13

Circular fabric knitting

13.1 Weft knitted fabric production

Weft knitted fabrics may be approximately divided into single or double jersey ('double-knit') according to whether they were knitted with one or two sets of needles. It may be preferable to include some of these fabrics in separate groupings of underwear and speciality fabrics. Pelerine eyelet, sinker wheel mesh structures, and float plated fabrics are mainly used for underwear whilst high pile and plush fabrics are speciality fabrics. Many of the jacquard structures have already been described (Chapter 10).

Most weft knitted fabric in continuous lengths is knitted on large-diameter, multi-feeder, latch needle machines and is slit into open width during finishing. The emphasis is on productive efficiency and quality-control in the manufacture, finishing, and conversion of fabric into articles of apparel or other end-usages. This tends to encourage the establishment of large units with long production runs.

In post-knitting handling operations, the fabric must be maintained in as relaxed and tension-free a state as possible, in order to reduce the problems caused by dimensional distortion and shrinkage. Apart from scouring, bleaching, dyeing, and printing, the finishing process offers a wide range of techniques for modifying the properties of the knitted structure including heat setting, stentering, decating [1], raising [2], cropping, pleating [3] and laminating.

In the cutting room, the lengths of fabric are layed-up, many ply thicknesses deep, onto long cutting tables using a traversing carriage to transport and lay the fabric. Cutting-out techniques vary widely, from marked lays whose outlines are followed by hand-guided cutting knives, to press cutter blades shaped to the outline of the garment part, and cutting blades guided by a computerised programme.

In making-up weft knitted fabric, the lockstitch seam (Type 301) is not as suitable as it is for woven fabrics because it lacks extensibility. For jerseywear, the extensible double-locked chainstitch (Type 401) is useful. However, in the making-up of knitwear, the three-thread overlock (Type 504) is popular because, as well as being extensible, it securely binds the cut edges of the fabric after neatly trimming them.

For comfort in underwear and lingerie, a flat-butted seam secured by a flat seam such as the five-thread flatlock (Type 605) is generally preferred [4–6].

13.2 Single- and double-jersey compared

Single-jersey fabrics are mostly knitted on latch needle sinker top machines. These machines have a simpler construction than cylinder and dial machines, are easier to supervise and maintain, have higher running speeds and more feeders, and knit a greater range of structures with a wider tolerance of yarn counts.

In Europe, double jersey was generally preferred to single jersey, particularly for ladies' wear, because of problems of dimensional stability, structural breakdown, air porosity and snagging of floating threads. However, fashion trends since 1973 towards prints, fine-gauge lightweight fabrics and leisure wear, have increased the world popularity of single jersey to a level previously only experienced in the USA.

13.3 Simple tuck and float stitch single-jersey fabrics

Figure 13.1 illustrates the notations of some simple single-jersey fabrics, whilst Fig. 13.2 illustrates a loop diagram of *hopsack*, a single-jersey inlaid fabric.

In order to tie a lay-in yarn into the back of a single-jersey structure, selected needles are raised to tuck height to receive the lay-in yarn at a point in advance of the ground knitting feeder. The needles are then raised to clearing height prior to receiving and knitting the ground yarn.

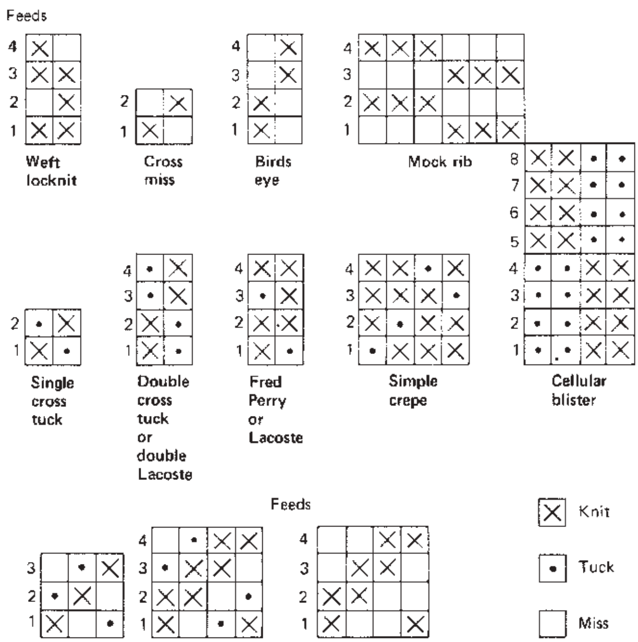

Fig. 13.1 Twill effects.

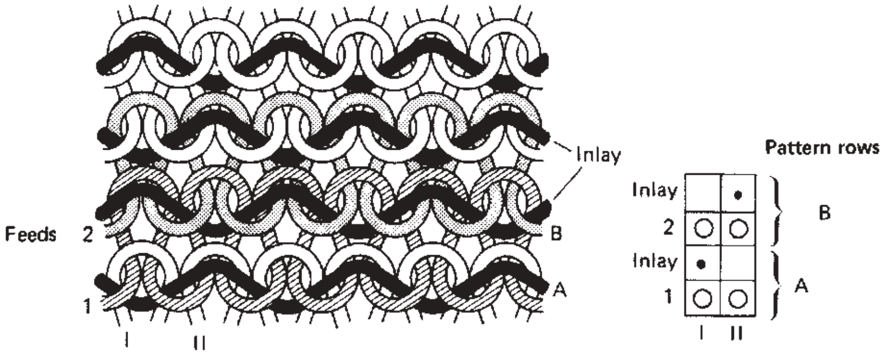

Fig. 13.2 Single jersey hopsack structure and notation.

Hopsack is a 1 × 1 inlay whose stability and appearance make it popular as a ladies suiting fabric when knitting staple spun yarns. In order to spread the inlay across the back of the fabric, it is the practice to centre the tuck on a different wale at the next inlay cycle.

Another popular structure is a 2 × 2 inlay with a plain ground course between each ground inlay course. The tuck limbs of the lay-in yarns are crossed by the sinker loops on the technical back, so they tend to grin through onto the technical face, especially as they push the two adjacent wales slightly apart at these points. This problem may be overcome with a plated yarn arrangement as in the case of *invisible fleecy*, which is, of course, a more expensive fabric to manufacture.

13.4 The history of double-jersey

Double-jersey suiting fabrics evolved in France using French spun yarns, with miss stitches introduced to improve the stability of the interlock or rib base. In the early 1950s, *Berridge* of Leicester, UK, produced the first specific-purpose machine capable of knitting these structures. The twelve-feed machine had a revolving cam-box with interlock needle tracks in cylinder and dial, and was the forerunner of the modern revolving-cylinder double-jersey machine that now has changeable camming for knit, tuck or miss stitches, and rib or interlock gating facilities.

Double-jersey achieved its success with 18 gauge, 30-inch diameter machines knitting 1/36's worsted or acrylic fibre yarns for ladies' autumn or winter suitings and dresswear, and 150 denier continuous filament textured polyester for spring and summer wear. Expansion started in Europe in the late 1950s, when worsted or *Courtelle* yarns were knitted into an evolving range of stable structures that were finished on continuous-finishing equipment adapted from woven cloth processes.

Between 1963 and 1973, yarn consumption in double jersey increased from 6 Mkg to 90 Mkg, of which 70 Mkg was continuous filament. *Crimplene* polyester yarn played a major part in this expansion, taking nearly 50 per cent of the market in 1969. Being non-torque, it could be used in singles form and had low shrinkage and low extension. The high 5 denier per filament (1/150/30 denier) yarn provided a crisp, resilient handle and was less prone to snagging. To mask the effect of feeder stripiness, it was introduced in surface interest structures such as *cloque* (single colour patterned blister) and *bourrelet* (horizontal relief stripes).

Soon, bright package-dyed yarns were being used to knit patterned blister fabrics. Fashion moved away from plain fabrics, such as *double pique*, to demand colour and surface texture with easy washability and lighter weights for use in centrally-heated environments.

In the early 1970's, attempts were made, with limited success, particularly in the USA, to break into men's leisurewear with a switch to E 22 and E 24 gauge machines, using 120–135 denier textured yarn. This finer gauge was necessary in order to obtain lighter weights and achieve more critical standards of stitch definition, and resistance to snagging, bagging, air porosity and shrinkage.

However, 1973 proved to be the peak year of the narrowly-based double-jersey boom, as an over-expanded industry failed to penetrate into new fields and at the same time received a rebuff from ladies' fashion, which was turning to natural fibres and woven cloths as a change from textured polyester. Whereas the proportion of double-jersey to single-jersey fabrics was 1:0.4 in 1975, by 1981 it was 1:0.9. The double-jersey industry is now smaller and uses a wider range of yarn types and counts and gauges, ranging to as fine as E 28 for rib jacquard and E 40 for interlock print-base fabrics.

13.5 Types of double-jersey structure

There are two types of double-jersey structure – non-jacquard structures, knitted mainly on a type of modified interlock machine, and jacquard structures, produced on rib jacquard machines (The latter are covered in Section 10.4.4).

Various modifications to the interlock machine have been necessary in order to produce the new structures. Originally, only alternate tricks were fully cut through to accommodate long needles so that mock eight-lock was achieved by knitting normal interlock with every third dial needle removed; now, all tricks are cut through and inserts placed in tricks under short needles. Verge bits are required for knock-over during single-bed knitting; other modifications may include exchangeable or changeable knit, tuck and miss camming, variable needle timing, rib/interlock-gating and feeder guide positioning.

13.6 Non-jacquard double-jersey structures

Most interlock variation structures have six- or eight-feeder sequences, as only alternate needles in one bed are in action in a course. *Single pique* or *cross tuck interlock* (Fig. 13.3a) was one of the first to be produced, by placing tuck cams in the dial at every third feeder. The tuck stitches throw the fabric out approximately 15 per cent wider than normal interlock to a satisfactory finished width of over 60 inches (approximately 1.5 m) for a 30-inch diameter machine. They break up the surface uniformity and help to mask feeder stripiness, but they also increase fabric weight.

Texi pique (Fig. 13.3b) is wider and bulkier and shows the same pique effect on both sides. *Cross miss* (Fig. 13.3d) is the knit miss equivalent of single pique, but it is narrower and lighter in weight. *Piquette* (Fig. 13.3e) is a reversible knit miss structure with a light cord effect.

