22

Aspects of knitting science

22.1 Knitted loop-shape and loop-length control

Weft knitted structures, especially those used for hosiery, knitwear and underwear, have unique properties of form-fitting and elastic recovery based on the ability of knitted loops to change shape when subjected to tension. Unfortunately, dimensional changes can also occur during production, or washing and wearing, when problems of shrinkage and size variation can cause customer dissatisfaction and increased production costs.

During the 1950s, HATRA (the Hosiery and Allied Trades Research Association) investigated the problems of knitted garment size variation and created a much clearer understanding of the influence of stitch length on knitted fabric dimensions, which led both to further research in this field and to the practical application of this knowledge in production. *Doyle* [1] emphasized the relationship between stitch length and fabric dimensions when, in plotting stitch length against stitch density for a wide range of dry, relaxed, plain weft knitted structures, he showed that, irrespective of yarn type or count or of machine type or gauge, the points lay close to a general curve. HATRA was thus able to establish three basic laws governing the behavior of knitted structure:

1 Loop length is the fundamental unit of weft knitted structure.
2 Loop shape determines the dimensions of the fabric, and this shape depends upon the yarn used and the treatment that the fabric has received.
3 The relationship between loop shape and loop length may be expressed in the form of simple equations.

The acceptance of these rules has encouraged the introduction of yarn loop-length measuring and yarn feed control devices, has accelerated improvements in shrink-resist and fabric relaxation treatments, and has provided a basis for the theory of knitted fabric geometry.

22.2 Loop length

Loop lengths combine in the form of course lengths and it is these that influence fabric dimensions and other properties, including weight. Variations in course length between one garment and another can produce size variations, whilst course length variations within structures (particularly when using continuous filament yarns) can produce horizontal barriness and impair the appearance of the fabric.

With the exacting demands of modern knitting technology, the need to maintain a constant loop length at one feed for long periods of time between one feed and another on the same machine, and between different machines knitting the same structure has become of major importance in the control of fabric quality. This requirement has encouraged the development of yarn feed measuring and control devices.

Under normal circumstances, about 15 per cent of the yarn drawn into a newly-formed loop is actually robbed from already-formed neighbouring loops. Although a machine may be set to knit a specific stitch length, fluctuations in yarn or machine variables can affect yarn surface friction or yarn tension and ultimately influence yarn input tension at the knitting point. As a result, the ratio of 'robbed back' to newly-drawn yarn changes and this alters the size of the knitted loop.

Course length measurements can be obtained by unroving the yarn from a knitted fabric. This is time consuming, destructive of material, and only provides information after knitting. Two types of meter may be employed to monitor yarn feed during knitting – yarn length counters and yarn speed meters – which may be considered to be respectively analogous to tachometers and speedometers in cars.

The yarn length counter is simplest in construction, providing a reading of the amount of yarn fed in a certain time period. It is particularly suitable for attaching to a moving yarn feeder on a circular revolving cam-box machine. After a specific number of machine revolutions, the machine is stopped to enable the yarn length reading to be taken; this is then divided by the number of knitting machine revolutions in order to obtain the course length for that feed.

The yarn speed meter may require calibrating and provides a direct reading of the rate of yarn feed, usually in metres per minute, whilst the machine is running. The meter may be hand-held and can be used on a revolving cylinder machine without the need to stop it. To obtain the course length it is necessary to divide the reading by the number of knitting machine revolutions per minute.

Monitoring every feed of a large diameter multi-feeder machine is time-consuming and provides no guarantee that the course length will remain constant after measuring. *Positive feed devices* are designed to overcome this problem by positively supplying yarn at the correct rate under low yarn tension to the knitting point instead of allowing the latch needles or loop-forming sinkers to draw loops whose length could be affected by varying yarn input tension. HATRA introduced the nip roller positive feed device during the early 1960s. It consists of a lower roller driven by gearing at a speed directly proportional to the machine speed, with an upper, freely running, weighted roller turning in contact with the yarn completing the nip.

Devices of this type tended to have complicated drive linkages, required a complex yarn path, and needed careful adjustment at each device if uniformity of course length was necessary at a number of feeds. For these reasons, the cheaper, simpler, more adaptable, tape positive feed system developed by *Isaac Rosen* proved

to be more acceptable. A continuous tape driven from the machine drive by a single pulley encircles the machine above the feeders and provides identical and constant feed for any yarn threaded through the nip it forms with a free-running feed wheel at each feed position (Figures 13.12 and 22.1). On clockwise revolving machines, the yarn passes from its package into the right-hand side of the tape/wheel nip and on leaving the nip on the left it passes down through a detector to the feeder. The faster the tape speed relative to the machine speed, the faster the rate of yarn feed and the longer the resultant course length. The tape speed is altered by adjusting the scrolled segments of the drive pulley to produce a larger or smaller driving circumference.

Punto di roma, *milano rib* and *double pique* require much longer course lengths at the feeders where most needles knit than at the other feeders. For structures of this type, up to four tiers of tapes, each driven at a different speed by a different diameter drive pulley, can be accommodated. Facilities for yarn disengagement are provided and sometimes the yarn is guided around the wheel in a coil to prevent slippage.

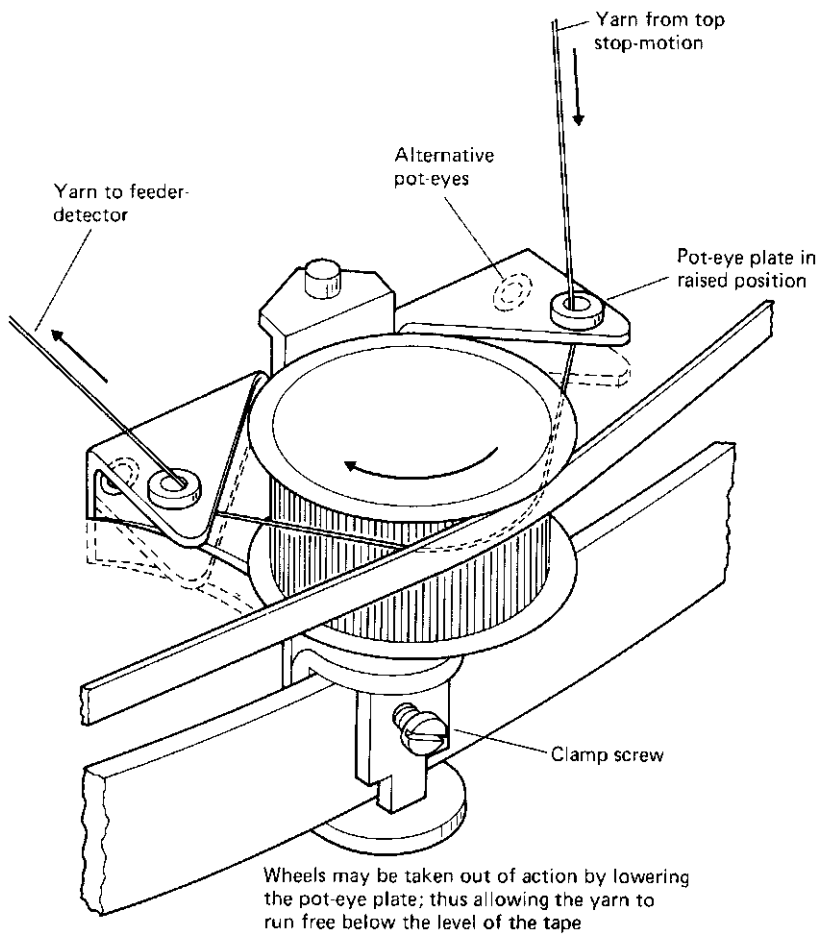


Fig. 22.1 Trip-tape positive feed.

Tape positive feed is generally only suitable for structures having a maximum of four different course lengths and requiring a constant course length at each feeder, but some small-area jacquards and diagonal twills can be produced with it. Large-area jacquards and similar structures whose individual needle selection causes large fluctuations in feed rate requirements (both between feeders and at the same feeder from one machine revolution to the next) cannot be supplied from positive-feed devices.

The other type of yarn furnishing device is the *storage feeder* (Fig. 17.1), which supplies yarn at a uniform tension rather than at a uniform rate of feed and is thus suitable for a wide range of yarn feeds. It may also be used for supplying patterning and weft insertion yarns on some warp knitting machines. Yarn is withdrawn from the package and wound tangentially as equally-spaced coils on a 'store'. Demand at the knitting point causes axial withdrawal of yarn from wraps at the opposite end of the store.

On one design, the spool rotates to wrap the yarn at the top of the store and a lightweight circular plastic comb ensures controlled take-off tension from the base of the store. An inclined disc resting over the wraps senses when they have reached a minimum and switches on the electric motor for the spool drive. It later switches the motor drive off when the required maximum number of wraps have been produced. On another design, the yarn input is through the centre of a stationary spool, with a rotating disc winding the yarn on at the base of the store, the coils being moved upwards by reciprocation of the spool surface. Yarn stop motions and indicator lights are fitted to most units.

A further development is the combination of positive feed and storage feed with a choice of mode available by means of a clutch. With this design, even for positive feed, the tape, which has punched holes, never contacts the yarn; instead it is used to drive a studded wheel and thus wind the yarn onto the store.

Storage feeders provide a store of yarn as the machine stops after a yarn breakage, so it is possible to simplify the yarn path and eliminate the top stop detectors. It is also possible to place yarn packages on supply creels separate from the machine because the storage feeds can compensate for a variation in yarn tension produced by a difference in the angle of the path.

Structures produced with constant and identical course lengths may have a differing or impaired appearance if the allocation of the course length between the knitting elements, and therefore between the components of the stitch structure, varies. Factors that can cause a variation include element timing, element gauge in relation to machine gauge, and the depth of knock-over of one needle bed compared to the other. This effect can be magnified or minimized by the type of structure and yarn, the machine gauge, and the type of relaxation and finishing treatment.

