# 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 unroved 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

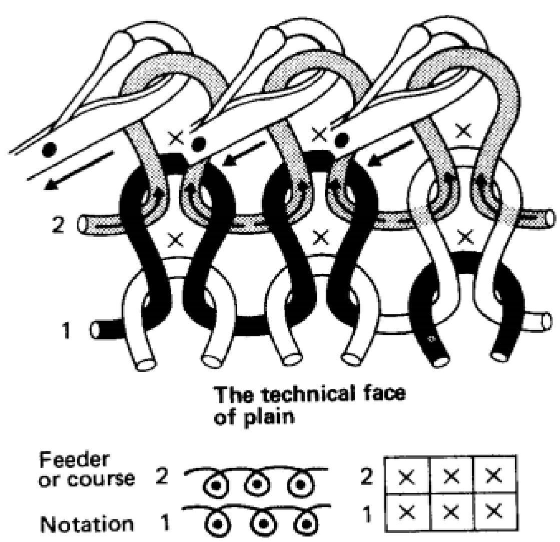



**Fig. 7.1** The technical face of plain weft knitted fabric.

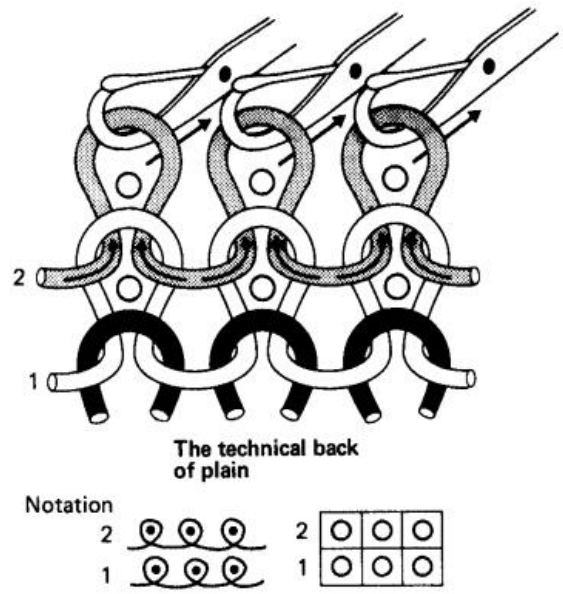



**Fig. 7.2** The technical back of plain weft knitted fabric.

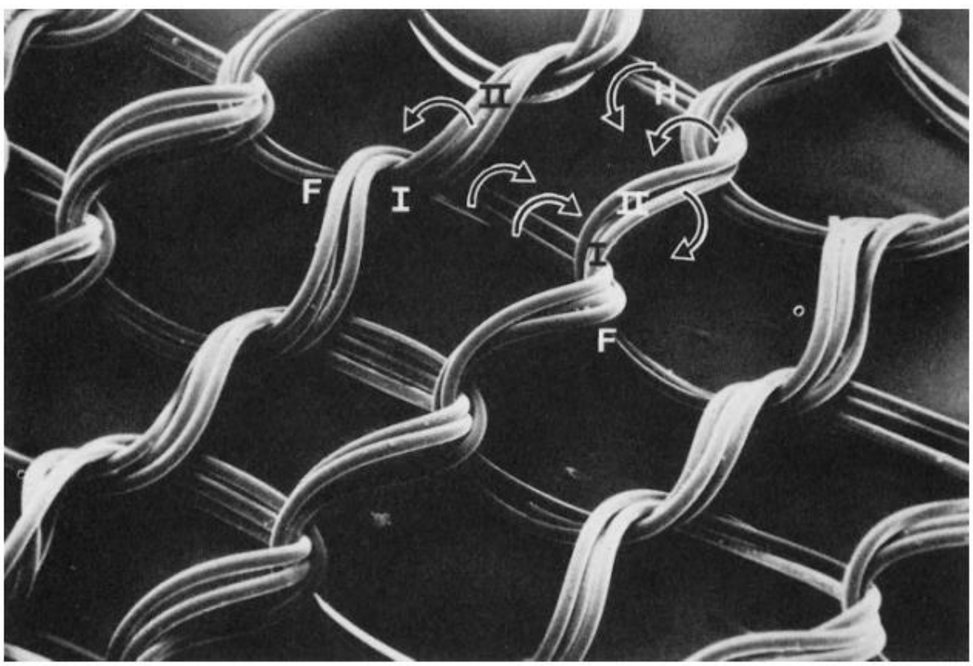



**Fig. 7.3** The three-dimensional structure of plain weft knitting magnified ×130 by a stereoscan electron microscope. The arrows indicate the direction in which the fabric will tend to curl if it is cut.

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 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.