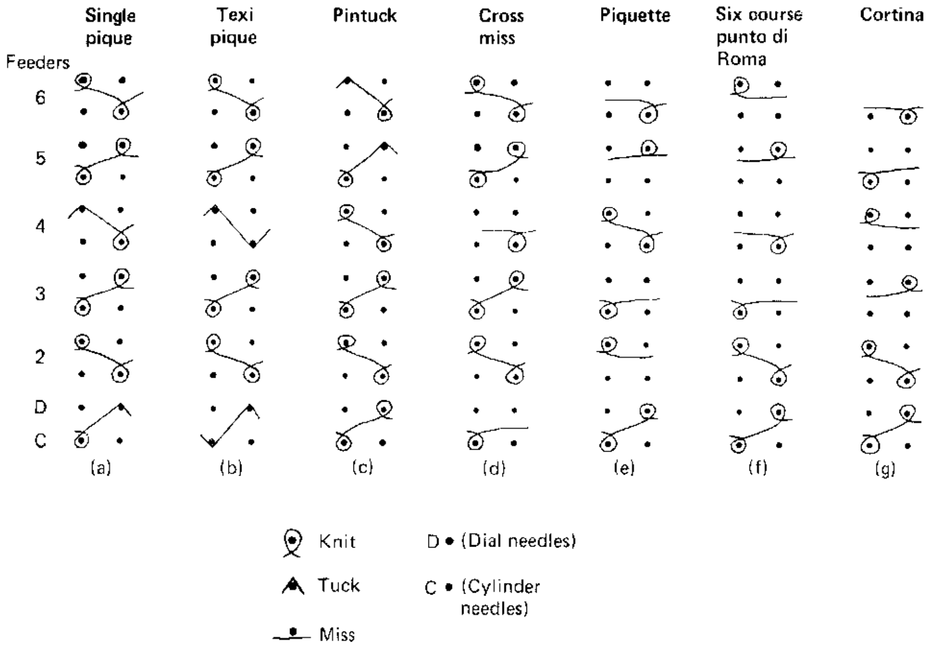

Fig. 13.3 Double jersey non-jacquard fabrics.

Bourrelet fabrics have pronounced horizontal cords at regular intervals, produced by knitting excess courses only on the cylinder needles; the cord courses may be in a different colour to the ground courses. There may be half, more than half, or less than half the total number of feeders knitting the cord courses. Interlock rather than rib base bourrelet is usually preferred because it provides a softer, smoother more regular surface with less extensibility, but it requires two feeders per cord row.

Jersey cord (Fig. 13.4a) is an example of a *miss bourrelet*, and *super Roma* (Fig. 13.4b) is its equivalent in *tuck bourrelet*. The latter, sometimes termed *horizontal ripple* fabrics, tend to be heavier and to have a less pronounced cord than the former, which are termed *ottomans* in the USA.

Costa Brava is a plain, single-colour structure that requires individual needle selection on a width of four cylinder needles. A diagonal effect is developed on two adjacent cylinder needles, which move by one needle at the first of every three-feeder sequence; the third feeder complements this. These loops are extended by the dial-only knit course at every second feeder. Alternate dial needle knitting produces a twill backing.

Gabardine (Fig. 13.5a) is a simple 2 × 2 twill 'double-blister' fabric (see below) which is useful for fine-gauge men's leisurewear. It has a four needle width repeat, with the dial needles all knitting the backing at every third (ground) feed. A flatter structure, used for the same purpose, is called *poplin* (Fig. 13.5b), a type of single blister with a two needle width repeat.

The most popular relief design is *blister* (or *cloque*), which is normally produced only on circular rib jacquard machines. Each cylinder needle is selected to knit either a ground yarn, which also is knitted on alternate dial needles, or a blister yarn

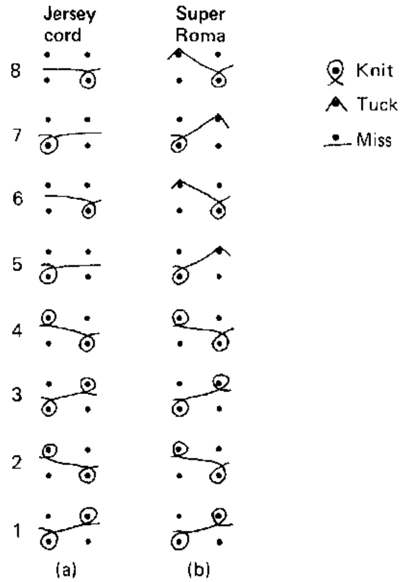

Fig. 13.4 Further double jersey fabrics.

which is only knitted on the cylinder side and floats between blister loops inside the structure, hidden by the ground loops of the face and back.

Double-blister structures have two blister feeder courses between each ground feeder course (Fig. 13.6b). This produces a more pronounced blister relief, with twice as many courses of blister loops to ground loops. It is heavier and has a slower rate of production than single blister. Blister loops at two successive feeders may not necessarily occur on the same needles. They may be in one or more colours with a self-colour or a one- or two-colour ground.

Single blister is sometimes termed *three-miss blister* (Fig. 13.6a) because each dial needle misses three feeders after knitting; similarly, double blister may be termed *five-miss blister*. All blister structures show only the ground loops on the back.

Quilted structures are types of blister fabrics where blister yarn knitting occurs on a large number of adjacent cylinder needles so that enclosed pockets, or quilts, are formed by lack of connection between cylinder and dial courses. A number of colours may be used.

Ripple designs show as figured rolls or welts on the all-dial knit side of the structure because there are more loops per wale on this side and every dial needle knits at every feeder. The cylinder needles are only selected to knit to balance the dial loops where the ripple is not required.

Double pique, *wevenit* and *overnit* are synonymous terms for the same stable knit miss rib-gated fabric (Fig. 13.7), which is narrower and has a less pronounced pique appearance than single pique and tends to be rather heavy. Although it is now also produced on rib machines, it was originally produced by modifying the interlock machine as follows:

1 Changing from interlock to rib gating.
2 Changing dial cam systems 2 and 3 over in every four-feed sequence.

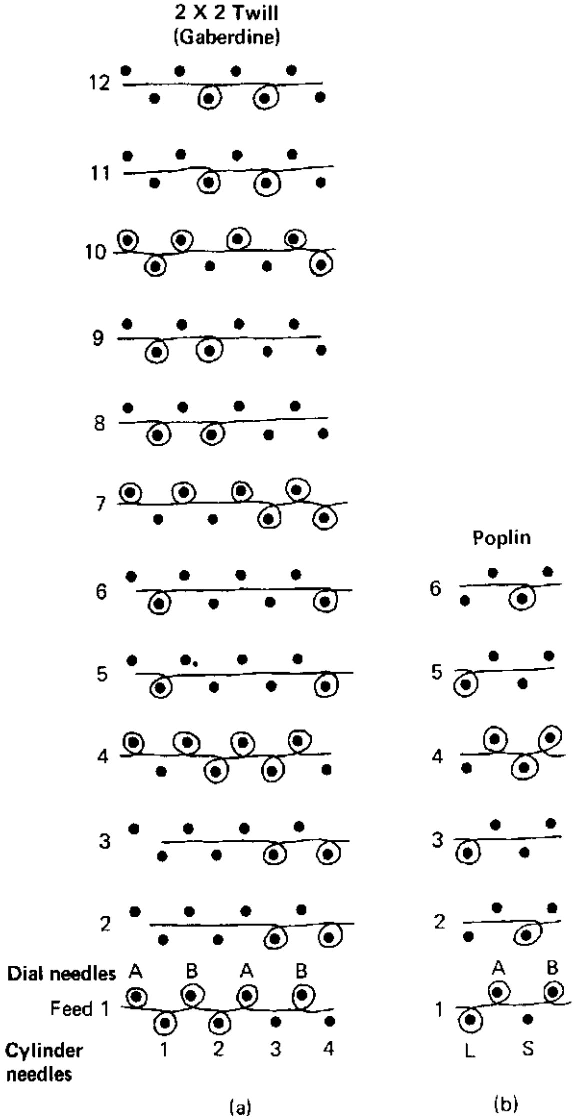

Fig. 13.5 Twill and poplin double jersey.

3 Placing all long needles only in the cylinder if *Swiss double pique* is required, or all short needles only if *French double pique* is required.

This arrangement causes all cylinder needles to knit at every alternate feeder as there are no other long cylinder needles, whilst alternate dial needles knit at two successive feeders because identical cam systems are in a two-feeder sequence in the dial. French double pique tends to be wider and slacker than Swiss double pique because, in this structure, the dial needle loops that are held for two feeders can rob extra yarn from the cylinder loops that are knitting in the same course, thus producing long, held loops. *Rodier* is a term sometimes applied to either double pique or texi pique and *mock rodier* to piquette.

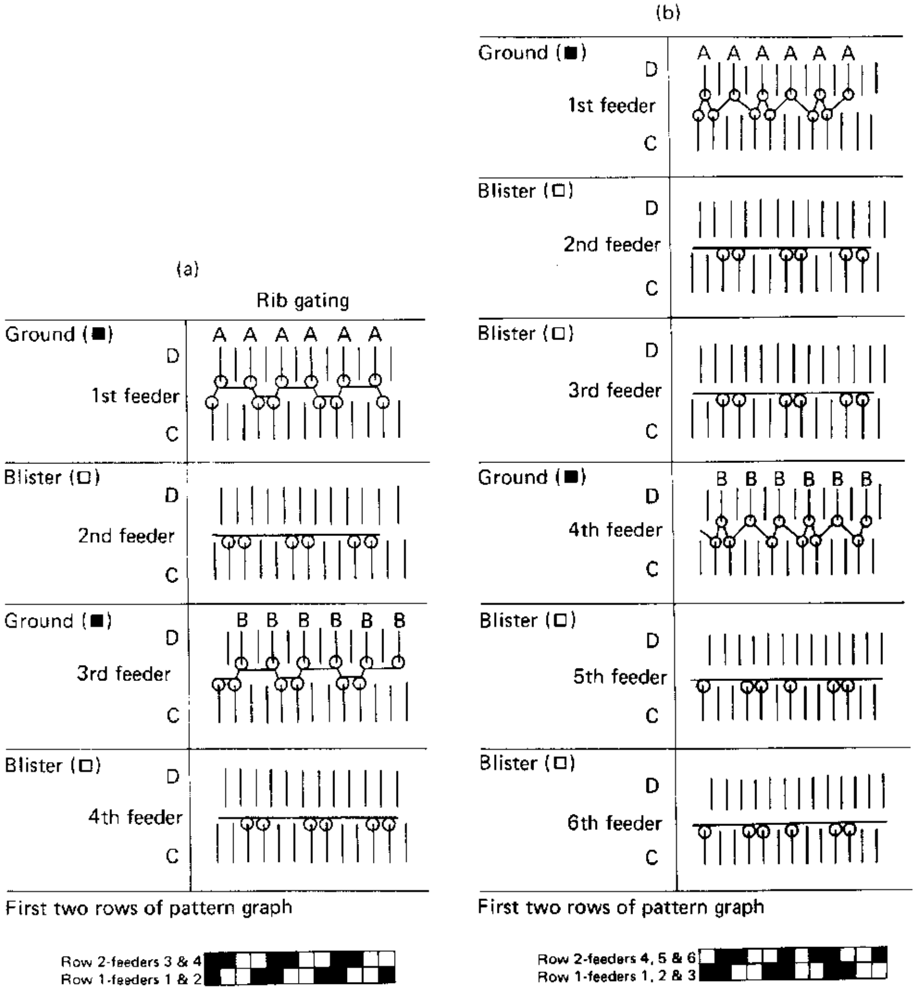

Fig. 13.6 Single and double blister.

Punto di Roma (Fig. 13.8b) has replaced double pique as the most popular non-jacquard double jersey structure. It belongs to a group of structures that are reversible and have a tubular sequence of dial only and cylinder only knit. It has an acceptable weight and finishes with a width of about 70 inches (1.77 m) from a 30-inch diameter machine.

Cortina (Fig. 13.3g) is a six feed version produced on interlock camming with run-through cams where missing is required. *Milano Rib* (Fig. 13.8c) is the rib equivalent of punto di Roma, with greater extensibility and width, and 50 per cent greater production but there is a danger of a yarn breakage causing a press-off at the all-knit course. It is particularly used in the production of fashioned collars. *Evermonte* (Fig. 13.8a) has a row of tuck stitches on one side after each tubular course, which produces a slight ripple effect.

