and coarser yarn is required for machine with higher gauge. If the gauge of a machine is 10 in English then the equivalent gauge in Metric system is 25.4. The relationship between the two systems is 254 i.e., if gauge in one system is known then the gauge in other system can be obtained by dividing 254 with the known gauge. Although the common range of gauge is 5 to 12 npi, the machine may be coarse as 2.5 npi and may as fine as 18 npi. Further by removing or keeping idle alternate needles the gauge of the machine can be reduced to half. Recently keeping in view the need of producing fashion garment having zones of finer and coarser gauge loops in the same fabric, multiple gauge technique of knitting has been brought in to the market by M/S Stoll.

The width of flatbed machines also varies widely in the range of 6 to 96 inches (15 to 244 cm) but it has no relationship with gauge. The strapping machines are narrower and width tends to range in between 6 to 20 inches. The hand operated machines are available in the range of about 24 to 48 inches and the power driven machines are manufactured having width about 24 *to 80 inches. In the recent years, there is a trend to manufacture machines with higher width in* order to get higher rate of production of fabric particularly for manufacturing cut and sewn type garments.

5.4 Simple V-Bed Rib Machines

The cross-sectional view of simple V-bed Rib machine is shown in Fig. 5.1. As observed, the two beds are in inverted 'V' position. The yarn package in the form of cone is placed on the cone holder (spindle), generally at the back of the machine. Till date in most of the ordinary flatbed machines yarn supply package is in the form of ball (circular coreless package) which rotates randomly during unwinding. In order to have smooth unwinding, the balls are kept in a bucket and the yarn is withdrawn through a hole on the lid. Under both the situations the yarn is overhead withdrawn and passes through guides, tensioner and yarn take up or compensating spring before entering the yarn carrier. The yarn carrier moves with the cam carriage on each bed. The fabric is made in the small gap between the two beds and taken downwards by the take down load.

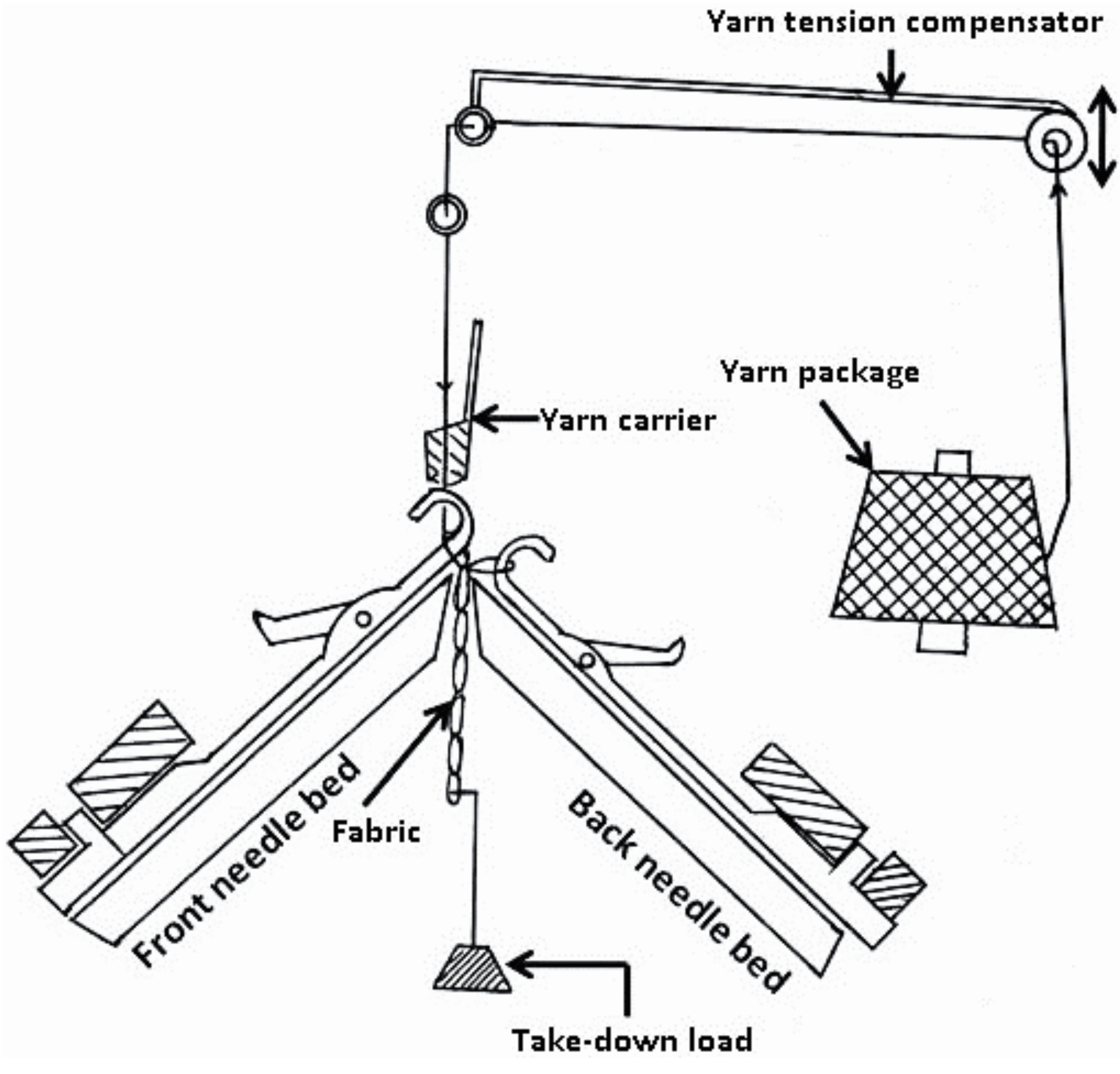


Figure 5.1 Cross-sectional view of simple V-bed Rib machine.

Hand driven flatbed machines are provided with a handle in the cam carriage. The knitter catches the handle and traverses the cam carriage from one side of the machine to the other. In case of double bed machines, the two cam carriages are joined together by means of a detachable handle lever and both the carriages are given traverse by means of the handle lever. In power driven machines, the cam carriage is connected with a motor. As soon as the carriage reaches from one side to the other, a two way switch changes the direction of current in the motor and the carriage moves in opposite direction.

The needles used now-a-days in flat knitting is invariably of latch needle type. The details of latch needle as well as the loop forming cycle in flat knitting using latch needles are same as already been discussed in Chapter 4. A few of the other knitting elements found in flat knitting machines are as follows:

Jack: In most of the modern flat knitting machines there are additional knitting elements in the tricks which are involved in the formation of knitted loop. These are called jacks. The jacks which have different shapes according to the manufacturer are used to facilitate the needle selection required for patterning. The other names used to describe the different jacks are 'intermediate jack' and 'selector'.

Knock over bits: The trick walls are replaced at the needle bed verges by fixed, polished and specially shaped thin knock over bit edges (not shown in figure). In rib machine, a knock over bit in one bed aligned opposite to a needle trick in the other bed. During knitting, the edges of the knock over bits restrain the sinker loops as they pass between the needles and thus assist in knocking over of the old loops and in the formation of the new loops. Flat machines generally employ holding down sinkers as the take down tension and the loops in the other bed help to hold the old loops down on the needle stems.

Cover plate: This is a thin metal blade located in a slot across the top of the needle bed tricks which prevents the stem of the needles from pivoting upwards out of the tricks as a result of the take down tension drawing the needle hooks downwards, whilst allowing the needles to slide freely in their tricks. The plate can be withdrawn sideways out of the needle bed to allow needles to be removed.

Security spring: The tail of each needle is supported by a security spring which fits at the lower edge of the needle bed. The position of the needle in the trick can be changed with the help of this security spring for its selection during loop formation due to traverse of the cam carriage.

Latch brushes: The latch brushes are attached to the cam-plates of both needle beds to ensure the full opening of the latches. The supports of the brushes are adjustable to ensure precise setting of the bristles relative to the needles.

Cam carriage: The cam carriage contains the knitting cams and many other important parts or attachments required for knitting. The carriage is fitted with a handle and some setting knobs on the top. The carriage is traversed manually by means of the handle for imparting required motions to the needles on the stationary needle bed for loop formation. In modern automatic machines the carriage is given to and fro motion by means of electrical motor. The knitting cam system inside the carriage has been discussed later in detail. The cam carriage of computerized double flatbed knitting machine of M/s. Brother Industries Ltd. (Model KR-850) is shown in Fig. 5.2. The tension dial fitted on the cam carriage basically regulates the stitch cam setting (say 1 to 8) and thus effects the tension on the yarn but it is not a tensioner.

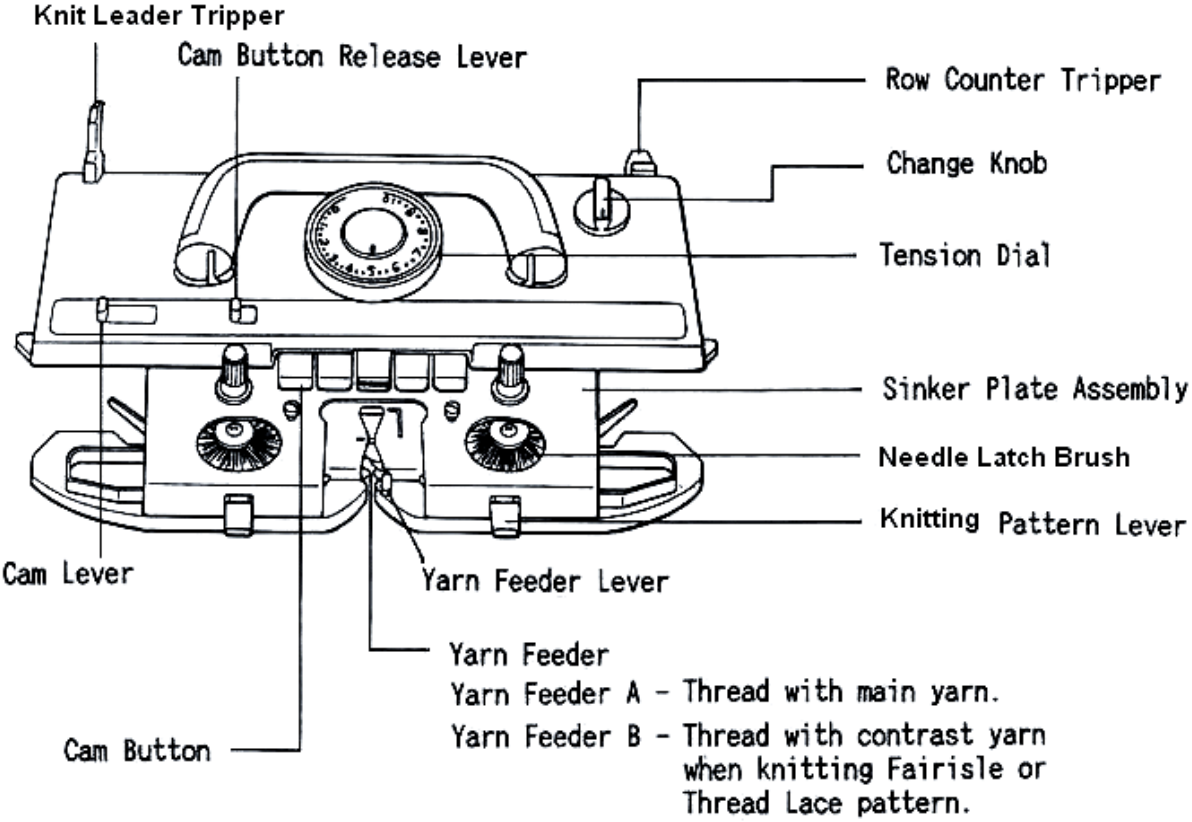


Figure 5.2 The cam carriage of computerized double flatbed knitting machine

Carriage guide rails: The cam carriage either slides or runs on ball bearings or wheels along guide rails, one of which is fixed over the lower end of each needle bed.

Yarn carrier: Yarn carrier is a small attachment through which each yarn used in knitting is fed to the needle hook for loop formation. Each yarn carrier is threaded separately and attached to a block which slides along a bar like carriage guide rail. It extends the full width of the machine. The yarn carriers are picked up and pulled along the needle bed or left behind by the carriage as per requirement of the design either manually or automatically. The construction as well as the function of yarn carriers is different in different machines particularly during plating and intarsia knitting.

5.5 Knitting Cam System

The typical cam system, underside of a cam-carriage, forming the track which guides the needle butts for knitting action in single jersey flatbed machine is shown in Fig. 5.3. The symmetrical camming arrangement is typical in many flatbed machines as it enables a similar knitting action to be achieved in both directions of carriage traverse in the needle bed. The needle butts enter the cam system from the right during a left to right carriage traverse and from left during a right to left traverse. Therefore two raising/clearing cams and two stitch cams are required in each cam system. Only one cam of each type does its function during a traverse and the other acts as a guard cam by forming part of the cam-track for the butts. So the roles of the two cams are reversed in the traverse of the carriage in opposite direction.

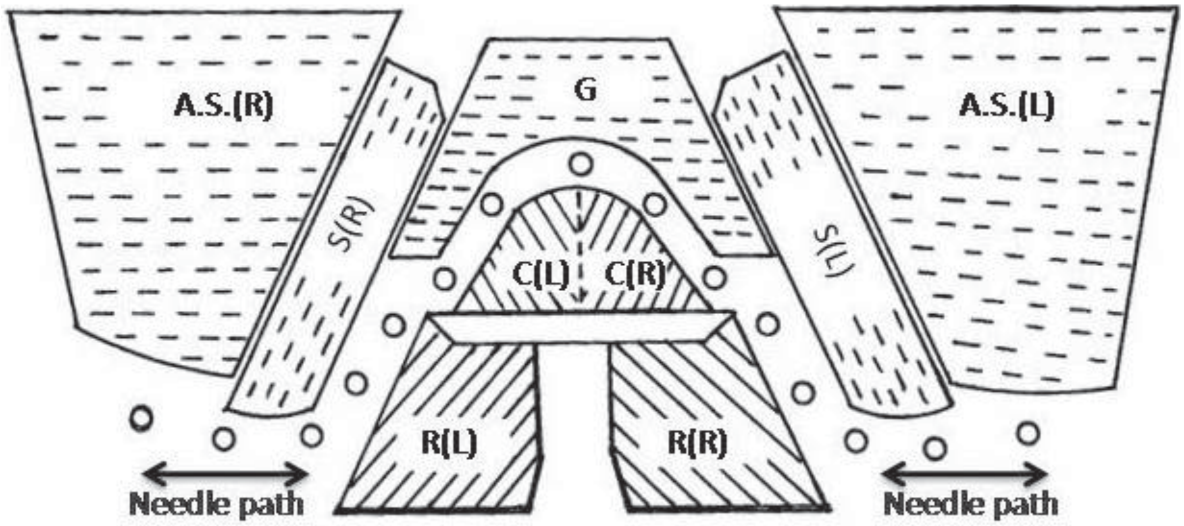


Figure 5.3 Simple flatbed knitting cam.

Considering left to right traverse of the carriage, the needle butts enter the cam system from right side. The idle position of the needles are maintained so long they are under the control of the auxiliary stitch cam {A.S. (L)} and stitch cam {S. (L)}. The needles start rising under the control of the raising cam {R. (R)} and the upward motion of the needles is completed by the clearing cam {C. (R)}. The clearing cam has been made of two pieces

– raising cam and cardigan cam – in order to get tucking and normal loop formation facilities. When the needles move up under the control of the right side raising and clearing cam, the stitch cam acts as a guard cam. After reaching of the clearing or tucking height, the needles start descending under the control of the stitch cam {S.(R)}. During this stage, the raising cam {R. (L)} acts as a guard cam. After loop formation, the needles moves up to some extent to reach the idle position due to the take-down load and guarded by the auxiliary stitch cam {A.S. (R)}. However, during traverse of the carriage in opposite direction, the stitch cam {S. (R)} becomes guard cam and stitch cam {S. (L)} performs the function of stitch cam. Similarly, the raising cam {R. (L)} along with cardigan cam {C. (L)} perform the clearing action and the raising cam {R. (R)} becomes guard cam.

The stitch cams are located in slots by studs. By moving the stud along the slot, the stitch cams can be raised up or lowered down to different setting positions. The stitch cam settings (generally five different positions) are indicated by pointers on a calibrated scale or knob on the outside of the cam-plate.

As tucking in simple (1x1) rib design results cardigan structure, the upper portion of the raising cam is known as cardigan cam. On hand knitting machine it is useful to have split cardigan cams so that a different setting can be achieved in each direction without having to stop the carriage at the end of each traverse. As the automatic flat knitting machine can change the cam settings for each traverse, these machines usually have a single cardigan cam for both traverse directions instead of split cardigan cams. The raising cams R and cardigan cams C are of spring loaded type and can be depressed into the under surface of the cam-plate against the action of a spring. Moreover, the cams are often of sinkable setting type so that they can be set:

a) Fully out of the cam-plate so that they act on every needle butt.

b) Partly withdrawn into the cam-plate so that they miss the low or short butts which pass undisturbed across their face.

c) Fully withdrawn into the cam-plate so that all the butts pass undisturbed across their face

The reversible cam system shown in Fig. 5.4 is a simplified line diagram of the same for easy understanding. However, the actual view of the cam system found in modern flatbed knitting machine is much more complicated and consists of a large number of components. The line diagram of such cam system found in computerized double jersey flatbed knitting machine of M/s. Brother Industries Ltd., Japan (Model : KR-850) is shown in Fig. 5.4(a) and the simplified needle path of the said cam system is shown in Fig.5.4(b).

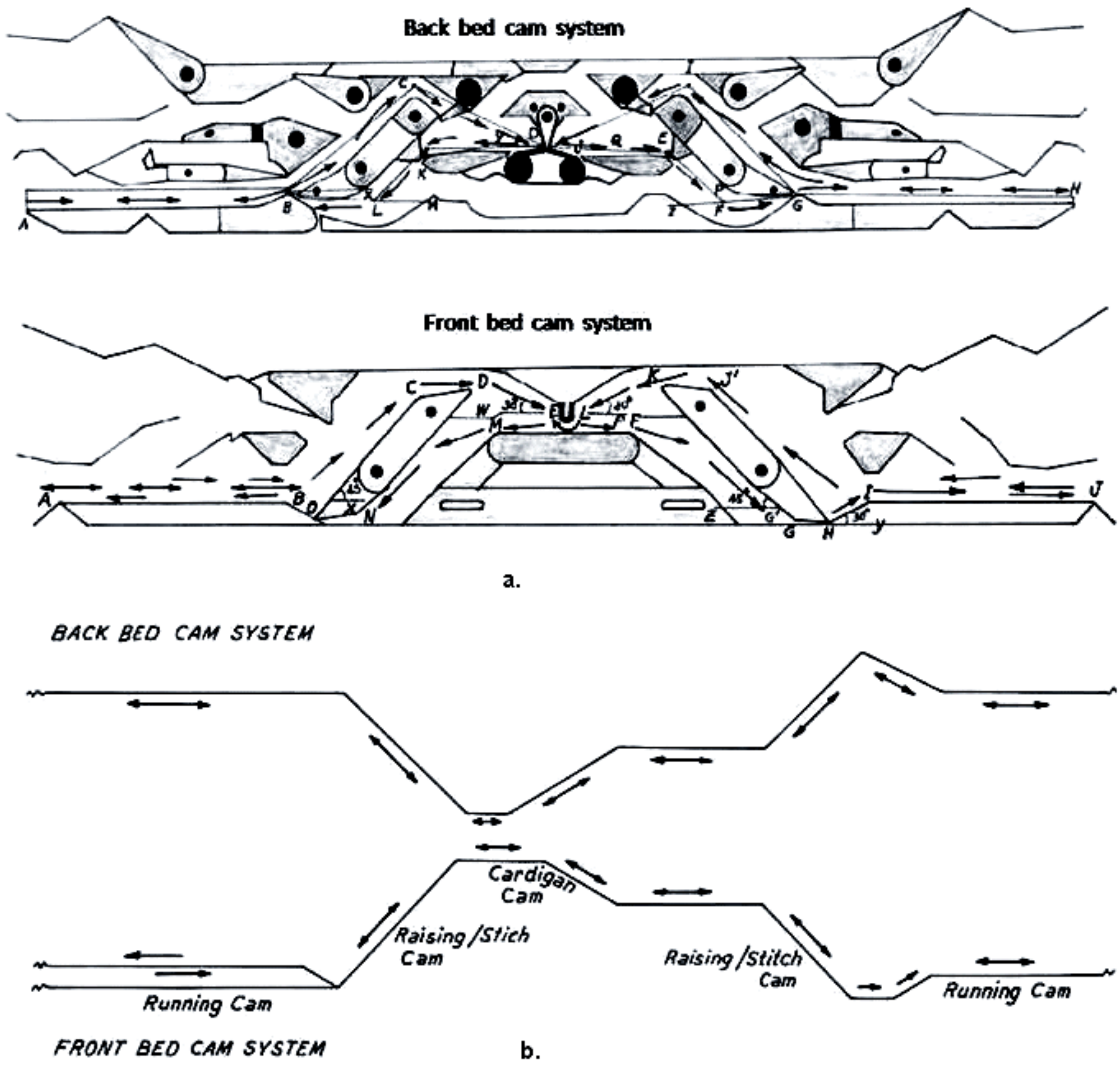


Figure 5.4 Flat DJ cam profile and needle path

Needles with different butt heights (high/long and low/short) may be used in desired proportion to get different needle butt set-out. For example two long and one short in alternative order in each bed will result 2x2 rib knitting.

Since the needles are close to each other and the carriage has sufficient width, many needle butts are inside the cam track at every moment during its traverse across the needle beds. The needle butts, and of course the needles attached to them, moves up and down like a traveling wave while the loops are formed sequentially.

5.6 Double Cam Systems

In order to achieve higher production, double cam systems with two complete sets of knitting cams have been arranged side by side in the same carriage each working with a separate yarn carrier in some automatic power flat machines. This arrangement produces two courses in a single traverse of the carriage from two different yarns. Although it is assumed but never the production is double of the single cam system. The rate of carriage traverse is reduced in case of double cam systems because –

a) Cam carriage becomes heavier.

b) Cam carriage is longer.

c) Traverse length is more in order to clear of the needle at each end. Moreover, the machine becomes much wider.

5.7 Yarn Tensioner and Storage Feeder

Yarn tension variation is one of the major problems in flat knitting which can easily vary the size of the manufactured knit panels. To eliminate or minimize the yarn tension variation, now-a-days storage feeder are used in modern flat knitting machines along with auxiliary yarn tensioner and automated tension controller in addition to the tensioners and guides used in ordinary machines. The auxiliary tensioner is required to monitor the yarn between storage feeder and yarn carrier. A continuous tension monitoring and regulating device (Sensofil) can be employed to ensure a constant yarn tension to the knitting zone. This is required for the production of identical knitted panels and to eliminate the need to knit the panels a little larger to compensate for variations. The automated tension controller can handle up to four yarns and works in conjunction with the storage feeder units and the auxiliary yarn tensioners at the side of the machine. In the Sensofil, the yarn is detected in such a way that it pushes against a spring loaded ball bearing. When the tension exceeds the limitation or drops under it, the bearing moves, a photo-electric circuit is triggered and the brake discs in the auxiliary yarn tensioner are readjusted by motor.

5.8 Fabric Take-down

The newly formed portion of the fabric in every knitting cycle must be withdrawn (generally downward direction) from the knitting zone at a constant rate and the motion used for the purpose is known as take-down motion. In fact, in order to allow the formation of new row of knitted loops, the previous row of loops located in the hooks must be prevented from riding up with the ascending needles so that old loops are cleared of the hooks. The position of the old loops is maintained to a particular level by applying the take-down tension. There are different techniques to apply the take-down tension. The simplest and oldest technique is to hold the fabric in place by pulling it downwards. Generally, dead weight is attached with the fabric in most of the flat bed machines for developing the take- down tension/load. However, in some modern machines special take-down rollers are used for the said purpose. In case of dead weight system, the attachment of the dead weight with the fabric is to be changed after regular interval otherwise the dead weight will touch the ground and disturb the knitting process. The take-down roller arrangement permits continuous knitting.

5.9 Loop Transfer

The flat knitting machines have the ability to transfer loops from one needle to other needle with appreciable effect on the knit structure. The transfer loop is not another new type of loop. Loops can be transferred only from a needle in the front bed to a needle in the back bed or vice-versa. The transfer can be done either manually by means of an additional hook or automatically with the help of transfer spring. The mechanism of loop transfer with the help of transfer spring is described as follows (Fig. 5.5). For easy understanding, the receiving and delivering needles have been shown in horizontal and vertical planes respectively instead of being in inclined planes.

a) The delivering needle is raised by a special cam in the carriage to a height more than the one necessary for clearing. The old loop slides much below the latch and reaches the very high profile of the needle where the transfer spring is positioned on needle stem. The transfer spring is switched on, i.e., the spring protrudes out and the loop is laterally stretched.

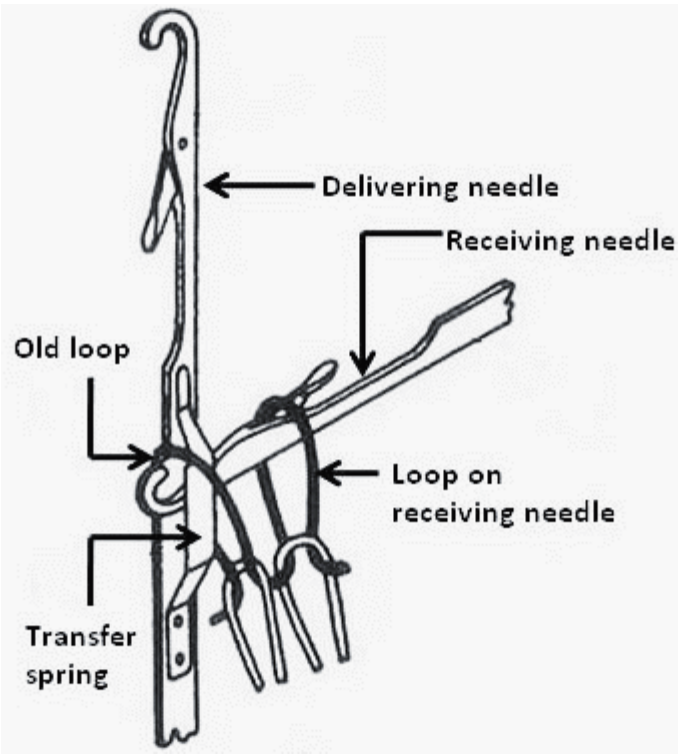


Figure 5.5 Loop transfer.

b) The receiving needle is raised slightly without clearing the loop in the hook. The receiving needle hook enters the loop stretched over the transfer spring of the delivery needle and catches the same.

c) The receiving needle retreats a little to a position beyond the reach of the transfer spring.

d) The delivering needle retreats fully leaving the loop on the receiving needle. The transfer spring is stitched off.

In order to transfer a loop from needle to needle in the same bed, two transfer operations are to be carried over. The loop of a needle is first transferred to an empty needle in the opposite bed. One of the two needle beds is then racked sideways by one needle space and the same loop is transferred back to a needle adjacent to the original delivering needle.

Loop transfer can cause any of the following effects:

a) Appearance of hole in the fabric surface.

b) Deformation of vertical look of the wale and formation of cable effect.

c) Change in width of the fabric.

5.10 Racked Structures

The double/V-bed flat machines are made with the facility of lateral shifting of one bed with reference to the other. This lateral shifting of one bed during knitting produces a unique range of racked (inclined loop) rib structures based on the facility of racking one needle bed by one or more tricks past the other in either direction as and when required. The needle set-out of 1x1 rib or its modifications like half cardigan, full cardigan etc. can be used during racking. Due to racking the loops or the wales become inclined. The basic principles observed in racking are as follows.

a) The structure must be rib based so that the loop of a wale one bed is racked past a loop of a wale in the opposite bed.

b) When a single-needle rack occurs after a 1x1 rib knitting course, the inclination is about 45°. The inclination may further be increased by racking of two or more needles.

c) Prominence of racking depends on the loop structure as well as colour combination.

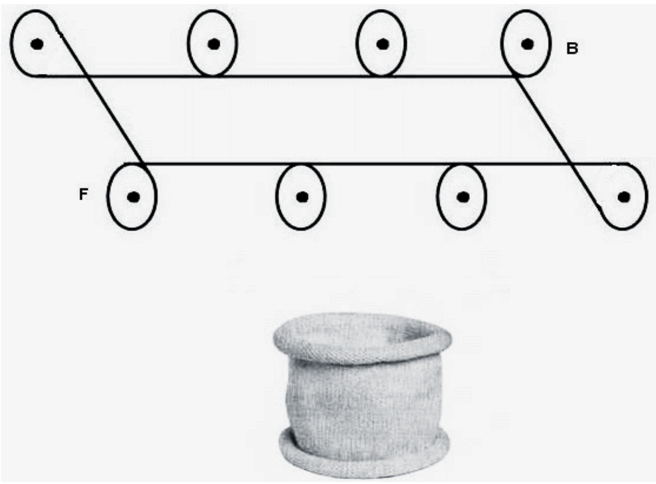
d) Change in direction of racking after regular interval produces zig- zag effect.

e) Racked loops are more prominent if the needle bed is half gauged with every alternate needle removed.

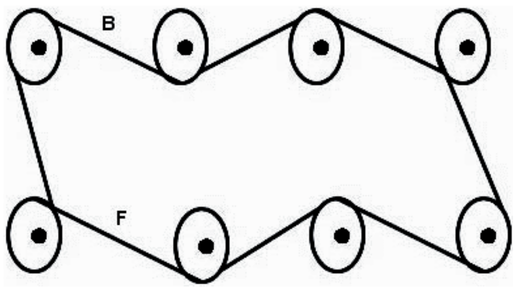
A typical application of racking in combination with transfer of stitches is the cable stitch. Cable stitch is a 3-D design of cords of face loop wales centered in a panel of reverse loop stitches bordered on either side by rib wales of face stitches. The cords are knitted from one needle bed and the background panel from the other.

5.11 Knitting of Circular Fabrics

The need of producing seamless garment in flat bed knitting made it possible to knit circular or tubular fabric in flat bed machine too. Of course double bed machine is essential for the purpose. The basic structure of the circular fabric may be plain or rib. For knitting plain circular fabric, never needles in both the bed knit as practiced in rib knitting. In consecutive knitting cycles, knitting takes place in the two beds in alternate order, say knitting in the back bed (B) in the first cycle and then knitting in the front bed (F) in the second cycle using the same yarn and so on. The technique is very simple, only the movement of the non-knitting cam is to be controlled carefully. The formation of plain circular fabric in flat bed knitting machine as well as appearance of such fabric is shown in Fig. 5.6.



5.6 Plain circular fabric.



5.7 Rib circular fabric.

The knitting of rib type circular fabric as shown in Fig. 5.7 is possible but complicated and requires a specific sequence of knitting. In Fig. 5.7, B is the back bed and F is the front bed.

5.12 Mechanically Controlled Jacquard Knitting

The working principle of a mechanical-controlled jacquard found in flat knitting machines is shown in Fig. 5.8. The hexagonal or octagonal cylinder, the main part of the jacquard, is positioned underneath the needle bed. A chain of metallic punched cards is placed over the cylinder. The cylinder surface is provided with maximum possible number of holes in the punched cards. The cards extend across the full (or part) width of the needle bed. In addition to needle, there is a needle selector in each trick (two selectors in each trick for double cam systems), i.e., the selectors are positioned in between needles and jacquard cylinder. The tails of the selectors rest on the steel and the tails of the needles are supported at the top of the selectors. Whilst the carriage is clear of the needle bed at the end of its traverse, the cylinder can turn and present a new card onto its upper surface. According to the holes or punches in the card, a set of needles are selected for the next carriage traverse. A punched hole allows the selector tail to pass through it into the hole of the cylinder and the needle above it is left at the inactive level. But an un-punched portion in a card causes the corresponding selector to be pushed upwards in the trick which in turn pushes the corresponding needle up so that the same is raised to the knitting height by the raising cam in the carriage.

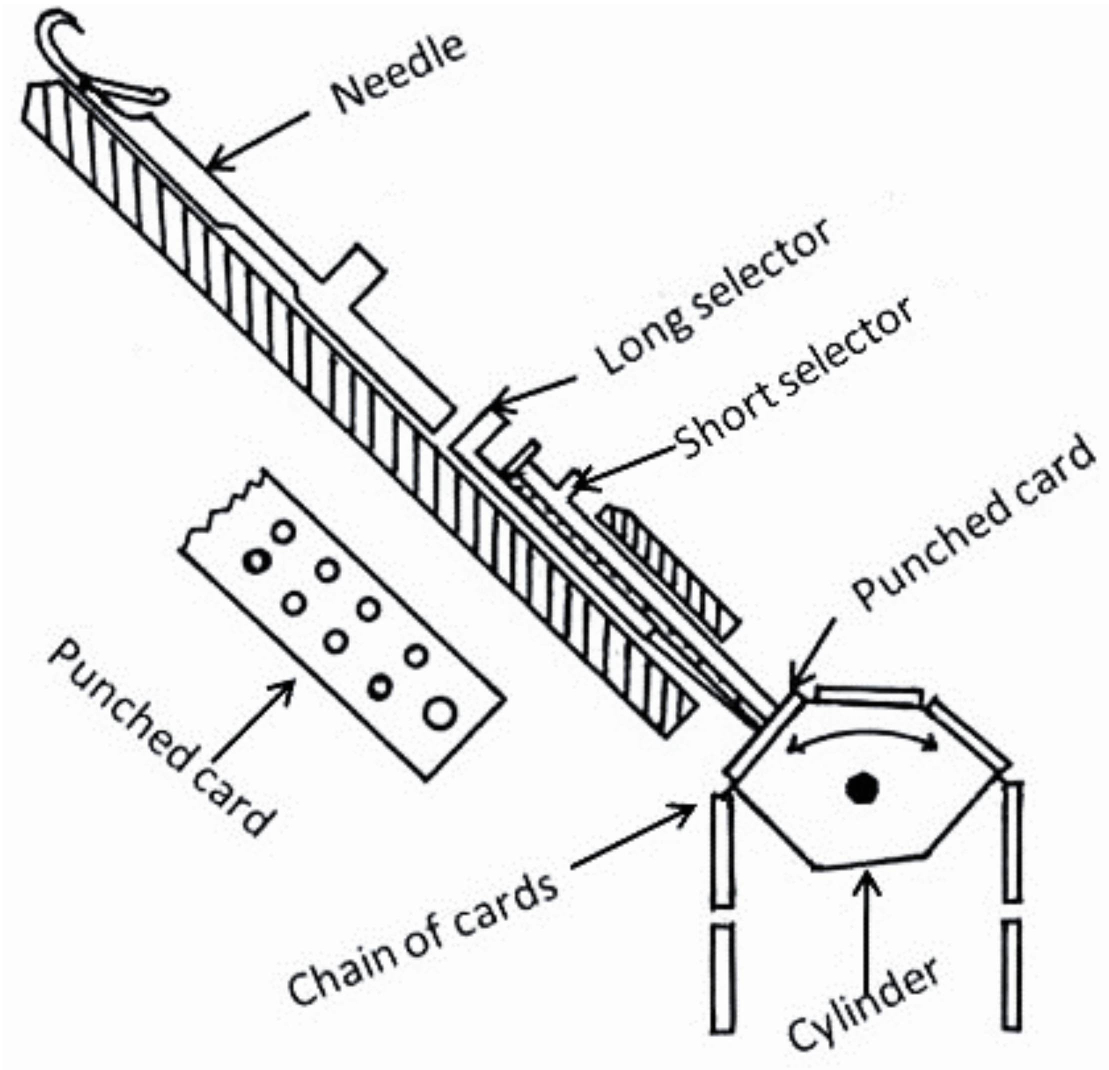


Figure 5.8 Flatbed mechanical jacquard

In case of racking of the needle bed, the jacquard attachment moves sideways to keep alignment with it. The selection mechanism in a machine with double cam systems as well as the construction of the double cam systems is slightly more complicated.

5.13 C.M.S. Machines

The computer controlled latest generation flatbed knitting machines were introduced in the I.T.M.A. exhibition, 1987 in the shape of the C.M.S. series. This new concept of "total knitting" is characterized in machine design that combines textile technology, economy, ergonomic and fashion trends. The C.M.S. machines have been developed keeping in view the increasing garment manufacturing market of the future.

The C.M.S. is the first knitting machine with an integrated computer-controlled carriage driving system. With his system it is neither compulsory to move the carriage from one side of the needle bed to the other, nor is it necessary to drive it in a constant reciprocating movement. According to knitting programme, carriage can be moved to any location along the needle bed and reciprocate over a varying number of needles for as many courses as are required by the design. When the knitting process for a certain area is completed, the carriage can be driven in any direction to a new location. The two main advantages of this system are:

1. Patterning scope is enlarged.
2. Productivity is improved to a high extent.

The C.M.S. by M/s. Stoll has been built with unusual combination of features with useful old ideas along with brilliant new innovations. A few of the features of such machine are listed below.

a) The needle beds are precision cut and working width of each bed is up-to 230 cm.

b) A well combination of new latch needle (spring loaded latch) design and holding down sinker enhances the range of knit designs.

c) Cam boxes are sophisticated but very simple in construction.

d) Position of yarn packages on a side table makes the changing, replacing and threading easier.

e) Individual yarn passes through pot eyes, knot catcher and tensioner.

f) Separate plunger arrangement for engagement of every yarn carrier.

g) For the production of fully fashioned or shaped panels, the yarn carriers can be activated and stopped at various locations along the needle bed during knitting.

h) Different knit structures can be obtained in the same garment with plating technique by means of a special yarn carrier.

i) The unique ability of C.M.S. machine to engage and disengage the yarn carriers at any location as a response to a computer signal, makes the machine suitable for the production of intarsia designs.

j) The storage feeding device supplies yarn with minimum tension variation and results better fabric appearance with minimum yarn break during knitting

k) Loop transfer technique is simple due to semi-open latch position.

l) Needle can individually be selected to perform different functions according to the design. The term “Three way technique” means the ability of the knitting machine to provide the knit, tuck and miss position within each cam system.

m) A pulse synchronizer fitted on the carriage synchronizes and times the pulses transmitted from the computer to the selection mechanism.

n) An extraction unit activated at regular intervals by compressed air removes fluffs generated by the knitting yarn inside the knitting zone.

o) The display monitor shows required information – parameters of the knitting programme or production – at any instant.

p) A knitting programme can be put into the knitting machine by a punched tape or pen drive/CD which is prepared with the help of CAD.

q) New colours and pleasant machine contours improve the working environment.

5.14 Yarn Storage And Delivery Systems on Flat Knitting Machines

Flat knitting machines characteristically offer efficient patterning and 2D and 3D shaping for smaller scale productivity. As flat knitting machines require a smaller quantity of yarn and fewer feeders or cam systems and bobbins, the standard creel may be placed at the upper rear part of the machine (Fig. 5.9). The yarn is fed from the bobbins (1) to the checking device (2) and then to either the left or right side of the machine where yarn tensioners and/or feeders (3) are situated. This prevents the yarn from coming into collision with the carriage (6) bow. After

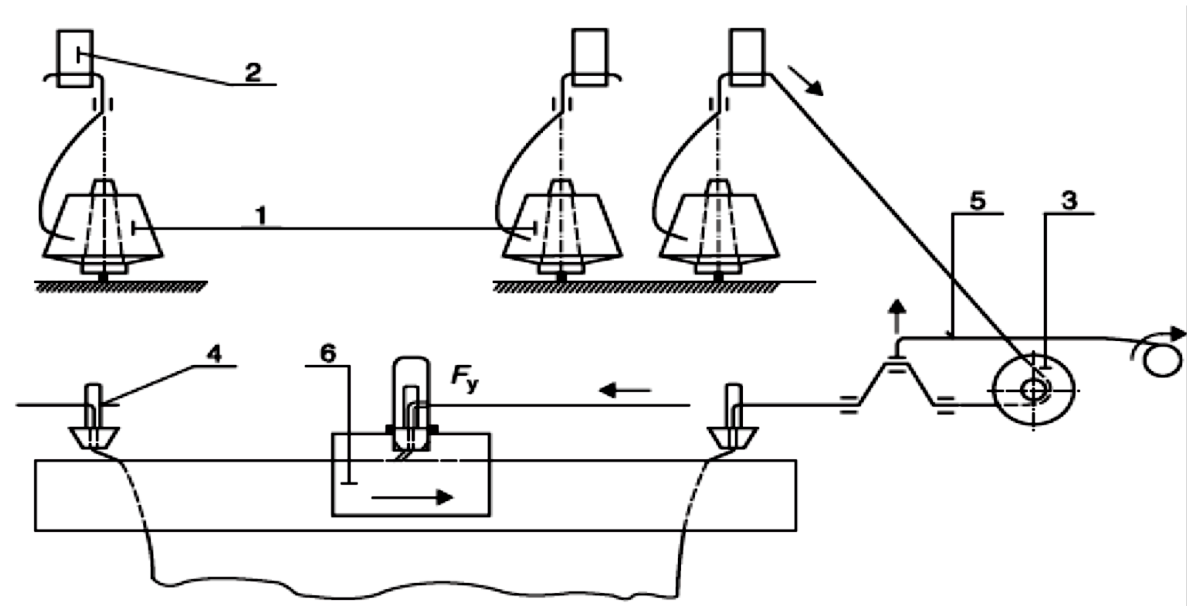


Figure 5.9 Yarn storage systems

the yarn guide returns from the extreme left or right position, a length of yarn is released. To permit this change, a yarn length compensator (5) is used. This is typically a spring-loaded thread eye, which enables the yarn to return and form a loop. This is not a perfect solution as the tensile force Fy of the yarn fed from this loop is less than that imparted by the tensioner (3). The creel capacity (the number of package pins) will be at least twice the number of yarn guides, as two or more ends are threaded in one guide to form a plaited fabric. A solution, providing two yarns with a loose twist, is introduced in Fig. 5.20a. The yarn from bobbin (1) goes through bobbin (2), and one yarn balloon turn forms one twist on the yarns.

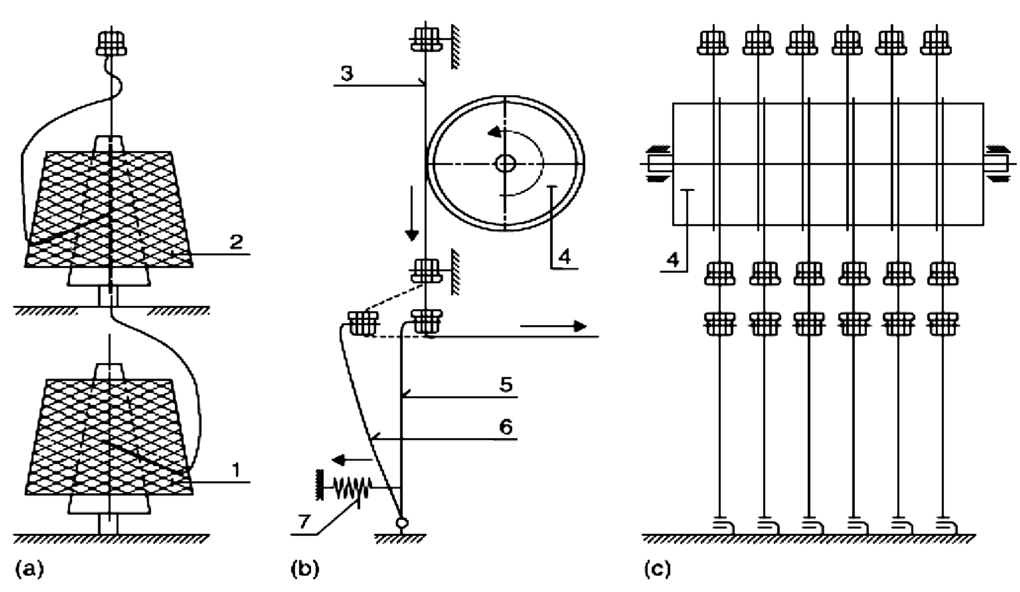


Figure 5.10 Yarn supply system

Controlling the length of fed yarn is not easy on this type of knitting machine. Difficulties may arise from the interrupted unwinding of yarn from the packages due to reciprocated knitting, or in the case of intarsia machines, by guides and yarn exchange during the knitting. Fortunately, the majority of flat knitting machine products are patterned fabrics, which are not very sensitive to striping.

Another problem is consistency of dimensions in plane shaped or ready to wear products. High quality yarn stress control stabilization (negative feeding system) is a partial solution.

Flat knitting machines often use frictional feeders (Fig. 5.10), adapted for changed conditions. The principle is shown in Fig. 5.10b, 5.10c (two aspects). One drum (4) controls all the yarns (3), which are fed from one side of the machine. Similar systems are usually used on each side of the machine. Actually, knitting yarns are pressed towards the drum (4), which decreases yarn tensile force in accordance, and yarns that are disengaged slip on it; (5) and (6) are yarn length compensators. An advanced solution is to measure the yarn length consumption in the knitted courses with feedback to the stitch cam position DSCS (Digital Stitch Control System).8 The sensor could be a very light pulley driven by wrapped yarn so that the peripheral speed of the yarn and the pulley is the same. Movement of the pulley is monitored, usually optically without any mechanical contact. The machine's computer is able to calculate the required yarn length per course by summing up the pre-set length in knitted stitches multiplied by the number of knitted stitches, and does the same with tuck stitches and other structure elements.

Predicted and actual yarn length may be compared and differences corrected by adjusting the stitch cams. Another similar approach (i-DSCS) is the intelligent active control of fed yarn length.

5.15 Santoni Seamless Knitting Technology

Seamless garment knitting can be achieved either on the circular knitting machine or flat (V-bed) knitting machine. However, seamless circular knitting machines differ from seamless flat knitting machines in that seamless circular machines create only a single tubular type of garment such as those produced on Santoni machines.

Seamless knitting machines can create more than one tube and join the tubes together on a machine. The complete garments knitted on circular machines may also only need a minimal cutting operation.

In addition, seamless circular machines require different diameters to make major changes in garment size, whereas seamless flat machines can adjust to different garment sizes on the same machine. Consequently, seamless knitting on circular machines is not true seamless knitting. It should be mentioned that knitting on V-bed seamless machines produces truly seamless garments since they do not require any cutting or sewing. In recent years, Santoni has developed a four-feed single-jersey electronic circular machine, which enables the creation of a shaped garment by reciprocal movement.

To get a higher quality knitted garment, it is crucial to control the manufacturing functions. It is critical for designers and manufacturers to communicate effectively in order to create successful new products in the knitting industry. Designers complain that the designs that they specified are not accurately created, while technicians are of the opinion that the designers do not understand the technical problems in knitting feasibility. It has been proposed that one way to overcome the communication problem between designers and technicians would be the use of intelligent CAD systems. The CAD system gives designers and manufacturers the opportunity to specify and evaluate their design more precisely without requiring great time investment and technical expertise. Diverse computer controlled systems including CAD/CAM controlled machines have been developed to facilitate communication. Please refer Figure 5.11

Companies have been offered new types of CAD system, which use two different monitors including a technical window and a design window for designers and manufacturers, who require different information for the same design.

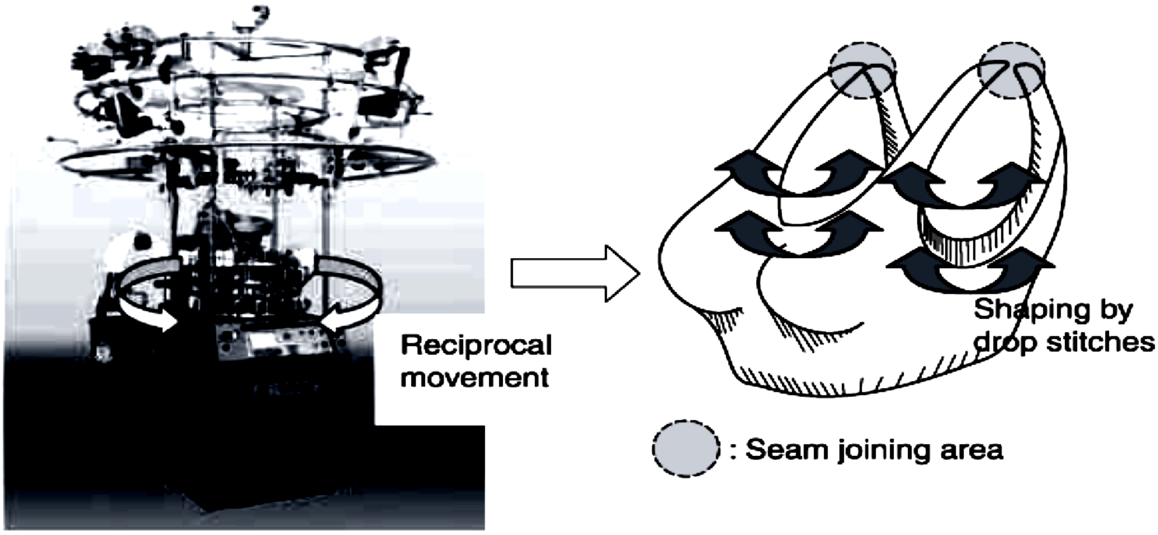


Figure 5.11 The seamless circular knitting system with CAD/CAM.

5.16 Ultra Fine Gauge Knitting Machines

Fine knitted fabrics known as ‘second skin’ are produced on fine gauge circular knitting machines. Cotton, polyester and viscose yarns of 90 to 120 Ne are applied to produce fine circular knitted fabrics. The appearance of these fabrics is similar to woven fabrics but they are more flexible.

Groz-Bekert E68, Mirandsai MV4-3.2 II E60, Havertex BSM2100 E62, and other models are well known, and can produce ultra-fine gauge machines. New models by Carl Mayer (MV4-3.2 single and IG 3.2 QC double) are ultra-fine with gauge E96. Speeds up to 1.3 m/s in these types of machine (with 3.2 feeders per inch) have been reached.

High-grade circular knitting cylinders provide the ideal complement to the company’s premium range of needles and system parts to create the perfect knitting system from a single reliable supplier. It is only with the guarantee of a consistently high standard of component quality and outstanding durability that circular knitting machines are able to reach their full potential for high-performance operation on the factory floor. Ensuring the pinpoint precision of individual elements in existing machines not only simplifies the workflow but also improves capacity utilisation in production.

Fine gauge automotive fabrics, known as woven-like fabrics, are produced on fine gauge double cylinders in Pai Lung ultra-fine gauge machines. Pile technology is applied to these machines, where the fine gauge of loop makers is adjusted near to the sinkers.

5.17 Loop Transfer Technology in Circular Knitting Machines

Stitch transfer is an important operation, as a higher number of transfer modes means more possibilities of making structured designs and shaped fabrics in which the stitch is transferred from one cylinder to the other or within the same cylinder. All the electronic flatbed machines manufactured in Italy offer the double stitch transfer option, i.e. from one cylinder to the other and vice versa, independently of the carriage direction.

In addition, some manufacturers have equipped their machines with an extra cylinder arranged above the machine cylinder and provided with special points to receive stitches from and transfer stitches onto other needles with great freedom of movement. In addition to facilitating the knitting of fabrics with braids or embroideries that require stitch transfers, the third bed also allows significant advantages in the production of shaped fabrics, as the narrowing stitches are transferred onto this cylinder and not onto the dial, diminishing the straining and improving the process conditions. An Italian manufacturer introduced some models including an extra bed with individually selectable points, which operate independently on the front and back bed needles for the lateral transfer of stitches. The production of high-quality knitted fabrics – i.e. of homogeneous appearance as a result of a smooth knitting process and the absence of holes and barring – essentially depends on the application of certain technical solutions that are now adopted by all Italian manufacturers, sometimes with mechanical variants (whether patented or not).

