

# KNITTING TECHNOLOGY

**A comprehensive handbook and practical guide**

*Third edition*

**David J Spencer**



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## 6

# Comparison of weft and warp knitting

### 6.1 Yarn feeding and loop formation

In a *weft knitting* machine, even when the needles are fixed or are caused to act collectively, yarn feeding and loop formation will occur at each needle in succession across the needle bed during the same knitting cycle (Fig. 6.1). All, or a number of, the needles (A, B, C, D) are supplied in turn with the same weft yarn during the same knitting cycle so that the yarn path (in the form of a course length) will follow a course of the fabric passing through each needle loop knitted from it (E, F, G, H).

In a *warp knitting* machine there will be a simultaneous yarn-feeding and loop-forming action occurring at every needle in the needle bar during the same knitting cycle (Fig. 6.2). All needles (A, B, C, D) in the needle bar are simultaneously lapped

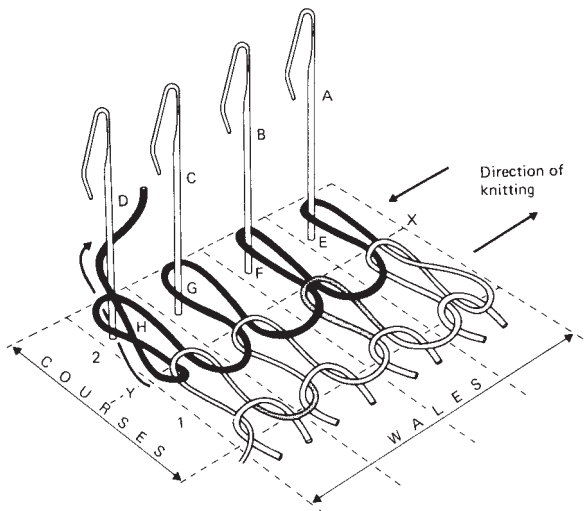


Fig. 6.1 Weft knitting.

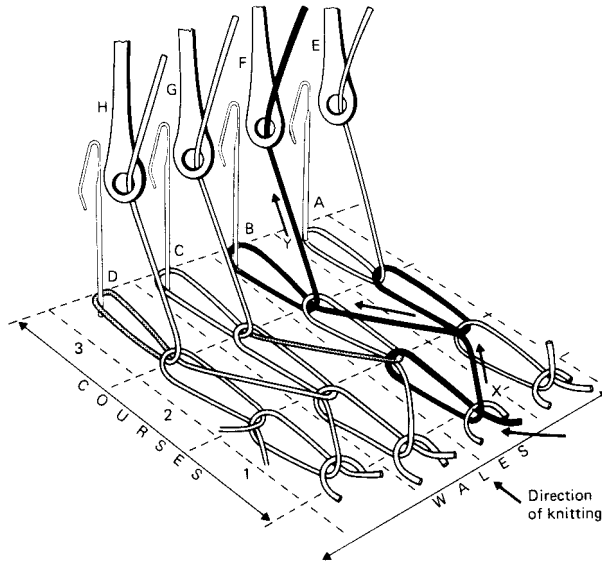


**Fig. 6.2** Warp knitting.

by separate warp guides (E, F, G, H). As all needles receive their overlaps simultaneously, a guide underlapping from one needle to another will be passing from one knitting cycle or course to the next. Thus, the warp yarn passes from an overlap produced in one course to an overlap produced in the succeeding course (for example, guide F underlapping from needle B to needle A).

## 6.2 The two industries

Occasionally parts of both knitting techniques are combined in a single machine; generally, however, the techniques have tended to diverge to produce entirely separate industries each having its own specialist technology, machine builders, fabric characteristics and end-uses.

### 6.2.1 Weft knitting

Weft knitting is the more diverse, widely spread and larger of the two sectors, and accounts for approximately one quarter of the total yardage of apparel fabric compared with about one sixth for warp knitting. Weft knitting machines, particularly of the garment-length type, are attractive to small manufacturers because of their versatility, relatively low total capital costs, small floor space requirements, quick pattern and machine changing facilities, and the potential for short production runs and low stock-holding requirements of yarn and fabric.

A major part of the weft knitting industry is directly involved in the assembly of garments using operations, such as overlocking (Fig. 6.3), cup seaming (Fig. 6.4), and linking, that have been specifically developed to produce seams with compatible properties to those of weft knitted structures. There are, however, production units

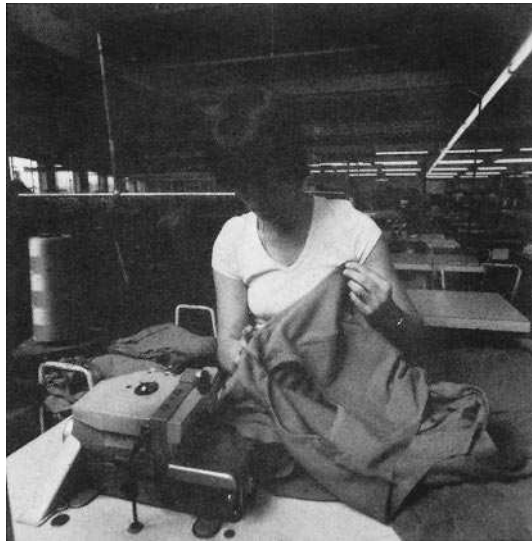


**Fig. 6.3** Overlock seaming [Corah].



**Fig. 6.4** Cup-seaming.

that concentrate on the knitting of continuous lengths of weft knitted fabric for apparel, upholstery and furnishings, and certain industrial end-uses.

### **6.2.2 Warp knitting**

Warp knitted fabric is knitted at a constant continuous width, although it is possible to knit a large number of narrow width fabrics within a needle bed width, usually separating them after finishing. There is considerable potential for changing fabric properties during the finishing process, as well as during knitting.

It is also possible to produce length sequences such as scarves with fringed ends, articles produced on double needle bar raschels based on the tubular knitting principle, and scalloped shaping of net designs by cutting around the outline after finishing.

British Celanese set the trend for the establishment of large, vertically-organized warp knitting plants self-sufficient in beaming, and in dyeing and finishing operations. During the 1930s they installed large plants with a total of 600 two-guide bar locknit machines, in order to convert their acetate and viscose rayon yarn into lingerie, shirting, blouse and dress fabrics. The much later introduction of continuous filament nylon and polyester yarn provided ideal raw materials for high-speed conversion into fine-gauge warp knitted fabrics.

From the mid 1950s, the patterning potential of multi-guide bar raschels has been progressively improved, based particularly on the conversion of nylon and polyester filament yarns. Thus, the lace and curtain net trade taken from warp knitting during the 1820s by twist, bobbinet and Leaver's lace machines has been extensively regained [1]. Warp knitting suffered in the swing of fashion away from continuous filament synthetic yarns towards blended spun yarns in solid fabrics, so there has been a tendency for the industry to seek new markets in household furnishings, car upholstery (Fig. 6.5) and industrial cloths.

Staple fibre spun yarns and textured continuous filament yarns create major difficulties for warp knitters. The precise setting of the elements, their fine gauge, the plating of two yarns in a needle hook, and the supply of parallel ends of yarn necessitate the use of fine and therefore expensive yarns. Problems can be caused by lint accumulation or filamentation, and the increased cross-sectional area caused by these seriously reduces the total length of warp yarn that can be accommodated on a specific warp beam flange diameter, thus increasing handling costs and machine down-time. For example, increasing the warp beam diameter from 21 to 40 inches (53 to 100cm) enables the total length of accommodated warp to be quadrupled, but changing the yarn from 30 denier nylon to 150 denier textured polyester decreases the total length of accommodated warp ten-fold.



**Fig. 6.5** Warp-knitted car upholstery [Karl Mayer].

### 6.3 Productivity

Productivity ( $P$ ) is expressed in pattern rows per minute. In warp knitting this is the same as courses, but in weft knitting a pattern row may be composed of more than one course (feed).

In warp knitting,  $P = R \times E$ , where  $R$  is the number of camshaft revolutions per minute and  $E$  is the machine efficiency.

In weft knitting,  $P = F \times R$  or  $T \times (E/C)$ , where  $F$  is the number of active yarn feeds,  $R$  or  $T$  the number of machine revolutions or cam-carriage traverses per minute, and  $C$  the number of courses or colours which comprise one pattern row.

### 6.4 Machine design

In warp knitting machines, all elements of the same type (needles or sinkers or guides of one guide bar) act as a single unit and are therefore fitted into, and controlled from, an element bar. Each guide in the same (conventional) guide bar requires the same warp-yarn feed rate and tension. This is most conveniently achieved by supplying a large number of parallel ends of warp yarn to the guide bar from a *warp beam*.

The shogging movement of the guide bars is controlled from one end of the machine. All these factors tend to restrict warp knitting machines to *rectilinear frames* and *straight needle bars*.

In weft knitting machines there are only a limited number of yarn feed positions, often requiring different rates of yarn feed, so these are supplied from yarn packages such as cones. Since the needles knit in serial formation, the weft knitting machine frame may be arranged with either a circular or a straight needle bed, depending upon end-use requirements.

### 6.5 Comparison of patterning and fabric structures

Individual element movement (particularly of latch needles) enables weft knitting machines to produce designs and structures based upon needle selection for loop intermeshing and transfer. This also facilitates the production of garment parts shaped on the knitting machine. Weft knitted loops tend to distort easily under tension and yarn can freely flow from one loop to another that is under greater tension, a characteristic which aids form-fitting and elastic recovery properties (Figures 6.6, 6.7 and 6.8). Change of yarn by horizontal striping is another major weft knitting patterning technique.

Weft knitted structures can generally be unroved, a course at a time, from the end of the fabric knitted last and this, together with a tendency for loop breakdown to cause laddering, can create problems.

Most patterning on warp knitting machines is based on selective control over guide bar lapping movements (i.e. the direction and extent of the overlap and underlap movements) and on the threading of the individual guides of each guide bar (i.e. with or without warp threads or with different types or colours of yarn). Yarn change by striping is not available on warp threads.

Warp knitted threads tend to have an approximately vertical path through the

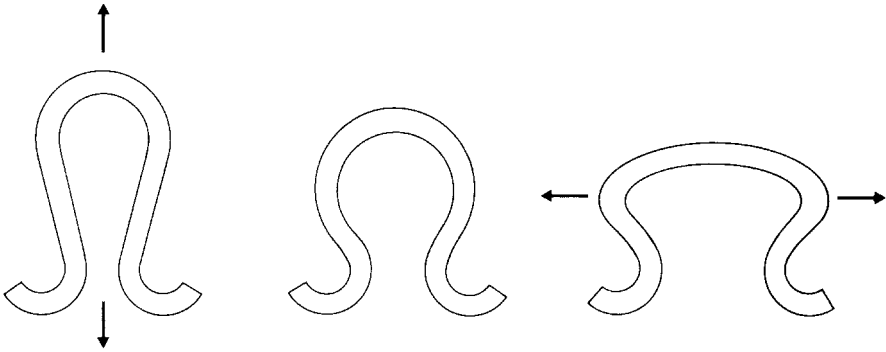


**Fig. 6.6** Loop extension and recovery.

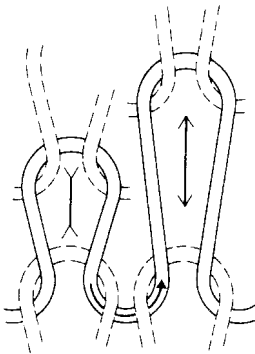


**Fig. 6.7** Yarn flow in knitted structure.

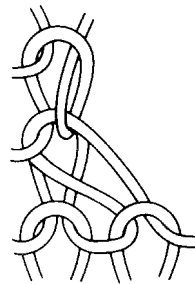


**Fig. 6.8** Weft knitted loop transfer.

structure, which makes the warp threads less likely to fray or unrove and, in the absence of weft threads allows almost any width up to the full knitting width to be achieved. Effects in open work and colour can be obtained without the use of special mechanisms, and lapping movements can be arranged to produce fabrics ranging from dimensionally stable to highly elastic without necessarily changing the type of yarn.

## 6.6 Course length and run-in per rack

In weft knitting, the term '*course length*' refers to the measurement of a straight length of yarn knitted by all or a fraction of the needles in the production of a particular course. It consists of the stitch length multiplied by the number of needles knitting that stitch length. It may be measured at a yarn feed during knitting or after unroving the yarn from a knitted fabric, either as a complete course length or from the counted wales between two vertical cuts in the fabric. In Fig. 6.1, the length of black yarn between *X* and *Y* would be the course length.

In warp knitting, *run-in per rack* is equivalent to course length in weft knitting and is measured in inches or millimetres. All threads from the same warp are supplied from the same beam-shaft under identical conditions of yarn feed and tension,

so it is only necessary to measure the length of one representative runner from each warp. The *rack* is an internationally recognized unit of 480 courses or knitting cycles. For fabric weight calculations, the threading arrangement of each bar must also be taken into consideration.

The simplest method of measuring run-in is to divert one thread through two guide eyes so that it runs at right-angles to the rest of the warp sheet at that point. It is then marked and, after the machine has been run for 480 cam-shaft revolutions, the distance the mark has moved towards the needles is measured. The length of yarn in an average stitch unit can be calculated by dividing the run-in by 480.

In Fig. 6.2, the length of black warp thread between *X* and *Y* would be the run-in if the measurement was multiplied by 160, giving a total of 480 courses.

## 6.7 Fabric quality

The term fabric '*quality*' is sometimes used when referring to wales and courses per inch or centimetre, either in a knitted or a finished relaxed state. As knitted loops tend to assume a recognizable configuration, the results can give an indication of the approximate stitch length and possible machine gauge used in knitting the structure, provided the state of relaxation and type of structure is taken into consideration. Generally, the higher the figure for a given linear measurement of wales, the finer the machine gauge and the smaller the stitch length.

## 6.8 Structural modifications commonly used in weft and warp knitting

Certain techniques are possible during the knitting action that can radically change the physical appearance and properties of a knitted construction without seriously affecting the cohesive nature of the loop structure. These techniques may be broadly divided into four groups – laying-in, plating, open-work and plush/pile. Although these techniques can be achieved on most knitting machines, slight modifications are often necessary and the more sophisticated versions of these techniques may require specially-designed knitting machines.

### 6.8.1 Laying-in

*Inlaid* (or laid-in) *fabric* consists of a ground structure of knitted or overlapped (warp knitted) threads that hold in position other non-knitted threads which were incorporated (laid-in) into the structure during the same knitting cycle.

*An inlaid yarn is never formed into a knitted loop*, although in weft knitting, when using only one bed of needles, it is necessary to form the inlay yarn into occasional tuck stitches in order to hold it in the technical back of the structure.

When weft knitting with two sets of needles, or when overlapping on the front guide bar of a warp knitting machine, it is possible to introduce the inlaid yarn into the structure merely by supplying the yarn across the backs of the needles (the front of the machine) in order to trap the yarn in the fabric.