Tuck lace or *mock transfer* (Fig. 13.9) designs consist of two fabrics knitted with different yarns or colours, one produced on the dial and the other on the cylinder.

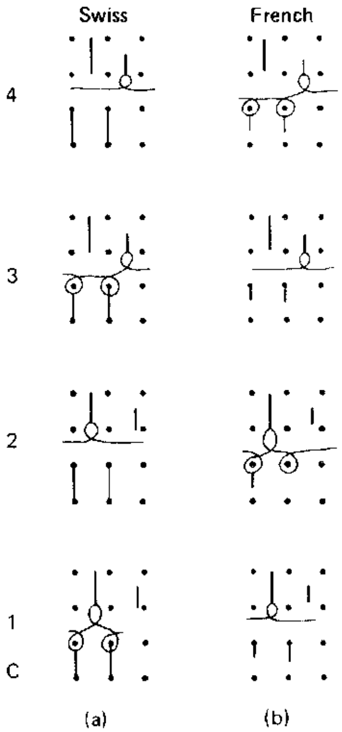

Fig. 13.7 Double pique.

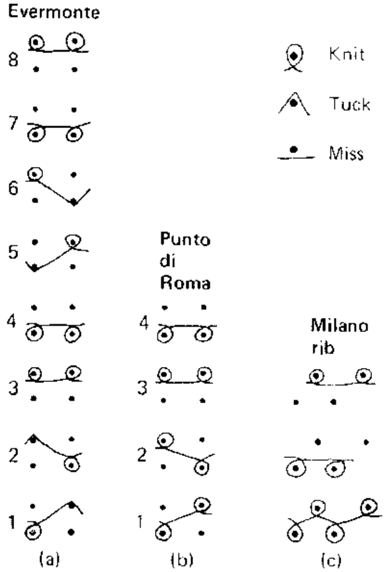

Fig. 13.8 Milano, punto di Roma and evermonte.

At the all-dial-knit feeders, selected tucking may occur on alternate cylinder needles if required; often the selection is repeated at the next two-feeder sequence to emphasise the effect. The tucks produce a 'semi-breakthrough' effect by displacing the wales of the dial side, which is the effect side, so that the cylinder loops show through at these points as a different colour.

13.7 Double-jersey inlay

On double-jersey machines, laying-in may be achieved by the *tunnel inlay* technique. The inlay is fed in advance of the knitting yarn at a feed and is trapped as an almost straight horizontal yarn inside the fabric, behind the cylinder and dial face loops.

To reduce weight, the inlay is usually supplied at every third or sixth feed of a three-colour jacquard design at feeders that always knit some loops on the cylinder.

The tube inlay feed is attached to the feeder guide to supply its yarn low and in advance of the cylinder and dial needles moving out to clear for the ground yarn. To make the inlay visible and to reduce the fabric width and weight, alternate cylinder needles are removed and replaced by dummy or blank needles that prevent the tricks from closing-up or becoming clogged with dirt. Needle selection thus takes place on half-gauged cylinder needles with the inlay (either boucle or over fed yarn) protruding through between these wales.

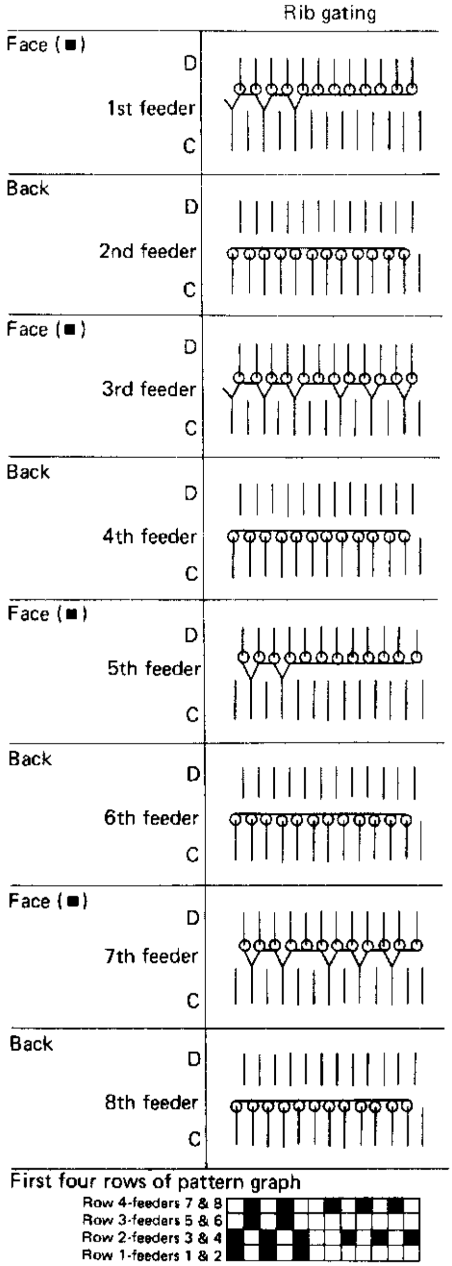

Fig. 13.9 Tuck lace.

Although tunnel inlay is a simple technique (Fig. 13.10), the yarn is not very secure when the fabric is cut into open width; also the yarn has a straight configuration, with little surplus available for elastic extension. If an elastomeric yarn is employed, there is width-wise, but no length-wise, extension and recovery.

The alternative to tunnel inlay is to use a knitting feeder for inlay by missing and tucking on one or both needle beds. *Texi pique* (Fig. 13.3b) is an example but, as

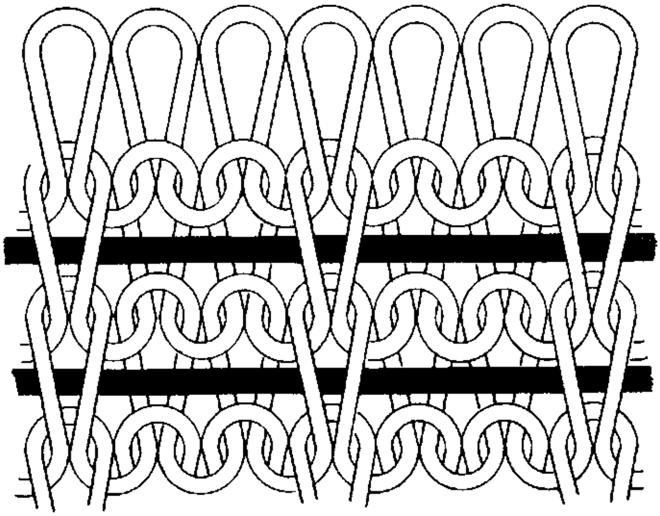

Fig. 13.10 Tunnel inlay.

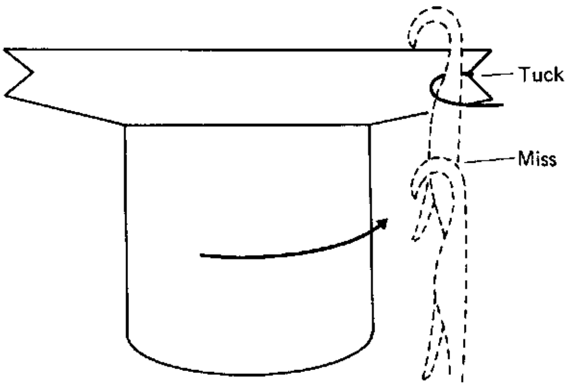

Fig. 13.11 Faneknit inlay device.

tucking occurs on both beds and the cylinder needles are full gauged, the inlay is hidden inside the structure.

The *Faneknit* device (Fig. 13.11) achieves inlay by tucking only on one bed by employing a V-bladed weft insertion wheel to which the inlay yarn is supplied, and presents it in the correct position to the needle bed. If a needle is lifted to tuck height, the blades present the yarn into its hook. Needles not lifted miss the yarn as the blades take it past the top of their heads.

13.8 The modern circular fabric knitting machine

Figure 13.12 illustrates some of the features of a modern circular fabric-producing machine that ensure that high quality fabric is knitted at speed with the minimum of supervision:

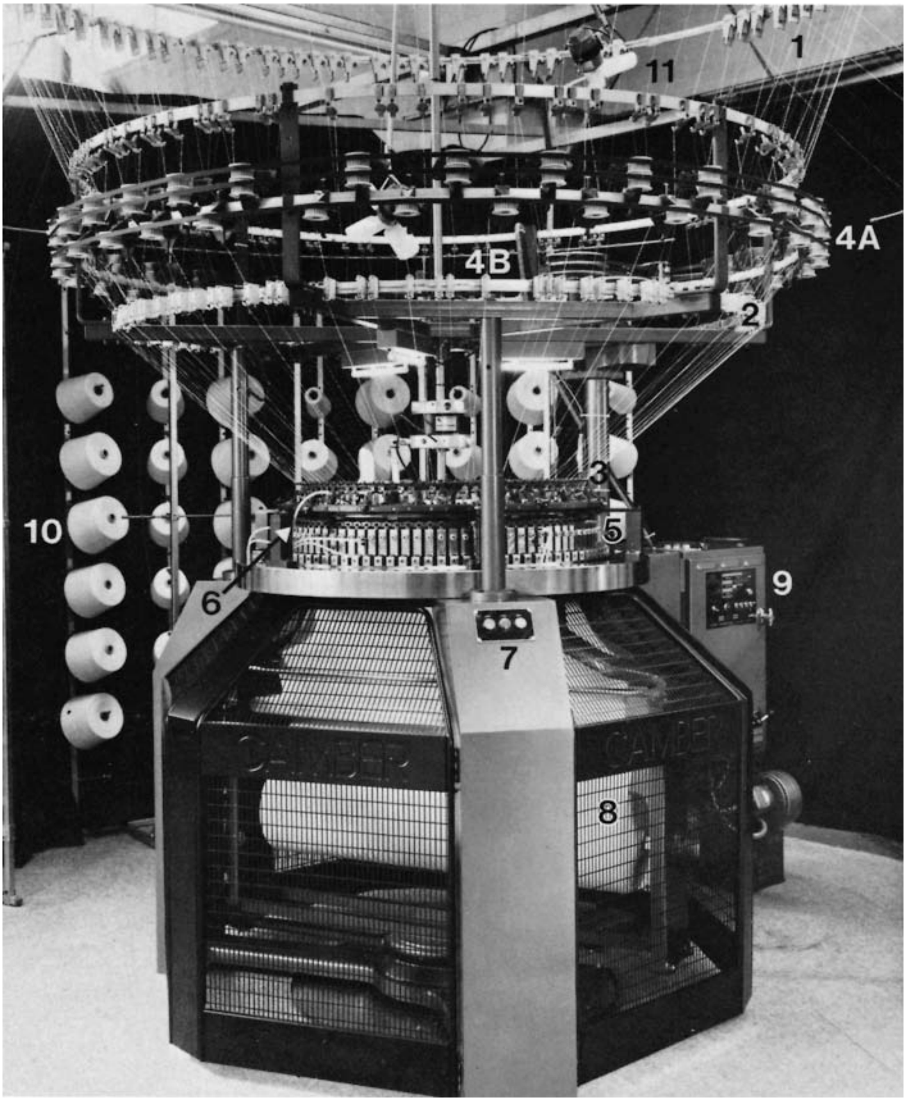

Fig. 13.12 The modern circular single jersey fabric machine.