As for the type of needle used, Italian machines incorporate latch needles, which operate according to the drowned butt principle. This kind of needle remains in an idle position with its heel completely drowned in the needle bed groove without being involved in the action of cams, and retains the loop, which in this case is not subject to strain.

5.18 Pile And Sliver Insertion Mechanism in Circular Knitting

A special sliver knitting process locks individual fibres directly into a lightweight knit backing, allowing each fibre to stand upright, free from the backing, to form the soft pile on the face of the fabric. This makes comfort pile fabrics softer, warmer, more drapeable and more resilient than fabrics made from yarns. Each fabric originates from premium loose fibres. These fibres include high-tech microfiber acrylics, polyesters and mod-acrylics specially developed for fabric, along with natural fibres such as wool. Each blend is chosen for its specific end result. By engineering the fibre mix, an incredibly wide range of colours, density, weight, patterning, texture and performance features can be produced in comfort knit pile fabrics.

The selected fibres are solution-dyed to ensure consistent, rich, deep colours. The fibres are then blown together in an air chamber, similar to down, blending their colours and fibre types in a predetermined mix. The mixed fibres are then sent through a series of special carding machines that comb the fibres, aligning them parallel to one another. They are then gathered into a soft rope called 'roving' or 'sliver' – hence the term sliver knitting. The slivers are then fed into sliver inserted fabric state-of-the-art electronic knitting machines. The machine's fine gauge needles, rotating in a circular motion, pick up fibres from each sliver in a predetermined sequence, locking them directly into soft but strong polyester knit backing. Secured at one end, the length of the fibres remain upright and perpendicular to the backing, allowing them to maintain their resilience, softness, breathability, comfort and light weight. After knitting, the pile fabric is sheared to the desired height. It is then put through a series of technical finishing processes specially developed by this kind of knitting process to control the surface texture and special characteristics of the final fabric.

Chapter 6 Quality Aspects in Knitting

6.1 Introduction

Acceptability of a product, in addition to other factors, largely depends on its quality. Whether it is against export or against Government order or for the trade, the quality has to be maintained. The average consumers have become quality conscious. The manufacturer has a moral and ethical duty to ensure that the customer gets material of quality commensurate with price he is buying. For this purpose, in-built quality control by individual manufacturer is essential, which can be achieved only by regular checking and testing of the raw material, knitting process and finished product. Control at different stages of manufacture is also important. Further to ensure sustained marketing of the products, it is essential that the materials are manufactured according to some standard specifications. Even for the quality, the manufacturer should maintain a uniform standard of his/her own in order to ensure that the customer gets the correct material. At the same time, to manufacture the goods according to specifications as well as to maintain quality, the hosiery industry should employ qualified persons passing out from hosiery/textile/fashion institutes.

To be effective, the quality control scheme for knitted fabric must begin with checking incoming yarn and extend through and beyond dyeing and finishing. As discussed earlier, the dimensions of weft knitted fabrics are determined by the number of stitches per unit area and their size, which in turn is determined by loop length. The difference in loop length within a fabric produces appearance defects, the most common one being the occurrence of width wise bars or streaks. In fact, the most important criterion of quality control in knitting is aimed to control the loop length.

6.2 Measurement of Loop Length

The simplest way of checking loop length in a knitted fabric is by measuring the uncrimped length of yarn unravelled from a knitted fabric of known number of stitches (wales). Yarn unravelled from a knitted fabric is crimpy. So, to get the exact length, the yarn is straightened but not stretched by applying a load (say, 0.2 g/Tex). The decrimping load can be calculated with the help of any standard tensile tester. The measurement of straightened length of yarn can be carried out by using any simple apparatus. The HATRA course length tester may be used for the purpose. Of course such measurement is of destructive type and carried out after knitting of the fabric and popularly known as off-machine measurement. For measurement of loop length during knitting rather than at inspection, a variety of yarn speed metres and yarn length counters are available, which are used to measure yarn consumption rates in relation to the speed or number of machine revolutions in circular knitting, and the loop length is calculated by simple calculation. Measurement of loop length during knitting in the machine is known as on-machine measurement.

The most recently developed technique of image analysis can also be used for the determination of loop length in any fabric with the help of computer. The fabric sample is scanned or viewed with magnifying lens and the photographs of the components of yarn making a loop are taken in the memory of the computer either in 2D or in 3D form for calculation of loop length and further analysis of the loop structure. The image analysis technique is non-destructive but produces accurate result.

6.3 Control of Loop Length

The size of the loops and hence the dimensions of the knitted fabric are influenced by the amplitude of the kinking movements used in loop formation and for this reason the machines are provided with adjustable cams that enable this amount to be varied. The control exerted by such fine adjustments is not itself sufficient to dictate the amount of yarn drawn from the supply package. Yarn tensioner and fabric take-down setting, which can be adjusted by the knitter, exert an important effect and there are many other factors (temperature, humidity, yarn extension, friction, package hardness and build), largely outside the control of the knitter, that exert their influence by producing variations in yarn friction and tension. Attempts were made to produce constant tension devices that would eliminate the effect of these variations and allow the needles to draw an amount of yarn determined solely by the cam setting on the machine. These were only partly successful. The positive (measured) feed devices subsequently developed to perform this task have resulted in significant amount of elimination in course length variation and dimensional variation. Fabric made with positive feed has more even appearance and less barre. The adjustment of positive feed is quick and simple. The required course length is obtained by changing the roller diameter and/or gearing and contact drive between the friction surfaces, and the yarn is maintained on a nip or capstan roller principle. The flat bed knitting machines or circular knitting machines with jacquard where positive feed devices cannot be attached for loop length control, the storage feed assembly can make a significant contribution to knitting efficiency by improving yarn control and allowing the economic use of effect yarns that were formerly regarded as difficult to knit because of draw-off problems.

6.4 Important check points in knitting

6.4.1 Checking/testing of yarn

- Count ● U % (Unevenness)
- Strength ● Twist
- Elongation ● Appearance
- Coefficient of friction ● Bending rigidity

6.4.2 Checking of machine

- Stop motion ● Machine speed
- Feeding arrangement ● Lubrication system
- Take–down mechanism

6.4.3 Checking/setting of process and machine parameters

- Yarn input tension ● Stitch cam setting
- Take–down load ● Rate of yarn feeding
- Number of feeders ● Yarn patterning in feeders
- Needle gating ● Tucking and floating arrangements

6.4.4 Checking of knitted fabrics

- Loop length ● Yarn count
- Courses per inch ● GSM (mass per unit area)
- Wales per inch ● Fabric defects
- Stitch density ● Fabric tightness factor
- Yarn type ● Fabric construction (design)

6.4.5 Tests for knit fabric quality

- Fabric yield ● Fabric extension
- Fabric appearance ● Air permeability
- Fabric pilling ● Fabric bow and skewness
- Dimensional changes ● Fabric width
- Angle of spirality ● Abrasion resistance
- Bursting strength

6.4.6 Checking of knit-wear I garments

- General appearance ● Body, sleeves, collars, etc.

- Seams ● Tags and label
- Size and shape● Handle etc.

6.5 Faults in knitted fabrics

6.5.1 Sources of faults

- Raw material (yarn and package)● Yarn feeding and feed regulator
- Machine setting including pattern ● Climatic condition
- Machine maintenance ● Miscellaneous

6.5.2 Types of Faults in Knitted Fabrics

The types of faults along with probable causes are shown in Table 5.1. The defects as stated in the foregoing mainly occur during knitting and observed in grey knitted fabrics. After wet processing (scouring, bleaching, dyeing, printing, finishing), such defects generally become more prominent in one hand and some more new defects are added into the knitted fabric on the other. The additional defects which may be found in the wet processed fabric are as follows.

Table 6.1 Types of faults in knitted fabrics

1	Vertical lines	Defective needles and tricks
		Needles are loose or tight in the trick
		Mixing of needles/sinkers of different types
2	Horizontal lines	Uneven yarn
		Uneven yarn input tension
		Uneven take-down load
		Mixed yarn
		Loose stitch cam
		Uneven twist in yarn
		Poor unwinding of yarn
3	Holes and cuttings	Weak yarn
		Yarn with knots, slubs etc.
		Lint in yarn path
		Very high speed of the machine
		Rough or defective sinker
		Needles too tight in the tricks
		Higher yarn/fabric tension
		Unsuitable or very small loop length
4	Drop stitches	Low yarn tension
		Low take-down load
		Stiff needle
		Wrong stitch cam setting
5	Distorted stitches (Spirality)	Bad or bent needles
		Incorrect positive feed setting
		Uneven yarn input tension
		Bent trick wall

		Wrong stitch cam setting High twist (torque) in yarn
6	Press-off	Faulty stop motion Poor yarn quality Plugged yarn guide Machine running fast Weak knots and slubs
7	Bursting	Too tight fabric (very small loop length) Stiff needle latch Uneven yarn input tension
8	Barre (bars or streaks in course direction)	Uneven yarn input tension Defective yarn Improper needle action
9	Off pattern	Defects in design elements Incorrect feeding arrangement
10	Bias / Skew	Uneven take-down load Mixed yarn
11	Soiling	Bad handling Dirty working environment
12	Oil stains	Oil drippage from machine parts Bad lubrication technique
13	Big knots, slubs etc. on	Bad yarn quality the fabric surface
14	Motes & foreign matters	Poor yarn quality, motes and foreign Dirty working environment
15	Snagging	Mechanical strain during knitting in case of continuous filament yarns
16	Colour fly	Single fibres, bunches of fibres or yarn pieces in varying colours stickled on the yarn or knitted into the fabric
17	Winder line (lines at the two edges of a tubular knitting	Too high take-down load Long storage of fabric in roll form after knit fabric) Dense fabric structure

a. Metamerism b. Tiny holes

c. Stains d. Dried up marks

e. White patches f. Dyeing patches and lines

g. Stitching puncture h. Pin holes

6.6 Spirality in Knitted Structures

Spirality, a common defect, is generally found in single jersey structures. The first and the main source of spirality is the twist liveliness of the yarn used. Loop formation involves both twisting and bending, resulting in twist redistribution in the arms of the loop. If the yarn is twist lively so that it tends to snarl upon itself, then the loop shape is affected as the yarn in the fabric is prevented from snarling by its contact with adjacent loops. The net result is that all the loops in the fabric take up an inclined position giving the fabric a skewed or spiral appearance and the wale lines are no more at right angles with the courses. Spirality of more than 5° is clearly visible and objectionable. The spirality value generally increases after washing due to relaxation of the residual torque of the yarn. Yarn with higher twist multiplier always produces higher spirality than a yarn with low twist multiplier. The factors other than twist liveliness (high twist multiplier) which affect spirality are given below:

1. Tightness factor of the fabric (spirality decreases with increase in tightness factor)
2. Feeder density in the machine (spirality increases with increase in number of feeders)
3. Machine gauge
4. Yarn linear density
5. Variation in knitting tension and yarn frictional properties
6. Spinning technology (friction > ring > rotor >air jet)
7. Residual torque of the yarn

Spirality becomes more prominent when width wise striping is produced using two or more coloured yarns in a machine with very high number of feeder. Some of the practical problems arising from spirality encountered in garment production are displacement or shifting of seams, mismatching of patterns, sewing difficulties, etc. Spirality has an obvious effect on both aesthetic and functional performances of knitted structures and garments produced from them.

Spirality can be eliminated by setting the twist in yarn or by using balanced twofold yarns where possible. But with single yarns of natural fibres, the set is not generally permanent to washing. The effect of the direction of machine rotation with relation to the direction of twist in yarn has some effect on spirality but it becomes negligible after the washing of the fabrics. The easiest and popular technique of minimizing spirality in knitted structure is to use 'S' twisted and 'Z' twisted yarns in alternative feeders during knitting. The neighbouring yarns twisted in opposite direction act in an opposing manner and neutralize the tendency of spiral formation. Plating is an effective way to produce spirality-free fabric.

6.7 Relationship between Yarn Properties and Knitted Fabric Qualities

As there are multifarious links between yarn properties and quality of a knitted fabric, the appearance of a knitted fabric is therefore strongly affected by the defects in the yarn used. A few of the relationships between yarn defect and fabric appearance can be summed up as observed in Table 6.2.

6.8 Pre-requisites for Faultless Production in Knitting

With regard to the states of the machines the following points must be kept in mind for faultless production of knitted fabric.

(a) The machine must be installed on a true horizontal floor or surface, as far as possible, without any vibration.

(b) Yarn package holders must be mounted in such a way that yarn should not rub against the sides of the packages when it is withdrawn.

(c) Yarn should be guided from the package up to the knitting zone without unnecessary deviations in order to avoid additional increase in tension and entanglement with the neighbouring yarns.

(d) Yarn packages must be well built with proper package (cone) angle. The quality of yarn must fulfil the requirements in knitting.

(e) If basic knitted structures are used to a large extent, the machine should be equipped with yarn feeding units that generate a constant yarn tension and deliver uniform yarn length.

(f) Yarn guides must be flawless, eyelets made of porcelain or sintered ceramic must have a smooth surface without any furrows.

Table 6.2 Effect of Yarn Defect on Fabric Appearance

S.No	Cause (yarn defect)	Effect (fabric appearance)
a.	Very uneven yarn	Cloudy fabric
b.	Yarn with very low strength and/or too many thin places	Holes or cracks
c.	Yarn with long term unevenness	Fabric with stripes
d.	Bad dyeing or blending	Horizontal stripes
e.	Insufficiently paraffinated or rough yarn	Drop stitches and holes
f.	Too large or weak knots or bad splicing	Yarn end separation or breakage during knitting
g.	Uncleared thick places	Irreparable faults in the fabric
h.	Too much yarn hairiness	Diffused stitch appearance and fluff build-up
i.	Very high twisted yarn	Spirality or distorted stitches

(g) The needles must also be flawless and the shape of the needles especially of the hooks must be adapted according to the machine gauge and yarn count.

(h) The condition of needle bed(s) particularly that of tricks should be well maintained without wear and tear.

(i) The drive to the needle bed(s) should be smooth and free of play in between dial and cylinder.

(j) The needle beds must be exactly centred towards one another.

(k) The fabric take–down and wind-on mechanism must be capable of being set individually for maintaining desired tension.

(l) The operator must be thorough about the machine and should be quality conscious.

(m) The machine must be equipped with well- maintained highly sensitive stop motions.

(n) The machine must be oiled and lubricated regularly. Automatically operating lubrication systems are absolutely necessary to get a high machine performance and a good operating reliability.

(o) The machine must be cleaned, i.e. the deposition of fluffs and dirts all over the machine as well as deposition of residual paraffin on the tension discs and yarn guides should be removed regularly.

(p) The knitting plant must have clean working environment with proper temperature and humidity, preferably it should be air conditioned so that yarn does not dry up during knitting.

6.9 Main factors affecting the Dimensional Properties of Knitted Fabrics/Garments

1. Fabric structure – different structures relax differently
2. Fibre(s) type – fabric or garment made from different fibre(s) relax differently
3. Stitch length – the length of yarn in a knitted loop is the determining factor for all structures
4. Relaxation/finishing route – the fabric dimensions vary according to relaxation/finishing sequence
5. Yarn linear density – yarn diameter affects the dimensions slightly but affects the fabric tightness, area density and other physical properties

6.10 Online Quality Control

The modern trend in quality control during knitting is the online quality control with the help of computer. For the purpose, many sensors and/or transducers are used to detect faults and deviation from set values. This detection or signal goes to the central computer which processes and interprets the results and then sends the same to the controllers which are generally electronically controlled devices. These controllers either control the process directly or stop the process temporarily. This online control system can be attached with a group of machines and can produce cumulative results related to quality aspects for any particular duration and store for future applications. A few of the sensors and controllers found in modern knitting machine are given below:

1. Yarn breakage and speed monitoring sensor
2. Yarn tension monitoring sensor
3. Monitoring of group of needle selection during shaping
4. Fabric quality monitoring sensor
5. Machine speed control servo motors
6. Production monitoring and display unit
7. Automatic lubrication monitoring and controlling unit
8. Needle monitoring and electronic needle selection device

This online control system is equivalent to the ring-data or loom data system widely popular in textile industry.

Chapter 7 Warp Knitting Elements and Knitting Machines

7.1 Introduction

A warp knit fabric has a structure made of several warp threads or warps that form similar loops in a course. The different stitches are knitted by changing the sideways motion or shogging movement of the guide bars during knitting. There are three basic types of fabric – woven, weft knit, and warp knit. Woven and warp knit fabrics need a warp to form a fabric and a weft knit needs an end to form a fabric. A woven fabric is formed by interlacing warp ends with filling or weft ends to form courses. Only one end is needed to form a course in weft knit, but many ends are needed to form a course in a warp knit.

In the United States, many technicians call weft knit fabrics ‘circular knits,’ while warp knit fabrics are called ‘flat knits’. In reality, both weft and warp knit fabrics can be knitted on circular as well as flat machines. However, most weft knit fabrics are knitted on circular machines, and most warp knit fabrics are made on flat machines.

The history of warp knitting is closely associated with two names – William Lee and Karl Mayer. In 1589 the English clergyman applied for a patent for the first mechanical machine for producing knitted structures, thereby laying the foundations for mechanical stocking production and creating the technical basis for developing warp knitting technology. In 1947, 358 years later, the farsighted businessman and mechanic Karl Mayer exhibited his first warp knitting machine in an international trade fair. That very machine had only two guide bars and used to run at 200 rpm and that marked the beginning of an era full of innovative leaps in the world of warp knitting. As early as 1953, Karl Mayer GmbH introduced the company’s own first Raschel machine paving the way for the “Super-Rapid” era.

Warp knitting is defined as a loop forming process in which the yarn is fed into knitting zone, parallel to the fabric selvedge. In warp knitting, fabric is made by forming loops from yarns coming in parallel sheet form which run in the direction of fabric formation (like warp in weaving).

Every needle is fed by a separate yarn for loop formation. In order to connect the loops into a fabric, the yarns are shifted (shogged) between the needles. In this manner the needle draws the new loop through the loop formed by another yarn in the previous knitting cycle. For the purpose of shogging, each yarn passes through a guide fitted on guide bar. Large numbers of yarns in parallel sheet form are supplied from warp beam. Hence, warping is essential in warp knitting. Warp knitting machines are flat and comparatively more complicated than weft knitting machines. A few of the popular warp knitted structures are locknit, sharkskin, queens cord, double atlas, velour etc.

7.2 Knitting Elements

In both Tricot and Raschel warp knitting machines, yarns coming from the beam as parallel sheet are converted into fabric by loop formation before being wound in open width form on the cloth roller. Although the said two types machines differ to certain features, their loop formation technique is almost similar and the functional elements required for the purpose are as discussed in the undergoing.

Needles and needle bar – All the three types of needles (bearded, latch & compound) as described while discussing weft knitting in Chapter 3 are used in warp knitting as well. Whatever may be the type of needle, all the needles move up and down together for loop formation, i.e., all the loops in a course are made simultaneously. So instead of giving motion to the individual needles, all the needles are connected/fixed to a bar called needle bar (Fig. 7.1) and the needle bar is lifted up and lowered down by means of a cam fitted outside the machine, generally at the driving side. Needles are set in tricks cut in the needle bed of the machine.

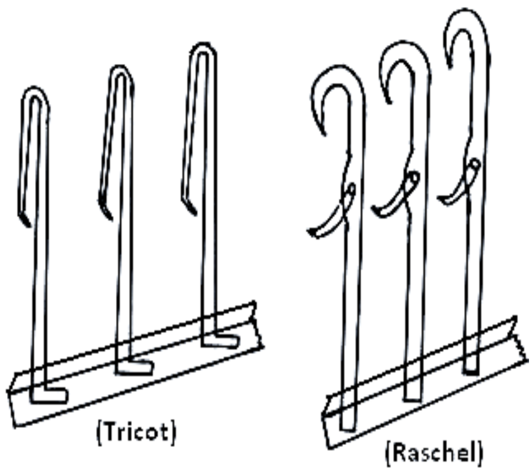


Figure 7.1 Needle bar.

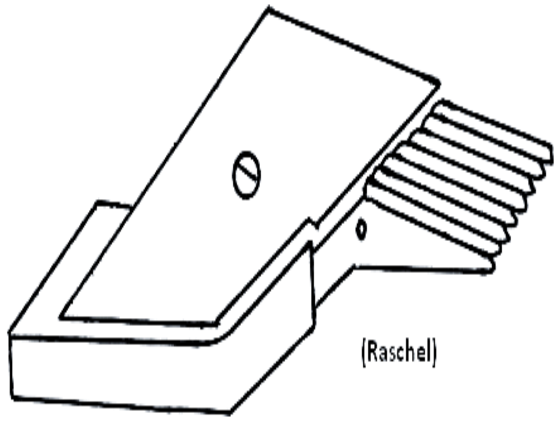


Figure 7.2 Sinker bar.

Presser bar – In order to close the hook for casting-off of the old loop in Tricot machine, some closing element (Presser bar) is must. The elements needed in Tricot machine are set in a separate bar across the full width of the machine which also get motion from a cam or crank fitted on the main shaft. The presser bar closes the hook of the bearded needle when the same moves downward after catching of the new yarn for loop formation.

Latch guard or wire – In Raschel machines, when the loops of the fabric clear the latches, the later have sometimes the tendency to flick back and close the hooks of the needles. A closed hook does not receive a new yarn. So a steel wire stretched across the whole width of the machine, parallel to the needles, is used as latch guard to stop the flicking latches.

Sinkers and sinker bar – The sinker is a thin plate of metal which is placed between every two needles. The sinkers are usually cast in units (Fig. 7.2), 1 inch long, which in turn are screwed into a bar called sinker bar. The sinkers are given almost linear horizontal (forward and backward) motion through the sinker bar. The drive generally comes from a crank or eccentric arrangement. The neb and the throat of the sinker are used to hold down the fabric while the belly of the sinker is used as a knocking over platform.

Guides and guide bars – Guides are thin metal plates drilled with a hole in their lower end through a warp end may be threaded if required. The guides are held together at their upper end in a metal lead of 1 inch width (Fig. 7.3) and are spaced in it to the same gauge as the machine. The leads in turn are attached to a horizontal bar to form a complete guide bar assembly bar, so that the guides hang from it with each one occupying a position at rest midway between two adjacent needles. In this position the needles do not receive the warp yarns. The needles only receive the warp yarns in their hooks if the guides wrap or lap the yarns across the needles. For the purpose, the guide bars are given a compound lapping movement. The number of guide bars in a machine is equal to the number of warp beams and each guide bar contains guides equal to the number of yarns in each warp beam. All guides in a conventional guide bar produce an identical lapping movement at the same time and therefore have requirements of same warp tension and rate of feed although yarns may differ in colour and composition. But the two guide bars may have different lapping movement where requirement of warp feed and warp tension may vary also.

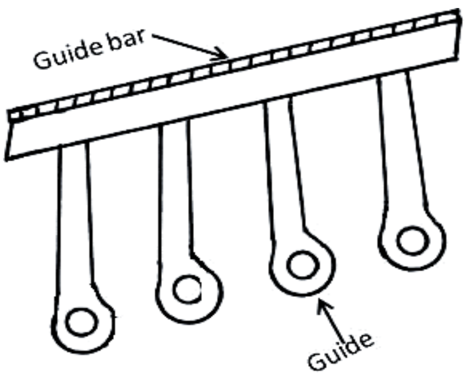


Figure 7.3 Guide bar

Trick plate – The other name of needle bed is trick plate. Tricks or grooves are made on the bed for properly accommodating the needles so that they can move up and down freely without having any lateral tilt.

Pattern wheel and chain links – These two are very important elements for the loop formation in warp knitting.

7.3 Warp Beams

The required numbers of yarns are wound as parallel sheet of warp on a flanged beam under uniform tension for supplying of yarn in the knitting zone at a constant rate and tension. The warp beams (Fig. 7.4) in knitting are similar to the beams used in weaving but the technique of preparation may differ. There is no need of sizing but application of certain amount of oil/wax on warp may improve the knitting performance. Both sectional warping and direct warping are applicable depending upon nature of warp to be produced. Utmost care should be taken particularly for staple yarns so that variation of yarn diameter and presence of defects such as slubs, knots etc. shall be minimum in the final beam. Content of yarn in the beam depends on the fineness and density of yarn and flange diameter. The beam width (flange to flange) is generally equal to the width of needle bar. However, for easy manipulation of the beams, particularly in wider machines, two or more sections of beams are used instead of one wider beam. The number of full width beams in the machine is equal to the number of guide bars. The beams are situated at the top of the back side of the machine.

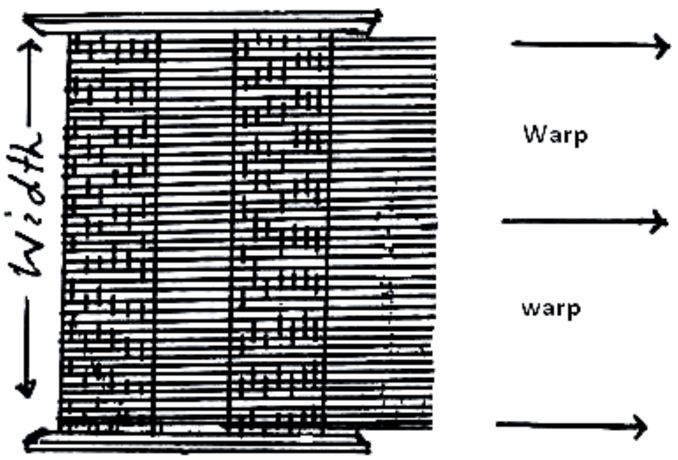


Figure 7.4 Warp beam containing parallel sheet of yarns.

7.4 Types of warp Knitting Machines

Based on the features of warp knitting, the machines available are classified into two categories, namely Tricot and Raschel. Both Tricot and Raschel may be made with either single needle bar or double needle bar. A brief classification of warp knitting machines has been given in Fig. 2.4 of Chapter II.

7.4.1 The Tricot Machine

Tricot machines have a gauge expressed in needles per inch (E) and chain link numbering 0, 1, 2, 3, 4, etc., generally with three links per course. Their sinkers, which are joined to each other at the front and back, never move clear of the needles as they combine the functions of holding-down, knocking-over, and supporting the fabric loops.

The fabric is drawn-away towards the batching roller almost at right angles to the needle bar. The warp beams are accommodated in an inclined arc towards the back of the machine, with the top beam supplying the front guide bar and the bottom beam supplying the back guide bar. The warp sheets pass over the top of the guide rocker-shaft to their tension rails situated at the front of the machine. The machines have a simple construction and a short yarn path from the beams. Mechanical attention to the knitting elements is carried out at the front of the machine as the warp beams prevent access to the back. As all the warp sheets are drawn over the rocker-shaft to the front of the machine it is easier to thread up the guide bars commencing with the back bar; otherwise the front warp will obscure this operation. The guide bars are therefore numbered from the back towards the front of the machine because of this threading sequence. The conventional tricot beam arrangement generally restricts the maximum number of beams and guide bars to four, but this is not of major importance as the majority of tricot machines employ only two guide bars.

The small angle of fabric take-away and the type of knitting action produce a gentle and low tension on the structure being knitted. This is ideal for the high-speed production of simple, fine-gauge (28–44npi), close-knitted, plain-and-patterned structures, particularly for lingerie and apparel, especially using two guide bar structures with both bars overlapping and underlapping.

In the past, the two guide bar tricot or locknut machine proved most popular in E 28 and E 32 gauge, with knitting widths of 84 and 168 inches (213 and 426cm) using 40-denier nylon. It is possible to knit from 10-denier nylon up to 1/20’s cotton count. Machine gauges can range from E 10 for coarse staple fibre yarns to E 20– E 24 for textured yarn fabrics and E 36–E 44 gauge for fine fabrics, in knitting widths up to 260 inches (660 cm).

The needles, like the sinkers and guides, may be cast in leads or they may be individually cranked to fit into the needle bar.

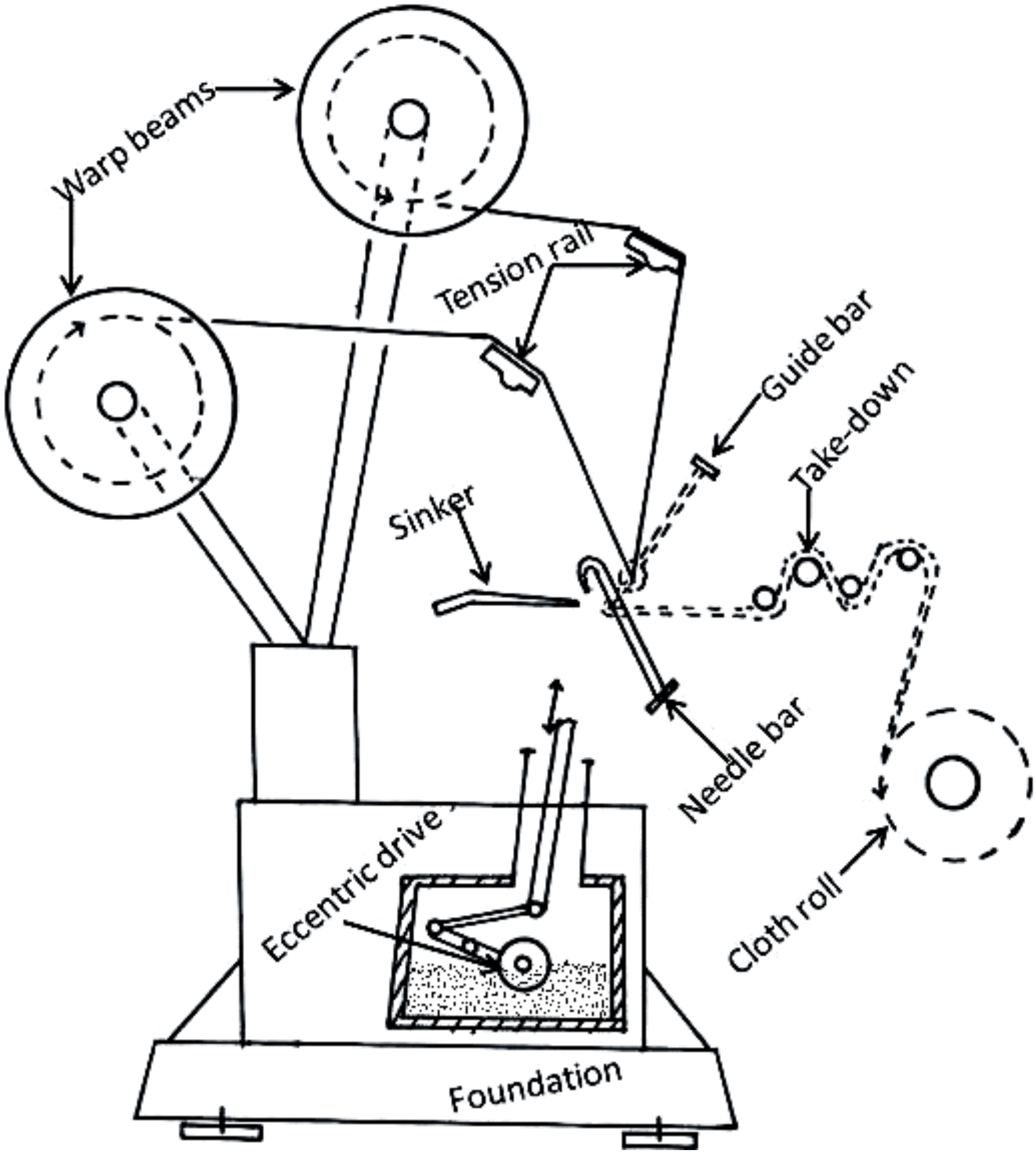


Figure 7.5 Line diagram of different elements and zones of a warp knitting machine

In the past, it was usual to distinguish between Tricot and Raschel by the needle used in each machine type. Tricot machines were equipped with bearded needles while Rachel machines only used latch needles. With the production of modern warp knitting machines, however, the compound needle replaced the bearded needle in Tricot and penetrated into the Raschel as well. The classification of warp knitting machines by the needle type is therefore no longer possible. An accurate definition can be made by regarding the type of sinkers with which the machine is equipped and the role they play in loop formation. The sinkers used in Tricot knitting machine control the fabric throughout the knitting cycle. The fabric is held in the throats of the sinkers while the needles rises to clear and the new loops are formed/knocked over in between them. In Rachel knitting machine, however, the fabric is controlled by a high take-up tension and the sinkers are only used to ensure that the fabric stays down when the needle rise. The other differences in features along with the above mentioned two features of these two types of machines are given below. With the help of line diagram the different elements and zones of a typical warp knitting machine is shown in Fig. 7.5 and only the knitting zones of Tricot and Raschel machines are shown in Fig. 7.6.

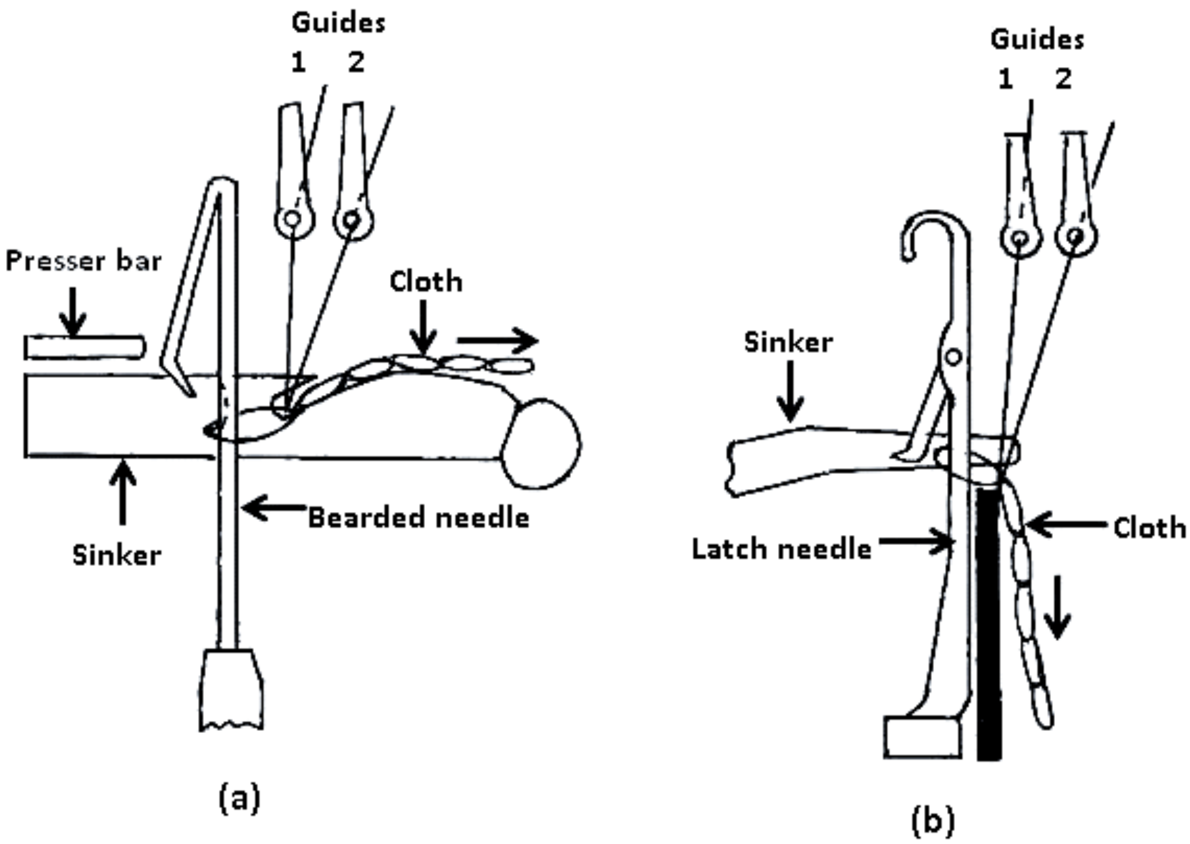


Figure 7.6 Knitting zones of Tricot and Raschel type warp knitting machines

7.4.2 The Raschel Machine

The history and development of the raschel machine: In 1855, German warp knitters in Apolda used warp rib machines made by Redgate of Leicester to knit lace stoles which they sold under the name of Raschel Felix, the famous French actress , so that when Wilhelm Barfuss began to build his latch needle rib machines, he named them raschel machines. Originally, two vertical needle bars arranged back-to-back, mid-way between each other, were employed for producing simulated rib fabrics. In 1914, when the needle bars were placed directly back-to-back, only even-numbered chain links were required. Until the mid-fifties, the raschel industry tended to be small, employing slow, cumbersome but versatile coarse-gauge universal raschels. These had two needle bars, one of which could be removed or replaced with plush points, changeable cams and patterning mechanisms that might include fall plate, crepe and fringing motions, chain switching, and possibly weft insertion or jacquard.

The development of modern specific-purpose raschels dates from 1956, when a twelve guide bar raschel machine led to the rise of the raschel lace industry. There are now single needle bar raschels for simple and multi-guide bar dress and household fabrics, elastic laces, trimmings and curtain nets; high-speed standard raschels for simple structures such as suitings; versatile multi-purpose raschels for fancy fabrics, weft insertion; and jacquard raschels and double needle bar raschels for plush, tubular articles, scarves and string vests. There is an increasing demand for finer, lighter fabrics with minimum elongation and transparency. Warp knitting is able to meet this requirement by producing fabrics weighing much less than 100g/m2 with very little edge-curling.

Description of the Raschel Machine:

Raschel machines originally had a gauge expressed in needles per 2 inches (5 cm), so that, for example, a 36-gauge Raschel would have eighteen needles per inch. Now, the standard E gauge (needles per inch) is generally used. There is a wide gauge range, from E 1 to E 32. Their chain links are usually numbered in even numbers, 0, 2, 4, 6 etc., generally with two links per course. Figure 7.7 shows the cross sectional view of a typical Raschel machine. Raschel sinkers perform only the function of holding down the loops whilst the needles rise. They are not joined together by a lead across their ends nearest to the needle bar so they can move away clear of the needles, towards the back of the machine, for the rest of the knitting cycle. The needle trick plate verge acts as a fabric support ledge and knock-over surface. The fabric is drawn downwards from the needles, almost parallel to the needle bar, at an angle of 120–160 degrees, by a series of take-down rollers. This creates a high take-up tension, particularly suitable for open fabric structures such as laces and nets. The warp beams are arranged above the needle bar, centred over the rocker shaft, so that warp sheets pass down to the guide bars on either side of it. The beams are placed above the machine so that it is accessible at the front for fabric inspection and at the back for mechanical attention to the knitting elements. The guide bars are threaded, commencing with the middle bars and working outwards from either side of the rocker-shaft. They are numbered from the front of the machine. With the raschel arrangement, there is accommodation for at least four 32-inch diameter beams or large numbers of small diameter pattern bars. The accessibility of the raschel machine, its simple knitting action, and its strong and efficient take-down tension make it particularly suitable for the production of coarse gauge open-work structures employing pillar stitch, inlay lapping variations and partly threaded guide bars. These are difficult to knit and hold down with the tricot arrangement of sinkers. Additional warp threads may be supplied at the selvedges to ensure that these needles knit fabric overlaps, otherwise a progressive press-off of loops may occur.

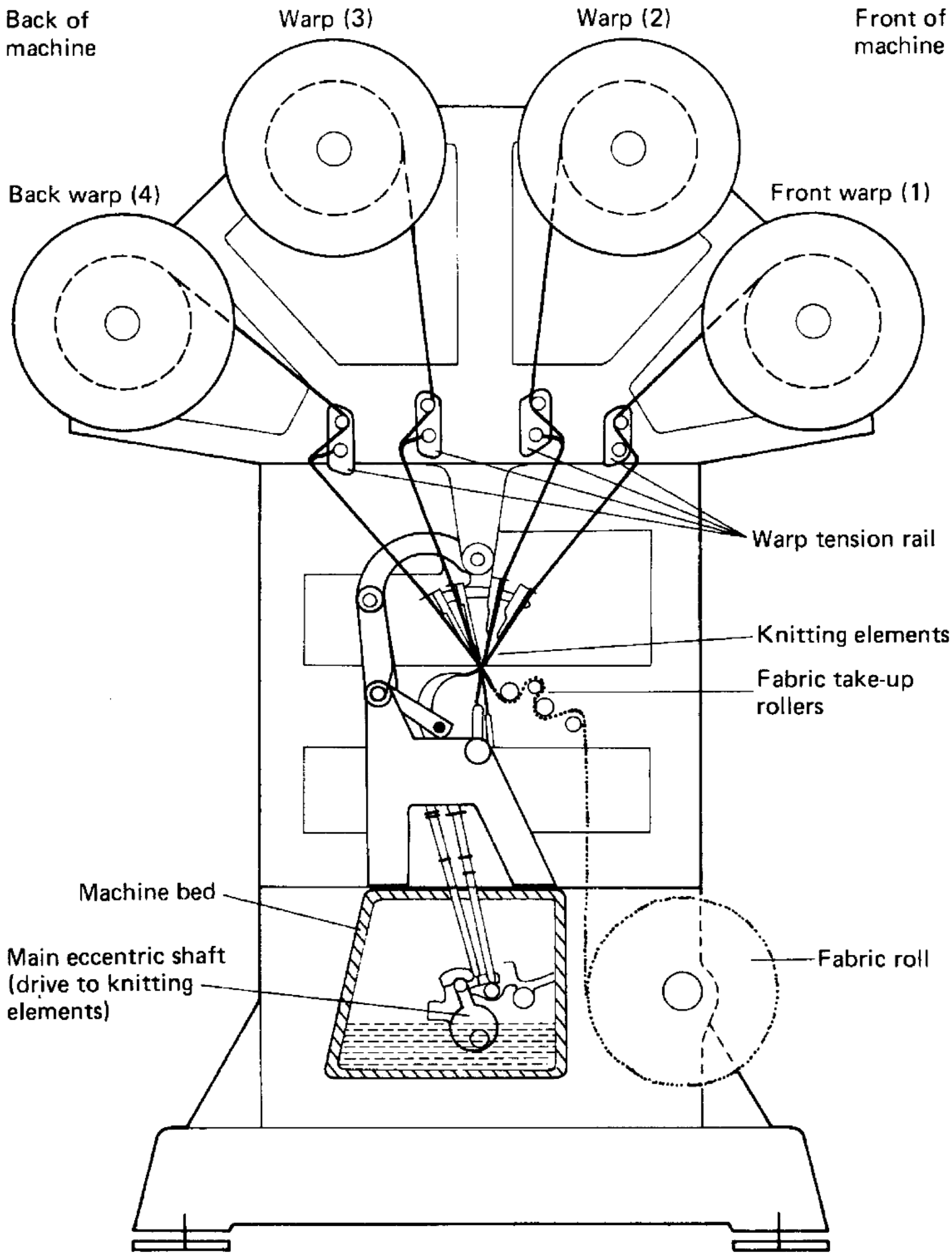


Figure 7.7 Cross-section of a latch needle Raschel machine

7.5 Comparison between Tricot and Raschel type Warp Knitting Machines

To understand warp knit Raschel machines, it will be helpful to compare them with warp knit Tricot machines. The following are the 12 basic differences.

1. Raschel machines are heavier and produce heavier fabrics.
2. Older Raschel machines have latch needles with knitting speeds of 800–900 spm whereas the older Tricot machines have spring bearded needles with knitting speeds of 800 to 2 000 spm.
3. New Raschel and Tricot machines use compound needles, with Raschel machines knitting more than 1 300 spm and Tricot machines knitting more than 2 000 spm.
4. Raschel machines use two 50-inch beams for 100-inch wide machines, or four 50-inch beams for 200-inch wide machines, six 21-inch or three 42-inch beams for 130-inch wide machines. Tricot machines use four 42-inch beams for 168-inch wide machines.
5. In Raschel machines the gauge of the machines is measured in needles per two inches and common gauges are 64 gauge (32 npi) and 56 gauge (28 npi). On the other hand, in Tricot, gauge equals needles per inch, and common gauges are 28, 32, and 36 (40 gauge machines have been developed but are not used widely).
6. The fabric angle to the warp on Raschel machines is 160° take-up whereas in Tricot machines the angle is 90° take-up. This is the reason why Raschel stitch constructions such as heavy Gentlissimo and Power Net cannot be knitted on Tricot machines.
7. On Raschel machines, fabric take-up tension is high, whereas on Tricot machines take-up tension is lower.
8. Raschel machines with latch and compound needles do not need a presser bar. Since the needles are heavier and bigger, Raschel machines can use spun yarn or heavier spandex yarn, whereas the Tricot machines with spring bearded needles need a presser bar, and since needles are smaller, knitting of spun yarn is more critical.
9. Raschel machines knit up to 1 500 denier yarn, whereas Tricot machines knit up to 240 denier hard yarn (for spandex 1 000 versus 140 denier respectively).
10. In Raschel machines, the links move half a course, whereas in Tricot machines the links move one course. Because of this, lap notation of Raschel is written 2-0, 2-4 for the back bar Jersey stitch. The same lap notation for Tricot is written 1-0, 1-2.
11. Raschel machines are more versatile and are used for fancy pattern work, whereas Tricot machines are less versatile in styling and designing.

12. Raschel mills are smaller whereas Tricot mills are larger and more likely to be integrated mills.

The general comparison between the two types of warp knitting machines is given in Table 7.1.

Table 7.1 Comparison between Tricot and Raschel Warp Knitting Machines

	Tricot	**Raschel**
1.	Bearded or compound needles are used	Latch needles are commonly used but compound needles may also be used
2.	Sinkers control the fabric throughout the knitting cycle	Sinkers only ensure that the fabric stays down when the needle rise
3.	Less number of warp beams and guide bars (2 to 8)	More number of warp beams and guide bars (2 to 78)
4.	Warp beams are positioned at the back	Warp beams are positioned at the top
5.	Gauge is defined as needles per one inch	Gauge is defined as needles per two inch
6.	Machines are made in finer gauges	Machines are made in coarser gauges
7.	(28 to 40) needles per inch) Mechanical designing allows less	(24 to 64) needles per two inch) Mechanical designing allows more accessibility on the machine
8.	The angle between needle and fabric take-down is about 90° Knitting tension is lower	The angle between needle and fabric take-down is about 160° Knitting tension is higher.
9.	Machines are wider	Machines are narrower
10.	Machine speed is high (up to 3500 courses per min.) produced	Machine speed is comparatively lower (up to 2000 courses per min.) produced
11.	Machines are suitable for filament yarns	Machines are suitable for spun yarns
12.	For guide bar movement the chain link numbering are 0, 1, 2, 3, 4, etc.	For guide bar movement the chain link numbering are 0, 2, 4, 6, etc.
13.	Number of links per course is 3	Number of links per course is 2
14.	Number of needle bar is one or two	Number of needle bar is one or two

7.6 Needle Bar Movement

The needle bar is lifted up and lowered down for the purpose of loop formation. During upward movement, the old loop is cleared and needle catches the yarn wrapped around it by the guide and forms the new loop during the downward movement. Such movement is imparted on the needle bar by means of a cam or eccentric fitted on a shaft called eccentric shaft. The shaft extends to the full width of the machine and the cam is located outside the machine, generally at the driving side. The cam is kept in an enclosed oil bath in order to have less vibration, noise, heat generation but higher life (Fig. 7.7).

7.7 Guide Bar Movements

In order to feed the yarn to the needle for loop formation as well as to connect the adjacent wales, the guides of a guide bar are required to execute a compound lapping movement. This compound lapping movement (Fig. 7.8) is composed of two separately derived motions – swinging and shogging. A swinging motion and a shogging motion act at right angle to each other in order to form overlap and underlap. The swinging motion of the guides takes place

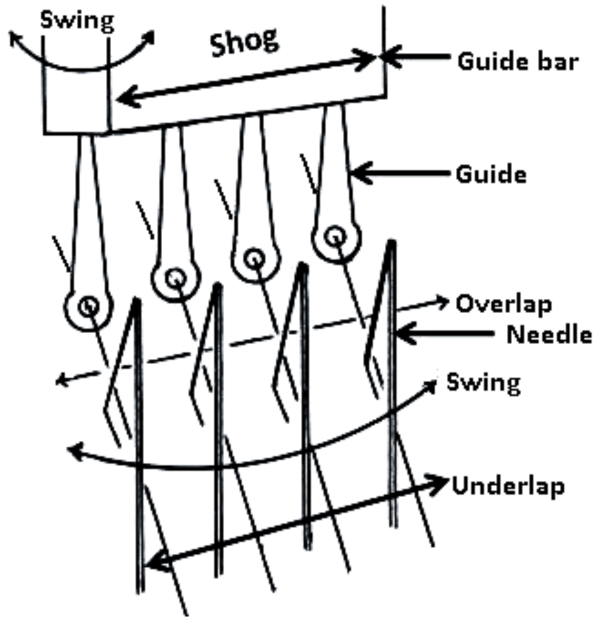


Figure 7.8 Guide bar movement.

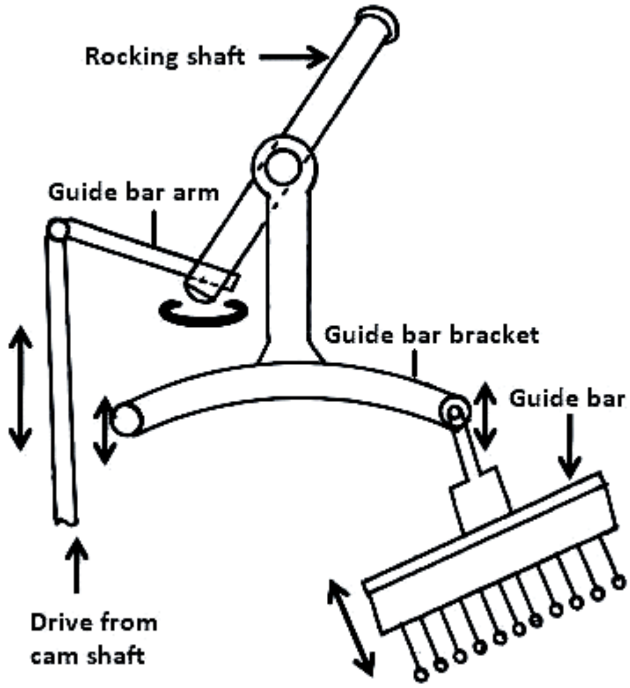


Figure 7.9 Swinging motion of guide bar.

either from the front of the needles to the back or from the back of the needles to the front (Fig. 7.9). It is in arc and it occurs between adjacent needles. This motion is derived from the main cam shaft and is adapted via levers, pivots and linkages. As the one end of the guide bar arm is lifted up and lowered down the other end of the same connected with the rocking shaft causes an angular movement on the rocking shaft. Due to angular rotation of the rocking shaft, the guide bar bracket also moves from the front of the machine to the back and vice versa and ultimately the guide bar derives the desired swinging motion. The two swinging movements produce the two side limbs when combined with the overlap shog.

The shogging movement of the guide bar is the lateral motion of the guides which occur parallel to the needle bar. The shogging movement of guides may be from left to right or from right to left. Moreover, the extent of shog may vary from cycle to cycle or from bar to bar. The shogging of the guide bar may occur either in the front of the needles or at the back of the needles and accordingly produces the overlaps or underlaps. A shogging movement can occur when the guides have swung clear of the needle heads on the back or front of machine. The occurrence, timing, direction and extent of each shog is separately controlled for each guide bar by its pattern chain links or pattern wheel attached to a horizontal pattern shaft driven to each other in order to form overlap and underlap. The swinging motion of the guides takes place either from the front of the needles to the back or from the back of the needles to the front (Fig. 7.8). It is in arc and it occurs between adjacent needles. This motion is derived from the main cam shaft and is adapted via levers, pivots and linkages. As the one end of the guide bar arm is lifted up and lowered down the other end of the same connected with the rocking shaft causes an angular movement on the rocking shaft. Due to angular rotation of the rocking shaft, the guide bar bracket also moves from the front of the machine to the back and vice versa and ultimately the guide bar derives the desired swinging motion. The two swinging movements produce the two side limbs when combined with the overlap shog.