Inlaid yarns are trapped inside double needle bed fabrics by the loops or

overlaps; and towards the back of single needle bed fabrics by the sinker loops or underlaps.

Dependent upon the fabric construction and the types of yarns employed, laying-in may be used to modify one or more of the following properties of a knitted structure: stability, elastic stretch and recovery, handle, weight, surface 'interest', and visual appearance.

Laying-in offers the possibility of introducing fancy, unusual, and/or inferior or superior yarns whose physical properties such as thickness (linear density, count), low strength, irregular surface or cross-sectional area, elasticity or lack of elasticity render them difficult to knit into intermeshed loops. An inlay yarn may have a yarn count that is 6–8 times heavier than the optimum count for that machine type and gauge when operating under normal knitting conditions.

Laying-in yarn carriers or feeder guides may be of the conventional type or they may be specially designed for their function and the type of yarn; the ground yarn is knitted normally as for any structure. An inlay yarn normally assumes a relatively straight configuration, with hardly any reserve of yarn to distort or flow towards an area of the fabric under tension. It therefore requires less yarn than for knitted loops and tends to confer stability unless an elastomeric yarn is used, in which case the elastic stretch and recovery properties of the fabric will be improved.

### 6.8.2 Weft insertion

*Weft insertion* is a special type of laying-in where the yarn is laid onto special elements that, in turn, introduce it to the needles at the correct moment during the knitting cycle, instead of the yarn guide laying the yarn directly into the needles.

Although the possibility exists for introducing both weft and warp threads into either weft knitted or warp knitted fabrics during knitting, many attempts at this technique have failed to produce viable alternative structures as regards cost, design or end-use properties to effectively compete against woven structures [2–5].

In warp knitting, laying-in is achieved even on single needle bar machines by omitting the overlap movement and merely underlapping on the inlay guide bar. Provided the inlay guide bar is always behind a guide bar that is overlapping the front guide bar, overlaps and underlaps will trap the inlay underlaps into the technical back of the structure (Fig. 27.1).

When weft knitting with one set of needles, it is not possible to lay-in a yarn by merely traversing a yarn carrier across the backs of the needles because the yarn will not be trapped by the sinker loops of the knitted loops. The inlaid yarn must occasionally pass across the hooks of a needle to form a tuck stitch and thus hold itself into the structure.

### 6.8.3 Plating

A *plated structure* contains loops composed of two (or more) yarns, usually with differing physical properties. Each has been separately supplied through its own guide or guide hole to the needle hook, in order to influence its respective position relative to the surface (technical face and technical back of the fabric).

Plating (as an all-over effect or on selected stitches) may be used to produce surface interest, coloured patterns, open-work lace or to modify the wearing properties of the structure.

*Perfect plating*, so that the underneath yarn does not show or 'flash' onto the surface, is difficult to achieve with yarns that have a circular cross-section and variable physical properties. It is essential to control yarn tension, angle of feed and the already-formed loops throughout the whole knitting cycle. If the two yarns are of similar count, they should be approximately half the normal yarn count for that gauge of machine.

As the yarns slide along the underside of a normally-curved needle hook, they may roll over each other and thus destroy their plating relationship; for this reason, needles with specially shaped hooks for plating are often employed.

The basic rule of plating is that the yarn positioned nearest to the needle head shows on the reverse side of the needle loop and therefore shows on the surface of the technical back (Fig. 6.9). The second yarn is in a lower position and tends to show on the face stitches of weft- and warp-knitted structures (Figures 6.10 and 6.11). The second yarn will be prominent on the surface of face loops on both sides of rib fabrics unless it is tucked ('tuck plated') by the second set of needles. In purl fabrics, face stitches will show the second yarn and reverse stitches the first yarn.

In single jersey plating, the yarn for the technical back is fed at a low angle across the open latches from a hole drilled vertically in the feeder guide. The face yarn is fed at a sharp angle above it into the open hooks from a hole drilled horizontally into the side of the guide. As the latches close, the back yarn is lifted into the hook above the face yarn, thus ensuring the correct plating relationship in the fabric.

In tricot warp knitting, many fabrics are knitted where two guide bars simultaneously overlap the same needle in opposite directions and thus produce a plated structure. The front guide bar threads strike the needle stems first and at a lower

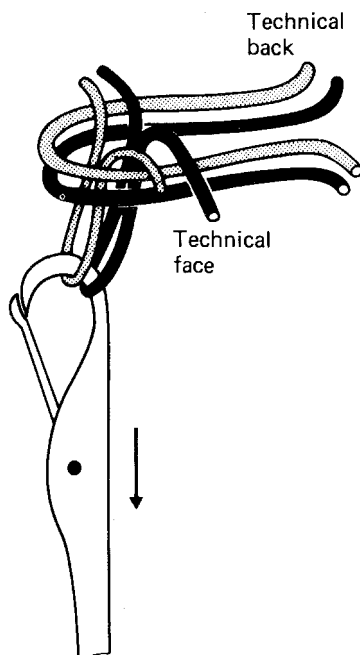


**Fig. 6.9** The plating relationship of two yarns.

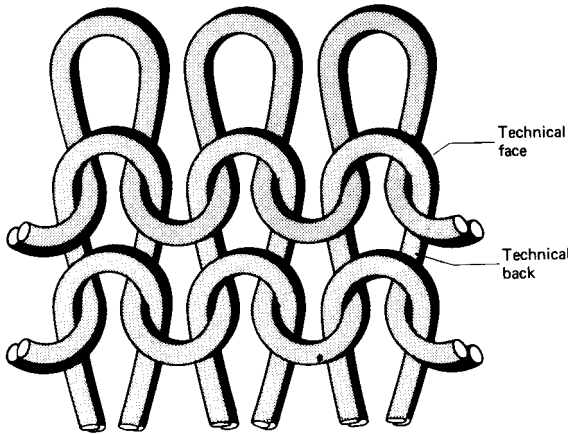


**Fig. 6.10** Plating in weft knitting.

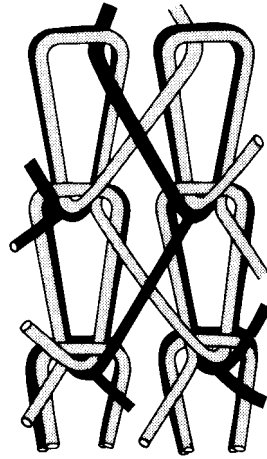


**Fig. 6.11** Plating in warp knitting.

level during the return swing after the overlap, so they tend to plate on top on the technical face.

This relationship may, however, be upset if the two guide bars overlap in the same direction, because the back guide bar threads then tend to slide over the front bar threads and thus assume a lower position on the needle.

Normally the front guide threads also show on the technical back, as well as the front, because, as the underlaps emerge from out of the head of the previous loop, they are laid on top of the new overlaps in turn and the front bar underlap (black) is laid down last (Fig. 6.11).

#### 6.8.4 Open-work structures

Knitting is noted for its production of open-work as well as close structures.

A *close structure* is one where the stitches provide a uniform cover across the fabric and hold the wales securely together. An *open-work structure* has normal securely-intermeshed loops but it contains areas where certain adjacent wales are not as directly joined to each other by underlaps or sinker loops as they are to the wales on their other side. The unbalanced tension causes them to move apart, producing apertures at these points. The arrows in Fig. 6.12 indicate the movement of adjacent wales towards each other at points where they are most securely joined together, thus producing an aperture on the other side of the wale.

*Semi-transparent structures* are produced in a similar manner but, instead of having apertures, there is less yarn crossing between the wales than elsewhere and this provides less cover at these points ('float plating', Section 9.5).

*Semi-breakthrough* or honeycomb structures have certain yarns that produce an open-work effect whilst others produce an all-over close structure, so that the aperture is closed on one side of the fabric.

Open-work apertures may be a number of courses in depth and, as a result of tension distortion within the structure, they may cause adjacent wales to be considerably further apart than the actual distance between two adjacent needles during knitting.

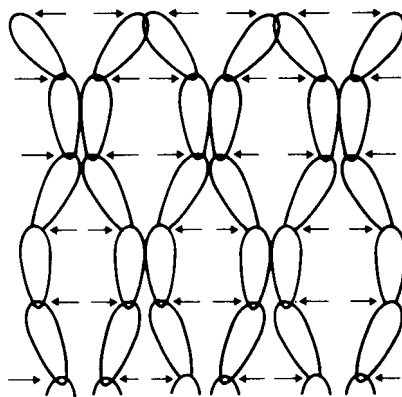


**Fig. 6.12** The movement of loops to form open work.

In weft knitting only, open-work structures may be produced by the introduction of empty needles and/or by using special elements to produce loop displacement. An alternative technique is by selective press-off of fabric loops.

Open-work structures are used for fancy laces and nets for dresswear, underwear (Fig. 6.13), nightwear, lingerie, sportswear, linings, blouses and shirts, drapes and curtains, and industrial fabrics.

### 6.8.5 Plush and pile constructions

Although the terms 'plush' and 'pile' originally referred to specific woven structures, they are often used synonymously today in referring to a very wide range of weft and warp knitted constructions.

The essential difference between a plush and pile structure is that the *pile* is normally composed of a different type of yarn and should stand out almost at right angles from the knitted ground surface whereas the *plush* has neither of these characteristics. Both plush and pile surfaces may consist of either cut or uncut loops of yarn and, in the case of *high pile*, slivers of fibres instead of yarns are used. Generally, the production of pile fabrics tends to be a very specialized technique for both knitting and finishing. One or more of the following techniques is normally involved in the production of the two types of fabric – special points or other elements in the knitting machine, excess feeding of the pile yarn, and raising or brushing of the pile surface during finishing.

Although a certain amount of double-faced pile fabric is produced, the majority of plush and pile fabric has its surface effect on the technical back of single-faced constructions, with the sinker loops or underlaps being used to produce the effect. A variation of this technique is to use a double needle bar machine, pressing off on the second set of needles to produce the pile surface. Yet another method is to employ a double needle bar raschel to knit two separate ground constructions, one on each needle bar, each with its own yarns, and to supply a pile yarn across between the needle bars. The pile is later cut to separate the two ground fabrics and thus produce two single-sided cut pile fabrics.



**Fig. 6.13** Bra and briefs made from elastic raschel lace fabric. Note also the scalloped, elasticated edge trimmings [Dupont 'Lycra'].

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## The four primary base weft knitted structures

### 7.1 Introduction

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 unrove (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.

## 7.2 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 popularised 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  $3\frac{1}{2}$  needles per inch (25 mm). The term '*plain knit*' may be used instead of just 'plain', particularly when the structure has a surface design.

Its technical face (Fig. 7.1) 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. 7.2), whose appearance is sometimes emphasised by knitting alternate courses in different coloured yarns.

Plain can be unrove 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 unroving 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' [1].

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 unrove

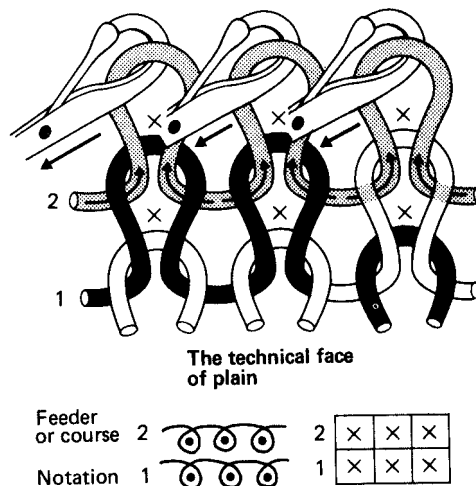


Fig. 7.1 The technical face of plain weft knitted fabric.

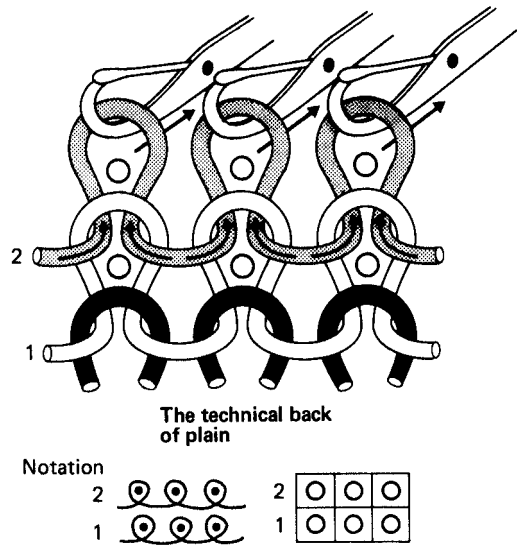


**Fig. 7.2** The technical back of plain weft knitted fabric.

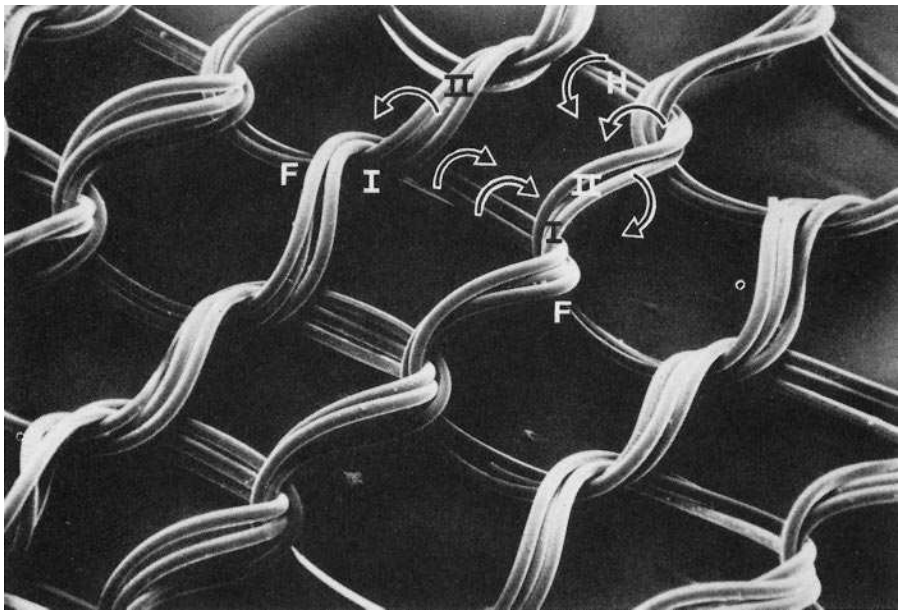


**Fig. 7.3** The three-dimensional structure of plain weft knitting [Milliken AGILON] magnified  $\times 130$  by a stereoscan electron microscope. The arrows indicate the direction in which the fabric will tend to curl if it is cut. [By permission of *Knitting Times*, official publication of NKSA USA].

and fray when not in tubular or flat selvedged form can be overcome by securing them during seaming.

Knitted structures have a three-dimensional structure as shown in Fig. 7.3. At the point where the new needle loop is drawn through the old loop (I), the structure is

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composed of two yarn thicknesses (diameters) instead of one. The needle loop is therefore held down, both at its head (H) and its feet (F), by loops in the same wale, but its side limbs tend to curve upwards at (II).