1,2 *The top* (1) *and bottom* (2) *stop motions*. These are spring-loaded yarn supports that pivot downwards when the yarn end breaks or its tension is increased. This action releases the surplus yarn to the feeder, thus preventing a press-off, and simultaneously completes a circuit which stops the machine and illuminates an indicator warning light.

3 *Various spring-loaded detector points*. These are carefully positioned around the cylinder according to their particular function. A pointer is tripped to stop the machine by a fault or malfunctioning element such as a yarn slub, fabric lump, needle head, latch spoon, etc.

4 *The tape positive feed* (4A). This provides three different speeds (course lengths) and is driven and can be adjusted from the drive arrangement (4B).

5 *The cylinder needle cam system* for each feed – contained in a single replaceable section and having an exterior adjustment for the stitch cam slide.
6 *The automatic lubrication system.*
7 *Start, stop and inching buttons.*
8 *The cam-driven fabric winding down mechanism*, which revolves with the fabric tube.
9 *The revolution counters* for each of the three shifts and a pre-set counter for stopping the machine on completion of a specific fabric length (in courses).
10 *Side creel* (optional).
11 *Lint blower*. This reduces the incidence of knitted-in lint slubs, to improve quality when using open-end spun yarns. It also reduces cross-contamination by fibres from other machines.

13.9 Versatility and quick response

Market requirements involving smaller orders and shorter production runs have led machine builders to develop quick-response techniques to reduce costs and downtime during machine changes on large diameter multi-feeder machines. Amongst areas addressed are the following:

- *Centralised stitch control* can be used to simultaneously reset all cylinder stitch cams in a particular cam track, when required, instead of the time-consuming task of resetting each stitch cam individually
- *The Monarch/Fukuhara rotary drop cam system* is a unique, quick and convenient method of changing cam set-outs without the need to replace cams or needles. On the outside of the dial and the cylinder cam system at each feed and needle track there is a disc that can be set by a turnkey to various rotational positions up to 180 degrees. Each position corresponds to a specific needle-height position: for example, knit (delayed timing), knit (synchronised timing), tuck, miss and fabric support (for the other bed when only that is knitting, e.g. in double blister). The new cam setting drops into action as a small group of half-butt needles pass across it and are unaffected. As the machine slowly turns, the cams then come fully into action to control the full-butt needles.
- *Changes of diameter and/or gauge.* The three-leg portal frame provides sufficient space between pillars to enable dial and cylinder to be removed horizontally. A gauge change on a single-jersey jacquard machine can take a few hours; on a double-jersey machine it can take $1\frac{1}{2}$ to 2 days. Gauge changing costs 20 to 25 per cent of the machine cost price; diameter changing costs 30 to 40 per cent.
- *Compatibility of modules between machine types* provides for quicker conversion and changes of knitted structure at a lower cost in extra parts. Monarch/Fukuhara have conversion kits to interchange between high-speed rib or interlock knitting and versatile eight-lock knitting. With the conversion kit, changes from E 14–E 18 gauge rib to E 18–E 28 gauge interlock or eight-lock takes minutes rather than hours.
- Machines with *industrial frames* can accommodate cylinders up to 38 inches for single-jersey and 42 inches for double-jersey, with fabric batch rolls up to 105 cm.

- *Automatic doffing of fabric rolls* and their ejection from the machine has been developed only as far as the prototype.

13.10 The 'contra' knitting technique

On certain single-jersey machines, the '*contra*' ('*relative*' or '*shared loop*') knitting technique is now employed, for example by the Mayer method (Fig. 13.13). As well as having the normal radial movement between the needles, the sinkers move vertically down, in opposition to the needles rise to clearing height, and rise as the needles descend to knock-over. This considerably reduces the extent of the needle movement. One loop is almost fully formed before the next is started. There are thus less yarn/metal contact points (each of which doubles the tension of the previous point). This reduces the tendency to 'rob back', produces less stress on the knitting elements, improves fabric quality, and enables weak and delicate yarns to be knitted. The shorter needle movement allows shallower cam angles and faster speeds to be obtained.

Two different approaches are being used:

- The *Mayer Relanit* uses specially designed sinkers that occupy adjacent cylinder tricks to the needles, thus dispensing with the sinker cam ring and improving accessibility. The sinkers pivot on a fulcrum point that produces the horizontal

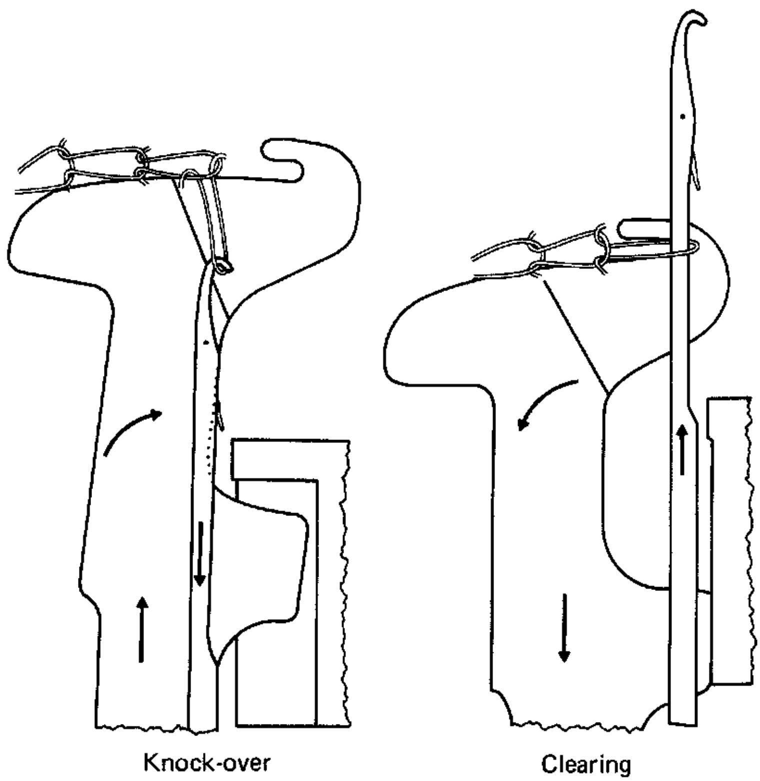

Fig. 13.13 The Relanit contra knitting action.

movement. It is the setting of the sinkers at knock-over, and not the needles, that determines the stitch length. As well as the Relanit 3.2, which knits bulk quantities of basic single jersey and runs at 45 rpm with a 30-inch diameter cylinder (1.8 m/sec), there are also electronic full jacquard single-jersey machines with three-way selection.

- The *Monarch 'Z'* or *'Slant Sinker' technology* employs conventional holding down/ knock-over sinkers that move diagonally along a 20 degree inclined dial. The sinker top has a fixed inclination to the needle hook; this ensures a controlled plating relationship between the pile and ground yarns.

13.11 Circular-machine production calculations

13.11.1 Machine speed

The speed of a circular machine may be expressed in three ways: –

- As *machine revolutions* per minute.
- As *circumferential speed* in metres per second.
- As *Speed Factor* (rpm × diameter in inches).

1 The *machine revolutions per minute* is only relevant to a specific machine and machine diameter. A larger-diameter machine, or one having more patterning facilities, would be expected to run at less revolution per minute
2 The *circumferential speed* in metres per second is a constant for a range of machine diameters of the same model and can be used to calculate the rpm for a particular machine diameter. An average circumferential speed is about 1.5 m/sec; 2 m/sec is 'high speed'.

   Example: A 30-inch diameter machine runs at 40 rpm.
   Circumference of circle = πd, where $\pi = 3.142$, and $d = 30$ inches.
   $\pi d = 94.26$ inches, or 239.4 cm (2.4 m).
   In one minute the machine turns 2.4 metres × 40 (rev) = 96 m.
   The circumferential speed is therefore 96/60 = 1.6 m/sec.
   To convert circumferential speed to rpm:
   1.6 m/sec × 60 = 96 m/min.
   96 m/min divided by 2.4 = 40 rpm for a 30-inch diameter machine.
3 The *Speed Factor (SF)* is a constant obtained by multiplying the rpm (e.g. 30) by the diameter in inches (e.g. 30) = 900. As can be seen, rpm and diameter vary inversely to each other – when the diameter increases, the rpm decrease.

Modern high-speed fabric machines can operate in factory conditions at speeds of 1.6 to 1.7 m/sec. Under laboratory conditions, speeds of 2.0 m/sec have been achieved.

13.11.2 Number of feeds

The number of feeds can be expressed as a *total* for a particular cylinder diameter or as the *number of feeds per inch of the cylinder diameter*, in which case the total number of feeds for any cylinder diameter in that particular range of machinery can then be calculated.

Example: A single-jersey 4-track machine with 3 feeds per *diametral inch* will have 12 × 3 = 36 feeds in a 12-inch diameter, 54 in an 18-inch diameter, 90 in a 30-inch diameter, and 102 feeds in a 34-inch diameter.

13.11.3 Speed of fabric production

The speed of fabric formation expressed in linear metres per hour is equal to (speed of machine in rpm × percent efficiency × number of knitting feeders × 60 minutes) ÷ (number of feeds per face course × face courses per cm × 100).

Example: Calculate the length in metres of a plain, single-jersey fabric knitted at 16 courses/cm on a 26-inch diameter 28-gauge circular machine having 104 feeds. The machine operates for 8 hours at 29 rpm at 95 per cent efficiency.

$$\text{Number of courses knitted in 8 hours} = \frac{8\times 29\times 104\times 95\times 60}{100}$$

$$\text{Therefore the total length of the fabric in metres} = \frac{8\times 29\times 104\times 95\times 60}{16\times 100\times 100}$$

$$= 859.6\ \text{metres}$$

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14

Speciality fabrics and machines

14.1 The range of speciality fabrics

Speciality fabrics include fleecy, plush, high pile and wrap fabrics. Although some constructions are unique to a single type of circular machine, others may be knitted on a range of machinery.

The surface effects of fleecy, plush or pile are developed during the finishing process usually on the technical back of single faced fabric.

In *fleecy fabrics*, the fleece yarn fibres (usually in the form of inlaid yarn) become entangled and indistinguishable from the base yarn on the effect side, despite having been separately supplied during knitting.

In *pile* and *plush* structures the pile and plush is clearly distinguishable from the base. Pile is considered to stand out at right-angles to the base, whereas plush lies at less of an angle from the base surface. High-quality three-thread *invisible fleecy* and *sinker loop terry* (*plush plating*) are still produced on a rapidly declining number of old loopwheel and sinkerwheel frames respectively [1], but they are facing intense competition from modern, high-speed, more productive, single-jersey, latch needle machines.

Invisible fleecy (Fig. 14.1) is a plain plated structure composed of a face and binding yarn with a fleecy backing yarn tucked into the technical back at every fourth wale to mesh only with the binding yarn. The face yarn prevents the arms of the fleecy tucks being visible between the wales on the face, which would spoil its clean appearance. The fleecy inlay is spread across the technical back by centring the fleecy tucks of the next three-feed sequence on the middle of the three needles that missed the fleecy yarn in the previous sequence.

