7

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

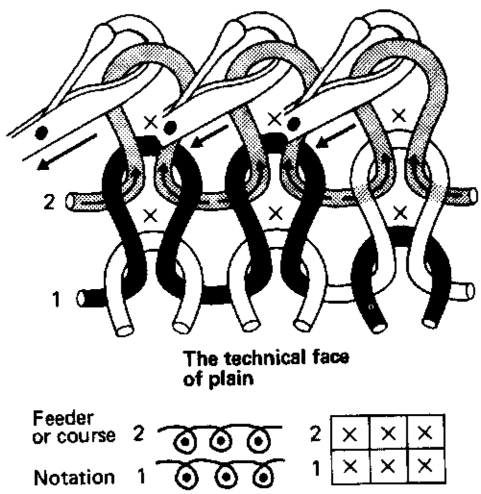

Fig. 7.1 The technical face of plain weft knitted fabric.

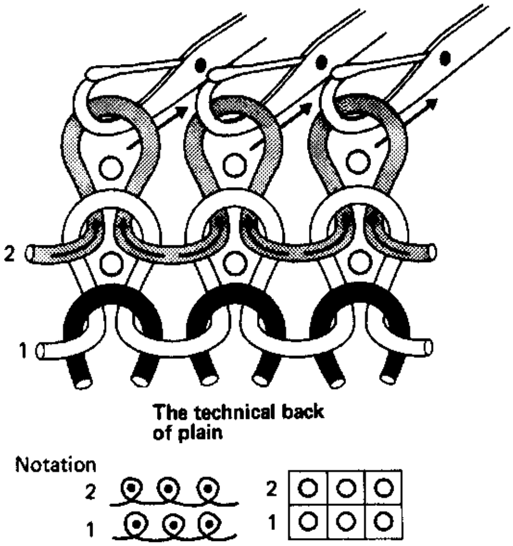

Fig. 7.2 The technical back of plain weft knitted fabric.

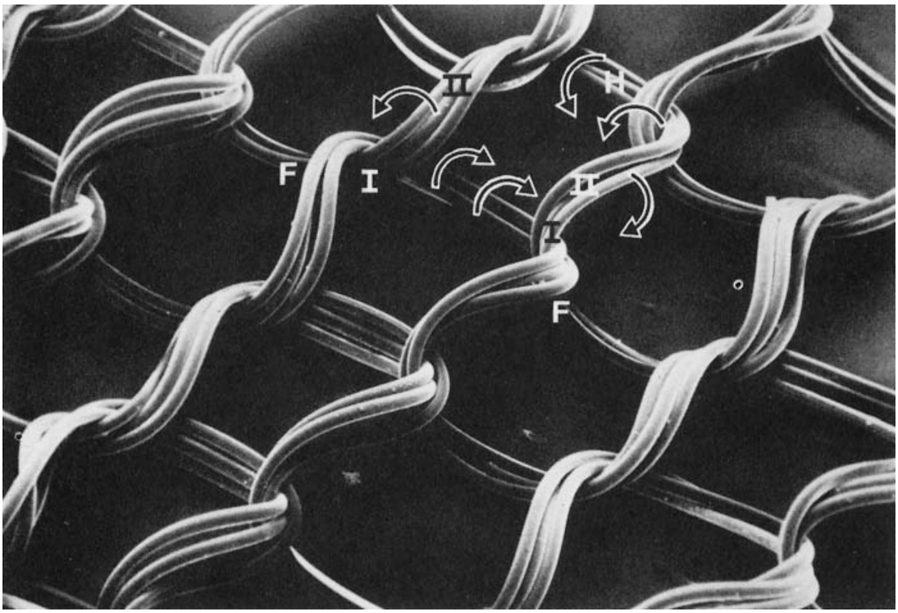

Fig. 7.3 The three-dimensional structure of plain weft knitting [Milliken AGILON] magnified ×130 by a stereoscan electron microscope. The arrows indicate the direction in which the fabric will tend to curl if it is cut. [By permission of *Knitting Times*, official publication of NKSA USA].

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 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.

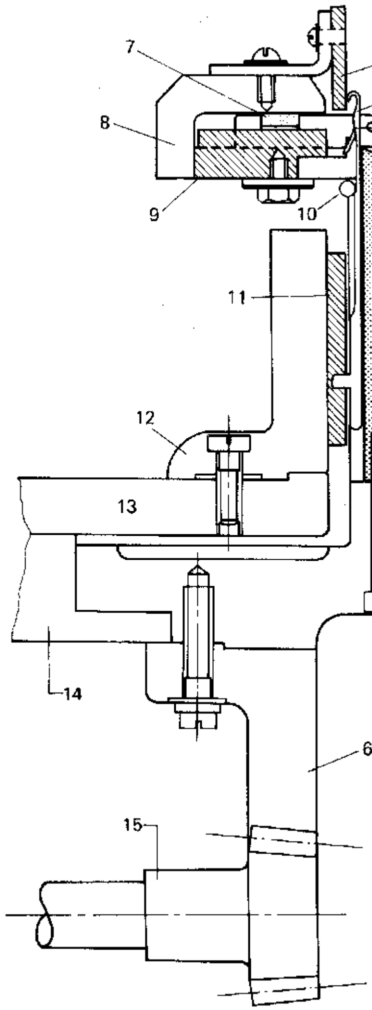

Fig. 7.4 Cross-section of knitting head of a single jersey machine.

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.

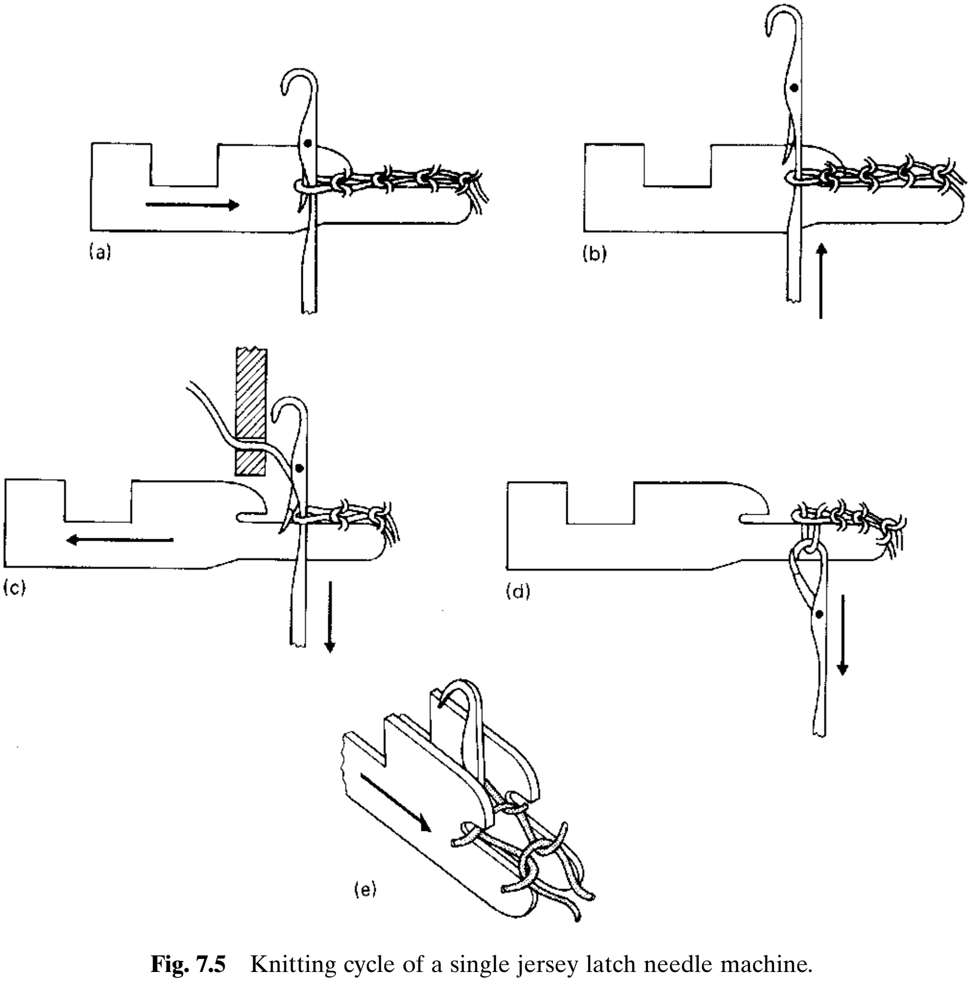

Fig. 7.5 Knitting cycle of a single jersey latch needle machine.