22.3 Warp let-off

Loop length is equally as important in warp knitting as in weft knitting. In the form of run-in, it is determined by the warp let-off which is either negative or positive. In the first arrangement, tension on the warp causes it to be pulled from the beam as it turns against a controlled friction. The mechanism is self-compensating, releasing warp on demand. An overall increase of run-in is obtained by increasing the speed of the fabric take-up rollers, which increases the tension.

In the second arrangement, the warp beams are positively driven to deliver a predetermined run-in. The surface speed is monitored so that, as the beam circumference decreases, the beam drive speed is increased to maintain a uniform rate of let-off. The arrangement must also be capable of catering for fluctuating let-off requirements in patterned fabrics. Tension fluctuations that occur during the knitting cycle are compensated by spring-loaded tension bars over which each warp sheet passes in its path to its guide bar.

On multi-guide bar raschel and tricot lace machines, the spot beams that supply the partly-threaded pattern guide bars are completely negatively turned. These light-weight beams turn easily and have a three-spoked star attached to one end on which small weights are placed and positioned in order to ensure balanced rotation. At the other end, weights attached to a collar provide controlled friction.

An intermittent negative-brake-type let-off may be employed on slow speed machines (below 600 cpm) that are knitting fabrics from full-sized beams. The friction of a belt brake restrains the beam rotation until the warp tension is sufficient to cause the tension bar to be lowered, which in turn lifts the belt, allowing the beam to turn freely.

On high-speed raschel and tricot machines, the lightweight tension rails are completely separate and can oscillate rapidly at high knitting speeds. Each warp beam shaft has a separate positive drive and warp-speed-to-machine-speed adjustment arrangement (Fig. 22.2). A machine-driven 'nut' and a warp driven 'bolt' are 'fast screwed' together, so that when the bolt turns at a different speed it moves sideways, moving a steel ring sideways as it transmits the drive between two opposed cones (3). The slowest beam speed is achieved with the ring on the smallest circumference of the lower (driver) cone transmitting to the largest circumference of

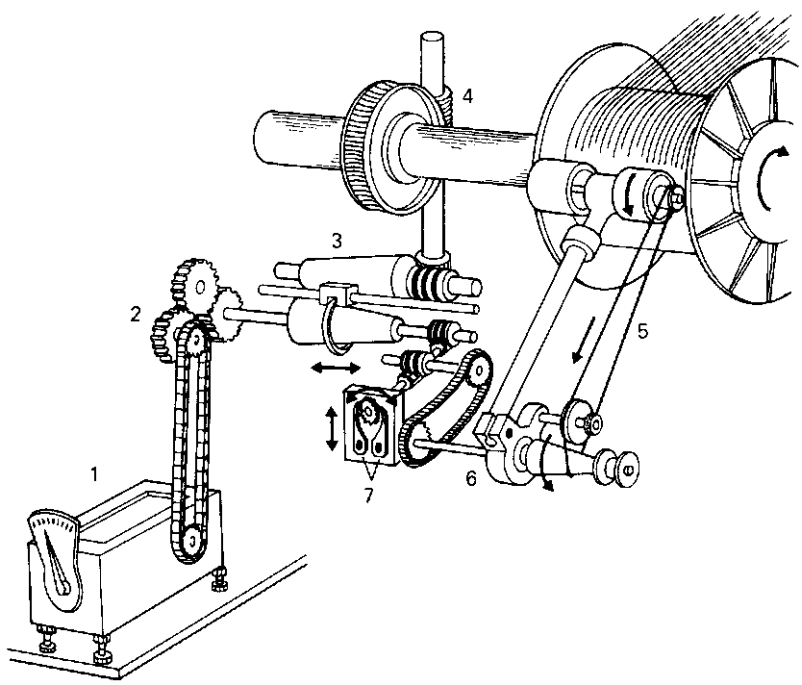


Fig. 22.2 Warp let-off regulator.

the higher (driven) cone. As the warp beam decreases, the ring is gradually progressed towards the largest circumference of the lower cone. The upper cone shaft drives a vertical shaft through bevel gearing and its worm (4), then drives the worm wheel of the warp beam shaft.

The ring can adjust in either direction, controlled by a two-way rackwheel, dependent upon either one of two side racking pawls on a slide (7) that is moved by the 'bolt'. The bolt spindle shaft (6) is driven by a belt (5), from a metering roller driven by contact with the warp of the beam surface. The 'nut' shaft is driven at a constant machine speed by the lower cone shaft.

A change gear system (1), positioned between the main machine drive shaft and the lower cone shaft, enables the gearing to be altered to produce different run-in rates. A clutch arrangement can be employed to alter the warp drive speed, if required for patterning purposes, or to disconnect the drive in interrupted warp let-off sequences.

Karl Mayer have now developed a computer control unit that, from fabric parameters inputted via a keyboard, automatically regulates the warp let-off of the machine. The computer receives the machine data pulses from encoder emitters on the warp beam shafts and the main machine shaft. Control data computed by the system is then transmitted as pulses to the individual warp beams to drive a series-wound d.c. motor and worm gearing [2].

22.4 Weft knitted fabric relaxation and shrinkage

Changes of dimension after knitting can create major problems in garments and fabrics, especially those produced from hydrophilic fibres such as wool and cotton. Articles knitted from synthetic thermoplastic fibres such as nylon and polyester can be heat-set to a shape or to dimensions that are retained unless the setting conditions are exceeded during washing and wearing.

In the case, of wool fibres, dimensional changes can be magnified by felting shrinkage. When untreated wool fibres are subjected to mechanical action in the presence of moisture, the elasticity and unidirectional scale structure of the fibres causes them to migrate and interlock into a progressively closer entanglement. Eventually, the density of the felted fabric restricts further fibre movement but, long before this point, the fabric properties (including appearance) will have been severely impaired. Fortunately, it is now possible to achieve a shrink/felting-resist finish in wool yarns during spinning so that, as with cotton yarns, little yarn shrinkage will occur during washing and wearing.

Knitted fabrics tend to change dimensions in width and length after being taken off the machine, even without yarn shrinkage, indicating a change of loop shape rather than of loop length. During knitting, the loop structure is subjected to a tension of approximately 15–25 grams per needle from sources such as the take-down mechanism and, in the case of fabric machines, the width stretcher board. Unless the structure is allowed to relax from its strained and distorted state at some time during manufacture, the more favourable conditions for fabric relaxation provided during washing and wearing will result in a change of dimensions, leading to customer dissatisfaction.

In theory, knitted loops move towards a three-dimensional configuration of minimum energy as the strains caused during production are allowed to be dissipated so that eventually, like all mechanical structures, a knitted fabric will reach a

stable state of equilibrium with its surroundings and will exhibit no further relaxation shrinkage.

Unfortunately, there are a number of states which may be achieved by different relaxation conditions, such as dry relaxation, steaming, static soaking, washing with agitation, centrifuging, and tumble drying. These states are difficult to identify, define, and reproduce because friction and the mechanical properties of the fibres, yarn, and structure can create high internal restrictive forces and thus inhibit recovery. However, agitation of the knitted structure whilst it is freely immersed in water appears to provide the most suitable conditions for relaxation to take place as it tends to overcome the frictional restraints imposed by the intermeshing of the structure.

A satisfactory relaxation technique applied during the finishing of cotton fabric in continuous length form is the compacting or compressive shrinkage technique. The fabric is passed between two sets of roller nips, with the feed rollers turning at a faster rate than the withdrawing rollers so that the courses are pushed towards each other and the fabric is positively encouraged to shrink in length. This technique can create difficulties with interlock fabric, which tends to buckle outwards three-dimensionally to produce ripples on the surface known technically as 'orange peel'.

22.5 Knitted fabric geometry

Early concepts of fabric geometry were based on models having maximum cover, so that adjacent loops touched each other with a constant ratio of stitch length to yarn diameter. Doyle [1] initiated a new approach to fabric geometry by deriving his concepts from an interpretation of experimental data. He showed that for a range of dry, relaxed, plain weft knitted fabrics, stitch density could be obtained using the formula $S = k_s/l^2$, where S is stitch density, l is loop length and k_s is a constant independent of yarn and machine variables.

Munden [1] took this work a stage further in 1959, with experimental results that indicated that the linear dimensions as well as the stitch density for a wide range of thoroughly relaxed, plain knitted, worsted yarn fabrics were uniquely determined by their stitch length and that all other variables influenced dimensions only by changing this variable.

He suggested that, in a relaxed condition, the dimensions of a plain knitted fabric are given by the formulae;

$$\text{cpi} = \frac{k_c}{l}$$

$$\text{wpi} = \frac{k_w}{l}$$

$$S = \frac{k_s}{l^2}$$

$$\frac{\text{cpi}}{\text{wpi}} = \frac{k_c}{k_w} = R$$

where R = loop shape factor.

His k values for plain worsted fabrics in dry and wet relaxed states were supplemented later by values proposed by Knapton for a 'fully relaxed' state that required agitation of the fabric. To achieve this state, it was suggested that the fabrics be wetted out for 24 hours in water at 40°C, briefly hydro-extracted to remove excess water, and tumble dried for 1 hour at 70°C.