A popular gauge for sweat shirts and track suits is E 20, using 1/28's to 1/30's (NeB) cotton or acrylic yarn or 1/70's (Td) nylon and 1/9's to 1/12's (NeB) cotton or acrylic fleece yarn. A 30-inch diameter machine will give a finished width of 54–60 inches (1.37 m–1.52 m). The loosely-twisted fibres of the fleece yarn respond easily to napping during finishing.

The standard sweatshirt weight is 250 to 300 g/m^2.

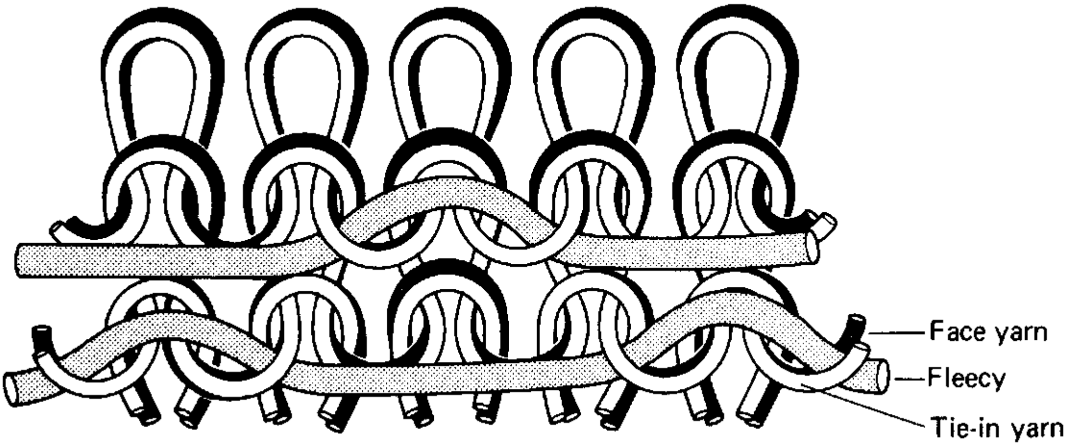

Fig. 14.1 Three-thread fleecy loop structure.

14.2 The production of fleecy on sinker-top machines

Three-thread fleecy was at first knitted as a quality fabric on the (no longer viable) loopwheel frame. (The loopwheel frame was described in detail in the first and second editions of this book, Sections 14.1 and 14.2). Three-thread fleecy is now produced mainly on single-jersey latch needle machines in the manner first patented by *Lestor Mishcon* in the USA in 1937. Pattern wheel selection was used for fleece yarn tucking. The preferred method today is to use a top needle butt and cam-track for knitting the ground (face) and tie-in (binding) yarns, and four tracks and corresponding butt positions (which can be rearranged) for the fleecy tucking sequence.

Figure 14.2 shows a typical knitting sequence for producing three-thread fleecy:

1 Selected needles are raised to tuck height to receive the fleecy yarn (F) (usually one out of four). The sinkers then move forward so that the top throat controls the fleecy tuck (F) whilst the lower throat controls the previous course.
2 All needles are raised to clear the previous course and receive the tie-in yarn (T).
3 The needles descend to the normal 'tucking-on-the-latch' position so that the previous course remains on the outside of the closed latch. The fleecy tuck, which is higher on the closed latch, slips off the needle head. As the fleecy tuck rests on the upper sinker belly, with the sinker withdrawing, the tie-in yarn (inside the closed hook) is drawn downwards through it.
4 The upper sinker throat holds the tie-in loop on the open latch whilst all needles rise to receive the ground yarn (G).
5 The needles again descend to the 'tucking-on-the-latch' position, to form loops from the tie-in yarn over the sinker crowns.
6 The sinkers finally withdraw and, as the needles descend, the new plated course slips onto their lower sinker bellies and the old course is knocked-over. Very carefully adjusted cam settings encourage the ground yarn to plate on the technical face (the underside) of the structure.

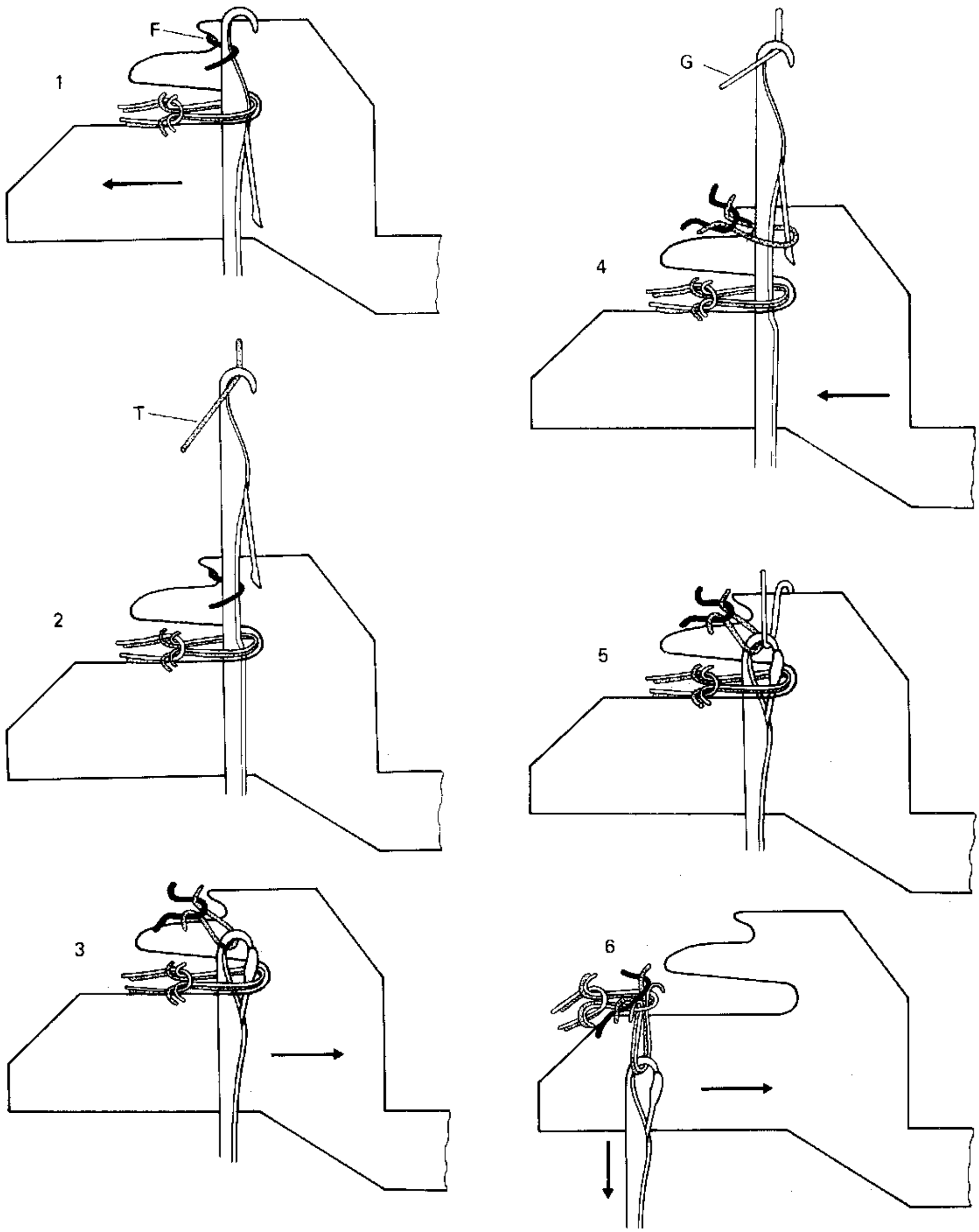

Fig. 14.2 Three-thread fleecy knitting cycle.

14.3 Fleecy interlock

Fleecy interlock is a plated fleecy fabric consisting of a main yarn, which is fed to knit on both needle beds and a fleecy yarn, which is fed first, and at a lower level, below the latches of the dial needles whilst they are at clearing height. It does not enter their hooks or show on the dial side of the fabric (Fig. 14.3).

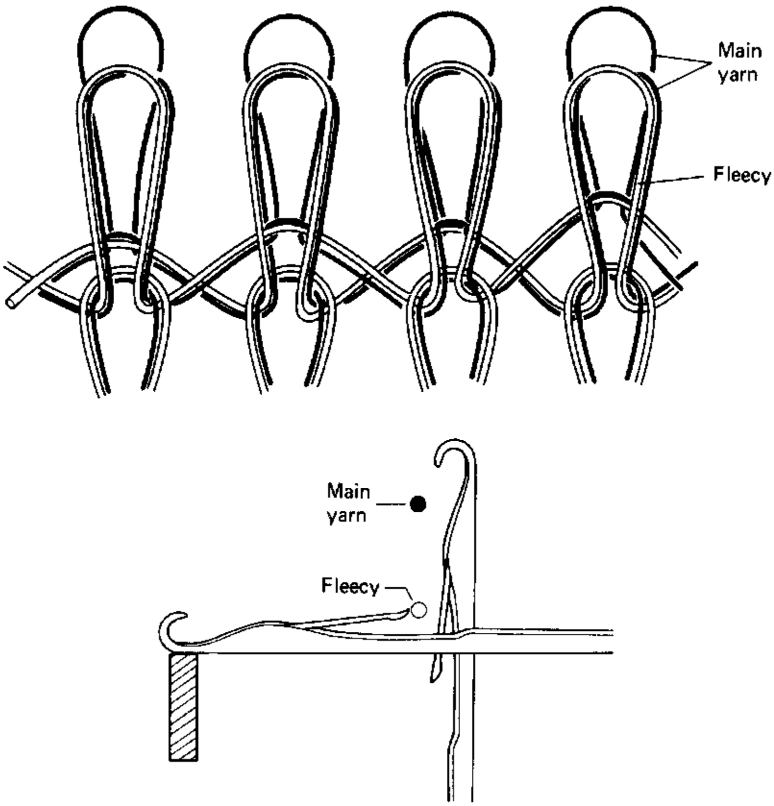

Fig. 14.3 Fleecy interlock.

14.4 Plush

Single-sided plated plush or *terry* is a popular leisurewear and sportswear structure that has the form-fitting properties of single jersey and is used in both fabric and sock form. The elongated plush sinker loops are formed over a higher knock-over surface than the normal-length ground sinker loops with which they are plated (Fig. 14.4). The plush sinker loops show as a pile between the wales on the technical back of the fabric.

Henkel plush or *velour* is achieved during finishing, by cropping or shearing the plush sinker loops in both directions. This leaves the individual fibres exposed as a soft velvety surface whilst the ground loops remain intact. It requires a fine gauge structure and involves a considerable loss of cropped fibre.