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-

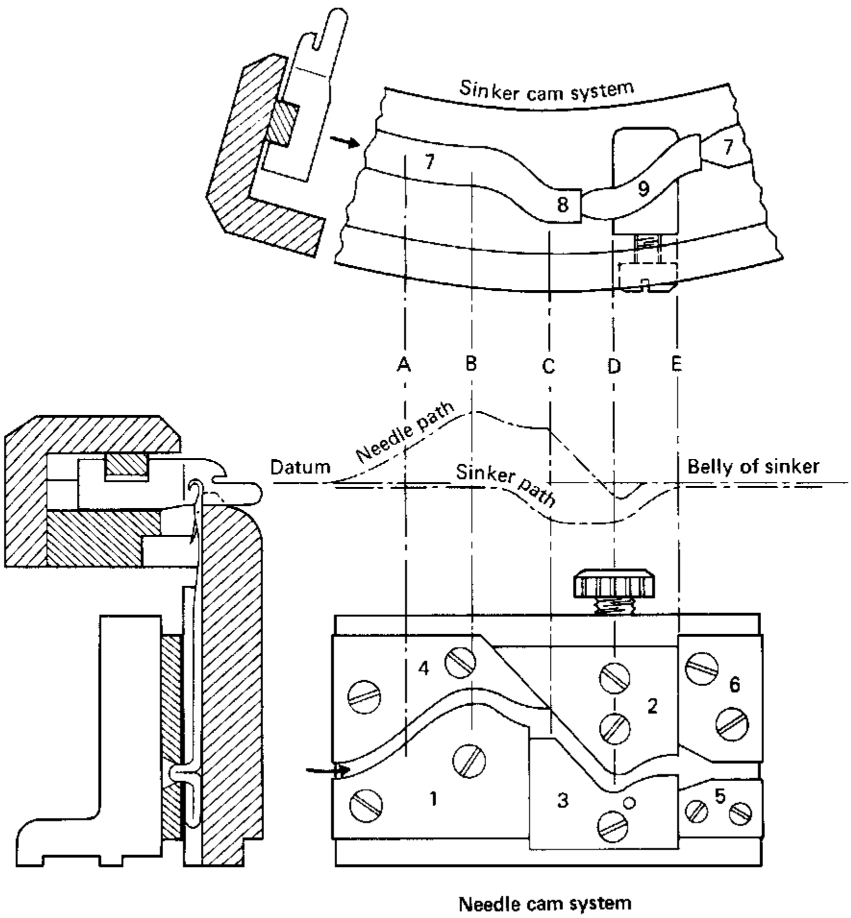

Fig. 7.6 Sinker timing on a single jersey machine.

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 × 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).

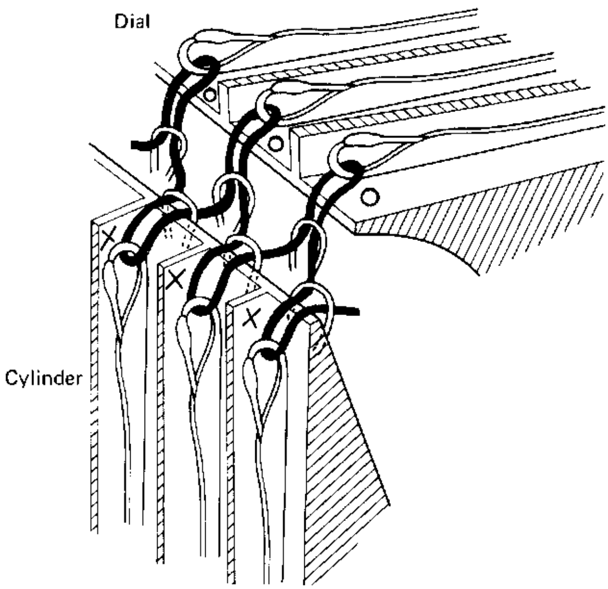

Fig. 7.7 Structure of 1 × 1 rib.

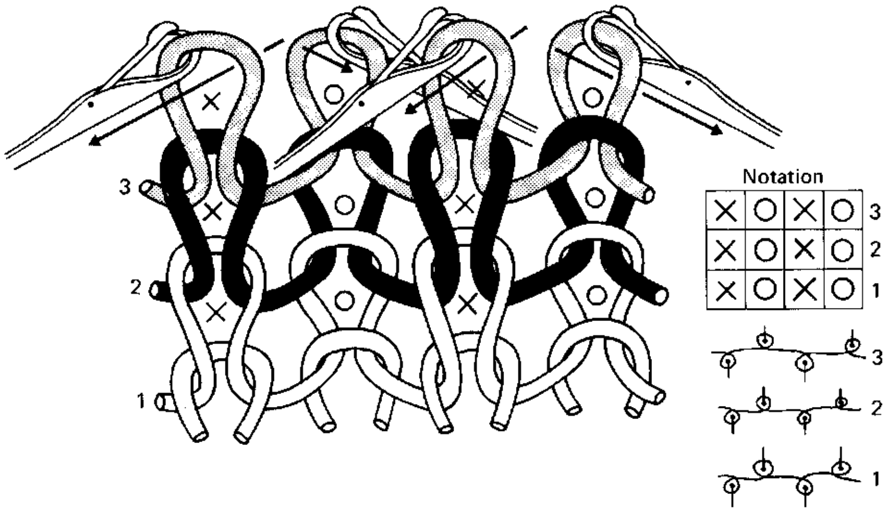

Fig. 7.8 Face and reverse loop wales in 1 × 1 rib.

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.

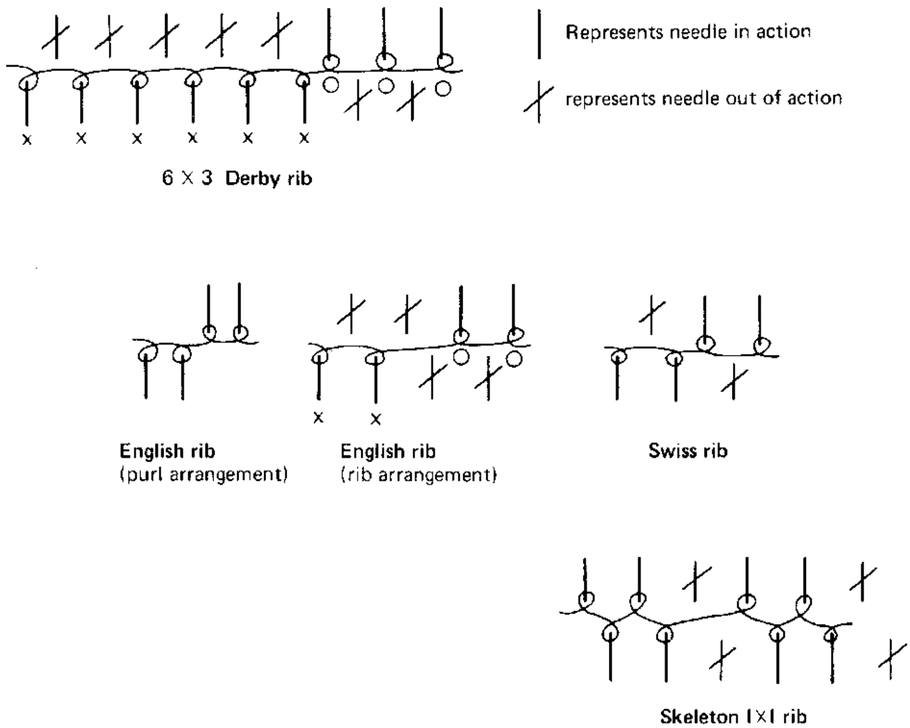

Fig. 7.9 Rib set-outs.

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.

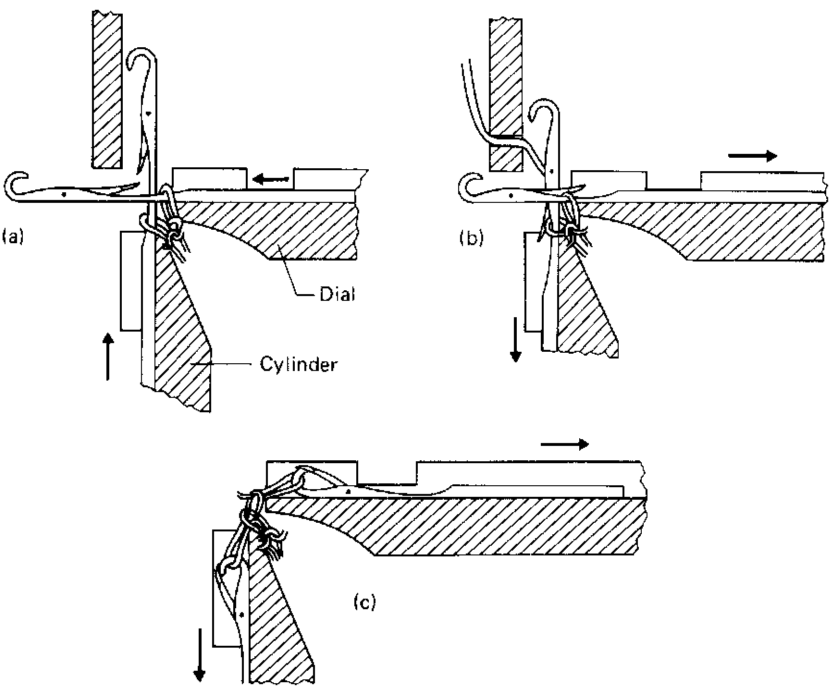

Fig. 7.10 Knitting action of a circular rib machine.

