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

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.

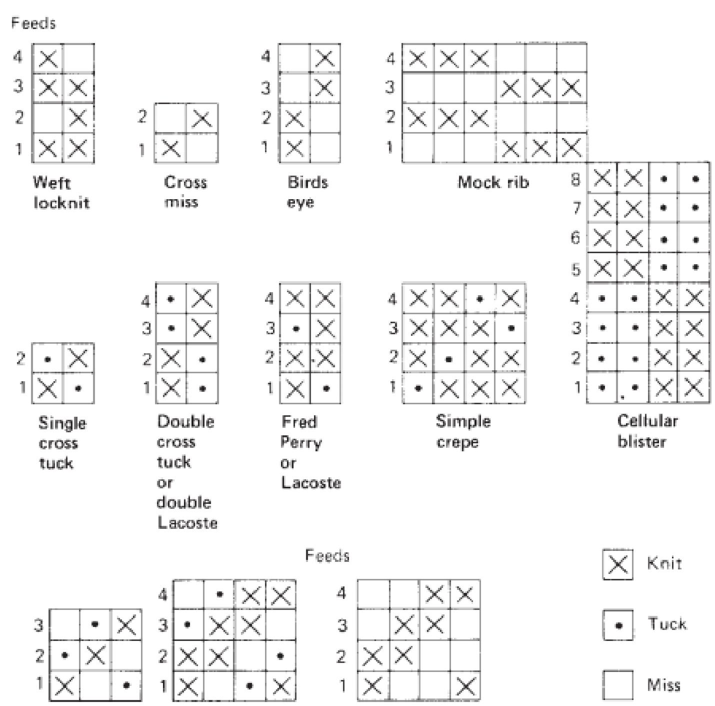

Fig. 13.1 Twill effects.

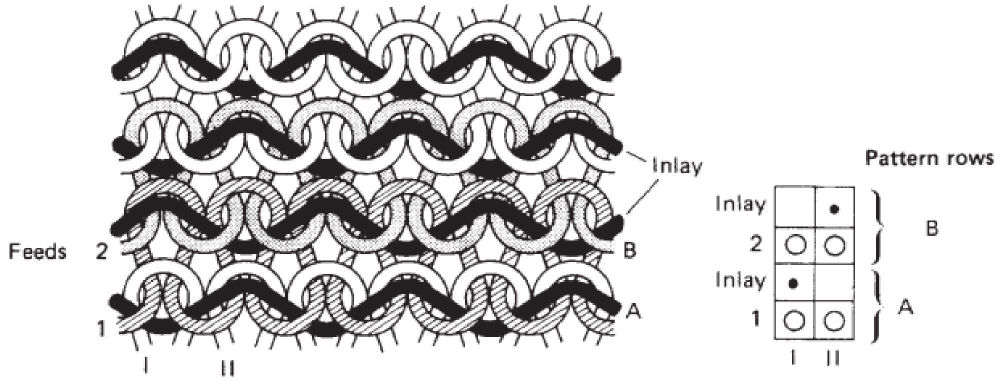

Fig. 13.2 Single jersey hopsack structure and notation.

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.