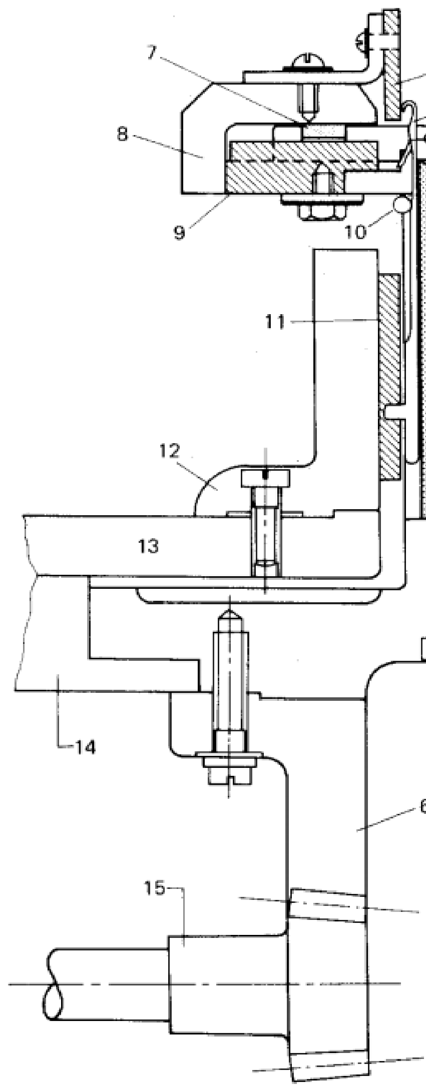



**Fig. 7.4** Cross-section of knitting head of a single jersey machine.

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.

(a) *Tucking in the hook or rest position*. The sinker is forward, holding down the old loop whilst the needle rises from the rest position.
(b) *Clearing*. The needle has been raised to its highest position clearing the old loop from its latch.
(c) *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.
(d) *Knock-over*. The sinker is fully withdrawn whilst the needle descends to knock-over its old loop on the sinker belly.
(e) *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.