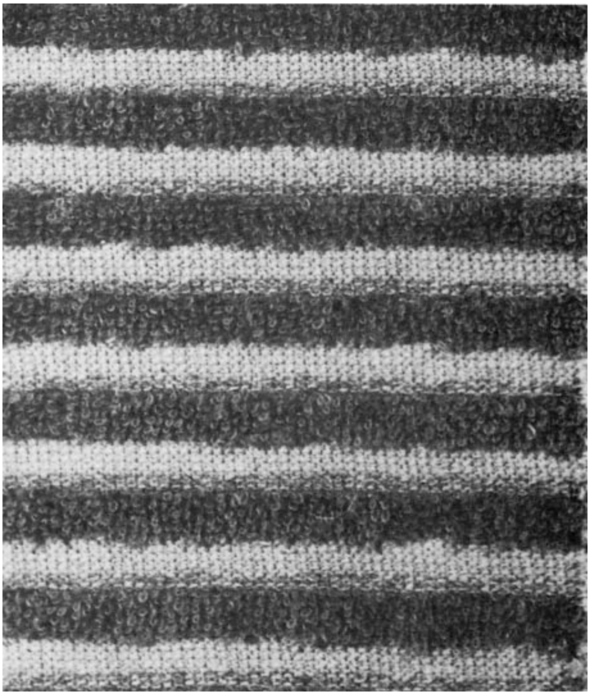

Fig. 14.4 Horizontal ribs with an ottoman effect on two-tone towelling [Alwin Wild, Switzerland].

14.5 The bearded needle sinkerwheel machine

In the past, this machine was renowned for the production of high-quality plush fabric but its productivity was low, with a speed factor of 500 and only 4 to 12 feeds in a diameter range of 10–44 inches. With the demand for increased production, knitters turned to the more productive latch needle sinker top machines, which were progressively refined to meet the needs for high-quality plush.

(The sinkerwheel machine was described in detail in the first and second editions of this book, Sections 14.6 and 14.7.)

14.6 Sinker plush knitted on single-jersey latch needle machines

On the sinker top latch needle machine, the ground yarn is fed into the sinker throat and the sinker is then advanced so that the plush yarn fed at a higher level (Fig. 14.5) is drawn over the sinker nib. If the sinker is not advanced, the two sinker loops will be of equal size as they will both be drawn over the same knock-over surface.

The numerals 1–6 illustrate the production of one course of standard plush:

1 The ground yarn is fed onto the open latch and into the throat of the sinker which is fully withdrawn.
2 As the needle descends the stitch cam, the plush yarn is fed into its open hook. The sinker advances and its nib re-engages the plush loop of the previous course so that it stands up as a pile loop whilst the new plush loop is drawn over the

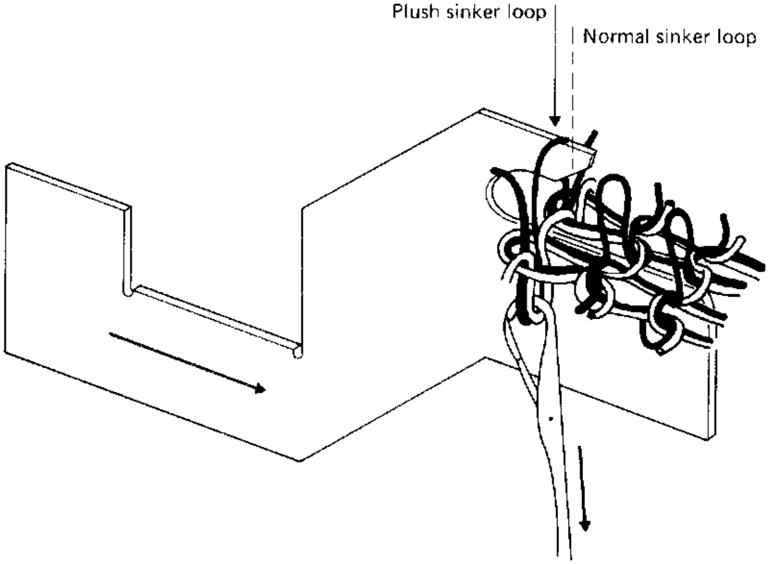

Fig. 14.5 Action of the plush sinker.

top of the nib. The back of the throat of the advancing sinker engages with the ground yarn loop, holding it against the inside of the needle hook in a lower position than the plush loop.

3 The sinker is advanced fully forward to retain the plating relationship and tighten the plush loop on the sinker step whilst the needle descends to knock-over.
4 The loops are relaxed as the needle rises to clear.
5 The new plush loop is retained on the sinker step as the needle rises.
6 When the needle is at maximum clearing height, the sinker advances to retighten the plush loop.

Mechanical or electronic selection may operate onto the backs of sinkers and thus produce designs in plain and plush stitches. A range of plush heights from 2 to 4 mm is possible, using different heights of sinkers. Precise camming of needles and sinkers, sharper angles of stitch cams, and control of loops (such as by sinker nib penetration methods after formation) are all being employed to improve accuracy of plating and reduce plush loop robbing.

On a 20 npi machine 1/30's (NeB) cotton might be used for the plush with a ground of 2/70's (Td) S- and Z-twist nylon alternating at each feeder in a weight of approximately 285 g/m, whereas for 24 npi the more expensive 1/30's cotton and 100 denier nylon is required. The speed factor is about 500–600, with between 1.3 and a maximum of 2 feeders per diametral inch.

Polar fleece is not a fleece fabric, it is actually a reverse plated plush fabric. The micro fibre plush yarn face loop is pushed towards the back of the needle hook, causing the two yarns to change positions so that the plush yarn is below the ground yarn loop. It therefore plates on top on the technical face, in addition to being on top on the sinker loop side of the technical back. Both sides of the fabric are lightly raised during finishing.

14.7 Full-density patterned plush

The durability of plush fabrics is strongly influenced by the density of the pile. In plain, single-colour pile there is an optimum pile density of one pile loop to each ground loop.

When knitting patterned plush (either in colour or self-colour with different plush heights), optimum pile density cannot be achieved. The reason is that, although the plush yarn plates with a complete ground course on the technical face side, it only produces a part course in pile on the effect side.

Mayer and Cie have developed the model MCPE to knit high-density jacquard plush fabrics, using electronic selection. Two independently-controlled sinkers operate in each trick to separately form the ground yarn and the pile yarns into loops. All the loops are then knocked-over together. On the technical face side, the ground yarn is required to perfectly plate over the pile yarn. One of the sinkers holds down the fabric and the pre-formed ground yarn loop; the other knocks-over and holds-down the pile loops.

At preliminary loop forming, all needles are taken down to 'tucking-on-the-latch' height so the old loops remain on the closed latches. For two-colour plush, at pile feeder for colour A, selected needles rise to receive pile yarn A. At pile feeder for colour B, the remaining needles are selected to receive pile yarn B. At knock over, all the ground and pile loops are knocked over together.

When a needle is not selected to knit the pile yarn, it floats on the pile surface and is clipped out in finishing. It is only knitted into the ground when selected, so there is less wasted yarn.

The 30-inch diameter machine has 48 cam segments. In three-colour plush there will be 12 knock-over/ground segments and 36 pile loop segments, in a sequence of 1:3.

14.8 Cut loop

Pai Lung have developed a cut loop cylinder and dial jacquard terry machine. The dial needles knit single jersey. The cylinder contains the pile elements, which are actuated by electronic selectors. The cutting elements are in a separate sinker ring and co-operate with the cutting edges of the pile elements in a shearing action.

14.9 Double-sided plush

Double-sided plush can be obtained using a machine with two sinkers per needle, the face plush yarn being drawn by the throat of a second, specially-shaped sinker placed alongside the plush sinker in each dial trick.

Babygro, a special two-way stretch babywear fabric, has been knitted on loop-wheel frames using bearded needles. The plated cotton yarn is pressed-off odd needles at odd feeds and even needles at even feeds to obtain float pile loops.

A wide range of plush fabrics in single-jersey construction can also be knitted on modified rib machines by drawing loops with the second set of needles and then pressing them off to form the plush loops. Sometimes plush points are employed.

Uneconomic rates of production make these techniques non-viable.

14.10 Sliver or high-pile knitting

Sliver or *high-pile knitting* is single-jersey made on a circular machine having sliver feeds where the stock- or dope-dyed slivers are drawn from cans at ground level. They are then prepared by mini three-roller drafting card units followed by two wire-covered rollers that draw and transfer the thin film of fibres to the needles (Fig. 14.6). At each sliver feed, the needles are lifted to an extra high level where they rise through the wires of the doffer roller to collect a tuft of staple fibres in their hooks.

Air-jet nozzles over the knitting points ensure that the tufts are retained in the needle hooks and that the free fibre ends are orientated through to the inside of the fabric tube (the technical back), which is the pile side.

As the needles start to descend, the ground yarn is fed to them, so that each has a ground loop and a tuft of fibres that are drawn through the previous loop. A range of facilities are available from different machines including up to 16 roller speed settings, the use of two different fibre lengths, and mechanical or electronic needle selection and sliver selection. Electronic selection can select needles to take fibres from one of four different coloured slivers.

Borg Textiles pioneered specialised sliver knitting in the 1950s in co-operation with *Wildman Jacquard* although *J. C. Tauber* obtained US patents as early as 1914. A typical machine now has a diameter of 24 inches in a gauge of 10 npi and runs at 45 rpm with 12–18 sliver feeds.

The fabric finishes 54–58 inches wide (137–147 cm) in a weight of about 450 g/m when knitting 360 denier fibrillated polypropylene ground yarn and a modacrylic sliver having a 3 denier $1\frac{1}{2}$ inch staple.

Fibre staple lengths can range from 20 to 120 mm, in sliver weights from 8 to 25 g/m^2, giving greige (unfinished) weights of 200–2000 g/m^2, for end-uses such as fun furs, linings, gloves, cushions, industrial polishers and paint rollers.

A typical high-pile finishing route is: rough shearing, heat setting and back-coating, pile cropping, electrifying or polishing (to develop the lustre and remove

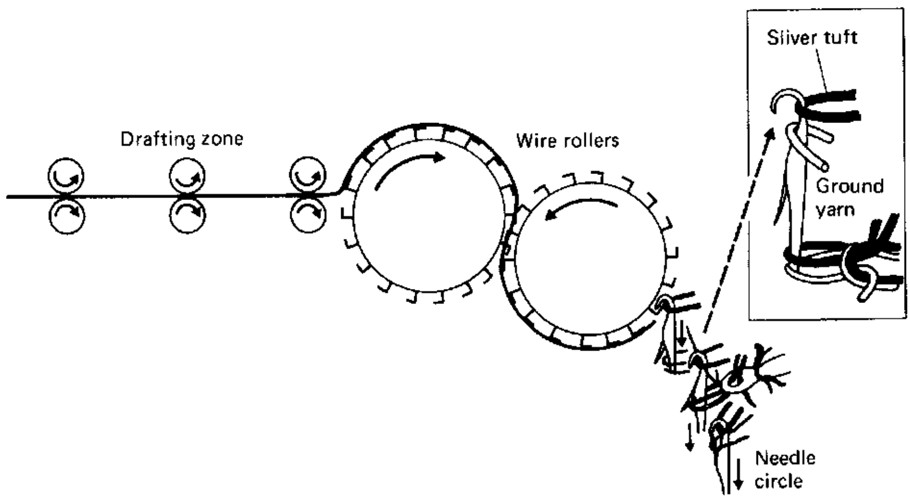

Fig. 14.6 Sliver high pile machine.

crimp from the fibre ends), tiger framing (to distribute the pile effect), and controlled torque winding (to further develop the pile uniformity).

14.11 Wrap patterning

Wrap patterning was popular in single jersey, especially in underwear, for producing vertical stripe effects, often in conjunction with horizontal patterning (Fig. 14.7). The fingers or wrapping jacks, with their warp yarn pins, must rotate in unison with the cylinder in order for each to remain with its section of needles.