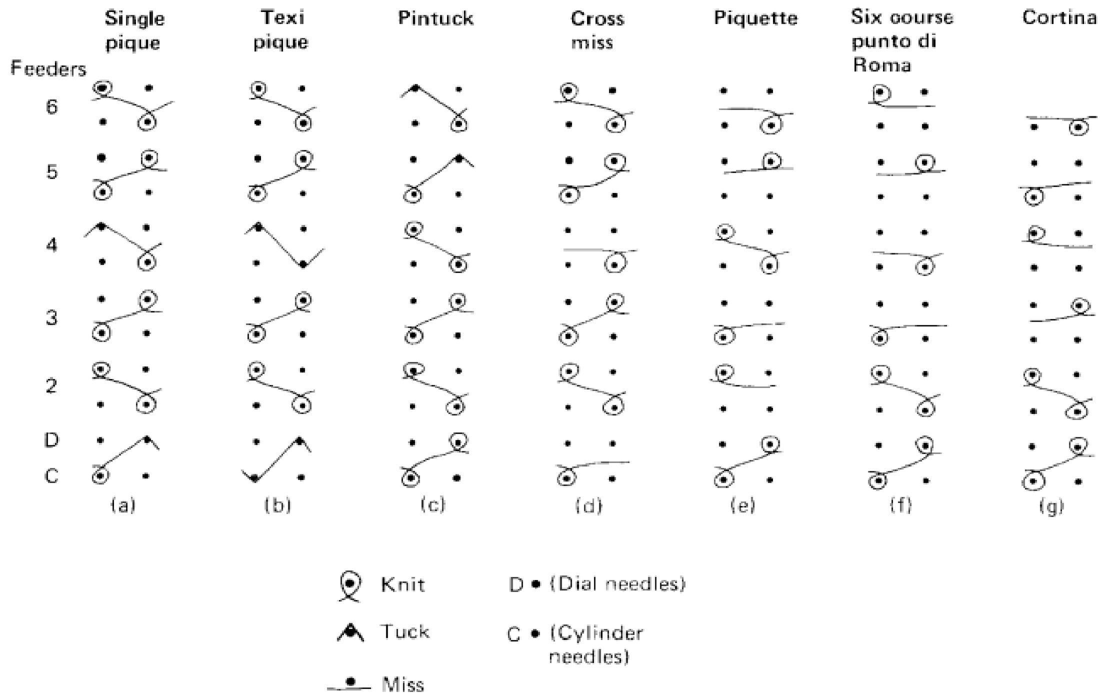

Fig. 13.3 Double jersey non-jacquard fabrics.

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

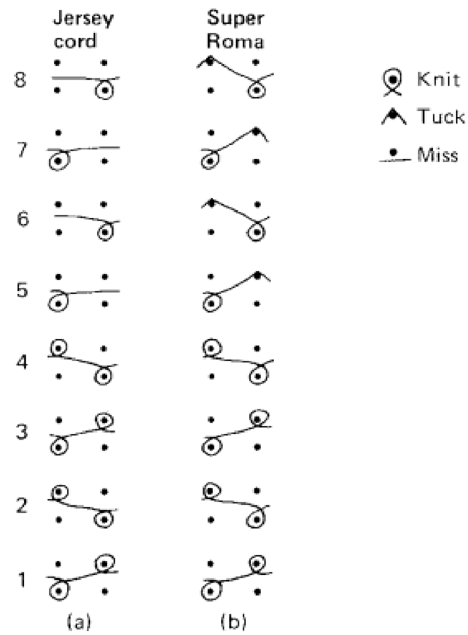

Fig. 13.4 Further double jersey fabrics.

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.