The k values for the three states were as follows:

	Dry relaxed	Wet relaxed	Fully relaxed
k_s	19.0	21.6	23.1
k_c	5.0	5.3	5.5
k_w	3.8	4.1	4.2
R	1.3	1.3	1.3

It is now thus possible to pre-determine the fully-relaxed dimensions of shrink-resist (felting-resistant) treated plain knitted wool fabric before knitting. Similar experimental work has been carried out on the relaxed dimensions of rib, interlock and some double-jersey structures, as well as some structures knitted from cotton yarns. It is suggested that for complex structures, the loop should be replaced by the structural knit cell as the smallest repeating unit of the structure

Most theoretical models of knitted loops are based on an adaptation of a geometrical shape known as an 'elastica'. This is the shape that a slim body such as a uniform rod will assume when buckled by the action of forces. Munden has suggested a relaxed configuration so as to achieve the minimum bending of the yarn. The widest part of the loop coincides with the narrowest part of the feet above it. The theory is, however, complicated by such factors as the three-dimensional shape of loop structures, the jamming of loops, yarn friction, and the pre-setting of loop shapes. Fabric compactness when expressed as a factor is the ratio between the yarn diameter and its loop length in the structure. It is not an absolute value and does not refer to the area occupied by the loop, so the state of relaxation of the structure does not affect the ratio. It is thus possible to have two fabrics with the same compactness, one with a small loop length and fine yarn count and the other with a large loop length and heavy yarn count. Compactness is an important fabric property that influences durability, drape, handle, strength, abrasion resistance, dimensional stability and, in the case of wool, felting behaviour.

22.6 Tightness factor

Munden first suggested the use of a factor to indicate the relative tightness or looseness of plain weft knitted structure, to be used in a similar manner to that of the cover factor in the weaving industry. Originally termed the *cover factor* but now referred to as the *tightness factor* (TF), he defined it as the ratio of the area covered by the yarn in one loop to the area occupied by that loop.

The total area covered by yarn is: $S \times l \times d$, if l is loop length in mm and d is yarn diameter in mm (assuming the yarn to have a circular cross-section and the fabric to be theoretically flat and not three-dimensional).

Introducing the expression $S = k_s/l^2$, the area covering 1 cm^2 of fabric is:

$$\frac{k_s \times l \times d}{l^2 \times 100} = \frac{k_s \times d}{100l}$$

A correction for the four areas of each stitch covered by two thicknesses of yarn is then necessary, together with an expression of yarn diameter in terms of linear density.

When comparing structures of the same type and yarn in similar states of relaxation, it is possible to use the simplified formula;

$$\text{TF, } K = \sqrt{\frac{\text{tex}}{l}} \text{ in SI units}$$

For most plain fabrics knitted from worsted yarn the TF ranges between 1.4 and 1.5.

The TF in Imperial units is:

$$K = \frac{1}{l\sqrt{N}}$$

where N is the worsted count and l the loop length in inches.

22.7 Robbing back

Knapton and Munden suggested the phenomenon of 'robbing back' to be the reason why the measured loop length in a knitted structure is smaller than the theoretical loop length when calculated from the depth of the stitch cam setting, as well as the reason for fluctuations in input tension producing large variations in loop length.

As the needles descend the stitch cam, the tension required to pull yarn from the package increases rapidly and it becomes easier to rob back yarn in the opposite direction from the already-formed loops of needles further back that are then beginning to rise from their lowest (knock-over) position.

With reference to Fig. 22.3, it was suggested that, under the dynamic conditions of loop formation, yarn tension increases (according to Amontons' Law of Friction) as it passes over the knitting elements from point A. Robbing back occurs from needles on the other side of the stitch cam. The lowest point of tension is reached at B. The tension on the yarn is determined by the yarn/metal friction and the number of angles of yarn wrap. Thus, a two-fold increase in yarn/metal friction can cause a six-fold increase in maximum knitting tension.

As robbing back reduces tension, flat-bottom cams would obviously be undesirable and a cam angle shape of 60 degrees was preferable to one of 45 degrees because the number of yarn/metal contacts was reduced. It was further proposed that smoothly designed, non-linear camming with a pressure angle of greater than 50 degrees could provide smooth acceleration of needles for much higher knitting speeds. Camming of this type has been incorporated into some simple high-speed single-jersey machines but it requires adaptation for more complex and alterable cam arrangements.

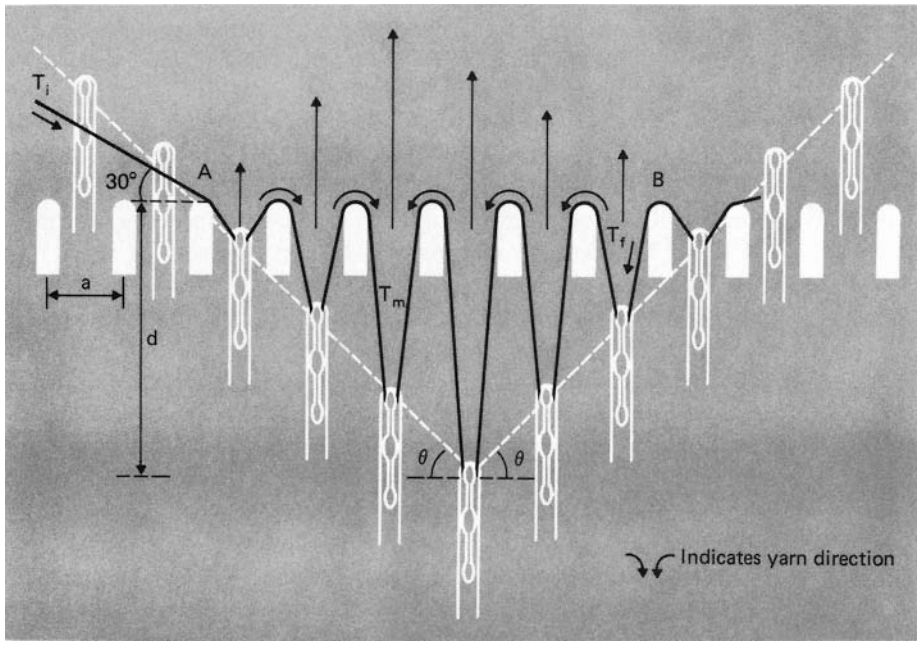


Fig. 22.3 Model of weft-knitted loop formation indicating the mechanism of 'robbing-back' and the build-up in yarn tensions acting on the needles.

22.8 Needle bounce and high-speed knitting

On circular knitting machines, higher productivity involves faster needle movements as a result of an increase in the number of knitting feeds and of machine rotational speeds. On fabric machines, the machine revolutions per minute have almost doubled and the number of feeders have increased twelve-fold over the past 25 years, so that as many as 4000 courses per minute can be knitted on some plain machines, whilst on some high-speed seamless hose machines the tangential speed of the needles can be more than 5 metres per second.

To achieve this productivity, research and development has been necessary into machine, cam and needle design. The horizontal cam track sections have been reduced to a minimum whilst needle hooks and latches have been reduced in size wherever possible in order to reduce the extent of the needle movement between the clearing and knock-over points.

'*Needle bounce*' is a major problem in high speed knitting. This is caused by the needle butt being suddenly checked by the impact of hitting the upper surface of the up-throw cam after it has accelerated away from the lowest point of the stitch cam. At this moment, inertia at the needle head may cause it to vibrate so violently that it may fracture; also the up-throw cam becomes pitted in this section. Needles passing though in the miss section are particularly affected as their butts contact the lowest part of the cam only and at a sharp angle that accelerates them downwards very rapidly. To reduce this effect, a separate cam is often used to guide these butts at a more gradual angle. The smoother profiles of non-linear camming help to reduce needle bounce and a braking effect is achieved on the butts by keeping the gap between the stitch and upthrow cams to a minimum. For this reason, on some hose

machines the up-throw cam is horizontally-adjustable in conjunction with the vertically-adjustable stitch cam.

The *Reutlingen Institute of Technology* has carried out a considerable amount of research into this problem and, as a result, a new design of latch needle with a meander-shape stem, a low smooth profile, and a shorter hook is now manufactured by *Groz-Beckert* for high-speed circular machines. The meander shape assists in the dissipation of the impact shock before it reaches the needle head, whose shape improves resistance to stress, as does the low profile, whilst the gently-shaped latch is designed to open more slowly and fully onto a cushioned position produced by a double saw cut.

22.9 The Cadratex unit

During take-down, a fabric tube changes its shape from a circular section at the needle bed level to a flattened form at the take-down rollers. To reduce creasing at this point, it is also spread outwards by a specially-shaped former placed inside the fabric tube. Unfortunately, the conventional system creates fabric distortion such as the bowing of striped designs and as the take-down tension is not equal around the needle bed, a higher take down tension is necessary to prevent tuck stitches occurring where tension is low during knock-over. The high take-down tension leads to a greater incidence of cuts and holes in the fabric, wear on the knitting elements, problems when knitting weaker yarns, and a greater length-wise deformation and consequent shrinkage after knitting.

The *Cadratex* unit [3] now commercially fitted to machines, has been developed by *ITF Maille* of France. It replaces the conventional spreader with two complementary elements, one inside and the other outside the fabric tube, that cause the tube to adopt a square cross-section and then a gradually flatter configuration but of constant circumference, right into the nip of the take-down rollers. The distance from any needle to the take-down rollers is the same so that wale and course density remains constant around the fabric tube and throughout its length whilst enabling a lower uniform take-down tension to be employed. During adjustment, the outer guide frame is maintained in an exact relationship with the inner frame.

Experiments by *ITF Maille* have demonstrated the possibility of employing a second pair of take-down rollers above the first so that the unit may be placed 12 inches (30 cm) higher than for a conventional stretcher board, thus enabling the fabric roll diameter to be increased from 19 to 32 inches (47 to 82 cm), increasing the potential fabric length in the roll by over 350 per cent.

22.10 Positive needle control

Positive guiding of needles through a cam system can be achieved on circular machines knitting plain unpatterned fabrics. In cam systems on jacquard machines, needle butts have to be switched to a choice of cam-tracks. At this point they cannot be under positive control so the cam-track is open. To reduce the chance of the unguided needle butt moving to a wrong position, needle movement is slowed down by using one or more of the following methods:

- Reducing the machine speed.
- Using friction needles, which also cause wear.
- Using flatter cam angles, which cause holes in the fabric.