Solid-colour warp insertion can be achieved with the *Camber* wrapping method, which may be used on any of their needle selection machines. The first selection system of the sequence selects needles to receive the wrap yarn, and the second selects the remaining needles to receive the weft ground yarn. According to machine model, diameter, and gauge (E 5–32), up to 100 or more fingers will successively pass through each section and be capable of wrapping across up to eight or more selected adjacent needles.

As each finger in turn contacts a stationary cam at the wrapping section, it pivots out of the cylinder and rises up its clockwise moving post, wrapping its warp yarn into the passing hooks of those needles selected to rise to take it. It is then cammed to return to its inactive position inside the cylinder whilst the needles pass to the next system, where those previously unselected rise to take the ground yarn. On a 28-gauge machine, 70–200 denier yarn might be used for the warp and 1/30–1/50 (NeB) for the ground.

On the *Mayer Vilonit* machine, wrapping and striping are incorporated into fabrics in the form of tuck-miss inlay patterns, thus providing an opportunity to use a wide range of yarn counts. A 26-inch diameter machine has twenty-four feeders, six with four-colour striping and six using the 46 wrapping fingers. Needle selection is by punched-tape controlled peg drums. Cam sections are in sequences of eight. At feeders 1 and 5, needles are selected to tuck the striping yarn, at 3 and 7 they

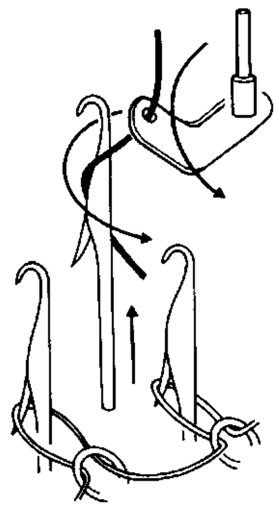

Fig. 14.7 Wrap patterning.

are selected to tuck the wrap yarns, whilst at feeds 2, 4, 6 and 8 needles are selected to knit the ground yarn.

Wrap patterning produces small, vertically-arranged designs without restrictive horizontal floating threads, but it requires a more expensive machine, it is time-consuming to set-up patterns, and productivity in numbers of feeds and speed of production is slow.

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15

Loop transfer stitches

Weft knitting offers considerable scope for the transfer of a full or part needle loop or sinker loop onto an adjacent needle, either in the same bed or in an opposing bed.

15.1 Uses of loop transfer

The object of loop transfer is to achieve shaping, produce a design, or change the stitch structure. In addition, loop transfer is used

- in ladies' stockings, when producing the double-thickness, plain fabric, in-turned welt,
- in running-on and doubling rib loop fabric onto the needles of a straight bar frame to form the rib border of a garment part, and
- when running the loops of two separate fabrics onto the points of a linking machine for linking these fabrics together.

Loop transfer by hand-controlled points is a tedious and skilled operation, but automatic loop transfer requires a specific arrangement of specially shaped needles and/or transfer points.

15.2 The four main types of transfer stitches

There are four main types of transfer stitches;

1 *Plain needle loop transfer stitches*, produced by transference of a loop from one needle to another in the same bed.
2 *Fancy lacing stitches*, produced by modification of the plain loop stitch.
3 *Rib loop transfer stitches*, produced by transferring a loop from one needle bed to the other.
4 *Sinker loop transfer stitches*

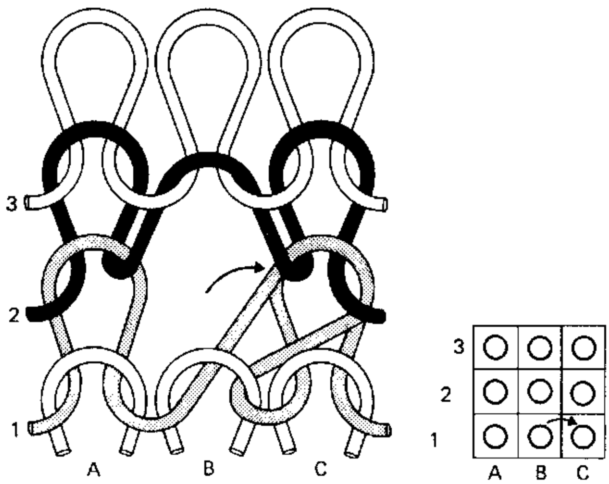


Fig. 15.1 Plain loop transfer stitch.

15.2.1 Plain loop transfer stitches

Needle loop transfer on plain fabric is most commonly achieved on straight bar frames using specially-shaped, rackably-controlled transfer points (Fig. 15.1).

In designs it is termed a *lace stitch* [1] whereas in selvedge shaping it is termed *fashioning*. When crossing over transfer stitches or narrowing, it is possible to transfer a loop to the next-but-one adjacent needle.

When the needle loses its loop and is required to knit at the next cycle, it will form a loop configuration having the appearance of a tuck loop which, when widening, may require *filling-in* (split stitch, Chapter 19). Two-needle widening is not practical because an insecure stitch is produced by two adjacent empty needles re-starting knitting at the same time.

Loop transfer to adjacent plain wales in rib structures has seldom been achieved automatically by means of transfer points and, even then, it has tended to be restricted to the narrowing of collars and sleeves. The method can be mechanically complex and slow. Only a few straight-bar rib frames were ever built. Although there are some electronic V-bed flat machines that have beds of loop transfer points, most use rib loop transfer needles and needle bed racking to achieve that purpose.

15.2.2 Fancy lacing stitches

The bearded needle sinkerwheel machine produced the largest range of fancy lacing stitches [2]. Some are unique to it and have the term '*à jour*' in their description, which implies a sequence of samples. *À jour C* or *knupf* (Fig. 15.2) – also termed *filet lace*, *weft knitted net* and *knotted stitch* – has square apertures in an all-over effect that is popular for men's athletic underwear. On an E 16 fine gauge machine, 1/18's cotton or 2/70 denier nylon might be used. A course of long loops is knitted and the two side limbs of every second needle loop 'B' are spread sideways onto the needle loops 'A'. The second is knitted with a short stitch length and tucking occurs on needles 'B' to make the aperture wider.

Another stitch, known as *à jour B*, has a twisted transferred loop, produced by

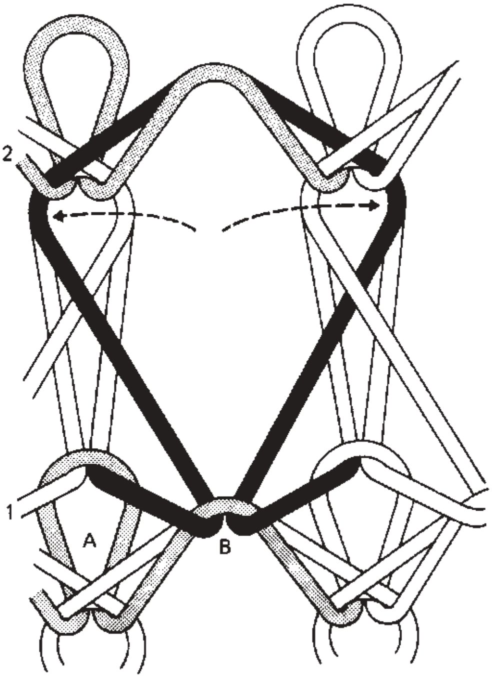


Fig. 15.2 À jour knupf.

deflecting the beard of the receiving needle across into the eye of the delivering needle so that, as the loop is pressed-off from the delivering needle, it twists over. The effect is achieved by using toothed lacing wheels with the upper wheel's teeth coupling two beards together; these teeth are arranged according to pattern requirements.

À jour H is loop displacement without transference, and is produced by deflecting alternate needles (receiving needles) underneath and past the loops on the delivering needles so that, when the receiving needles spring back into position, they draw the limbs of the adjacent needle loops sideways over their heads.

15.2.3 Rib loop transfer stitches

Figure 15.3 illustrates an example of a rib loop transfer stitch. At the first course, needles are knitting only in one bed. At the second course, an empty needle in the opposite bed commences knitting, producing 1×1 rib, and at the third course, this needle transfers its loop to a needle knitting in the opposite bed.

The rib loop transfer stitch is a very popular stitch. Modern automatic V-bed flat machines have special loop transfer needles, and individual needle selection and camming facilities for rib loop transfer from either bed, in addition to selection facilities for knit, tuck and miss. The RTR type circular garment-length knitting machine has a similar arrangement at transfer cam sections in the cylinder.

On some underwear models there is also collective dial-to-cylinder rib loop transfer for changing from 1×1 rib to 2×2 rib needle set-out at the transition from the welt and border to the body section of the garment. (Knitwear models tend to use

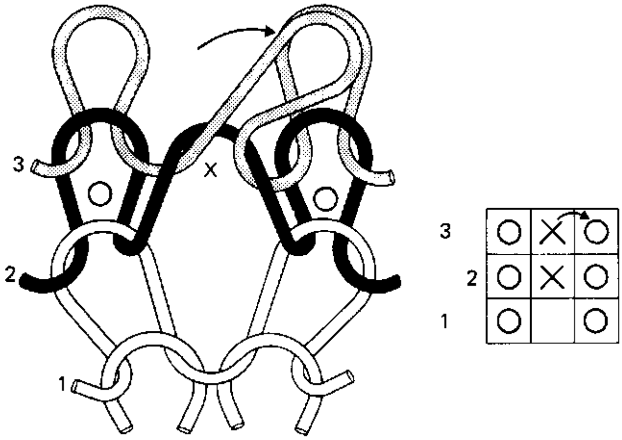


Fig. 15.3 Knitting on empty rib needle followed by rib loop transfer.

press-off cam facilities acting onto the back butt of every third dial needle prior to the start of a garment).

Whereas the RTR type of machine produces designs involving selective transfer of cylinder loops onto dial needles that already have a loop of their own, V-bed flat machines can select needles to transfer their loops onto empty needles in the opposite bed to knit links-links designs, cables and cross-over stitches and selvedge edge shaping.

15.2.3.1 The requirements for rib loop transfer

The basic requirements for rib loop transfer on any rib machine are:

1 Specially-designed latch needles with a ledge for lifting the delivering loop and either a recess or a spring clip on the side of its stem to assist entry of the receiving needle hook into the spread loop.
2 A delivering needle cam that lifts the needle higher than normal clearing-height, lifting and spreading its loop so that the hook of the receiving needle can enter it as its cam lifts it to approximately tuck height. Normal needle selection arrangements can thus be employed to select those needles required to be lifted by the delivering needle transfer cam.
3 A needle bed rack of between 1/3 and 1/2 of a needle space so that the stems of the delivering and receiving needles are very close during the loop transfer action.

Figure 15.4 illustrates the transfer action, together with its associated cam system. There is a receiving cam (R) and a delivering cam (D) in each needle cam system at the end of each system, thus providing the possibility of two-way loop transfer in the leading system in each direction of carriage traverse.

The delivering needle cam has a double peak; the first peak lifts the loop to stretch and open it ready for transfer on the second peak. The receiving needle cam in the opposite bed is aligned with it and the under edge of, the delivering cam in its system acts as a guard cam for the receiving needle butts.