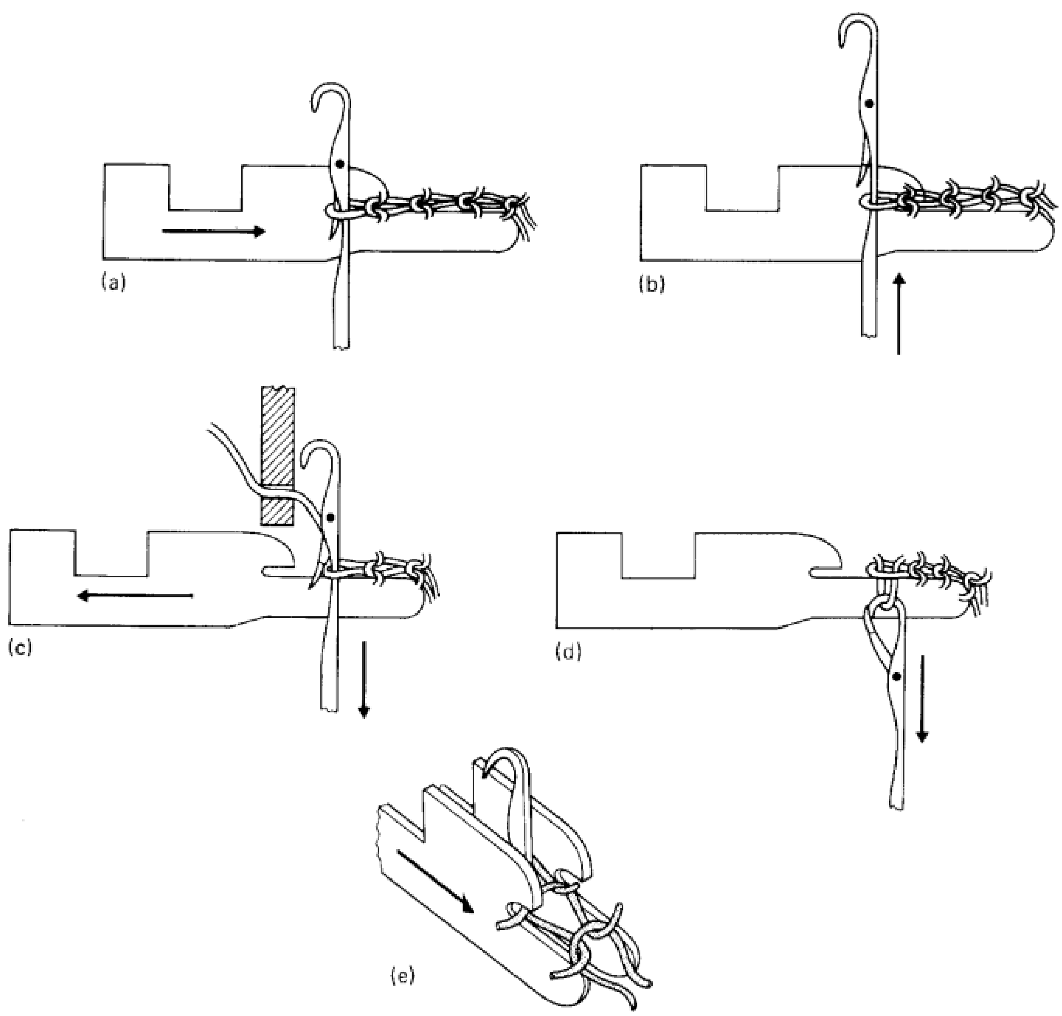



**Fig. 7.5** Knitting cycle of a single jersey latch needle machine.

*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-

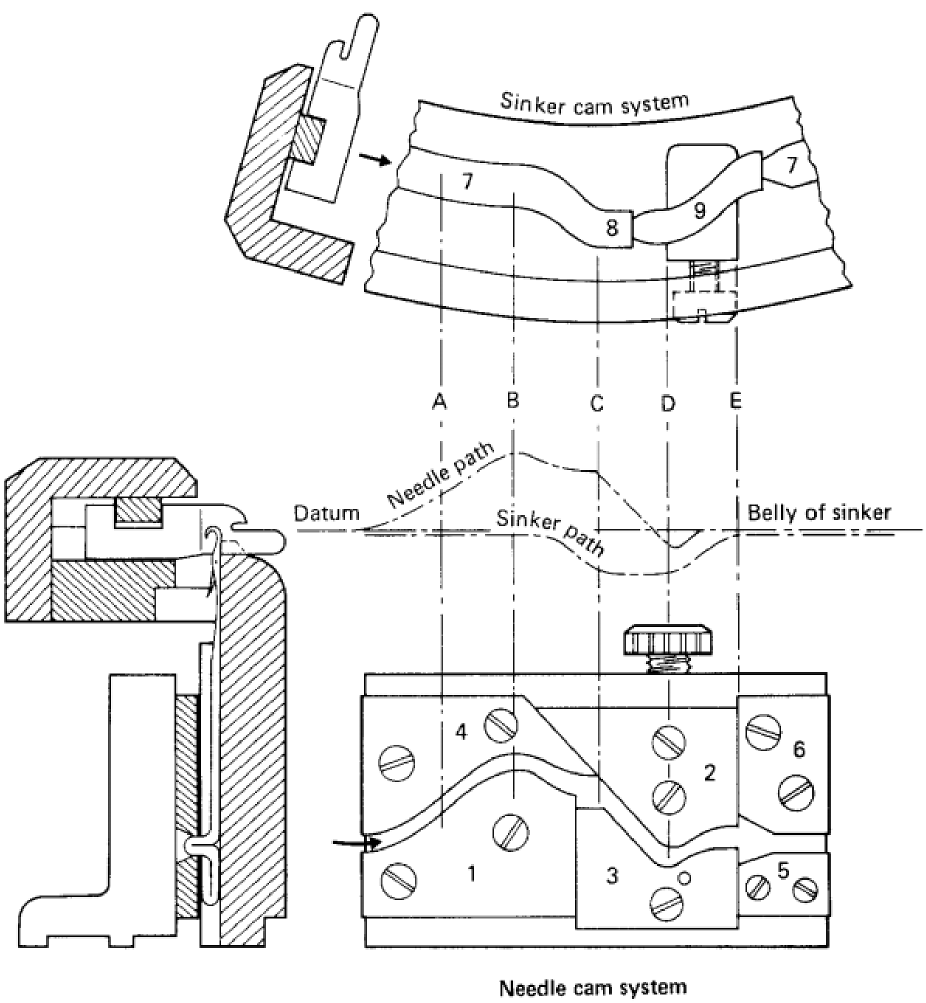



**Fig. 7.6** Sinker timing on a single jersey machine.

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 1.4 m/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).