With positive needle guidance, the needle has an additional control butt that is attached to a jack. This slides in a slot in the tail of the needle without causing unnecessary movement to the needle.

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23

Basic warp knitting principles

23.1 Construction of warp knitted fabrics

In a warp knitted structure, all ends supplied from the same warp sheet normally have identical lapping movements because each is lapped by a guide attached to the same guide bar (Fig. 23.1). Beams (Fig. 23.2) supply the warp sheets in parallel form to the guide bars, whose pattern control determines the timing and configuration of the lapping movements in the form of overlaps and underlaps. The needles intermesh the new overlaps through the old overlaps to form the intermeshed loop structure.

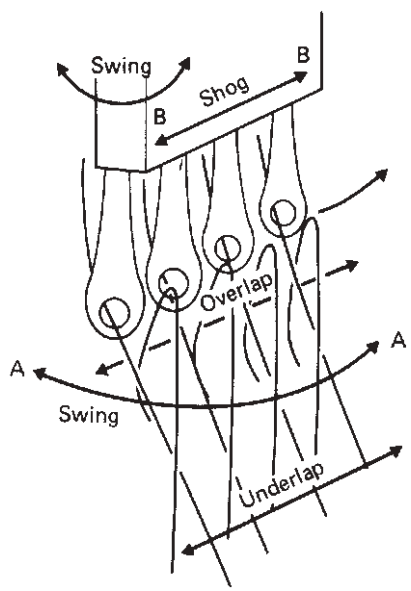


Fig. 23.1 Guide bar lapping movement.

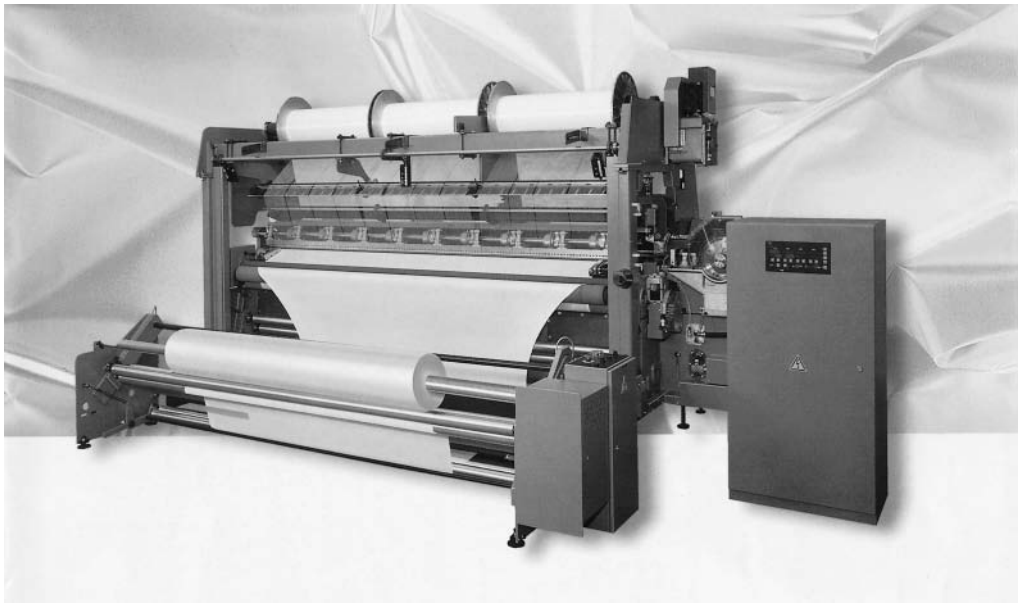


Fig. 23.2 Tricot machine HKS 2-3 [Karl Mayer].

23.2 The warp beams

To ensure uniform conditions of warp feed and tension, the yarn ends are supplied from flanged beams attached to shafts that turn to unwind the warp sheet in parallel formation. For convenience of handling, a number of beams may be attached to a beam shaft to achieve the full width of the warp sheet; for example, a warp sheet 84 inches (213 cm) wide might be supplied from a full-width beam, from two beams each 42 inches (106 cm) wide, or from four beams each 21 inches (53 cm) wide.

23.3 The guide bar

Each guide bar is normally supplied with a warp sheet from its own beam shaft to suit its requirements of threading and rate of warp feed for its particular lapping movement. Occasionally, two partly-threaded guide bars may be supplied from the same fully-threaded beam, provided they make lapping movements of the same extent to each other whilst moving in opposite directions. The minimum number of guide bars and warp sheets for commercially acceptable structures is usually two.

23.4 The guides

Warp guides are thin metal plates drilled with a hole in their lower end through which a warp end may be threaded if required. They are held together at their upper end as a single unit in a metal lead and are spaced to the same gauge as the needles.

The leads are attached to a guide bar so that the guides hang down from it, with each one occupying a position, when at rest, midway between two adjacent needles.

In this position, the warp thread cannot be received by the needles and it will merely produce a straight vertical float. The needles only receive the warp thread in their hooks if the guide bar overlaps across their hooks, or across their backs when the guide bar underlaps. All guides in a conventional guide bar produce an identical lapping movement at the same time and therefore have identical requirements of warp tension and rate of feed, although the threads may differ in colour or composition from each other.

23.5 Single needle bar structures

In the following description, for purposes of simplicity it is assumed that only one needle bar is being employed. Essentially, the principles remain the same for double needle bar machines which are described later in the book (Chapter 29).

When the needle bar is observed in plan view from above, it can be seen that the guides of a guide bar are required to execute a compound movement composed of two separately derived motions (Figures 23.1 and 23.3):

A *swinging motion* (A-A) and a *shogging movement* (B-B) act at right-angles to each other in order for their threads to form overlap and underlap paths that combine as one thread path around the needles.

The swinging motion is in an arc from the front of the machine to the hook side and a later return swing. It occurs between adjacent needles and is a fixed, collective, and automatic action for all the guide bars as they pivot on a common rocker-shaft. It is derived, in a similar manner to the needle and other element bar motions, from the main cam-shaft and is adapted via levers, pivots and linkages. The two swinging movements produce the two side limbs when combined with the overlap

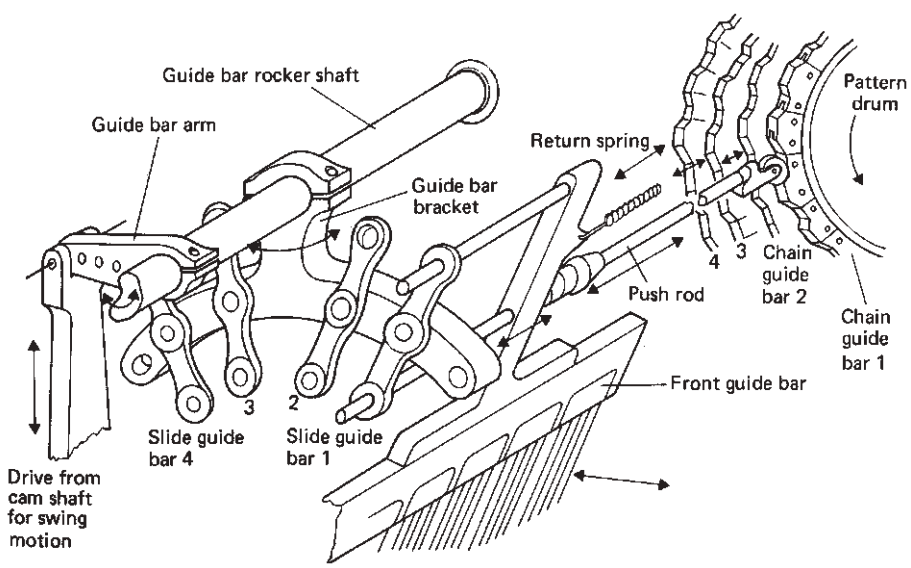


Fig. 23.3 Guide bar swinging and shogging mechanism [Reprinted by permission of *Knitting Times*, official publication of the NSKA in the USA].

shog. When the overlap is omitted, the guides swing idly between adjacent needles and achieve no useful purpose.

On some machines, such as mechanical jacquard raschels and some multi guide bar and double needle bar machines, it is more convenient to swing the needle bar and trick-plate between the guide bars after they have shogged for the overlap and underlap. This considerably reduces the complexity of movement of the heavy guide bar assembly to only that necessary for shogging and thus increases the speed and efficiency of the machine.

The sideways shogging movement that occurs parallel to the needle bar produces the underlaps and overlaps. The occurrence, timing, direction and extent of each shog is separately controlled for each guide bar by its pattern chain links or pattern wheel attached to a horizontal pattern shaft driven from the main cam-shaft but set at right angles to it at one end of the machine. The guide bars are shogged independently sideways, parallel to each other, along linear bearings that support them in the swinging frame assembly, which is keyed to the guide bar rocker-shaft.

A shogging movement can occur when the guides have swung clear of the needle heads on the back or front of the machine. On the hook side it will produce an overlap and on the side remote from the hooks it will produce an underlap. The timing of the shog during the 360 degrees of the main cam-shaft revolution will thus determine whether an overlap or underlap is produced.

23.6 The pattern mechanism

The shogging movement is initiated by varying the radius of the continuously-turning pattern shaft, either in the form of different heights of pattern links that pass over a pattern drum attached to the shaft, or in the form of carefully-shaped solid metal circular cams, termed pattern wheels, attached to it (Fig. 23.3).

