Comparison of weft and warp knitting

6.1 Yarn feeding and loop formation

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

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

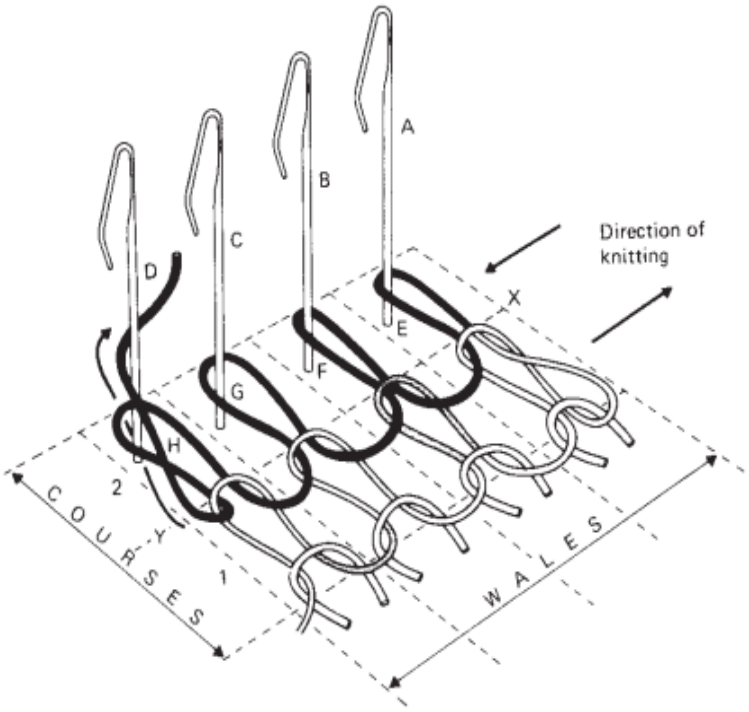

Fig. 6.1 Weft knitting.

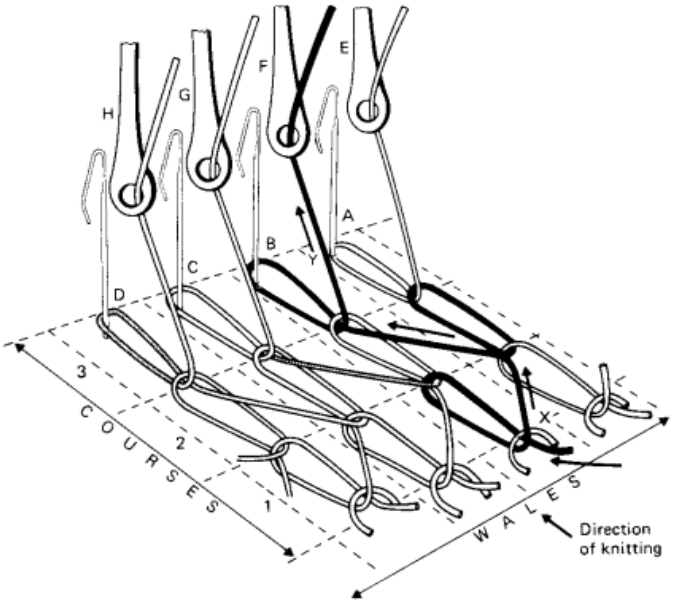

Fig. 6.2 Warp knitting.

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

6.2 The two industries

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

6.2.1 Weft knitting

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

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

Fig. 6.3 Overlock seaming [Corah].

Fig. 6.4 Cup-seaming.

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

6.2.2 Warp knitting

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

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

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

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

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

Fig. 6.5 Warp-knitted car upholstery

6.3 Productivity

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

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

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

6.4 Machine design

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

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

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

6.5 Comparison of patterning and fabric structures

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

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

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

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

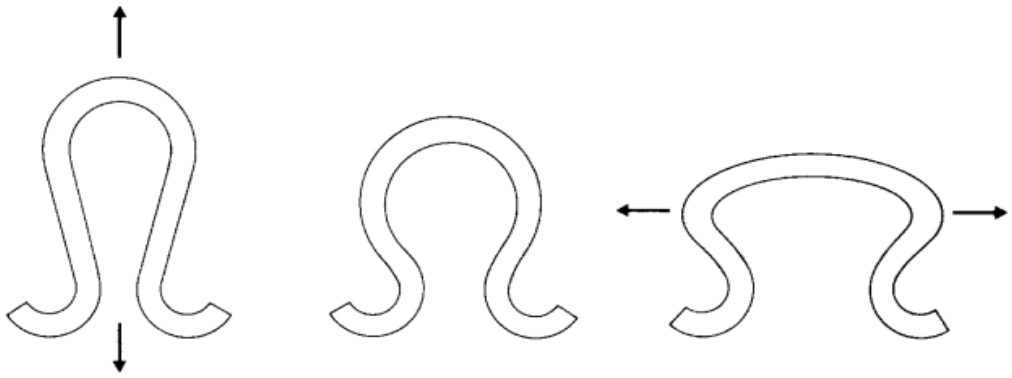

Fig. 6.6 Loop extension and recovery.