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

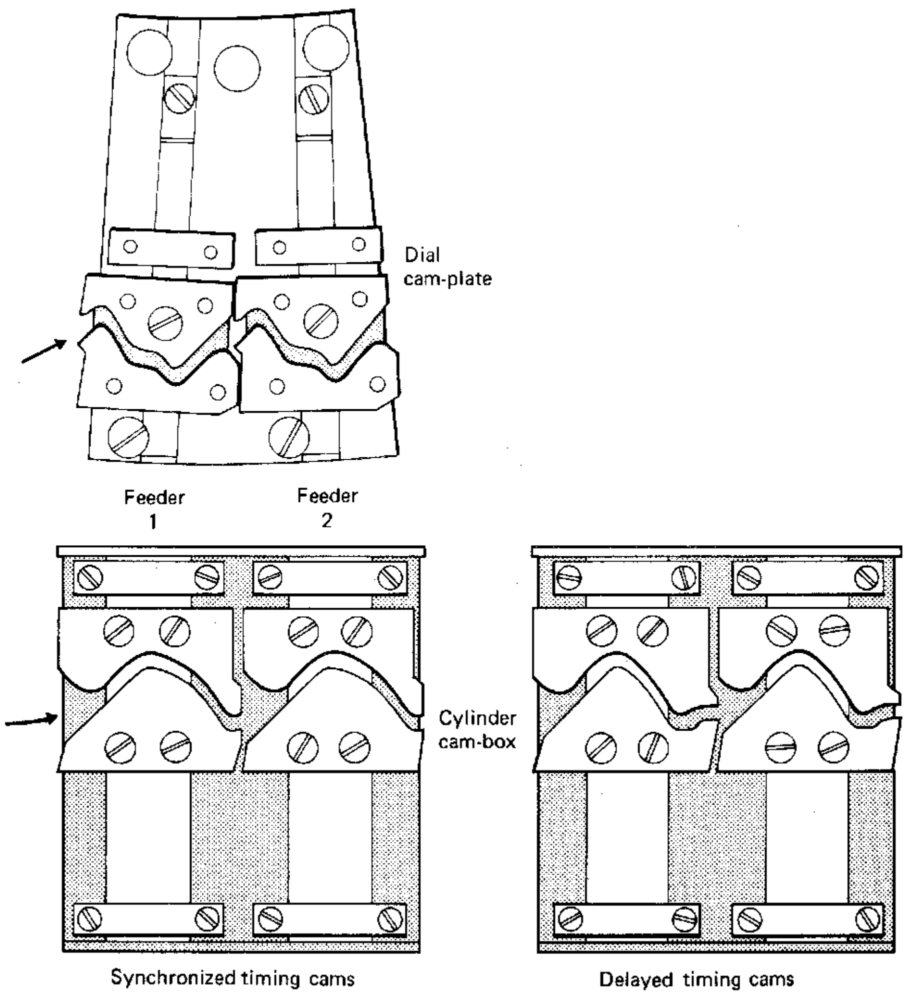

Fig. 7.11 Needle cam timing for a circular rib machine.

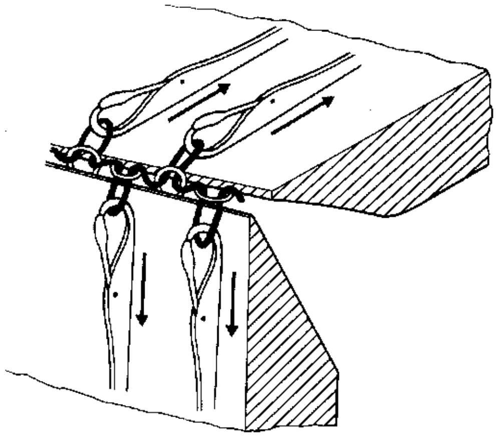

Fig. 7.12 Synchronised timing.

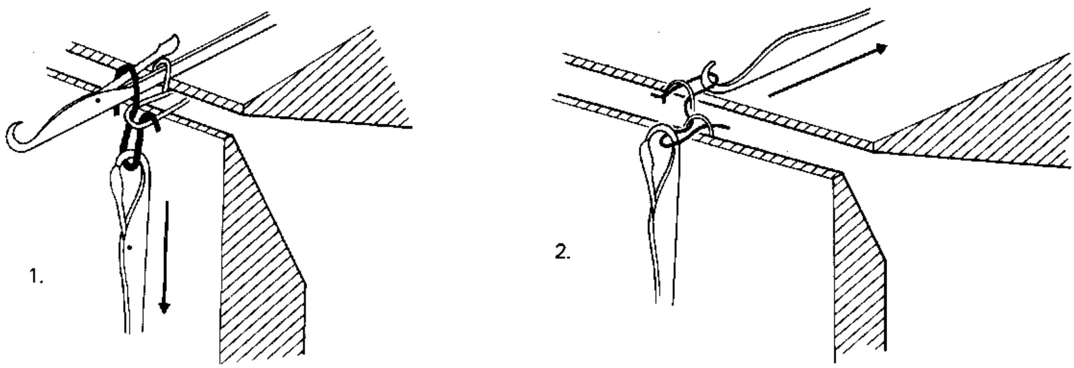

Fig. 7.13 Delayed timing.

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

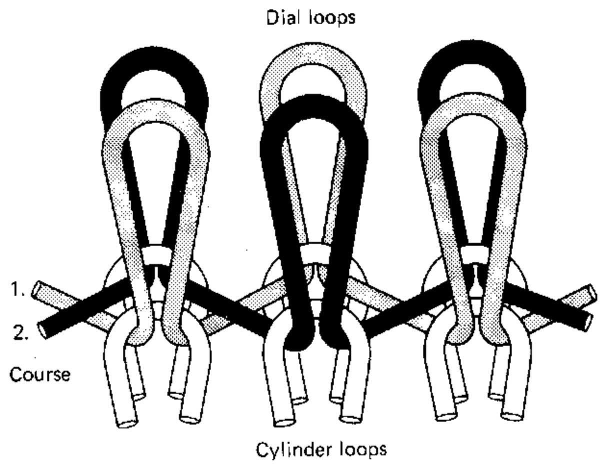

Fig. 7.14 Interlock fabric structure.

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 2×2 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 4×4 and 3×3 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.

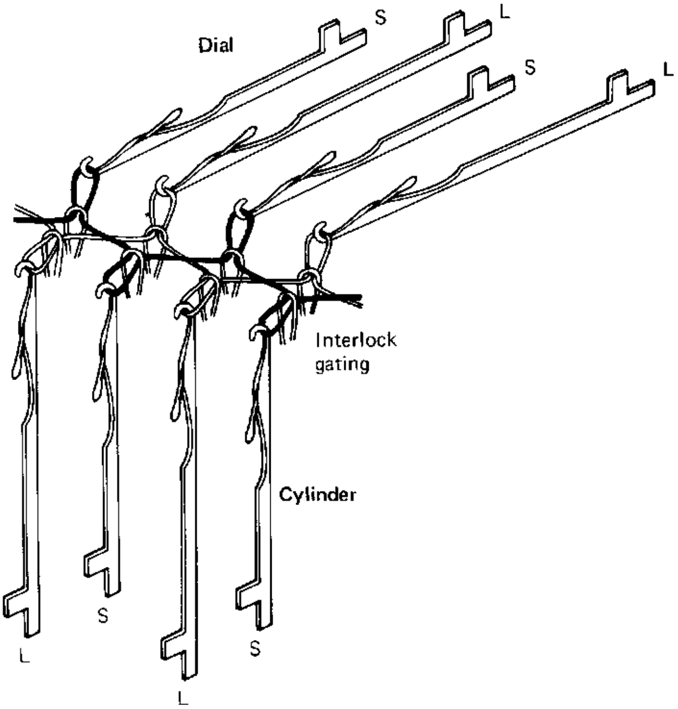

Fig. 7.15 Knitting interlock.

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.

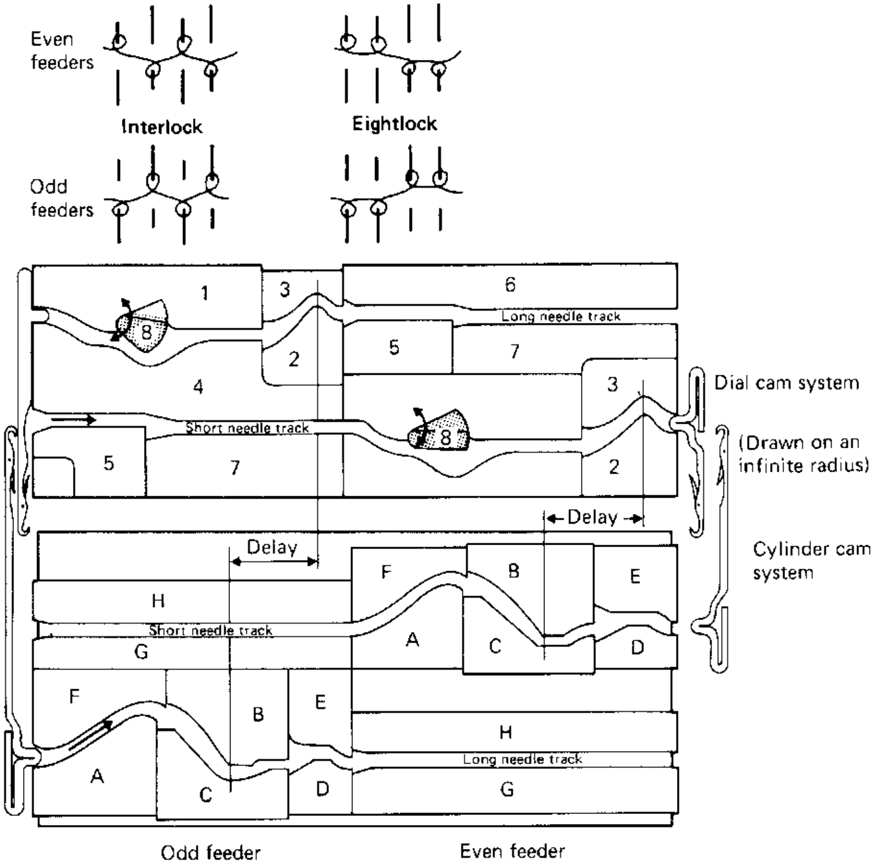

Fig. 7.16 Interlock cam system.