An increase in height from one link to the next produces a thrust against the end of the guide bar, shogging it positively into the machine; a decrease will produce a negative shog towards the pattern shaft as the result of the action of a return spring. A constant height will produce no shog and the guide bar will continue to swing through the same needle space. The periphery of the pattern wheel or chain track is scanned by a roller that is linked by a flexible, ball-jointed push-rod to the end of a guide bar. The underside of the rod near the roller is supported on a slide that moves freely on a metal surface as shogging occurs.

The drive for the pattern shaft is obtained from the main cam-shaft, via bevel gears and a universal joint, to a worm that drives the worm-wheel of the pattern shaft. The ratio of cam-shaft speed to pattern shaft speed is usually 16:1; therefore, 1/16th of the surface of a pattern wheel would represent one course or knitting cycle.

Pattern wheels provide accuracy and smooth running at high speeds, but they are only economical for long production runs of the common, simple repeat structures. For fancy structures, frequent changes of pattern, and long pattern repeats, the shogging movements are obtained by assembling a chain of re-usable pattern links.

23.7 The chain links

In plan view, the identically Y-shaped chain links are similar in appearance to a tuning fork with the fork end leading. The tail of the preceding link fits into the fork

of the succeeding link. The links are held together by pins that are pushed through holes in the sides of the fork and tail. The pins pass through all the tracks and chains, and the ends fit into grooves in the serrated flanges of the pattern drum so that as the drum turns, the chain links are advanced in unison in a correct timing relationship.

Chain links require accurate grinding at the fork and/or the tail if they are higher than the preceding or succeeding link, so that a smooth transition and an accurately-timed shog occur (the ground ends of two successive links must never be adjacent to each other). Too sharp a gradient will produce an early-timed shog and too gradual a gradient a late-timed shog for the knitting sequence. There are four types of link: plain unground, fork ground, tail ground and fork and tail ground.

With *direct transmission* of the shogging movement from chain links to guide bar, as described, the exact distance shogged is the difference in heights between the two successive links. This method is employed on most high-speed machines and on the ground guide bars of many multi-bar raschels.

A second method, *indirect transmission*, magnifies or adapts the thrust derived from the links by transmitting it through a pivoted lever whose leverage can be adjusted, thus altering the throw of the shog. This is a versatile method used on the pattern guides of multi-bar machines that enables links of one gauge to be employed for a range of machine gauges and also for arrangements that economise on chain links.

Chain link numbering commences with '0' height and every chain sequence must contain at least one of these '0' links. When the guide bar is on this link it will be in its nearest position to the patterning mechanism during that particular lapping movement. Tricot links are numbered 0, 1, 2, 3, 4, 5, etc. With direct shogging, each successive number is one needle space higher than the previous link. On a 28-gauge tricot machine, a '2' link will be 1/28th inch higher than a '1' link, which itself will be 1/28th inch higher than a '0' link. If a '1' link is placed after a '0' link, a one-needle space shog away from the pattern mechanism will be produced. If a '0' link is placed after a '3' link, a three-needle space shog towards the patterning mechanism will occur. If two links of the same height are placed next to each other, for example a '3' followed by a '3', no shog will be produced and the guides will remain between the same needle spaces.

It must be understood that the height of a link, for example '0', does not represent a fixed position between two needle spaces because all the guides in the same guide bar will have been positioned by the same '0' link, but each will be between a different pair of needles across the knitting width.

For any guide, a '0' link is the nearest that guide will approach towards the pattern mechanism for that particular lapping movement repeat. Likewise, two guides in different guide bars may occupy the same space between two adjacent needles and yet be on different heights of links at that point.

A chain notation is a list, in correct sequence of chain link numbers, spaced into knitting cycles, for each guide bar necessary to produce a particular fabric structure repeat (Fig. 23.4D). The difference between the first two links is normally the overlap. It must be remembered that the links are joined together in a closed loop, with the starting link for each guide bar joined to its last link. For this reason, underlap movements towards left and right tend to balance each other. It does not matter from which direction the chain numbering takes place (left or right) providing it takes place consistently from the same side for all guide bars in a particular structural repeat.

The number of links per course is fixed for each machine. A minimum of two is usually required, with the underlap occurring between the second link of one course and the first link of the next. On tricot machines, a third intermediate link is often used so that the underlap is also spread between the second and third links, giving it more time and coinciding more closely with the knitting cycle requirements.

23.8 The electronic guide bar control system

Both pattern wheels and chain links are ground to suit the pattern requirements of a specific fabric. When a new pattern is required, it is necessary to assemble a new pattern chain and prepare a new set of pattern wheels.

To overcome this problem, the *Karl Mayer* EL system uses a separate linear motor to directly shog each guide bar. The sensitive shogging movement is built-up in 1/100 mm increments by the patterning computer. Mechanical movement, and therefore inertia, is reduced, resulting in 30 per cent higher production speeds compared to those with profiled chain links. Direct drive of the guide bar by linear drive enables a 12 needle shog in E 28 gauge to be obtained, and the length of the pattern repeat no longer limits the machine speed.

23.9 The development of lapping diagrams and chain notations

Lapping diagrams are drawn around horizontal rows of points that represent needles in plan view, usually assuming the pattern mechanism to be on the right. As the guides position themselves in the spaces between needles, the positions between the vertical columns of points can be given chain link numbers commencing with the '0' position, which is to the right of the right-hand column of points.

Provided the direction and extent of the overlaps are correctly indicated in the lapping diagram and chain notation, the underlaps will always be correctly positioned as each extends from the end of one overlap to the start of the next.

Figure 23.4A represents a diagrammatic plan view of a two-course repeat sequence. S_1 and S_2 represent the swinging motions and O and U represent the overlap and underlap shogs at each course.

In the lapping diagram (Fig. 23.4C), the first overlap will be drawn in a curve over a point from space '1' to space '0' and the second from space '2' to space '3'. The lapping diagram is completed by joining the overlaps to each other with underlaps and the chain is notated as 1-0/2-3/ where-represents an overlap and / an underlap.

The shogging movements are produced by the transition from one link to the next, whereas the swinging motions occur whilst the push-rod roller of the guide bar is in the centre, so that no shog is produced.

23.10 Single- or double-needle overlaps

Overlap movements are normally across only one needle space because two-needle overlaps cause both the warp thread and the needles to be subjected to the severe

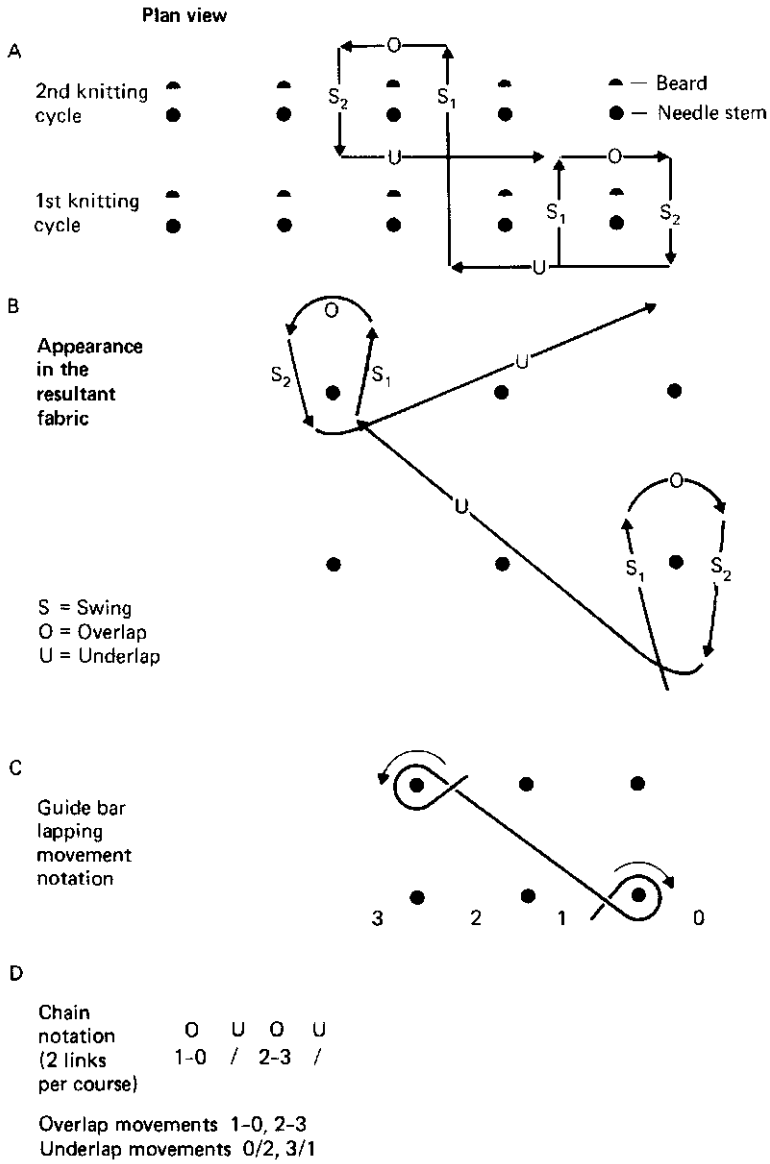


Fig. 23.4 Warp knitting lapping and chain notation.

strain of two simultaneous adjacent knock-over actions. In addition, different tensions on the two loops in the structure adversely affect their appearance. The underlap between the double overlaps has the appearance of a sinker loop. Only in a few raschel fabric structures is the double-needle overlap used and there the needles are less easily deflected than on tricot machines, and there are no knock-over sinkers over which to draw the loops. A single, full-threaded guide bar making a double-needle overlap will cause each needle to receive two overlapped threads at that course.

23.11 The five basic overlap/underlap variations

All guide bar lapping movements are composed of one or more of the following lapping variations (Fig. 23.5):

1 An overlap followed by an underlap in the opposite direction (closed lap) (Fig. 23.5a).
2 An overlap followed by an underlap in the same direction (open lap) (Fig. 23.5b).
3 Only overlaps and no underlaps (open laps) (Fig. 23.5c).
4 Only underlaps and no overlaps (laying-in) (Fig. 23.5d).
5 Neither overlaps nor underlaps (miss-lapping) (Fig. 23.5e).