When the fabric is cut, the loops are no longer held in this configuration so that the fabric curls towards the face at the top and bottom and towards the back at the sides. The same configuration causes face meshed wales of loops to be prominent in rib fabrics and the heads of loops and the sinker loops to be prominent in wales of purl stitches.

Plain is the simplest and most economical weft knitted structure to produce and has the maximum covering power. It normally has a potential recovery of 40% in width after stretching.

### 7.2.1 Production of single-jersey fabric on a circular latch needle machine

Most single-jersey fabric is produced on circular machines whose latch needle cylinder and sinker ring revolve through the stationary knitting cam systems that, together with their yarn feeders, are situated at regular intervals around the circumference of the cylinder. The yarn is supplied from cones, placed either on an integral overhead bobbin stand or on a free-standing creel, through tensioners, stop motions and guide eyes down to the yarn feeder guides.

The fabric, in tubular form, is drawn downwards from inside the needle cylinder by tension rollers and is wound onto the fabric-batching roller of the winding-down frame. The winding-down mechanism revolves in unison with the cylinder and fabric tube and is rack-lever operated via cam-followers running on the underside of a profiled cam ring. As the sinker cam-plate is mounted outside on the needle circle, the centre of the cylinder is open and the machine is referred to as an *open top* or *sinker top* machine.

Compared with a rib machine, a plain machine is simpler and more economical, with a potential for more feeders, higher running speeds and knitting a wider range of yarn counts. The most popular diameter is 26 inches (66 cm) giving an approximate finished fabric width of 60–70 inches (152–178 cm). An approximately suitable count may be obtained using the formula  $NeB = G^2/18$  or  $NeK = G^2/15$ , where  $NeB$  = cotton spun count,  $NeK$  = worsted spun count,  $G$  = gauge in npi. For fine gauges, a heavier and stronger count may be necessary.

Examples of typical metric cotton counts for machine gauges are:

E 18 Nm1/24–1/32,  
E 20 Nm1/28–1/40,  
E 22 Nm1/32–1/44,  
E 24 Nm1/34–1/48,  
E 28 Nm1/50–1/70

#### 7.2.1.1 The knitting head

Figure 7.4 shows a cross section of the knitting head all of whose stationary parts are shaded.

- 1 Yarn feeder guide, which is associated with its own set of knitting cams.
- 2 Latch needle.
- 3 Holding-down sinker – one between every needle space.
- 4 Needle cylinder (in this example, revolving clockwise).
- 5 Cylinder driving wheel.

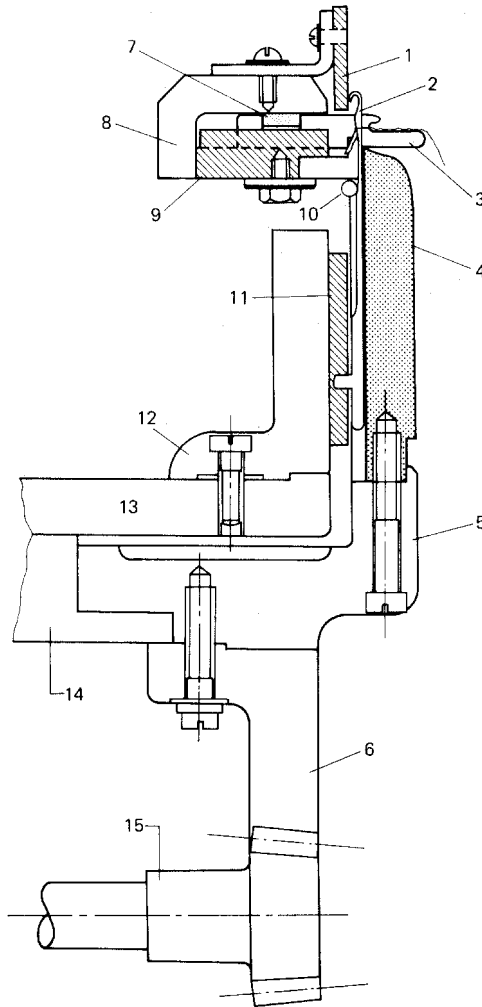


**Fig. 7.4** Cross-section of knitting head of a single jersey machine.

- 6 Cylinder driving gear.
- 7 Sinker-operating cams, which form a raised track operating in the recess of the sinker.
- 8 Sinker cam-cap.
- 9 Sinker trick ring, which is simply and directly attached to the outside top of the needle cylinder thus causing the sinkers to revolve in unison with the needles.
- 10 Needle-retaining spring.
- 11 Needle-operating cams which, like the sinker cams, are stationary.
- 12 Cam-box.
- 13 Cam-plate.
- 14 Head plate.
- 15 Cylinder driving pinion attached to the main drive shaft.

### 7.2.1.2 The knitting action

Figure 7.5(a-e) shows the knitting action of a latch needle and holding-down sinker during the production of a course of plain fabric.

- Tucking in the hook or rest position.* The sinker is forward, holding down the old loop whilst the needle rises from the rest position.
- Clearing.* The needle has been raised to its highest position clearing the old loop from its latch.
- Yarn feeding.* The sinker is partially withdrawn allowing the feeder to present its yarn to the descending needle hook and also freeing the old loop so that it can slide up the needle stem and under the open latch spoon.
- Knock-over.* The sinker is fully withdrawn whilst the needle descends to knock-over its old loop on the sinker belly.
- Holding-down.* The sinker moves forward to hold down the new loop in its throat whilst the needle rises under the influence of the upthrow cam to the rest position where the head of the open hook just protrudes above the sinker belly.

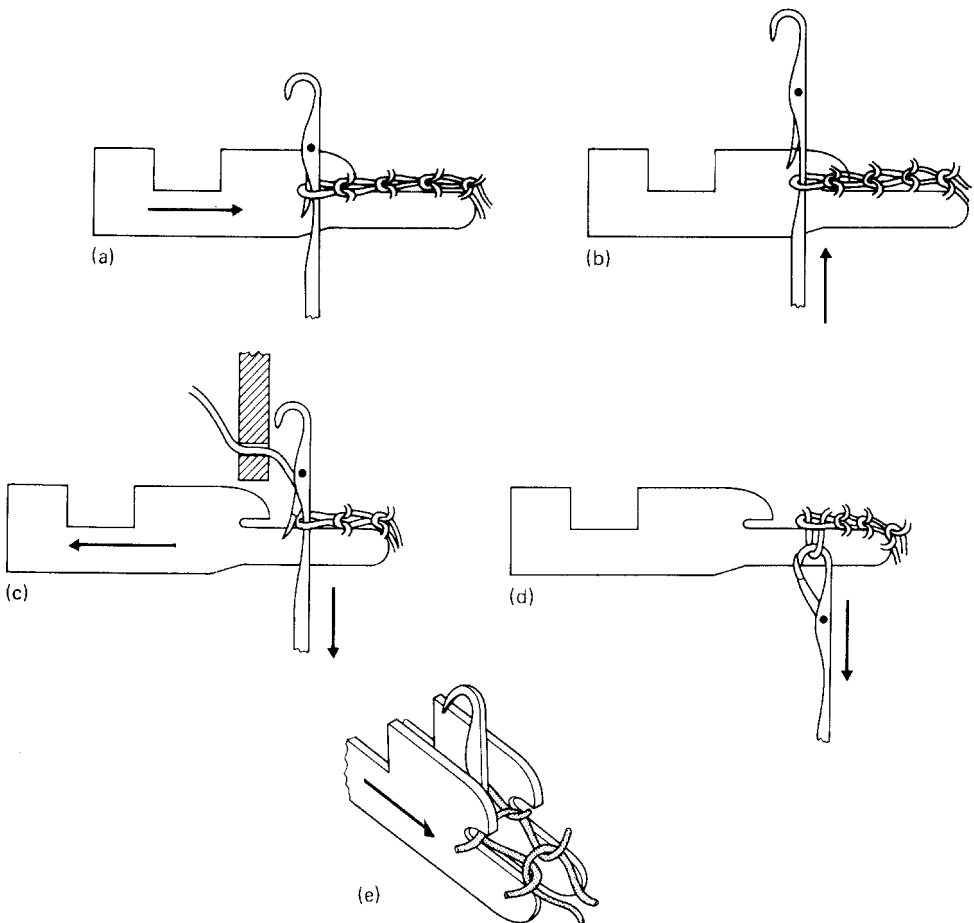


**Fig. 7.5** Knitting cycle of a single jersey latch needle machine.

### 7.2.1.3 The cam system

Figure 7.6 shows the arrangement and relationship between the needle and sinker cams as the elements pass through in a left to right direction with the letters indicating the positions of the elements at the various points in the knitting cycle. The needle cam race consists of the following: the clearing cam (1) and its guard cam (4), the stitch cam (2) and upthrow cam (3) which are vertically adjustable together for alteration of stitch length, and the return cam (5) and its guard cam (6).

The three sections of the sinker cam race are the race cam (7), the sinker-withdrawing cam (8) and the sinker-return cam (9) which is adjustable in accordance with the stitch length.

### 7.2.1.4 Sinker timing

The most forward position of the sinker during the knitting cycle is known as the *push point* and its relationship to the needles is known as the *sinker timing*. If the sinker cam-ring is adjusted so that the sinkers are advanced to the point where they rob yarn from the new stitches being formed, a lighter-weight fabric with oversized sinker loops and smaller needle loops is produced. If the ring is moved in the oppo-

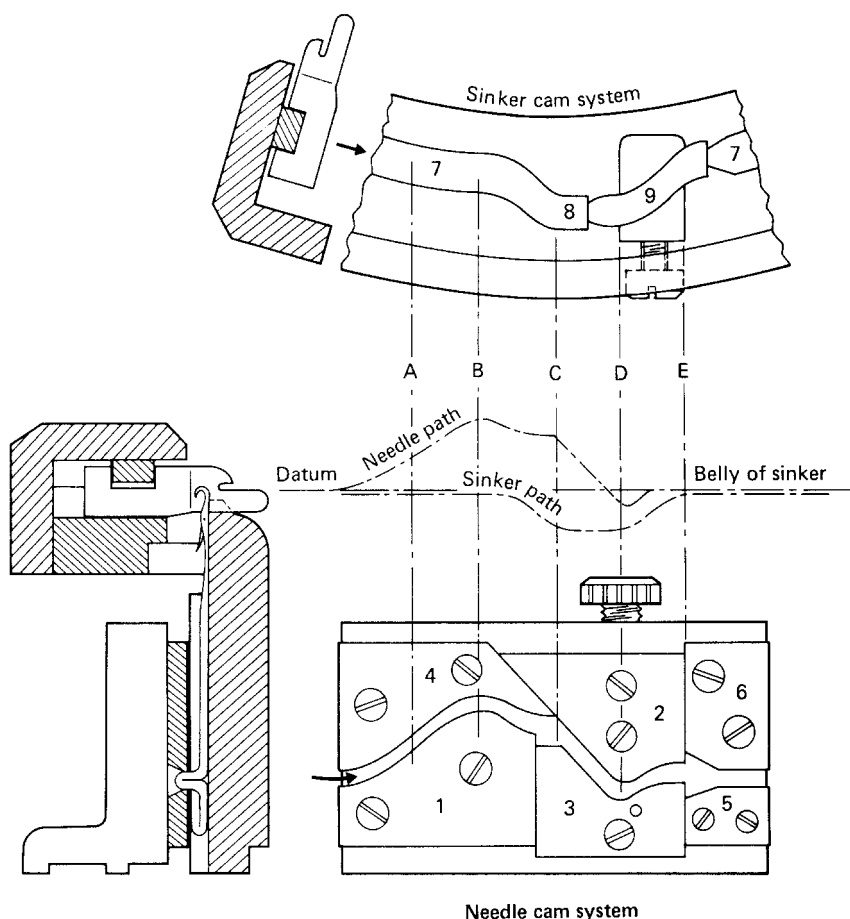


Fig. 7.6 Sinker timing on a single jersey machine.

site direction, a tighter, heavier fabric is produced having smaller sinker loops and larger needle loops. The timing is normally set between the two extremes.

### 7.2.2 The 'contra' knitting technique

The 'contra', *relative* or *shared loop* knitting technique is used on some modern circular single-jersey fabric machines. The sinkers move vertically, to positively assist in holding-down and knocking-over the fabric loops so that they move in opposition to both the rise and the fall of the needles, as well as having the normal radial movement between the needles. The contra movement of the fabric loops considerably reduces the extent of the needle movement.

As on the old bearded needle sinker-wheel machines, one loop is almost fully formed before the next loop is commenced. There are thus less metal/yarn contact points (each of which doubles the tension of the previous point). Contra knitting therefore reduces the tendency to 'rob back', produces less knitting element stress, improves fabric quality, 'handles' yarns more gently, and enables weaker and lower quality yarns to be knitted. The smaller needle movement enables cam angles to be employed so that speeds up to 1.4m/sec can be achieved. (See also Section 13.10.)

## 7.3 Rib structure

The simplest rib fabric is  $1 \times 1$  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 (Figures 7.7, 7.8).

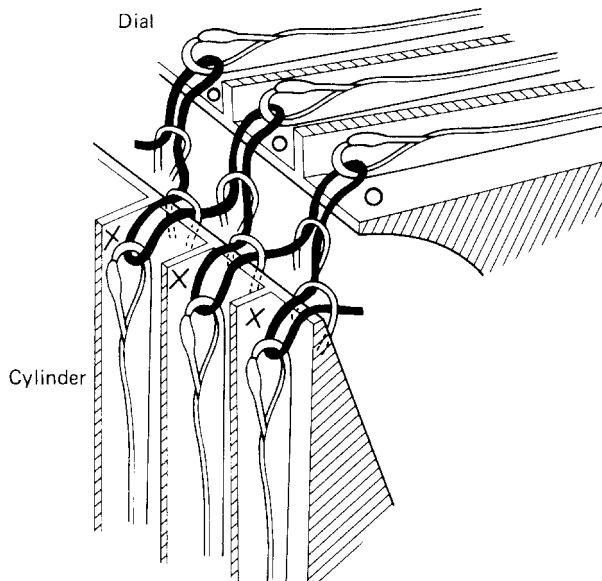


Fig. 7.7 Structure of  $1 \times 1$  rib.