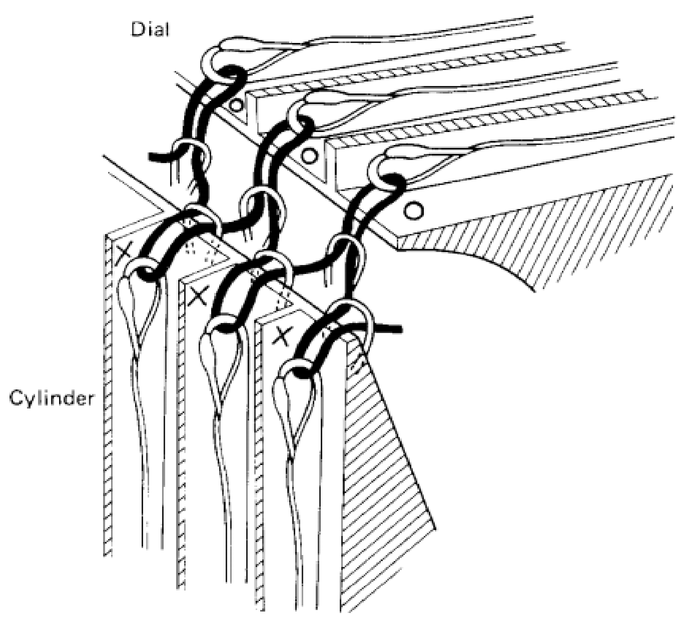



**Fig. 7.7** Structure of $1 \times 1$ rib.

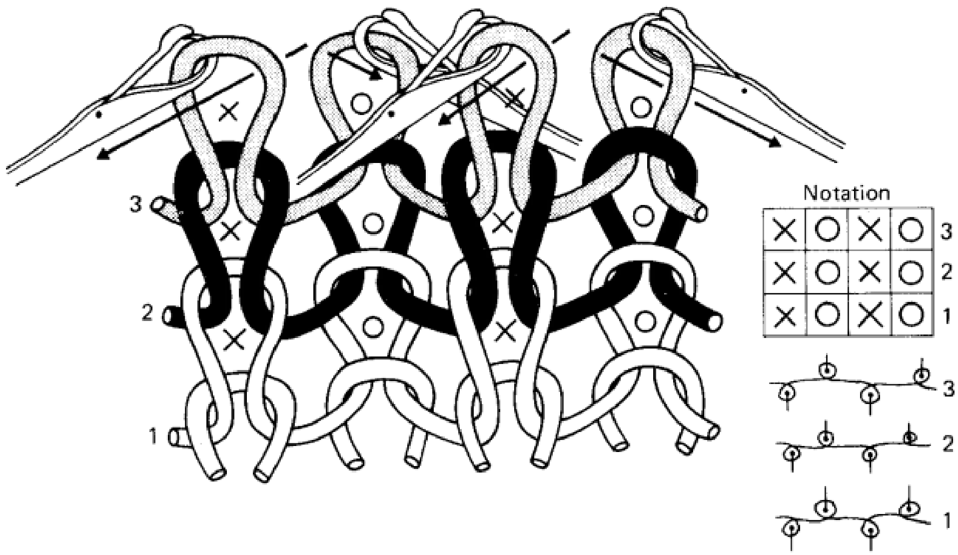



**Fig. 7.8** Face and reverse loop wales in 1 × 1 rib.

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 production of 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 unroved 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 unroved 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 × 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 × 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 × 2 needle set-out is arranged for 1 × 1 rib; this is termed '*skeleton 1 × 1*'; after knitting the set-up course, the bed is racked back so that 2 × 2 rib knitting can commence.

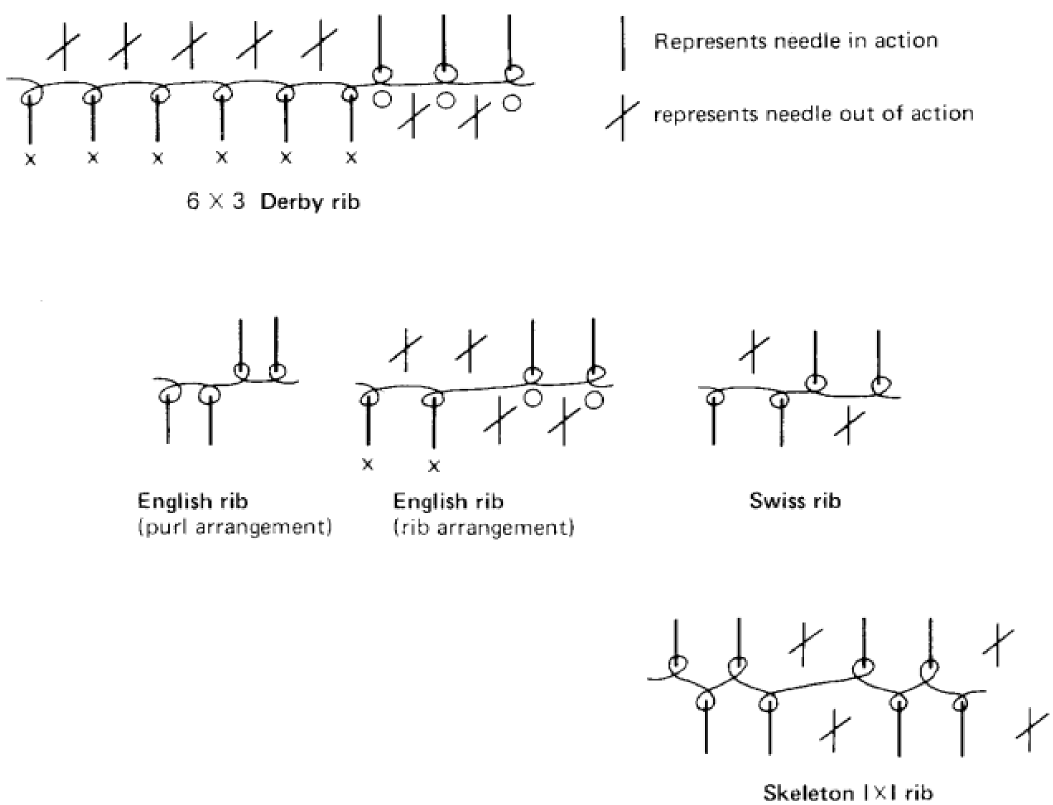



**Fig. 7.9** Rib set-outs.

*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 × 2 to 1 × 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:

(a) *Clearing*. The cylinder and dial needles move out to clear the plain and rib loops formed in the previous cycle.
(b) *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.
(c) *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.