Movements 4 and 5 require the overlaps of another guide bar in front in order to hold them into the structure.

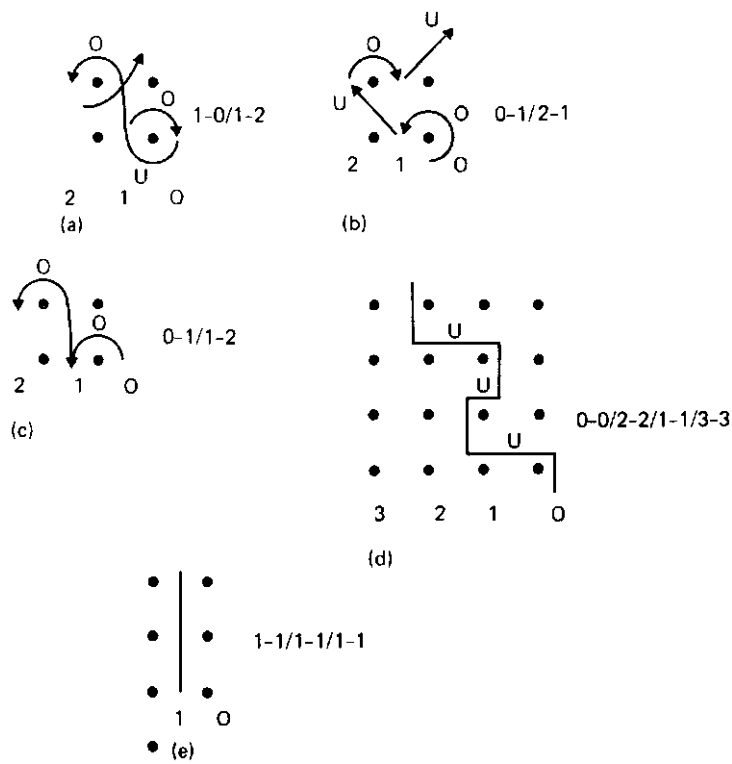


Fig. 23.5 Overlap/underlap variations.

23.12 The direction of lapping at successive courses

When using either open or closed laps there are three possible arrangements of lapping at successive courses, which may be used alone or in combination:

1 *The pillar stitch*. In the pillar or chain stitch, the same guide always overlaps the same needle. This lapping movement will produce chains of loops in uncon-

nected wales, which must be connected together by the underlaps of a second guide bar.

Generally, pillar stitches are made by front guide bars, either to produce vertical stripe effects or to hold the inlays of other guide bars into the structure.

Open-lap pillar stitches are commonly used in warp knitting. They can be unroved from the end knitted last.

Closed-lap pillar stitches are employed on crochet machines because the lapping movement is simple to achieve and is necessary when using self-closing carbine needles, which must always be fed with yarn from the same side (Fig. 23.6).

2 *Balanced advance and return lapping in two courses* (23.5a). Many tricot structures are based on this type of lapping movement. Its extent may be described by indicating the number of needles underlapped, followed by the number of needles overlapped (usually one). With a fully-threaded guide bar every one-needle space increase in the underlap movement will cause an extra warp thread from that bar to cross between each wale.

Tricot lapping or 1×1 is the simplest of these movements, producing overlaps in alternate wales at alternate courses with only one thread crossing between adjacent wales. Two threads will cross between wales with a 2×1 or *cord lap*, three threads with a 3×1 or *satin lap*, four threads with a 4×1 or *velvet lap*, and so on.

Each increase in the extent of the underlap tends to make the structure stronger, more opaque and heavier. The increasing float of the underlap has a

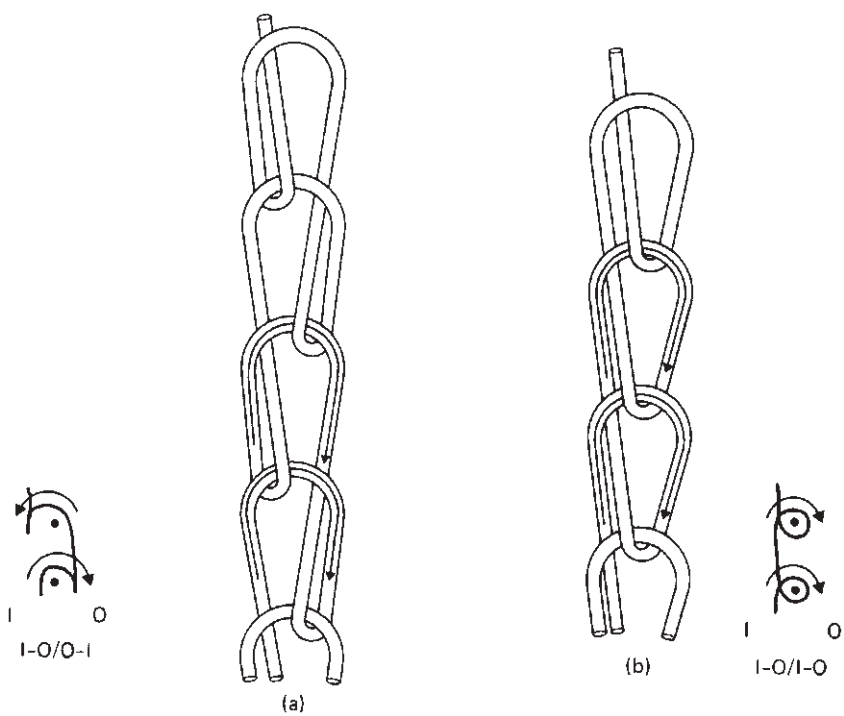


Fig. 23.6 Open and closed lap pillar stitches.

more horizontal appearance, whilst overlaps produced by the same thread will be separated from each other at successive courses by an extra wale in width.

3 *Atlas lapping* (Fig. 23.7). This is a movement where the guide bar laps progressively in the same direction for a minimum of two consecutive courses, normally followed by an identical lapping movement in the opposite direction. Usually, the progressive lapping is in the form of open laps and the change of direction course is in the form of a closed lap, but these roles may be reversed. From the change of direction course, tension tends to cause the heads of the loops to incline in the opposite direction to that of the previous lapping progression. The change of direction course is normally tighter and the return progression courses cause reflected light to produce a faint, transverse shadow, stripe effect.

The underlaps on the technical back give the appearance of sinker loops in a spirally weft knitted structure. With a single guide bar having different coloured warp threads, zigzag effects can be produced. This is sometimes termed *single atlas* or *vandyke*. More elaborate geometrical patterns can be achieved with patterned warps using atlas lapping on two or more guide bars. Atlas is also the base for many simplex and all Milanese fabrics.

Cohesive single guide bar structures (Fig. 23.8a, b) may be knitted using a single, fully-threaded guide bar producing underlaps and overlaps. However, these are seldom commercially viable because of their flimsiness, low strength, lack of stability, poor covering power, distortion caused by loop inclination, and limited patterning potential.

Loop inclination is caused by the underlaps of the guide bar entering and leaving the head of the needle loop from the same side and thus producing an unbalanced tension from that direction (unlike weft knitting where the sinker loops enter and leave from opposite sides of the head of the loop).

A more balanced tension is achieved by having two sets of warp threads underlapping in opposition to each other so that the underlaps of each enter and leave

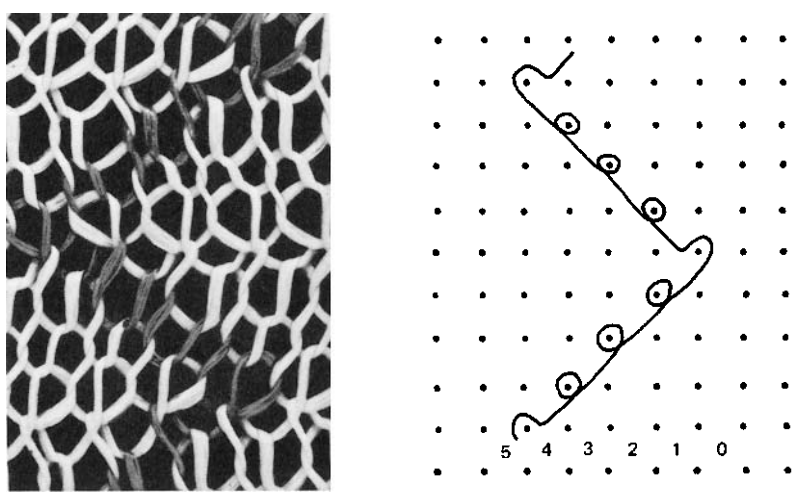
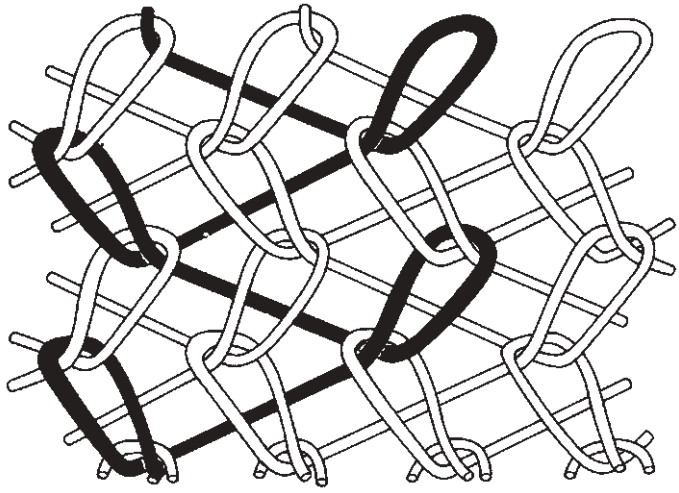
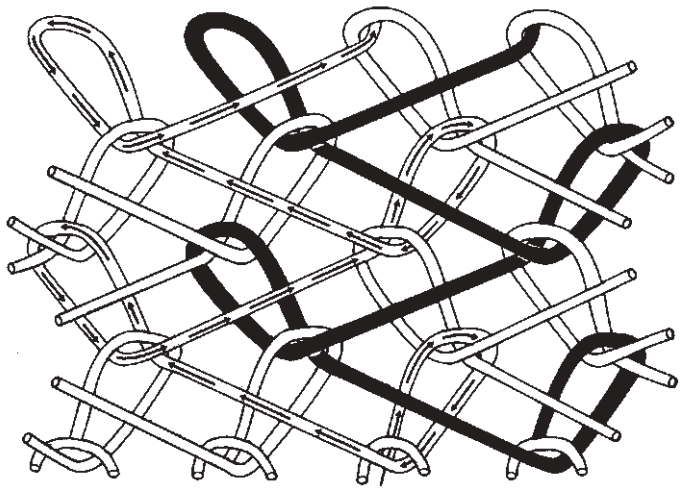


Fig. 23.7 Atlas lapping.