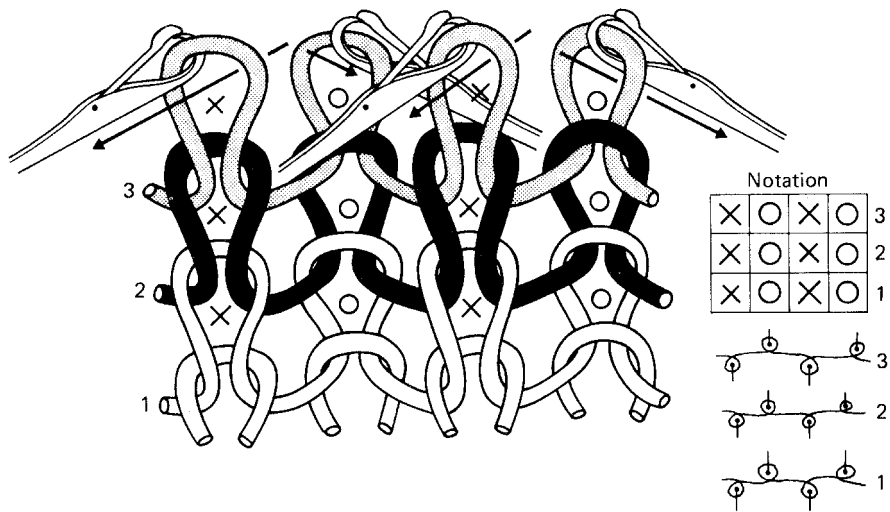


**Fig. 7.8** Face and reverse loop wales in 1 × 1 rib.

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 × 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.

1 × 1 rib is produced by two sets of needles being alternately set or gated between each other. Relaxed 1 × 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 × 1 rib normally relaxes by approximately 30 per cent compared with its knitting width.

1 × 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 unraveled 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 × 1 rib. It is knitted at the tops of plain knit socks and gloves.

Rib cannot be unraveled 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.

### 7.3.1 Rib set-outs

There is a range of rib set-outs apart from  $1 \times 1$  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* (Fig. 7.9). 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 (Fig. 7.9).

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* (Fig. 7.9), 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  $2 \times 2$  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  $2 \times 2$  needle set-out is arranged for  $1 \times 1$  rib; this is termed '*skeleton  $1 \times 1$* '; after knitting the set-up course, the bed is racked back so that  $2 \times 2$  rib knitting can commence.

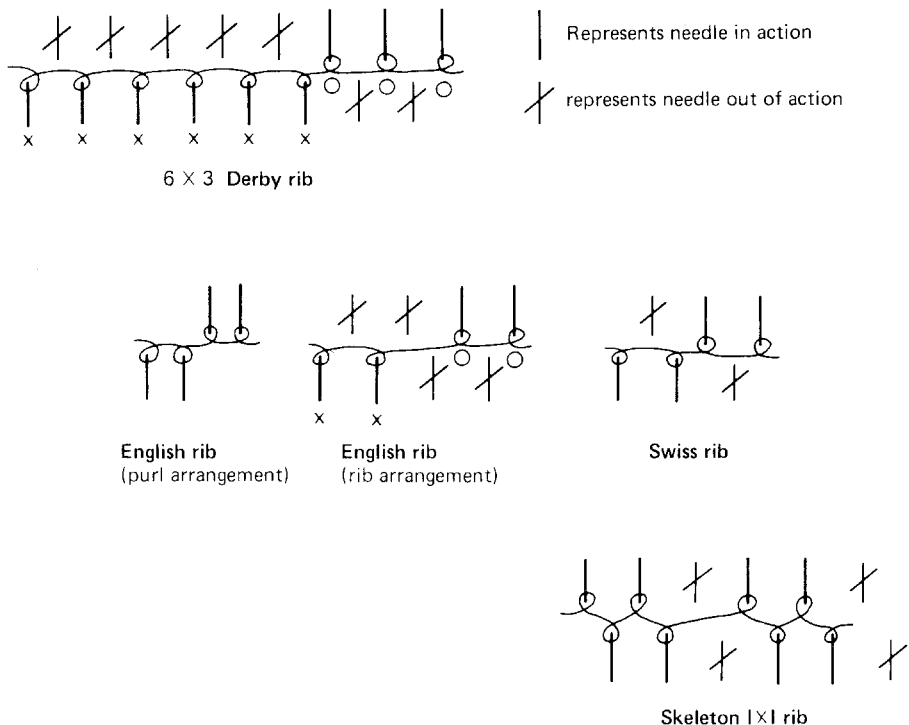


Fig. 7.9 Rib set-outs.

*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  $2 \times 2$  to  $1 \times 1$  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.

### 7.3.2 The knitting action of the circular rib machine

The knitting action of a circular rib machine is shown in Fig. 7.10:

- Clearing.* The cylinder and dial needles move out to clear the plain and rib loops formed in the previous cycle.
- Yarn Feeding.* The needles are withdrawn into their tricks so that the old loops are covered by the open latches and the new yarn is fed into the open hooks.
- Knocking-over.* The needles are withdrawn into their tricks so that the old loops are cast off and the new loops are drawn through them.

In a gauge range from 5 to 20 npi, an approximately suitable count may be obtained using the formula  $NeB = G^2/8.4$ , where  $NeB$  = cotton count and  $G$  = gauge in npi.

For underwear fabric, a popular gauge is E 14 with a count of 1/30's.

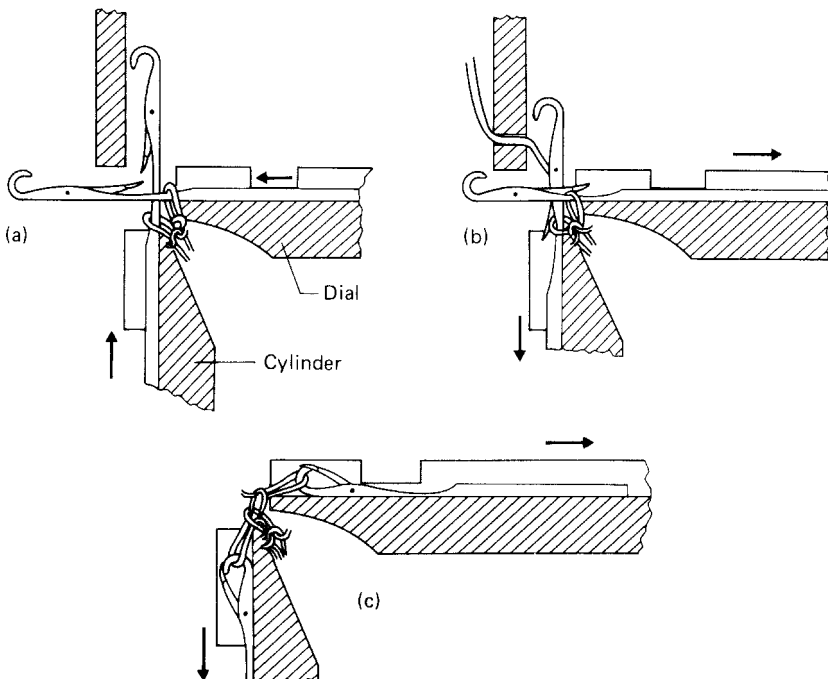


Fig. 7.10 Knitting action of a circular rib machine.

### 7.3.3 Needle timing

*Needle timing* (Fig. 7.11) is the relationship between the loop-forming positions of the dial and cylinder needles measured as the distance in needles between the two stitch cam knock-over points. Collective timing adjustment is achieved by moving the dial cam-plate clockwise or anti-clockwise relative to the cylinder; individual adjustment at particular feeders (as required) is obtained by moving or changing the stitch cam profile.

*Synchronized timing* (Fig. 7.12), also known as *point, jacquard* and  $2 \times 2$  timing, is the term used when the two positions coincide with the yarn being pulled in an alternating manner in two directions by the needles, thus creating a high tension during loop formation.

With *delayed timing*, also called *rib* or *interlock timing* (Fig. 7.13) the dial knock-over occurs after about four cylinder needles have drawn loops and are rising

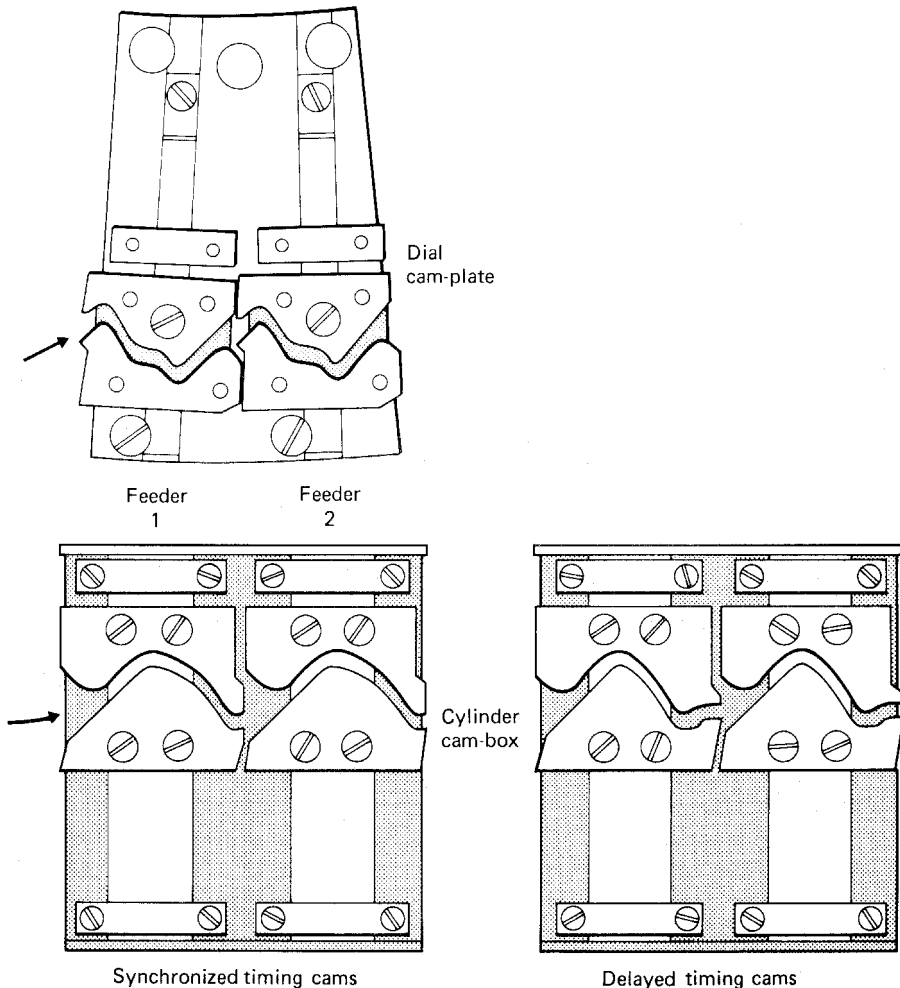
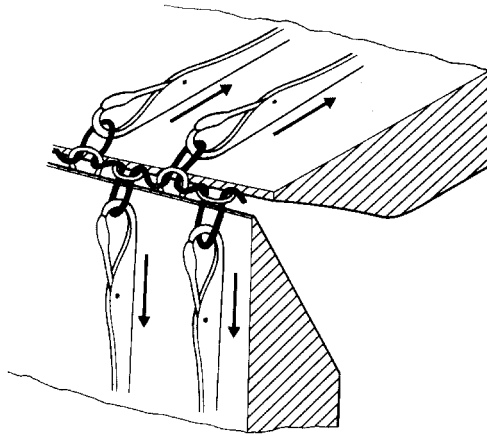
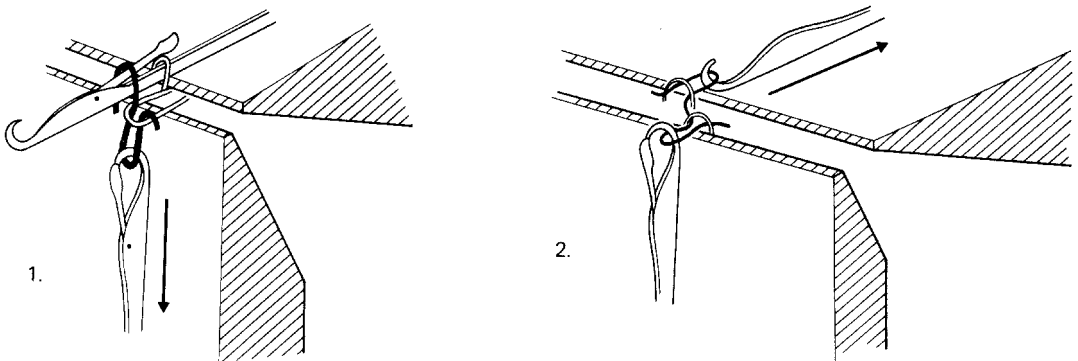


Fig. 7.11 Needle cam timing for a circular rib machine.

**Fig. 7.12** Synchronised timing.**Fig. 7.13** Delayed timing.

slightly to relieve the strain. The dial loops are therefore composed of the extended loops drawn over the dial needle stems during cylinder knock-over, plus a little yarn robbed from the cylinder loops. The dial loops are thus larger than the cylinder loops and the fabric is tighter and has better rigidity; it is also heavier and wider, and less strain is produced on the yarn.

Rib jacquard or broad ribs cannot be produced in delayed timing because there will not always be cylinder needles knitting either side of the dial needles from which to draw yarn. Although the dial knock-over is delayed, it is actually achieved by advancing the timing of the cylinder knock-over (Fig. 7.11).

*Advanced timing* is the reverse of delayed timing. The cylinder loops rob from the dial, producing tighter dial loops; advancement can only be about one needle. This type of timing is sometimes used in the production of figured ripple double-jersey fabrics, where selected cylinder needles can rob from the all knitting dial needles [2].

## 7.4 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 (51cm) 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 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. 7.14). 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  $1 \times 1$  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.

Interlock relaxes by about 30–40 per cent or more, compared with its knitted width, so that a 30-inch (76cm) diameter machine will produce a tube of 94-inch (2.4m) 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  $1 \times 1$  rib, it will not unrove 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

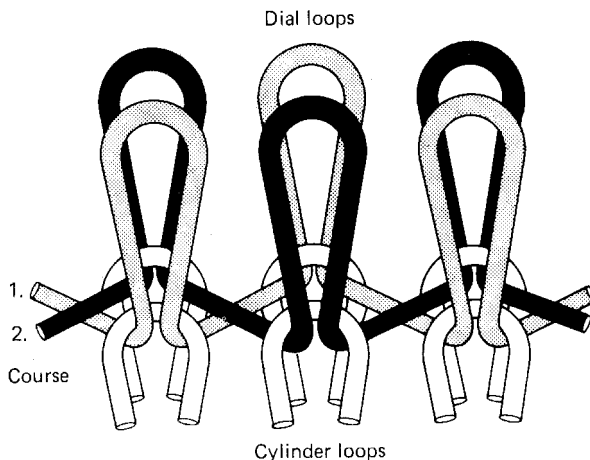


Fig. 7.14 Interlock fabric structure.

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.

*Eightlock* is a  $2 \times 2$  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  $4 \times 4$  and  $3 \times 3$  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.

#### 7.4.1 Production of interlock fabric

Interlock is produced mainly on special cylinder and dial circular machines and on some double-system V-bed flat machines (Fig. 7.15). 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.