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The combined effect of underlap and overlap is the lapping of yarn around the needle. Depending upon the relative direction of underlap and overlap there are two types of laps – closed lap and open lap. The loops made of closed and open lap are shown in Fig.7.9. A closed lap is produced when an underlap follows in the opposite direction to the overlap and thus laps the thread around both sides of the needle. An open lap is produced either when the underlap is in the same direction as the overlap, or it is omitted so that the next overlap commences from the space, where the previous overlap finished. Closed laps produce heavier, compact and less extensible fabric than open lap produces.

7.8 Lapping Diagram

Lapping diagrams are drawn around horizontal rows of points which represent needles in plan view. One simple type of lapping diagram and its notation are shown in Fig. 7.10 and Fig.7.11 In order to produce various warp knitted structures for in-number end uses, various types of lapping have been invented. The representation of the lapping is shown in Fig.7.12.The lapping movements of the guide bars are composed of one or more of the following lapping variations (Fig. 7.13) at any time during knitting of fabrics.

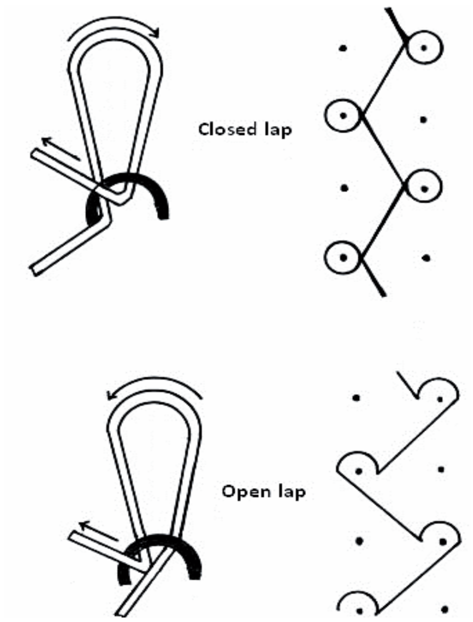


Figure 7.10 Closed and open lapping

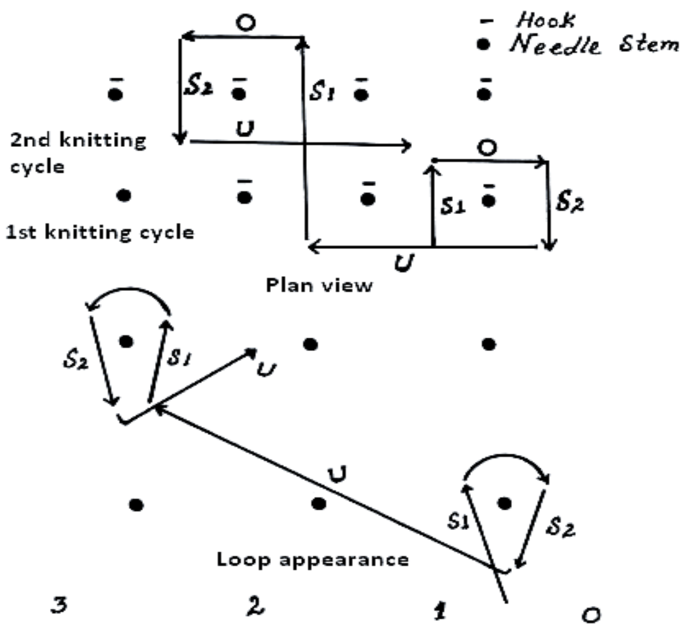


Figure 7.11 Simple type of lapping motion

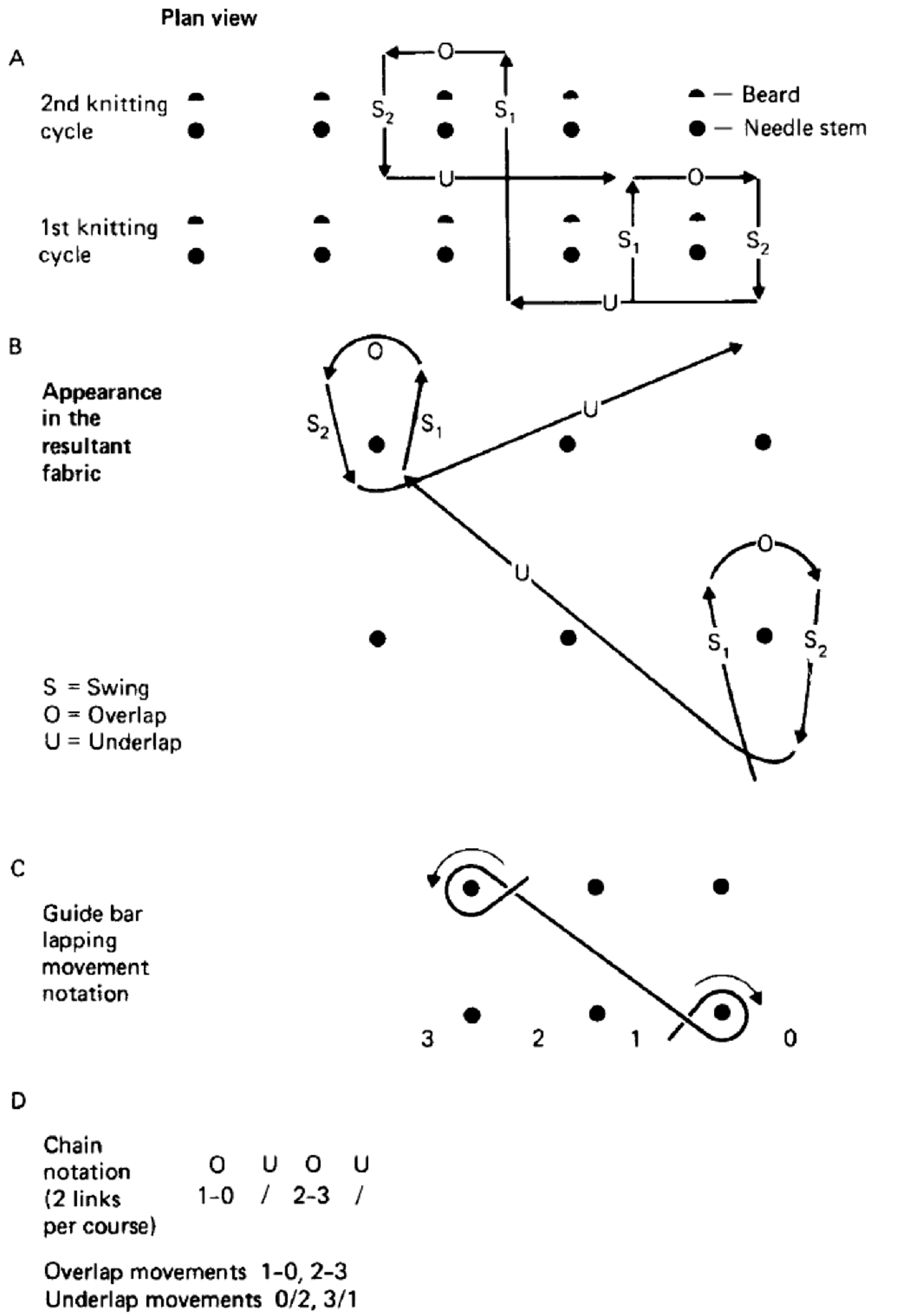


Figure 7.12 Representation of lapping movements

a) An overlap followed by an underlap in the opposite direction (closed lap).

b) An overlap followed by an underlap in the same direction (open lap).

c) Only overlaps and no underlaps (open lap).

d) Only underlaps and no overlaps (laying-in).

e) Neither overlaps nor underlaps (miss-lapping).

In the last two cases, overlapping of another guide bar is required to hold them into the structure.

Overlap movements are normally across only one needle space because two-needle overlaps cause both the warp thread and the needles to be subjected to the severe strain of two simultaneous adjacent knock-over actions. In addition, different tensions on the two loops in the structure adversely affect their appearance. The underlap between the double overlaps has the appearance of a sinker loop. Only in a few raschel fabric structures is the double-needle overlap used and there the needles are less easily deflected than on tricot machines, and there are no knock-over sinkers over which to draw the loops. A single, full-threaded guide bar making a double needle overlap will cause each needle to receive two overlapped threads at that course.

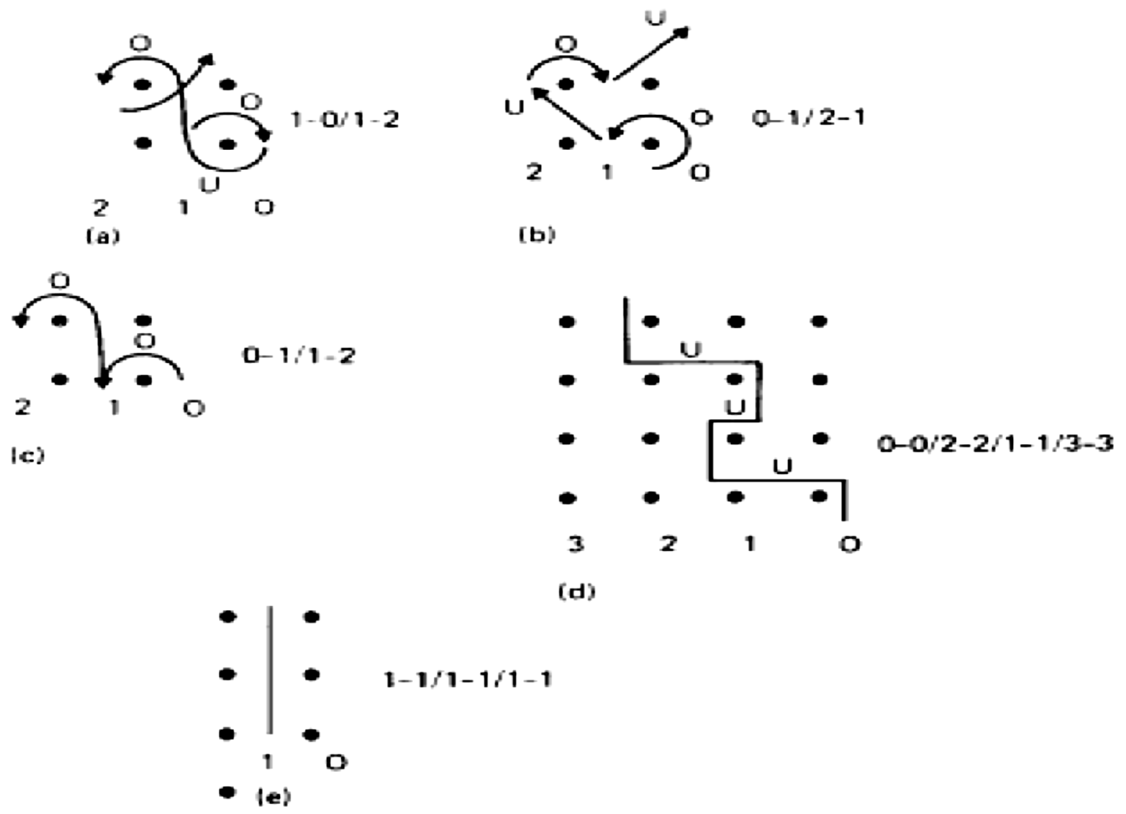


Figure 7.13 Overlap/underlap variations

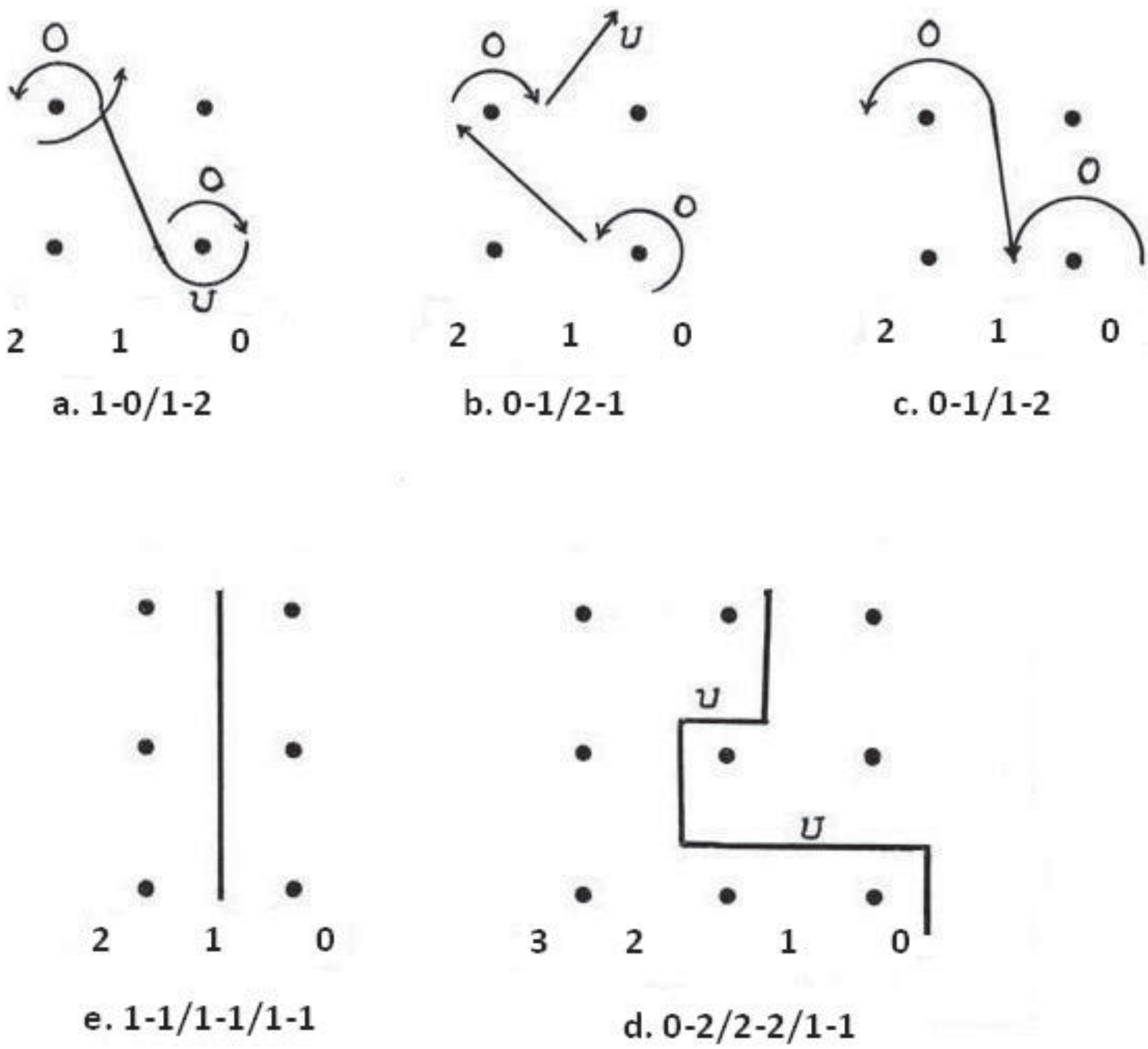


Figure 7.14 Variable lapping motions

7.9 Tricot Machine Knitting Cycle with Bearded Needle

The different stages in loop formation using bearded needle as shown in Fig. 7.15 are as follows. Only one guide bar has been considered for making the diagrams.

(a) The needles are in rest position at 2/3 of their full height from knock over and their beards are facing towards the back of the machine. The presser is withdrawn and the guides are at the front of the machine with the sinkers forward holding the old overlaps in their throats so that they are maintained at the correct height.

(b) After swinging through the needles to the beard side, the guides are overlapped across the beards usually by one needle space in opposite direction.

(c) As the guides swing to the front, the needles rise to their full height so that newly formed overlaps slip off the beards onto the stem above the old overlaps (d)The needle bar descends so that the open beards cover the new overlaps, there is a slight pause whilst the presser advances and closes the beards.

(e) As the sinkers move backward, the upward curve of their bellies places the old overlaps onto the closed beards. The presser is withdrawn.

(f) The needles continue descending movement and the old loop is cast- off. The sinkers now move forwards to hold down the fabric loops and push them away from the ascending needles which are rising to the rest position.

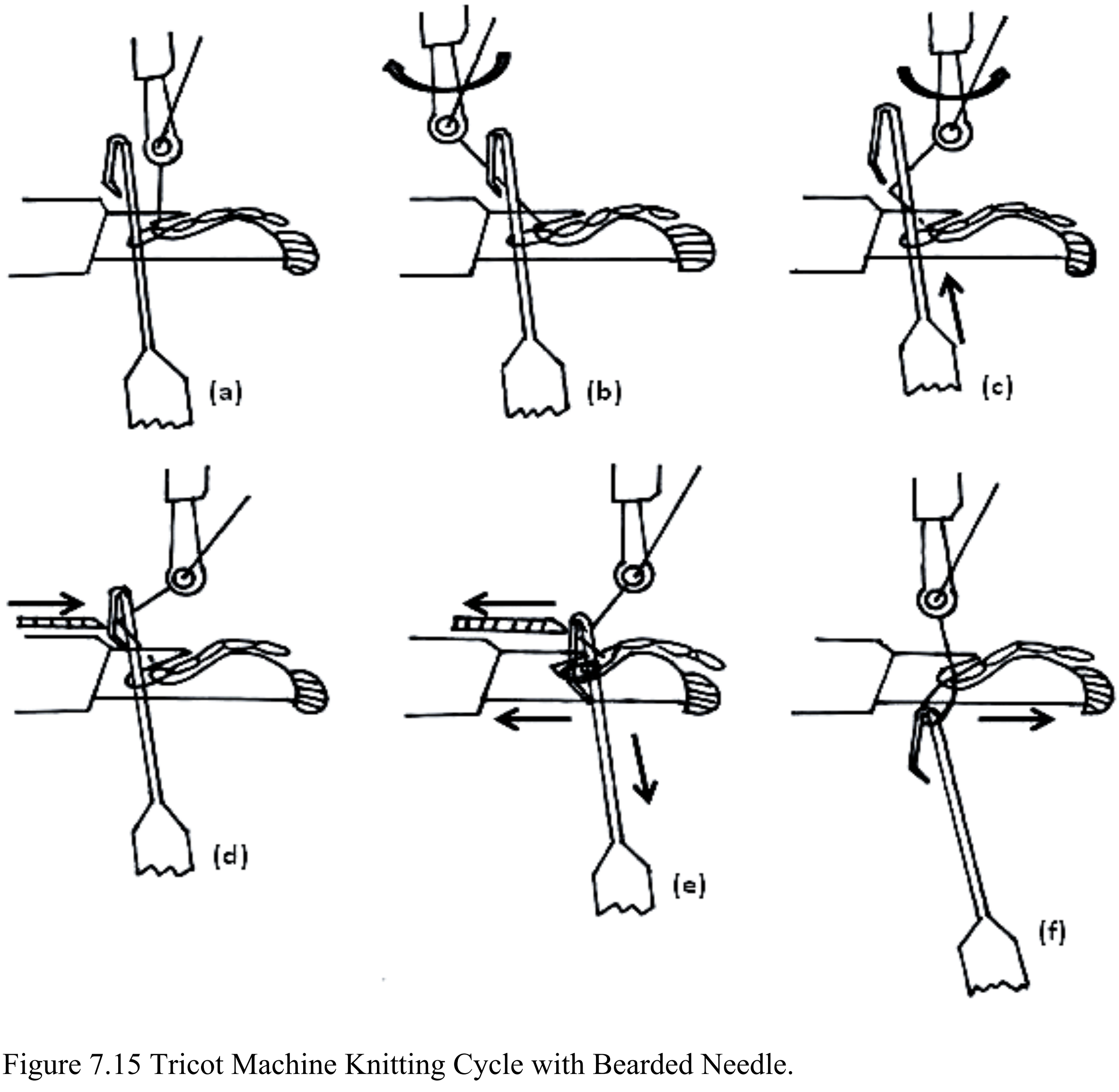


Figure 7.15 Tricot Machine Knitting Cycle with Bearded Needle.

The Direction of Lapping at Successive Courses

When using either open or closed laps there are three possible arrangements of lapping at successive courses, which may be used alone or in combination:

1 The pillar stitch. In the pillar or chain stitch, the same guide always overlaps the same needle. This lapping movement will produce chains of loops in unconnected wales, which must be connected together by the underlaps of a second guide bar.

Generally, pillar stitches are made by front guide bars, either to produce vertical stripe effects or to hold the inlays of other guide bars into the structure.

Open-lap pillar stitches are commonly used in warp knitting. They can be unraveld from the end knitted last.

Closed-lap pillar stitches (Fig.7.16) are employed on crochet machines because the lapping movement is simple to achieve and is necessary when using self-closing carbine needles, which must always be fed with yarn from the same side

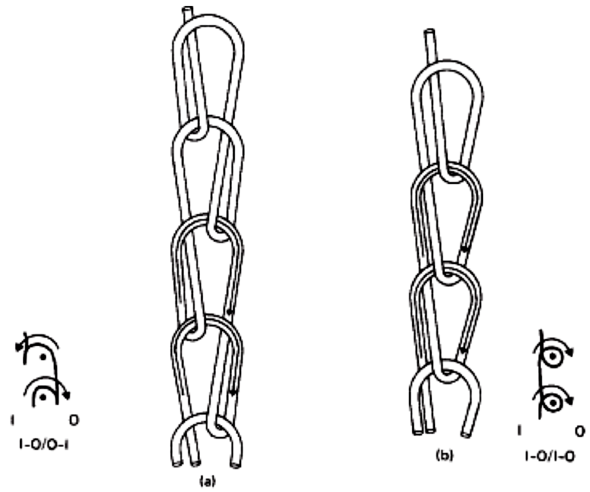


Figure 7.16 Closed-lap pillar stitches

2 Balanced advance and return lapping in two courses: Many tricot structures are based on this type of lapping movement. Its extent may be described by indicating the number of needles underlapped, followed by the number of needles overlapped (usually one). With a fully-threaded guide bar every one needle space increase in the underlap movement will cause an extra warp thread from that bar to cross between each wale.

Tricot lapping or 1 X 1 is the simplest of these movements, producing overlaps in alternate wales at alternate courses with only one thread crossing between adjacent wales. Two threads will cross between wales with a 2 X 1 or cord lap, three threads with a 3 X 1 or satin lap, four threads with a 4 X 1 or velvet lap, and so on.

Each increase in the extent of the underlap tends to make the structure stronger, more opaque and heavier. The increasing float of the underlap has a more horizontal appearance, whilst overlaps produced by the same thread will be separated from each other at successive courses by an extra wale in width.

3 Atlas Lapping (Fig. 7.17). This is a movement where the guide bar laps progressively in the same direction for a minimum of two consecutive courses, normally followed by an identical lapping movement in the opposite direction. Usually, the progressive lapping is in the form of open laps and the change of direction course is in the form of a closed lap, but these roles may be reversed. From the change of direction course, tension tends to cause the heads of the loops to incline in the opposite direction to that of the previous lapping progression. The change of direction course is normally tighter and the return progression courses cause reflected light to produce a faint, transverse shadow, stripe effect.

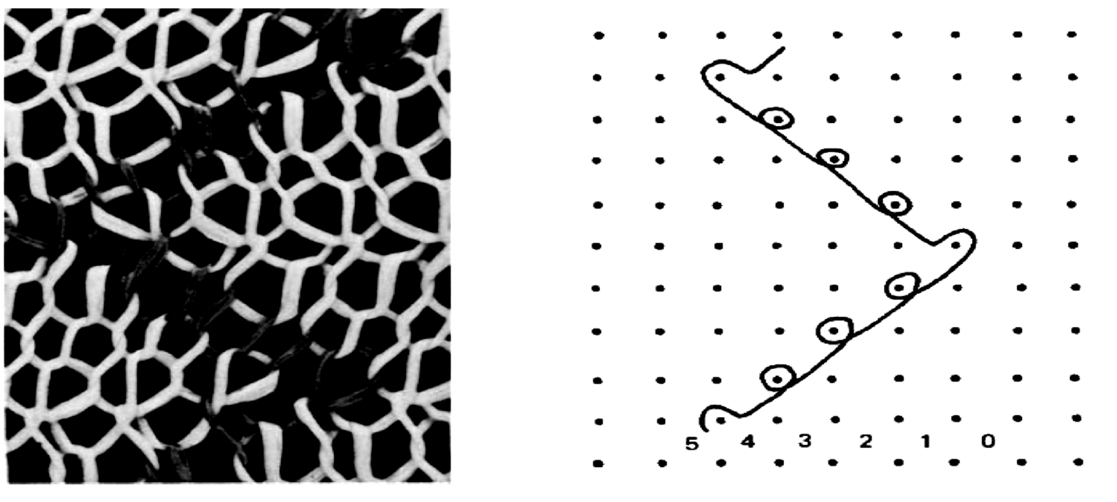


Figure 7.17 Atlas Lapping

The underlaps on the technical back give the appearance of sinker loops in a spirally weft knitted structure. With a single guide bar having different coloured warp threads, zigzag effects can be produced. This is sometimes termed single atlas or Vandyke. More elaborate geometrical patterns can be achieved with patterned warps using atlas lapping on two or more guide bars. Atlas is also the base for many simplex and all Milanese fabrics.

Cohesive single guide bar structures (Fig.7.18) may be knitted using a single, fully-threaded guide bar producing underlaps and overlaps. However, these are seldom commercially viable because of their flimsiness, low strength, lack of stability, poor covering power, distortion caused by loop inclination, and limited patterning potential.

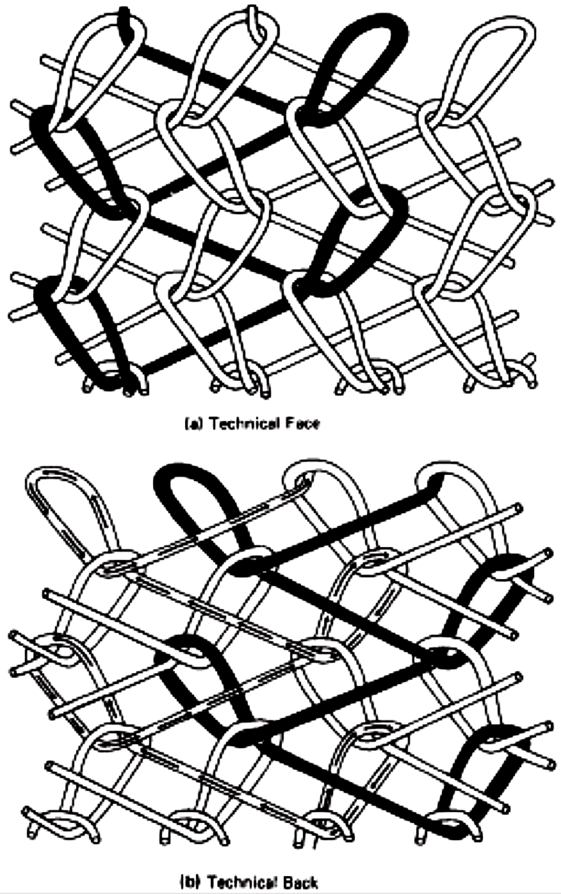


Figure 7.18 Cohesive single guide bar structures

Loop inclination is caused by the underlaps of the guide bar entering and leaving the head of the needle loop from the same side and thus producing an unbalanced tension from that direction (unlike weft knitting where the sinker loops enter and leave from opposite sides of the head of the loop).

A more balanced tension is achieved by having two sets of warp threads underlapping in opposition to each other so that the underlaps of each enter and leave from opposite sides of the head of the loop. For these reasons, the simplest warp knitted structures are usually composed of two sets of warp threads, and most machines have a minimum of two guide bars.

7.10 Raschel Machine Knitting Cycle with Latch Needle

The loop forming cycle of Raschel machine using latch needle and one guide bar is shown in Fig. 7.19. The main stages are as following:

(a) The guide bar is at front of the machine completing its underlap shog.

The sinker bar moves forward to hold the fabric whilst the needle bar starts to rise from knock-over.

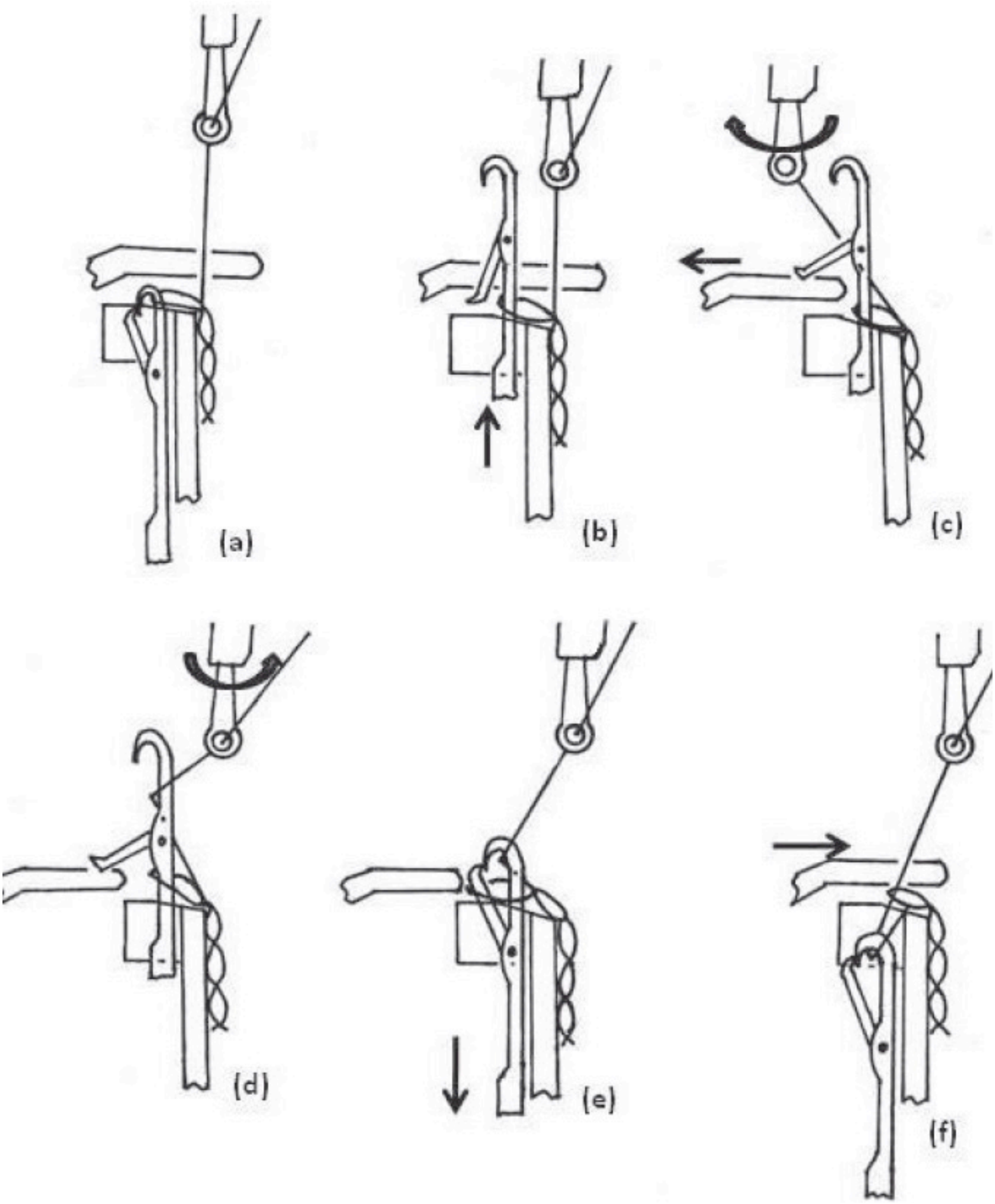


Figure 7.19 Raschel Machine Knitting Cycle with Latch Needle.

(b) The needle bar rises to its full height and the old overlaps slip down onto the stems after opening the latches which are prevented from flicking closed by latch wires.

(c) The guide bars swing to the back of the machine and then shog for the overlap. The sinker bar then starts to withdraw for allowing the guide bar to overlap.

(d) The guide bar swings to the front to wrap the warp threads into the needle hooks.

(e) The needle bar descends; the old overlaps contact and the latches are closed. The sinker bar now starts to move forward.

(f) The needle bar continues to descend and its head passes below the surface of the trick plate drawing the new overlap through the old overlap which is cast-off and as the sinkers advances over the trick plate.

7.11 Fabric Take-down

The take-down mechanism is mainly used to pull down the fabric produced at the knitting zone and then roll the same on the cloth roller. This taking down of the fabric also influences the quality and appearance of the fabric. The take-down is always positive as well as continuous type. So the motion is generated from the main shaft through worm and worm wheel. The rate of take-down can be varied by changing the change wheel in the train of wheels in the mechanism. The cloth take-down roller is specially designed to impart high frictional coefficient for efficiently gripping and pulling the fabric without any damage of the same.

7.12 Warp Let-off:

As the fabric is taken-down by the take-down roller from the knitting zone, required amount of warp is to be released from the warp beams. The rate of delivery of warp from the warp beams depends not only on the rate of fabric take-up but also on the extent of traverse of the individual guide bars. It is obvious that unequal length of yarn is consumed in loop construction, if the traverse of a guide bar is more or less than the other bar(s). Therefore, the rate of feeding of the two warps should be accurately controlled so that the correct ratio is maintained during knitting. In addition the let-off motion should maintain desired tension on warp. Both negative and positive type let-off motions are found in warp knitting machines for feeding of warp to the knitting zone. In old negative type let-off motions, the warp beam is held under a frictional force and the warp is pulled by the take-down mechanism by overcoming the applied frictional force. The warp tension is adjusted by varying the braking system or weights used in the motion for generating the frictional force. The negative motions are simple but do not guarantee uniform tension throughout knitting. Positive let-off motions are superior in this respect. The let-off of warp in any positive let-off motion is controlled by regulating gears consisting of infinitely variable cone drive (PIV drive) and the motion is capable of (a) adjusting let-off according to different fabric construction and (b) increasing the beam revolution per minute with decrease in beam diameter. Most of the modern warp knitting machines are provided with positive let-off motion. The latest trend in the warp let-off is the application of micro-processor controlled warp feeding device. Whether mechanical or micro-processor controlled, the basic aims are to supply the warp at constant rate as well as to maintain uniform warp tension through knitting. If necessary, warp tension should be measured and adjusted accordingly.

7.13 Patterning Mechanisms

As discussed earlier, the guides have two types of motions– shogging and swinging. Such motions not only produce lap of the yarns around the needles but also shift the yarns from one needle to other. The ultimate pattern or structure of the fabric depends on the nature (direction, relative position and extent) of movements of the guides. So, control of nature of movements of the guides is very much important. The following pattern controlling mechanisms are generally used in warp knitting machines for imparting the necessary motions to the guides.

(a) Pattern wheel

(b) Pattern chain Links

(c) Electronic jacquard

7.13.1 Pattern Wheel

A pattern wheel (Fig. 7.20) is a steel disc (drum) which has different slopes on its circumference. These slopes stroke a shogging roller or bowl as the pattern wheel revolves and the shogging motion is transmitted to the guide bar through a push rod. The pattern wheel is just like a cam with curves or slopes made on its circumference according to the pattern. These curves which are required for the overlapping and underlapping of the needle bar are smoothly shaped and have a well formed transition to and from each other. This ensures quiet and smooth running and makes the pattern wheel suitable for high speed machine. The heights of the slopes decide the extent of lateral displacement of the guide bars.

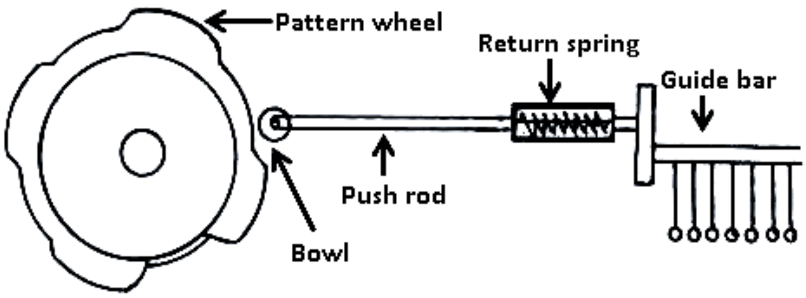


Figure 7.20 Pattern wheel mechanism

In real situation the circumference of the pattern disc is generally divided into 48 equal parts. If 3 movements are needed for 1 course (3 phase) i.e., 1st phase or graduation is overlapping, 2nd phase or graduation is first part of underlapping and 3rd phase or graduation is the second part of underlapping, then, 16 (48 / 3) courses are produced with one revolution of the pattern disc. If two graduations per course (2 phase) are employed then 24 (48 / 2) courses can be accommodated round the circumference of the disc. Therefore pattern wheel can only be used if the number of curves on the pattern disc is divisible by the number of movements or phases required for a course.

Pattern wheel provides accuracy and smooth running even at high speed.

But, pattern wheel is economical for producing longer fabrics of simple structure. A pattern wheel has restricted utility because pattern cannot be changed to produce some other structure and it is not interchangeable between machines of different kinds.

7.13.2 Pattern Chain

In this case a pattern chain is constructed by connecting a large number of individual pattern links and placed over a pattern drum. The shogging roller moves in contact with this chain and transfers required motion to the guide bar. Each pattern link is equivalent to a curve in the pattern wheel. These pattern links are made from hardened steel and have different shapes (four types – A, B, C and D as shown in Fig. 7.21) depending upon the type of lap to be carried out. The links have also different heights representing the amount of guide bar movement in terms of needle spaces, being numbered 0,1,2,3,4 and upwards. The chain is prepared by laying the required number of links side by side on a flat surface in such a way so that the projected right side of the links enter the circumferential grooves of the others and then are joined by inserting on the holes provided for the purpose. The chain should be correctly placed on the machine so that overlap takes place on the hook/beard side of the needle. For smoother movement of the guide bar, the links need precision grinding at the points where they connect. As the number and the shape of the pattern links in a pattern chain can be changed, the pattern range is greater and the technique is more versatile. But it needs higher inventory of pattern links. The chain links vary in thickness by multiples of machine gauge, i.e., on 32 gauge machine by multiples of 1/32 inches. Each link is generally stamped with the gauge and with a number, e.g. 0, 1, 2, 3, 4 etc. The lowest value link (size 0) will place the guide bar in lowest position, i.e. nearest to the pattern drum. Links of size 1 are 1/32 inch thicker than the links of size 0, and will position the guide bar 1/32 inch, i.e. one needle space, higher. Progressively, as the link number increases, guide bar will be positioned further away from the pattern drum. Thus a link of height 4 will cause the guide bar to take up a position of 4/ 32 inch (four needle spaces) further away from the drum than a link of height 0. For smoother running condition, grinding is done on the trailing and leading edges of certain links. The four conditions encountered in practice are shown at A, B, C and D in Fig. 7.21 (a).

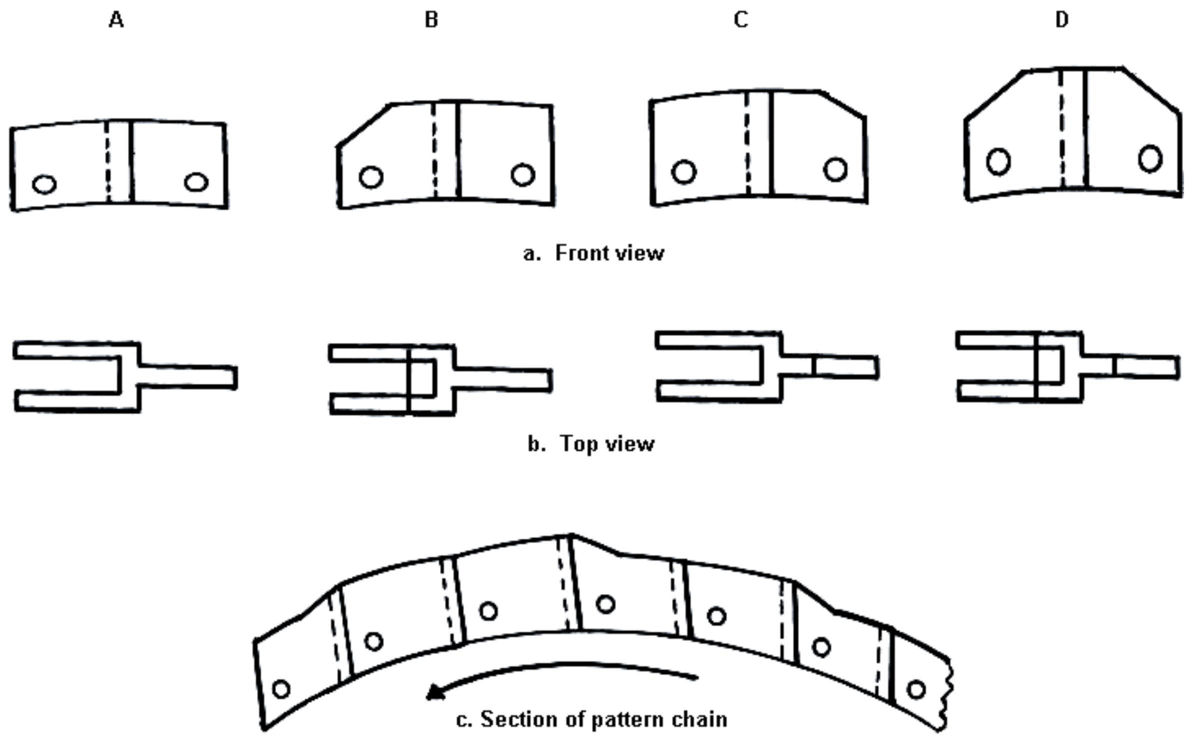


Figure 7.21 Pattern Chain mechanism

Link A is unground.

Link B is ground at the front.

Link C is ground at the back.

Link D is ground at both front and back.

A section of pattern chain constructed by joining six links is shown in Fig. 7.21. (c). This example is for just demonstration only and does not follow the specific order for any typical structure. Links of four different thicknesses – 0, 1, 2 and 3 are joined to make the chain.

7.13.3 Electronic Jacquard

Electronic jacquards are nowadays also used in warp knitting machines. Karl Mayer has come out with 'Jacquadronic' series of machines. With the advent of electronics, a new generation of electronically controlled multibar Raschel machines has achieved position in jacquard lace manufacturing. The main parts in the system are –

Pattern computer – The pattern details are fed from a diskette into the memory cards of the storage system. High storage capacity and easy access to stored data whenever required are the advantages of this system.

Binary mechanism – A selector mechanism has six crank units and it co-ordinates these units with each pattern bar. The crank drives operate on the binary system and carry out following needle jumps.

1st crank unit = 1 needle, 2nd crank unit = 2 needles

3rd crank unit = 4 needles, 4th crank unit = 8 needles

5th crank unit = 16 needles and 6th crank unit = 16 needles. This can give a maximum displacement path of 47 needles.

Electronically controlled jacquard – The pattern details are transmitted from the storage and control unit to the electronically controlled jacquard device via a mobile loading unit. An electromagnet is assigned to each jacquard guide needle. The transmission of the displacement path from the selector units to the patterning guide bars takes place via rocker cam units.

Mobile loading device – The data display unit and diskette mechanism (loading device) transmits the pattern information from the cassette into the pattern computer and also serves as a communication system between the pattern computer and him operating personnel.

7.14 Warp-Knitted Stitches and Structures

It is experienced by many knitters that production of warp knitted fabric may be possible by using only one guide bar with necessary underlaps and overlaps. However, these fabrics are not commercially viable on account low strength, lack of stability, less cover, distortion of the loops etc. Moreover the fabric is like a film and the production technology does not provide patterning facility. A reasonably stable warp knitted structure with desired properties can be produced with minimum two guide bars. So, most of the warp knitted structures are produced in machine provided with minimum two guide bars. Addition of guide bars improves the stability and other desired properties as well as the patterning facility. But presence of too many guide bars makes the machine complicated and costly. So, selection of number of guide bars in the machine is very important for producing warp knitted structures.

Basic Commercial Warp Knit Fabrics

Among all of the machines, Tricot machines are the most popular in production. Within the Tricot fabric, the king of all stitch construction is Jersey stitch construction.

The Jersey stitch can be knitted from spun yarn, textured yarn, filament yarn, and spandex yarns. The spun fabric yarn fabrics are not commercially feasible, as they cannot be knitted at high speed. Commercial fabrics are made from filament yarn and spandex yarns only. Within that, filament yarn is the most used, as it is utilized in women's undergarments. If there is one stitch that dominates the warp knit industry, it is the Jersey stitch. This two-bar warp knit structure is known by many names. It is called Jersey in the USA, Locknit in the United Kingdom and Chaemeuse in Europe. In common usage, Jersey means a knitted fabric. Jersey fabric is a warp knit which is knitted on any single needle bed warp knitting machine (Tricot or Raschel). This fabric is knitted with two fully-threaded guide bars, where the front bar is knitting a three needle float (Silk Float) using closed stitches (2-3, 1-0 or 1-0, 2-3) and the back bar is knitting a two needle float (Cotton Float) also using closed stitches (1-0, 1-2 or 1-2, 1-0). Both the bars, while knitting, are shogging independently in opposite directions. Long float (LF) Jersey or satin, a modified Jersey fabric, is the same as conventional Jersey except that the front bar shoggs four needles instead of three. In the super float Jersey, the front bar shoggs five needles and in the short float Jersey it shoggs two needles. It is very important to remember that in a Jersey stitch construction, the back bar yarn is always sandwiched into the front bar yarn and when one touches the hand of the fabric on both sides, one feels only the front bar yarn. If the front bar contains white yarn and the back bar contains black yarn, the Jersey fabric will look almost white; a little of the back bar yarn can be seen between the wales and the fabric will look slightly coloured.

Jersey fabric is knitted at about 1 000 stitches per minute (spm) on older machines and at about 2 000 spm on newer, compound needle Tricot machines. Faster machines are being developed. Good filament yarns are knitted on 168-inch wide machines, knitting at about 1,000 to 2,000 racks per end out, which is considered an excellent knitting performance.

There are three types of finishing sequence that are used in finishing Jersey and modified Jersey fabrics. They are:

1. Heat-set, scour and dye. This sequence is preferred when nylon is used by heat-setting first and the final yield of a fabric is obtained. However, the disadvantage of this sequence is that it fixes the stains and dirt that are picked up during knitting.

2. Scour, heat-set and dye. This sequence is preferred for polyester. It eliminates the impurities in the fabric, offers greater bulk and contains a bleaching step that removes yellowing caused during heat-setting, but this finishing sequence is expensive as it requires pin stentering twice.

3. Scour, heat-set and dye. This sequence is preferred for polyester. This finishing sequence is the most economical as it combines scouring and dyeing. However, there are two problems associated with it. One is that it sometimes imparts rope marks, a defect in a fabric. The other is that heat yellowing affects the final colour of the fabric. Plain Jersey is the most important structure.

7.15 Types of Stitches and Structures

The popular warp knitted structures are mainly produced with two full guide bars. The structures are based on two-course repeat cycle and direction of lapping changes in every course. The two guide bars should invariably make different lapping movement otherwise the resultant structure would be equivalent to the structure produced with single guide bar. The proportion of yarns in the fabric is influenced by the extent of underlap and overlap of the guide bars. The presence of yarns in the face or back side of the fabric depends on the controlling guide bar. Under normal conditions the threads of the front guide bar dominate on both face and back sides of the fabric. Considering two guide bars (front guide bar and back guide bar), the nature of guide bar lapping movement is shown in Fig. 7.22 for producing some of the popular warp knitted structures. The resultant appearances of those structures have been shown later.

7.17 A few Popular Warp Knit Structures

Please refer figure 7.23 for the interlooping structures.

Locknit:

Most popular of all warp knitted structures, accounts for 70 to 80%.

Longer overlaps of the front bar (shogs 2 needle spaces) on the back improve the extensibility, drapeability and soft handle.

Preferred machine gauge is 28 and a wale per inch in fabric is about 37.

Mainly nylon filament is used, sometimes spandex is used at the back.

GSM depends on filament denier. A few popular GSM are 30, 32 and 152 made from filament denier of 20, 40 and 70 respectively.

High elasticity makes it suitable for intimate wears. Fabric has a tendency to curl near the selvedge, which can be overcome by heat setting as, yarns are thermoplastic.

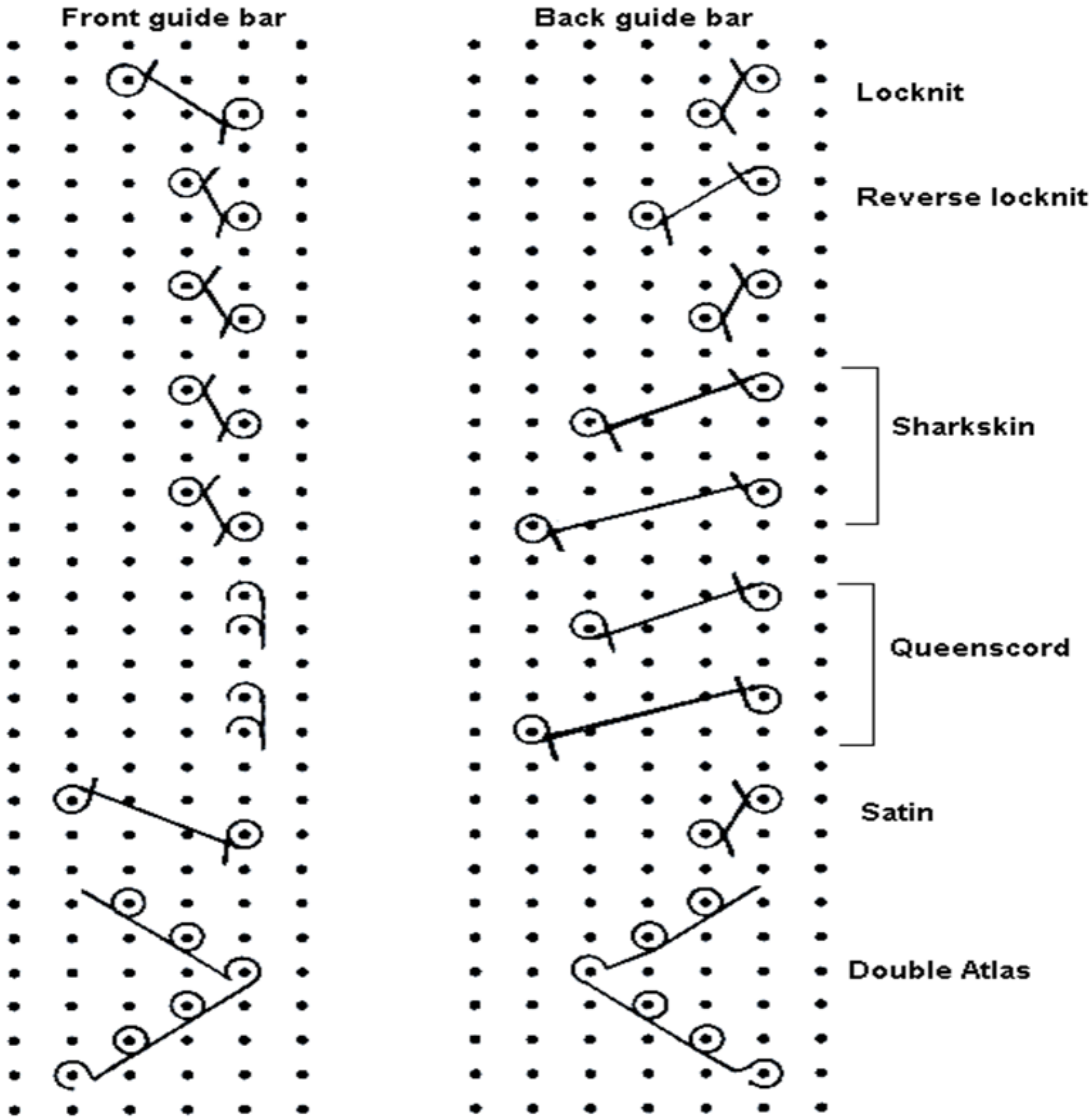


Figure 7.22 Guide bar lapping movement for popular two guide bar warp knitted structures.