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.

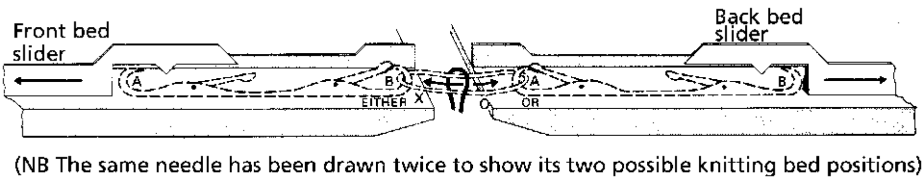

Fig. 7.17 Purl knitting using sliders.

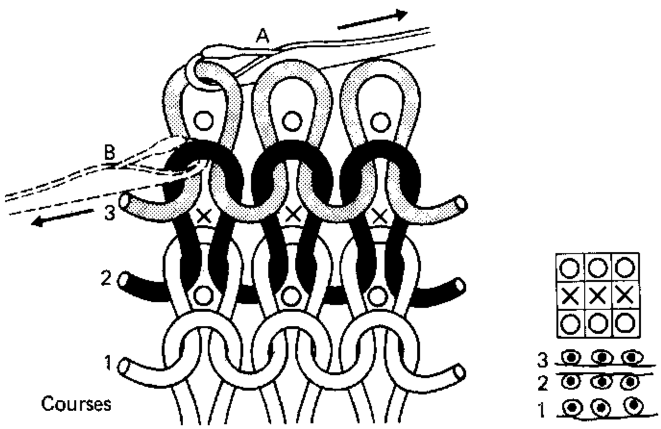

Fig. 7.18 Purl fabric structure.

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.

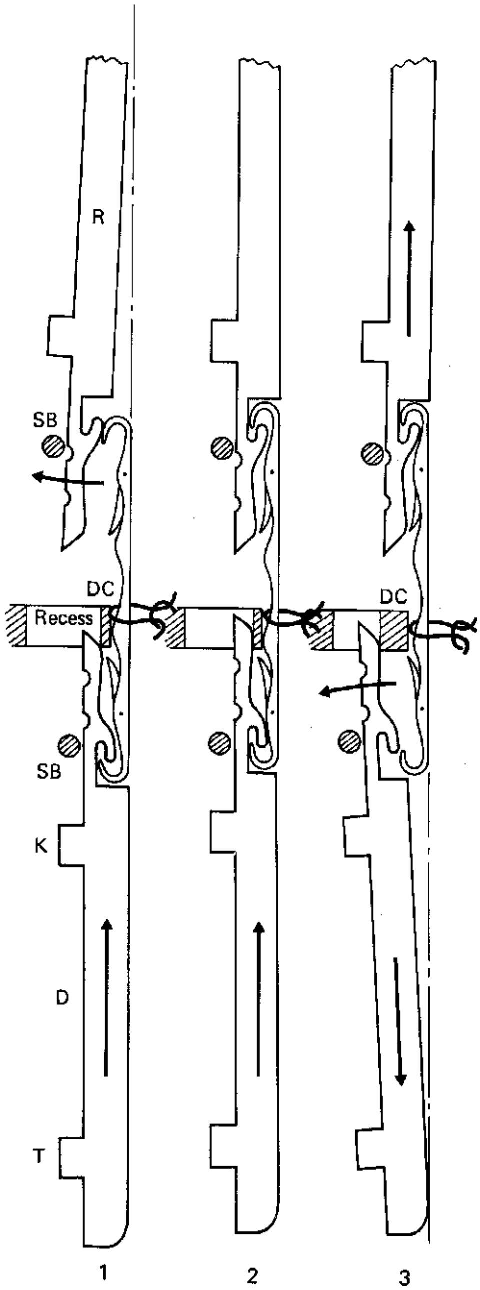

Fig. 7.19 Purl needle transfer action.

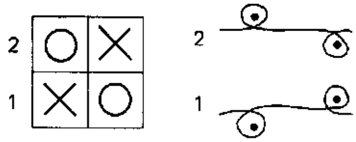

Fig. 7.20 Purl notation.

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

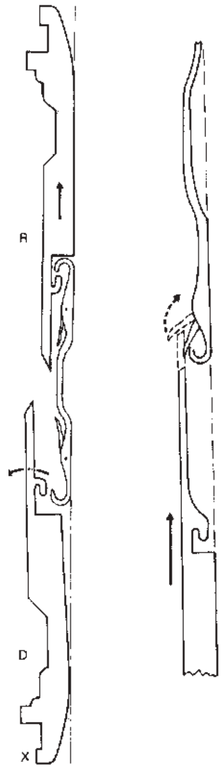

Fig. 7.23 Purl needle transfer using spring loaded cams.

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).

References

1. DAVIES, W., *Hosiery Manufacture*, (1923), Pitman, London, UK, 129.
2. PAEPKE, H., Fundamentals of delayed and synchronised timing, *Knit. O'wr Times*, (8 May 1967), 145–51.
3. WILLKOMM, G., *Technology of framework knitting*, (1885), (Eng. trans. ROWLETT, W. T., Hewitt, Leicester, UK. First Part, Chapter 2, p.78).
4. LANCASHIRE, J. B., Focus on purl knitting, *Hos. Trade J.*, (March 1961), 84–8.

8

The various types of weft knitting machines

8.1 Fabric machines and garment-length machines

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

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

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

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

8.1.1 Fabric machines

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

Circular machines employing bearded needles are now obsolete. Although sinkerwheel and loopwheel frames could knit high quality speciality fabrics, their production rates were uncompetitive.

Unless used in tubular body-width, the fabric tube requires splitting into open-width. It is finished on continuous finishing equipment and is cut-and-sewn into garments, or it is used for household and technical fabrics. The productivity, versatility and patterning facilities of fabric machines vary considerably. Generally, cam settings and needle set-outs are not altered during the knitting of the fabric (see also Chapter 13, *The production of weft knitted fabric*).

8.1.2 Garment-length machines

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

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

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

Garments may be knitted to size either in tubular or open-width; in the latter case more than one garment panel may be knitted simultaneously across the knitting bed. Large-diameter circular machines and wide V-bed flat machines can knit garment blanks that are later split into two or more garment widths (*blanket-width* knitting) (see also Chapter 20, *Circular garment-length machines*).

8.2 Knitting welts and rib borders

Garment-length knitting sequences vary considerably. The simplest circular garment machines knit repeat sequences of rib borders and body panels in a continuous structure at high speed. This structure requires cutting into garment lengths and seaming to produce a secure welt edge.

Most garment machines knit some form of secure welt edge at the start of the garment sequence and either a 'knitted-in' separation course (draw-thread or dissolving thread) or 'press-off' separation between each garment piece. In the latter case, the machine must be capable of commencing knitting of the next garment length on empty needles.

Shaping of flat garment panels is either in the form of cut edges or in the form of knitted selvedges (in the case of reciprocating knitting on a flat machine). The amount of shape introduced into the garment also varies; in some cases this is achieved entirely by the cutting and making-up operation, in others it is by stitch shaping, stitch length variation, loop transfer and fashioning, held stitches or reciprocation.

8.3 Integral knitting

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

Some V-bed glove knitting machines are of this type, as are some hosiery machines with integral toe-closing facilities. Some V-bed flat machines can knit complete garments in tubular form [1].

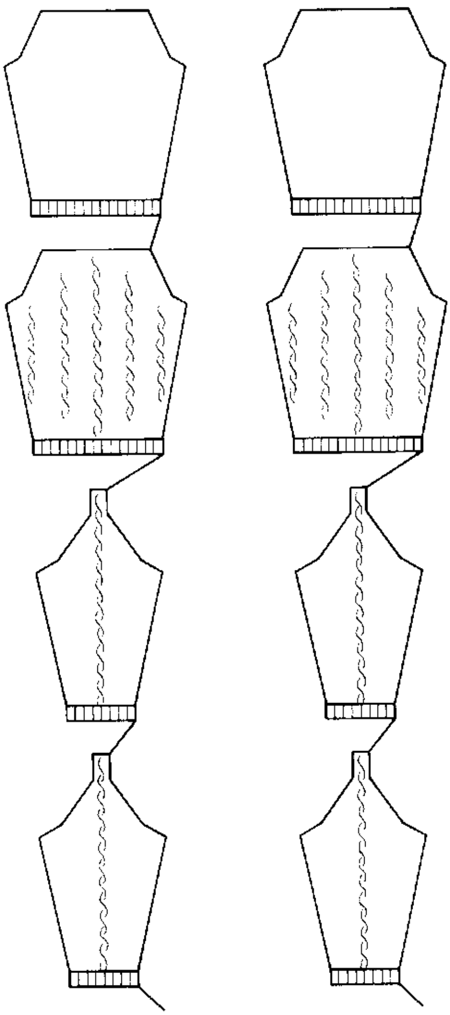

Fig. 8.1 Sequential knitting.