Typical cotton counts for particular gauges would be:

|                    |                     |
|--------------------|---------------------|
| E 16 Nm 1/28–1/50, | E 22 Nm 1/50–1/80,  |
| E 18 Nm 1/34–1/60, | E 24 Nm 1/56–1/90,  |
| E 20 Nm 1/40–1/70, | E 28 Nm 1/60–1/100. |

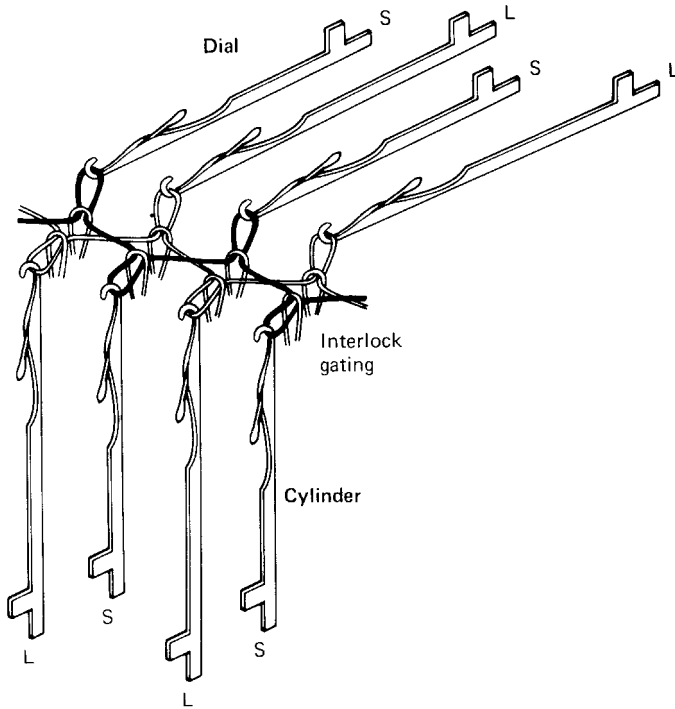


**Fig. 7.15** Knitting interlock.

A 30-inch (76 cm) diameter E 28 machine running at 28 rpm and 85% efficiency, knitting 38 courses/in (15 courses/cm) from Nm 1/70 yarn would produce 34.4 lb/hr (15.6 kg/hr) of 4.45 oz/yd<sup>2</sup> (151 g/m<sup>2</sup>) interlock fabric.

#### 7.4.2 Example of an interlock cam system

Figure 7.16 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.

##### *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.

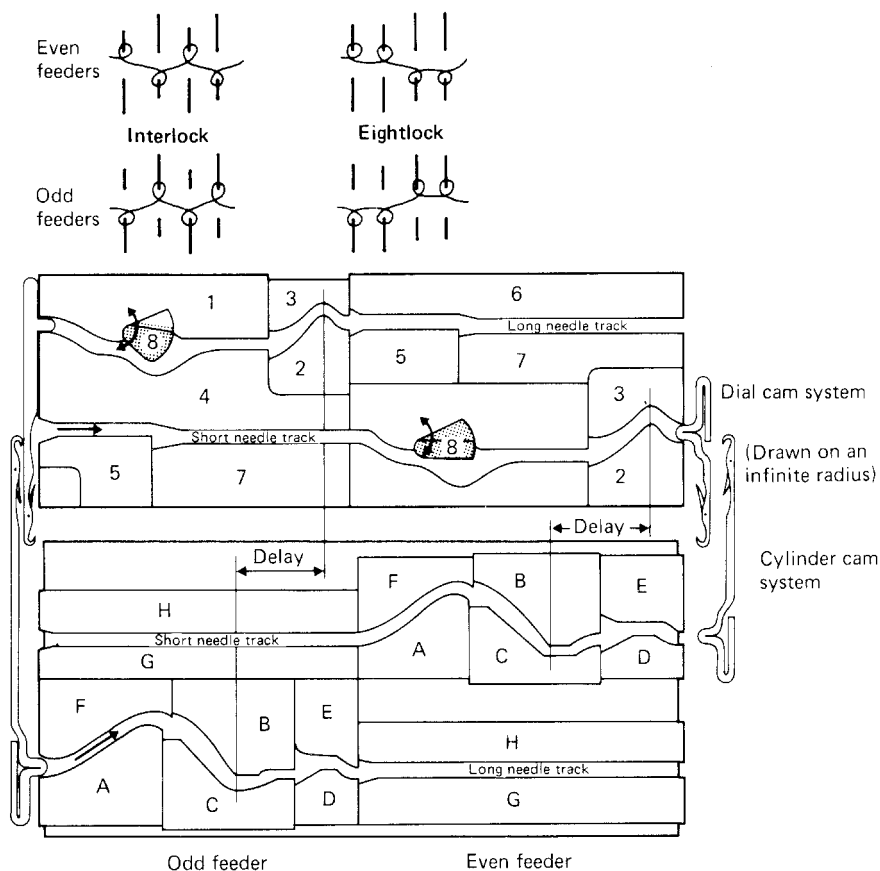


**Fig. 7.16** Interlock cam system.

- 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 *eightlock machines*.

## 7.5 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

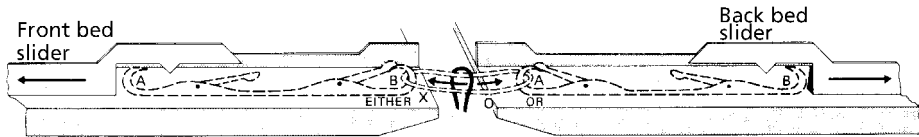
to the term '*links-links*' being generally applied to purl fabrics and machines. Links is the German word for left and it indicates that there are *left* or *reverse* loops visible on each side of the fabric [3]. In a similar manner, the German term for rib is rechts-rechts (right-right).

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. 7.17). 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 (Fig. 7.18).

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* (Fig. 7.19). 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.



(NB The same needle has been drawn twice to show its two possible knitting bed positions)

Fig. 7.17 Purl knitting using sliders.

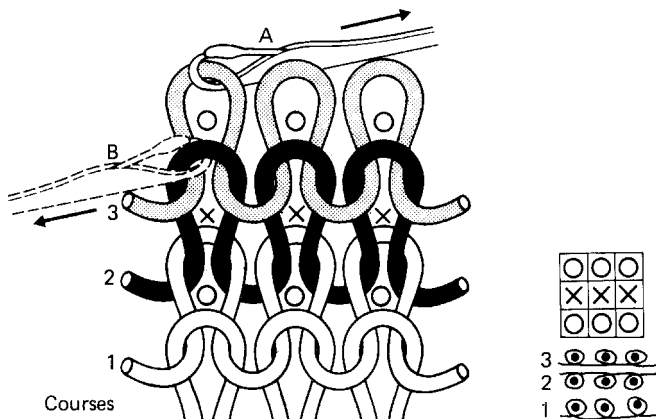


Fig. 7.18 Purl fabric structure.

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.

Flat bed purls are no longer built because electronically-controlled V-bed flat machines can now knit types of links-links designs. Small diameter (6 inch/15 cm 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  $1 \times 1$  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 (Fig. 7.18). 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 unraveled from both ends because the free sinker loops can be pulled through at the bottom of the fabric. In the USA,  $1 \times 1$  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 (Fig. 7.20). *Basket purls* consist of rectangular areas of all X or all O loops, which alternate with each other. Examples include  $5 \times 3$  (Fig. 7.21),  $7 \times 3$ ,  $4 \times 4$  (Fig. 7.22). 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 [4].

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.

### 7.5.1 Purl needle transfer action

The following conditions are necessary in order to achieve the transference of a purl needle from the control of a slider in one bed into the control of a slider in the opposite bed (Fig. 7.19):

- 1 Engagement of the head of the receiving slider with the needle hook that was originally knitting from the opposing bed.
- 2 Cam action causing the head of the delivering slider to pivot outwards from the trick and thus disengage itself from the other hook of the needle.
- 3 Sufficient free space to allow the heads of the sliders to pivot outwards from their tricks during engagement and disengagement of the needles.
- 4 A positive action which maintains the engagement of the head of a slider with a needle hook throughout its knitting cycle by ensuring that it is pressed down into the trick.

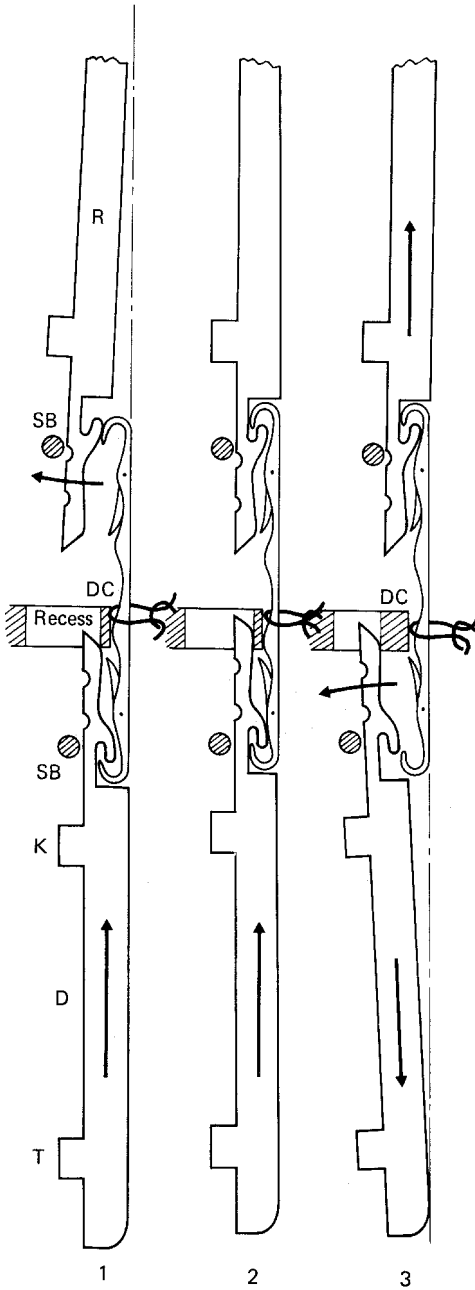


**Fig. 7.19** Purl needle transfer action.

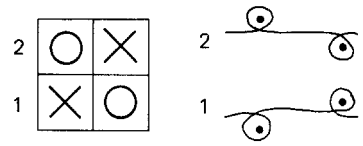
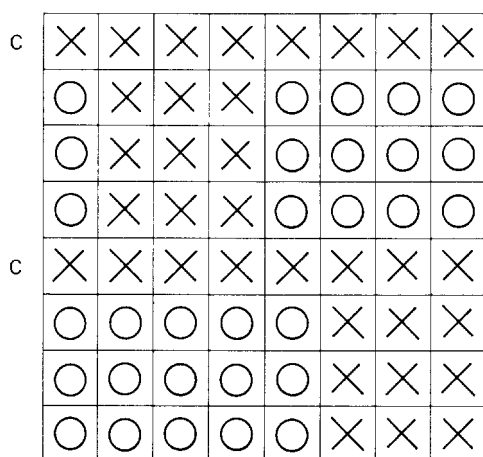


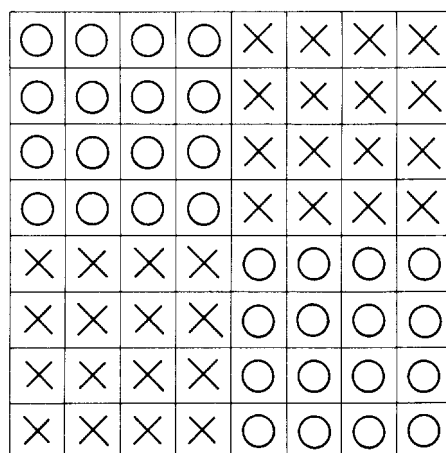
**Fig. 7.20** Purl notation.

### 7.5.2 The use of dividing cams

Figure 7.19 illustrates the transfer action using *dividing cams*, on a revolving double-cylinder machine with internal holding-down sinkers and stationary cam-boxes. The dividing cam principle for slider disengagement was, until recently, in widespread use on half-hose machines, although it had already been replaced on the double-



(c = collecting row)

**Fig. 7.21** Basket purl with a collecting course.**Fig. 7.22** Basket purl without a collecting course.

cylinder garment-length purl machines that succeeded the original Spensa purl machine.

The dividing cam is an internally-profiled, cut-through recess in a flat plate, attached horizontally and externally to the cylinders at a position half-way between them. There is a recess cam position for the top cylinder and another for the bottom cylinder in a different position in the same plate. The principle of the dividing cam operation is that it forms a wedge shape of increasing thickness between the upper surface of the needle hook and the under surface of the extended nose of the delivering slider, pivoting it away from the cylinder so that it disengages from the needle hook.

- 1 The delivering slider (D) advances with the needle so that the nose of the slider, which is extended into a latch guard, penetrates the profiled recess of the dividing cam. The outer hook of the needle contacts the hook underneath the head of the receiving slider (R), pivoting it out of the cylinder, but it immediately returns and –
- 2 engages with the needle hook under the influence of a coil spring band (SB) that surrounds each cylinder and ensures that the slider heads are depressed into contact with the needle hooks.
- 3 As slider D revolves with the cylinder, it passes along the wall of the dividing cam (DC), which increases in thickness so that the slider is pivoted outwards and disengages from the needle hook. Slider D then returns to its cylinder whilst slider R retires into its cylinder, taking the needle with it, ready for the next knitting feed.

### 7.5.3 The use of spring-loaded cams

Figure 7.23 illustrates the *spring-loaded cam method of slider disengagement*, used in the SPJ type machine, which is the successor of the Spensa purl but has stationary cylinders (without internal sinkers) and revolving cam-boxes. A similar

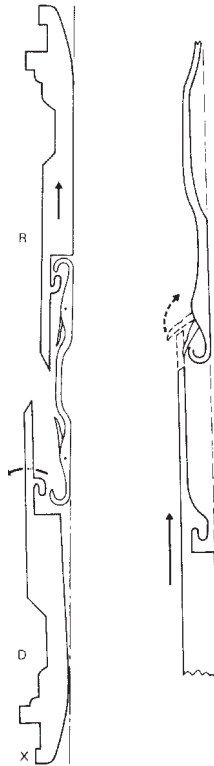


**Fig. 7.23** Purl needle transfer using spring loaded cams.

technique is being generally introduced into double-cylinder half-hose machines, although these have revolving cylinders. At the moment of disengagement, the spring-loaded cam presses onto the tail of the delivering slider (D), causing its head to swing away from the cylinder and to disengage itself from the needle hook. The action is made possible by the tapering under-surface of the slider tail.

This method is simpler and safer and operates well at high speeds. The latch guard nose of the slider is extended and pointed to act as a latch-opener as the receiving slider meets the approaching head of the needle, whose latch is specially shaped to facilitate the action. This action reduces the danger of press-offs occurring through latches closing onto empty hooks. (On the *Spensa* purl, two ends of yarn were knitted so that yarn breakage and a subsequent press-off were less likely to occur).

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# 18

## Flat knitting, basic principles and structures

### 18.1 History

The first *flat bar machine* (Section 8.4.2) was demonstrated in 1862 and patented in 1865 by the Rev. Isaac Wixom Lamb, an American clergyman. He later changed the arrangement to the inverted V-bed shape patented by *Eisenstuck*.