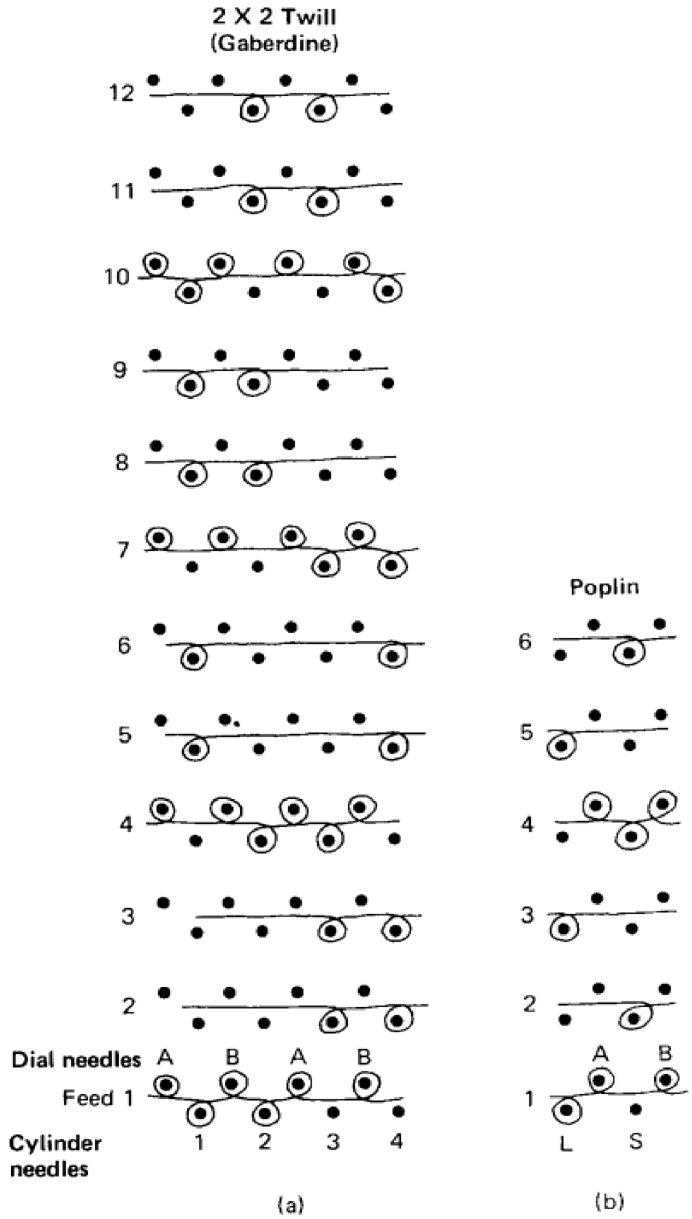

Fig. 13.5 Twill and poplin double jersey.

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.