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

Certain electronically-controlled straight bar and V-bed flat machines can now be programmed to carry out a sequence of knitting a front, a back and two sleeves in turn thus using the same yarn and stitch lengths. Programming *sequential knitting* requires adequate computer memory and gives the advantages of quick response, less work in progress and better matching of component panels (Fig. 8.1).

8.4 The three classes of weft knitting machines

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

8.4.1 Straight bar frame machines

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

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

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

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

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

1 Knitting a rib border fabric and welt on a separate V-bed flat machine, running it onto the empty needles of the frame and then commencing to knit the body panel onto the rib.
2 Employing a welt-turning device on the frame to produce a double thickness plain fabric. This method is more popular in the USA. It is the only method of knitting welts on fully-fashioned stockings.

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

The machines are noted for their production of high-quality garments as a result of the gentle knitting action, low fabric tension and fashion shaping, which reduces the waste of expensive yarn during cutting and is emphasised on the garments by carefully-positioned fashion marks.

The straight bar frame is the only bearded needle weft knitting machine that is still commercially viable, although it now faces serious competition from electronically-controlled V-bed flat machines (see also Chapter 17).

8.4.2 Flat machines

The typical flat machine has two stationary beds arranged in an inverted V formation. Latch needles and other elements slide in the tricks during the knitting action. Their butts project and are controlled as they pass through the tracks formed by the angular cams of a bi-directional cam system. It is attached to the underside of a carriage that, with its selected yarn carriers, traverses in a reciprocating manner across the machine width (Fig. 8.2).

The machines range from hand-propelled and -manipulated models to automated, electronically-controlled, power-driven machines.

The classes of flat machines are:

1 the V-bed flat machines, which form by far the largest class;
2 the flat-bed purl machines, which employ double-headed needles;

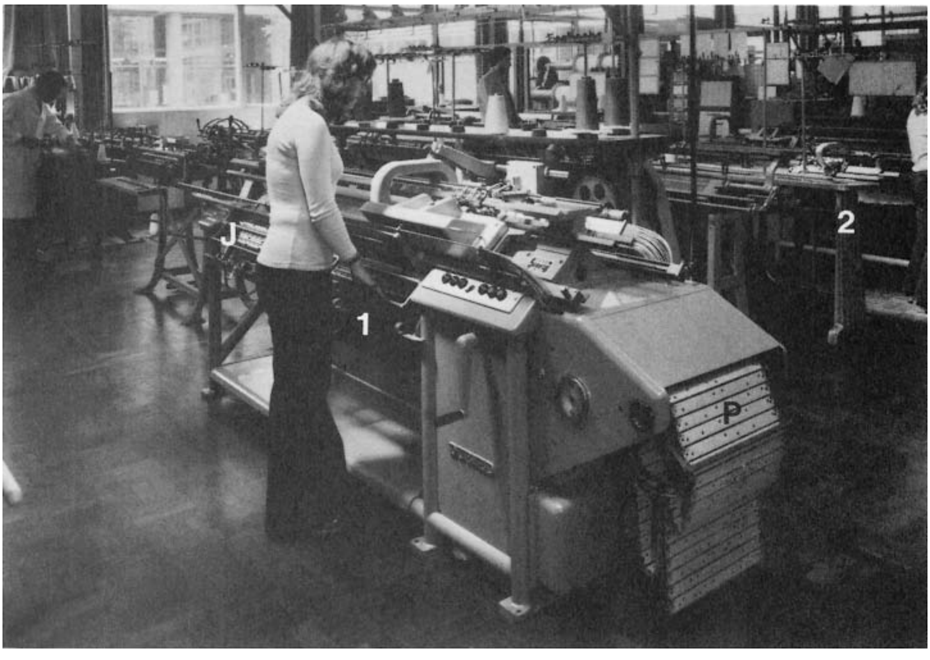

Fig. 8.2 Mechanically controlled flat knitting machines. 1 = jacquard power flat; 2 = hand flat; J = jacquard selection steels; P = paste board movement cards.

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

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

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

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

Articles knitted on flat machines range from trimmings, edgings and collars, to shaped panels, integrally-knitted garment pieces, integrally-knitted complete garments and other articles. (see also Chapter 19, *Automatic power flat knitting*).

8.4.3 Circular machines

The term 'circular' covers all those weft knitting machines whose needle beds are arranged in circular cylinders and/or dials, including latch, bearded, or (very occasionally) compound needle machinery, knitting a wide range of fabric structures, garments, hosiery and other articles in a variety of diameters. Circular garment-length machines are either of body size or larger (Fig. 8.3), having a cylinder and dial arrangement, single cylinder or double cylinder, as is also the case with small diameter machines for hosiery (Fig. 8.4).

During the last 200 years, numerous inventors have assisted the development of circular weft knitting technology towards its present state of sophistication and diversity [2]. Whilst *Decroix's* patent of 1798 has been considered to be the first for a circular frame, *Marc Brunel's* 'tricoteur' of 1816 is probably the first practical working example of such a frame. Efforts were concentrated during the subsequent 30 years on improving the knitting action of this frame, with its revolving dial of fixed bearded needles radiating horizontally outwards and having their beards uppermost.

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

Fig. 8.3 Mechanically controlled circular knitting machines. 1 = plain cylinder and dial fabric machine; 2 = rib jacquard machine; 3 = double cylinder purl garment length machine.

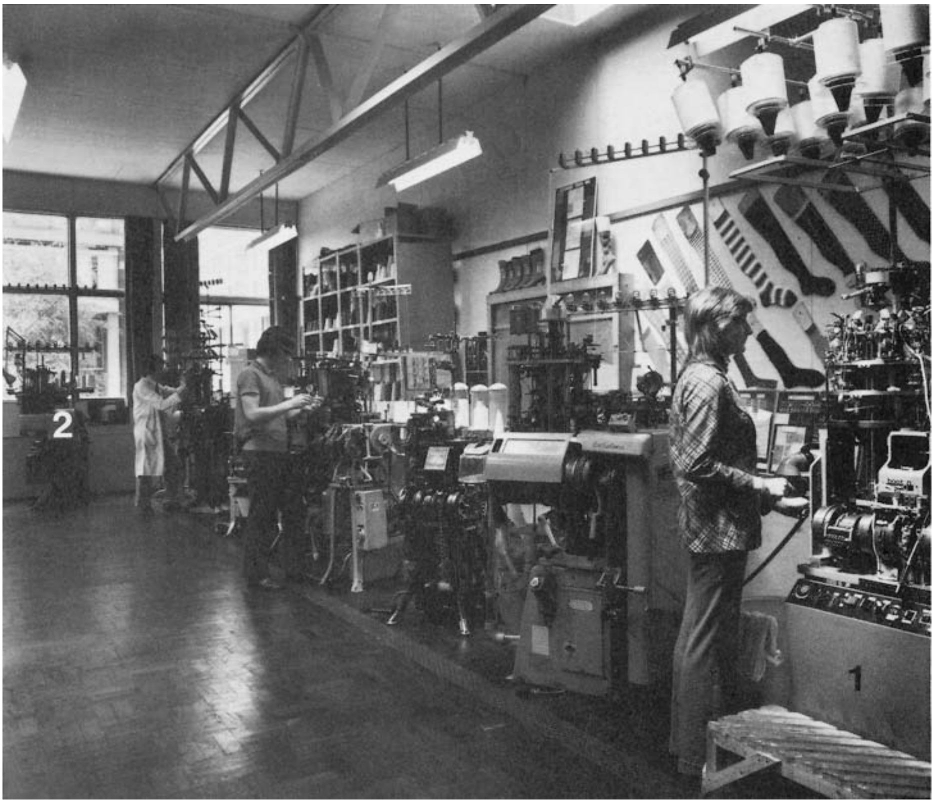

Fig. 8.4 Mechanically controlled hosiery machines. 1 = seamless hose machine; 2 = double cylinder half-hose machine.

In 1849, *Moses Mellor* produced a revolving circular frame with vertically-arranged bearded needles facing outwards from the needle circle; this later developed to become the loopwheel frame. In the same year, *Matthew Townsend* patented uses for the latch needle and by 1855, *Pepper* had produced a commercial machine with a single set of movable latch needles and two feed points. This was soon followed by *Aiken's* circular latch needle rib machine of 1859, which also contained movable needles. *Henry Griswold* took latch needle knitting a stage further by moving the needles individually and directly via their bent shanks in his world-famous, hand-operated, revolving cam-box, small-diameter sock machine of 1878 (Fig. 4.4).