### 18.2 The two types of flat machine

Two types of flat machine evolved. The widely used *V-bed rib* machine and the slower, more specialised *flat bed purl* or *links-links machine*.

*V-bed machines* have two rib gated, diagonally-approaching needle beds, set at between 90 and 104 degrees to each other, giving an inverted V-shape appearance.

*Flat bed purl (links-links) machines* have horizontal needle beds. They have been employed mainly in knitting simulated hand-knitted constructions of a speciality type, such as cable stitch, basket purl, and lace patterning. They use *double-headed latch needles* that are transferred to knit in either of two directly opposed needle beds. The non-knitting hook is controlled in the manner of a needle butt by a *slider* that hooks onto it. There is a set of sliders in each needle bed whose butts are controlled by the traversing cam-carriage to produce knitting or transfer of the needles (see Section 7.5).

These complex and slow machines are no longer built because the modern electronic V-bed machines can knit all the links-links designs using the facilities of rib loop transfer and needle bed racking.

Early *intarsia* machines employed a different approach, using only one needle bed to knit solid colour designs. Now, however, many modern V-bed machines have intarsia-patterning facilities and are no longer restricted to geometrical designs because the mechanically-controlled carrier stops have been replaced by more versatile electronic controls.

### 18.3 Flat machine gauges

Flat machines (Fig. 8.2) are normally gauged on the *English system* (*E*) of *needles per inch* (npi). The *Metric system*, which is based on the distance in tenths of a millimetre from the centre of one needle to the next, is rarely used. The latter is a direct system, with a higher gauge number indicating a coarser gauge – the opposite of the English system.

Generally, flat machine gauges range from E 5 to E 14, with the main gauges being 5, 7 and 10, but there are machines as coarse as E  $2\frac{1}{2}$  and as fine as E 18 or even finer now being built.

NB: All flat machines can be *half-gauged* by removing every alternate needle; thus, an E 10 gauge machine will become an E 5 gauge. Also, different needle hook sizes are available, and gauge conversion by changing needle beds is possible.

### 18.4 Conversion from Cottons Patent to V-bed gauge

To convert from Cottons Patent gauge ( $G^*$ , needles per  $1\frac{1}{2}$  inch) to V-bed gauge (*E*, needles per inch)

- 1 Convert from  $1\frac{1}{2}$  inches to 1 inch needle bed width.
- 2 In the gauge range G9 and below, reduce the resultant *E* gauge by 1. Above G 9 reduce the resultant *E* gauge by 2. This is to fit commercial practice in flat knitting, where a slightly coarser gauge is preferred.

*Example:* Convert G9 and G21 fully-fashioned (needles per  $1\frac{1}{2}$  inches) to V-bed flat *E* gauge (npi)

$$G9 \times 2/3 = 6$$

$$6 - 1 = E5$$

$$G21 \times 2/3 = 14$$

$$14 - 2 = E12$$

### 18.5 Knitting widths

Strapping machine needle bed widths tend to range from about 14 to 50 cm (5.5–20 inches); hand-operated garment-width machines range from about 80 to 120 cm (31–47 inches); power-driven automatic garment length machines range approximately in width from about 66 cm to 240 cm (26–95 inches).

Wider '*blanket width*' machines are approximately 244 cm (96 inches) wide, to knit unshaped garment pieces for cut-and-sew knitwear.

Narrow bed '*compact*' machines are approximately 127 cm (50 inches) wide for fashion shaped knitwear.

For *integral garment* knitting, the approximate width is 183 cm (72 inches).

\* '*G*' is sometimes expressed as '*gge*'. For example, G 9 = 9gge.

## 18.6 Yarn counts

An indication of an approximately suitable count for a flat machine may be calculated using the formula:

$$\text{worsted count (NeK)} = \text{gauge}^2 / 9$$

The following are typical NeK count ranges for particular E gauges:

12npi – 2/26's to 2/42's

8npi – 2/14's to 2/22's

5npi – 6/14's to 6/18's

2npi – 8/7's to 8/9's

It can be seen that a characteristic of the flat machine is the large number of ends of yarn that may be knitted at the same time. However, if light-weight structures are required, the number of ends may be much fewer (See multi gauges, Chapter 19).

## 18.7 Simple hand-manipulated V-bed rib flat machines

Figure 18.1 shows a cross-section of a simple hand-powered and manipulated V-bed rib flat machine. The trick walls are replaced at the needle bed verges by fixed, thinner, polished and specially shaped *knock-over bit edges*. In rib gating, a knock-over bit in one bed will be 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 the knocking-over of the old loops and in the formation of the new loops. The takedown tension and the needles in the other bed help to hold the old loops down on the needle stems as the needles rise to clear. Many modern electronic flat machines have movable knock-over and holding-down elements, which assists in the knitting of shaped and single-bed structures.

On hand flat machines, after the first or *set-up course* of rib is taken by the needles, a *fabric comb* is hand-inserted into it, upwards from under the needle beds, so that the eyelet holes of the comb protrude above the course. The comb wire is then inserted through the eyelets, over the set-up course, so that the comb is suspended from the course, and a takedown weight is attached to it.

The *cover plate* is a thin metal blade, located in a slot across the top of the needle bed tricks. It prevents the stems of the needles from pivoting upwards out of the tricks as a result of the fabric 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 damaged needles to be replaced.

Supporting the tail of each needle is a *security spring* that fits over the lower edge of the needle bed. When the spring is pushed fully into position, it locates into a groove on the under-surface of the needle bed. The butt of the needle that it supports is then aligned with the knitting cam track on the under-surface of the traversing cam-carriage. When a needle is not required to be in action, its security spring is not located in the groove, so that the needle is nearer to the lower edge of the needle bed and its butt misses the traversing cam-carriage.

On machines employing jacquard selection, the function of the security spring is replaced either by the thrust of a jacquard steel onto the tails of the elements or by

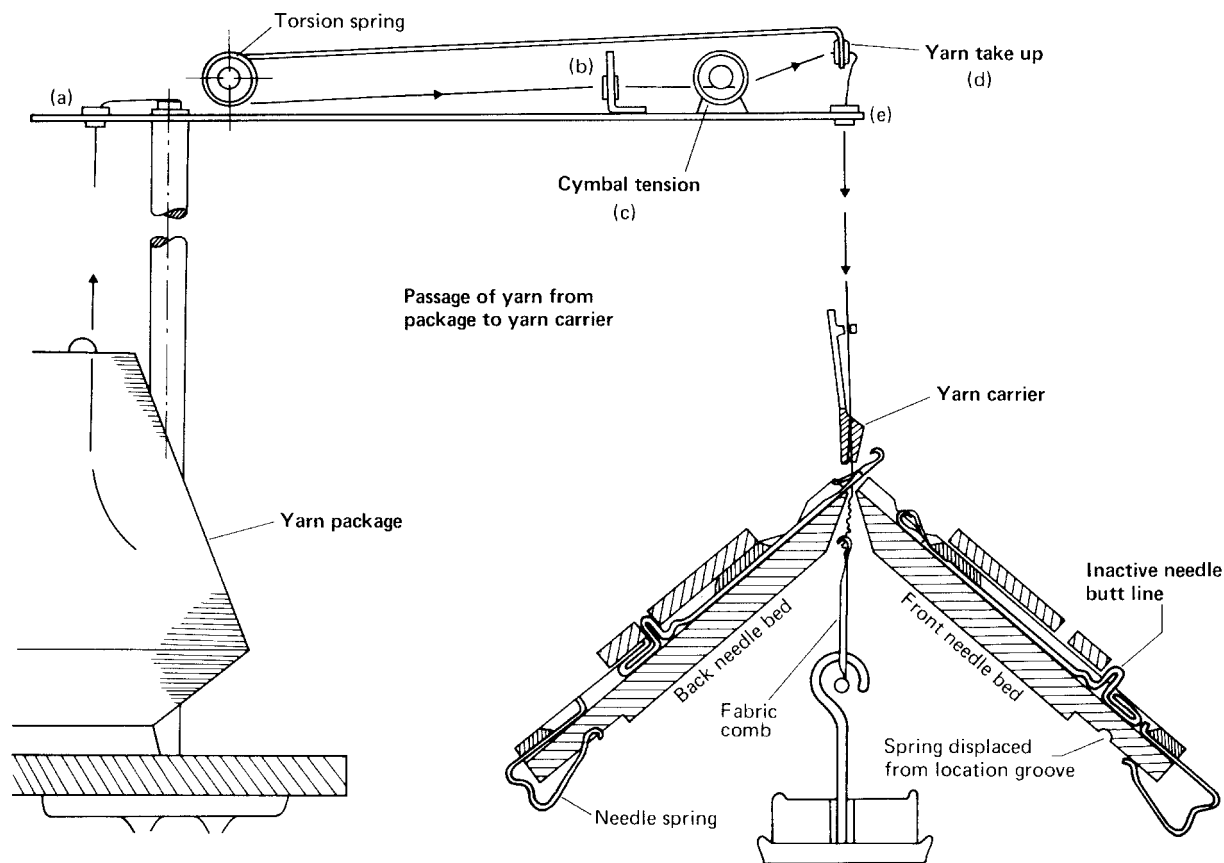


**Fig. 18.1** Passage of yarn from package to yarn carrier.

the raising or depressing of the knitting butts into the tricks, in order to position the needle butts for each carriage traverse.

*Latch opening brushes* are attached to the cam-plates of both needle beds to ensure that the needle latches are fully opened. The supports of the brushes are adjustable to ensure precise setting of the bristles relative to the needles.

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. It is propelled either by hand or from a motor-driven continuous roller chain or rubber belt.

Each *yarn carrier* is attached to a block which slides along a bar, which, like the carriage guide rails, passes across the full width of the machine. The carrier bar may be of the double prism type so that yarn carriers may be attached to slide along both the front and the back surfaces. The yarn carriers are picked up or left behind by the carriage, as required, by means of driving bolts or pistons that are attached to, and controlled either manually or automatically from, the carriage bow. There is a bolt for each carrier bar track that, when lowered, entrains with a groove in the shoulder of a yarn carrier block. Stop plates having inclined edges are positioned on the carrier bars at the knitting selvages. On contact with a stop plate, the base of the bolt rises and is lifted out and disconnected from the groove of the carrier block so that the carriage continues its traverse without that carrier.

Two levers are usually provided, one at each end of the needle bed. One is for *racking the back needle bed*, to change the gating of the needle beds for changes of rib set-out or rib loop transfer. The other is to *open the gap* between the needle beds for easier access to the knitted fabric hanging from the needles.

### 18.7.1 The cam system of the V-bed hand flat machine

Figure 18.2 illustrates the knitting action of a V-bed hand flat machine and Fig. 18.3 shows the underside of the cam-carriage and the cams forming the tracks that guide the needle butts through the knitting system. The single knitting system cam-box is symmetrically designed for knitting a course of loops on both the front bed and back bed needles during a right-to-left traverse and a second course during the return left-to-right cam box traverse.

The needle butts will enter the traversing cam system from the right during a left-to-right carriage traverse and from the left during a right-to-left traverse. For each needle bed there are two raising cams (R), two cardigan cams (C) and two stitch cams (S).

In the direction of traverse, the leading raising cam is responsible for knitting and the trailing raising cam acts as a guard cam. The leading stitch cam is raised out of action and the trailing stitch cam is in operation. In the reverse direction of traverse, the roles of the two raising cams and of the two stitch cams are reversed.

A raising cam lifts the needle to tuck height, but if the cardigan cam above it is in action the needle is lifted to full clearing height. Thus, the cardigan cam is taken out of action if a tuck stitch is required. To produce a miss stitch, both the raising cam and the cardigan cam are out of action. To produce a course of tubular plain knitting, a pair of raising cams that are diagonally opposite each other in each bed (RL and RR) are out of action.

The arrangement as shown in Fig. 18.3 is referred to as a *knitting system*. A *single system* machine will knit one course of rib in one traverse whereas a *double system* machine will knit two courses of rib per traverse. Sometimes a set of cams in one bed is referred to as a *lock*.

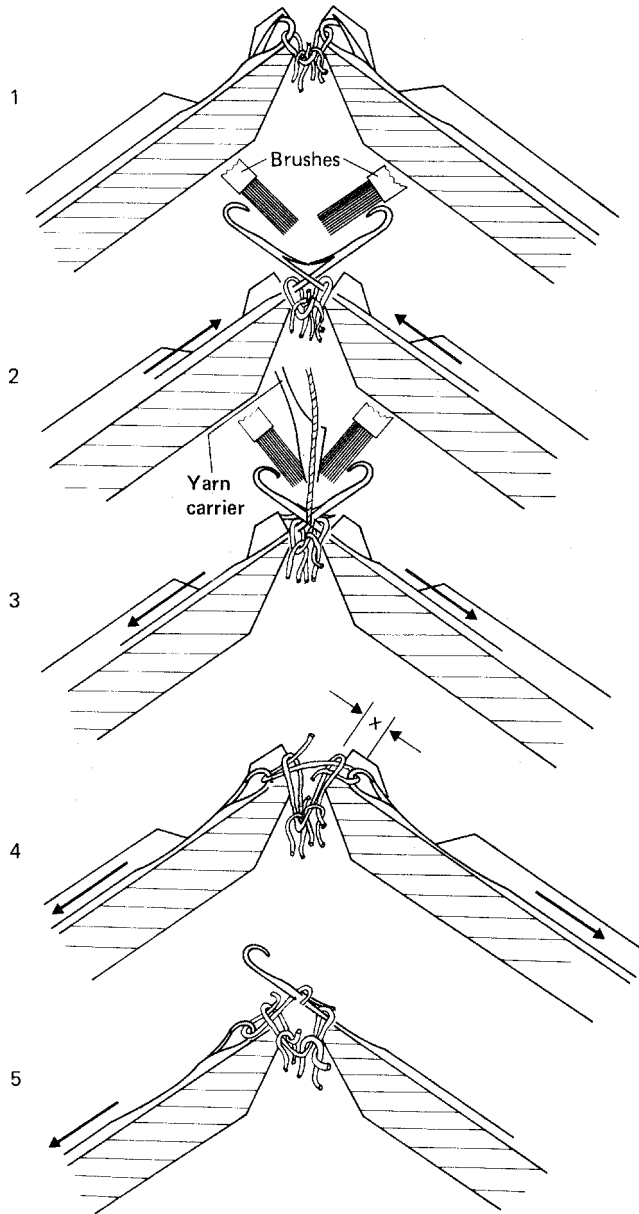


**Fig. 18.2** Knitting action of V-bed flat machine.

### 18.7.2 The knitting action of the V-bed hand flat machine

Numbers 1 to 4 below correspond to the numbers in the knitting action illustrations (Fig. 18.2), assuming a carriage traverse from left-to-right. Similar positions may be plotted for the return traverse, using the cams given an (L) designation to provide the positive movements.