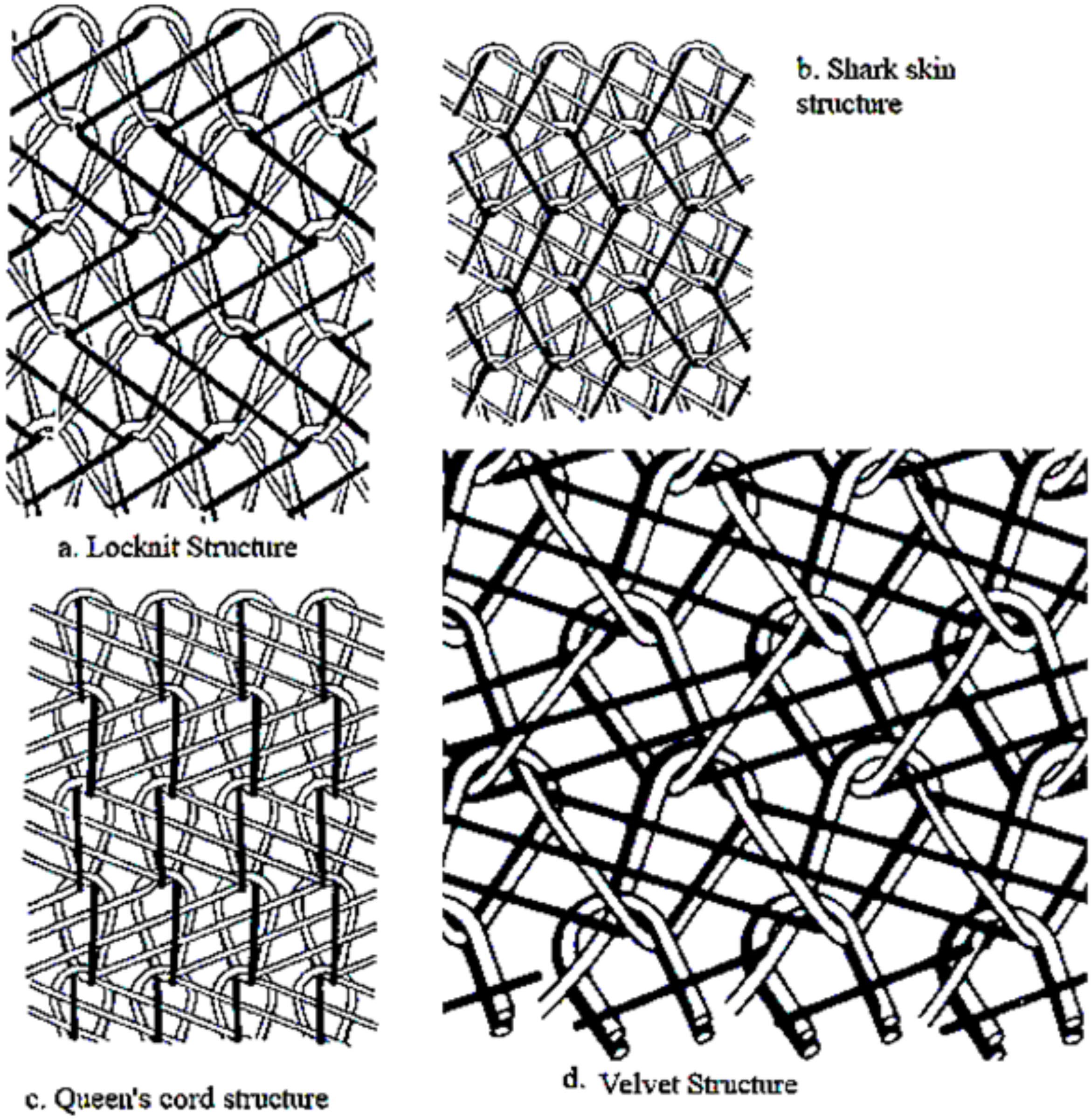


Figure 7.23 Popular warp knit structures

Sharkskin:

Back guide bar underlap up to 3 needle space.

Rigid and heavier fabric.

Suitable for print base fabric.

Queenscord:

More rigid than sharkskin fabric.

Front bar produces shortest possible underlap.

Pillar stitch structure.

Shrinkage is up to 6% only.

Some cord effect along the wales.

Velour or Velvet:

The long overlap (6 to 8 needle space) of the front guide bar forms pile on the technical back of the fabric.

Piles may be brushed i.e., cut or cropped by knife to produce velvet like appearance during finishing.

Satin stitch

40 to 60 denier nylon in the body or ground structure and 55 to 100 denier viscose/acetate in piles.

Popular GSM is 150 for using in apparels.

Shrinkage is about 35 to 50%

Heavier variety made with 90 denier nylon is used in furnishing.

Figure 7.24 Double Atlas structure

Double atlas: (Please refer Fig.7.24).

Two guide bars atlas lap in opposition with identically balanced lapping movement

Balanced symmetrical design including checks, diamonds, circles etc.

Intense and paler colour effect on the surface from threads of different colour

Attractive handle, drape-ability and elastic recovery

7.18 Milanese Fabrics and Machines

Milanese fabrics are generally acclaimed as the superior warp knitted product, but due to their peculiar construction they cannot be made on ordinary warp knitting machines. The term 'Milanese' was originated from Milan, the city in Italy, the centre of production of warp knitted silk fabric. Originally, it was a fine gauge warp knitted silk fabric characterized by superb hand and smooth texture. The appearance of Milanese fabric gives resemblance to the plain weft-knit structure. The machines employed in the production of Milanese fabrics are specially constructed for this purpose. A Milanese fabric is equivalent to a two bar fabric made on a bearded needle machine in that it is effectively constructed from two sets of warp threads, but the lapping movements for Milanese fabrics are arranged so that each warp thread traverses across the full width of the fabric from one selvedge of the fabric to the other, and not over a limited number of needles as on other types of machines. The warp threads are divided in to two sets (the equivalent of the front and back warps on a bearded needle machine), and one set of threads is traversed across the fabric from left to right while the other set traverses at the same speed in the opposite direction (Fig. 7.25).

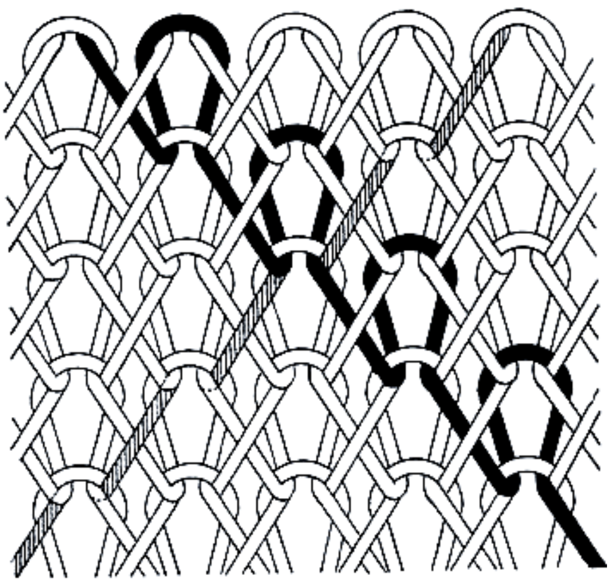


Figure 7.25 Milanese fabric (cotton lap).

At each side of a straight bar Milanese machine the threads are transferred from one set to the other to preserve the alignment of the threads with the needle bar. Thus any single warp thread will traverse across the full width from left to right in the equivalent of the front guide bar, and on reaching the selvedge, it will be transferred to the equivalent of the back guide bar, hence it will be traversed across the whole fabric again, this time moving from right to left. On reaching the left hand selvedge the warp thread will be transferred back again to the original series of warp threads and the operation will be repeated. The machine is therefore provided with two sets of warp threads which are moving continuously in opposite directions across the needles, and, with the usual-set threading, each needle will receive two warp threads at each course. As the warp threads traverse across the whole width of the fabric, warp cannot be supplied from a stationary beam. Moveable sectional beams or flanged bobbins are used in the warp creel for supplying the warp. Fine bearded needles are used for straight bar Milanese machine and latch needles can be used in circular Milanese machine.

There are basically two different types of Milanese fabrics and they differ from each other in the manner in which the threads are traversed across the fabric. When the cotton lap is used the warp threads of both sets traverse across the machine by passing from one needle to the next, as each successive course is knitted. The lapping movement for the silk lap, however, is such that each warp thread makes overlaps on alternate needles only, and thus moves two needle spaces at each course, passing under one needle and over the next. Another peculiarity of these overlaps is that they form open laps. The cotton lap is used when knitting spun yarns, while the silk lap is used for continuous filament yarns. The following two types of machines have been designed for knitting Milanese fabrics.

i) Continental Milanese Machine

ii) English Milanese Machine

7.19 Warp Knitted Nets

Different types of nets are the most interesting products of warp knitting, particularly using Raschel machine. Different techniques such as inlay, weft insertion, fall plate and tulle are used for producing nets with attractive designs and mesh openings. The selection of technique fully depends on the end application of the nets and the design and mesh size are produced accordingly. The inlay technique is mainly utilized for producing marquisette curtain net and the tulle net is used as a ground structure for general curtain fabrics. The traditional nets used for foundation wear are the power nets. Power net is a four bar structure where both ordinary and elastomeric yarns are used. The elastomeric yarns become straight and lie vertically in the fabric when knitted under high tension and forces the loops of other yarns to distort. Production of net is basically creation of surface interest on the fabric.

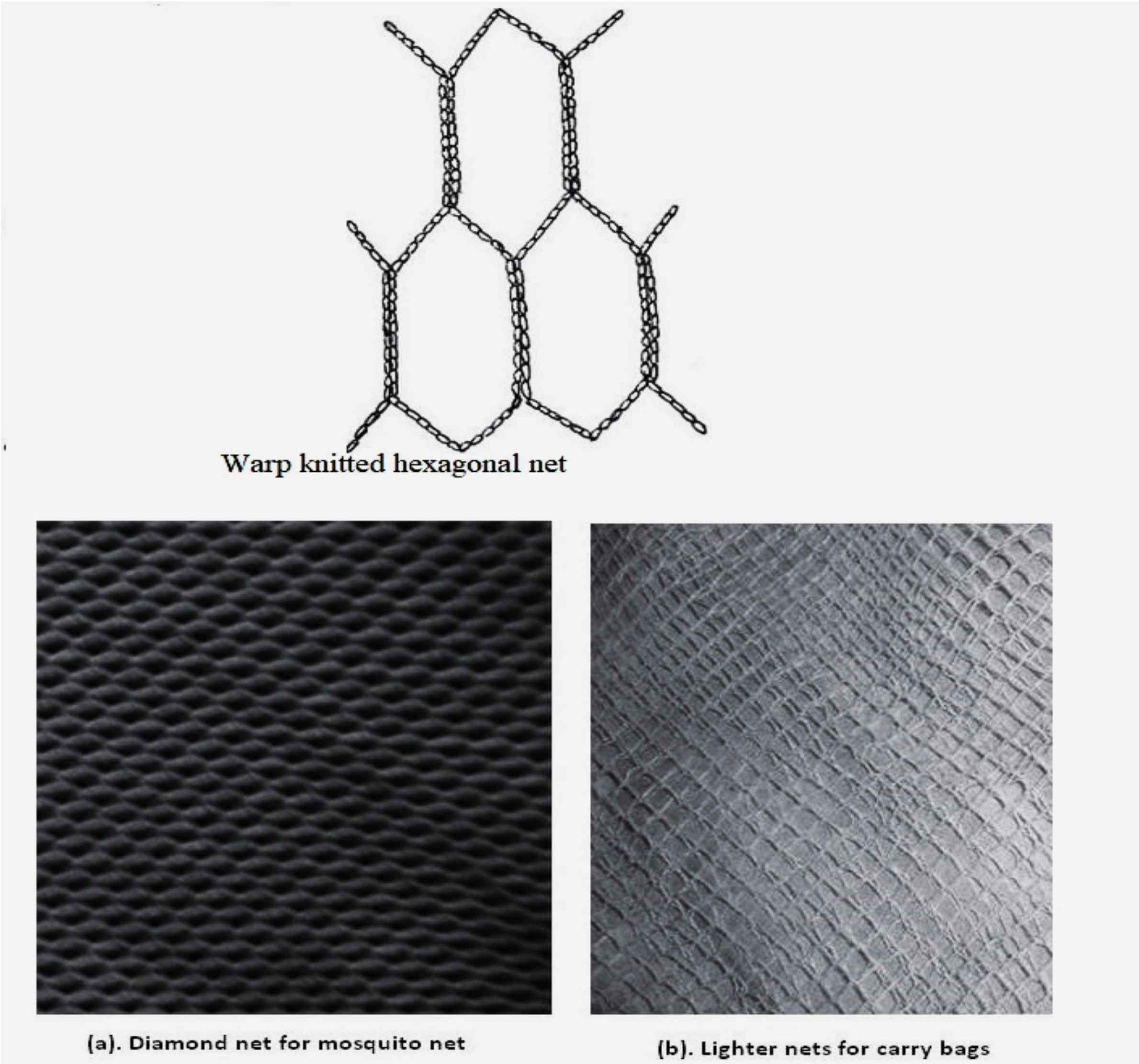


Figure 7.26 Warp Knitted Nets

This surface interest can be produced either by variation in threading in one or more guide bar(s) or by variation in extent of under lapping. Net formation in warp knitting is much easier than weft knitting. No special requirement is must for the purpose in the machine, but two bar frames are sufficient. Generation of suitable lapping movement in conjunction with two partially threaded guide bars are the minimum requirement for knitting nets. The manipulation of the above mentioned parameters may result mesh or opening size to be very fine to coarse and at the same time mesh of different shapes like diamond, hexagonal or nearly circular. The line diagram of hexagonal warp knitted net structure is shown in Fig.7.26. The net fabrics are mainly used for decorative purposes in one hand and for packing fruits and vegetables on the other. The manufacturing of green bags (carry bags) may be the newer field of application of warp knitted net fabrics. The GSM of such fabric may even be as low as 20 (Fig. 7.26). The weight of a carry bag of 45 cm × 45 cm made of the fabric shown in Fig. 7.26 b is only 8 g.

7.20 Common Products of Warp Knitting Machines

A very wide range of products can be produced in warp knitting machines. However, only a limited number of items produced in different types of warp knitting machines are shown in Table 7.2.

Table 7.2 Product Range of Warp Knitting Machines

		Type of machine / Product range
Tricot	Single Needle Bar	Lingerie, shirts, ladies' and gents' outerwear, leisurewear, sportswear, swimwear, car seat covers, upholstery, bed linen, towelling, lining, nets, foot wear fabrics, technical fabrics, medical textiles.
	Double Needle Bar	Double faced or simplex fabrics, dress wear fabrics, technical textiles
Raschel	Single Needle Bar	Curtains, curtain laces, foundation garments, nets, fishing nets, sports nets, power nets, table cloths, bed covers, elastic bandages, cleaning cloths, upholstery, ladies' underwear, velvets, fruit and vegetable bags, carry bags, geo-textiles, medical textiles
	Double Needle Bar	Pile & plush fabrics, carpets, tubular fabrics and sacks, seamless shaped stockings and garments, nightwear and knitwear, string vest, scarf, medical textiles, artificial turf etc.

7.21 Laying-in

During knitting of certain structures, for technological, design or commercial reasons, yarns of some guide bars are not knitted into fabric. Instead, the warp yarns passing through those guide bars are only inserted into the fabric which is known as laid-in. To inlay yarn into the fabric only a special lapping movement is required, no special equipment is needed. The basic principles of laying-in technique are as follows.

1. Laying-in can be produced by a back bar. When two or more bars are used, all the bars excepting the front one can inlay their yarns into the fabric. Usually the front bar produces the ground structure.
2. A laying-in guide bar may be partly or fully threaded, as required.

Fully threaded guide bars increase the fabric stability by laying-in whereas the partly threaded guide bars are used to pattern the fabric.

3. The inlaid yarn shogs only on the back side of the needles, thus an underlap is produced but the yarn does not enter the hook of the needles.

Laying-in technique is advantageous in technical, design and commercial aspects. From the technical point of view, it allows yarns which otherwise cannot be knitted to be used. Since the inlay yarns have no loops, they contribute less to the weight of the fabric than normally knitted yarn and hence the commercial benefits are even greater when considering that patterning yarns are more expensive and a large quantity is saved by this technique.

7.22 Co-We-Nit

The term "Co-We-Nit" was introduced initially to describe the technique of knitting woven-like structures. So the Co-We-Nit fabrics can be considered a modification between woven and knitted structures and are found suitable for ladies' and gents' outerwear, upholstery, furnishing fabrics and industrial cloths. The term is applied to the fabric as well as to the machine which produces it. The technique is of warp knitting in which another set of yarn (warp) is laid in front and back of the regular warp threads to simulate a typical woven structure. The laying in is done generally by "fall-plate" technique. The pillar stitches of the Co-We-Nit fabrics are held together by a second series of threads which are laid-in by fall-plate technique.

7.23 Full Width Weft Insertion

Weft insertion during warp knitting is carried out to achieve both aesthetic and technical advantages. It is mainly done to produce dimensional stable fabric for technical uses. In a similar technique to laying-in, the yarns introduced into the fabric do not enter the hooks of the needles and do not form loops. It is therefore possible to insert different yarn types which are otherwise not suitable for knitted fabric production. Figure 7.27 shows the locked-in position of the weft yarns inside the warp knitted structure. The inlaid weft yarns run horizontally from selvedge to selvedge as weft in woven fabric, as a result the width wise shrinkage and other properties of the warp knitted fabric are similar to those of woven fabric.

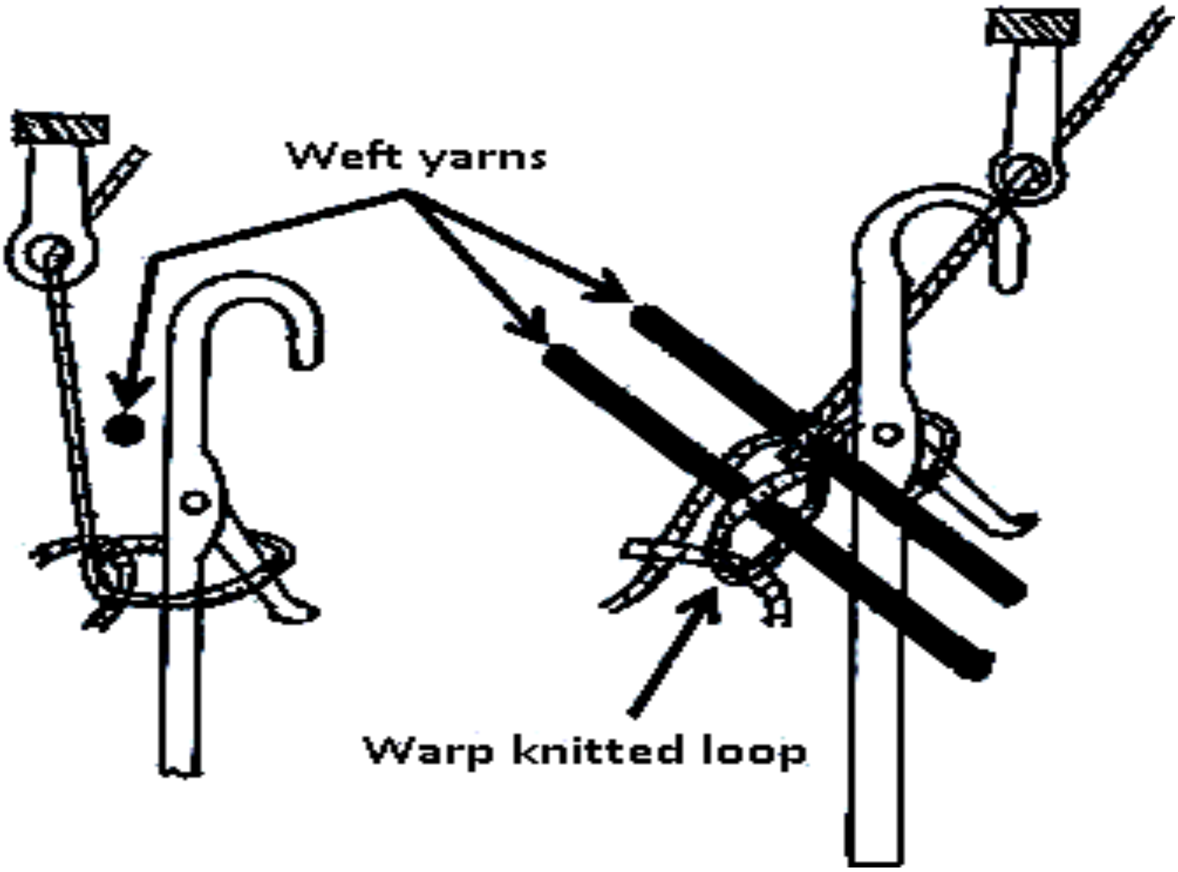


Figure 7.27 Full width weft insertion

The main objects of weft insertion may be summed up as follows:

(i) To stabilize the fabric in width direction

(ii) To improve fabric cover

(iii) To introduce fancy yarns and yarns of multiple colours in width direction

(iv) To introduce materials or lower quality yarns which could not normally be used in warp knitting

(v) To introduce functional property in the fabric required for special end uses, weft insertion during knitting requires a special attachment/device termed as weft inserting element, to be fitted in the knitting machine along with other knitting elements. In addition to the weft inserting element, the other requirement is the supply of weft yarn from a creel positioned at the back. Now-a-days both Tricot and Raschel machines are available with weft insertion facility.

In the old machines, the mechanisms consisted of a single thread, being stretched across the back of the machine by a traversing eyelet. This mechanism was later replaced by the magazine weft insertion mechanism. A stationary creel with 18 to 24 yarn cones and an equal number of reserve ones is used to feed the magazine. The storage yarn feeding units may be attached to maintain a constant low tension of the yarns being inserted. Using a magazine of 24 yarns which are being stretched simultaneously across the machine, weft insertion speed is up to 4000 metres/min which allows very high knitting speed. Since a magazine is used, the speed of each yarn pulled from the cone is much lower, about 200 metres/min, experienced in shuttle weaving. The weft inserting elements bar is driven by a special eccentric or cam arrangement. This bar must move backward and upward to collect the next weft yarn and then forward and downward to place it on the back of the needles.

Although the weft insertion technique was developed by Karl Mayer in 1960's for knitting fabrics with dimensional stability and some other special properties required in apparels, now such technique has been found more suitable in the production of technical textiles.

7.23 Multi-axial Knitting

For some specific end uses including composite reinforcement, there is a need of fabric which withstands forces (shearing, bursting, tensile etc.) in all direction. Traditionally manufactured woven or knitted fabrics and even the full width weft inserted warp knitted fabric do not fulfil the requirement. In fact there is need of producing multi-axial fabrics. The technique of producing tri-axial woven fabric developed for the purpose is not yet commercialized. But commercial warp knitting is available for producing multi-axial warp knitted fabrics in which four yarn sets are inserted in different direction during knitting. Apart from normal warp (S3) and weft (S4) directions (mentioned earlier), two diagonal yarn sets (S1 and S2) are placed at the required angles. The structure of such fabric is schematically shown in Fig. 7.28

As observed, the four sets of straight and parallel yarns are bound together by the knitting yarn performing a 1and1 lapping movement. Figure 7.26 shows the travelling of straight yarns inside the knitting zone. A special warp knitting machine (RS 2 RD) has been manufactured by M/s. Karl Mayer to knit such multi-axial structures. The four sets of yarns are connected to produce the multi-axial structure as stated below:

(a) A fully threaded ground guide bar knits a 1and1 lapping movement which binds all other sets of yarns together.

(b) A fully threaded guide bar is used to insert straight warp yarns in to the structure by the principle of inlaying.

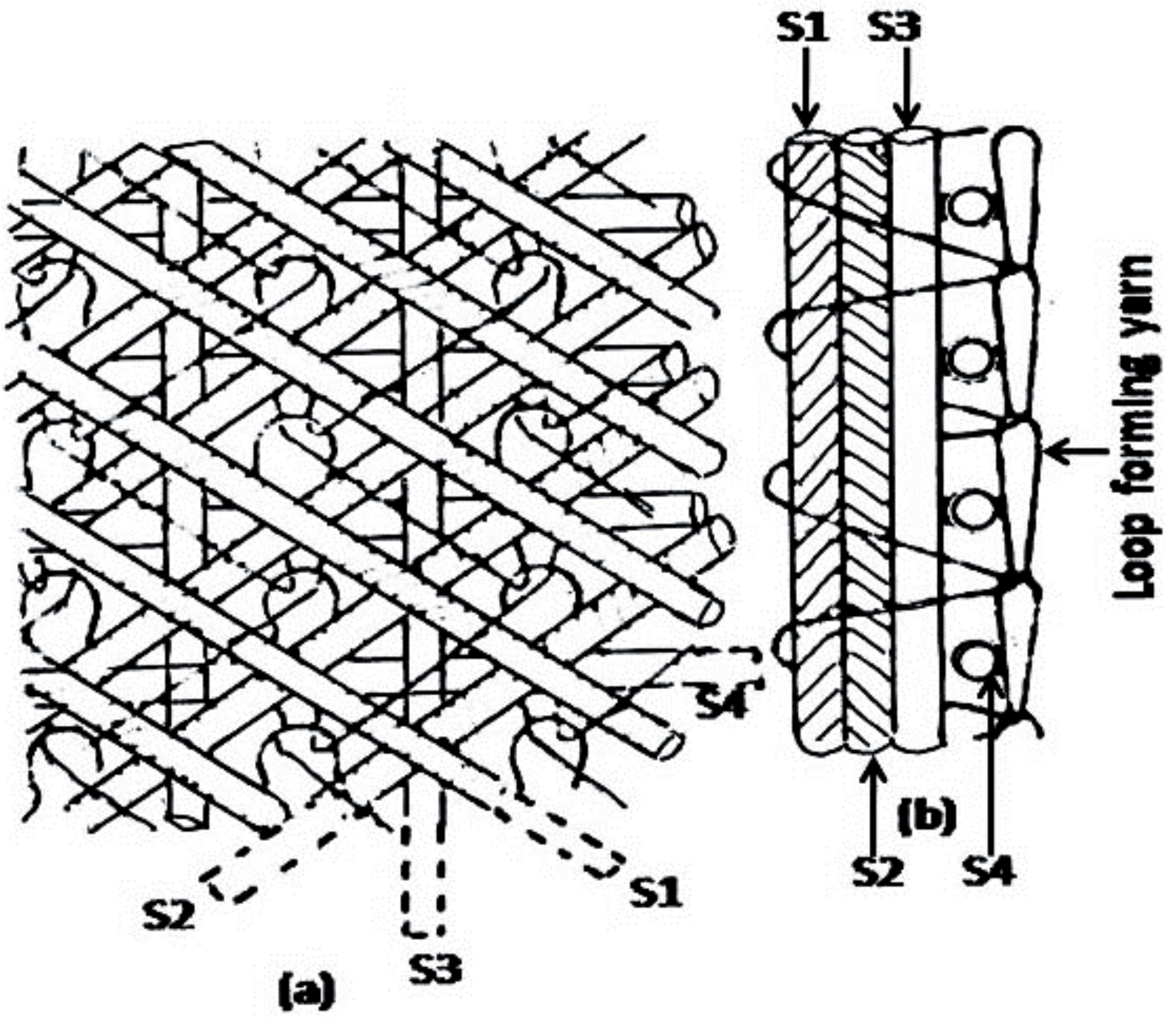


Figure 7.28 Multi-axial warp knitted fabric

(c) The weft insertion magazine placed at the back of the machine feeds one straight weft in every knitting cycle.

. (d) The technique of placing the diagonal threads into the structure is the new development, only for this machine. The technique is complicated. However, for the sake of simplicity, the principle has been described as two fully threaded guide bars, continuously miss- lapping while at the same time moving one needle space every knitting cycle. Each guide bar moving in same direction, places its yarn in a diagonal formation across the width of the fabric.

It is obvious that machine is too much complicated and movements of different sets of yarns along with the relevant elements are to be controlled precisely for achieving the desired product. Multi-axial fabrics are made of high tenacity yarns and have tremendous potential in the fields of technical textiles. Whether in fabric form or as composite, the prospective consumers are the aviation, marine and sports equipment industries. Such multi-axial fabrics are also termed as directionally oriented structures (D.O.S.). Sometimes only two sets of straight and parallel yarns are inlaid into the warp knitted structures as warp and weft for producing bi-axial

D.O.S. Production of such fabric needs only weft insertion system to be attached in a conventional warp knitting machine.

7.24 Double Needle Bar Warp Knitting Machine

Operating principles

Double needle bar raschels and bearded needle simplex machines are symmetrically arranged, with each needle bar usually having identical facilities and knitting once during the 360-degree revolution of the machine's cam-shaft. The vertical needle bars work back-to-back in line with the fabric being drawn downwards in the gap between them.

Guide bars are thus able to pass between needles in both beds as they swing from the front to the back of the machine and vice-versa. The guide bar lapping sequence involves overlapping and underlapping on each bar in turn so it is not possible to achieve the same actions simultaneously on both bars and the production rate is thus approximately halved.

Also, compared with single needle bar knitting, an extra or triple swing of the guide bars is necessary after each underlap in order to swing the guide bars over the needle bar that has completed knitting, so that the other needle bar can rise to commence its knitting cycle.

Double needle bar production is thus very much slower than single needle bar warp knitting, and basic double-faced fabrics knitted with two fully-threaded guide bars are heavier and more expensive than equivalent weft knitted double-bar fabrics. To compete, it is therefore necessary for warp knitted double needle bar products to exhibit unique properties.

Twice as many chain links will be required per complete cycle as compared with a single needle bar machine, with the first half of the links of each complete cycle being used for lapping on the front needle bar. When drawing a lapping notation, it is useful to indicate that every alternate horizontal row of points represents the front bed, either by lettering or by a heavier line of points or both. It may also be useful to space the rows in pairs, thus indicating each complete cycle on the two beds.

Using only one fully-threaded guide bar, overlapping on one bed only will produce a single-faced structure. Overlapping on both beds will produce a double-faced structure but this will only be cohesive if each guide overlaps at least two different needles in one of the beds during the repeat. To understand the appearance and properties of two-bar structures, it is necessary to consider the lapping movements that occur on each needle bed in isolation, as if produced by two separate guide bars.

Figure 7.29 a illustrates a lapping movement which is unsatisfactory because the warp threads cannot hold the double-faced wales of loops together. Although the raschel lapping movement is 2-0, 4-6/ the overlapping on the front bed is always 4-6, which is equivalent to a closed lap chain on each bed. Thus, the wales cannot be held together in either bed.

Figure 7.27 b illustrates the simplest lapping movement that can produce a cohesive structure. In this case the lapping movement is 2-4, 4-6/4-2, 2-0. On the front bed, upright loops are produced because an open lap pillar stitch notation 2-4/4-2 is lapped, whereas on the back bed the lapping movement is 4-6/2-0, which causes alternate courses to be inclined in opposite directions, but ensures that the wales are held cohesively together (Fig. 7.30).

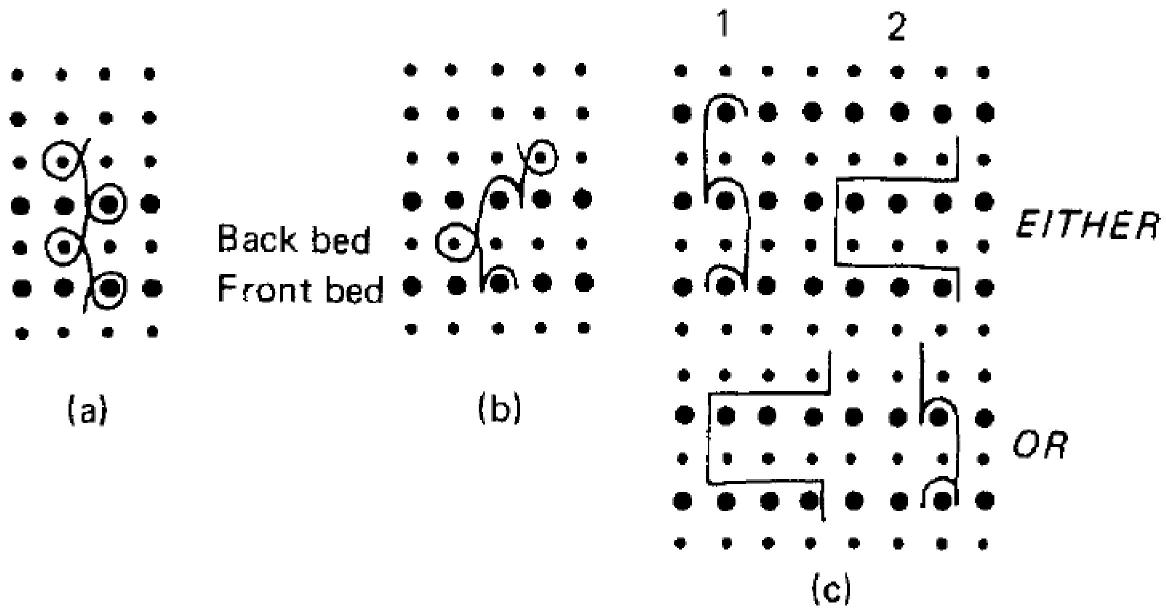


Figure 7.29 Double needle bar lapping notations

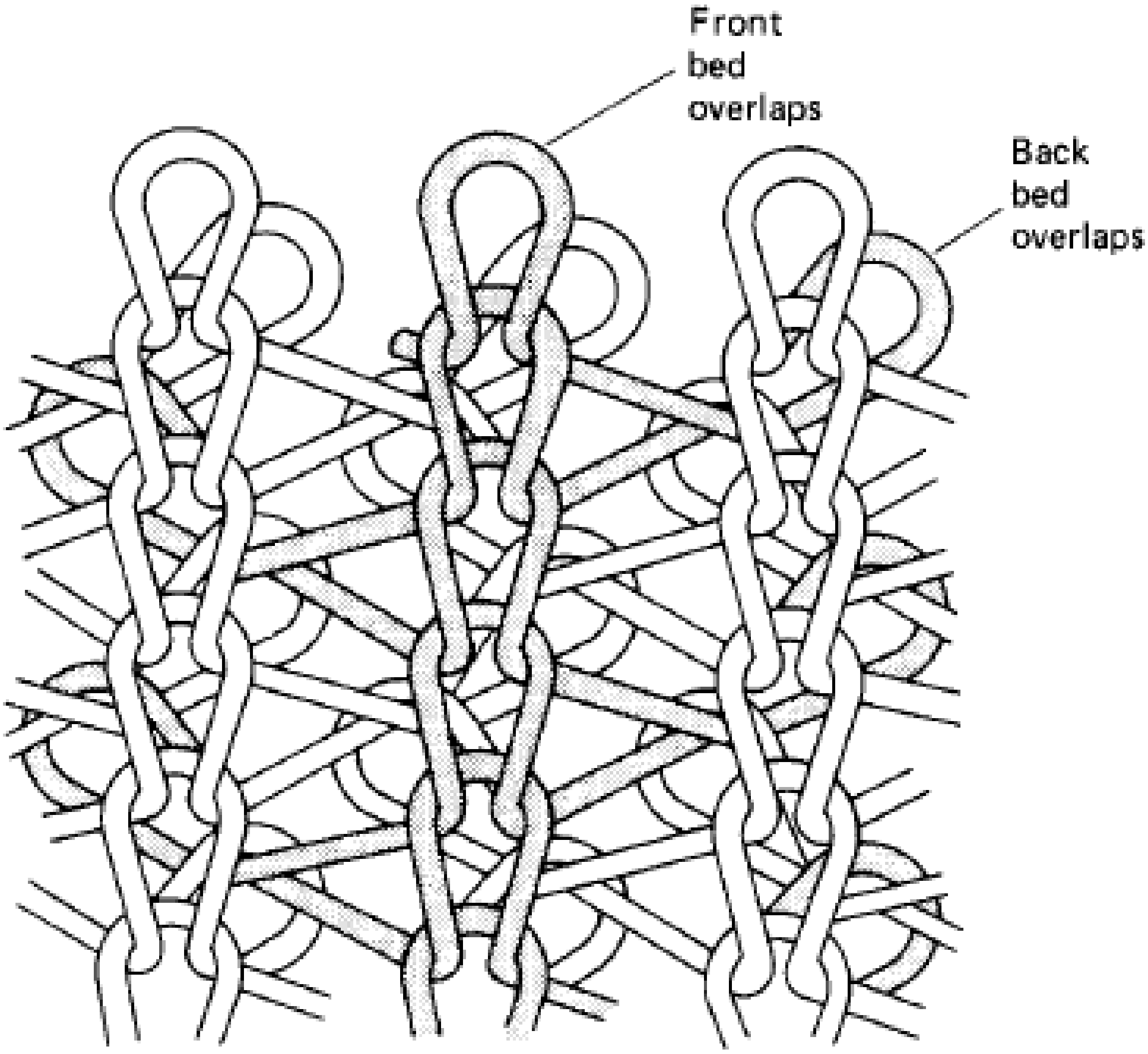


Fig. 7.30 Loop diagram of double faced double needle bar fabric.

If the front guide bar overlaps only the front needle bed and miss-laps on the back bed, and the back bar overlaps only the back bed and miss-laps on the front bed, two separate single-faced fabrics will be knitted back-to-back.

If the back bar overlaps only the front bed and the front bar overlaps only the back bed, the two separately knitted fabrics will be connected together by the crossing over of their underlaps.

A fabric of double-faced loops, each composed of a warp thread from each guide bar, is produced if both guide bars overlap both beds.

To understand inlay principles on two beds, it is best to consider each bed as a separate machine with its front (fabric draw-off) on the side remote from the hooks. With inlay, the guide bar nearest to the front overlaps and holds in place the inlay produced by the back guide bar. Thus, for the front bed, the back guide bar can overlap to hold the inlay of the front bar, whilst on the back bed, the front bar can overlap to hold the inlay of the back bar, but not vice-versa (Fig.7.20 c).

A double-faced net structure can be produced with two partly-threaded guide bars making a carefully arranged lapping movement so that every needle in both beds receives at least one overlapped thread at every knitting cycle.

The Simplex Machine

The simplex machine knits fine-gauge, high-quality, and specialist double-faced fabrics at rather low rates of production. It was originally designed to knit simplex fabric in order to replace duplex glove fabric, which was composed of two single-faced fabrics stuck together back-to-back. It has two guide bars, which overlap and underlap each needle bar to knit plain types of fabric and simple mesh designs on standard lapping movements, usually controlled from pattern wheels. The gauge range is approximately E 28 to E 34, with E 32 being a popular gauge. Cotton glove fabric is still knitted in typical counts of Ne 80/1 to 90/1 but yarns as fine and as expensive as Ne 120/1 have been knitted.

Atlas lapping on a 48-cycle repeat is normally employed to hide count irregularities in the structure and improve the elastic recovery. To obtain the 65–75 per cent width-wise stretch required for glove fabric, the fabric is treated with a 30 per cent caustic soda solution during finishing. This causes an approximate 50 per cent width shrinkage, and it is followed by a mild raising process with emery-covered rollers in order to achieve a suede appearance. Stable print-base fabrics for dress wear are produced with simple repeat movements using 40-denier nylon. A cheaper, lighter-weight fabric may be produced from heavier yarns by causing each guide bar to knit only on one bed and inlay on the other, so that they hold each other together in the double-faced fabric.

Unlike in the tricot machine, the sinkers are not leaded at the front so they can be completely withdrawn from the needles. In order to bring the needle bars closer together, they have no profiled sinker belly and on the newer machines, no throat.

The beds converge at an angle of less than 45 degrees. Landing is achieved by taking the needle bar downwards whilst still in contact with the presser which, in order to simplify machine movements, may be mounted on top of the sinker bar and move with it. On simple designs knitting high quality yarn, speeds of 300 courses per minute are possible on each needle bar.

Figure 7.31 shows the knitting action on the front needle bar; an identical sequence occurs afterwards on the back needle bar to complete the machine cycle.

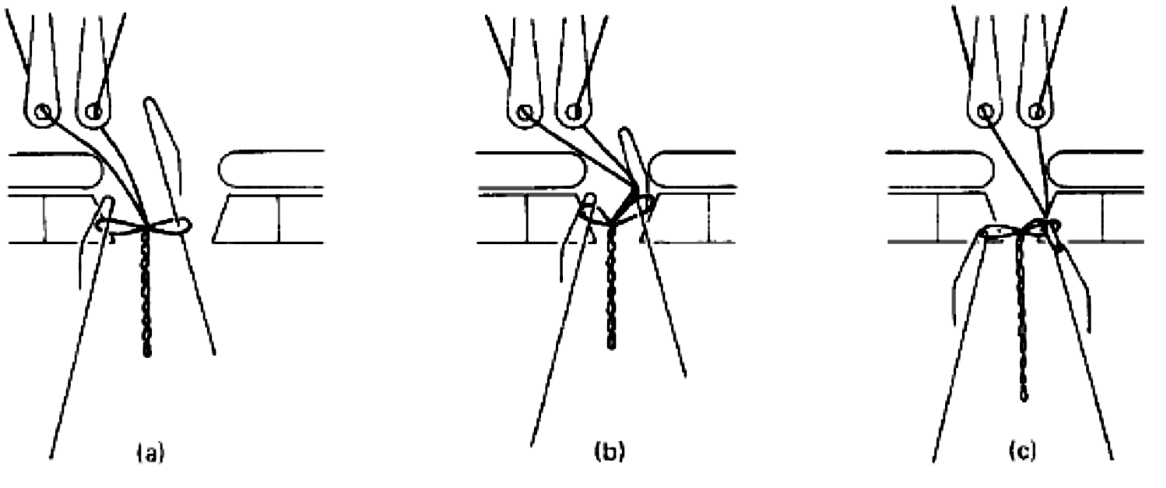


Fig. 7.31 Knitting action of bearded needle simplex machine.

(a) First rise of the needle bar.

The knitting action has been completed on the back needle bar for the previous machine cycle. The front sinker/presser bar has withdrawn, leaving the back sinker bar to support the fabric. The guide bars have completed their third swinging movement so that they are now swinging towards the back of the machine, allowing the front needle bar to rise with the back needle bar still near to knock-over and thus helping to hold down the fabric. The front needle bar rises sufficiently to enable the old overlaps under the beards to slide down onto the needle stems.

(b) Return swing, second rise then lowering and pressing.

As the guides swing to the back of the machine, the warp ends are wrapped over the needle beards. The front needle bar is now lifted to a higher position so that the new overlaps slip from the beards to a high position on the needle stems. As the front needle bar is lowered to cover the new overlaps, the front sinker presser bar moves to contact and press the beards so that the old overlaps slide onto the closed beards which descend through them.

(c) Completion of landing and knock-over, underlap and third guide bar swing.

Whilst the needles descend further to knock-over the old overlaps, the guide bars make their underlap shog behind the front needle bar and then commence their swing towards the front of the machine to allow the back needle bar to rise for the second part of the machine sequence.

Simplex fabric is in demand as a result of its smooth surface, soft handle, elegant drape and extensibility, all of which make it suitable for moulded brassiere cups. To meet this demand with up-to-date technology, Karl Mayer have produced a double needle bar raschel with two latch needle bars and four guide bars that can knit the fabric at a maximum rate of 500 courses per minute on each needle bar in E 32 gauge and a width of 4318 mm (170 inches). Maximum stitch density is 32 stitches/cm. The machine can also knit ultra-fine spacer fabrics.

Double needle bar machines are available in both Tricot and Raschel type warp knitting machines. These machines were developed keeping in mind the production of double faced rib structures in double bed weft knitting machine. The introduction of two needle bars opened-up the new horizon in warp knitting. The two needle bars work back-to-back and those are arranged in such a way so that some of the guide bars can move through the needles of both the beds for swinging purpose. As the guide bar lapping sequence consists of overlapping and under lapping on each bed in turn, it is not possible to achieve the functions (clearing, lapping, and loop formation) on both the beds simultaneously. The front needle bed knits first and then the back needle bar. Similar to double bed weft knitting, the ultimate fabric formed due to combined actions of the needles in the two beds comes down in between the two beds. Fabrics made in double needle bar machines are necessarily thicker than fabrics made from a single needle bar machine. Such fabrics will show knitted loops on both sides of the fabric. Therefore, it is possible to produce reversible fabrics. Two needle bar machines are mainly used for the production of knitted structures such as outerwear fabrics, open work net like fabrics, plush fabrics, thermal fabrics and pleated effect fabrics. On account of more complex construction, the double needle bar machines generally run at a comparatively slower speed.

7.24.1 Double Needle Bar Tricot Machine

Tricot machines with double needle bar are called Simplex machines. Traditionally, double needle bar Tricot machines were used in glove industry, however, these machines can produce fabrics for outerwear and innerwear as well. Although the gauge (needles per inch) range is 28 to 34, the most popular gauge is 32 and the machines are used for producing finer fabrics. The two needle beds are not parallel but are approximately at an angle of 45° to each other. The speed of Simplex machine may be up to 300 courses per minute while knitting simple designs with quality yarns. The knitting cycle of the front needle bar starts only when the back needle bar completes the knitting action of the previous cycle. The first (clearing) phase of the knitting cycle of the front needle bar has observed in Fig. 7.32.

The back needle bar has completed its knitting action for the previous machine cycle. The front needle bar rises to a medium height (clearing) so that old overlap under the beard can slide down on to the stem.

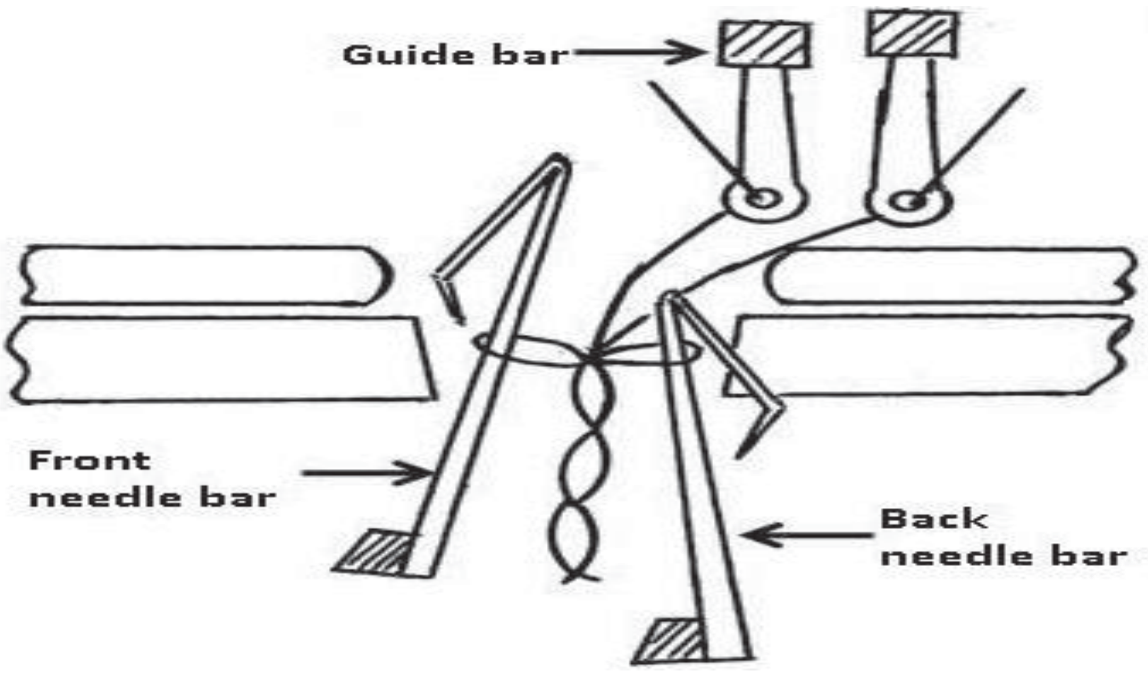


Figure 7.32 Knitting zone of the double needle bar Tricot machine.

Swinging of the guide bar towards the back of the machine wraps the yarn over the front needle beard. The front needle bar rises further and the overlap slips into the needle stem. Thereafter, the front needle bar is lowered and the new overlap is trapped into the needle hook and at the same time the pressure bar closes the beard.

The front needle bar is lowered further so that the needle with the yarn in the hook moves down through the old overlap towards the knitting point (down most point). At this instant the guide bars complete the underlap shog behind the front needle bar and then swing towards the front of the machine to allow the back needle bar to rise for second part of the machine sequence.

7.24.2 Double Needle bar Raschel Machine

Different types of double needle bar Raschel machines are built today for the production of a wide variety of products ranging from sacks to artificial blood vessels. Seamless tubular fabrics, pile fabrics and many other special fabrics can easily be produced in double needle bar machine by using 4 to 6 guide bars. But by using more number of guide bars (16 and above), production of branching tubular fabrics such as artificial blood vessels, patterned panty-hose etc. and shaped innerwear is no more a problem.

In case of Raschel, the two needle bars are vertical as well as parallel to each other and the needles in the two beds face back-to-back. Moreover, the gap between the two beds is adjustable. The arrangement of the knitting elements as well as the knitting action is not complex like Simplex machines. At the same time attachments like Fall-plate, Creeping motion, Weft inlay etc. can be fitted for producing speciality products. The creeping motion is used to disengage any one of the needle beds for a specific number of knitting cycles. These machines are generally made with coarser gauges compared to Simplex machines. The first (clearing) phase of knitting action of the front needle bar is shown in Fig. 7.33 (for simplicity, only one guide bar has been considered). A similar action is observed for back needle bar also.

The front needle bar is lifted up for clearing the previous overlaps from the hook and latches. The back needle bar holds down the last row of loops of the fabric at the idle position.

The guide bar swings from the back of the needles to the front of the machine and then shogs for producing the overlap and again swings back.

The needle bar moves down and new loop passes through the old loop and the old loops are cast-off.

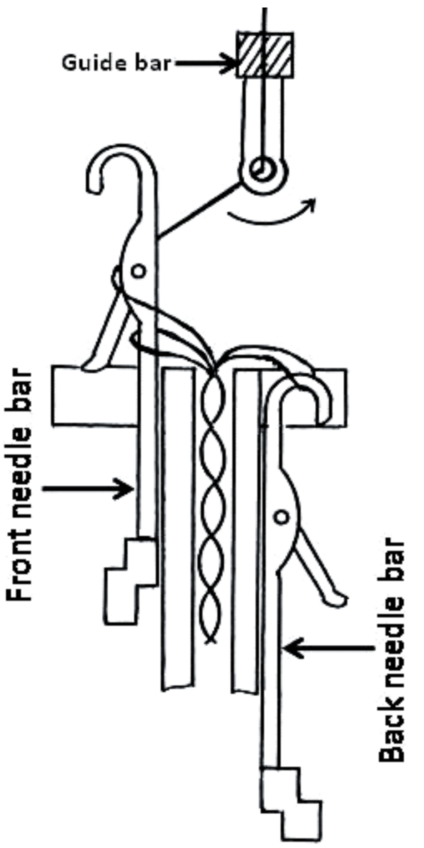


Figure 7.33 Knitting zone of the double needle bar Raschel

The guide bar swings over the front needle bar so that the back needle bar can be lifted for commencing knitting action.