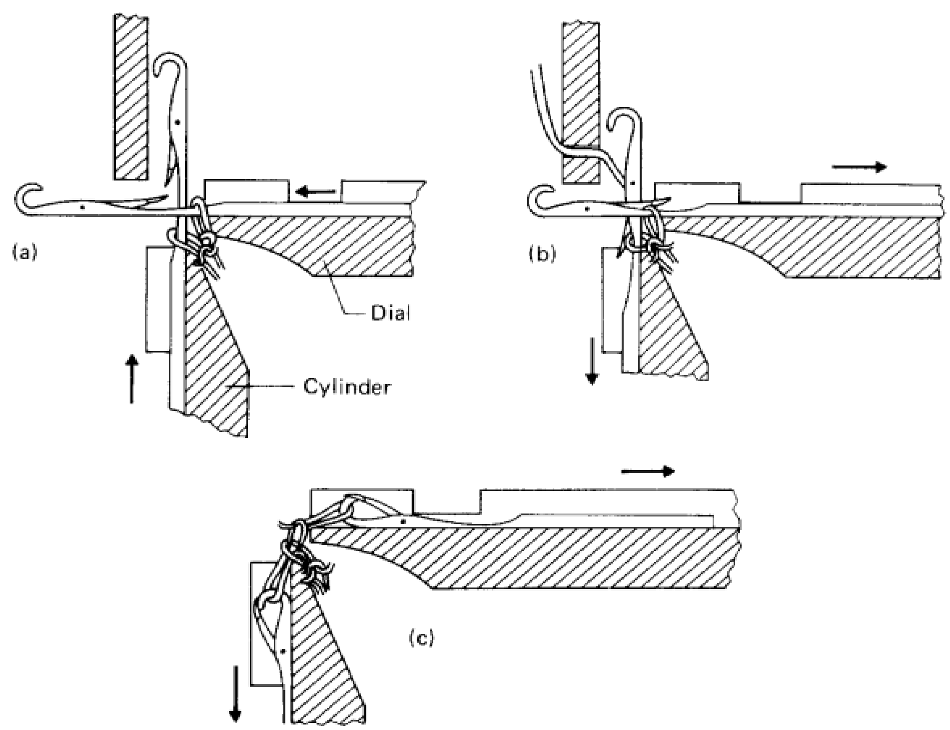



**Fig. 7.10** Knitting action of a circular rib machine.

### 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 × 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

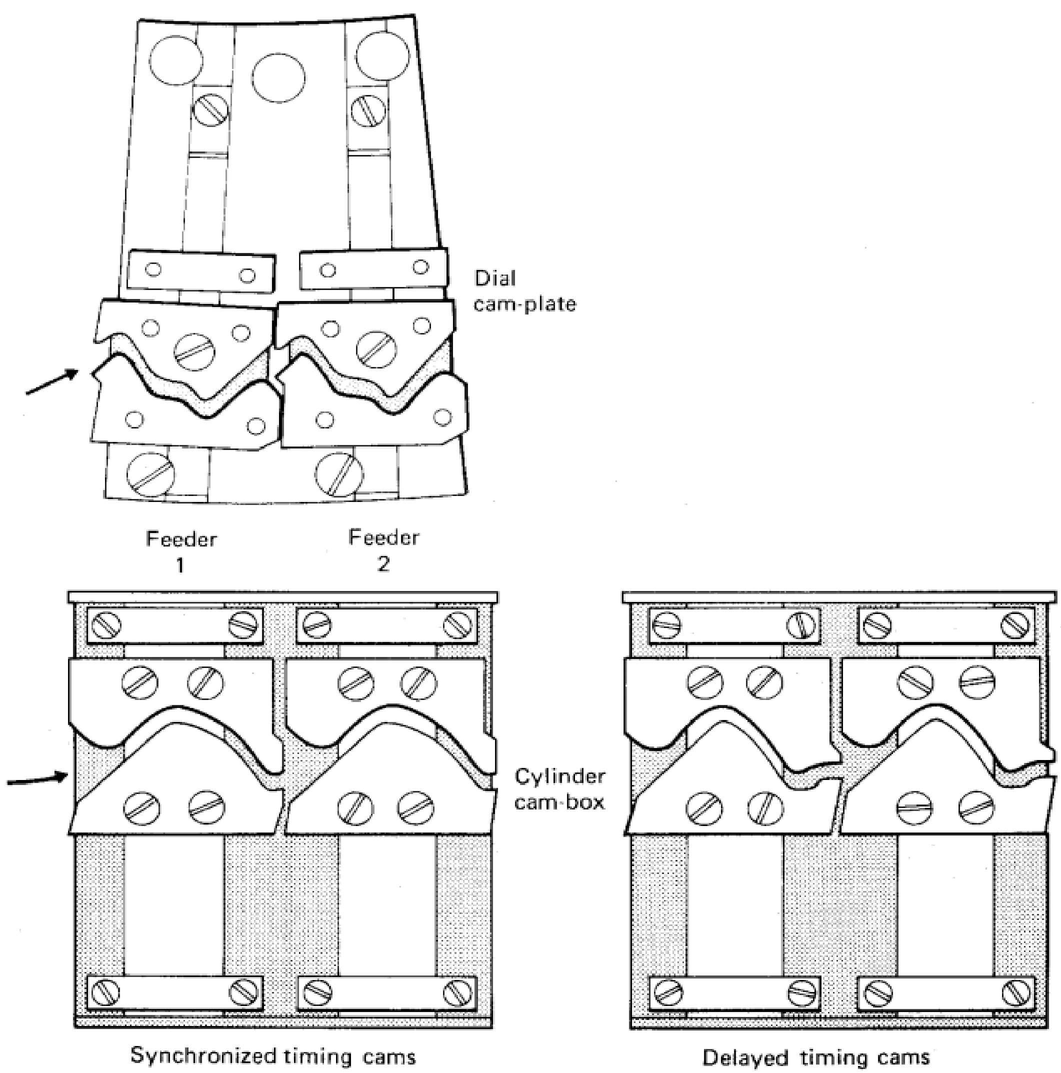



**Fig. 7.11** Needle cam timing for a circular rib machine.

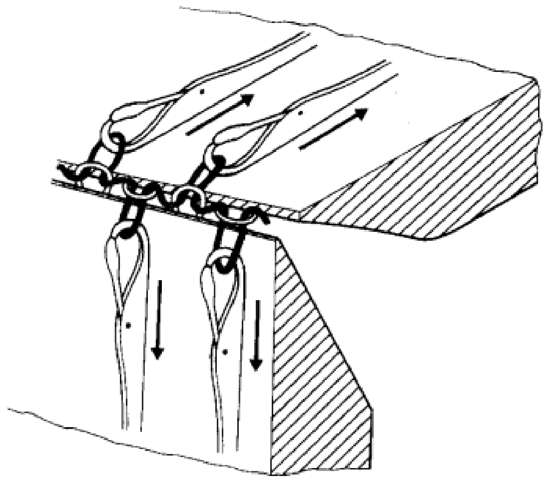


**Fig. 7.12** Synchronised timing.

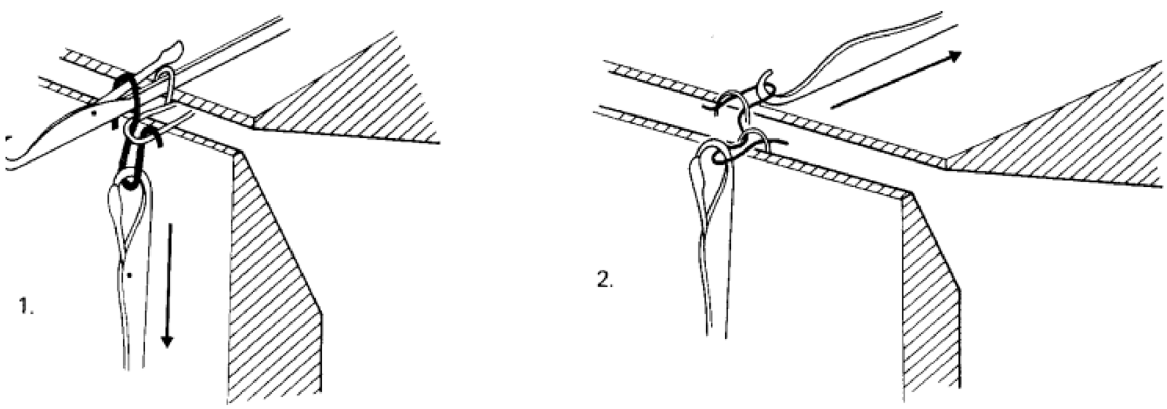



**Fig. 7.13** Delayed timing.

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 (51 cm) diameter model. Suitable hosiery twist cotton yarn only became available in 1925, and the first stationary cam-box machine appeared in 1930.

Originally, interlock was knitted almost solely in cotton on 20 gauge (needles per inch) machines for underwear, a typical weight being 5 oz per square yard (170 g per square metre) using 1/40's s cotton, but from the 1950s onwards, 18 gauge machines were developed for knitting double-jersey for semi-tailored suiting because the open-width fabric could be finished on existing equipment. As the machines became more versatile in their capabilities, the range of structures became greater.