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

References

1. MILLINGTON, J., The automated production of complete hosiery, knitwear and bodywear garments, IFKT Conference, *Knit. Int.*, (Oct. 1998), 56–60.
2. SCHWABE, C., Thoughts on the history of the circular knitting machine, *Knit. Tech.*, Vol. 11, (1989), No. 3, 186–9.

Further information

ANON., Knitting machinery: a guide to primary types, *Knit. O'wr Yr Bk*, (1970), 97–9.
HURD, J. C. H., Towards automation in hosiery, knitwear and knitted fabric, *Text. Inst. and Ind.*, (1974), 12, (4), 113 (4 pages).
LANCASHIRE, J. B., 75 years of weft knitting history, *Hos. Trade J.*, (Jan. 1969), 178–86.
SPENCER, D. J., Knitwear machinery, *Knit. Int.*, (1994), Aug., 36–7.
SPENCER, D. J., Weft knitting at ITMA '99, *ATA Asia*, (Jan. 2000).

9

Stitches produced by varying the sequence of the needle loop intermeshing

9.1 Knitted stitches

Weft knitted stitches described so far have been composed entirely of knitted loops. A *knitted loop stitch* is produced when a needle receives a new loop and knocks-over the old loop that it held from the previous knitting cycle. The old loop then becomes a needle loop of normal configuration.

Other types of stitch may be produced on each of the four-needle arrangement base structures by varying the timing of the intermeshing sequence of the old and new loops. These stitches may be deliberately selected as part of the design of the weft knitted structure or they may be produced accidentally by a malfunction of the knitting action so that they occur as fabric faults. When these stitches are deliberately selected, a preponderance of knitted loop stitches is necessary within the structure in order to maintain its requisite physical properties.

The needles generally produce knitted loop stitches prior to the commencement, and at the termination, of these selected stitches, and there are usually certain needles that are knitting normally during the same cycles as those in which these stitches are produced.

Apart from the knitted loop stitch, the two most commonly-produced stitches are the *float stitch* and the *tuck stitch*. Each is produced with a *held loop* and shows its own particular loop most clearly on the reverse side of the stitch because the limbs of the held loop cover it from view on the face side.

9.2 The held loop

A *held loop* (Fig. 9.1) is an old loop that the needle has retained. It is not released and knocked-over until the next, or a later, yarn feed. A held loop can only be retained by a needle for a limited number of knitting cycles before it is cast-off. A new loop is then drawn through it, otherwise the tension on the yarn in the held loop becomes excessive even though there is a tendency to rob yarn from adjacent loops in the same course.

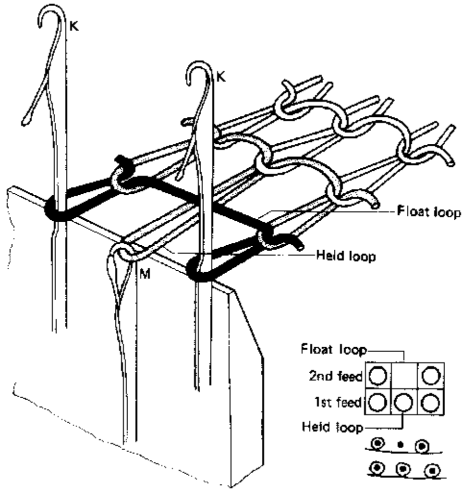

Fig. 9.1 Float stitch produced on a latch needle machine.

The limbs of the held loop are often elongated. They extend from its base, intermeshing in one course, to where its head is finally intermeshed a number of courses higher in the structure. Alongside it, in adjacent wales, there may be normally-knitted loops at each course.

A held loop may be incorporated into a held stitch without the production of tuck or miss stitches in either single- or double-faced structures.

In single-faced structures, it can only be produced on machines whose feeds or needles have a reciprocating action so that the yarn only passes across needles that are knitting, otherwise a float stitch would be produced. Held stitches of this type are used for producing three-dimensional shaping such as heel and toe pouches for footwear, held-loop shaping on flat machines, and designs in solid colour intarsia. Held stitches are produced in double-faced structures by holding loops on one bed whilst continuing to knit on the other, thus producing horizontal welt and cord effects.

9.3 The drop or press-off stitch

A *drop stitch fault* will result if a needle releases its old loop without receiving a new one. Sometimes this technique is used to achieve a press-off on all needles at the end of a garment-length sequence. A *drop stitch* or *press-off stitch* is used very occasionally in flat knitting to cause certain loops in a plain structure to be much larger than the rest. Knitting takes place on only one bed of needles and selected needles in the other bed pick up loops that are immediately pressed-off by not receiving yarn at the next feed.

The yarn from the pressed-off loops flows into the adjacent loops in the other bed, making them larger and giving the impression of a much coarser gauge. Drop stitch wales are sometimes used to provide a guide for the cutting operation. Generally, a secure structure is only produced when a needle retains its old loop if it does not receive a new loop.

Open-work 'crochet' type designs (also termed *drop-stitch*, *press-off*, or *latch-opener fabrics*) can be produced in single jersey by carefully pressing-off the loops of selected groups of needles, then recommencing knitting on the empty needles. Off-set yarn feeding is employed, the yarn feeders being collectively repositioned to feed the yarn from outside the needle-line across the front of the ascending needle hooks. The yarn itself brushes open the closed latches and does not damage the needles, unlike conventional steel point latch-openers.

An example produced on a E 28 *Monarch* machine has 4 feeds knitting plain with 1/30's cotton. Feeder 5 is knitted with a minimum stitch length and two ends of yarn to lock-in the following course. Feeder 6 is a slack course, knitted at half the normal tension and half the normal yarn count. It is jacquard-selected to produce a course of open-work pattern by pressing-off on these needles. The pick-up course is then knitted at high tension to avoid drop stitches and ladders at the edges of the pressed-off areas.

9.4 The float stitch

A *float stitch* or *welt stitch* (Fig. 9.1) is composed of a held loop, one or more float loops and knitted loops. It is produced when a needle (M) holding its old loop fails to receive the new yarn that passes, as a float loop, to the back of the needle and to the reverse side of the resultant stitch, joining together the two nearest needle loops knitted from it.

In Fig. 9.2, the float stitch shows the missed yarn floating freely on the reverse side of the held loop. (This is the technical back of single-jersey structures but is the inside of rib and interlock structures.) The float extends from the base of one knitted or tucked loop to the next, and is notated either as an empty square or as a by-passed point. It is assumed that the held loop extends into the courses above until a knitted loop is indicated in that wale.

A single float stitch has the appearance of a U-shape on the reverse of the stitch. Structures incorporating float stitches tend to exhibit faint horizontal lines. Float

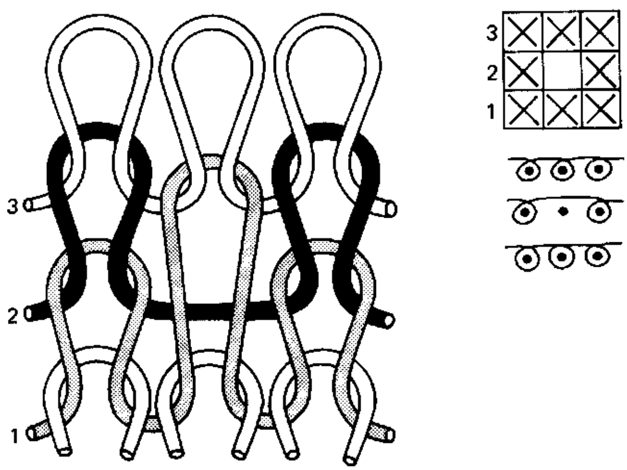

Fig. 9.2 Technical face of float stitch.

stitch fabrics are narrower than equivalent all-knit fabrics because the wales are drawn closer together by the floats, thus reducing width-wise elasticity and improving fabric stability.

Under normal take-down tension and with normal yarn extensibility, the maximum number of successive floats on one needle is four. Six adjacent needles are usually the maximum number for a continuous float because of reduced elasticity and problems of snagged threads, especially in continuous-filament yarns and with coarse machine gauges.

A floating thread is useful for hiding an unwanted coloured yarn behind the face loop of a selected colour when producing jacquard design in face loop stitches of different colours (adjacent needle floating in shown in Fig. 9.8, successive floating on the same needle in Fig. 9.7). The miss stitch can occur accidentally as a fault due to incorrectly set yarn feeders.

9.5 Float plating

Float plating (Fig. 9.3) produces an open-work mesh structure in single jersey and involves feeding two yarns in a plating relationship to needles having forward hooks. A thick yarn (A), for example 30 denier, is fed at a high level and is received only by needles selected to that height. A fine yarn (B), possibly 15 denier, is fed at a lower level and is received and knitted by every needle.

Two-course fishnet is the most popular structure, having a repeat of two wales and four courses deep. At the first two feeders, odd needles (O) knit only the thin yarn and even needles (E) knit plated loops. At the next two feeders the sequence is reversed.