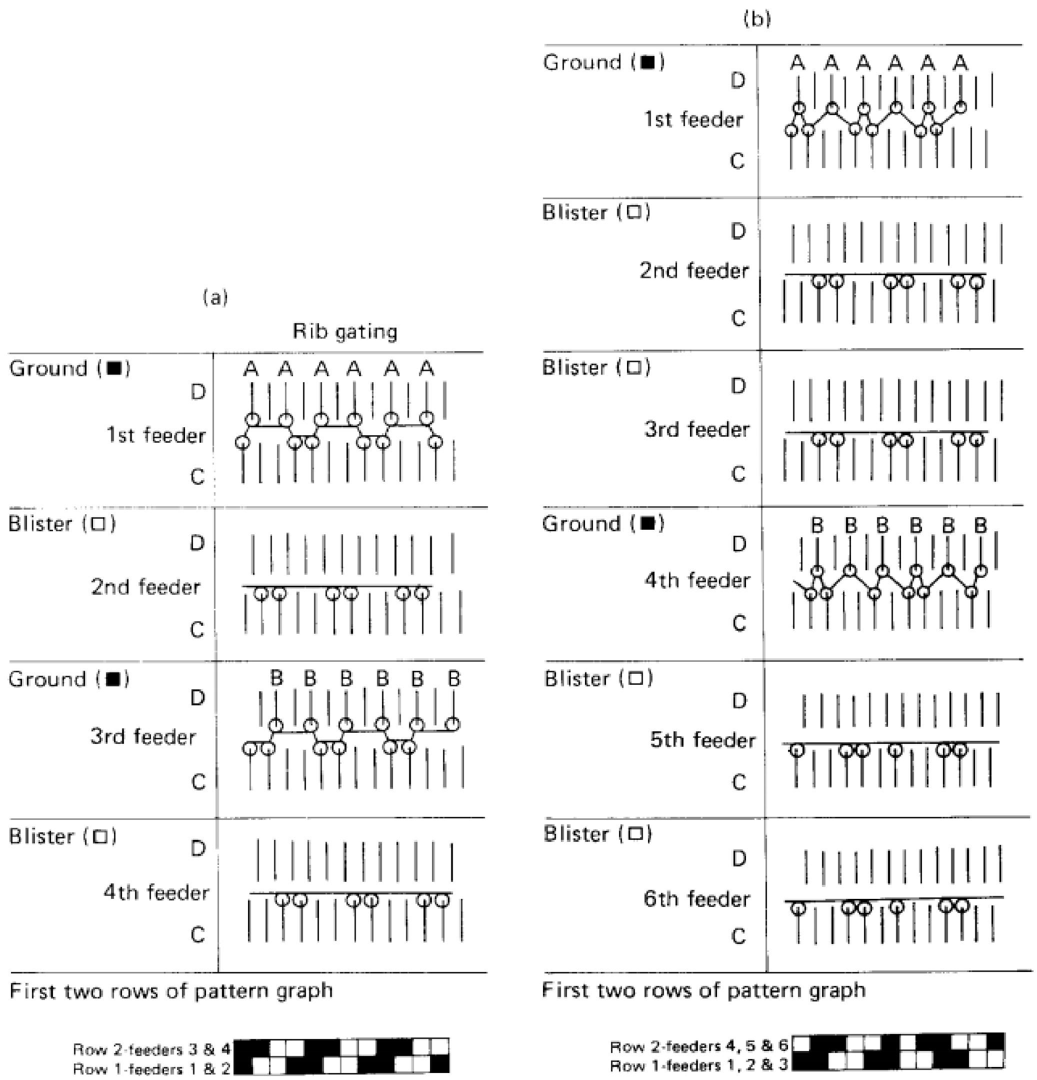

Fig. 13.6 Single and double blister.

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.

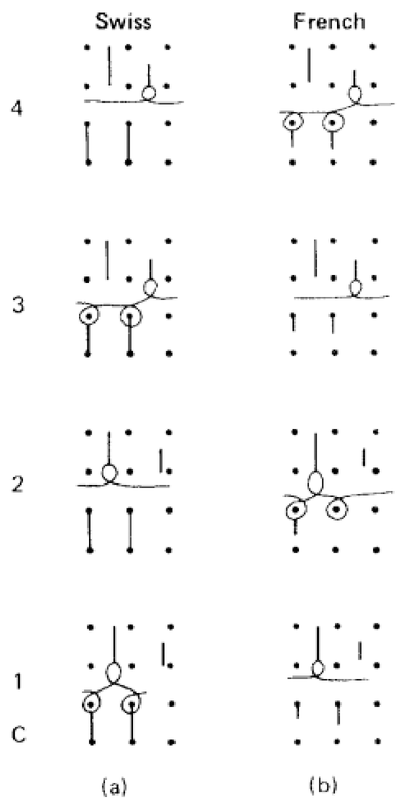

Fig. 13.7 Double pique.

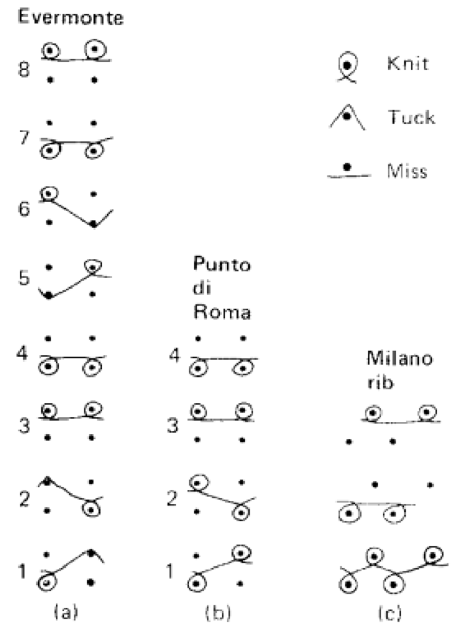

Fig. 13.8 Milano, punto di Roma and evermonte.