- 1 *The rest position.* The tops of the heads of the needles are level with the edge of the knock-over bits. The butts of the needles assume a straight line until

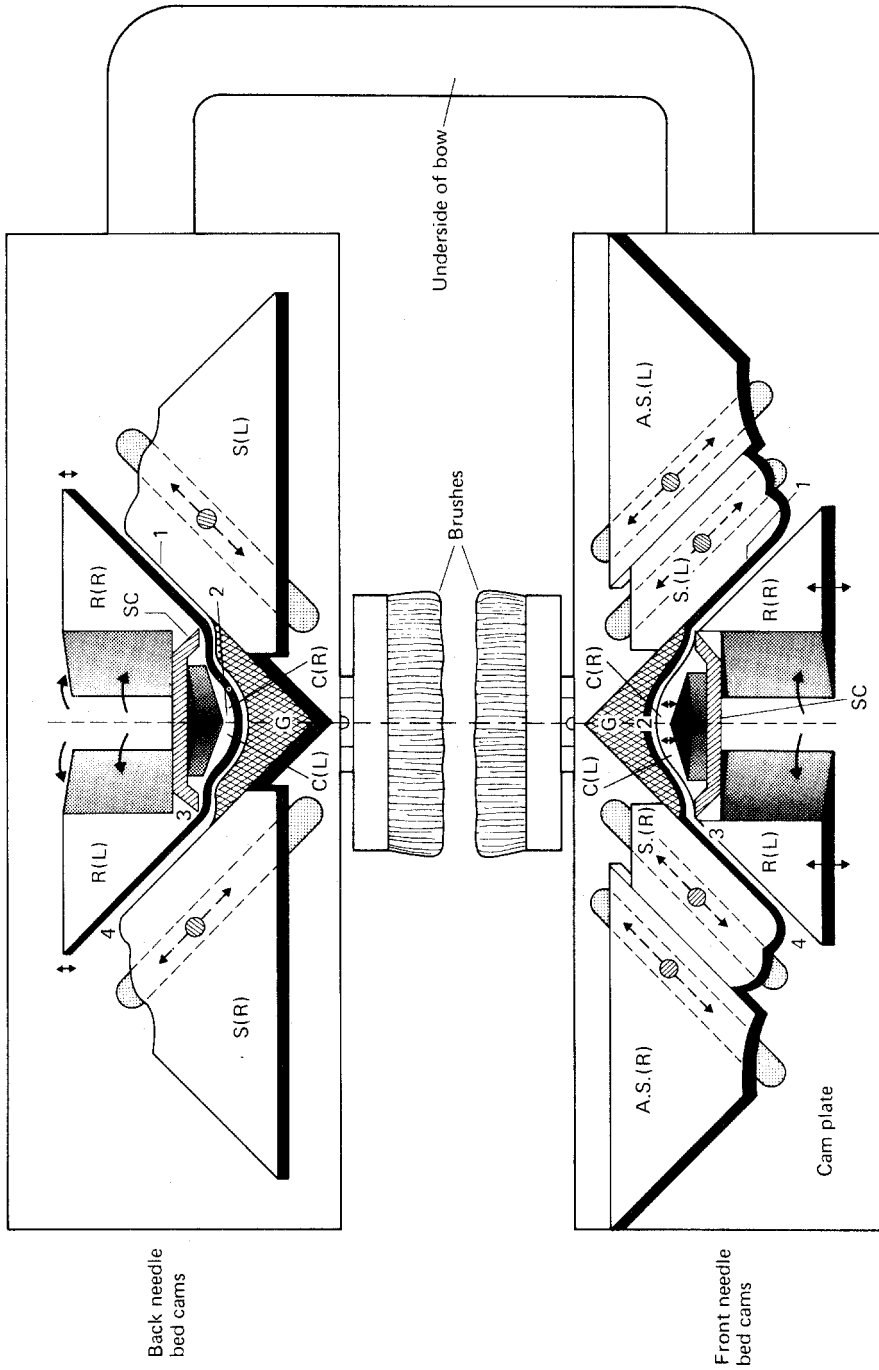


Fig. 18.3 Cam system of simple hand flat.

contacting the raising cams R (R) because the leading stitch cams S and AS (L) are lifted to an inactive position. The lifting action is an *alternating action* that always lowers the trailing stitch cams and raises the leading stitch cams in each system as the traverse commences. This action prevents needles from being unnecessarily lowered and a strain being placed on the old loops prior to the start-up of the knitting action.

- 2 *Clearing.* The needle butts are lifted as they contact the leading edge of cams R (R), which raises the needles to 'tucking in the hook' height with the under-surface of cams S (L) acting as guard cams. The needles are lifted to full clearing height as their butts pass over the top of cardigan cams C (R) and C (L).
- 3 *Yarn feeding.* The yarn is fed as the needles descend under the control of guard cam (G). The required loop length is drawn by each needle as it descends the stitch cam S (R).
- 4 *Knocking-over.* To produce *synchronised knocking-over* of both needle beds simultaneously, the stitch cam S (R) in the front system is set lower than the auxiliary stitch cam AS (R), so that the latter is rendered ineffective. If, however, *delayed timing of the knock-over* is employed, knock-over in the front bed will occur after knock-over in the back bed. In this case, stitch cam S (R) is not set as low as AS (R) (Number 5 in Fig. 18.2) so that the depth setting of the latter cam produces the knock-over action. Delayed timing is only normally used on gauges finer than 8npi and cannot be used for broad ribs.

## 18.8 Stitch cam settings

The stitch cams are located in slots by studs and they may be raised or lowered to a different setting position by moving the stud along the slot (Fig. 18.3). Unless the rate of yarn feed is controlled, the setting of the stitch cam at knock-over will determine the *stitch length* because it controls the distance the head of the needle descends below the knock-over bit edge from the rest position. The alternating stitch cam settings are indicated by pointers on a calibrated scale on the outside of the cam-plate.

On hand flats, the adjustment of the settings is obtained by hand controls, whilst on modern electronically-controlled flats, each stitch cam is raised and lowered by its own *step motor*, so a wide range of stitch lengths can be achieved during the knitting of a garment.

## 18.9 Spring-loaded cams

Raising cams (R) and cardigan cams (C) (Fig. 18.3) are of the spring-loaded type that can be depressed into the under-surface of the cam-plate against the action of a spring. The leading edge of a leading raising cam is straight so that it causes the butts to follow its profile. However, the trailing inner edge of the cam, which is the leading edge when that cam is trailing, has a gently sloping edge. Needle butts deliberately not raised by the leading cam thus ride up the trailing cam, depressing the cam into the cam-plate and then follow an undisturbed path across its face. After the butts have passed, the cam springs outwards from the cam-plate to resume its active position for the return traverse.

On hand flat machines, the cams are often of the sinkable setting type so that they can be set either:

- 1 *fully in action* out from the cam plate so that they act on every needle butt,
- 2 *partly withdrawn* into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface, or
- 3 *fully withdrawn* into the cam-plate so that all butts pass undisturbed across their surface.

The standard set-out when using different lengths of butts is two long and one short in each bed, with the short butt centred between the two long butts in the opposite bed. This enables changes from  $1 \times 1$  to  $2 \times 2$  rib knitting to occur.

Changes of cam settings are achieved by the movement of controls that are placed on the outside of the cam-plate. In the case of mechanical automatic power flats, these controls can consist of metal push slides, each corresponding to a different cam whose sideways movement produces the required change of cam setting. At each end of the machine is a contact post containing striking plates, aligned to contact the slides as the carriage reaches the end of its traverse so that the cams may be set for the return traverse. Control of the plates is achieved from the main garment (machine) control of the machine.

Electronic machines have continuous electronic contact with the cam carriage and therefore do not require the cam slide arrangement.

On hand flat machines 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.

The automatic machine can change the cam settings for each traverse; split cardigan camming is unnecessary and these machines usually have a single cardigan cam for both traverse directions.

## 18.10 Two or more cam systems

Although hand flat machines have single cam system carriages, many automatic power flat machines have two, three or four cam systems, each with a complete set of knitting cams arranged side by side in the same cam-plate each working with a separate yarn carrier. Thus, in one cam carriage traverse, as many courses as there are cam systems can be knitted.

However, compared with a single system machine, the rate of carriage traverse is often reduced, firstly because of the heavier carriage, and secondly because it is longer and must traverse further, thus making the machine longer. There is also a problem of vertical floating threads at the selvedge edges of the fabric. Compact cam design and machine construction, together with the use of lightweight alloys and automatic thread cutters, have largely overcome these problems.

## 18.11 Split cam-carriages

Another useful development is the *split cam-carriage*. For example, a double system cam carriage operating across the full width might also be split into two single system ( $2 \times 1$ ) cam-carriages, each covering half the needle bed or both co-

operating in the knitting of wedge-shaped or other complex designs. Split cam-carriage machines have been built with a total of two ( $2 \times 1$ ), four ( $2 \times 2$ ), six ( $2 \times 3$ ), and even eight ( $2 \times 4$ ) systems.

### 18.12 Direct and indirect yarn feed

On mechanically-controlled flats, it is necessary to join the front and back needle bed cam-plates with a *bow* or *bridge* in order to drive the cam-carriage as a single unit. However, the traversing bow necessitates an unbalanced diversion of the yarn path down to the needles. This in turn produces unbalanced yarn tension, depending on whether the cam carriage is traversing towards or away from its yarn supply.

On some of the latest electronically-controlled power flats, the bow has been eliminated by driving the front and back needle bed cam-plates separately but in unison, thus giving the cam carriage an open construction. Additionally, the yarn carriers are no longer mechanically connected to the cam-carriage and are each individually driven. They need not be synchronised with the carriage traverse. A yarn carrier can be selected either for knitting, plating or laying-in. Precise placing is achieved both for selvedge shaping and intarsia, where swing yarn carriers are no longer needed (Chapter 19, *Tsudakoma*).

*Direct yarn feed* is often used on hand flat machines as it allows weak yarns to be knitted because the yarn is supplied directly down from the centrally-positioned yarn tensioner to the reciprocating yarn carrier, so that the tension is kept fairly constant at a minimum level. With this arrangement, the carrier must always remain on one side of the carriage bow, for example on the right, and not pass underneath it, as the yarn path would be disturbed. Yarn carriers can therefore only be collected and left by the carriage at the right side of the machine so that only double course striping can be produced. The pick-up device for the yarn carrier is located on the outside of the low bow.

*Indirect yarn feed* is used on power flat machines, and is characterised by a high carriage bow passing over the carrier bars, with the yarn path parallel to them, from guide eyes at the end of the machine to the yarn carriers. The yarn is deflected in its downward path from the yarn tensioners across to the guide eyes, thus increasing the tension on the yarn and tending to cause fluctuations depending upon whether the carrier is traversing away from, or towards, the yarn guide eye end of the machine. However, it does enable the yarn carrier to be picked up or left on either side of the machine, using plungers that operate down onto the carrier blocks from the underside of the carriage bow.

### 18.13 Yarn carrier arrangement

The yarn carriers are arranged to slide on both sides of double prismatic guiding bars and there are usually six or seven carriers operating on two or three double bars. When two carriers operate on the same track of the same bar, it is essential to arrange the sequence so that if the two carriers are deposited on the same side, the one nearest to the cam-carriage will be the one first required to traverse back in the opposite direction.

There are two methods of entraining carriers with cam systems on double system

machines: uncrossed and crossed. With the *uncrossed* arrangement, the same yarn carriers operate with the same cam systems in both directions of traverse. This simplifies the control and is essential when two carriers are on the same track, but it causes problems with vertical yarn floats at the selvages because the yarn with the leading cam system will finish the first course but will not knit the return traverse.

With the *crossed* arrangement, one yarn carrier will always be entrained with the leading cam system and the other with the trailing cam system, so that if the carriers have different coloured yarns, each will knit alternate courses.

In carrier positioning and traversing for jacquard (Fig. 18.4), the yarn carriers

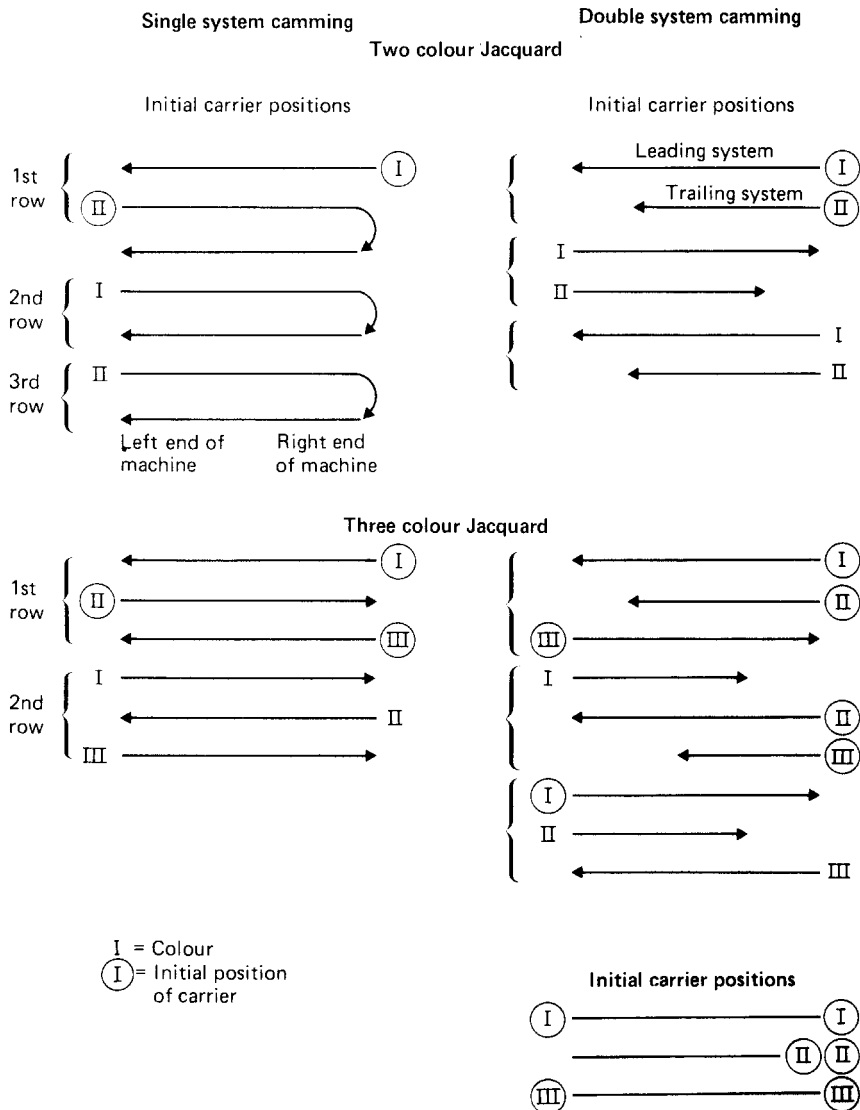


Fig. 18.4 Yarn carrier positioning.

must be carefully positioned initially in order to keep their number to a minimum whilst ensuring that empty traverses (without knitting a course) are avoided whenever possible, as they reduce productivity. By drawing a plan of traverses and colours, and indicating each time a new yarn is picked-up, the initial positions can soon be established. For double system knitting in two- or three-colour jacquard, each system will require as many carriers as there are colours, but two carriers of the same colour can use the same track. Only in the case of single-system two colour jacquard is it necessary to alter the sequence of coloured courses. This is because, after their first course, each colour is knitted at two consecutive courses.