(a) Technical Face



(b) Technical Back

Fig. 23.8 Face and back of single guide bar warp knitted fabric.

from opposite sides of the head of the loop. For these reasons, the simplest warp knitted structures are usually composed of two sets of warp threads, and most machines have a minimum of two guide bars.

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24

Classes of warp knitting machines

24.1 Characteristics of tricot and raschel machines

The two major classes of warp knitting machines are *tricots* and *raschels* (NB: In some countries tricot machines are termed *automatic warp knitting machines*). In the past, tricot machines mainly employed *bearded needles* with a presser bar and raschels used *latch needles* together with a latch wire or blade. Now, despite widespread use of the compound needle (Fig. 23.1), there are still distinctive differences between the two types.

24.2 The tricot machine

Tricot machines (Figures 24.1 and 24.2) have a gauge expressed in needles per inch (E) and chain link numbering 0, 1, 2, 3, 4, etc., generally with three links per course. Their sinkers, which are joined to each other at the front and back, never move clear of the needles as they combine the functions of holding-down, knocking-over, and supporting the fabric loops.

The fabric is drawn-away towards the batching roller almost at right angles to the needle bar. The warp beams are accommodated in an inclined arc towards the back of the machine, with the top beam supplying the front guide bar and the bottom beam supplying the back guide bar. The warp sheets pass over the top of the guide rocker-shaft to their tension rails situated at the front of the machine. The machines have a simple construction and a short yarn path from the beams.

Mechanical attention to the knitting elements is carried out at the front of the machine as the warp beams prevent access to the back. As all the warp sheets are drawn over the rocker-shaft to the front of the machine it is easier to thread up the guide bars commencing with the back bar; otherwise the front warp will obscure this operation. The guide bars are therefore numbered from the back towards the front of the machine because of this threading sequence.

The conventional tricot beam arrangement generally restricts the maximum

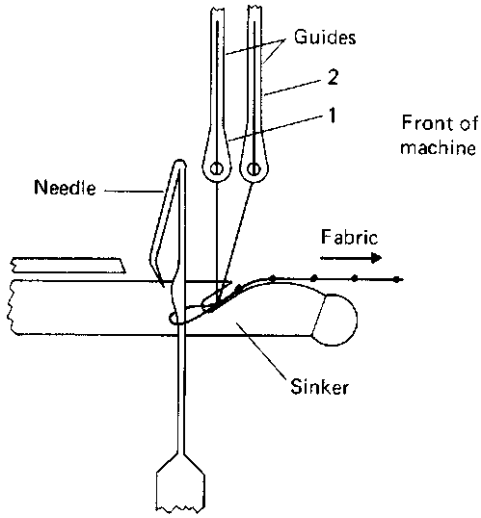


Fig. 24.1 Knitting elements in a bearded needle tricot machine.

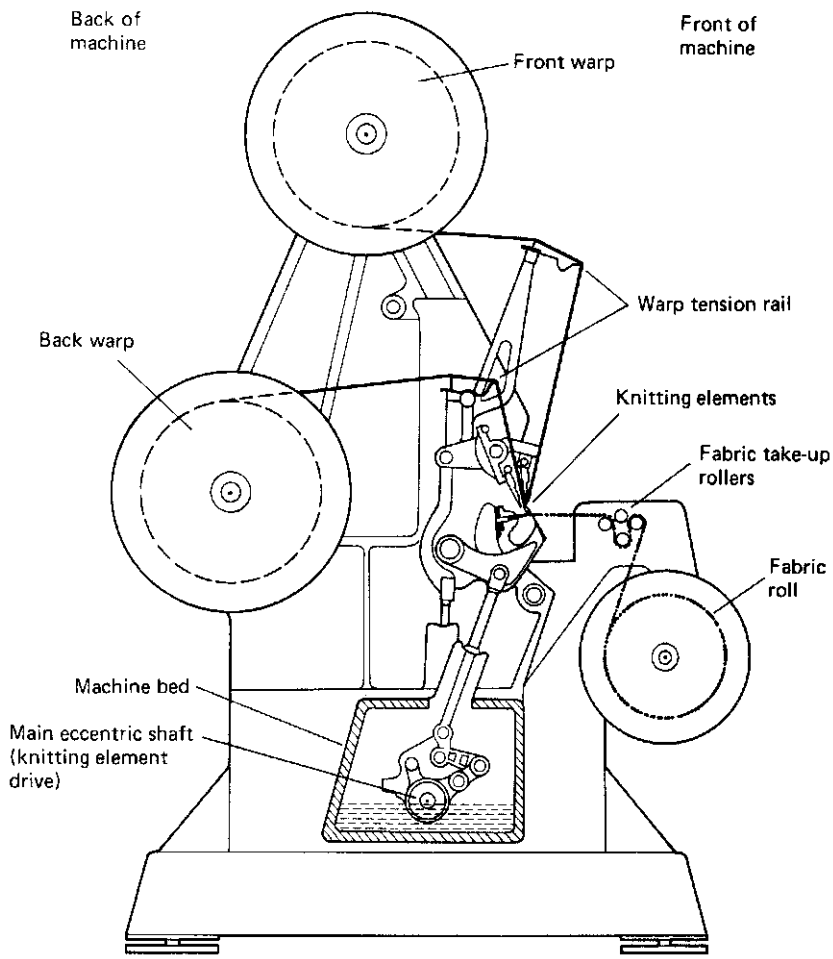


Fig. 24.2 Cross-section of a bearded needle tricot machine.

number of beams and guide bars to four, but this is not of major importance as the majority of tricot machines employ only two guide bars.

The small angle of fabric take-away and the type of knitting action produce a gentle and low tension on the structure being knitted. This is ideal for the high-speed production of simple, fine-gauge (28–44 npi), close-knitted, plain-and-patterned structures, particularly for lingerie and apparel, especially using two guide bar structures with both bars overlapping and underlapping.

In the past, the two guide bar *tricot* or *locknit* machine proved most popular in E 28 and E 32 gauge, with knitting widths of 84 and 168 inches (213 and 426 cm) using 40-denier nylon. It is possible to knit from 10-denier nylon up to 1/20's cotton count. Machine gauges can range from E 10 for coarse staple fibre yarns to E 20–E 24 for textured yarn fabrics and E 36–E 44 gauge for fine fabrics, in knitting widths up to 260 inches (660 cm).

The needles, like the sinkers and guides, may be cast in leads or they may be individually cranked to fit into the needle bar.

24.2.1 The knitting cycle of the bearded needle tricot machine

Figure 24.3 illustrates the knitting cycle of the bearded needle tricot machine:

1 *The rest position* (a). The needles have risen to 2/3 of their full height from knock-over and have their beards towards the back of the machine. The presser

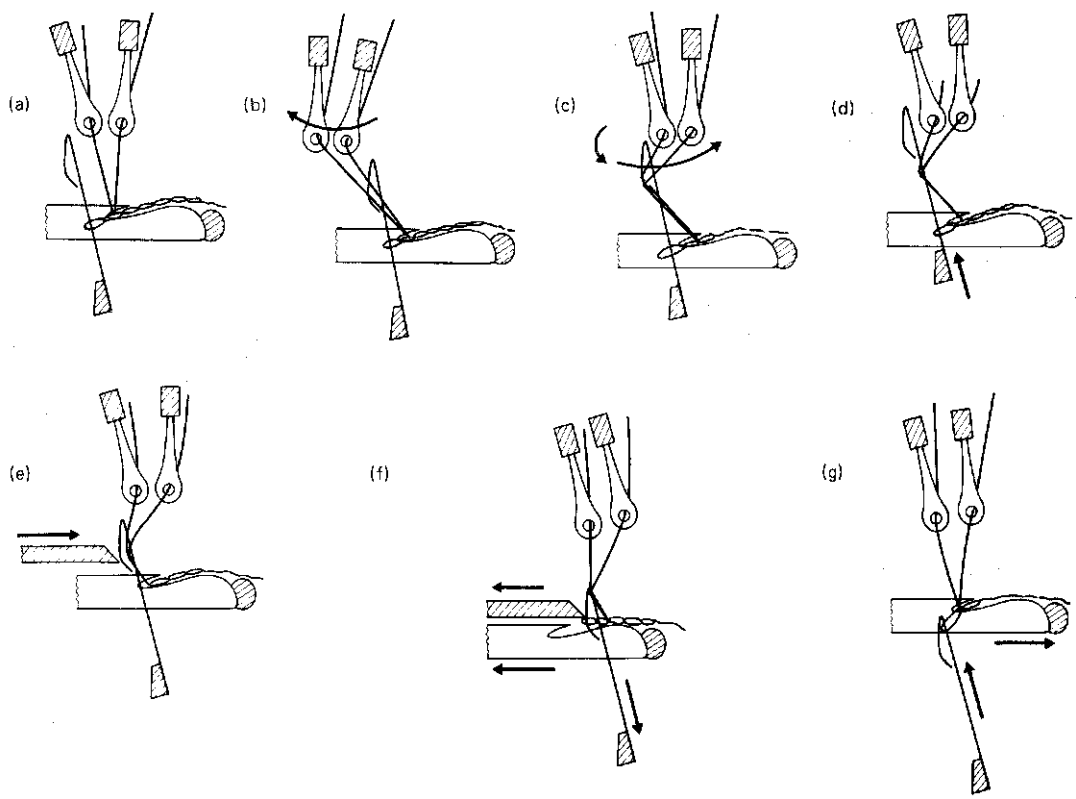


Fig. 24.3 Knitting cycle of a bearded needle tricot machine.

is withdrawn and the guides are at the front of the machine with the sinkers forward, holding the old overlaps in their throats so that they are maintained at the correct height on the needle stems.