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.

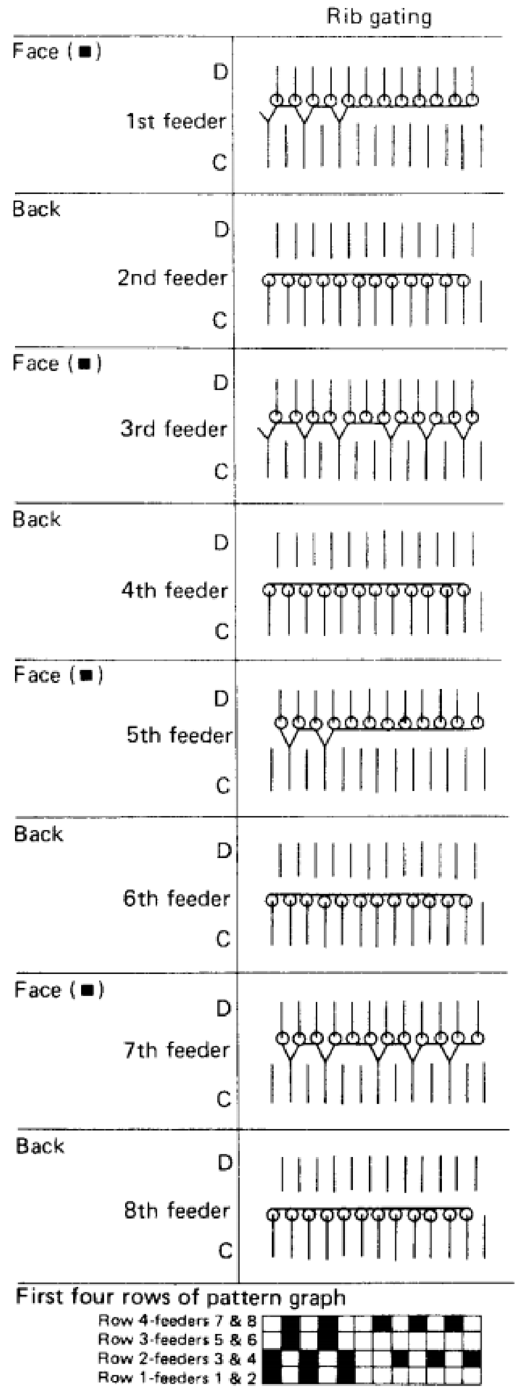

Fig. 13.9 Tuck lace.

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

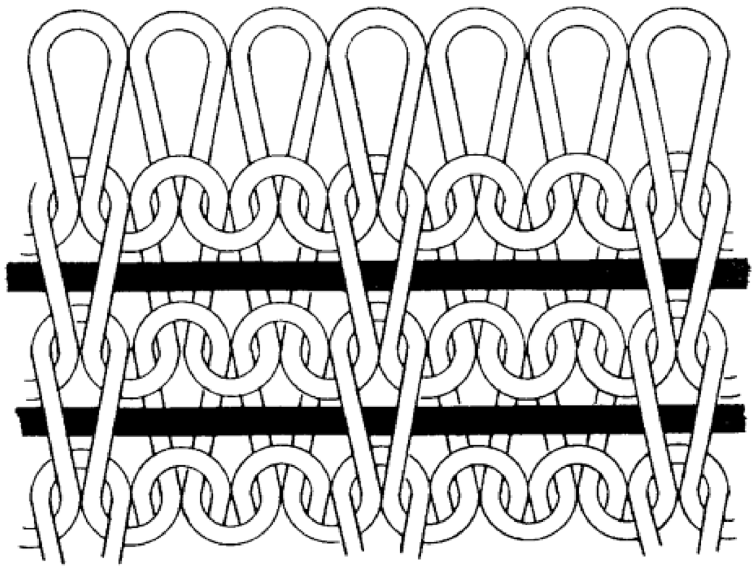

Fig. 13.10 Tunnel inlay.