Interlock has the technical face of plain fabric on both sides, but its smooth surface cannot be stretched out to reveal the reverse meshed loop wales because the wales on each side are exactly opposite to each other and are locked together (Fig. 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 × 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 (76 cm) diameter machine will produce a tube of 94-inch (2.4 m) open width which finishes at 60–66 inches (1.5–1.7 m) wide. It is a balanced, smooth, stable structure that lies flat without curl. Like 1 × 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

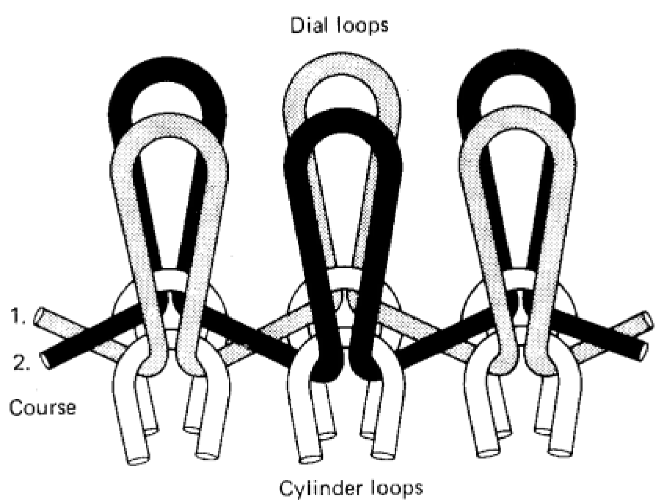



**Fig. 7.14** Interlock fabric structure.

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 widthwise 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. |

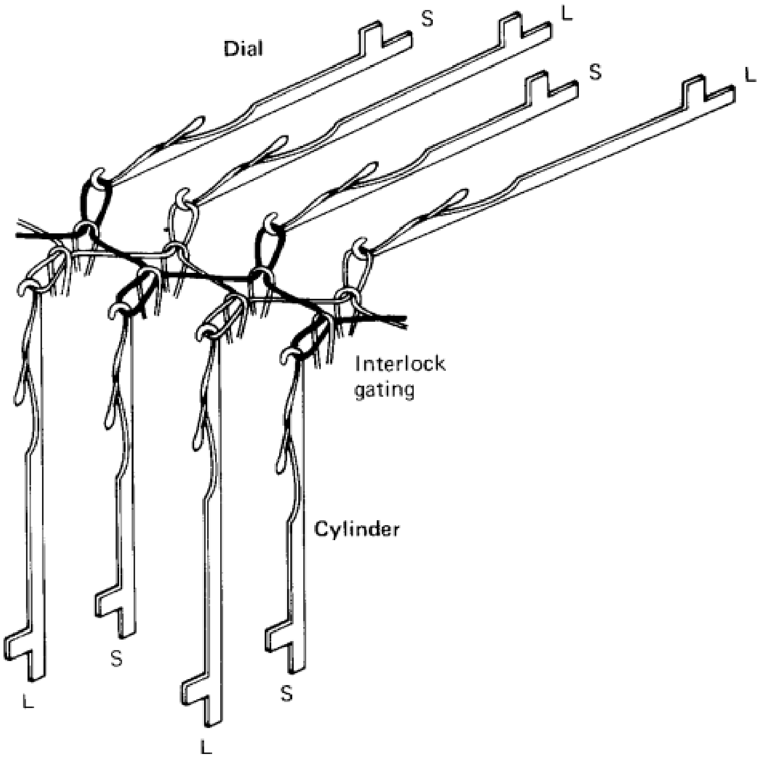



**Fig. 7.15** Knitting interlock.

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$^2$ (151 g/m$^2$) 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.