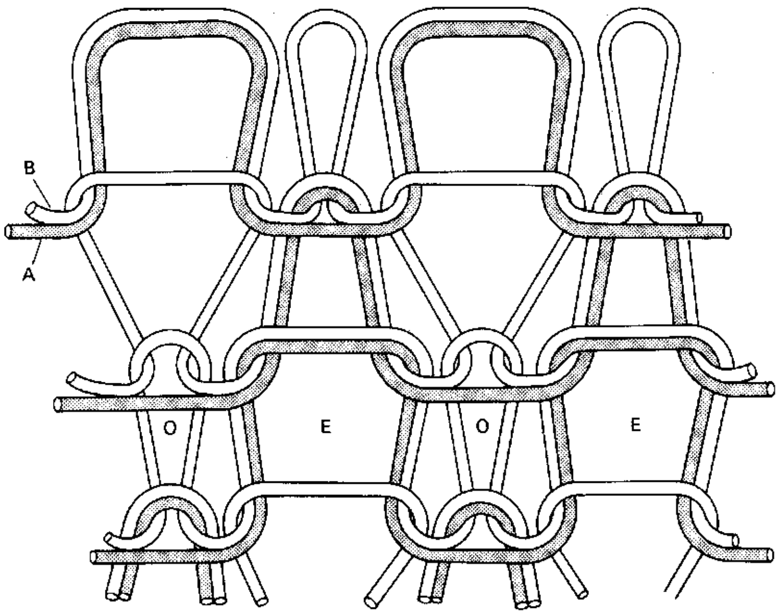

Fig. 9.3 Float plated fabric.

Knitting and missing of the thick yarn causes an expansion of alternate stitches. The two-course sequence may be extended to three or four courses and it is possible to plate the thick yarn on a needle selection basis. The structure has been used for ladder-resist shadow welts in stockings and for textured designs, as well as for underwear mesh structures on circular single-jersey machines [1] in gauges from E 14–24.

9.6 The tuck stitch

A *tuck stitch* is composed of a held loop, one or more tuck loops and knitted loops (Fig. 9.4). It is produced when a needle holding its loop (T) also receives the new loop, which becomes a tuck loop because it is not intermeshed through the old loop but is tucked in behind it on the reverse side of the stitch (Fig. 9.5). Its side limbs are therefore not restricted at their feet by the head of an old loop, so they can open outwards towards the two adjoining needle loops formed in the same course. The tuck loop thus assumes an inverted V or U-shaped configuration. The yarn passes from the sinker loops to the head that is intermeshed with the new loop of a course above it, so that the head of the tuck is on the reverse of the stitch.

The side limbs of tuck loops thus tend to show through onto the face between adjacent wales as they pass in front of sinker loops. Tuck stitch structures show a faint diagonal line effect on their surface.

In analysis, a tuck stitch is identified by the fact that its head is released as a hump shape immediately the needle loop above it is withdrawn. A knitted loop would be required to be separately withdrawn and a miss stitch would always be floating freely on the technical back.

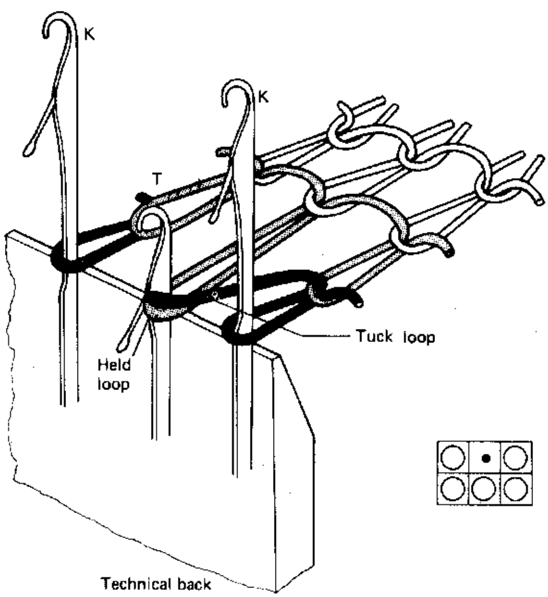

Fig. 9.4 Tuck stitch produced on a latch needle machine.

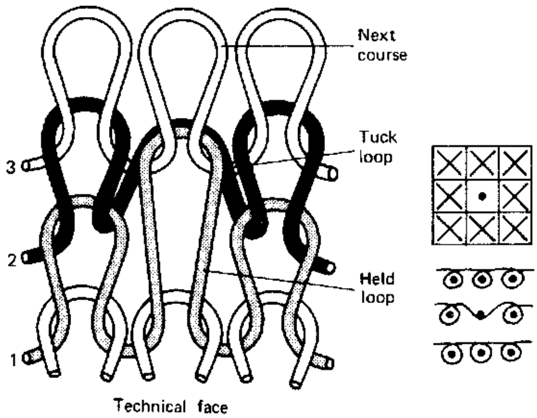

Fig. 9.5 Technical face of tuck stitch fabric.

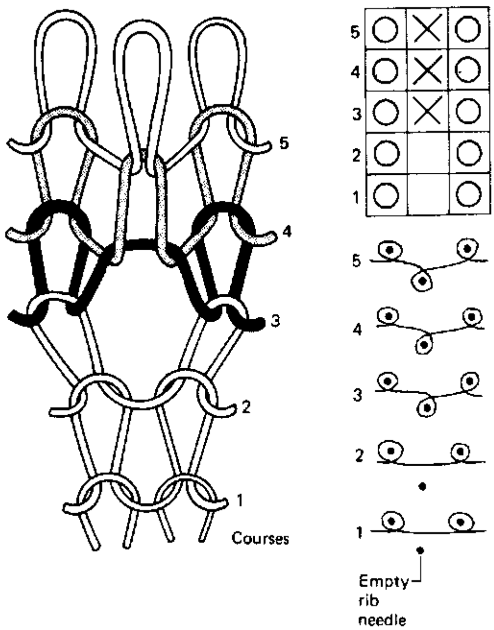

Fig. 9.6 Commencing knitting on an empty rib needle.

The tuck loop configuration can be produced by two different knitting sequences:

1 By commencing knitting on a previously empty needle (Fig. 9.6). As the needle was previously empty, there will be no loop in the wale to restrict the feet of the first loop to be knitted and, in fact, even the second loop tends to be wider than normal. The effect is clearly visible in the starting course of a welt. By introducing rib needles on a selective basis, an open-work pattern may be produced on a plain knit base.
2 By holding the old loop and then accumulating one or more new loops in the needle hook. Each new loop becomes a tuck loop as it and the held loop are knocked-over together at a later knitting cycle and a new loop is intermeshed

with them. This is the standard method of producing a tuck stitch in weft knitting (Fig. 9.4).

Successive tucks on the same needle are placed on top of each other at the back of the head of the held loop and each, in turn, assumes a straighter and more horizontal appearance and theoretically requires less yarn. Under normal conditions, up to four successive tucks can be accumulated before tension causes yarn rupture or needle damage. The limit is affected by machine design, needle hook size, yarn count, elasticity and fabric take-down tension (Fig. 9.7).

Each side of the head of a tuck loop is held by a sinker loop (S) from the course above (Fig. 9.9). When tucking occurs across two or more adjacent needles, the head of the tuck loop will float freely across between these two adjacent sinker loops, after which a sloping side limb will occur.

Dependent upon structural fineness, tucking over six adjacent needles is usually the maximum unit before snagging becomes a problem. (NB: Tucking across no more than two adjacent needles is generally the limit because the tuck is not secured at the middle wales when tucking across three or more needles.) For a greater number of adjacent needles, the accordion sequence (Section 10.4.3) where occasional tucks tie-in a floating thread, is preferred.

A tuck loop is notated either as a dot placed in a square or as a semi-circle over a point. A held loop is assumed to extend from the course below, up to the course where the next knitted loop is notated in that wale, as this is where it intermeshes.

Selective '*tucking in the hook*' (Fig. 9.10) is achieved on latch needle weft knit-

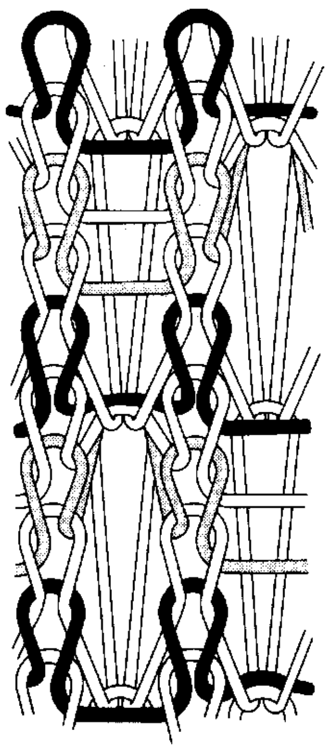

Fig. 9.7 Successive tucks and floats on the same rib needle.

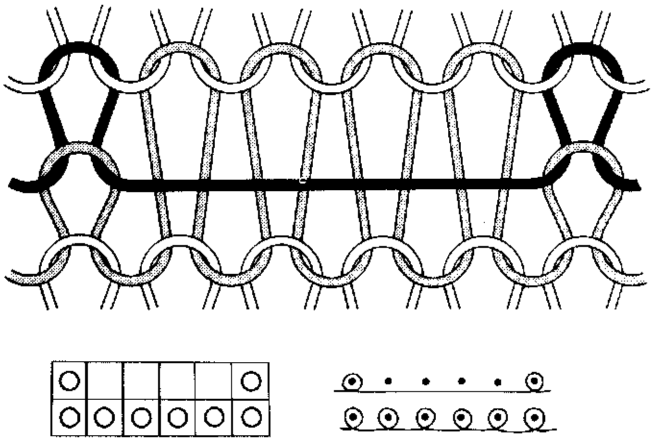

Fig. 9.8 Floating across four adjacent plain needles.