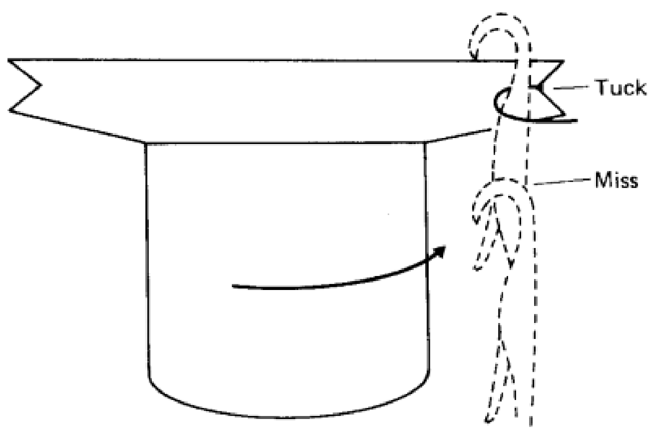

Fig. 13.11 Faneknit inlay device.

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:

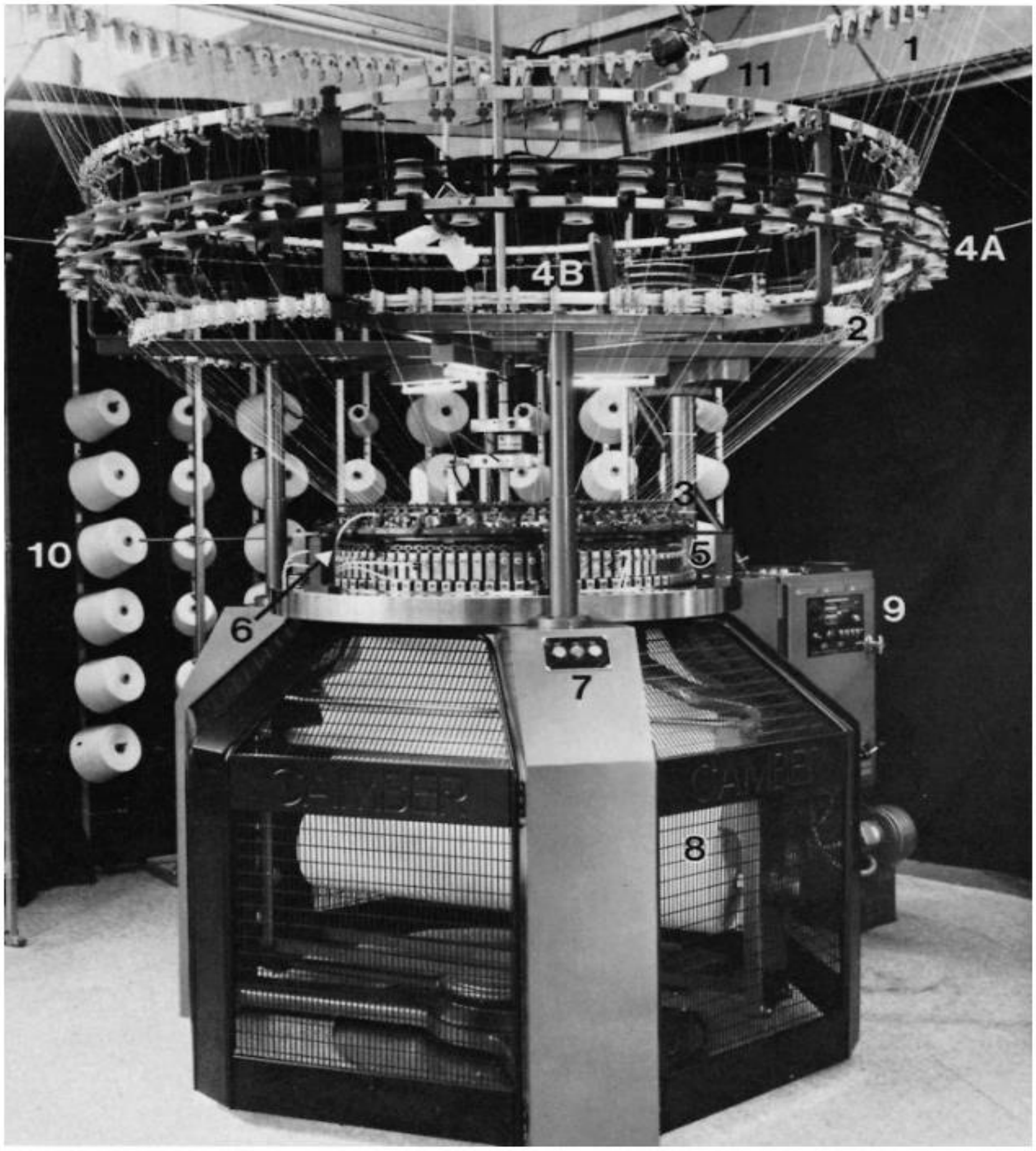

Fig. 13.12 The modern circular single jersey fabric machine.

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