7.25 Pile Fabrics on Double Needle bar Machine

There are two main groups of pile fabrics produced on double-bar raschels: cut pile and point pile. Cut pile is achieved by knitting a separate base fabric on each needle bed but joining the two together by the lapping movement of the pile, which is later slit to produce the two cut pile fabrics. Point or looped pile is produced by replacing the front bar needles by a point or pin bar around which the pile yarns are overlapped. For security, the pile yarn may be overlapped in the base fabric on the needle bar or it may be inlaid to economize on yarn and produce a lighter-weight fabric.

Pile fabrics (both cut pile and point pile) are produced on double needle bed Raschel machine. Cut pile is achieved by knitting a separate base fabric on each needle bed but joining the two together by lapping movement of the pile which is later slit to produce the two cut pile fabrics. Cut pile fabrics are employed for a wide range of end uses such as, simulated fur and skin fabrics, upholstery and coat/jacket lining. Each bed knits alternatively and has a cam shaft, needle bar, trick plate, sinker bar and two guide bars with no swinging action. The needle bar and trick plate swing through these two guide bars to produce the base structure on that particular needle bed. The middle (pile) guide bar has normal swinging facilities for lapping the pile alternatively on each needle bed. As the pile is severed in the centre, its height is half the distance between the two trick plates. This distance may be altered to produce a range of pile height. The effect produced is determined by a combination of type of fibre, denier, lapping movement and finishing treatment applied. In point pile, the loops are produced at right angle to the common base fabric knitted together by both the needle beds. The pointed or projected piles are sometimes cut or sharpened to achieving softer feel. Such fabrics are mainly suitable for floor covering and carpeting. The technique of producing spacer fabric in double needle bar warp knitting machine is also applicable for producing cut pile fabric.

Cut pile fabrics are employed for a wide range of high pile end-uses such as simulated fur and skin fabrics, upholstery and coat linings. The Karl Mayer HDR 5PLM is designed specifically for this type of fabric. Its raschel gauges range from 18 to 36, with 32 being most common, in widths of 75–180 inches (190–457 cm) and speeds of approximately 250–300 cpm per needle bar (five-times faster than weaving). The fabric made from polyester yarns weighs between 300 and 600g/m2 and is particularly used for automotive upholstery.

Each bed knits alternately and has a cam-shaft, needle bar, trick-plate, sinker bar and two guide bars with no swinging action. The needle bar and trick-plate swing through the two guide bars to produce the base structure on that particular needle bed. The middle (pile) guide bar has normal swinging facilities for lapping the pile alternately on each needle bed. As the pile is severed in the centre, its height is half the distance between the two trick-plates; this distance may be altered to give a range of pile heights between 2.5 and 30mm.

Figure 7.34 shows a simple three guide bar construction and Fig. 7.35, a more popular construction using five guide bars. By lapping the pile yarn into two wales, any irregularity in the yarn is disguised.

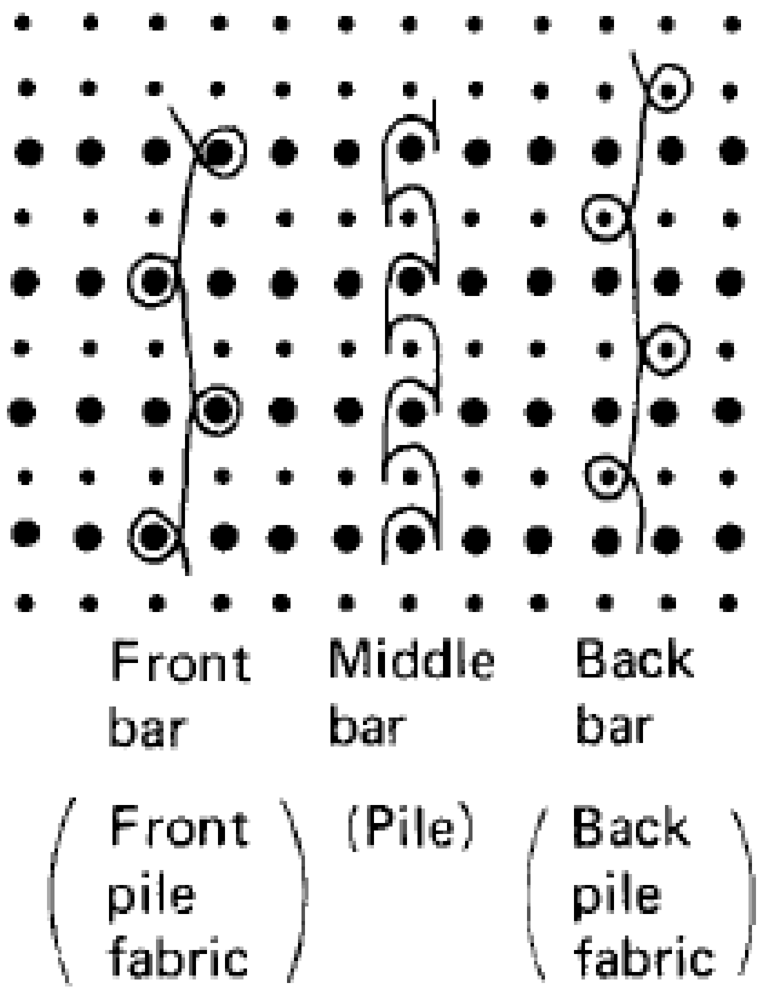


Fig. 7.34 Notation for a three guide bar cut plush

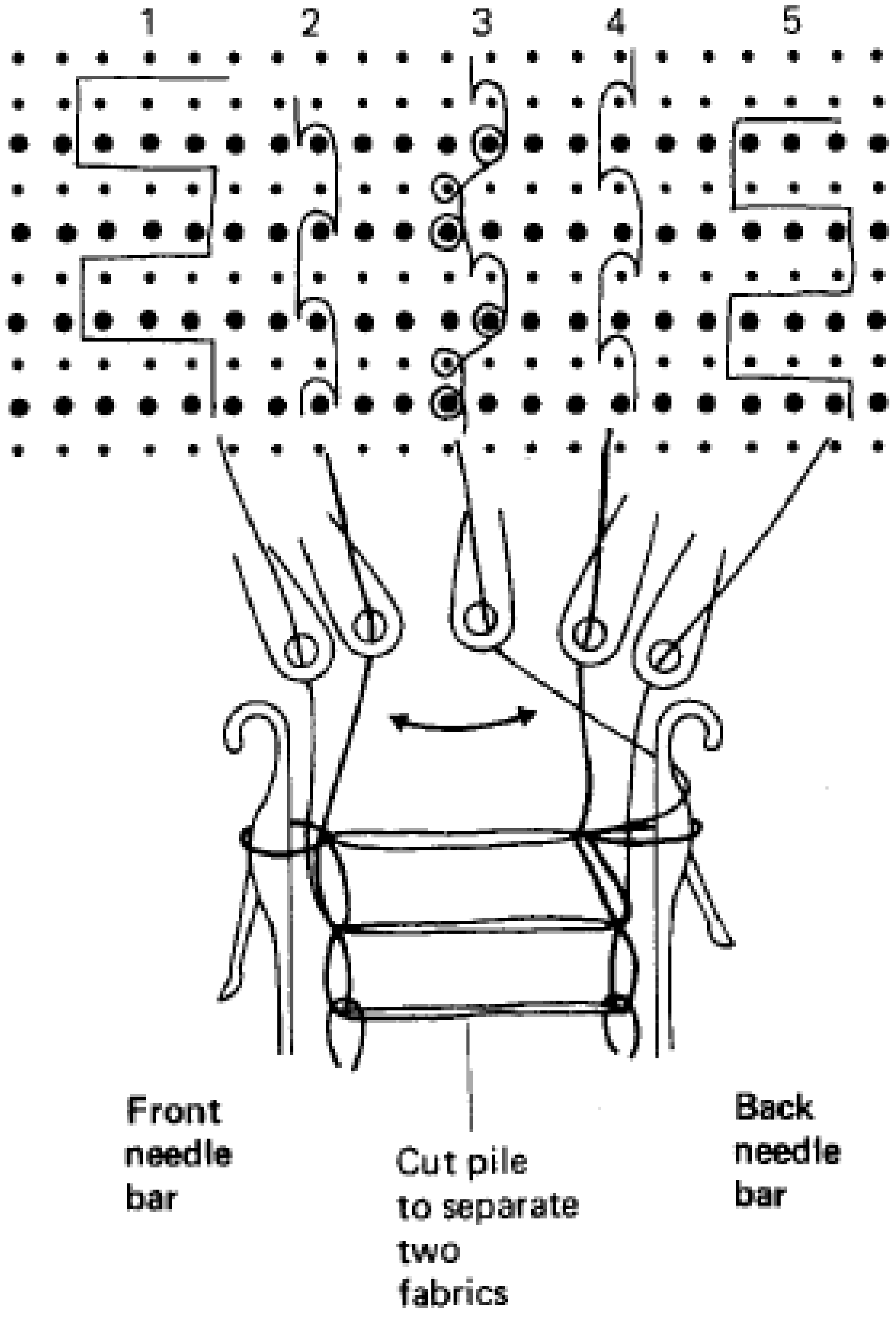


Fig. 7.35 Notation for a five guide bar cut plush.

The effect produced is determined by a combination of type of fibre, denier, lapping movement and finishing process sequences whose operations may include one or more of the following: raising, cropping, setting, dyeing or printing, and electro-polishing.

In point pile, the loops lie at right angles to the base fabric and on some machines the points are sharpened or contain rotating cutting blades for cutting the pile loops. The structures are particularly suitable for floor coverings and carpeting. On a five guide bar machine in 12 gauge, the front two bars might knit pillar stitches in opposition, threaded with spun polyester; the inlay might be supplied by 2/10 Ne spun polyester from the back bar; whilst the two middle bars might supply 5/400 denier textured polyester for the pile, overlapping the points and laying-in on the needle bar.

Using an eight-link-per-course cycle, the overlap for the points occurs between the first two links, the overlap for the pillar stitches on the needle bar occurs between the second two links, whilst the last four links allow the points and needles to descend for knock-over and for the underlap inlay on the back bar.

An unusual use is three guide bar structure for the artificial turf, Astro-turf, whose pile is composed of four, six or eight ends of 500 denier dope-dyed nylon ribbon on a nylon polyester knitted and inlaid base fabric.

7.26 Tubular and Branched Fabrics on Double Needle Bar Machine

Double needle bar Raschel machines also offer the scope for producing tubular sacks to artificial blood vessels. Loosely constructed tubular sacks can be used for packing vegetables, fruits and many other items. Tubular fabrics are generally produced on double needle bar machines using 4, 6, 8 or even more guide bars in such a way that the side connections are identical to the body structure for forming a seamless tube. In case of machines with four guide bars for producing tubular sacks, one fully threaded guide bar (say front guide bar) is utilized to produce the front fabric on the front needle bar, another fully threaded guide bar (say back guide bar) is utilized to produce the back fabric on the back needle bar and the inner two guide bars produce the necessary connection between the front and back fabrics on two sides.

A seamless tube of fabric may be knitted on a rectilinear double needle bed raschel in a similar manner to on a V-bed flat weft knitting machine. Each bed knits separate single-faced fabrics that are joined together only by underlaps of other partly threaded guide bars between the beds at the two opposing selvedge needles at each edge. The underlaps may be arranged to be the same as for the needle beds, thus producing a seamless join to the fabric tube.

Figure 7.36 illustrates the basic principles using a base structure of single tricot lapping and four guide bars. The front bar laps only the front bed, the back bar laps only the back bed, and the two middle bars are threaded with only one thread to each complete one selvedge join.

In the first underlap movement towards the right, the warp threads will rotate anticlockwise by one needle space in producing the tube on the machine beds. Underlapping on the front bed will be towards the right. The right-hand selvedge bar will underlap across from the front to the back bed. The back bar will underlap towards the left and the left-hand selvedge bar will underlap across from the back to the front bed. In the next underlap movement, the direction of lapping will be reversed for each of the guide bars, by a clockwise movement. As one selvedge bar is always overlapping one needle in each bed, the threading of the front and back bars must be one less than the number of needles knitting the fabric in that bed. Two selvedge guide bars are required because when one is overlapping the front bed in a particular cycle, the other is overlapping the back bed.

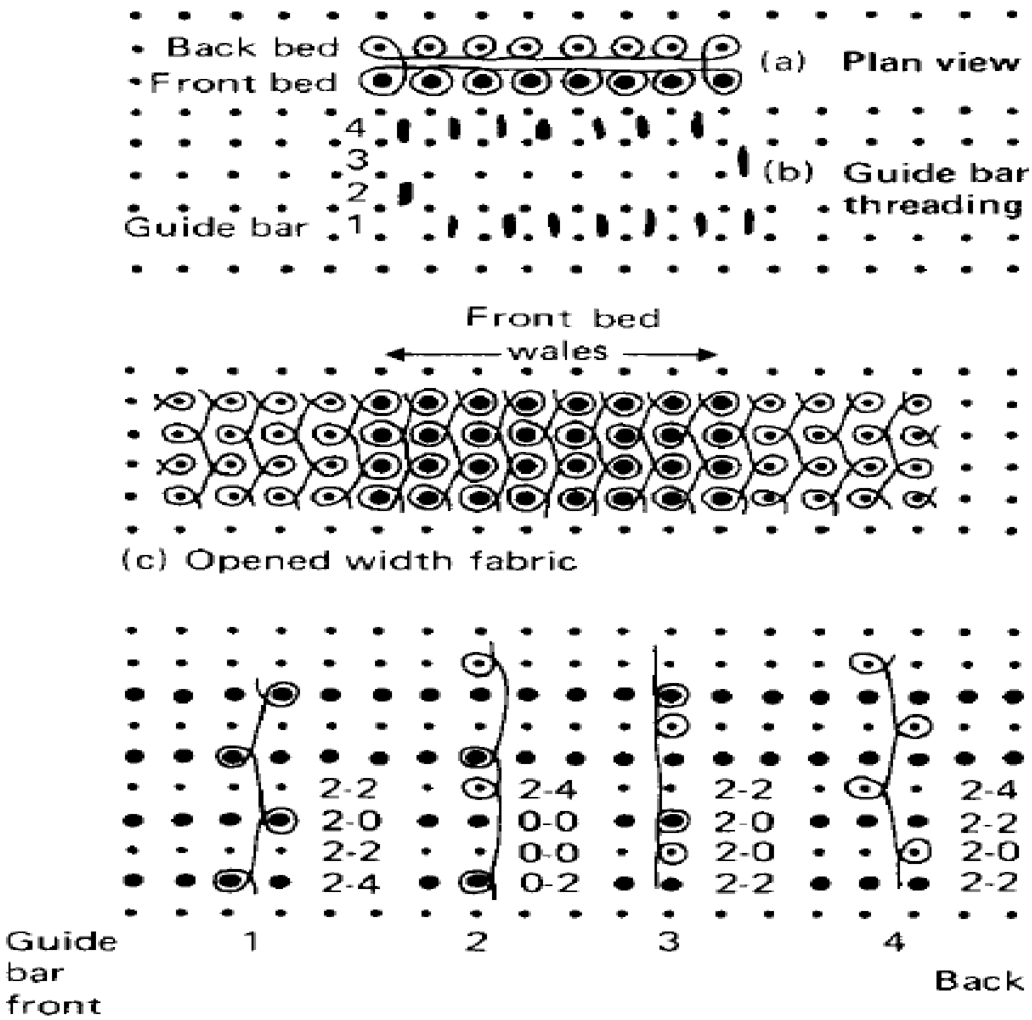


Fig. 7.36 Lapping diagram and notation of a seamless tube knitted on a double needle bar raschel.

Whilst knitting the tube, no guide bar must overlap on both the front and back beds during the same cycle, otherwise a single-thickness double-faced stitch is produced. If the base movement is a two-needle underlap, two selvedge threads will cross over the beds at each selvedge and each will require a separate guide bar. If the base movement was full tricot, a minimum of eight guide bars would be required, two for each bed and two for each selvedge. Inlay net or part-sett threaded net lapping movements may be used to produce tubes in a similar manner.

Some of the first tubular fabrics produced were for vests or for fishnet stockings, knitting eight to twelve tubes side by side. In 1967, the American Kidde Cocker company introduced the Fashion Master machine for knitting panty-hose and body stockings. By changing the lapping movement of an extra four bars that are lapping in the centre of the fabric, the large tube for the body portion can be divided into two smaller tubes with two of the bars joining two opposing needles across the needle beds for the inner selvedge of one leg, and the other two joining the adjacent needles for the other leg, thus knitting a bifurcated article. Graduating stiffening is achieved by infinitely-variable control of the fabric take-down and warp let-off, a shifting control moves the guide bar push-rods onto other chain tracks when required, and reinforcement is achieved by double-needle overlapping.

For approximately two years, hosiery produced on these machines was highly popular. The Karl Mayer HDR 16 EEW machine was introduced in 1970 for producing a range of simple garments such as seamless panties, brassieres and pocketings. The technique used, which has undergone continuous development, is to form the tube across the knitting width rather than down the wales. Although this causes the article in use to have its courses in a vertical direction, this is no major disadvantage and the possibilities for achieving simple shaping are considerably improved.

Figure 7.37 illustrates the production of a strip of briefs fabric; it is only necessary to cut through the centre of the connecting joins to separate each article from the next. These joins of short length are, in effect, knitted side seams, so the briefs are turned inside out after knitting to hide this seam. The first side seam is produced by guides lapping across between the two beds to form a solid double-faced fabric section. Guide bars inlaying on the left selvedge form the knitted-in waist band which is produced on each bed because the guide bars lap on the two needle beds separately in order to produce the waist opening on the left and the first leg opening on the right. Half-way through the courses for the sequence, the right selvedge needles are joined together for a number of courses to complete the first leg opening and close the crotch section of the brief. Single-bed fabric knitting then continues for the second leg after which the bars knit between the beds to form the second side seam and then commence the sequence for the next brief.

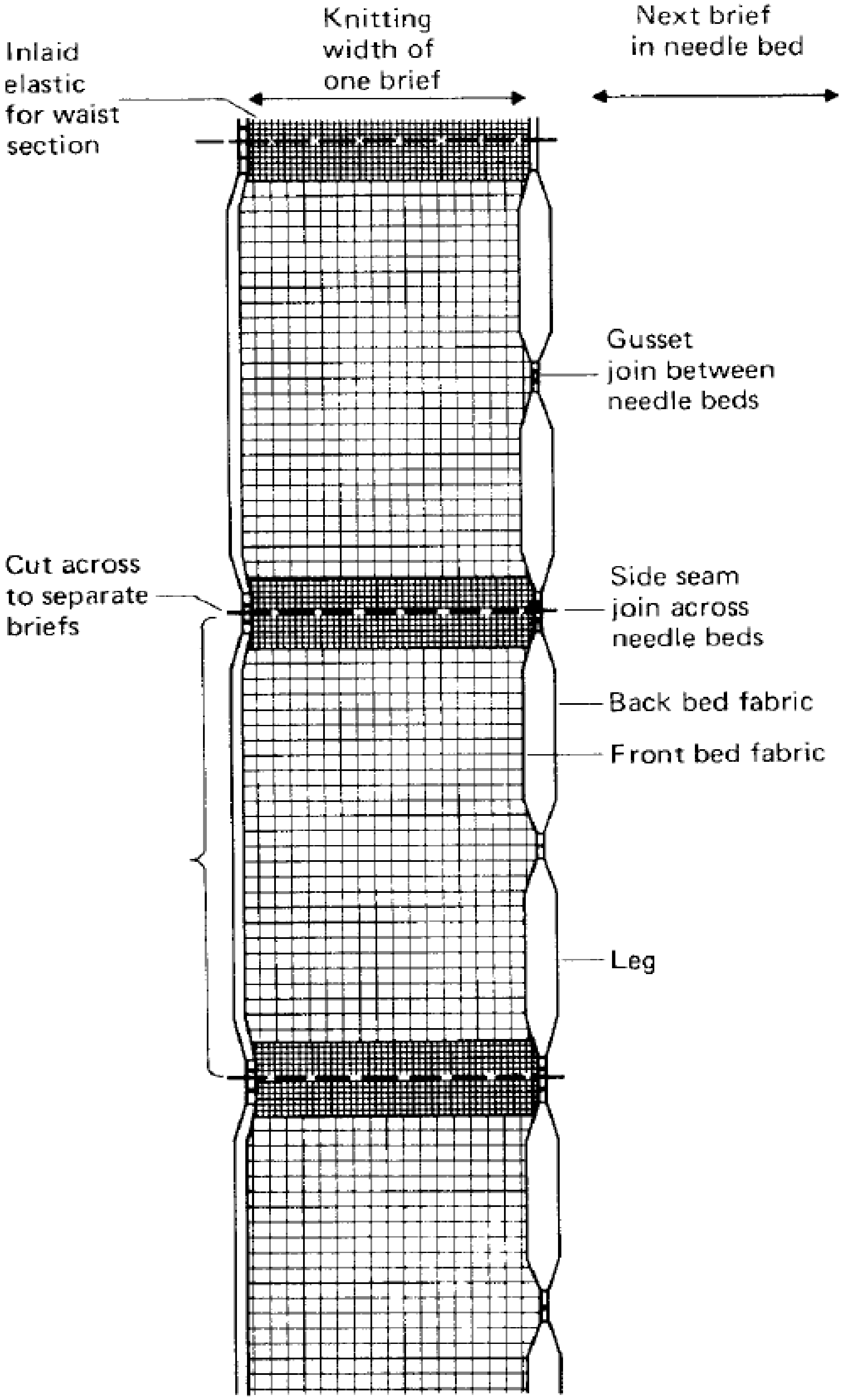


Fig.7.37 The principle of knitting tights on a double needle bar raschel.

On a 75-inch (190 cm) wide machine, three brief fabric strips can be knitted side by side giving a production of 360 briefs per hour. It is possible to achieve a cotton terry effect on the inside if desired. Upper and lower pattern chain drums are employed to control the guide bar shogging levers and these drums may have a split drive and chain stop facilities to further economise on links and provide greater versatility in lapping movements. The double needle bar raschel in 12–16 gauge has proved particularly useful for the production of packing sacks for fruit and vegetables made from polyolefin in fibrillated tape or mono-filament form.

The base structure is usually a pillar stitch inlay that provides a secure non-slip construction (Fig. 7.38). The polyolefin sheets may, if necessary, be fed directly into the back of the machine where they are split into separate ends without the need for warping.

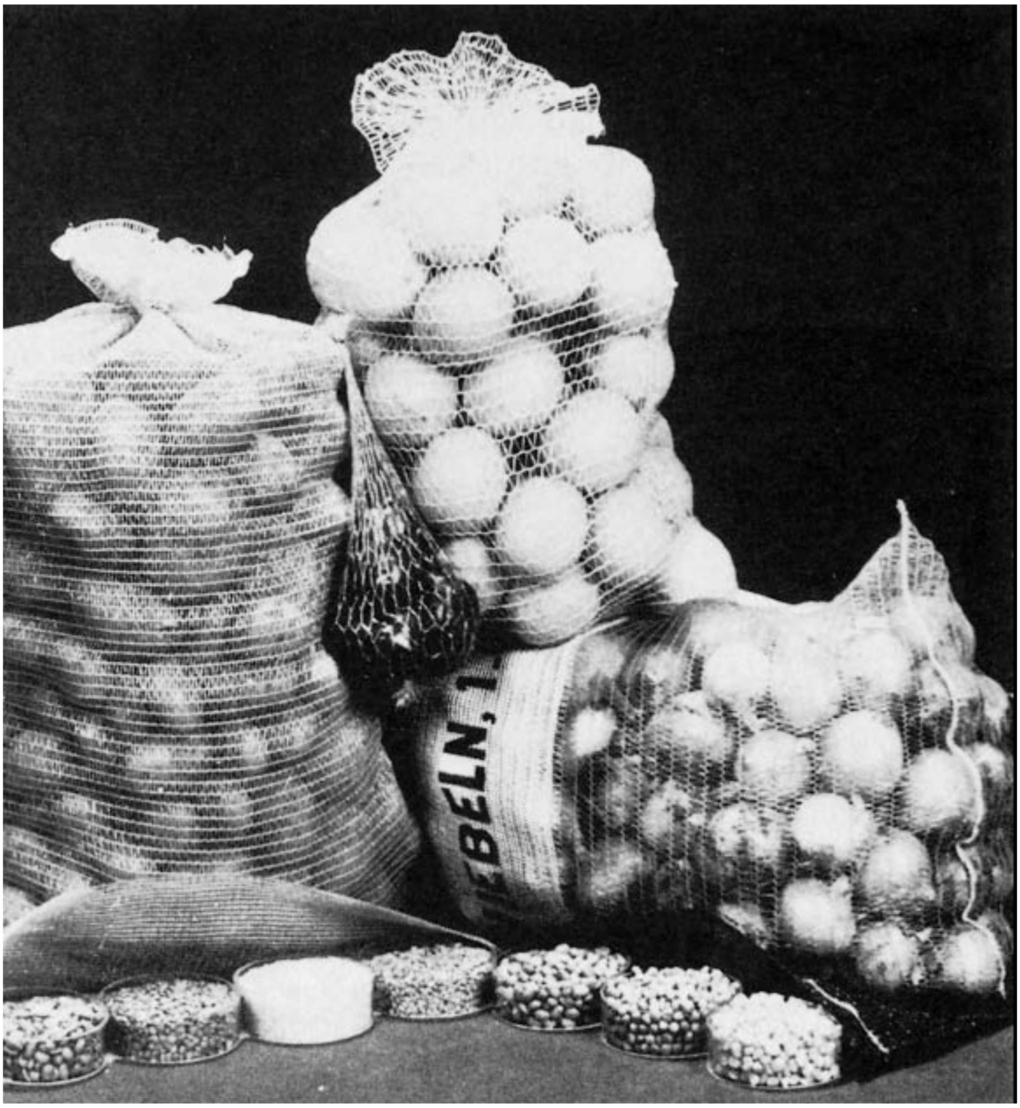


Fig. 7.38 Fruit and vegetable sacks knitted on double needle bar raschel machines [Karl Mayer].

The sacks are knitted sideways at a rate of 250 courses per minute on each bed in a similar manner to the briefs. Their depth can thus be varied according to the number of needles knitting in each section. The two fabrics are joined together at the top and bottom to form the side seams and at one selvedge to form the bottom of the sack. At the open end, a draw-thread may be knitted into each side of the fabric and separation of the sacks from the continuous warp knitted strip is achieved afterwards with a hot wire.

Another important product of double needle bar machine is the tubular fabrics with branches. The technique of producing branched tubular has opened a new horizon for producing artificial blood vessels (cardiovascular tube) as shown in Fig. 6.21 required in heart surgery. Generally 16 guide bars and two pattern drums are required for such products. The high number of guide bars are required for producing the different section of the tube and the two pattern drums operating alternately, produces the different parts of the product. Electronically programmable shaping device helps to vary as well control the diameter of the branches at any point. Knitting starts with one tube and, when required, branching takes place. The length of the base tube as well as of the branches can be controlled precisely. This same technique is now-a-days also used for producing seamless pantyhose (Fig. 7.39).

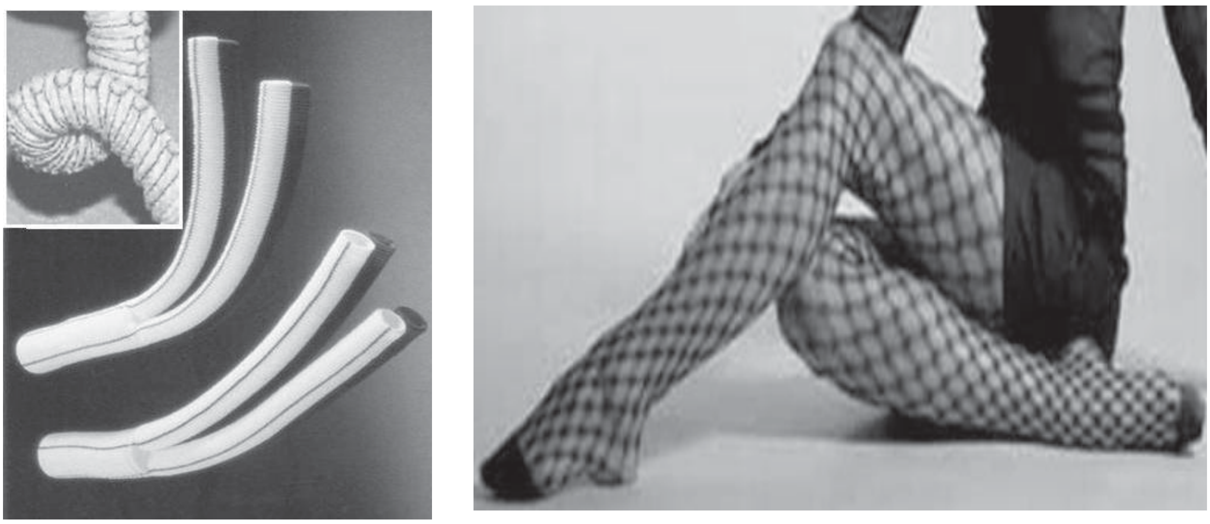


Figure 7.39 Cardio Vascular Tube and Seamless Pantyhose

7.27 Double Needle Bar Raschel Products

In the past, double needle bar raschels of 24-gauge and coarser were used to knit fancy fabrics in woollen yarn for baby-wear, nightwear and knitwear. Two such structures were rib and crepe. In the former, certain needles were never overlapped, whereas the latter is actually a knop fabric produced by taking the back needle bar out of action for between two and four courses to hold its loops whilst the front bar continues to knit. Fabrics of this type have faced increasing competition from the improved design possibilities now offered by flat weft knitting machines.

Two other structures that occasionally achieve a limited success in underwear or outerwear are waffle fabric and Byrne string vest, both of which were originally developed in the early 1950s as thermal underwear fabrics for US forces serving in cold climates. Both are produced with half-threaded guide bars although two other guide bars are often also used to produce the selvedge edges for making up.

In 24 gauge, 22/1 Ne combed cotton would be a suitable yarn count. String vest is a double-faced net structure with the underlaps hidden inside. Because it is a double needle bed fabric, the net openings are only half as large as the lapping movement representation.

Waffle fabric is a solid fabric composed of a series of open pockets alternately placed on both sides of the fabric. Each guide bar makes overlaps over two needles, which draws their two adjacent wales together thus leaving a gap between every two wales. Gaps on one side are opposite the two connected wales on the other.

This arrangement would give the fabric the appearance of a 2 X 2 rib but after five courses, the lapping movement is changed causing the gaps and connected wales to change positions.

7.28 Length-Sequenced Articles

Some raschel double needle bed products are in the form of articles, a number of which can be simultaneously knitted side-by-side across the needle bed. These articles have a length repeat composed of sections of fabric where the lapping cycle of one or more of the guide bars has been altered. The sequence involves a pattern change device for counting the number of repeat lapping cycles in each section and for initiating a changeover of guide bar push-rod control from scanning links in one chain track on to those in another track, in order to alter the lapping repeat for a particular guide bar. By this method, a guide bar may be controlled from a choice of two or more chain tracks, each having a short, simple repeat of chain links that may be used any number of times, instead of being controlled from one track of an excessively long and expensive chain containing links for every repeat cycle throughout the length of article.

The principle of 'pattern changing' is used in the production of a scarf with knitted-in fringes on each end. Lapping for the scarf section is taken from one set of chain tracks and lapping for the fringe section from another. Each guide bar shogging lever may be controlled from either of two pattern chain drums; the upper drum chain tracks may produce the simple lapping repeat for the scarf section whilst the lapping for the fringe section is achieved by switching the shogging control to the chain tracks of the lower drum.

The scarf fabric is knitted as a continuous strip of double-faced fabric with the fringe sections composed of two-wale wide strips, each unconnected by underlaps to its neighbour. Each scarf piece is separated from the next by cutting through the centre of the fringe section and seaming the cut ends to secure them. The simple tricot lapping movement produces the width-wise elasticity required for scarves.

Chapter 8 Knitting Science

8.1 Objectives of Studying Knitting Science

(a) To identify various input parameters which influence the knitting process.

(b) To optimize input parameters for desired output.

(c) To learn about the parameters/particulars of the fabrics which are important in end use.

(d) To gain an insight into the mechanics of loop formation

(e) (e) To redesign the machine parts in order to achieve higher productivity.

8.2 Factors of Study

Fabric parameters like loop length, cpi, wpi, stitch density, etc.

Fabric constants like K_c , K_w, K_s, etc.

Fabric tightness factor (TF)

Geometry of the knitting zone

Robbing back (R.B.%) of yarn

Yarn tension profile inside knitting zone and its measurement

Factors governing loop length in fabric

8.3 Importance of Knitted Loop Length and Loop Shape

It has been observed and reported by many scientists in the field of knitting that the properties of the knitted fabrics are mainly governed by two parameters, namely length of yarn in a loop and the shape of the loop. Although the shape of the loop is finalized upon relaxation treatment of the fabric, the length of loop is mostly decided on the machine during loop formation. The relationship between loop length and fabric dimension obtained by the researchers are applicable to any fabric irrespective of type and count of yarn as well as type and gauge of machine. Three basic laws governing the behaviour of knitted structure are as follows –

(a) Loop length is the fundamental unit of weft knitted structure.

(b) Loop shape determines the dimensions of the fabric, and this shape depends upon the yarn used and the treatment which the fabric has received.

(c) The relationship between loop shape and loop length may be expressed in the form of simple equations.

8.4 Loop Length

The length of yarn contained in loop unit is called loop length. Loop length is a very small value compared to the length of yarn in a fabric. The other name of loop is stitch and accordingly the length of yarn required to make a stitch is called stitch length. As the configuration of a complete loop is different in different structure and more than one simple loop is essential to show the structure of a complete loop of some knitted structures, nowadays another term called structural knitted cell (SKC) is also used to define the repeating units in knitted structure. Whatever may be the term its value ranges about 3 to 20 mm depending upon type of machine gauge, yarn, knitted fabric structure and end use. The loop length is on smaller side say 2.5 to 3 mm in finer circular single jersey weft knitting, and it is even more than 25 mm in case of coarser gauge flat double jersey knitting. If loop length is multiplied with the number of needles in the machine or wale lines in the fabric, course length is obtained. As measurement of individual loop length is difficult, loop length is obtained from course length or from the length of a large number of loops in a course. There are two types loop length – theoretical or nominal loop length and practical or actual loop length.

The theoretical or nominal loop length is the length of yarn taken by a needle at the knitting point during loop formation in the machine. This length can be calculated from stitch cam setting, machine gauge and other related parameters with due consideration of loop arm configuration. The length of yarn taken by the needle 'N' situated at knitting point in between two sinkers S_1 and S_2 of a single jersey machine is shown in Fig. 8.1. The simplest way of calculating the theoretical length of loop for the needle 'N' is to find out the length of each straight segment (neglecting the curved portions at the contact points) between the needle and the neighbouring sinkers and then add them together. If cam setting is 'h', horizontal gap between sinker and needle is 'a' ($a = 0.5/G$, where G is the machine gauge) and yarn in loop is in the form of 'V' at knitting point then theoretical loop length l is expressed as $2 \times \sqrt{(a^2 + h^2)}$. Both 'a' and 'h' are either known or can be measured, and above all the situation is very simple.

But, it is much difficult to determine the theoretical loop length for a double jersey machine as there are two knitting points and the knitted cell or loop is formed in multiple planes. Moreover no such expression is available for loop length in standard text books or in accessible international literature. It has been attempted to derive an expression for calculating theoretical loop length of 1 × 1 rib loop unit in dial and cylinder-type double jersey machine using computer for the study of mechanics of loop formation in double jersey machine.

The configuration of the 1 × 1 rib loop at knitting point under synchronized timing drawn in single plane by necessary shifting of the other planes is shown in Fig. 8.2. As observed, the configurations of loop arms as well as their length vary depending upon cam setting at the beds, gauge of the machine, gap between the two beds, stitch cam angles and the relative position of the two beds, i.e. timing of knitting. In the study they considered total 13 straight and curved segments whatever may be the extent for calculating the length of yarn making one complete 1 × 1 knitted rib unit. Moreover one 1 × 1 rib knitted cell is made-up of one cylinder loop, one dial loop and two links.

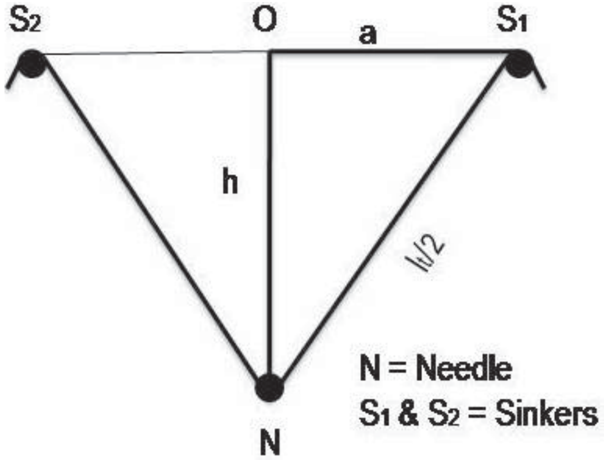


Figure 8.1 Single Jersey Loop configuration

So, either the total length of 13 segments or total length of cylinder loop, dial loop and two links will be the resultant length of one rib loop unit. The expression for the accurate calculation of the total rib loop unit will be complicated and can only be tackled with the help of programmable calculator or computer. The length of these components depends on the cylinder stitch cam setting, dial stitch cam setting and the gap between the two beds respectively as well as many other machine and process parameters.

The actual loop length (l_a) is measured from the off machine fabric. Loop length is generally measured by unravelling one or part of a course and subjecting the same under a tension which just removes the crimp in the unravelled yarn and makes the yarn straight without any stretch.

It has been observed both in single jersey and double jersey knitting that there is a significant amount of difference between theoretical and actual loop lengths. Moreover, the difference is such that which is not due shrinkage of yarn in the off machine fabric. The explanation of such difference was first given by research scientists. According to them this difference is due to robbing back.

8.5 Robbing back

Robbing back is an important phenomenon in weft knitting which deals with the mechanics of loop formation. As shown in Fig. 8.3 after catching of the yarn, when the needle moves downward to form the loop, it initially pulls the yarn from the package. But as the needle moves down and down, yarn passes over a large number of knitting elements, and tension in the yarn gradually increases. When the needle approaches the knitting point, the tension on the yarn is so high that the needle finds it difficult to pull yarn from the package but instead pulls the necessary yarn from the loop made by the previous needle. This is possible due to fall in tension in the loop arms of the needle which has crossed knitting point and rises up.

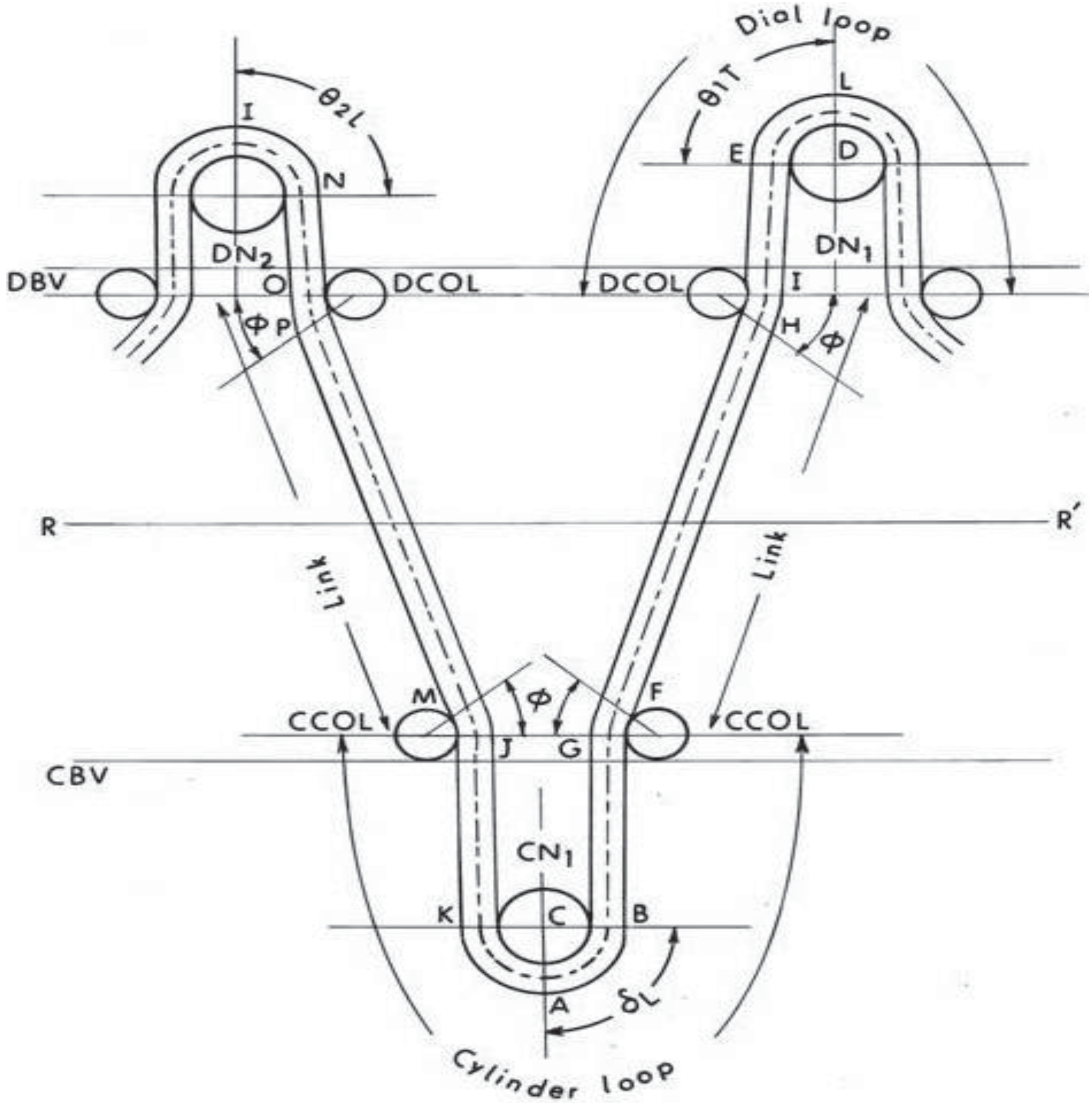


Figure 8.2 2-Dimensional view of 1x1 rib loop at knitting points under synchronized timing.
The pulling i.e. snatching or robbing of yarn from the loop which has been formed for the loop to be formed is termed as robbing back. This process of robbing continues for all the loops to be formed by the corresponding needles. Robbing back is expressed as follows.

The magnitude of robbing back mainly depends on yarn tension profile inside knitting zone which is governed by the yarn modulus, input tension, number of knitting elements in side knitting zone, type of knitting machine, etc. Generally the RB% is about 20 to 30 in single jersey knitting. RB% is comparatively lesser, i.e. about 12 to 20 in case of double jersey knitting.

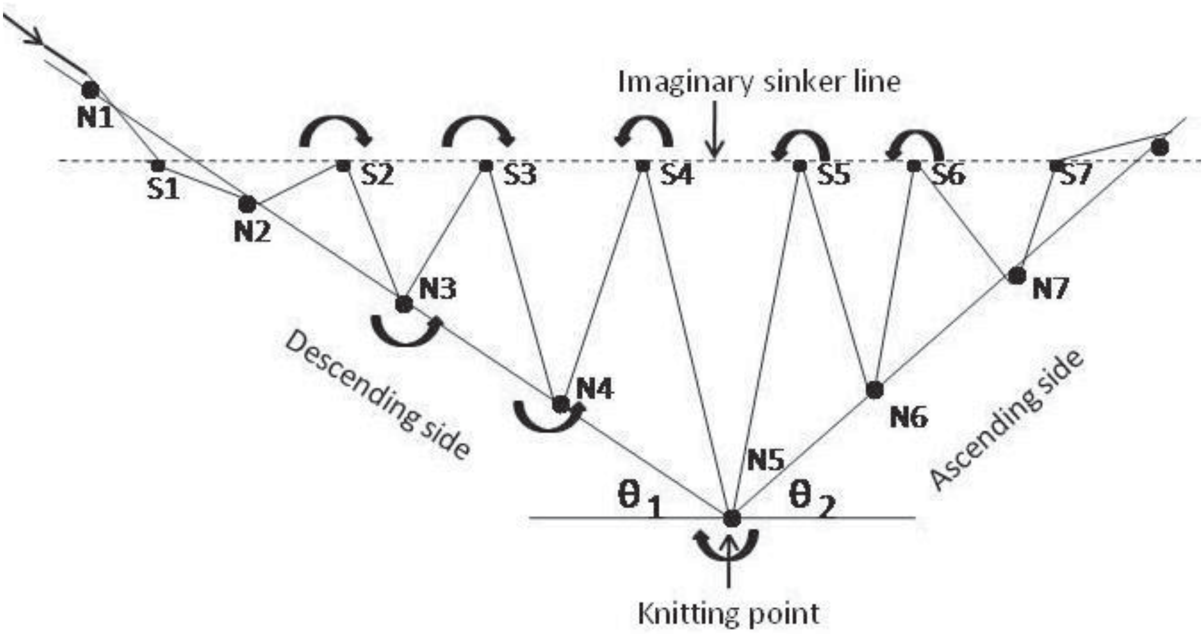


Figure 8.3 Robbing back in Single Jersey Knitting

8.6 Parameters of a Knitted Fabric

(a) Loop length in inch or millimetre, denoted by l

(b) Courses per inch or centimetre, denoted by cpi or cpcm

(c) Wales per inch or centimetre, denoted by wpi or wpcm

(d) Stitch density, denoted by S

(e) Loop shape factor, denoted by R

(f) Fabric tightness factor, denoted by TF

10.7 Constants of a knitted fabric

a) Course constant, $K_c = cpi \times l$

b) Wale constant, $K_w = wpi \times l$

c) Stitch density constant, $K_S = K_C \times K_w = S \times l$

d) Loop shape factor, $R = \frac{K_c}{K_w} = cpi/wpi$

As mentioned earlier, loop is decided during knitting and it does not change significantly in subsequent operations. But, the fabric dimension changes in subsequent operations / relaxation treatments and as a result the knitted fabric constants like, K_c , K_w and K_s also change until stable values are obtained in fully relaxed or tumble dried condition.

The average values of these constants in English system for plain knitted fabrics obtained over a large number of experiments under different conditions of relaxation are given in Table 8.1.

Table 8.1 Values of Constants for Plain Knitted Fabrics

Type of constant	Dry relaxed	Wet relaxed	Fully relaxed
Kc	5.0	5.3	5.5
Kw	3.8	4.1	4.2
Ks	19.0	21.6	23.1
R	1.3	1.3	1.3

In case the loop length is measured in millimetre and courses and wales are expressed per centimetre, then K_c and K_w become ten times and K_s becomes 100 times of the values shown above under different conditions of relaxations. But whatever may the unit of loop length, the loop shape factor, R remains same i.e., 1.3. For any typical relaxed fabric cpi/wpi or cpcm/wpcm is 1.3. So if the ratio is greater than 1.3, then it indicates higher shrinkage and consequently higher stretch property in width direction whereas if the ratio is less than 1.3, then it indicates higher shrinkage and consequently higher stretch property in length direction. In this research, the researcher has elaborated the loop geometry and different parameters of single jersey fabrics for establishing the basic laws of knitted fabrics. According to him, any knitter may find it necessary to adjust or control the following factors in order to obtain a finished fabric of the required physical properties.

Yarn variables

- Count
- Twist
- Condition (moisture content)
- Quality
- Package density etc.

Knitting Variables

- Temperature of the machine
- Machine gauge
- Stitch cam setting

Yarn input tension

Needle timing and knock-over

Sinker timing and knock-over

Take-down tension etc.

The large number and complexity of the variables may appear to explain difficulties in establishing relationship between knitted structure and constituent variables. Since they all are measurable and may be controlled, if necessary, the basic problem is to measure accurately and quantitatively the dimensional characteristics and physical properties of the knitted fabric.

Although the effect of fibre type was not explained, it was noted that high bulk acrylic fabrics were much wider than the average for fabrics knitted from other fibres. It was also observed that the K values of knitted fabrics under dry and wet relaxed states are different from fibre to fibre as shown in Table 8.2.

Table 8.2 Ks -Values of Knitted Fabrics under Dry and Wet Relaxed States

Fibres	Dry-Relaxed	Wet-Relaxed
Wool	19.0	21.6
Cotton	19.0	22.6
Regular orlon	18.5	18.5
Staple nylon	18.5	18.5

8.7 Relation between Fabric Properties and Geometry of a Loop

Property of a fabric is a function of properties of raw material employed and of structure used in making the fabric. Property of a structure is largely governed by the geometry of spatial configuration of the elements. Geometry is defined as properties and magnitudes (as lines, surfaces, solids etc.) in space. Deriving relations between critical geometrical parameters of a structure help in characterizing geometry. Owing to complexity of knitted structures, only the simplest one has been subjected to similar treatment.

Loop length and shape of loop are two important geometrical parameters. The effect of these two on physical and mechanical properties of a fabric is illustrated in the following. A loop may be thought of as a diamond (Fig. 8.4) having sides of unit length (say 1 inch). Thus it has a total length of 4 units and contributes 1.41 units each to length and width of the fabric. If the total length of loop is increased to 8 units (each side of 2 units) then it would contribute to 2 units each to length and width of the fabric.

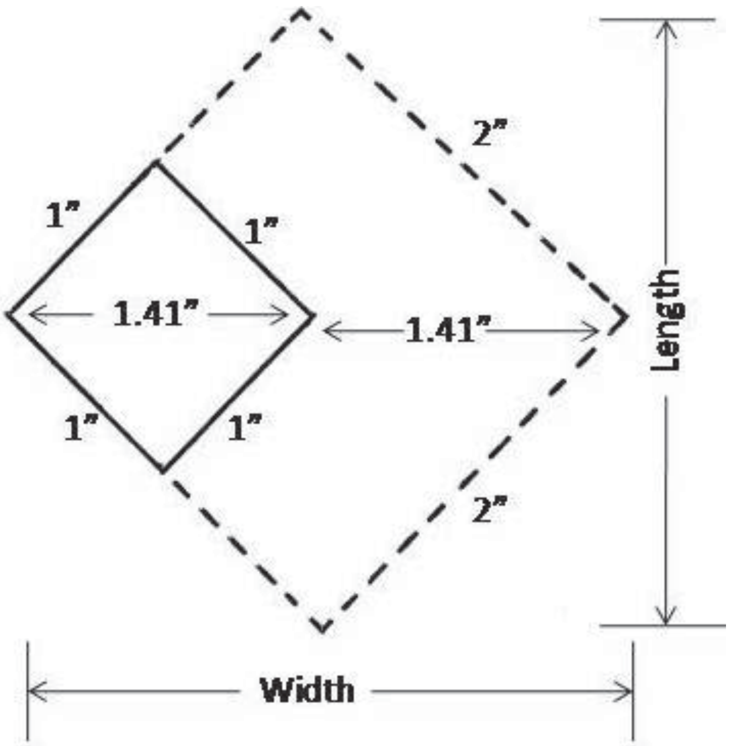


Figure 8.4 A plain loop in diamond form

In the first case the loop would occupy 1 sq. unit space in fabric and in the second instance it would occupy 4 times as much. Hence the loop length is directly related to length, width and area of the resultant fabric.