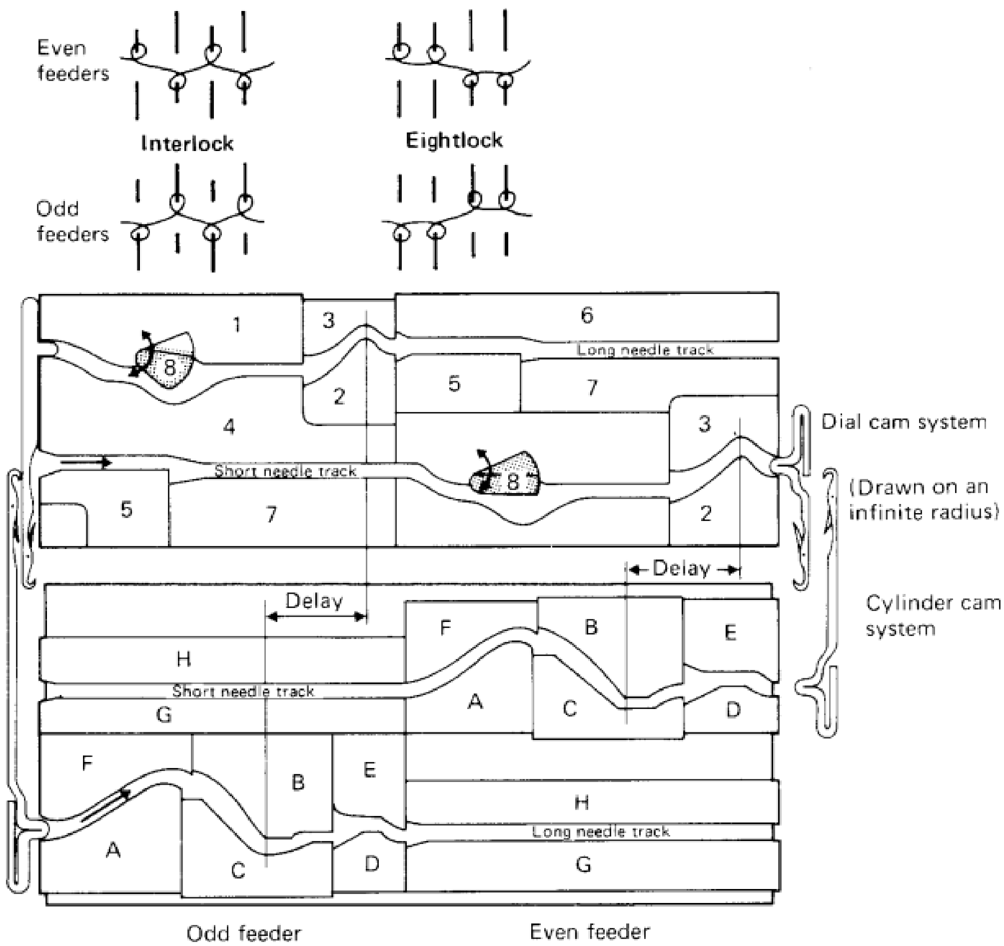



**Fig. 7.16** Interlock cam system.

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.

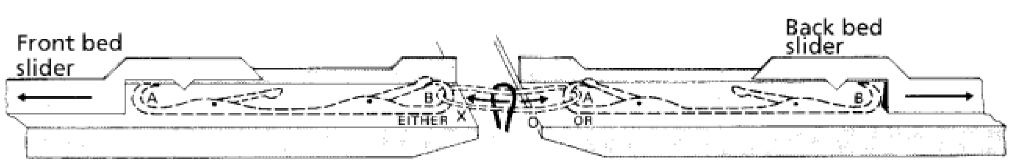
The semi-circles of the needle and sinker loops produced by the reverse loop intermeshing tend to be prominent on both sides of the structure and this has led to the term '*links-links*' being generally applied to purl fabrics and machines. Links is the German word for left and it indicates that there 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.

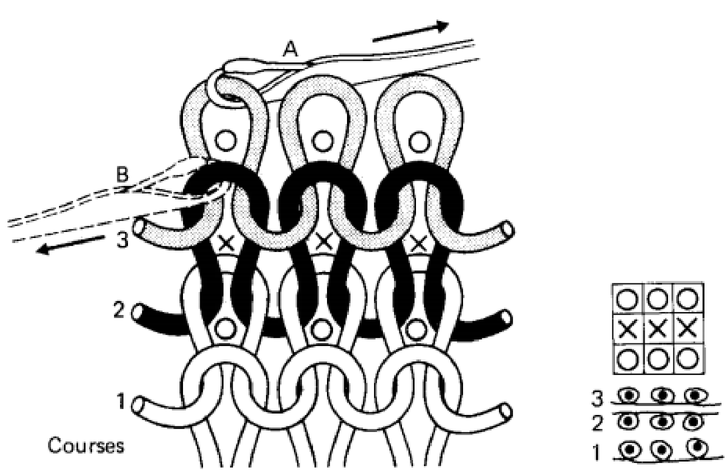



**Fig. 7.18** Purl fabric structure.

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 × 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 unroved from both ends because the free sinker loops can be pulled through at the bottom of the fabric. In the USA, 1 × 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 × 3 (Fig. 7.21), 7 × 3, 4 × 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.