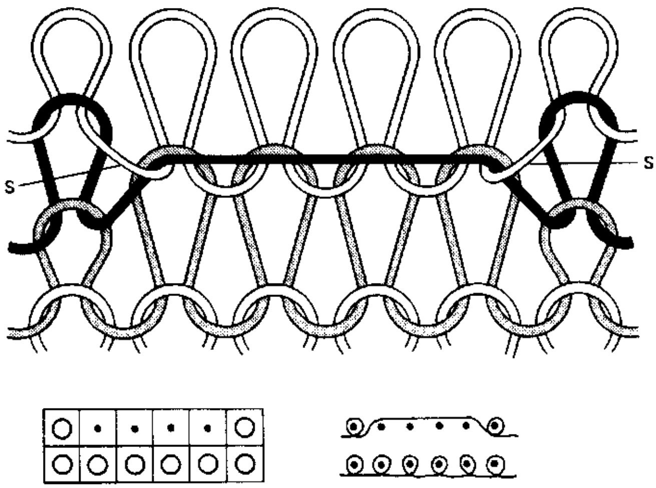

Fig. 9.9 Tucking over four adjacent plain needles.

ting machines by lifting the needle only half-way towards clearing height to tuck height. The old loop opens the latch but remains on the latch spoon and does not slide off onto the needle stem. It remains as a held loop in the needle hook where it is joined by the new loop, which becomes a tuck loop when the needle descends to knock-over.

The latch needle, because of its loop-controlled knitting action, is capable of being lifted to one of three stitch positions to produce either a *miss*, a *tuck* or a *knit stitch*; this is termed the *three step* or *three way technique* (Fig. 9.11).

On V-bed flat machines, raising cams, split into tuck and clearing height cams, are known as *cardigan cams*. They are not available on older machines so only collective '*tucking on the latch*' on all needles in one bed can be achieved. The stitch cam is raised so that the needles do not descend low enough to cast-off the held loops from the closed latches (Fig. 9.12). This is not a preferred technique because there

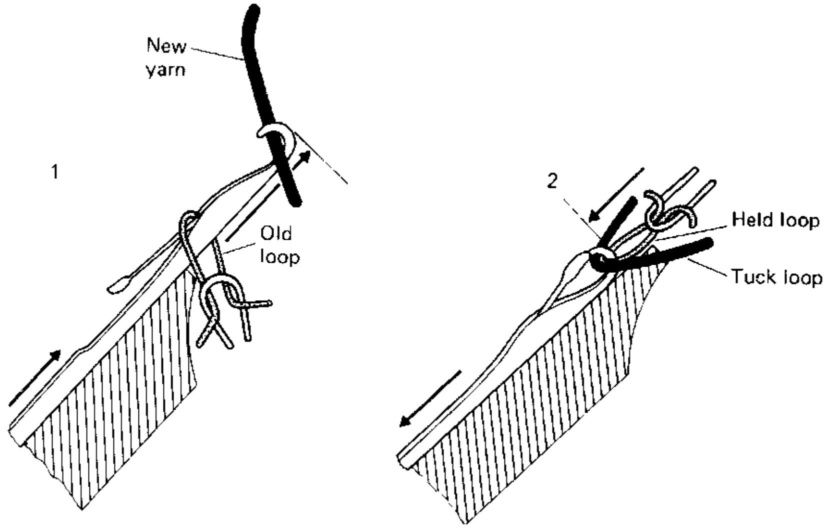

Fig. 9.10 Selective tucking in the hook.

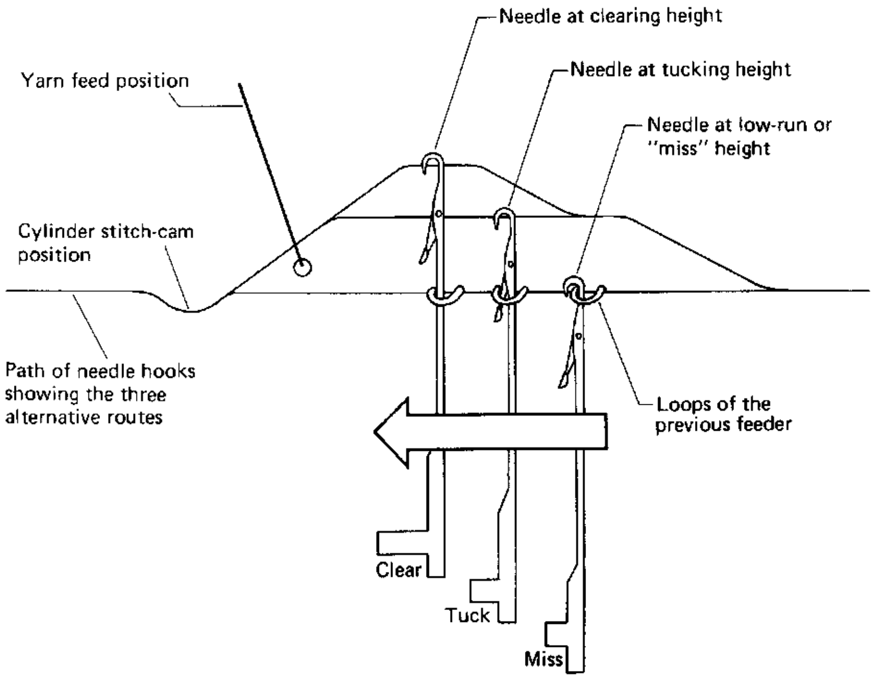

Fig. 9.11 Three step needle selection. The needles have been turned 90° in order to show the position of the latch in relationship with the loop of the previous feeder.

is no individual selection and there is the danger of the held loop slipping off and producing an intermeshed loop with the tuck, converting it into a knitted stitch.

The first tuck presser bearded needle frame was invented in Dublin in 1745. A bearded needle tucks when its beard is miss-pressed so that the old loop is not cast-off and remains as a held loop, inside the beard, with the newly-fed tuck loop.

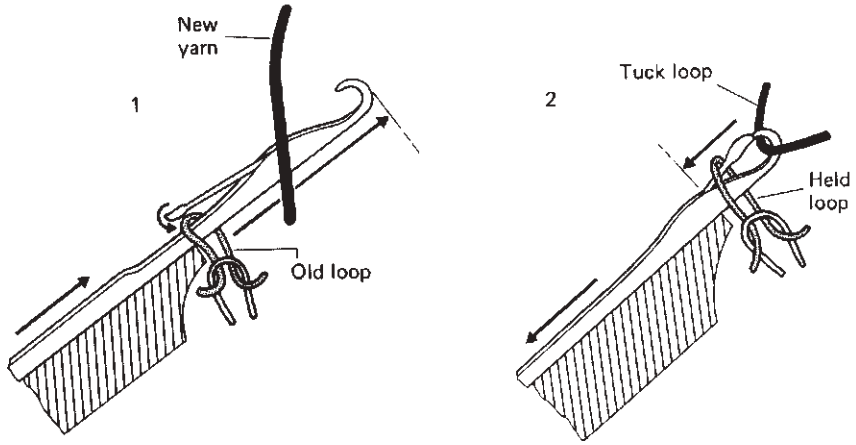

Fig. 9.12 Tucking on the latch.

Tucking for inlay may be achieved by deflecting certain needles during inlay feeding so that the yarn passes across the beards of the selected needles, forming a tuck instead of floating across their backs. Selective tucking requires cut-away pressing edges or individually controlled presser bits.

Tucking may occur accidentally as a result of stiff latches, imperfect pressing, imperfect knocking-over of old loops, or thick places in yarn.

Tuck loops reduce fabric length and length-wise elasticity because the higher yarn tension on the tuck and held loops causes them to rob yarn from adjacent knitted loops, making them smaller and providing greater stability and shape retention. Fabric width is increased because tuck loops pull the held loops downwards, causing them to spread outwards and make extra yarn available for width-wise extensibility. Fabric distortion and three-dimensional relief is caused by tuck stitch accumulation, displacement of wales, and by varying numbers of tuck and knitted stitches per wale.

Tuck stitches are employed in accordion fabrics to tie-in the long floats produced on the back of single-jersey knit/miss jacquard, thus reducing the problems of snagging that occur with filament yarns. The tuck stitch may also be employed to produce open-work effects, improve the surface texture, enable stitch-shaping, reinforce, join double-faced fabrics, improve ladder-resistance and produce mock fashion marks.

Reference

1. GOADBY, D. R., The Camber single jersey Louvnit machine, *Knit. Int.,* (Dec. 1978), 46–7.

Further information

ANON., Tuck loops in jacquard knitting, *Hos. Trade J.*, (April 1963), 123–8.
LANCASHIRE, J. B., Uses of the tuck stitch, *Hos. Trade J.*, (June 1961), 158–61.