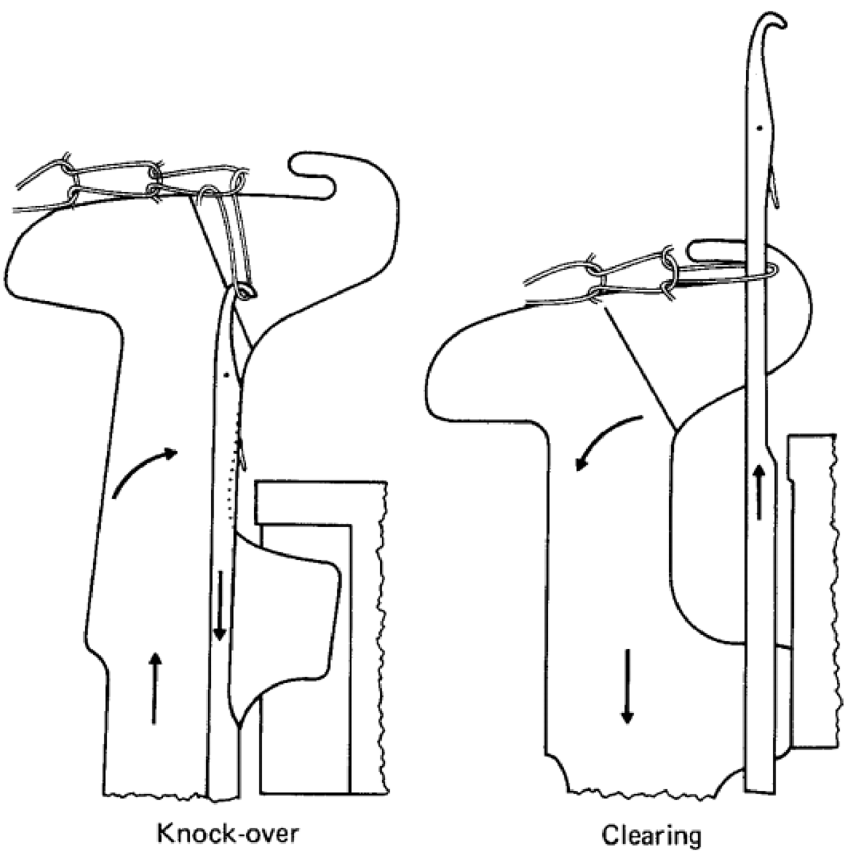

Fig. 13.13 The Relanit contra knitting action.

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.

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

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

$$= 859.6 \text{ metres}$$