In place of diamond shaped loop, one may construct hinged lattices and mount a loop on such a lattice (Fig. 8.5.a). The lattice may be easily deformed both lengthwise and width wise (Fig. 8.5.b and c). It can be observed and stated from these figures that even though the loop length remains unchanged the dimensions of the resultant fabric change. Hence, the shape of the loop along with its length determines the dimensions of the fabric.

Figure 8.6 (a and b) clearly demonstrate the role of loop length in determining mechanical property of fabric. Three cables differing in diameter but of same length have been bent into loop form. On application of the same load, the loop made of thinnest cable deforms to the largest extent and the thickest cable deforms least. In case the cables are replaced with yarns of different diameter, the deformations of the loops will be similar to that occurred with the cables.

Consequently if the loop lengths are varied in proportion to the yarn diameter, all the loops deform to the same extent. From these observations it can be inferred as follows –

a) If two fabrics are knitted with same loop length from different yarn count, the fabric containing finer yarn will be deformed more easily.

b) For same count of yarn, fabric made up of larger loops will be more susceptible to distortion than one containing smaller loop length

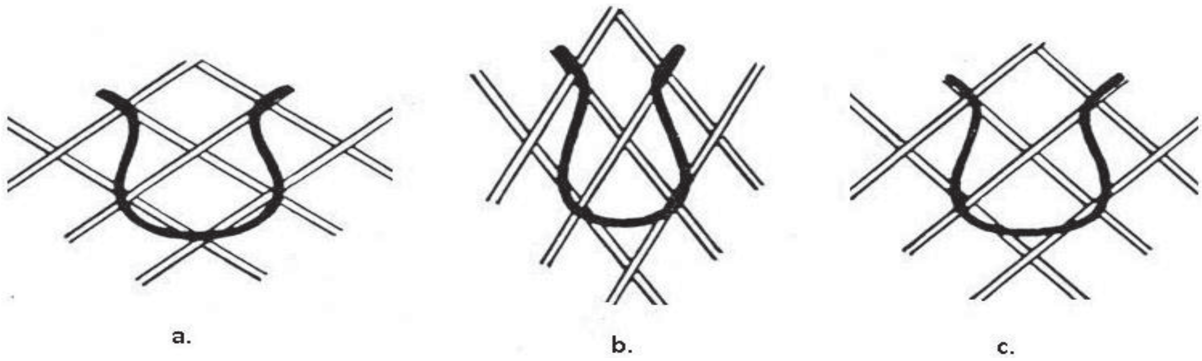


Figure 8.5 Plain loop in hinged form

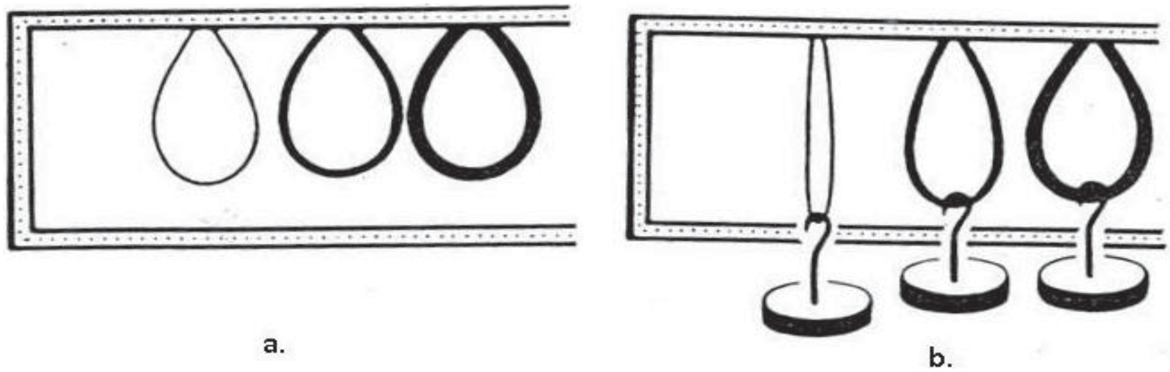


Figure 8.6 Different deformation in loops of equal length made of yarn of different diameter

8.8 Tightness Factor of Knitted Fabrics

Tightness factor (TF) is a number that indicates the extent to which the area of a knitted fabric is covered by the yarn. It is also an indication or measure of the relative looseness or tightness of a weft knitted fabric. It actually indicates the compactness of the knitted structure. Compactness is an important fabric property which influences durability, drape, handle, strength, abrasion resistance, shrinkage and dimensional stability. It also influences the dimensions such as length, width and thickness. It is equivalent to cover factor of a woven fabric and defined as the ratio of the area covered by the yarn in one loop to the area occupied by that loop (Fig. 8.7).

Let, length of loop or structural knitted cell is 'l', yarn diameter is'd' and stitch density is 'S'.

Tightness Factor= $1 / (\sqrt{N} \times l)$

The left side of this expression is termed as "Tightness Factor" (TF)) which can easily be obtained from the loop length if count of the yarn is known. The TF in metric system is expressed as √(Tex)/l where yarn count is Tex and loop length 'l' in mm.

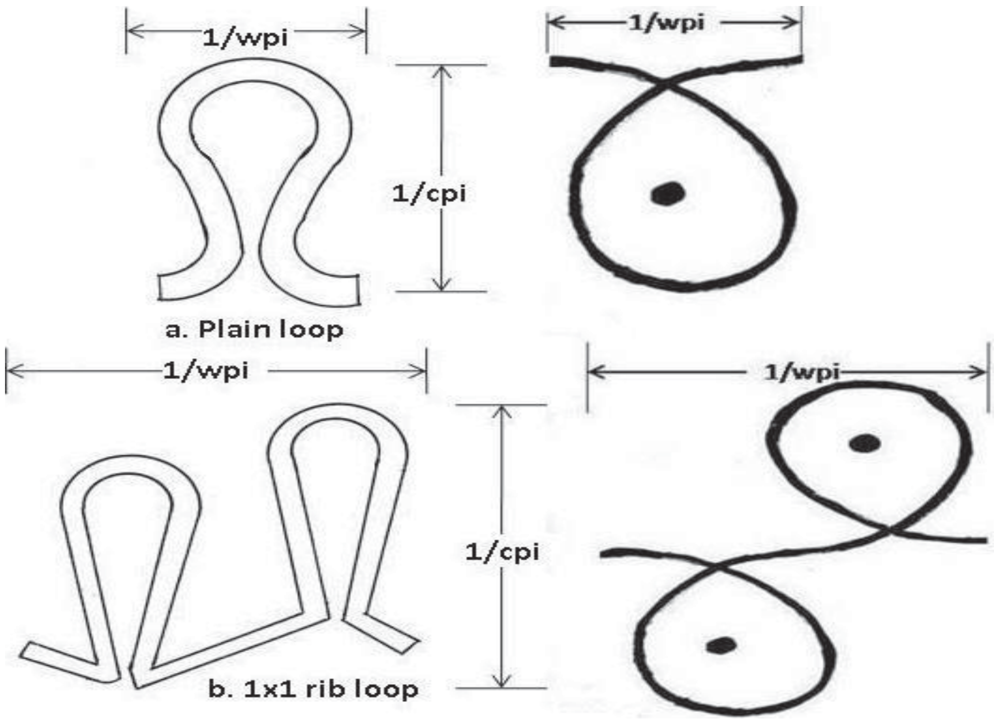


Figure 8.7 Tightness Factor of plain and rib knits

In general, the tightly knitted, compact structure with high tightness factor is more stable, less easily distorted than a slackly knitted open fabric with low tightness factor. The latter has the advantage of less rigidity and a generally softer handle and the task of the designer is to strike an acceptable balance between these conflicting demands of stability and handle. For most of the standard plain knitted fabrics (flat or circular), the TF ranges between 1.3 and 1.5, but the same may be even less than 1.0 or much higher than 1.5 depending upon the values of yarn count and loop length values.

The TF values of rib (double jersey) fabrics are not available in accessible text books and journals dealing with knitting. However, based on the findings of the research works carried out in the field of double jersey (rib) structure it is suggested that the expression of TF for plain fabrics is applicable for rib fabrics also. The values of the tightness factor of 1×1 rib knitted fabrics vary widely in the range of 0.3 to 0.6 for flatbed knitting and 0.48 to 0.67 for circular knitting. But, most of the values cluster around 0.5 to 0.55. It shows that single jersey fabrics are comparatively tighter than rib knitted double jersey fabrics. The indirect measurement of tightness may be the porosity or air-permeability of the fabrics. It has been observed that air-permeability of rib fabrics are much higher than single jersey fabrics made of same yarns under similar cam settings.

8.9 Relaxation of Knitted Fabrics

The loops of yarn that make a knitted fabric require little force for distortion, consequently the fabric will extend readily in width or length. Such loop distortion involves only change in shape, and yarn extension is not required except at high extension. Unless the yarn has poor recovery from bending, there is a chance that, once the deforming force is released, the potential energy of the stretched fabric will be sufficient to overcome the frictional forces opposing recovery and the undisturbed fabric will gradually recover from its distorted state. The difficulty is that, given a piece of knitted fabric, one does not know what state it is in. In the late 1940s systematic experimental studies of knitted fabric led to the concept of a "relaxed state" in which the fabric had a minimum of potential energy. Once the fabric is in this state, work must be done to distort it to any other state. On removal of the distorting force, the fabric will attempt to revert to its relaxed minimum energy state though it may not achieve this because of frictional restraints. These frictional forces can be minimized by application of lubricants and they may be overcome by supplying additional energy to the fabric. During 1960s, many different relaxation techniques

– soaking, steaming, agitation, vibration – were examined singly and in combination and a general agreement was reached that a combination of mild washing and tumble drying provides the most effective and reproducible method of relaxation. So to obtain fully relaxed state, the fabric should be wetted out for 24 hours in water at 40°C, briefly hydro- extracted to remove excess water and tumble dried for one hour at 70°C. Most recently an ultra-sonic technique has been applied for full relaxation of knitted structures.

8.10 Prediction of Weight and Shrinkage of Cotton Knits - The Starfish Project

There is a tremendous need to predict shrinkage and the final weight of any finished knitted fabric based only on a knowledge of the knitting parameters (machine, yarn and stitch length), the finishing process and the nominal finished dimensions. Conversely, the need is to specify the particular combination of knitting and finishing parameters that must be adhered to in order to generate the desired dimensions and shrinkage levels in the finished goods. If a simple and reliable such prediction system can be developed, that would be an invaluable tool in designing and developing new products and realistic manufacturing and finishing quality targets. Keeping this requirement in view "The Starfish Project" was conceived in 1978. It is an long term programme of applied research whose basic objective is to provide a set of working principles and a comprehensive data base for finished cotton knits so that just a simple, rational, reliable prediction system can gradually be developed and eventually perfected. Starfish is the short form of "Start as you mean to finish". The programme rests on the three logical foundations –

Defining a particular state of relaxation for cotton knits which is stable and reproducible called reference state on which all measurements and calculations are to be made.

Building a comprehensive data base of measurements made on systematic series of cotton fabrics which have been manufactured and processed under close quality control but nevertheless on a commercial scale and under commercially realistic conditions.

Developing suitable mathematical models for the reference state which connect the knitting for the reference state which connect the knitting and finishing parameters to the dimensions of the relaxed and finished fabrics in a simple and reliable manner.

8.11 Structural parameters of warp knitted fabrics

A simple warp knitted structure is shown in Fig. 8.8.

According to this figure, the course spacing, C = 1/(courses per inch)

= 1/c and wale spacing, W = 1/(wales per inch) = 1/w Where c = courses per inch and w = wales per inch.

As observed in the diagram, the loop length (l) in warp knitted structures is also proportional to the course and wale spacing in weft knitted structures.

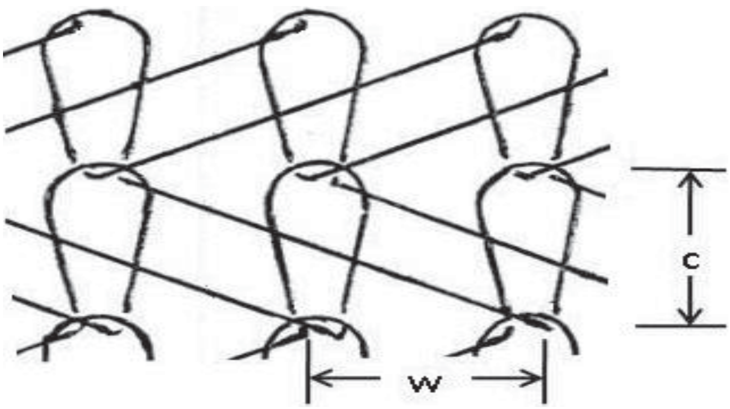


Figure 8.8 A simple warp knitted structure

So, [1/c × l]] or 1/c = constant × l or l × c = constant (K_c) and 1/w × al or 1/w = constant × l or l × w = constant (K_w).

8.12 Run-In Per Rack

In warp knitting all the yarn ends threaded through the guides of one guide bar knit the same construction and are fed equally from one beam only. The yarn consumption of each guide bar is called run-in and is measured as the length of each yarn knitted into the fabric during 480 knitting cycles. A working cycle of 480 knitted courses is called a rack. The yarn quantity can be measured with special measuring equipment or simply by marking one of the yarns close to the warp beam and then measuring its position after 480 cycles (1 rack). By feeding different amount of yarn into the knitting zone, the size of the loops is changed. A longer run-in per rack produces a slacker fabric with big loops while a shorter run-in per rack produces small and tight loops. Run-in per rack should always be recorded when a new fabric is produced. The run-in per rack may vary from guide bar to guide bar, the relative amount of yarn fed from each beam is also very important. The relation is called run-in ratio and the same is different for different fabric constructions and qualities. As reported by researchers, in a typical two bar machine the run-in ratio (front bar: back bar) is in the range of 1.19: 1.0 to 1.47 : 1.0. From the values, it can be stated that the loop produced by the front guide bar is bigger than the loop produced by the back guide bar. So, the length of warp to be wound in the beams shall vary according to the run-in ratio.

8.13 Yarn to Fabric Ratio

It is one of the important parameters for the calculations related to warp knitted fabric. The ratio between the length of yarn consumed by the knitting machine and the length of fabric which is produced can be calculated as:

“Yarn to fabric ratio” = (run-in per rack × courses per unit length) / 480.

This ratio may vary from guide bar to guide bar as well as with variation in courses per unit length. The length of warp required to produce a definite length of fabric which can be easily obtained if the ratio of yarn to fabric is known. For example, the yarn to fabric ratio for a particular guide bar when knitting a fabric of 20 courses per cm and run-in per rack of 240 cm

Yarn to fabric ratio = (240 × 20) / 480 = 10

So, 10 cm of warp is needed for knitting 1 cm of fabric.

It has been observed that run-in ratio values show a linear tendency when plotted against courses per centimetre and this linear relationship can be used to estimate the length of yarn needed to knit the length of fabric for most of the basic structures and for a full range of knitting qualities.

8.14 Tightness Factor of Warp Knitted Fabrics

As derived earlier, tightness factor (TF) of weft knitted fabric is expressed as

$TF = \sqrt{(Tex)}/l$

Where l is the loop length in millimetre and Tex is the yarn linear density. This relationship can simply be applied to warp knitted fabric produced on a machine with single guide bar. But for warp knitted fabrics produced with two or more guide bars, the tightness factor should be obtained by adding the tightness factors contributed by the individual guide bars. So, the tightness factor of a two guide bar fabric is given by the following relationship:

$TF= \sqrt{(Texf)}/l_f + \sqrt{(Texb)}/l_b$

Where suffixes f and b refer to front and back guide bars, and l is the stitch length equal to (run-in per rack)/480 and is measured in millimetres.

8.15 Standardization of Chain Link and Machine Gauge

Recently, on the basis of the success achieved in the coordinated conversion of guide bar identification to identical concepts, the two German warp knitting machinery manufacturers (Karl Mayer Textilmaschinenfabrik GmbH and Liba Textilmaschinenfabrik GmbH) have agreed on binding stipulations for their technology. According to agreement, there will be only one continuous numbering system with effect from 01/01/2004 onwards for pattern designation, beginning with 0, 1, 2 independently of the pattern drum version, and of whether a Tricot or Raschel machine is used. This also corresponds to the numbering system followed for all patterning systems operating by electronic guide bar control. At the same time the lapping numbering system will also be standardized to distinguish it adequately from the designations employed up to now. One example of such standardized system is as follows:

Closed lap construction –

Currently for a Tricot machine – 1 - 0 / 1 - 2 // Currently for a Raschel machine – 2 - 0 / 2 - 4//

From 01/01/2004, for all warp knitting machine – 1 - 0 / 1 - 2//

They have also agreed on a standardized system for specifying machine gauge (i.e., needles per 25.4 mm) on the pattern drum for both Tricot and Raschel Machines.

8.17 Yarn Count and Machine Gauge

The yarn thickness that can be used in warp knitting is limited by the size of the needle's hook and the space between the needle and the knock-over trick or sinker. A too fine yarn for the machine gauge only forms a mesh- like structure whereas, a too thick yarn will be chopped up by the descending needles into the tricks or the yarn may cause damage to the needle itself. When more than one guide bar is used, the resultant count of all the yarns wrapping any needle should be considered. The maximum yarn count for each machine gauge is given in Table 8.3. The Raschel knitting elements allow a somewhat coarser count to be knitted.

8.18 Grey Specification of Warp Knitted Fabric

A complete grey specification of a warp knitted fabric should include the following details:

Gauge of machine in needles per inch

Number of guide bars in use

Table 8.3 Maximum yarn count for Tricot and Raschel machines of different gauges

Machine gauge	Tricot Machine		Raschel Machine	
NPI)	Tex	Ne	Ne	Tex
10			165	4
12	115	5	130	5
14	92	6	105	6
16	76	8	88	7
18	62	9	72	8
20	52	11	60	10
22	44	13	50	12
24	36	16	42	14
26	29	20	35	17
28	25	24	29	20
30	21	28	24	25
32	16	37	19	31
36	10	59	13	45
40	6	100		

Number of ends in each warp beam

Types and linear densities of yarns used

Run-in per rack of warp coming from different beams

Knitted quality of the fabric in courses per inch or centimetre

Order of threading of warp in each guide bar

Lapping movement of each guide bar during one repeat of the pattern or details of the pattern wheels or pattern chains

Relative lateral positions of the guide bars at a given point in the lapping movements

Any special knitting instructions

8.19 Fabric Specifications

During recent years consciousness among purchasers and consumers has been developed for precisely specifying the standards of construction and performance of warp knitted fabrics. Such specifications may even include permitted tolerances on certain standards. Hence, in order to ensure the specifications, a lot of improvements have taken place in warping, knitting and subsequent dyeing and finishing operations. A typical composition of specifications for a widely used warp knitted locknit fabric may be as follows:

Yarn used in both guide bars (type, denier, lustre, twist, etc.)

Guide bar lapping movements

Finished fabric construction (cpi, wpi, etc.)

Run-in per rack and run-in ratio

Finished yield (length per unit weight and tolerance, GSM, etc.)

Dimensional stability (based on 30 minute boiling or some specified washing)

Colour fastness to washing, light and rubbing

Bursting strength

Type of finish

Fault rate

Additional tests for special fabrics (extensibility and recovery, air permeability, tear strength, seam strength, etc.)

Chapter 9 Application of Electronics in Knitting

9.1 Introduction

Knitting machines have been developed with mechanical controls and operated movements. The demanding requirements of modern knitting technology, however, emphasize the limitations of mechanical movements which are expensive to manufacture, slow and cumbersome in operation, difficult to adjust or alter, and subject to friction and wear.

Mechanical pattern and programming data for controlling knitting machines is stored in the form of punched cards, chains, rack-wheels, peg drums, and element butt arrangements. These are expensive in material, bulky in space on the machine or in storage, time-consuming to handle and alter, slow in operation, and provide restricted facilities.

Hydraulics, fluidics, and electronics provide alternative systems of power transmission and signal storage with the requisite speed and precision. Electronics offer the decisive advantages of convenient power-supply, compatibility with existing mechanical components, micro-miniaturization of circuitry, and economical data storage. In addition, electronic systems do not require to be of a size proportionate to their task or to operate on a one-to-one relationship with it.

Electronic selection or machine control is compatible with higher running speeds and eliminates complex mechanical arrangements, thus reducing supervisory requirements. It provides greater versatility as regards design parameters, simplifies the modification of repeat sequences and size, style and pattern-changing operations, and, in some cases, enables changes to occur whilst the machine is knitting

Electronic devices process information as binary digital logic signals that exist in two states, ON or OFF. This can be directly translated as 1 or 0, YES or NO, TRUE or FALSE, or magnetic ATTRACTION or REPULSION. This information can just as conveniently be translated into knitting states such as KNIT or TUCK, TUCK or MISS.

The binary digits can be arranged in the form of a programme where they can be encoded and converted into symbols to compose, for example, a knitting design or a machine programme.

9.2 Microprocessors and computers

The most important use of electronics is in microprocessor and computer systems. A computer can receive, store, retrieve, and communicate enormous quantities of information at phenomenal speeds. It can also manipulate, rearrange, select, and transform this information. It performs arithmetical or logical processes accurately at high speed after receiving the instructions (programme) and values (data) without the need for further intervention by the operator.

Flexibility in processing of data occurs because the system can be programmed to produce YES or NO decisions, based on the result of comparing and testing monitored data that then determine the choice of two alternative courses of action in the program of the system. These alternative courses within the main program sequence may include counted loop sequences, branching or jumping out of the main sequence, and selection of stored sub-routines.

It is these facilities that give electronically-controlled knitting pattern preparation and needle selection their extensive capabilities as compared with previously available methods. Inputs include switches, sensors on knitting machines, keyboards, light pens, tapes and discs; and outputs include actuators on knitting machines, lights, digital and graphical displays, tapes, and printers. Outside the system, the digital impulses may be changed from parallel to serial, or even analogue, form, or may be converted into light, sound, radio or carrier waves, or mechanical movements.

Although it is possible to directly program a system using switches, a matrix board, a keyboard or another input device, the processor (and probably the knitting machine) will be held waiting during this time-consuming operation. It is therefore preferable to record the program and data in an auxiliary memory store such as a tape or disc. Its contents can be rapidly inputted electronically into internal memory, as required, whilst using a direct input keyboard or switches for minor amendments or alterations during the running of the programme.

Some systems are programmed to interact with the operative who is thus able, within specified and guided limits, to change values of data, with the effects of the amendments being visually indicated by the system.

9.3 The Computerised Knitting Machine

Although knitting is still a mechanical action between the yarn and the knitting elements, the design of tomorrow's machines will be increasingly influenced by the facilities offered by electronics. Thus, whereas on mechanically controlled knitting machines nearly all the mechanical movements are linked to, and are triggered by, the revolution of the machine or traverse of the cam carriage, electronic controls can be dispersed and separately operated. In addition, their operation can be smoothly introduced in a series of gradual steps and not in a restricted number of large steps, as is the case with mechanical drive systems.

The electronically-controlled knitting machine can be part of a network of management communication links. A single control unit can control a complete bank of machines if necessary.

Unlike the mechanically-controlled machine, which is passively operated, stands alone and has no means of receiving and transmitting electronically generated data, the increasing automatic monitoring and adjustment facilities provided by microprocessor control on modern machines obviates the need for continual manual attention (Fig. 9.1).

Figure 9.1 Computerized Knitting Machine

Perhaps electronics has had its greatest impact in V-bed flat knitting, as a major factor in the successful development of shaping techniques. Electronics is also increasingly being employed in ‘intelligent’ stop motions, yarn feed systems, the design and preparation of knitting patterns, machine function control, pattern selection and striping.

9.4 Computer Graphics And Pattern Preparation

Of all knitting machines, the modern electronic V-bed flat machine, with its comprehensive patterning and garment shaping facilities, offers the greatest challenges as well as the greatest opportunities for the application of a CAD/CAM system.

Interactive computer graphics enables a dialogue to occur between the operator terminal and the system, with the resulting development of the design being immediately visually represented on the screen. The position is defined and located by two numbers in the Cartesian co-ordinate system. On the horizontal (X) axis, the numbering increases positively from zero towards the right, whilst on the vertical (Y) axis, the numbering increases positively upwards from zero at any point on the design.

Generally, an input device is employed that can be moved by hand in the direction of either axis, with its location and movement over the screen being indicated by a special character symbol termed a cursor. The physical movement of input devices such as digitizers, joysticks, and trackballs is converted by the system into the series of numbers, whereas a light pen detects the presence of light whose position is being generated on the screen.

Computer graphics provides a tool for the efficient creation and development of designs and overcomes tedious and repetitious aspects, enabling realistic representations of the knitted designs and garment shapes to be prepared, to be easily modified on the screen, and to be outputted as accurate, to-scale, coloured, hard-copy prints. It provides a much quicker response to customer requests than is possible with traditional knit sampling techniques whilst postponing the expensive knitting operation until such requirements have been fully identified. Recognized standards for these systems are now becoming established so that there will be greater compatibility in the future and choice of system will be less dependent upon the preference for a particular make of knitting machine.

The Quantel Paintbox has established the standard for an interactive computer graphic design system. It consists of a digitizing table, a pressure-sensitive stylus, an interactive computer with integral software, a digital frame store, hard disc storage and a colour monitor that communicates commands via menus displayed on the screen.

Selections include colour, brush size, paint mode, and the automatic drawing of various shapes and structures. Enclosed areas of the design may be filled in with a colour (if this facility is available) and the locations of the colours may be exchanged. Stored sub-routines may also be recalled to assist with the development of the design.

By relating the co-ordinate points of the design to other co-ordinate points within the design area, the design can be rapidly modified, with motifs being multiplied in number or geometrically transformed. Each transformation may occur separately or as a combined effect: for example, a motif may be reflected (mirror imaged) across the width (the X axis) or the depth (Y axis) of the design area. It can be translated (moved in a straight line without altering its appearance), rotated (moved in a circular path around a centre of rotation), and scaled (increased or decreased in size along the X or Y axis or along both axes). Graphic capabilities are obviously dependent upon the type of system and its software. Electronic pattern preparation thus provides the designer with an immediate visual representation of the design as it is being conceived, amended, and edited, without recourse to the knitting of trial swatches. The grading of sizes and the introduction, manipulation and placing of shapes and colours, is achieved with the minimum of effort and the elimination of all tedious and repetitious actions.

The program can be structured to guide and assist the designer and thus ensure that the resultant design is compatible with the knitting machine and the end-use requirements. Once a satisfactory design is achieved, a permanent record may be outputted onto hard copy and/or onto a carrier acceptable for controlling the knitting machine.

Not only is a programme required for knitting the fabric structure, one is also required for knitting the garment-length sequence, and a further programme is required for shaping. Many automatic modules are already installed that can be quickly recalled and ‘seamlessly’ co-operate with each other. The technician is guided throughout his programming by software that recognizes the constraints imposed by the fabric and the technical specification of the knitting machine.

9.5 The Stoll CAD Pattern Preparation System

The Stoll SIRIX is a complete design, patterning and programming system originally specially developed from Apple II PC software. It caters for every application in V-bed flat knitting. It uses icons and windows to graphically support the generation and development of knitting programmes for Stoll CMS electronic flat machines. SIRIX has a hierarchy of files holding folders. These can be opened by a double click of the mouse on an icon. It simplifies pattern drafting and speeds-up the processes required in the production of knitted fabric and garments. Fabric depiction and programme drafting is carried out on-screen, without the need to interrupt production on the machine.

The multi-tasking facility permits simultaneous operation of a wide variety of programmes. These are controlled via the graphically-oriented user interface. Patterns can be designed using jacquard colours and the Sintral programming language, or directly by defining stitches and modules. These can then be transformed automatically into a knitting programme simply by pressing a button. Sintral is the text editor, which facilitates the creation of knitting programmes using plain language instructions. Designs or programmes are analyzed, processed and tested, then automatically translated into Sintral, then presented to the monitor or loaded into the machine.

The design programme is a ‘Paint’ programme that provides a palette of colours, shades, brush shapes and sizes, and design tools. Using the yarn programme, yarn types, shades, and textures can be generated and stored to closely simulate knitted panels, in advance of the knitting process.

Sophisticated colour printers can produce realistic images of the garment which, it is hoped, will reduce the time-consuming process of swatching and sample development on the knitting machine. Once the design is completed, a model can be called-up onto the screen whose three-dimensional appearance simulates the wearing of a garment made from the design.

A recognition that designers and technicians require different information as the sample is developed has led to the provision of two separate but linked and constantly up-dated screen windows. The technical window presents the developing design in the form of running thread notations and technical data, whereas the design window shows the design as a knitted structure. Each can be displayed as and when required, and changes on one are automatically up-dated on the other (Fig. 9.2).

The grid or raster programme works with peripheral input devices including scanners and cameras, or any programme containing an image. It adjusts images to the correct size for the number of wales and courses in the required design. An automatic colour reduction programme reduces the number of shades to the number of yarn colours to be used in the jacquard design.

The jacquard programme takes over after the grid programme, and has an extensive tool and colour palette. The pattern field and stitch size are selected and the pattern motif is drawn onto a grid. Patterns can be depicted in the form of colours, stitch icons, or Sintral symbols. Stored designs can be called up. Shapes and areas can be re-scaled, manipulated, rotated, flipped, multiplied, deleted, or interchanged. Whilst a motif is being moved, it becomes transparent, so that the background can be seen through it, thus making it easier to accurately position.

Structure patterns are drawn using stitch icons that graphically depict stitch appearance. Pattern elements, such as cables, Aran and lace, are available in modules to build into the programme. The computer translates into machine language other relevant information that can be inputted by the designer, such as yarn carrier allocation and knitted stitch sizes.

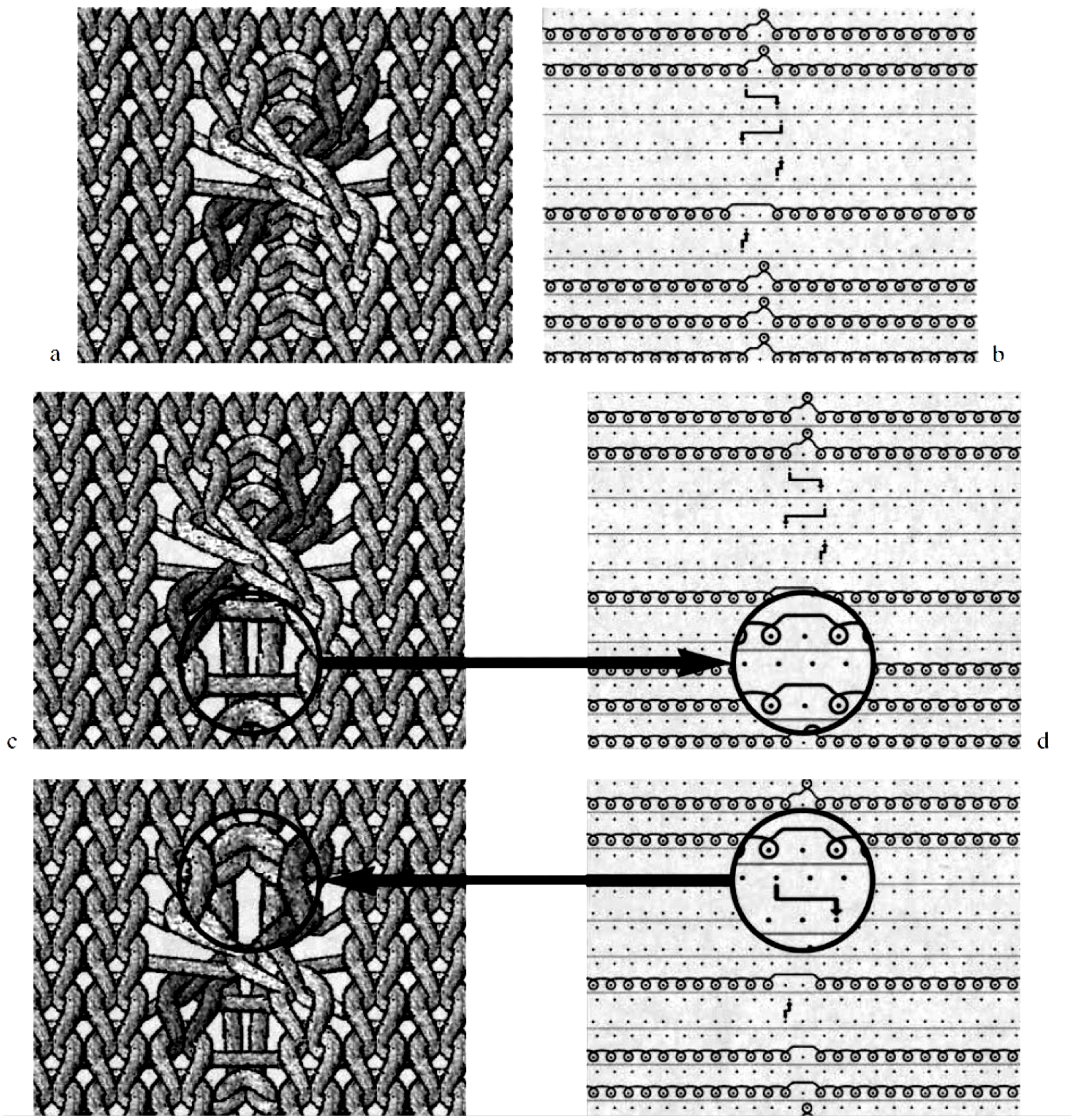


Figure 9.2 Linked windows optional views of fabric and Technical design

The intarsia programme enables complex programmes for the production of intarsia designs to be generated almost completely automatically, based on following the rules of intarsia knitting. The pattern sketch is converted into an intarsia design in several stages. Intarsia designs are drawn using intarsia stitch icons for colours, structure and, if required, ladder backing. From the intarsia motifs on the screen, the SIRIX generates individual colour fields that are allocated to individual yarn feeders. The programme step 'Yarn Feeder' works out the best starting point for the yarn feeder and inserts the lines necessary to position it. From the intarsia pattern needle selection, feeder paths and, if required, ladder backing on the rear bed is generated.

In the shaping (fully-fashioned) programme, the shape of the panel, e.g. sleeve, back, or front with a V-neck, is superimposed graphically over the ground pattern. Cables and Aran motifs are automatically faded-out at the selvedges. A complete automatic-knitting programme is generated from a drawn shape. A garment shape is selected from the file, inserted in the form of an area over the jacquard, and positioned where required. The width of the selvedge area can be varied and different stitch structures selected. The shape is cut out of the jacquard.

Narrowing modules are automatically inserted to give the required shape. The FF programme generates the Sintral programme that contains all the necessary data for machine control. The module programme breaks the modules down into complete knitting sequences. Stitch transfers can be programmed automatically.

The programme Sirix Auto-Sintral automatically generates the complete Sintral knitting programme. Starts and repeats for size changes can be selected. Once one size has been knitted, the CMS machine automatically changes-over to producing the next size.

The analyse programme tests the knitting programme, line-by-line, using an internal analysis routine, simulating without involving the knitting machine. Knitting information such as needle selection, yarn feeders, racking, etc. are carried in a programme log and can be assessed at any time. The selection programme presents the analyse data, course by course, in notation form, permitting rapid checking of pattern accuracy.

The DIM 3 programme permits the three-dimensional representation of knitted fabric on the screen. This can be enlarged, rotated and manipulated, from the face or reverse, at any angle. The fabric can be appraised as a whole or in fine detail.

On-line generates a direct connection to all the machines in the plant. Knitting programmes are transferred, on-line, to and from the knitting machines on the network, and production sequences are centrally controlled. Data on machine stoppages and reasons, as well as on production progress can be collected.

Tele-Service provides long-distance data transmission of knitting programmes as well as remote diagnosis of CMS flat knitting machines and SIRIX pattern preparation systems. On the CMS machine, the touch control screen displays pictogram symbols providing information on the progress of knitting production such as knitting speeds, settings of cams, yarn feeders and fabric take-down. Patterns and garment programme sequences can be read into the machine memory, either from floppy discs or directly on-line from the pattern-preparation unit.

9.6 Merits of electronic elements and devices

Smaller in size, micro-miniaturization of circuitry

Less response time

Compatible with existing mechanical systems

Very high capacity

Highly sensitive

Automatic monitoring

High adjusting facility

Easy to transport

Less power consumption

9.7 Fields of Applications of Electronics in Knitting

Stop motions

Yarn feed system

Course and stitch length

Yarn tension

Pattern selection

Stripping

Shaping of product

Monitoring of various motions and settings

Cylinder temperature and oil pressure

Online quality measurement and control

Operational data acquisition

Preparation of design and knitting pattern (CAD)

Production of knitted structures (CAM)

Out of many applications, only the last two points, i.e., CAD (computer- aided designing) and CAM (computer-aided manufacturing) have been discussed in the under-going. In both the cases, the main electronic device used is computer. In today's context, computer is an electronic device which can process (compute) raw input data for generating desired output. The input of raw data or information may be given to the central processing unit (CPU) through keyboard, mouse, scanner, video camera, floppy/CD, magnetic tape, digitizer, etc. After processing of the input data, the output data can be either viewed on the monitor or obtained as hardcopy printout, floppy/CD, magnetic tape, etc.

The monitor is the interface between the computer CPU and the user.

This interface sets up a two way (interactive) communication. The computer upon receiving the input signal can modify the displayed picture/design. To the user, it appears that the picture/design is changing in response to his or her command. He or she can give a series of commands each one generating a graphical response from the computer. In this way he/she maintains a conversation or dialogue with the computer. Hence, CAD is referred to as "interactive computer graphics or graphical user interactive (GUI)".

9.8 Computer-Aided Designing and Manufacturing

9.8.1 Introduction to CAD

In today's competitive and dynamic textile market, there is a need to produce new designs, structures, textures and blends at a competitive price and that too without wasting much time for the same. The conventional way of fabric designing based on graph paper technique and sample knitting on experimental knitting machine has limitations in terms of creativity and productivity. Also the designers have difficulty in keeping pace with the fast changing trends of the market. The invention of high resolution colour graphics computer has opened its use in textile design all over the world and has helped in reducing the time required from design conception to sample production.

9.8.2 Textile CAD

Textile CAD (CATD) is a computerized design facility for designing, simulating the fabric in the monitor / on paper and generating the necessary manufacturing documents to ensure total accuracy in implementation of the design concept. The system is conceived basically for novelty knitted structures, though it can be used as well as for less complicated designs. The CAD softwares presently available are for following textile uses:

1. Woven fabric design (dobby and jacquard)
2. Knitted fabric design
3. Printed fabric design
4. Garment design

9.9 Computer-Aided Knitted Fabric Design

9.9.1 Existing design mode

Designs – Designs are either drawn or painted on paper. The design calls for a level of artistry both in terms of free hand and painting expertise.

Pattern making – With the designs thus mode, the pattern maker works out the full knitting scheme on paper which includes the inter-looping pattern of the different yarns used in knitting. This serves as a manufacturing document to set the design elements in the knitting machine.

Problems in existing design mode

(a) The visual impact of the fabric is available only after the design is transferred to the knitting machine and sample fabric is made. In many cases, the fabric may not meet the customer's approval and the whole process may have to be repeated. This recursive process is time consuming with little guarantee for the optimality of the final solution.

(b) It is not possible to have an immediate understanding of the visual impact of the design with minor design/ colour/ yarn changes. This poses a serious obstacle in negotiations with overseas customers.

(c) The process of evolving a pattern from the design is tedious and is amenable to errors. The transfer from the pattern to the knitting machine (either through jacquard card punching, needle butt cam set-out or pattern wheel pegging) can also generate errors. All these errors will be noticed only after the sample fabric is made.

(d) Most of the expert firms in USA or elsewhere are accustomed to computer interface. Lack of this interface poses a problem in terms of design communication and response level.

(e) In most cases, the design expertise is concentrated among few specialists, with all consequent problems arising from sharing a scarce resource.

9.9.2 Computerized Mode

The important features of computerized mode of designing can be stated as follows:

(a) Designs can be drawn on the computer using free hand techniques, symbol manipulation and a host of other advance features, which enable evolution of computer designs within very short time period.

(b) Database can be built on all designs/ manufacturing parameters, including the design element (jacquard) capacity, yarn specifications, colour palette, knitted structures, etc., and thus data is available at hand for simulating the fabric and generating manufacturing documents.

(c) Using this data and the design, the total fabric is simulated and the full visual impact of the design is available on the monitor. Changes as desired in any of the specifications including colour can be effected and the simulated version can be immediately evaluated.

(d) The computer generates all the manufacturing documents required to set the design elements (jacquard).

(e) The computer can also be directly interfaced with an electronic jacquard thus enabling direct transfer of the design concept to manufacturing without error.

Advantages of Computerized Mode

(a) Creation of new designs on the computer permits trial of number of variations. Small design modules (motifs) which have been earlier found effective can be positioned and posted on new designs to create new patterns.

(b) Additionally, if a sample fabric or the design on paper is to be copied with some modifications, the same can be readily done using colour scanning facility.

(c) It is possible to play around with colour shades, motifs and other design variations and immediately assess the total effect.

(d) Computerization can display on screen and reproduce on paper, the total simulated fabric and thus makes it possible to understand the fabric right at design stage.

(e) There is no possibility of error while creating the pattern from the design.

(f) With CAD installation, the long-time of manual designing is shortened and the design process itself becomes skill independent.

(g) The use of computer in design in the long run will be a necessity, especially for the export market. With the CAD facility, it is possible to transit designs to remove locations with total integrity.

9.1 0 Types Of CAD For Knitting and Other Peripherals

CAD software for knitted textile design was developed around 1970s and became commercially available in the market in the beginning of the last decade of the last century and has gradually become popular throughout the world. Till today, the CAD soft-wares tried in India are mainly imported. Moreover, those are generally coming with the knitting machines fitted with electronic jacquards. The packages available are expensive and they work on dedicated specialized hardware, and therefore, it is difficult to maintain. In view of the above, there is a strong need to develop indigenously a low cost design system as in the case of woven textile design. The indigenously developed software packages (CAD) should fulfil the design requirements of all the sectors of knitting industry.

The common hardware system and other peripherals required for using CAD are given below:

(a) P.C. with Pentium IV and above processor

(b) 15 inch and above colour monitor

(c) High resolution scanner

(d) Inkjet/desk jet colour printer

(e) Dot-matrix printer

(f) Graphic/digitizing tablet with stylus or joystick (electronic pen)

(g) Uninterrupted power supply (UPS)

(h) Constant voltage transformer (CVT)

Generally, the jacquard software packages have been developed using latest Image – Processing Technique. The design motif can either be input through scanning devices like video camera, scanner or manually drawn with the help of keyboard and other input devices. The computer can be interfaced on-line to a knitting machine fitted with electronic jacquard. Design can also be saved in the format for electronic jacquard.

Computer-aided design system with electronic jacquard is a very powerful tool, now available in the market for designers. It has immense potential for creating either innovative designs or converting existing ideas into designs speedily and most cost effectively. Such a system would be very useful in meeting the challenges in international as well as domestic market by way of improving aesthetic appeal and increasing production speed.

9.11 Some of the exclusive features of standard software

The features of the available CAD software varies from make to make, but some of the important features should be:

Powerful drawing and editing tools

Import and export facility

User defined brushes.

Image resizing

Image wrapping

Choice of millions colours

Colour libraries

Loading/ saving colour palettes.

Unlimited knitted designs library

Automatic creation of simple knitted structures

Automatic drawing of various shapes and structures

Knitted design pattern manipulation

Designs with additional speciality yarns

Complex cloth structures

Auto pattern generation

Automatic float/tuck checking and correction

Graph printing with unique marks to distinguish layers and design segments

User defined grid size for scrutiny and image editing

Instant preview of front and back of fabric

View facility for multiple repeats

Yarn specification possible in different systems

Replicate pattern including mirror, rotation and copying at an angle

Save number of colour combinations of any design and view simultaneously

3D simulation

Yarn development facility for dyed, tie and dye, melange, grindelia etc.

Instant calculation of fabric weight and cost

Shaping and garment length sequencing

3-dimensional simulation of the garment on the virtual model

Out of many the latest software packages of M/s. Stoll, M/s. Shima Seiki, M/s. Mayer and Cie and M/s. Karl-Mayer have all these features and many more and those are dominating the world market.

9.12 Computer-Aided Manufacturing of Knitted Fabrics (CAM)

The design and related information produced in computer using CAD cannot be taken in the knitting machine with existing set up (say mechanical jacquard) for knitting the desired product. But the design developed using CAD can be converted into fabric in conventional knitting machines through card punching and using those punched cards in the mechanical jacquards. On the other hand, the computer can be interfaced with the knitting machine for directly transferring the design produced in the computer to the knitting machine. For interfacing the computer with knitting machine (CAM), there shall be some special devices in the knitting machine which will read the design information from the computer and the knitting machine must be equipped with electronic / computerized jacquard. The special device used for the purpose is generally micro- processor based and known as controller. The electronic jacquard not only interfaces the knitting machine with computer but also results considerable increase in knitting machine speed. The electronic jacquard offers:

Improved selection precision and less wear and tear due to less mechanical function

High flexibility through quicker design change

No need of card punching and card storing

Individual jacquard makers employ their own methods for converting the electronic control signals into needle selection/movements, but all incorporate the following elements:

Solenoids forming the interface between control signal and mechanism

A surge current to the solenoids for needle selection

A few reputed international manufacturers of knitting machines with electronic or computerized needle selection are:

(a) M/s. Shima Seiki (d) M/s. Bentley

(b) M/s. Brothers (e) M/s. Mayer and Cie

(c) M/s. Stoll (f) M/s. Karl-Mayer

9.13 Data Management System in Electronic Jacquard

9.13.1 Data Transfer

The design information produced in the computer using CAD may be sent to the knitting machine fitted with electronic jacquard by any one of the followings:

(a) Dedicated computer

(b) Ethernet networking

(c) EPROM

(d) Floppy / CD / Pen drive

Out of the different systems the last one is more popular and offers maximum advantages for commercial applications where as the dedicated computer is mainly used in academic and R and D purposes.

9.13.2 Operational Data Acquisition

The task of operational data acquisition is to punctually supply detailed and complete information on lot sizes, target dates and costs so that the correct product can be delivered at the correct time in optimum quality and with minimum storage time. To do this, it is necessary to continuously measure process parameters on knitting machine which include physical measurements as well as operational and financial indices. Instruments used for such control and monitoring functions must fulfil a number of network conditions in order to be able to offer specific computer-aided information. Operational data acquisition systems are nowadays considered as CIM (computer integrated manufacturing). For the purpose, each knitting machine is connected with a computer terminal which automatically registers data based on order and personnel during knitting, as well as running times, error based idle times and causes of faults and calculates performance values. Yarn consumption is permanently measured. If it deviates from prescribed tolerances the knitting machine is switched off, and this enhances quality assurance measures during periods when supervision is reduced. All the computer terminals in the knitting machines are connected with a central computer, which may be located inside the knitting plant or to a remote place over a long distance. The central computer can access and process data from the individual machine computers for getting production related information as and when required. The shift in-charge or manager is in a position to quickly note such machines which deviate from nominal range and resort to appropriate corrective actions. The system delivers conclusive data in order to utilize knitting machines article-based under optimum speeds and personnel allotments. Besides this, data is incorporated in cost accounting, payment and the momentary orders in hand. A further application of this system is in the field of piece good registration. Without being influenced by fly, dust and humidity, the computer terminal directly takes over the piece good weight from the balance, stores the number of the pieces, the machine and the person per code card via a traction scanner or a reading pistol, sends the data with a time registration to the control room and immediately triggers the linked label printer.

The combination of CAD and CAM in knitting is in general a costly affair. In order to make computer-aided designing and knitting cheaper, some knitting machines are available with built-in computer – a small monitor, key board with few function keys and memory. A large number of designs are in the library of the memory for application as and when required. Moreover, new designs can be developed using the functional keys. Any design available in the memory or developed by the knitter can be called on for knitting the same on knitted structure. Fig. 9.3 shows the typical example of such facility found in Model KR-850 of M/s. Brothers Industries Ltd., Japan.