### 18.14 Typical structures knitted on flat machines

*Cardigan stitches* are two-course repeat tuck rib knitwear structures, widely used in the body sections of heavy-weight stitch-shaped sweaters. The tuck stitches cause the rib wales to gape apart so that the body width spreads outwards to a greater extent than the rib border. The tuck loops increase the fabric thickness and make it heavier in weight and bulkier in handle, although the rate of production in rows of loops will be less than for normal  $1 \times 1$  or  $2 \times 2$  rib. The greater the proportion of tuck to cleared loops, the heavier and wider the finished relaxed structure (see Fig. 16.13).

In the production of a knitted stitch, the leading raising and cardigan cams for that bed and direction of traverse must be in action, whilst for a tuck stitch, the raising cams remain in action but the cardigan cam is taken out of action. It is important to arrange the camming for the needle beds so that, at the start of the traverse when tucking, the first needle is tucking and the last needle in action is in the opposite bed and is thus knitting. If the last needle is tucking, the selvedge tuck loop will withdraw from the needle hook as the reverse traverse commences.

*Half-cardigan* or *royal rib* (Fig. 18.5) is produced on a  $1 \times 1$  rib base, having tuck loops on one bed only at alternate courses. It is therefore an unbalanced structure with a different appearance on each side and with twice as many cleared loop courses per unit length on the all-knit side as on the tuck loop side. On the all-knit

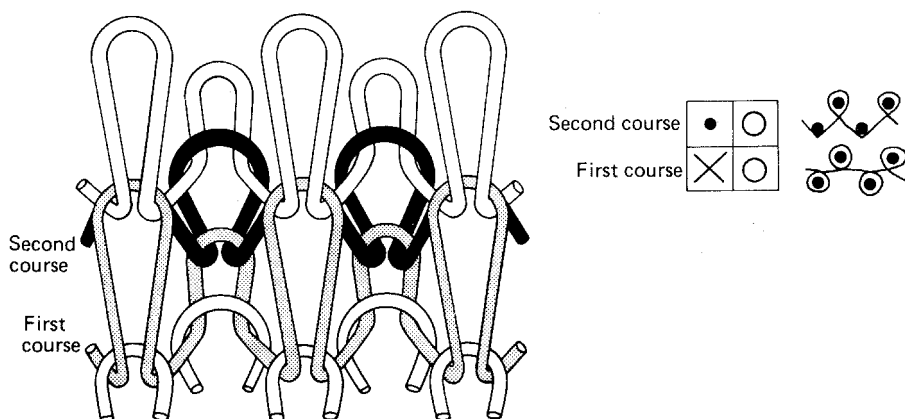


Fig. 18.5 Half-cardigan loop structure.

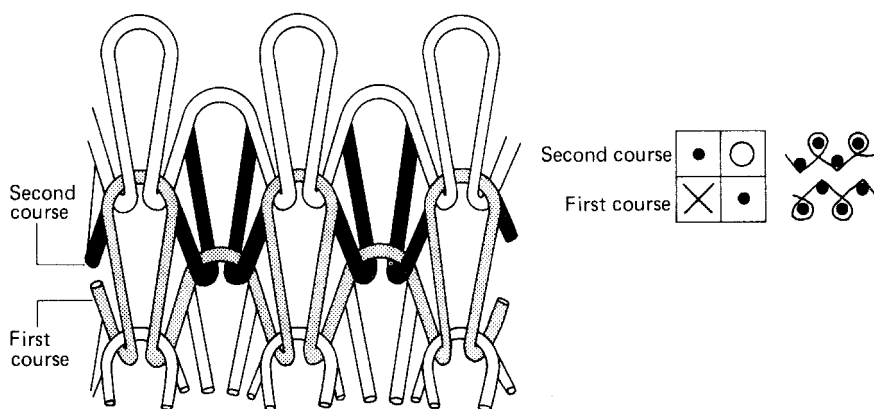


**Fig. 18.6** Full cardigan.

side, one course of loops has very large and rounded loops. This is because they receive yarn from the tuck loops on the other side. The other course of loops on this side has, in contrast, extremely small and insignificant loops because they are robbed of yarn by the elongated held loops on the other side, which consists only of held loops as the tuck loops lie behind them.

A two-tuck variation of half-cardigan, based on a four course repeat with each repeat sequence repeated at two consecutive courses, is useful as it produces rounded loops on the knit side as a result of yarn passing into it from the second tuck course.

*Full-cardigan or polka rib* (Fig. 18.6) consists of one course of loops knitted on the front bed and tucks on the back, and the second course with the sequence reversed, thus producing a balanced  $1 \times 1$  tuck rib structure with the same appearance on both sides. If different coloured yarns are knitted at alternate courses, a 'shot rib' will be produced which in the relaxed state will show one colour on one side and the second colour on the opposite side.

In open width, a  $1 \times 1$  rib fabric will relax by about 30 per cent, half-cardigan by only 5 per cent, and full-cardigan will show no width shrinkage compared with its original knitting width.

To knit half-cardigan on a single-system hand-flat, one of the four cardigan cams is taken out of action so that in one direction of traverse a tuck stitch will be knitted on one needle bed only.

To knit full-cardigan, diagonally opposite pairs of cardigan cams are taken out of action so that in one direction of traverse the front needle bed will tuck and in the return traverse the back needle bed will tuck.

The  $2 \times 2$  rib version of half-cardigan is termed *fisherman's rib* and the full-cardigan version is termed the *sweater stitch*.

#### 18.14.1 Racked rib structures

The V-bed flat machine is capable of knitting a unique range of racked rib structures (Fig. 18.7), based on the facility of racking one needle bed by one or more needle tricks past the other needle bed, either towards the right or the left as and when required. Usually, the needle set-out is  $1 \times 1$  rib, or a modified version with

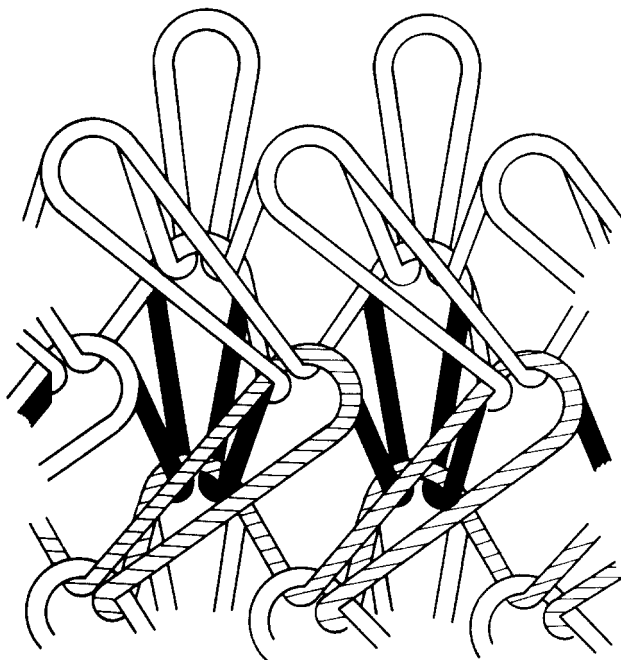


**Fig. 18.7** Racked rib.

selected needles taken out of action, and a knitting sequence of half- or full-cardigan [1].

The *basic principles of racked rib structures* are as follows:

- 1 A loop on a needle in one bed must be racked past a loop from the same course on a needle in the other bed. The structure must therefore be rib based.
- 2 After an all-knit course of  $1 \times 1$  rib, the 45 degree angle of inclination of a single needle rack would be shared by the loops in both beds and the appearance would be insignificant. A two-needle rack is thus required.
- 3 After a course with tucking on one bed and knitting on the other, a single-needle rack will produce a 45 degree inclination on the knitted loop side, irrespective of which needle bed was racked (Fig. 18.7). The open legs of the tuck loops resist the effect of racking so the tension only inclines the knitted loop side of the course. Half- or full-cardigan sequences (Figures 18.5 and 18.6), which consist of courses of knitted loops on one bed and tuck loops on the other, are thus an ideal base for racked structures.
- 4 With half-cardigan, racking can occur only after every alternate course of the two-course repeat – it cannot occur after the  $1 \times 1$  rib knitting course. The racked effect will show only on one side of the fabric – the all knitted loop side – at every second row. In-between the racked loop courses, the  $1 \times 1$  rib courses will appear as minute upright loops on the effect side.
- 5 In the full-cardigan sequence, every course has tucks on one bed and knitted loops on the other, so that racking can occur after every course. The racked loops will appear on one side of the fabric at the first rack and on the other side at the next, always on the side remote from the tuck loops of that course.

Racked loops can be produced at every row of knitted loops on each side of the fabric because the tuck loops are hidden inside the structure.

- 6 In a full-cardigan sequence, if racking occurs to the left at the first course and to the right at the second course, all loops will be racked in the same direction on both sides of the fabric. This is because racking knitted loops to the right produces the same direction of inclined loops as racking the tuck stitches to the left. If the colour of the yarn is changed at fixed intervals of courses and the fabric is cut in rectangular pieces at right angles to the inclined selvages, diagonal rather than horizontal stripes will be produced relative to the selvedge.
- 7 If in a full-cardigan sequence racking occurs in the same direction at two successive courses and is followed by two racks in the opposite direction at successive courses, alternate courses on each side of the fabric will show loops inclined in opposite directions.
- 8 A *Vandyke* or *zigzag selvedge edge* will be produced if the principles explained in 6 and 7 are combined. *Example*: 16 courses might be knitted with a rack to the right after every odd course and a rack to the left after every even course. This is then followed by a course without a rack so that the racking sequence recommences out of phase producing inclined loops in the opposite direction for a further 16 courses before the next no-rack course completes the repeat of the design. On each side of the fabric, courses will incline in one direction for 8 face rows before the inclination is reversed. Every 16 face rows there will be one row of small insignificant upright loops that alternates on one side and then on the other.
- 9 Racked loops are produced only if a needle in one bed racks past a needle in the other bed. If a needle racks past an empty trick (because the needle in the other bed has been removed or is out of action) there will be no inclined loop in that wale.
- 10 A pattern repeat of racked and straight wales can be produced across one side of a full-cardigan fabric. It is knitted with a needle-out sequence with racking to the right after every second course and to the left after the next two-course sequence. With this arrangement, a needle racked to the right and later to the left past a tuck loop on a needle in the other bed, will produce a wale of inclined loops whereas a needle racked to the right and left past an empty needle trick will produce a wale of upright loops. The sequence can be interrupted by making two successive racks in the same direction before continuing the previous sequence. The needle that was racked past the tuck will now be racking past an empty trick, so its wale changes from inclined to upright loops, whereas the needle previously racked past an empty needle is now racking past a tuck loop, so the loops in its wale are no longer upright but inclined. The changeover in either direction can be achieved whenever required.
- 11 The racked effect is more prominent if the wales are spaced further apart by *half-gauging*, i.e. removing every alternate needle from each bed before arranging the needle set-out.

#### 18.14.2 Knop structures

Knop fabrics are relief structures in rib where successive tuck stitches on all the needles or certain needles of one bed produce a three-dimensional effect. Some-

times the all-knit courses are produced in a different colour and sometimes racking occurs after the knop sequence so that the next knop is off-set.

### 18.14.3 The cable stitch

*Cable stitch* is a traditional hand-knitted stitch pattern incorporated into fishermen's sweaters in the islands of Jersey, Guernsey and particularly Aran, where it is one of a range of stitch patterns (Fig. 18.8) that includes *ladder*, *blackberry stitch* and *honeycomb* [2]. Traditionally, the yarn is partly-scoured wool in its ecru (undyed and unbleached) colour. The cable stitch is a three-dimensional design of cords of face loop wales, centred in a panel of reverse loop stitches bordered on either side by rib wales of face stitches. Each cord is usually three wales wide; these move as a unit when they are crossed (twisted) over another cord. The direction of twist of the cords is always the same relative to the surface of the design.

Cables are normally either two-cord or three-cord. In machine knitting, the cords are knitted on one needle bed and the background panel on the other. The cable loops are longer to reduce the tension where cords twist. At this point, the loops of

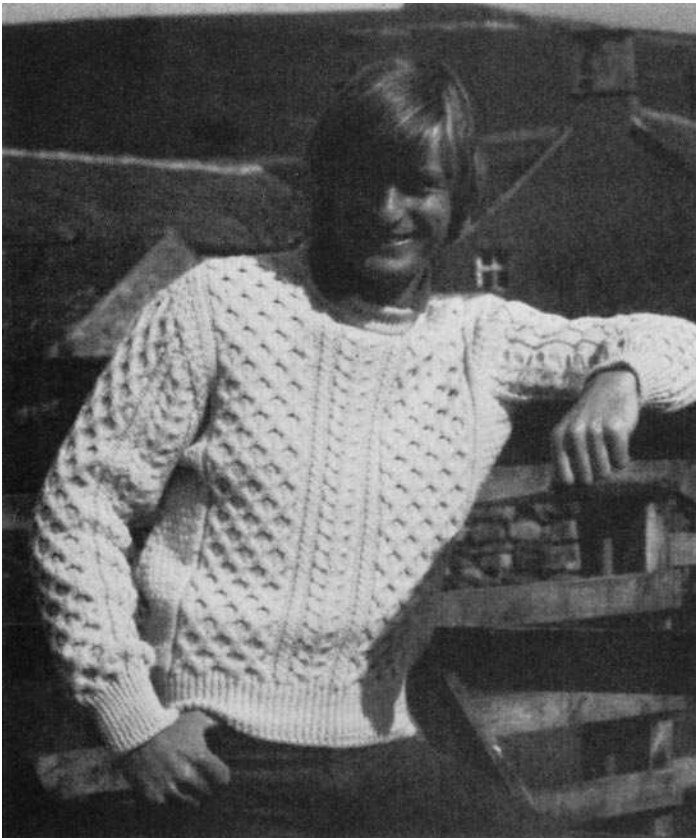


**Fig. 18.8** Aran crew-neck pullover knitted by T W Kempton on a 5-gauge JDR flat machine from 2/6's worsted count woollen spun yarn [British Wool Marketing Board/Marks and Spencer].

one cord are transferred over to the other bed so that the two cords can be racked past each other before they are transferred back to recommence knitting. Cable stitches are knitted on some automatic flat rib and purl machines, as well as on a few double-cylinder machines with the facility for shogging the top cylinder. Generally, double-cylinder machines knit only mock cable effects using purl stitch designs.

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