In Fig. 15.4a, the delivering needle (b) is moving towards transfer height, with the receiving needle (a) about to enter the recess on its underside. At this point

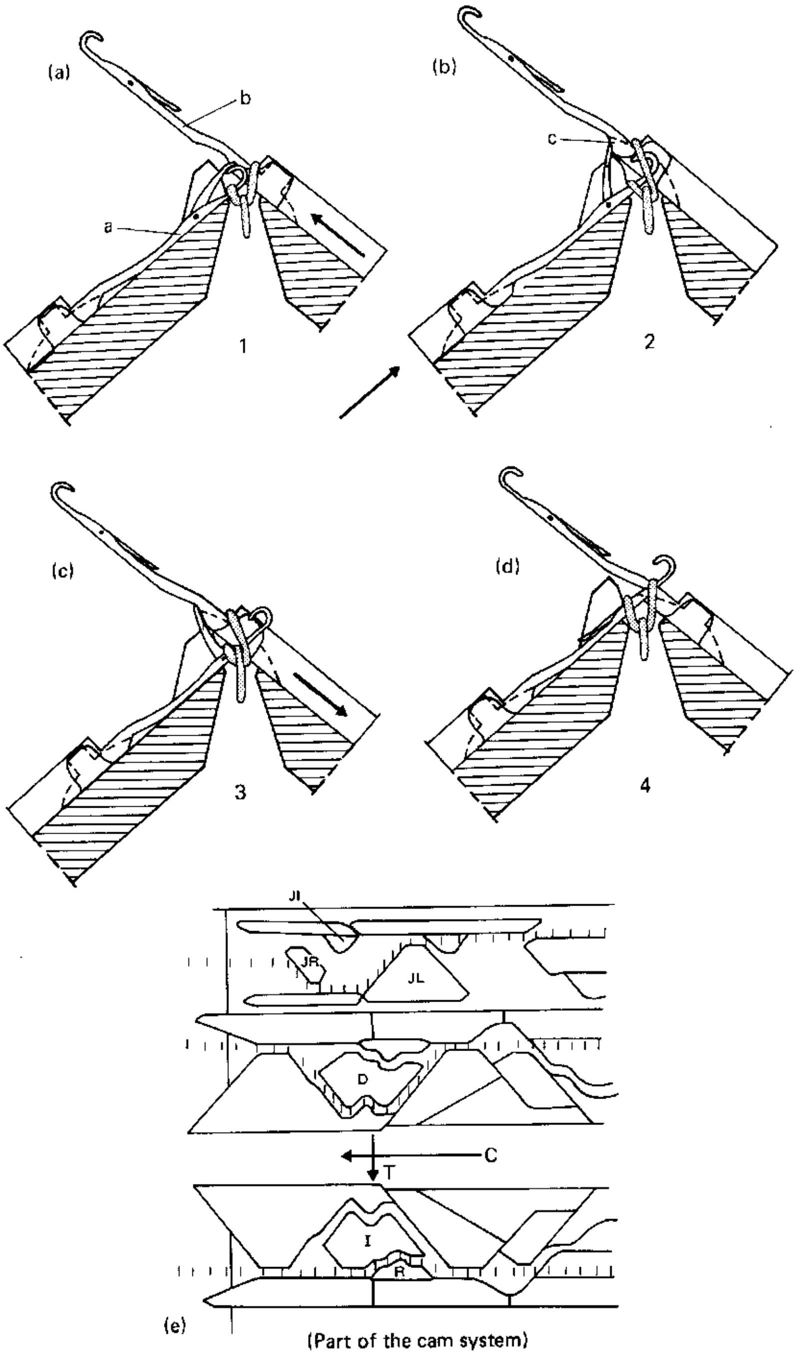


Fig. 15.4 Rib loop transfer on a modern V-bed machine.

(Fig. 15.4b), a stop ledge (c) on the rising delivering needle (b) contacts and opens the latch of needle (a) (this arrangement is necessary for opening the latches of empty receiving needles).

In Fig. 15.4c, needle (b) is cammed to full transfer height, lifting the loop to be transferred, and needle (a) is cammed into it with its hook open.

In Fig. 15.4d, transference is completed by lowering needle (b) so that its loop is knocked-over and fully transferred into the hook of needle (a). Single-bed knitting is possible whilst the beds are racked for transfer.

15.2.3.2 Rib loop transfer on a circular garment-length RTR-type machine

For rib loop transfer, the dial is shogged so that the cylinder needle is closer to the dial needle on its right. As the cylinder needle is raised, a gear-type deflecting mechanism, rotating with the cam-box, deflects the needle to the right so that the dial needle can now enter its recess on the left side and penetrate the lifted cylinder loop. The cylinder needle now descends, casting-off its loop into the hook of the dial needle and returning to its undeflected position. At the next knitting section, the empty needle may be selected to miss or to receive the new yarn.

Collective dial-to-cylinder rib loop transfer usually occurs on every third cylinder needle when changing from 1 × 1 to 2 × 2 rib in the knitting of stitch-shaped vests. Dial needles with back butts are cammed out so that the ledges on their stems align their loops with the cylinder needle hooks. An angular cam face deflects the dial needle against the direction of knitting so that the cylinder needle normally on its right enters its expanded loop on the left, aided by the recess in the back of the dial needle and a part shog of the dial. The dial needles then withdraw, transferring their loops and not taking part in knitting again until 1 × 1 rib is required.

15.2.4 Sinker loop transfer stitches

Pelerine eyelet is a cellular structure whose elliptical apertures are formed at courses where adjacent plain wales move outwards as a result of the absence of connecting sinker loops. Specially shaped pelerine points consisting of two shaped members occupying a single trick are employed to gather the sinker loops, usually at two successive courses, transferring them back at the next knitting cycle to the hooks of the two needles between which they were originally formed.

Pelerine eyelet is produced in the form of continuous fabric on circular plain web eyelet machines where it is used for lightweight underwear, as rib eyelet in one set of the 2 × 2 rib wales of ladies' body-length stitch-shaped underwear, and as eyelet designs in some types of socks.

Although the diameters of web eyelet machines range from 9 to 22 inches (23–56 cm), 16 inch (40 cm) tends to be popular, in a common gauge of E 16 using cotton counts between NeB 2/28's and 2/35's. The points are normally set-out in the cylinder for convenience of selection and re-arrangement, and the plain knit base structure is produced by a full set of needles in the dial.

Figure 15.5 illustrates standard all-over plain web eyelet, having a repeat area of three wales by four courses. After every three needles A,B,C, in the dial, a pair of points is placed in the trick of the cylinder. Courses 1 and 2 are knitted as plain fabric, with the points merely rising to act as holding down sinkers when the dial needles move out to clear. Before the start of the third course, a cam lifts a butt of the points, causing their head to protrude between the head of the two dial needles

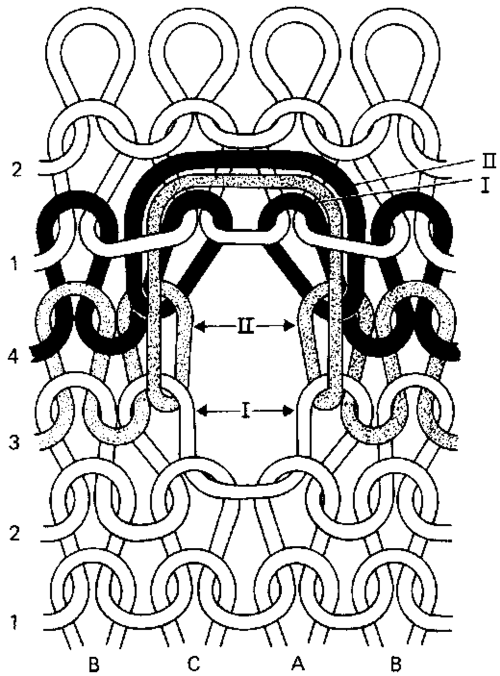


Fig. 15.5 Pelerine stitch.

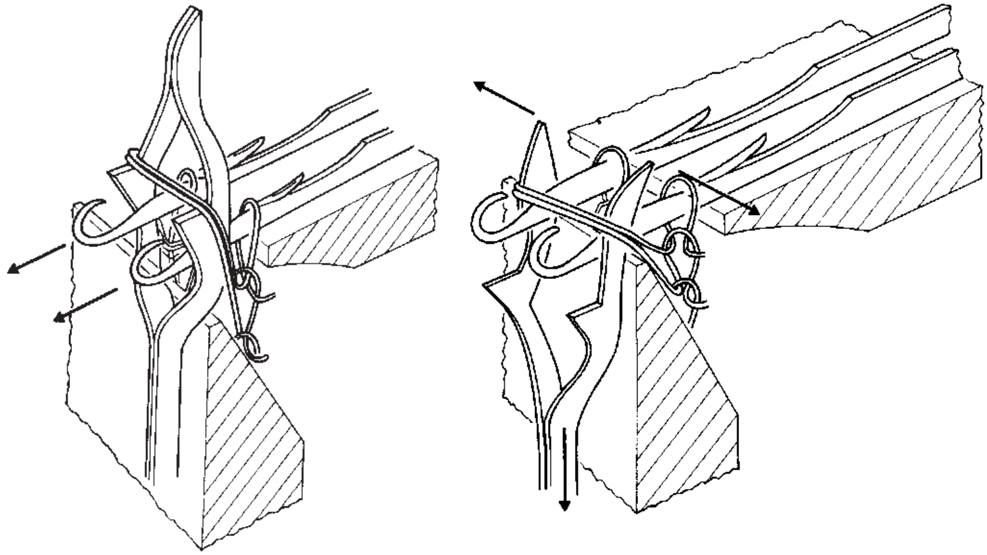
in the gather position. Thus, as the needles knit courses 3 and 4, extended sinker loops are drawn around the raised head of the points. The butt of the points now enters the transfer section and the points are cammed to a higher level so that the ledges on either side lift the gathered sinker loops that are spread by the wider eye-shape of the head.

The needles are then cammed outwards by a tuck cam so that the two adjacent needles enter the eye of the points (Fig. 15.6a) just beneath the gathered sinker loops. The points now descend and the two members spring apart (Fig. 15.6b) as they pass the outward dial needles, fully transferring the gathered sinker loops into the hooks of the two needles.

Diagonal eyelet has alternately staggered eyelet holes produced by odd pairs of pelerine points operating through their long top butt at the first four-feed cycle, and even pairs of pelerine points operating at the second four-feed cycle by means of their long bottom butt, and so on, with each butt position having its own cam-track.

Patterned eyelet can be produced by using a pattern wheel to select points for collection at every third feeder (the friction of the sinker loop holds the points in action at the fourth feeder). Dummy points engage the wheel from the other cylinder tricks and, as only every third pattern wheel trick is in use, three different pattern selections may be loaded. Designs may either be in the form of eyelet motifs on a plain ground or plain motifs on an eyelet ground.

Some of the newer eyelet structures employ two needles to a pair of points. *Fine eyelet* has a four-feed repeat sequence, *close eyelet* has a two-feed collect and transfer sequence using odd points at the first sequence and even points at the next, whilst *pin point* is a patterned eyelet having two plain courses and selection for a single collect and transfer course.



(a) (b)

Fig. 15.6 Pelerine transfer action.

For standard eyelet, a 16-inch diameter machine might have twenty feeds and five transfer stations, and for close eyelet sixteen feeds and eight transfer stations.

Occasionally, points with one straight member and one curved member have been employed to produce half sinker loop transfer stitches.

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