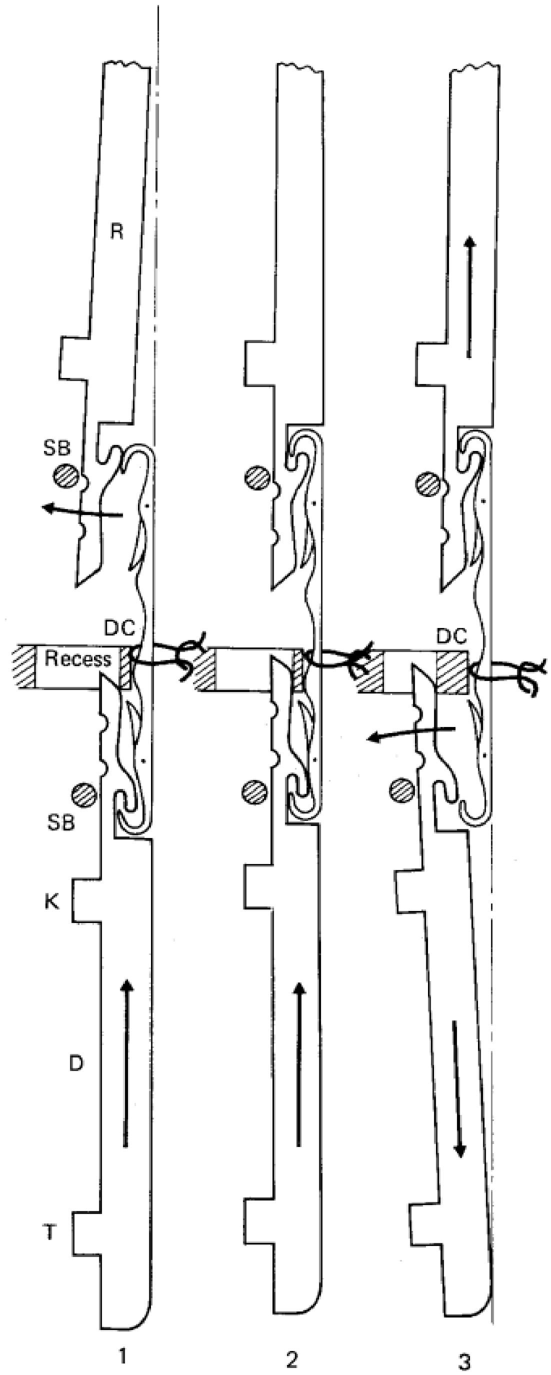



**Fig. 7.19** Purl needle transfer action.

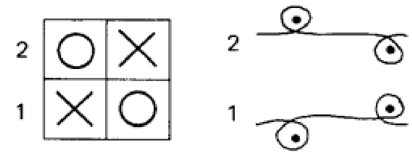



**Fig. 7.20** Purl notation.

### 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 | X | X | X | X | X | X | X | X |
| | O | X | X | X | O | O | O | O |
| | O | X | X | X | O | O | O | O |
| | O | X | X | X | O | O | O | O |
| c | X | X | X | X | X | X | X | X |
| | O | O | O | O | O | X | X | X |
| | O | O | O | O | O | X | X | X |
| | O | O | O | O | O | X | X | X |

(c = collecting row)

**Fig. 7.21** Basket purl with a collecting course.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| O | O | O | O | X | X | X | X |
| O | O | O | O | X | X | X | X |
| O | O | O | O | X | X | X | X |
| O | O | O | O | X | X | X | X |
| X | X | X | X | O | O | O | O |
| X | X | X | X | O | O | O | O |
| X | X | X | X | O | O | O | O |
| X | X | X | X | O | O | O | O |

**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

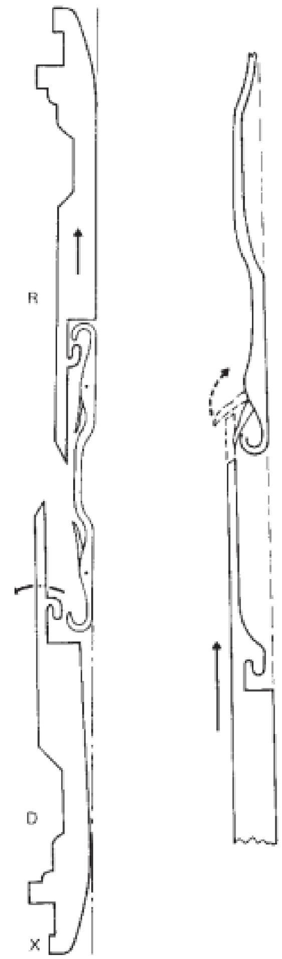



**Fig. 7.23** Purl needle transfer using spring loaded cams.

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).