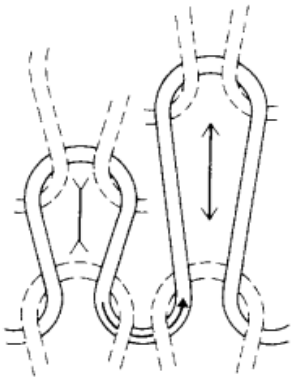

Fig. 6.7 Yarn flow in knitted structure.

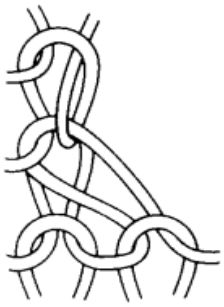

Fig. 6.8 Weft knitted loop transfer.

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

6.6 Course length and run-in per rack

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

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

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

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

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

6.7 Fabric quality

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

6.8 Structural modifications commonly used in weft and warp knitting

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

6.8.1 Laying-in

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

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

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

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

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

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

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

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

6.8.2 Weft insertion

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

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

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

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

6.8.3 Plating

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

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

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

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

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

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

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

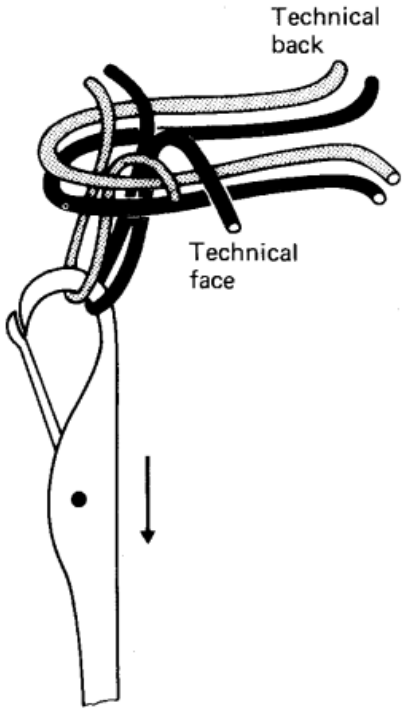

Fig. 6.9 The plating relationship of two yarns.

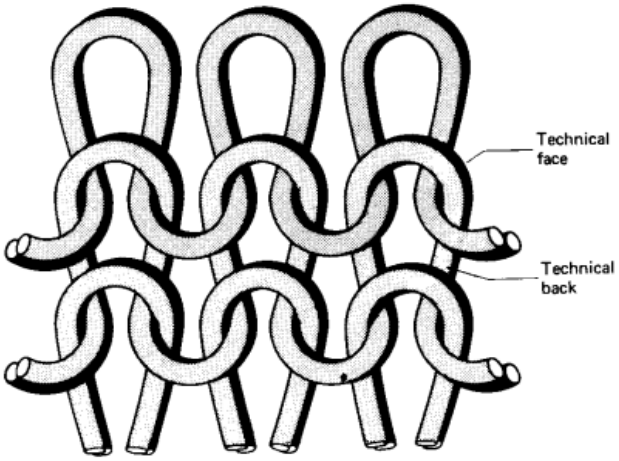

Fig. 6.10 Plating in weft knitting.

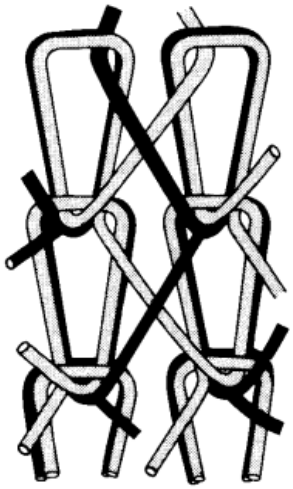

Fig. 6.11 Plating in warp knitting.

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

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

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

6.8.4 Open-work structures

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

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

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

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

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

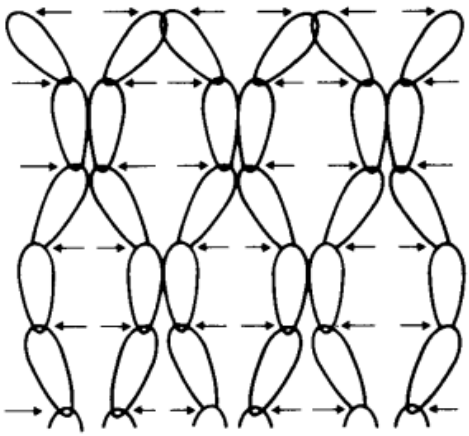

Fig. 6.12 The movement of loops to form open work.

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

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

6.8.5 Plush and pile constructions

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

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

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