9.9 Knitting Machine With Built-In Computer

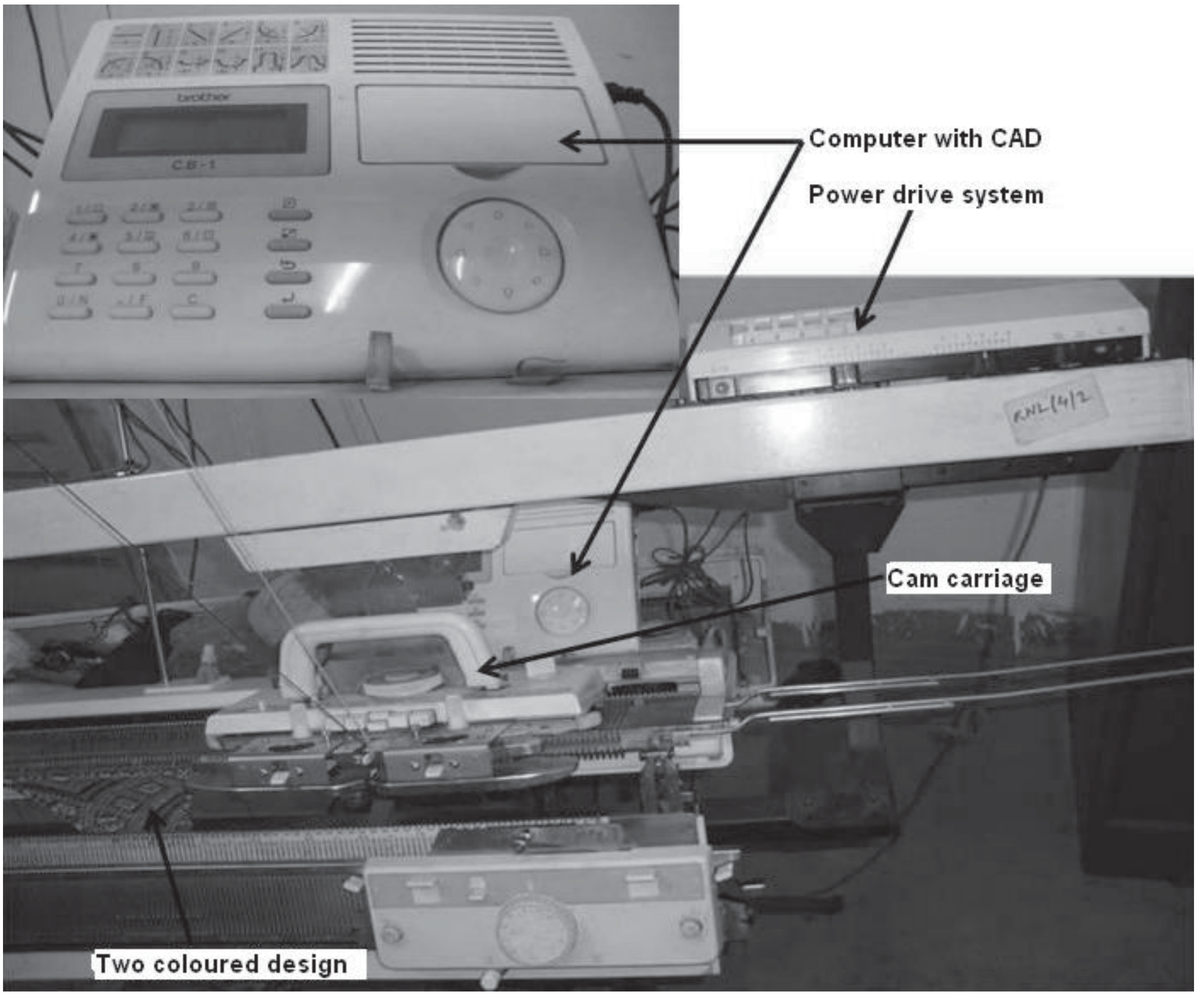
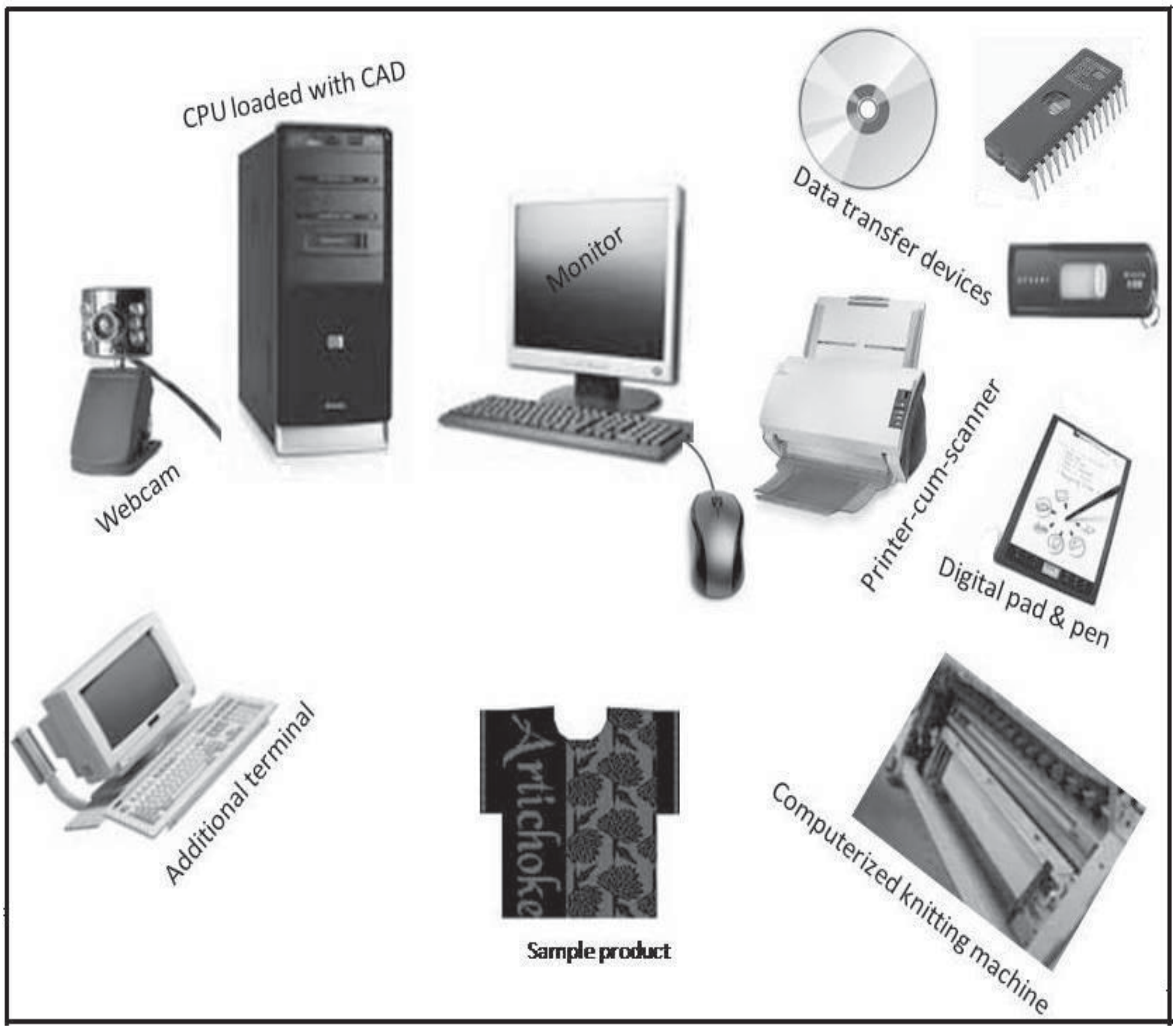


Figure 9.3 Flatbed knitting machine with built-in computer.

9.10 Design Studio

The design studio for effective implementation of the CAD and CAM system in knitting is the new concept and yet to be popularized. Generally, bulk commercial production of any design starts only when the sample produced is approved by the concerned persons. For the purpose of production of samples of new designs without wasting much time, the best and recent technique is to set-up a small studio having computer- aided knitted structure designing and knitting facilities. The proposed set- up of CAD and CAM studio as shown in Fig. 9.4, is not only essential for quick sample development but also must for global competition in the twenty first century. This set-up also makes it possible to exchange design information instantly throughout the world. A real fabric produced with the help of CAD and CAM is shown in Fig.

9.5. The signature of the author of this book made by digital pen (Stylus) was taken as input for making the design with the help of CAD and the output of the same was produced in the form of knitted fabric using two colours in 1996 at the University of Leeds, U. K.



9.4 Studio set-up for computer aided designing and manufacturing of knitted structures.

9.5 Fabric made in knitting using CAD & CAM.

Chapter 10 Developments in Weft and Warp Knitting

10.1 Introduction

Developments in knitting (machine, process and products), the second most popular technique of fabric manufacture has attained a very high level keeping in view –

1. Better quality product
2. Higher rate of production at higher speed / working width
3. Product diversification
4. Simplified/Short cut technique of production
5. Lower rate of production cost
6. Automation and more control of human on machine
7. Protection of environment
8. Better life style
9. Background
10. Curious and innovative mind
11. Will power
12. Desire for better living
13. Need to overcome the threats of nature

10.1.1 Developments in Flat Bed Weft Knitting

Power drive

Intarsia knitting

Multi-gauge machine (CMS 340 of M/s. STOLL) as well as intarsia attachment

Semi or full fashioned garment length machine (seamless garment knitting) (Fig. 10.1)

Provision for passing of individual yarn through pot eyes, knot catcher and tensioner

Yarn carrier up to 16

Individual drive

Option for selection

Four beds in a machine (Vesta Multi of M/s. Steiger)

Purl knitting

Electronic jacquard

CAD and CAM

10.1.2 Developments in Warp Knitting

Guide bars in a machine up to 78

Two needle bars in a machine

Seamless garment knitting

Steplessly adjustable pile height

Wide variety of special structures

Machines with multi guide bars can produce artificial blood vessels, patterned panty hose, tubular sacks, etc.

Dimensional stable fabric with weft insertion and Co-We-Nit technique

Geo-textiles, industrial textiles, fishing nets, etc., are the new product range

Light weight composite can be produced

Spacer and many speciality fabrics in double needle bar machine

Electronically controlled guide bar selection and its movement

Up to 3500 courses per minute

Some modern and popular models of warp knitting machines are -

Karl Mayer's Jacquardtronik MRP 73 / 1

Karl Mayer's Seamless Smart (RDPJ 4/2 and 6/2 and DJ 4/2 and 6/2)

10.2 The Shima Total Design System

Since developing the Micro SDS pattern preparation system, Shima have introduced a series of systems with improved hardware and software according to industry's needs.

The Shima Total Design System is a totally-integrated knit production system that allows all stages – planning, design, evaluation, production, and sales promotion – to be integrated into a smooth work-flow:

1. The designer, using computer-graphic paint software and a pressure-sensitive airbrush, creates concept drawings. Scanned-in images can be used to create storyboards.

2. A fully-fashioned pattern for shaping is created, using a pattern CAD program for knitting. The working pattern is then displayed using KnitPaint software. Courses and wales are converted into numbers of loops. Jacquard, intarsia and structure patterns can be created separately.

3. When each pattern is complete, KnitPaint automatically combines all patterns into usable knitting data, customised to the required Shima machine. Machine data is converted for intarsia using the auto yarn carrier selection function.

4. The loop simulation programme uses yarns either scanned or painted or created by the yarn creation programme.

5. The resulting simulated knit pattern can then be draped onto models using the mesh-mapping function. A mesh grid is created to conform to each fully fashioned piece, such as the front body, back body, and sleeves, and the simulated knit pattern is draped directly over that piece. The mesh mapping allows shadows and wrinkles to be maintained from the original image.

6. A database of models wearing various types of knitwear (V-neck, neck, cardigan, etc.) for which the mesh grids are ready-made is available.

10.3 Seamless Glove Knitting

The Shima Seiki Company has perfected a fully-automatic method of glove knitting in tubular plain on a small width V-bed machine (Fig. 10.1). Each finger is knitted in turn from its tip, with its loops then being held until the palm sequence commences. The glove is completed and pressed-off with an elasticated mock rib cuff. Control of knitting across the varying width is assisted by spring-controlled holding down sinkers (now housed in the needle cylinder) and a variable traverse of the cam-carriage. A digital inverter provides infinitely variable speeds and smooth operation.

Machine gauges range from coarse gauge E 5, E 7, E 8 to fine E 10, for work, driving and fashion gloves. E 13 and E 15 are ultra-fine for precision work and special applications. Knitting speeds are approximately 1 minute 40 seconds for an E 5 glove to 3 minutes 7 seconds for an E 13 glove. An associated development is the five-toe sock-knitting machine in E 10 and E 13 gauges with 60 and 74 needles.

It has a special picker mechanism for knitting the heel, and the step motor stitch control has 90 levels.

Figure 10.1 Short-Bed Computerised Flat Knitting Machine

10.4 The Wholegarment Knitting Technique

Shima Seiki launched their patented Whole Garment technique at ITMA‘95 with two different V-bed models, each having unique features. These involve integrally and seamlessly knitting a complete tubular garment on a V-bed rib machine. A new feature of this technique is the ability to knit tubular rib with a high wale density and therefore improved extensibility and appearance.

Whole Garment knitting removes or reduces the need for subsequent making-up (and in some cases cutting) operations, consequently reducing the garment throughput time and work in progress. It also provides the potential for introducing novel styling features into knitwear garments.

The key concept of Whole Garment knitting is the facility to knit seamless body and sleeve tubes of virtually any type of plain, rib or purl construction, plus the ability to increase or decrease the sizes of the tubes and to move or merge them together as and when required during the garment knitting sequence.

The technique of knitting tubular courses of plain knit on a conventional V-bed flat machine is well understood and is used in the production of complete gloves on Shima Seiki automatic glove knitting machines.

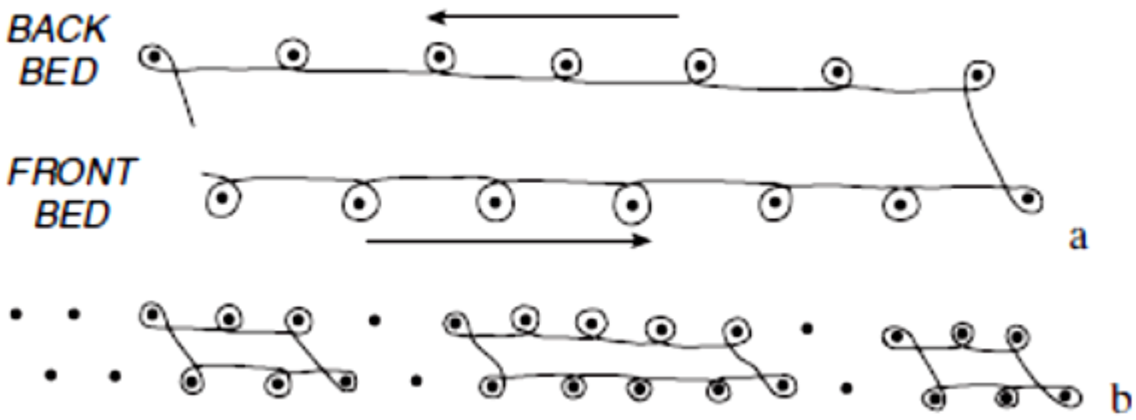


Fig. 10.2 Tubular plain knitting on a flat machine.

In Fig. 10.2a, the running thread notations show the production of tubular plain in two traverses on a conventional V-bed flat machine. As the yarn passes across to the loops on the other needle bed, at each turn round of the cam-carriage a tubular course is knitted in plain fabric with the face loops on the outside and the reverse stitches on the inside of the tube. A number of tubular structures can be knitted at the same time (Fig. 10.2 b); these can form the start of sleeves and a body.

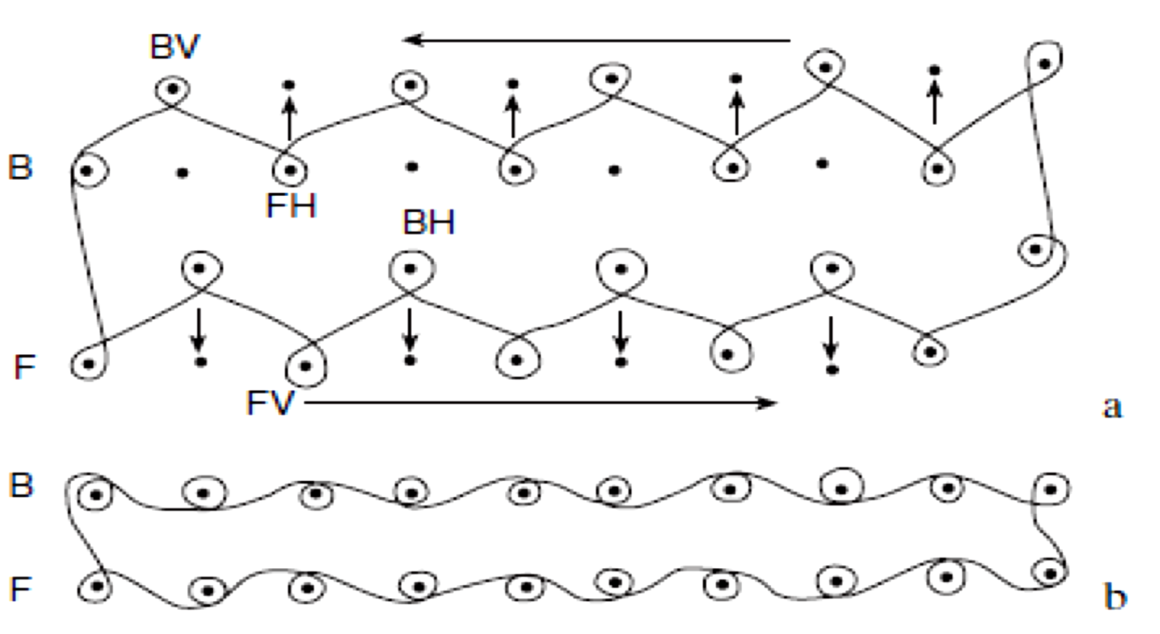


Fig. 10.3 Tubular rib knitted on a carefully arranged needle sequence.

Using loop transfer and other techniques to introduce or remove needles involved in knitting, it is possible to increase or decrease the size of the fabric tube, to move and merge it into other fabric tubes at a controlled rate, and to semi- or fully-close the tube either at the start or the end of the knitting sequence (Fig. 10.2 b).

In order to integrally knit tubular-shaped garments, however, it is necessary to be able to knit tubular rib courses as and when required, particularly for the garment borders and the cuffs of sleeves.

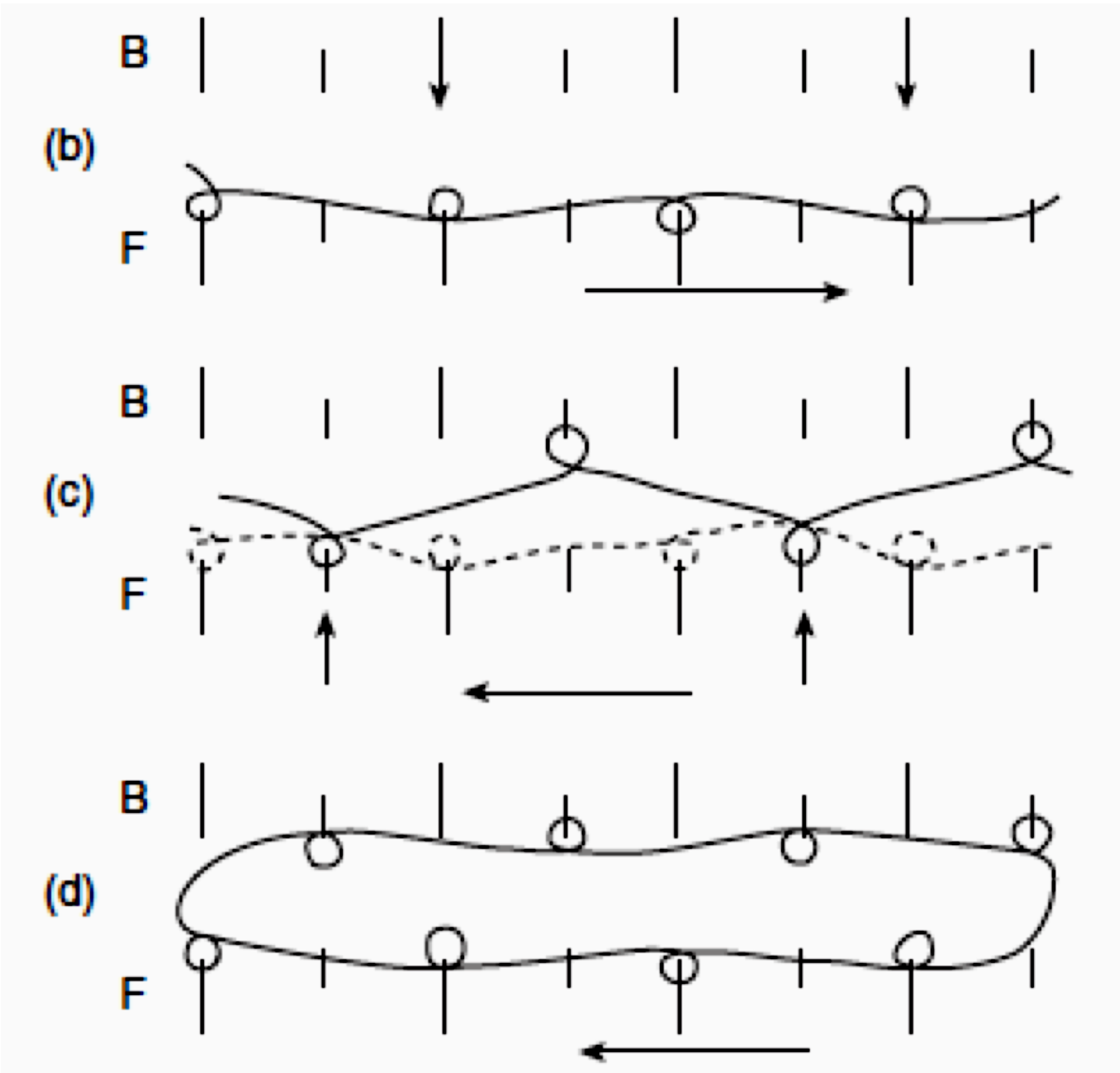


Fig. 10.3 Half Gauge Tubular Rib.

The knitting of tubular courses of rib on a V-bed rib machine (Figures 10.3 a and b) requires a carefully arranged sequence, particularly if a commercially acceptable wale density of rib is to be knitted. The problem is that in each traverse, front and back bed needles are required to knit the course of rib. The objective is for the front bed needles to eventually receive a complete traverse course of rib (face and reverse) loops and for the back bed to receive the return traverse course of rib loops.

The knitting of tubular rib on a conventional two needle bed flat machine does not, however, produce a rib that is very acceptable as far as extensibility and appearance is concerned because it is essentially knitted on only half the available needles (Fig. 10.3 d). A course of 1 X 1 rib is first knitted using both needle beds (Fig. 10.3 a) and is then transferred off onto one single bed (Fig. 10.3 b).

In order to receive transferred rib loops, complementary needles in the opposite bed must be empty of loops whilst other needles in that bed retain their loops from the same rib course of knitting. Additionally, in order to shape the garment by widening and narrowing or joining, tubular courses of rib are required to be transferred laterally onto other needles in the same bed.

The needles that are active therefore require careful selection so that the maximum possible number are involved in knitting. The linear distance between adjacent needles loops must be kept to a minimum, otherwise the extensibility of the rib wales will be seriously impaired.

The Shima solution to the dilemma is to provide machines with four sets of needles, two sets for each traverse row of the tubular rib, instead of the two needle beds available on conventional V-bed flat machines. Shima introduced two models each with a different needle bed configuration:

1 The model SWG-X configuration uses four needle beds, each having an identical arrangement of needles and selection elements providing for knit, tuck, miss and rib loop transfer. Two additional needle beds are positioned at an angle of 5 to 10 degrees from the horizontal, in a flattened V-bed arrangement above the conventional V-beds. Each needle in an upper bed is exactly aligned above a needle in the corresponding bed beneath it and can thus replace its action if required. Only compound needles, with their slim profile, short knitting stroke and sliding action, can perform efficiently in such a confined space. (The Shima model SES 122 RT introduced in 1993 also has four beds but the upper two beds contain loop transfer points instead of needles)

2 The model SWG-V configuration has two needle beds in the normal V-bed arrangement. The needles, however, are in a twin gauge arrangement offset in pairs. Thus on a 5-gauge machine there are 5 pairs of needles (10 needles per inch of needle bed). There is a normal gauge distance between each pair of needles, and a fine gauge distance between each of the needles in a pair in each bed. Thus, on the V model, the pair of needles can function in the same manner as the

two aligned needles in the upper and lower beds of the X model. The V model has a simpler configuration but, because of twin gauging, its finest gauge is 7 (14 npi), whereas the X model is available in 7, 10 and 12 gauges, and now has an additional loop presser bed.

10.5 The Shima Model FIRST

The name FIRST is an acronym representing F (fully fashioning), I (intarsia), R and T (rib transfer) and S (sinker). It employs a slide compound needle that has a number of unique design features. Its hook-closing slide is split to form a pair of loop-holding pelerine points at its forward edge. When the slide is advanced beyond its normal hook-closing position, it transports the loop on its shoulder across the beds to engage with the opposite bed and thus transfer the loop (Fig. 10.4).

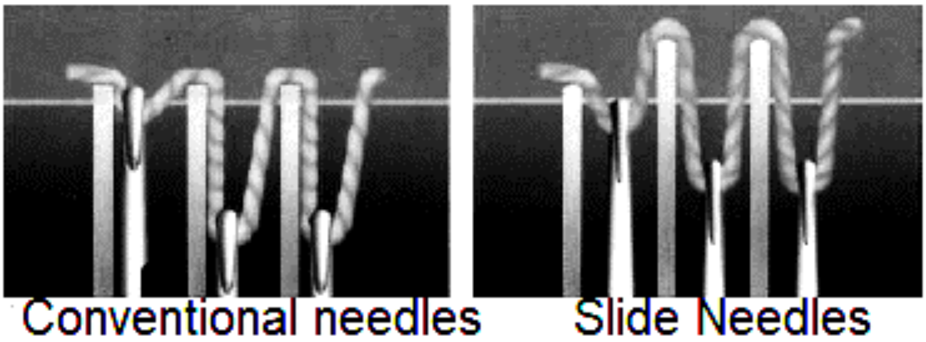


Fig. 10.4 Comparison of the new slide needle with the latch needle [Shima Seiki].

This transfer action does not require the assistance of a transfer spring on the needle. The needle is therefore centrally positioned in its trick, thus reducing yarn stress.

The outside shoulder of the slide is designed to retain a loop whilst another loop is inside the hook. Separate control of the two loops enables certain stitches to be knitted that were previously impracticable.

The slide needle has a thinner hook and a larger inside hook area, thus providing space for thicker yarns. The thinner hook is made possible because the hook does not receive the potentially damaging blows from a pivoting latch. Shima has three needle/needle bed arrangements designated small, medium and large. Small has fine needles and a small gap between the needle beds; medium has thicker needles but the same gap between the beds; and large has the same needles as medium but a larger gap between the beds.

In addition, there are four ranges of gauge based on needle pitch (the distance in millimetres between two adjacent needles in the same bed). '3.6' provides a gauge range up to E 7, '2.1' is the most popular giving a gauge range from E 6 to E 12, '1.8' provides a range up to E 14, and '1.4' provides the finest range up to E 18.

Three needle bed widths are available – 126cm, 156cm and 180cm (50, 60 and 70 inches respectively). The short bed has 2 knitting cam systems; the other widths have 3 or 4. Contra sinkers, moving in opposition to the needle movement, provide a knock over surface and reduce the needle movement. The resulting lower yarn tension enables different sizes of loops to be drawn. Above the V-bed are two horizontally-mounted beds containing ancillary elements. The upper front bed carries loop transfer jacks and is split into two sections that can be racked outwards for widening and inwards for narrowing to take place simultaneously at the selvedges, without the need for empty traverses and separate left and right racking of the transfer jack bed.

The upper rear bed holds special loop pressers that press down on selected individual loops in the front or back needle beds. With this arrangement it is possible to press an inlay yarn behind a non-knitting needle.

Conventionally, yarn carriers are moved into position by the cam-carriage. After a course of intarsia or integral knitting, the carriage must use an empty course to move the yarn carrier out of the way in order to knit the next course. The Shima FIRST machine has a motor-driven yarn carrier system that automatically ‘kicks back’ the yarn carrier into its field of knitting and out of the way of the carriage, thus eliminating the need for empty traverses.

10.6 The Tsudakoma TFK Machine

The first automatic V-bed machine to operate without cam boxes, the model TFK, was demonstrated by the Tsudakoma Corporation at the 1995 ITMA exhibition.

The Asahi Chemical Industry Co. supported its earlier development. The model TFK has a working width of 122 cm (48 in) in gauges 7, 8, 10 and 12, with a maximum variable speed of 1.2 m/sec.

Individual linear electric motors drive the needles in their tricks (Fig. 10.5). The computer and control system regulate the linear motors to simulate the conventional actions of the knitting and transfer cams.

As each course of knitting takes place, the knitting curves or waves of the needles are clearly visible. The machine is fitted with 12 or 16 yarn carriers on four double-sided rails. Each yarn carrier is driven by its own quick-start step motor, via a toothed belt. The yarn runs from the package to the yarn guide in a direct line via a yarn tensioner and knot catcher.

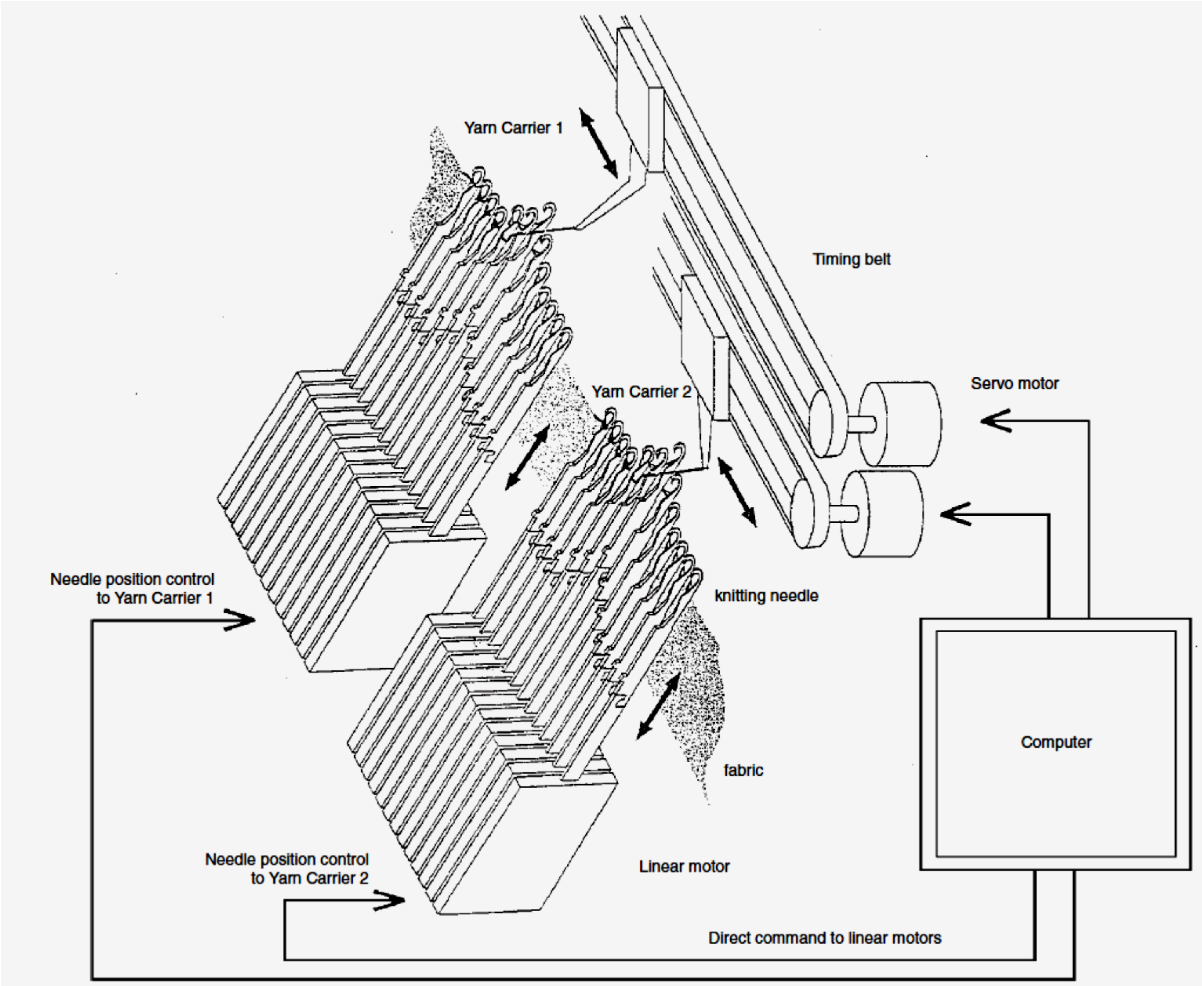


Figure 10.5 The Electric Motor Driven Individual Needle

The machine computer synchronizes the needle clearing with the yarn carrier drive. Stitch length is programmed for each needle, with the linear motor allowing the needle to draw whatever loop length is required. Up to 30 different stitch lengths can be drawn across the knitting width. The stitch length ranges up to 8mm in 0.1mm graduations.

There is a moveable holding-down sinker between every two needles, each of which is driven by its own linear motor. They can be used for accumulated tuck stitch fabrics or, when knitting without the takedown system, needle bed racking by means of a step motor can take place over up to 7 needles in either direction.

Knitting begins with the start-up comb engaging the first course of the fabric, which is then taken over by the sub-assembly and final takedown mechanism. All have individually-programmed motor drives. When the garment component is completed, the yarn ends are clamped and severed by an automatic cutting device. The needles are then activated to press-off, without taking the yarn, and the component is ejected. Blanks or fully-fashioned garment pieces can be produced, including sequentially knitted fronts, backs and sleeves.

Various problems have been encountered, particularly due to the absence of brushes, latch openers or stitch pressers, which are usually attached to the cam-carriage.

The greatest disadvantage is, however, the cost of the machine in comparison with conventional V-bed machines.

10.7 Spacer Fabrics

A spacer fabric is a double-faced fabric knitted on a double needle bar machine. The distance between the two surfaces is retained after compression by the resilience of the pile yarn (usually mono-filament) that passes between them.

One reason for the development of spacer fabrics was an attempt to replace toxic, laminated-layer foam with a single, synthetic fibre type fabric, thus facilitating future re-cycling.

Spacer fabrics are manufactured according to their function and have three variable components: fabric construction, yarn material and finishing. The hollow centre of the fabric may be filled with solid, liquid or gaseous materials (air can be used for insulation). Yarns with good moisture transportation properties may also be employed.

Partly-threaded guide bars can produce open-hole structures on each surface and air circulation can occur in the two millimetre space between the two surfaces. An important advantage is the low weight in proportion to the large volume.

The compression resistance can be adjusted by using different yarn counts in the rigid, synthetic mono-filament spacer yarns that connect the two surfaces of the fabric. Additional spacer yarns can be used where the choice of type of yarn determines properties such as moisture transport, absorbency, compression resistance, drapability, and thermal conductivity. The spacing can be up to 60mm and widths up to 4400mm. Fine fabrics knitted on E 32 raschels range in thickness between 1 and 4mm.

End-uses for spacer fabrics include moulded bra cups, padding, and linings. Medical applications are also being investigated.

10.8 Circular Warp Knitting

Tubular, seamless, extensible nets for fishnet patterned stockings, fruit sacks, and medical support bandages can be knitted on simple, small-diameter circular warp knitting machines. The vertical latch needles are fixed to the needle cylinder, collectively rising and falling with it. They are in a conical arrangement so the hooks form a smaller circle than the stems. The warp yarn is supplied through guide-eyes drilled in a ring. The ring turns to overlap the hooks when the needles are raised and produces underlaps at the back of the needles when they are lowered. For a simple balanced net, two full rings are used.

For more complex designs, up to 4 additional patterning rings may be employed. Tritex (Barwell, Leicester, UK) are supporting the development of a new prototype machine.

The rings can be cam-driven or electronically-controlled. At 80 per cent efficiency, approximately 100 metres of fabric will be knitted per hour. The stitch length is controlled by the positive warp let-off mechanism.

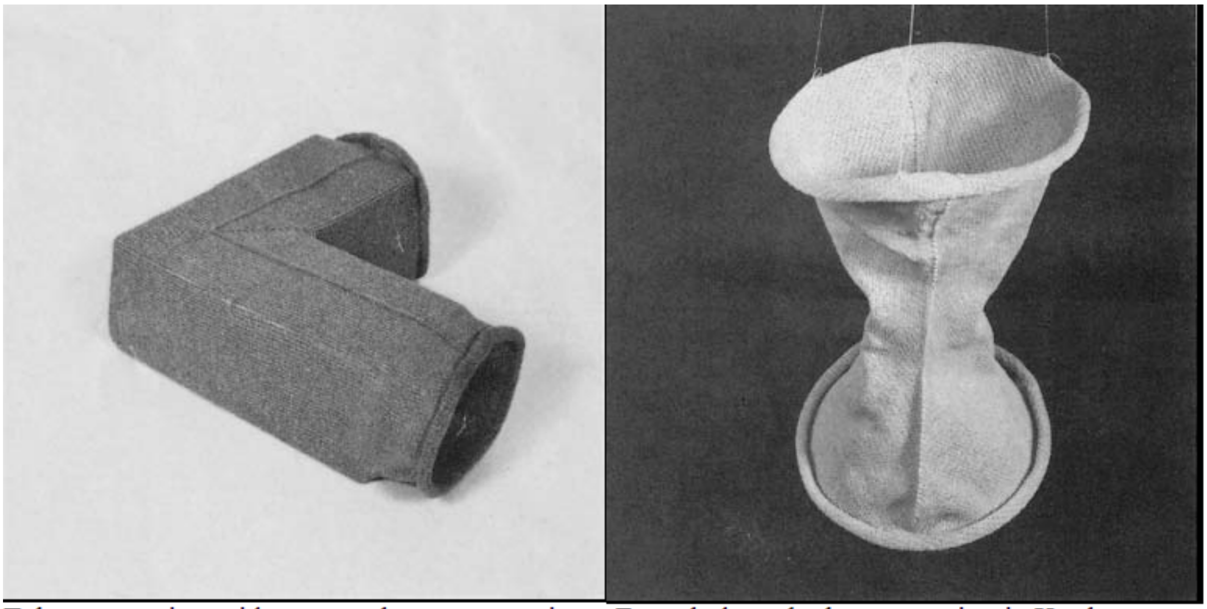
10.9 V-Bed Technical Fabrics

In v-bed weft knitting, the Stoll approach emphasises made-to-measure quick prefabrication of complex two- or three-dimensionally shaped articles (Figures 10.6) Raschel-knitted spacer structure used for car seat covers of the Daihatsu Move ‘Aero Down Custom’ model. The front is formed as an openwork mesh structure and the back as a dense structure, so that the air circulates freely in the space between, and the driver and passengers are guaranteed an optimum microclimate including the knitting of a wide range of materials such as metals in fibre or filament form. Examples of end-uses include upholstery for office furniture, one-piece seat-heating circuits, helmets, catalytic converters, pressure tanks made of composite materials, and support bandages that are knitted to size and shape.

There is no doubt that when used as a type of reinforced material, weft knitted fabrics have their disadvantage in mechanical properties (low resistance and modulus) due to the loop construction used, but in cases where elasticity, flexibility and high energy absorption are required, weft knitted fabrics have their advantages.

Compared with other techniques that have been used for the production of 3D fabrics, the advantages of flat knitting are as follows:

1. It is a flexible manufacturing process.
2. The change of fabric structures and forms is very fast.
3. The change of yarn types in the same structure is also possible.
4. Possibility of knitting to shape without cutting waste or making-up time.
5. Complicated shapes can be developed



Tube connection with rectangular cross-section Funnel-shaped tube connection in Kevlar

Fig. 10.6 a Tube connection with rectangular cross-section [Stoll, from Knitting Technique, Vol. 13 (1991), 2, 124].

Fig. 10.6 b Funnel-shaped tube connection in Kevlar [Stoll, from Knitting Technique,Vol. 13 (1991), 1, 123].

10.10 Warp Knitted Multi-Axial Weft Insertion Fabrics

Multi-axial layered fabrics are structures fixed by a stitch system retaining the several parallel yarn layers (Fig. 10.7). The yarn layers may have different orientations, differing yarn densities of the individual layers, and may include fibre webs and fleeces, film tapes, foams, etc.

Due to the drawn and parallel yarn layers, multi-axial layered fabrics are particularly suitable for bonding by resinous or polymeric materials to produce fibre polymer composites. The Liba Copcentra tricot machine has a multi-axial, magazine weft-insertion. It has been developed to stitch bond composite fibre mats at high production rates.

The feeding conveyor is approximately 15-metres long and is located at the back of the machine. Each creel-supplied yarn sheet layer is laid across or along the width of the conveyor at a specified angle. The continuous mat of yarn layers is conveyed through the knitting machine where the compound needles, supplied with warp threads, stitch through and stabilise the structure.

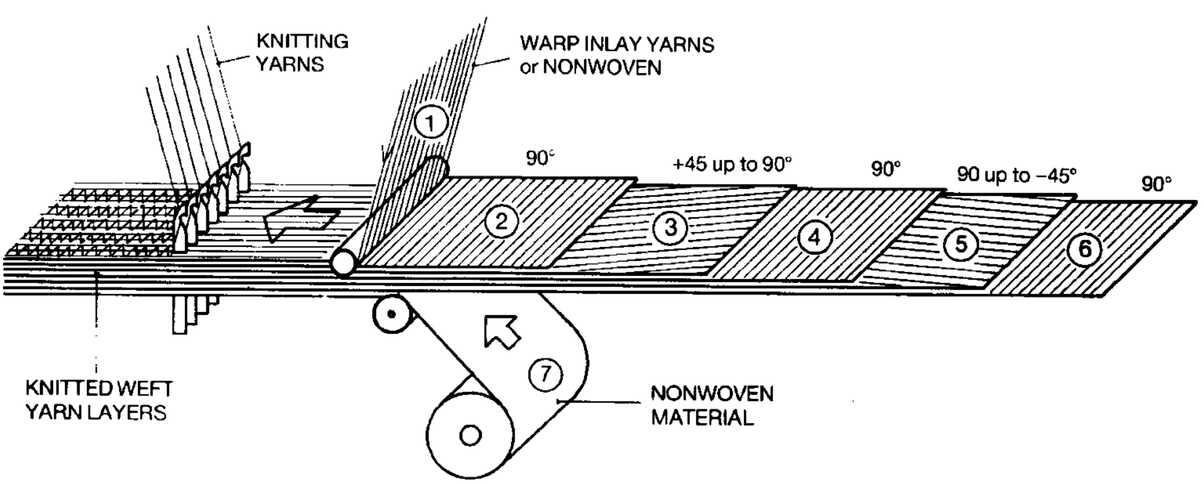


Figure 10.7 Principle of the LIBA multi-axial magazine weft insertion warp knitting machine. Up to 6 yarn layers and one fleece layer are possible [LIBA].

The standard arrangement uses 5 weft-insertion systems of which 3 systems supply parallel weft and 2 systems supply diagonal weft. Each diagonal weft thread layer can be laid at any adjustable angle from 60–45 degrees (or 90–45 degrees on request). The density of each layer can be varied and is not dependent upon the gauge. Non-woven webs can be fed into the knitting zone above or below the yarn conveyor; two guide bars can be used for stitch forming. The machine has a working width up to 245 inches (622 cm) in a gauge range of E 6 to E 24, and has a production speed of 1200 courses per minute.

10.11 Stitch Bonding or Web Knitting

Warp knitting machine builders Karl Mayer build a range of Malimo stitch bonding machines. Whereas warp and weft knitting construct fabrics from yarns, stitch bonding constructs fabrics from a medium such as a fibrous web using purely mechanical means. It is therefore a highly-productive method of producing textile substrates for industrial end-uses.

Using horizontally-mounted compound needles, the medium can be pierced by the pointed needle heads, so it is ideal for the production of textile composites. It is stitch-bonded either right through the structure or only on one surface in order to stabilise it. Dependent upon the model, additional yarns or fibres may or may not be supplied to the needles. Yarn layers, webs, films or materials such as glass fibres, rockwool, or re-cycled products can be processed Malimo web processing techniques include Maliwatt, Malivlies, Kunit, and Multiknit.

The Malimo machines operate with one or two guide bars and offer parallel weft and multi-axial alternatives. Pile and fleece can be produced on the Malipol (pile yarn feed) and Voltex (pile web feed) machines.

The Karl Mayer Maliwatt stitch-bonding machine is a high-performance machine for plain stitch-bonding of loose or pre-bonded fibrous webs, as well as of substrates of various materials within a wide range of thicknesses and weights per unit area.

The advantage of mechanical bonding is that it occurs in a single process without the use of chemicals. The resultant fabric can be used in a moulded resin laminate for boats, cars and sports equipment.

A special version of the machine for processing fibreglass into a web has now been developed. The fibreglass is fed to a chopper behind the machine. This cuts the glass fibres into pre-determined lengths (25–100mm).The chopped strands are randomly arranged in the form of a mat on a conveyor belt that feeds to the stitch forming area where they are bonded by means of a quilted seam. The mat is used to make reinforced plastic mouldings such as safety helmets and vehicle bodywork.

Working widths range from 2900mm to 6150mm and gauges from E 3.5 to E 22.

10.12 Mesh Structures

Mesh structures can be produced by pillar stitch/inlay, which may be used alone or as the ground for designs produced by pattern bars. The overlaps and underlaps of the front guide bar knitting the mesh will hold (on the technical back of the fabric) the inlay pattern threads of guide bars behind it at each course. That is the effect side of the fabric. Mesh is usually made by a single, fully-threaded guide bar knitting an open lap pillar stitch or its variant whose wales are reinforced and joined together by one or more inlay guide bars (often fully threaded).

Hexagonal mesh is achieved by wale distortion (because there are fewer underlaps joining the wales together) and by knitting tight loops in a fine yarn for the gauge of the machine. This mesh is produced by open laps followed by a closed lap which causes the lapping to alternate between two adjacent wales and forms the underlaps and inclined overlaps which close the top and bottom of the staggered mesh holes .(Fig.10.8)

Three-course tulle is the standard mesh for raschel lace.

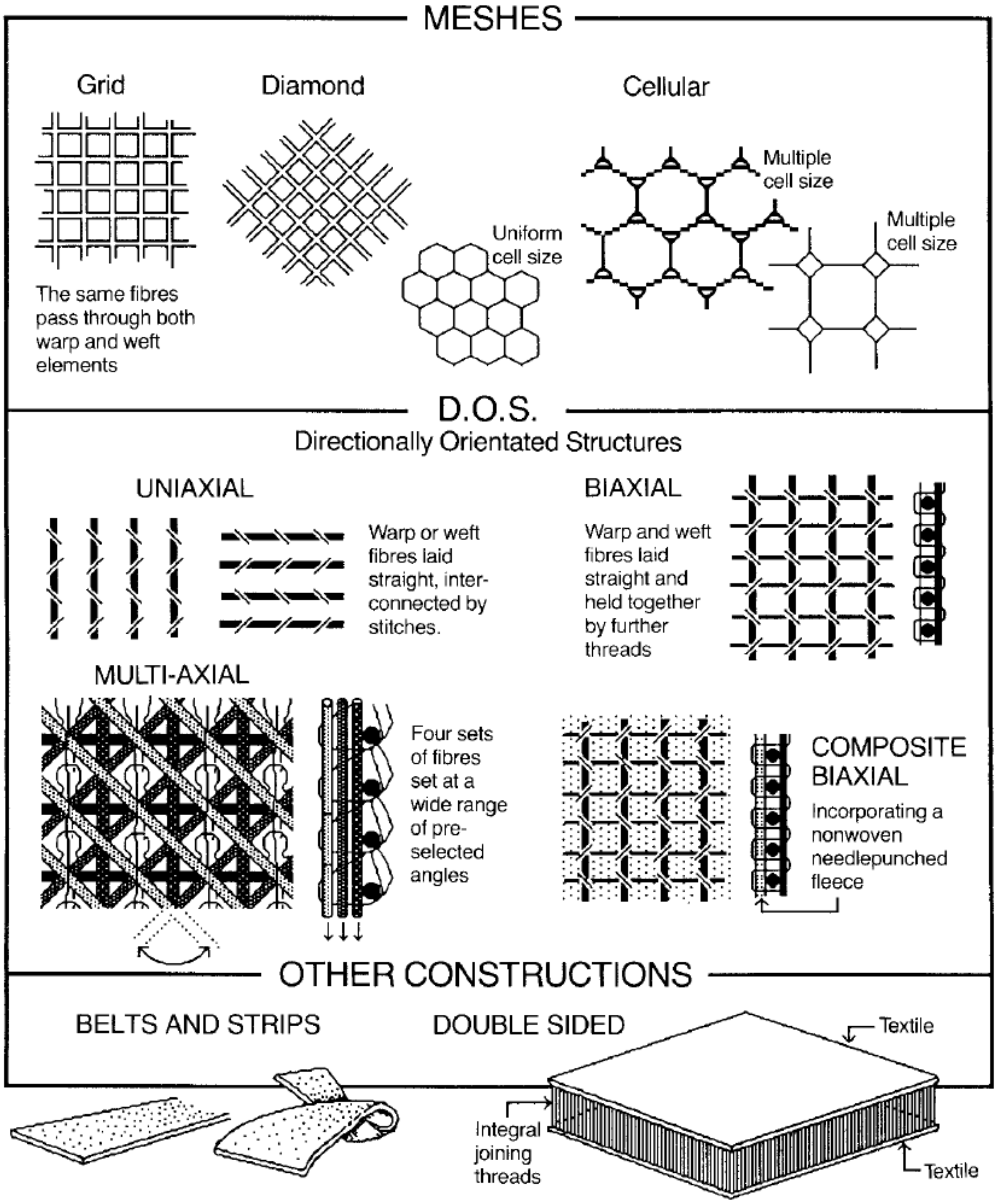


Figure 10.8 Directionally-structured fibre (DSF) geotextile constructions [The Karl Mayer Guide to Geotextiles, P R Ranilor and S Raz (1989), Karl Mayer, Germany].

10.13 Knit Structures For Fabric Composites

Plain warp- and weft-knitted structures are not commonly used for composite applications due to their inherent anisotropy in the wale and course directions. This causes the fabric preform to roll up on itself making handling and manufacturing more difficult. This problem is solved by using weft-knit structures such as the 1 × 1 rib and Milano rib, which exhibit balanced properties because of their through-thickness symmetry. However, the highly curved fibre architecture, or crimp, present in these and any knitted structure, means that composites produced using these structures exhibit relatively poor mechanical performance.

Characteristics of high conformability and low strength make them ideally suited to producing semi-structural complexly shaped components. To help increase mechanical performance, insert yarns can be placed between the planes of loops in either the warp or weft direction. The technique can be used for both warp- and weft-knitted fabrics which allow the insert yarns to remain perfectly straight, giving a greater yarn to fabric translational strength. This results in an increase in the composite stiffness and strength along the insert direction. Warp- and weft-knitted fabrics with inlay yarns are termed unidirectional knitted fabrics and the incorporation of insert yarns in two directions creates biaxial knitted fabrics.

10.14 Multiaxial Warp Knits

Multi-axial Warp Knit (MWK) fabric is a further development of this idea by utilising layers of insertion yarns for the in-plane reinforcement and warp stitch yarns for the through-thickness reinforcement. They consist of one or more parallel layers of yarns held together by a warp knit loop system. Theoretically, as many layers as preferred can be used but typical commercially available machines only allow four layers. The purpose of the knit loops is to hold the layers of unidirectional yarns together, but it has also been proven to be the key to increasing the damage tolerance of the material.

These types of knitted structure are termed non-crimp structures and can be produced in a single knitting process. They are particularly suitable for thin to medium thickness parts. The combination of the warp-knitted structure and non-crimp yarns means they have the ability to conform to complex shapes as well as the potential to meet the demands of primary load bearing applications.

MWKs have evolved through structural modifications of warp-knitted fabrics and are predominantly fabrics with inlay yarns in the warp (90°), wale (0°) and bias (± θ°) directions. Warp, weft and bias yarns are held together by a chain or tricot stitch through the thickness of the fabric. Layers of 0° need to be placed somewhere other than the top or bottom layer to ensure structural integrity. The amount of fibre and the orientation of the inlay yarns can be controlled, which is advantageous for preform engineering. As a result, the insert yarns are made from a much higher linear density yarn than the stitch yarns, since they form the load-bearing component of the fabric structure.

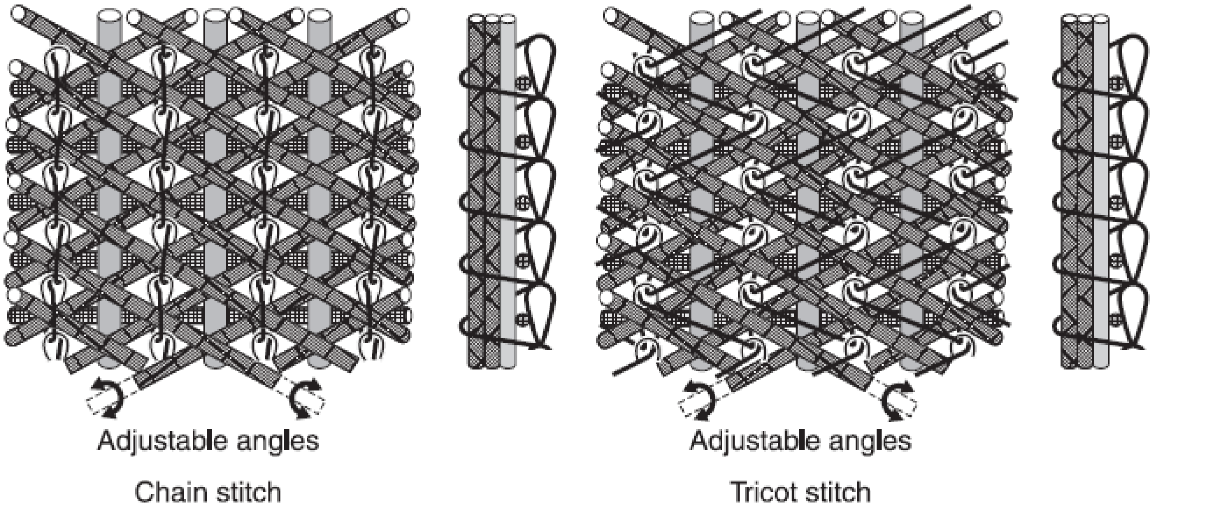


Figure 10.9 shows the configuration of the chain and tricot MWK structures.

An improved MWK structure for composite reinforcement, developed by replacing the tricot stitch with a 'double loop pillar stitch'. The modification has yielded improvements of up to 7% in breaking strength. The tribology or wear resistance of MWK has also been investigated and has been shown to perform better than biaxial nonwoven structures. With respect to composite mechanical properties, MWKs provide the most practical solution for the use of knitted structures in composite materials.

10.15 Integral Knitting

Integral knitting is where the near-net shape of the final composite component is manufactured on the knitting machine and subsequently used as the preform for the component to be produced. The added advantages are low material wastage and labour costs. With present day knitting machinery such as Shima-Seiki's 'whole garment' flatbed knitting machines, it is possible to produce gauge less (loops of any size) and seamless three-dimensional preforms directly by specifying the geometry using KnitCAD data. The manufacturing process is illustrated in Fig. 10.10; the only post forming manufacturing procedure that may be required is part trimming – however, this can also be incorporated into the tooling.

Knitted fabric composites are one of the many types of textile structural composite used in the composites industry. They fit neatly into the broad family of FRP structures where medium strength, stiffness and excellent processability are required. The high performance fibres used for these materials range from E-glass and carbon aramid to high strength polymer fibres, and even some selected high strength natural fibres. These fibres are knitted into the preform fabric for the composite, and a variety of thermoset, thermoplastic and even biodegradable polymer materials can be used as the matrix. Pre-impregnated materials are also available, although knitted

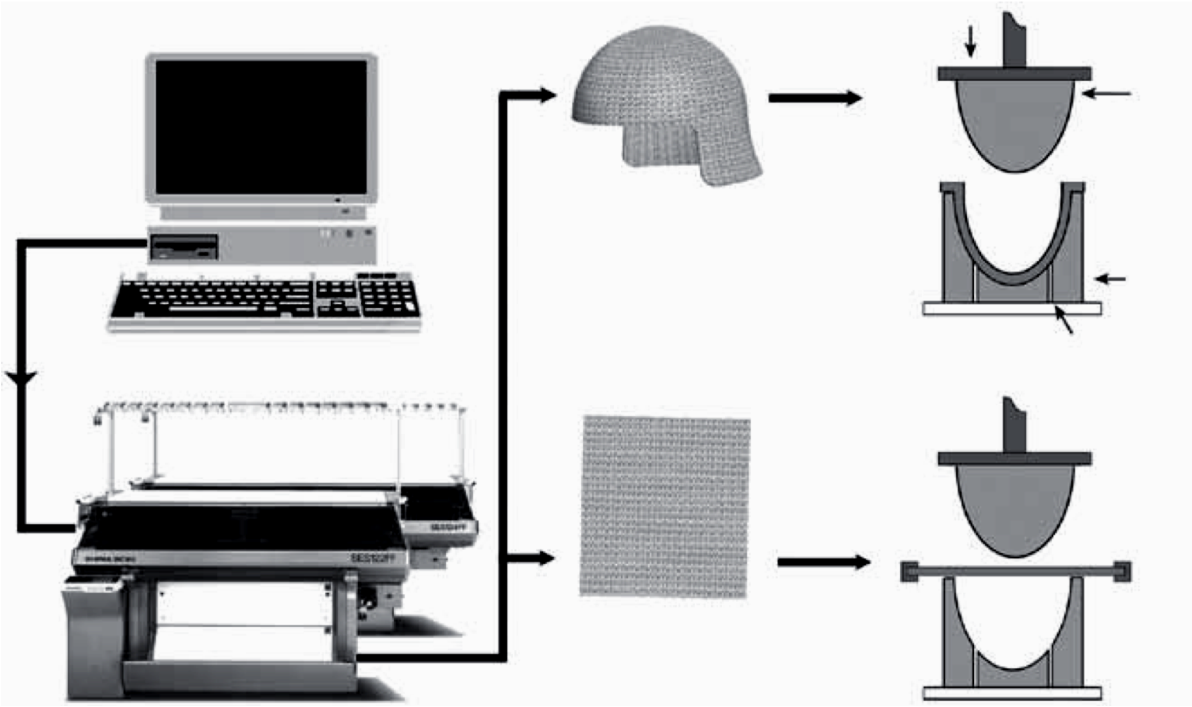


Figure 10.10 Forming Of 2D and 3D Commingled Knitted Fabric Thermoplastic Composite Preforms

structures are not as common as weaves. The most commonly used knit structure is the multi-axial warp knit because of its ability to meet the demands of primary load bearing applications. Forming methods for knitted fabric composites include sheet forming and draping. In the case of sheet forming, stretching can be applied to obtain desired mechanical properties, while for draping, integral shapes can be produced to minimise material wastage and eliminate cutting. Due to their complex geometric structures the mechanical properties of knitted fabric composites are not easily predicted. However, simulations to generate and examine the behaviour of these structures have been carried out. Knitted fabric composites have found applications in automotive components as well as consumer level items such as helmets, toecap protectors and medical prostheses.

10.16 Recent Developments in Knitted Underwear Fabrics

Underwear is traditionally made from cotton in single jersey or interlock knitted structures. However, in recent years, new fabrics have been developed using engineered fibres and special constructions to achieve improved wicking properties, quick drying, lighter weights, improved durability and easy care.

10.16.1 Akwatek® polyester fabric

Akwatek® polyester fabric is one of the performance fabrics that, it is claimed, can transport moisture and assist thermoregulation based on an electrochemical principle. Furthermore, it is also claimed that the chemicals cannot be removed by repeated laundering. The Akwatek® technology modifies the polyester fibre surface at the nano-particle level. With chemical treatment, Akwatek® modifies the chemistry of polyester and releases hydrophilic groups at the molecular level. The modified polyester has an active surface layer with anionic end groups that transport water molecules and release them to the atmosphere before they can form into liquid water. Consequently, it is claimed that Akwatek® polyester fabric can enhance wearing comfort properties.

10.16.2 Coolmax® fabric

Coolmax® is another functional fabric that, it is claimed, can keep the wearer cool and comfortable in any situation. Four channel fibres in Coolmax® fabric can rapidly transport moisture and heat to the outer surface, which makes it a quick drying and breathable fabric.

10.16.3 Nike® Sphere Cool fabric

Nike® has developed many different functional materials for making undershirts and sportswear. Nike® Sphere Cool is one of their innovative technologies to increase heat loss in order to enhance air circulation. It is claimed that the mesh structure accelerates the evaporation of perspiration, so that the wearer feels cooler and more comfortable. Good moisture absorbency by the inner layer is also claimed to improve the thermal comfort of the wearer.(Fig.10.11)

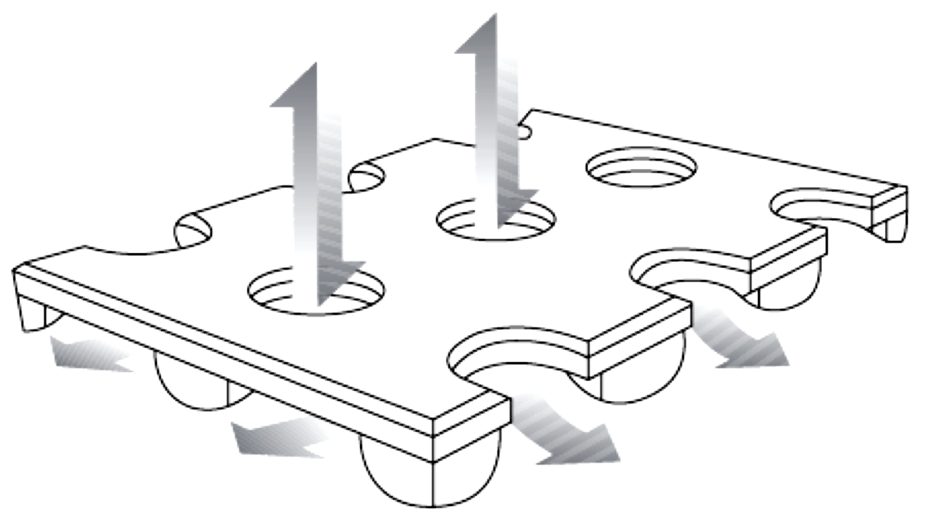


Figure 10.11 Nike® Sphere Cool fabric structure.

10.16.4 Nike® Dri-Fit

Nike® Dri-Fit71 is a popular inner layer fabric which is claimed to carry the perspiration rapidly from the skin to the outside of a T-shirt, where it then evaporates. It is proposed that it should be worn next to the skin to keep the body dry.

10.17 The welt

A welt is an attractive and secure edge of a knitted article that helps to prevent laddering or unravelling of a structure. It is formed either during the knitting sequence (usually at the start, and parallel to the courses), or as a later seaming operation during making-up.

10.17.1 The plain fabric welt

On machines with no facilities for rib welt sequences, the plain fabric is formed into either a turned-over inturned-welt or a mock rib welt. The ability to produce a knitted welt sequence usually distinguishes an article-producing machine from a fabric-producing machine. Some machines start at the closed toe end or finger-tip and finish with the welt end of the article. The last knitted course will unravel backwards from the last knitted loop unless it is secured.

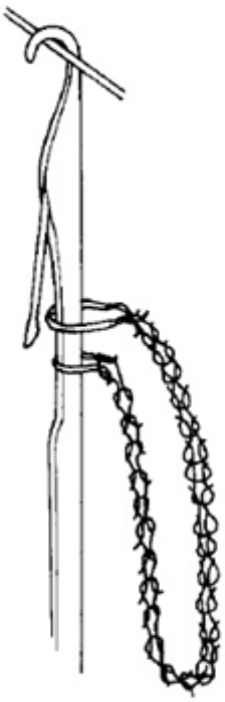
Sometimes the curling edge of plain fabric is used as the start of a garment or the curl of a collar instead of a welt.

10.17.2 The Inturned Welt

The inturned welt is used particularly for manufacturing ladies' hose and sports socks on circular machines (Fig. 10.12) and some knitwear on Cottons Patent machines (Fig. 10.13). Jacks or hooks collect the sinker loops of the third course or the set-up course and hold them, drawing the fabric away until sufficient has been knitted for the double-thickness welt.

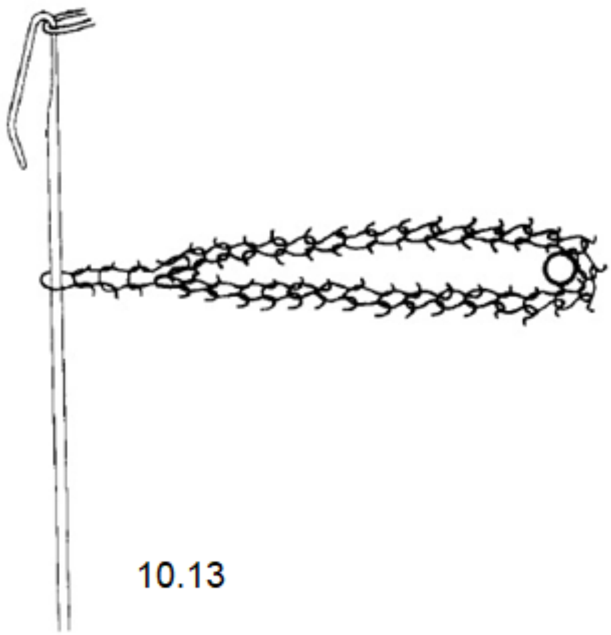
The welt is then turned by transferring the held course back onto the needles that knit it into the structure. A picot edge at the turn of the welt is achieved either by an alternate needle tuck sequence or by alternate needle loop transfer.

Cottons Patent plain machines often produce garment panels by knitting onto a rib border that has been run onto the needles, having been previously knitted on a V-bed rib machine.



10.12

Turned welt on latch needle machine.



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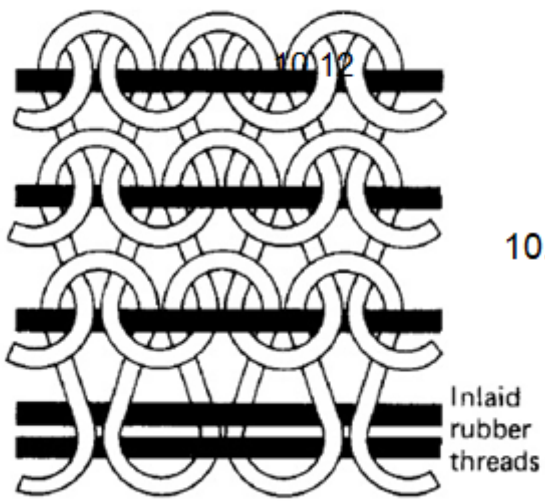
Turned welt on bearded needle machine.



10.14

10.17.3 Accordion Top

An accordion top (Fig. 10.14), welt and mock rib, can be produced on single-cylinder half-hose and sock machines, and on other machines using a single set of needles in a tubular arrangement. Elastomeric yarn is laid-in to odd needles only for a few courses so that when the first plain course is knitted by the textile yarn, the straight contracted elastomeric yarn lies through its sinker loops, forming a neat roll edge.

The elastomeric yarn is then usually inlaid on a two-tuck two-miss or a one-and one basis at each course or alternate courses for a number of courses. As the elastomeric yarn relaxes, it causes alternate wales to be displaced into a mock rib configuration.

Sometimes, the second course of textile yarn is knitted only on alternate needles.

10.17.4 Rib welts

Most fully-fashioned and stitch-shaped underwear and outerwear garments, half hose, and socks have ribbed borders containing a welt sequence that is produced by causing the sets of needles to act independently of each other after the 1 X 1 rib setup course.

When the rib border is to be knitted in 2 X 2 rib, the needle bed is either shogged to form a skeleton 1 X 1 rib needle arrangement or it is knitted on a normal 1 X 1 rib needle set-out followed by rib loop transfer to achieve 2 X 2 rib for the border.

Three types of welt are possible when needles are arranged in 1 X 1 rib set-out.

These are:

1 The tubular or French welt.

2 The roll or English welt.

3 The racked welt.

10.17.5 The Tubular Welt

The tubular welt (Fig. 10.15) is the most popular welt because it is a balanced structure that is reversible, lies flat, can be extended to any depth and is elastic. Its only disadvantage is that it can become baggy during washing and wear unless knitted tightly. Apart from old Cottons Patent Rib Frames, most garment-length knitting machines can knit this welt.

The split welt is actually a tubular welt knitted at the end of the garment sequence instead of at the beginning. It is used as an open tube for a collar or stolling¥, to fit over the cut edge of a garment to which it is then linked by a through stitch.

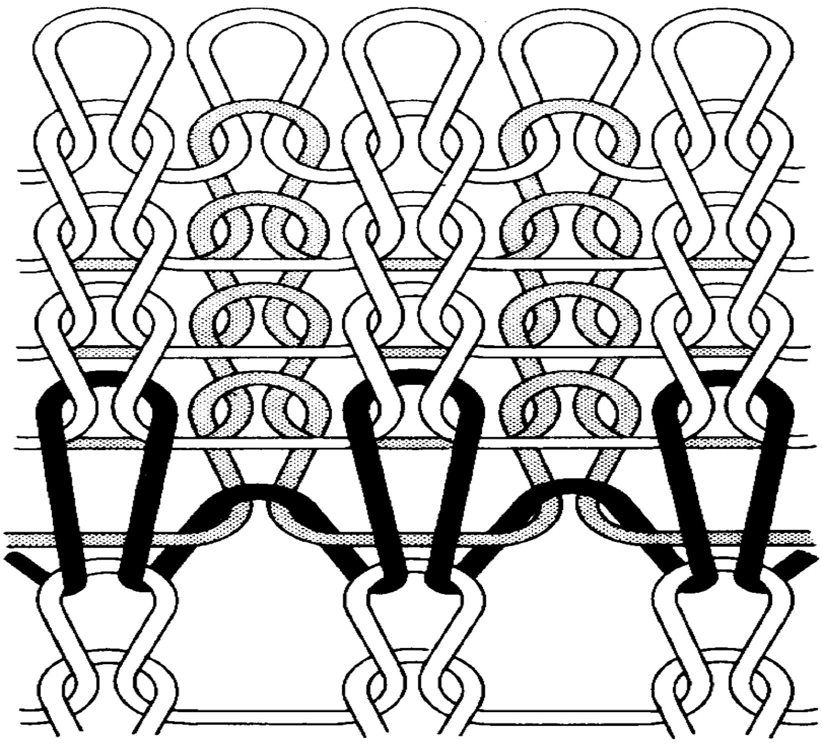


Fig. 10.15 Tubular welt.

10.17.6 The Roll Welt

The roll welt (Fig. 10.16) is produced by knitting approximately four courses on one set of needles only whilst continuing to hold the setting-up course of loops on the other set of needles. It is bulkier and less elastic than the tubular welt and has the disadvantage of long held loops. This welt is knitted particularly on half-hose and links-links garment-length circular machines.

A reverse roll welt is knitted for sleeves with turn-back cuffs and for turn-over top socks. To obtain this welt, the opposite set of needles (the bottom set of needles on half-hose machines) are caused to hold their loops so that the roll of the welt appears on the other side of the structure, but it is on the face when the fabric is folded over.

10.17.7 The Racked Welt

The racked welt (Fig. 10.17) is neat and inconspicuous, rather like the set-up course of hand knitting in appearance, and is favoured for collars and other trimmings. It is not as elastic as the other two welts and is normally only knitted on V-bed flat machines. It is produced by racking the needle bed by one needle space after the set-up course and retaining this arrangement.

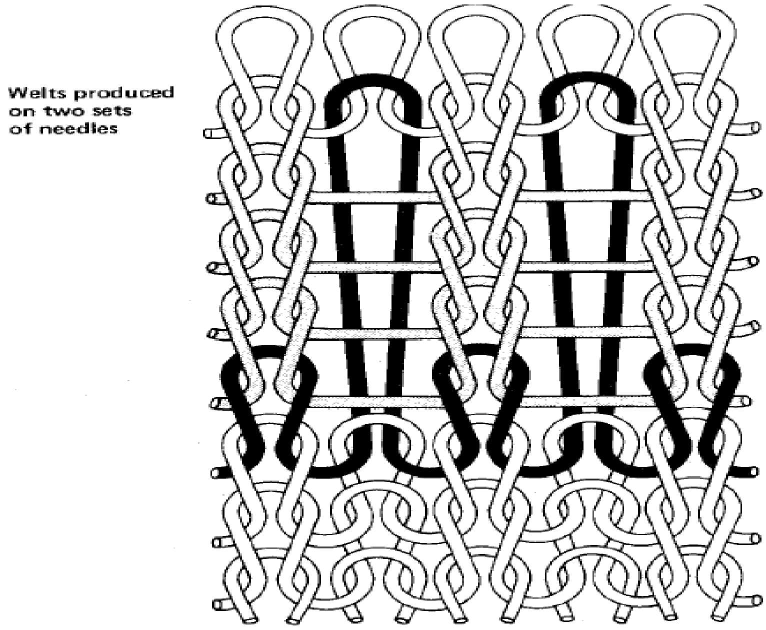


Fig. 10.16 Roll welt.

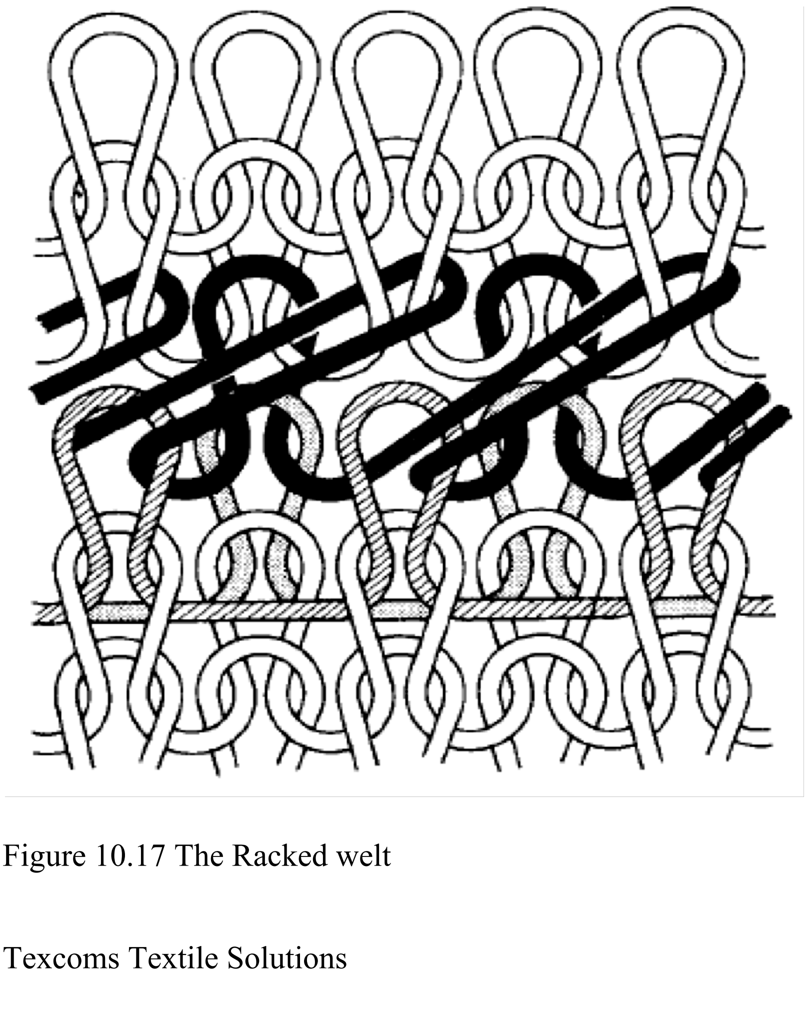


Figure 10.17 The Racked welt

Knitted articles are often produced separately on single-cylinder machines, Cottons Patent machines and some flat machines. Others are knitted in continuous string formation on many flat and circular rib and purl machines because fabric tensioning is dependent on a continuous length of fabric between the needles and the takedown rollers. Also, there would be a danger of latches not being open at the start of a new garment sequence.

If the string of garments is separated by cutting, there is a danger of either the welt being damaged or of unwanted yarn not being removed. For these reasons, some form of separation course is usually provided, normally in the form of a draw thread course, preceding the first course of the new garment.

The draw thread is usually a smooth strong yarn that may be knitted as a slack, plain tubular course to facilitate easy removal. The tubular draw thread course does not unravel accidentally during wet processing.

A second method is the press-off draw thread construction, which, although more expensive in time and yarn, tends to be more popular. The course preceding the start of the new garment is knitted in 1 X 1 rib and then one set of needles presses off its loops, leaving a single plain course of extra-long draw thread loops that can be quickly and easily removed. Prior to the press-off course, locking courses are produced by knitting three or more additional courses, only on the set of needles that are to press-off. These help to reduce tension in the structure after pressing-off and thus reduce the possibility of laddering back. A popular alternative to a draw-thread, employed on half-hose and sock machines, is to knit a number of courses in a soluble yarn such as alginate. The socks are separated by cutting, and the remaining courses of yarn are dissolved away during finishing to leave a neat edge to the welt. Most garment-length machines using two needle beds have a butt arrangement of two long, one short for each bed, enabling 2 X 2 rib knitting after pressing off the loops of a 1 X 1 rib set-out and recommencement of knitting on only long butts on each bed in turn.

10.18 Imparting Shape During Knitting

In addition to facilities for garment-length sequence knitting, weft knitting provides unique opportunities for width-wise shaping during knitting, with the sequence being initiated and co-ordinated from the same central control mechanism.

The three methods of width shaping are:

1 varying the number of needles in action in the knitting width,

2 changing the knitting construction, and

3 altering the stitch length.

10.18.1 Wale Fashioning

Wale fashioning is the normal manner of shaping (symmetrically or asymmetrically) on straight bar frames (Figures 10.18 and 10.19). It involves the transfer of loops from one needle to another within the same needle bed, either transferring onto selvedge needles that are to start knitting (widening) or transferring from needles that are to cease knitting (narrowing).

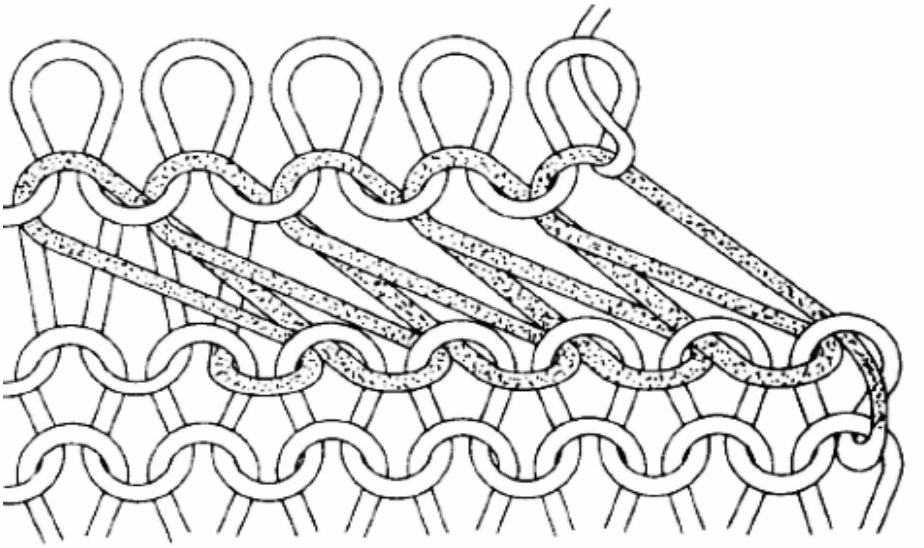


Fig. 10.18 Wale fashioning (narrowing).

The fashioning technique has, in the past, been generally restricted to plain fabric structures although there were a few rib straight bar frames. There is now an increasing number of automatic V-bed flat machines with additional beds of fashioning points or rib loop transfer needles. Each transfer bed operates onto a specific needle bed (Fig. 10.20).

Fashioning can also be achieved by needle-to-needle rib loop transfer, racking one bed, and transferring back to the original needle bed, but this technique requires receiving needles to be empty of loops.

The firm, fashioned selvedge edges can be point- or cup-seamed together, without the need for cutting and seaming to shape involving loss of expensive fabric. The shaping angle is varied by changing the fashioning frequency (i.e. the number of plain courses between each fashioning course), aided by the possibility of four needle or two-needle as well as single-needle narrowing. A block of loops is transferred at a time, so that the transferred loop effect (fashion mark) is clearly visible in the garment, away from the selvedge, as this is a hall-mark of classic fully-fashioned garments.

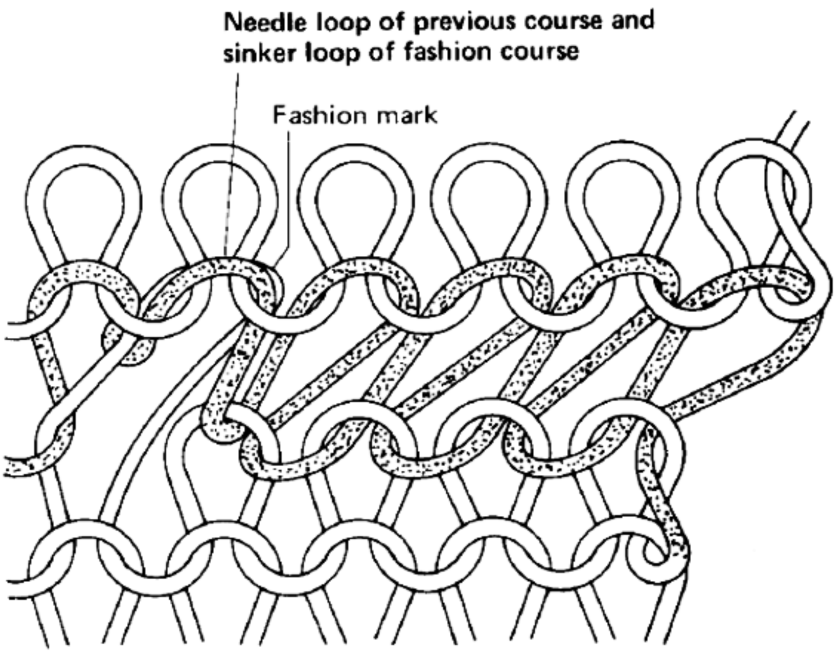


Fig. 10.19 Wale fashioning (widening).

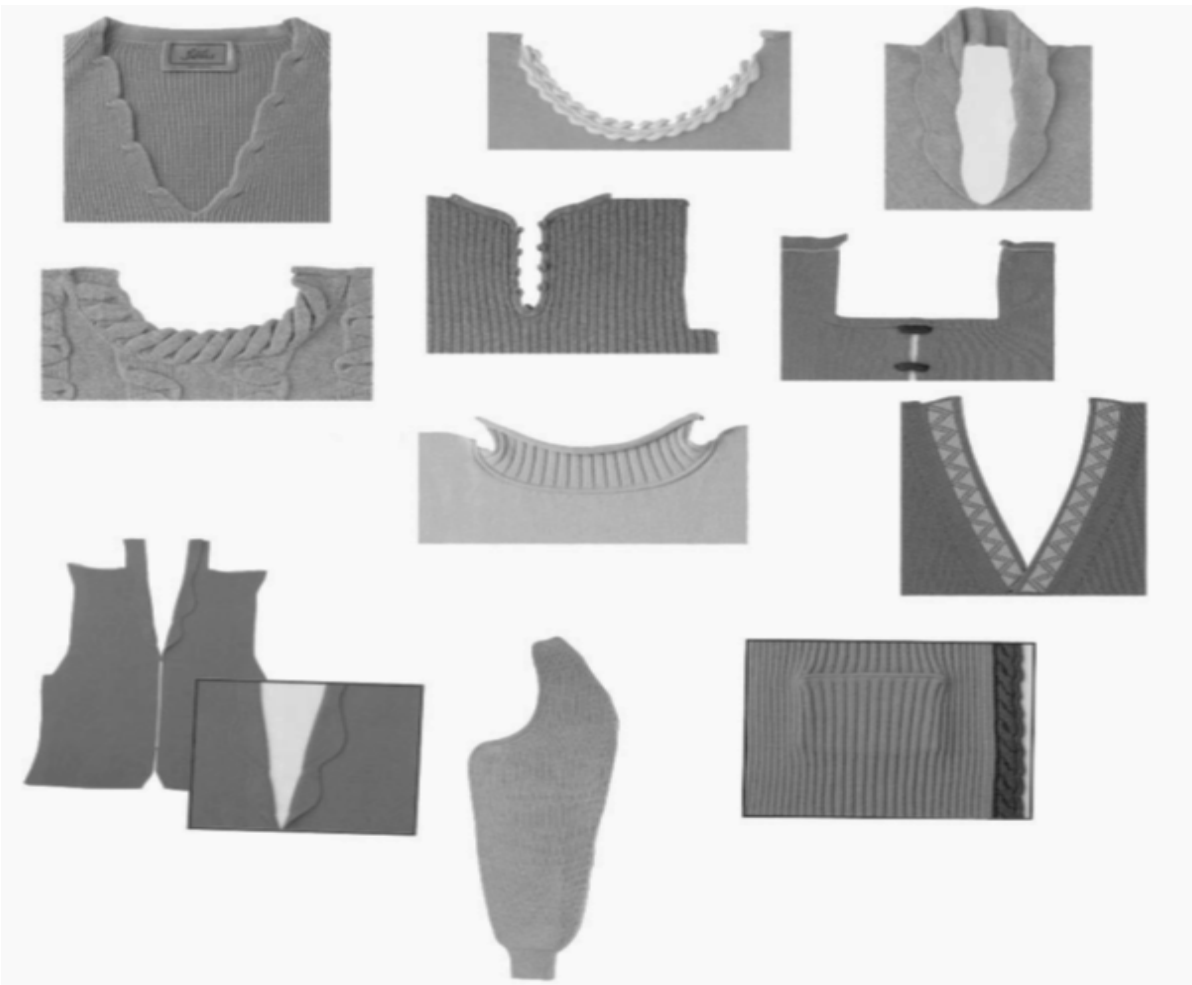


Fig. 10.20 Integrally shaped rib garment pieces. The machine has an additional bed containing the transfer points [Shima Seiki].

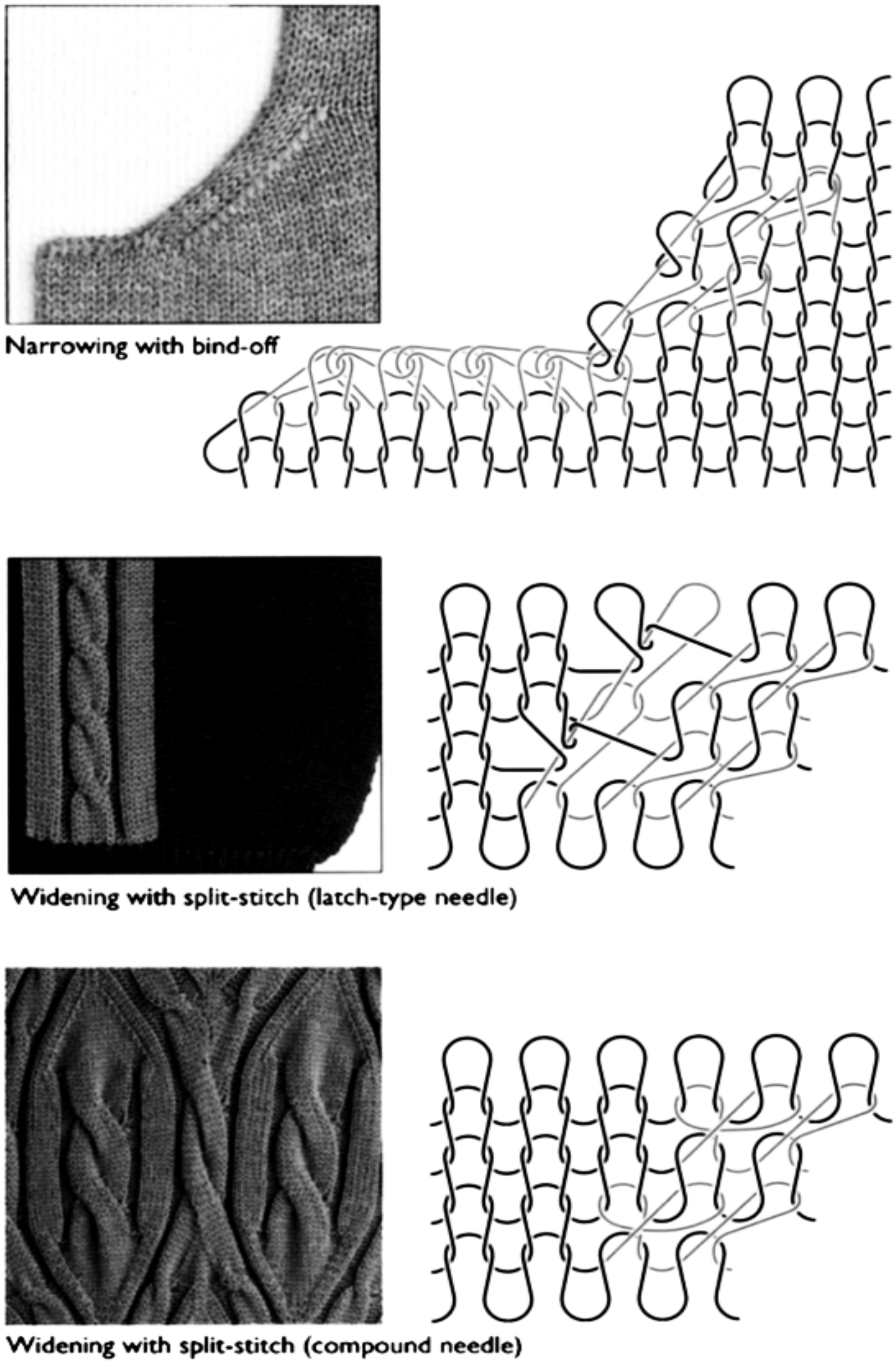


Fig. 10.21 Modern integral garment technology assures precisely-formed loops which are crucial to the production of shaped garments [Shima Seiki].

Widening involves transferring the loops of a group of needles outwards by one needle, thus leaving a needle without a loop that would produce a hole if it was not covered by the action of filling-in. Figure 10.19 shows the effect of using a single filling-in point that is set slightly in advance of the innermost fashioning point. It has an independent vertical movement and takes a stitch from the previous course, placing it onto the empty needle. Another technique in order to cover the hole is to use two half-points to transfer the half limbs of two adjacent needle loops sideways. A similar technique has been developed for automatic V-bed machines, when it is termed a split stitch (Fig. 10.21).

10.18.2 The Calculation of Fashioning Frequencies

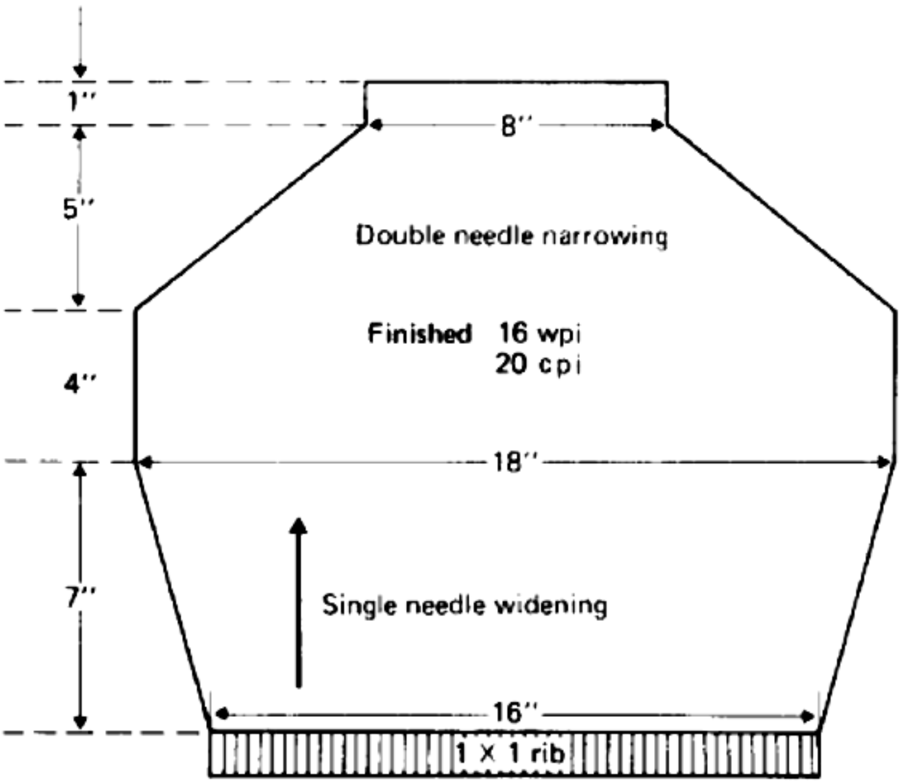


Fig. 10.22 Full-fashioned shaping calculation.

Using the details shown in Fig. 10.22 as an example, the following sequence is necessary in order to calculate the required fashioning frequencies from the dimensions of a garment part:

1 Convert the length dimensions in each section to total number of courses by multiplying the length measurement by the cpi. Thus, 7 X 20 = 140; 4 X 20 = 80; 5 X 20 = 100 courses.

2 Convert the width dimensions at the start of each section to total numbers of needles by multiplying the width measurement by wpi. Thus, 16 X 16 = 256;

18 X 16 = 288; 8 X 16 = 128 needles.

3 Calculate the total number of needles increased or decreased from one section to another by taking one total from the next.

4 Divide the totals obtained by 2 in order to obtain the increase or decrease of single needle widenings; 288 - 128 = 160; 160/2 = 80 needles, 80/2 gives 40 double needle narrowings

5 There are 16 single-needle widenings occurring during the knitting of 140 courses; assuming the first fashioning occurs in the first course, there will be 15 fashionings in 139 courses; 139/15 = 9 with a remainder of 4. Thus 4 fashionings must occur at 10 course intervals and the remaining 11 at 9 course intervals.

6 Forty double-needle narrowings occur during 100 courses, again assuming the first fashioning occurs in the first course; 99/39 = 2 with a remainder of 21. Thus, 21 fashionings occur at 3 course intervals and the remaining 18 fashionings occur at 2 course intervals.

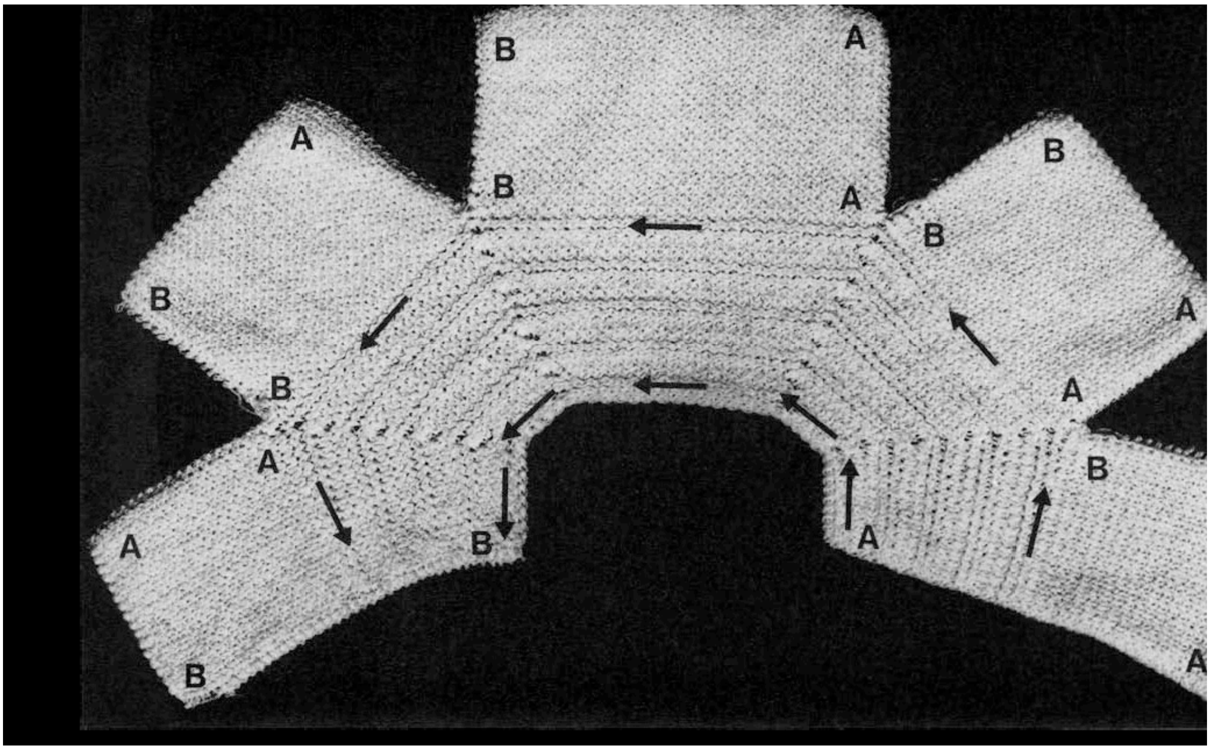


Fig. 10.23 Garment shaping by holding loops on a V-bed flat machine thus knitting wales with different numbers of courses.

(A) is the commencing course and (B) the pressed-off course. A presser foot device was employed [Knitting International].

It is even possible to introduce or remove a selvedge needle from the knitting action during tubular plain knitting on a V-bed flat machine, thus achieving a certain amount of shape in the tube.

The full shaping potential of the V-bed flat machine can only be exploited if the conventional roller take-down system is replaced by an arrangement capable of accommodating itself to varying rates of production and fabric widths and even to separated garments or garment pieces.

10.18.3 Three-Dimensional Wale Fashioning

Shaping by three-dimensional wale fashioning occurs within the width of needles, using an additional pair of independently-controlled fashioning boxes to shape stocking heels or bosom pouches. In the centre of the pouch, a number of needles knit plain fabric whilst on either side of them the extra sets of points widen outwards and later narrow again.

During widening, each needle that loses its loop and does not receive a new loop will commence a new wale in the next course, whereas, during narrowing, when a needle receives two loops, two wales will be caused to converge into one.

10.18.4 Needle Selection Shaping

In needle selection shaping, the selvedge needle(s) is introduced or withdrawn from the knitting width by means of needle selection. It is more convenient on automatic V-bed flat machines to employ the jacquard selection to introduce empty needles for widening and to take needles out of action for narrowing

(i) By transferring and re-transferring rib loops in conjunction with needle bed racking,

(ii) By pressing-off loops, or

(iii) By causing needles to hold their loops for large numbers of traverses (Fig. 10.23).

10.18.5 Reciprocated Knitting of Pouches

Three-dimensional shaping of pouches can be achieved on small-diameter hosiery machines by using held loop shaping in a similar manner to flat knitting, so that the number of courses knitted by adjacent needles is varied in order to knit a pouch for a heel and, if necessary, for a toe.

During pouch-knitting, the rotating movement of the cylinder changes to an oscillatory movement. In the first half of the pouch-knitting sequence, only half the needles continue knitting, and during the reciprocating knitting, a needle at each edge is lowered out of action (narrowing) to join (in the case of heel-pouch knitting) the instep needles, which are already holding their fabric loops. When only one-third of the needles remain in action, widening commences so that needles are successively brought back into action at the edge of the pouch. When all the pouch half of the needles have recommenced knitting, the cylinder returns to rotary knitting and circular courses are knitted, with all needles in action. A small-diameter garment machine was developed to produce shaping for the bust or shoulder section of integrally-knitted garments using the reciprocated pouch principle but has not been utilised to any extent. As oscillatory knitting is a much slower and more complicated process than circular knitting, the toe is produced as an open tube on many stocking and tights machines. It is later seamed to shape. The heel may also be knitted as a part of the leg tube, being boarded out and heat-set shaped during finishing. One method of producing a stocking heel pouch in completely circular knitting is to knit circular courses at the first feeder and to select needles for heel section knitting at the second feeder in conjunction with striping, cutting and trapping of yarn. With this method, a part circular course is sandwiched between each full circular course for the heel section.

10.18.6 Shaping By Changing the Knitted Stitch Structure

Stitch shaping is the imparting of shape into selvedge or tubular weft knitted structures by changing the nature of the stitch structure without altering the total number of needles that are in action. It may be used for garment-shaping sequences in knitwear, jersey wear and underwear produced on latch needle machines. It is a simpler and faster method than fashioning and does not require specially-shaped elements, but it can only be used for a few definite step-changes of shape rather than the graduated shaping technique of fashioning. In the sleeve and body panels of knitwear, the tuck stitches will cause half and full cardigan to throw out wider than the 1 X 1 rib border (Fig. 10.24). In ladies' stitch-shaped vests, patterned rib eyelet will produce a similar effect in the bust and skirt sections, compared with the 2 X 2 rib waist and border (Fig. 10.25).In plain tubular fabric articles such as some socks and gloves, elastic may be inlaid on an alternate tuck/miss basis on the same needle sequence, so that the fabric concertinas into a narrower elastic 'mock rib' effect for the tops.

10.18.7 Shaping By Altering the Stitch Length

Changes of stitch length by alteration of stitch cam positions are carried out at particular points in a garment-length knitting sequence. Even mechanical V-bed power flat machines have at least five pre-set positions that can be automatically obtained during traversing of the cam carriage. On both circular and flat machines it is also possible to change from synchronised to delayed timing in 1 X 1 rib knitting and thus produce tighter and more 'elastic' rib courses suitable for rib borders. In ladies' hosiery, a graduated stiffening or tightening of the stitch length occurs to obtain a certain amount of shape between the thigh and the ankle.

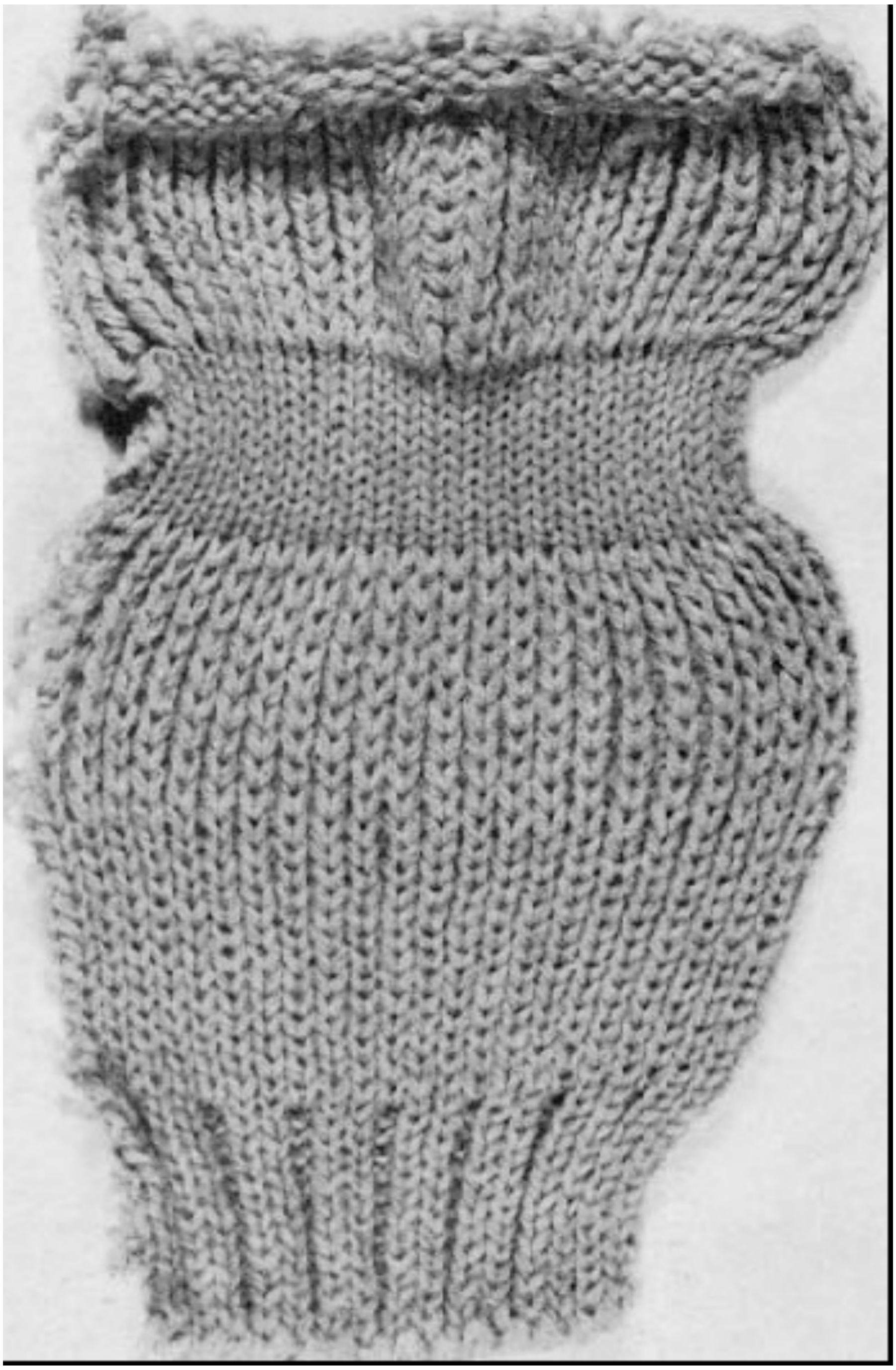


Fig. 10.24 Stitch shaping (1 = 2 X 2 rib; 2 = 1 X 1 rib; 3 = half-cardigan; 4 = tubular courses;

Fig. 10.25 Stitch-shaped thermal underwear in 1 X 1 rib with rib loop transfer and cylinder needle pick-up design knitted in 1/28's cotton spun 50/50 Viloft/polyester on a 10-gauge RTR (13-, 15-, and 17-inch diameters) by Twinlock [Courtaulds, Henrietta House, London].The introduction of a certain percentage of elastane yarn into the construction of a weft or warp knitted fabric improves extension and recovery properties and therefore its form-fitting properties. The percentage elongation of the elastane yarn may be controlled during fabric finishing by heat-setting.

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