2 *Backward swing and overlap shog* (b, c). After swinging through the needles to the beard side, the guides are overlapped across the beards, usually by one needle space in opposite directions.

3 *The return swing and second rise* (c, d). As the guides swing to the front, the needles rise to their full height so that the newly-formed overlaps slip off the beards onto the stems above the old overlaps. This arrangement reduces the amount of guide-bar swing necessary and therefore the time required.

4 *Pressing* (e). The needle bar descends so that the open beards cover the new overlaps. There is a slight pause whilst the presser advances and closes the beards.

5 *Landing* (f). As the sinkers withdraw, the upward curve of their bellies lands the old overlaps onto the closed beards.

6 *Knock-over and underlap shog* (g). The presser is withdrawn and the continued descent of the needle bar causes the old overlaps to be knocked-over as the heads of the needles descend below the upper surface of the sinker bellies. The underlap shog which can occur at any time between pressing and knock-over usually occurs in opposite directions on the two guide bars.

7 *The sinkers now move forward* to hold down the fabric loops and push them away from the ascending needles, which are rising to the rest position.

24.3 The raschel machine

24.3.1 The history and development of the raschel machine

In 1855, German warp knitters in Apolda used warp rib machines made by *Redgate* of Leicester to knit lace stoles which they sold under the name of *Raschel Felix*, the famous French actress [1], so that when *Wilhelm Barfuss* began to build his latch needle rib machines, he named them *raschel* machines [2]. Originally, two vertical needle bars arranged back-to-back, mid-way between each other, were employed for producing simulated rib fabrics. In 1914, when the needle bars were placed directly back-to-back, only even-numbered chain links were required.

Until the mid-fifties, the raschel industry tended to be small, employing slow, cumbersome but versatile coarse-gauge universal raschels. These had two needle bars, one of which could be removed or replaced with plush points, changeable cams and patterning mechanisms that might include fall plate, crepe and fringing motions, chain switching, and possibly weft insertion or jacquard.

The development of modern specific-purpose raschels dates from 1956, when a twelve guide bar raschel machine led to the rise of the raschel lace industry [3]. There are now single needle bar raschels for simple and multi-guide bar dress and household fabrics, elastic laces, trimmings and curtain nets; high-speed standard raschels for simple structures such as suitings; versatile multi-purpose raschels for fancy fabrics, weft insertion; and jacquard raschels and double needle bar raschels for plush, tubular articles, scarves and string vests.

There is an increasing demand for finer, lighter fabrics with minimum elongation and transparency. Warp knitting is able to meet this requirement by producing fabrics weighing much less than 100 g/m^2 with very little edge-curling.

The finest gauge single bed raschel is E 40. It can knit lightweight foundation and swimwear at speeds between 1900 and 2200 rpm in a yarn count of approximately 80 dtex.

24.3.2 Description of the raschel machine

Raschel machines (Figures 24.4 and 24.5) originally had a gauge expressed in needles per 2 inches (5 cm), so that, for example, a 36-gauge raschel would have eighteen needles per inch. Now, the standard E gauge (needles per inch) is generally used. There is a wide gauge range, from E 1 to E 32.

Their chain links are usually numbered in even numbers, 0, 2, 4, 6 etc., generally with two links per course. Raschel sinkers perform only the function of holding down the loops whilst the needles rise. They are not joined together by a lead across their ends nearest to the needle bar so they can move away clear of the needles, towards the back of the machine, for the rest of the knitting cycle. The needle trick-plate verge acts as a fabric support ledge and knock-over surface.

The fabric is drawn downwards from the needles, almost parallel to the needle bar, at an angle of 120–160 degrees, by a series of take-down rollers. This creates a high take-up tension, particularly suitable for open fabric structures such as laces and nets.

The warp beams are arranged above the needle bar, centred over the rocker-shaft, so that warp sheets pass down to the guide bars on either side of it. The beams are placed above the machine so that it is accessible at the front for fabric inspection and at the back for mechanical attention to the knitting elements. The guide bars are threaded, commencing with the middle bars and working outwards from either side of the rocker-shaft. They are numbered from the front of the machine.

With the raschel arrangement, there is accommodation for at least four 32-inch diameter beams or large numbers of small diameter pattern bars. The accessibility of the raschel machine, its simple knitting action, and its strong and efficient

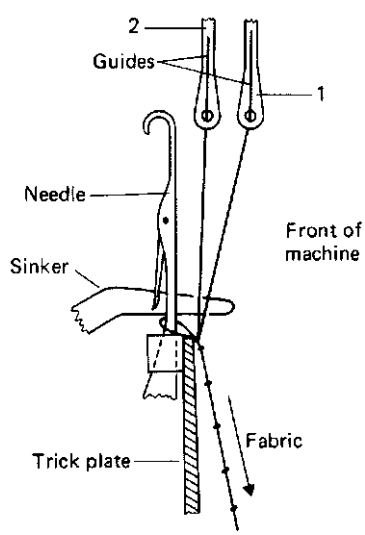


Fig. 24.4 Knitting elements in a latch needle raschel machine.

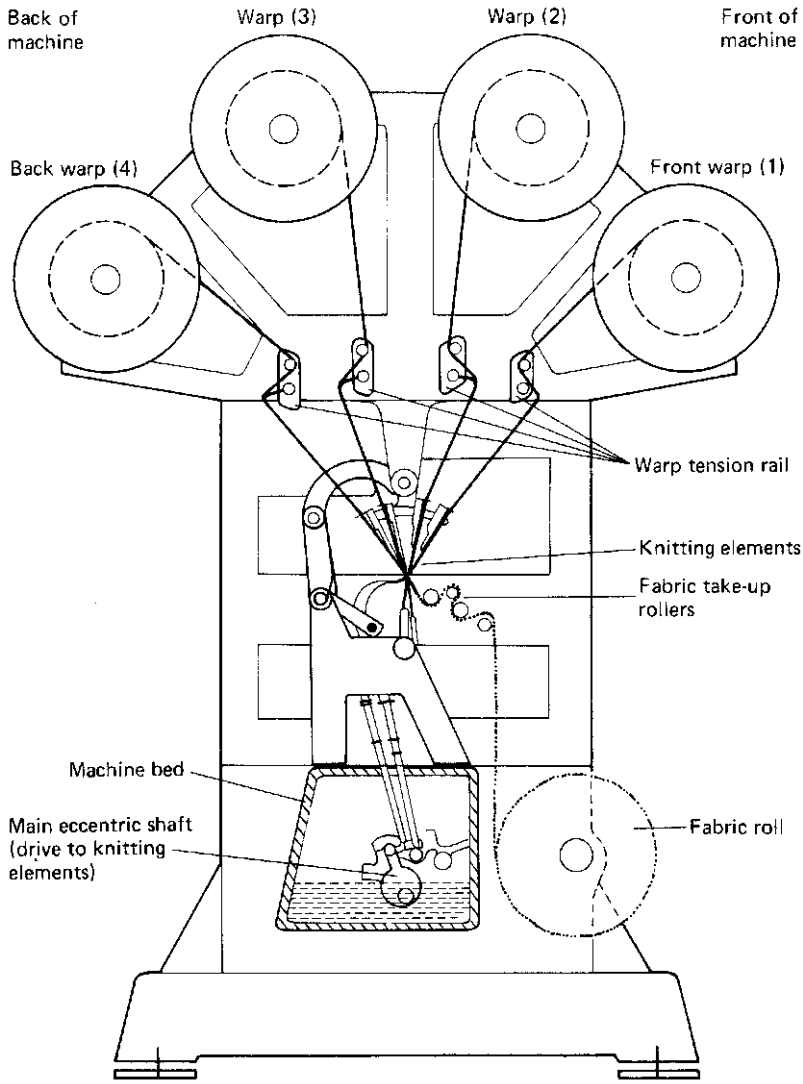


Fig. 24.5 Cross-section of a latch needle raschel machine [Reprinted by permission of *Knitting Times*, official publication of the NKSA in the USA].

take-down tension make it particularly suitable for the production of coarse gauge open-work structures employing pillar stitch, inlay lapping variations and partly-threaded guide bars. These are difficult to knit and hold down with the tricot arrangement of sinkers. Additional warp threads may be supplied at the selvedges to ensure that these needles knit fabric overlaps, otherwise a progressive press-off of loops may occur.

24.3.3 The knitting action of the single needle bar raschel machine

Raschel needles tend to have longer latches than weft knitting machine needles, to ensure that the wrapped yarns of the overlap goes onto and not below the open latch (Fig. 24.6). There is a trick-plate extending the full width of the machine, whose

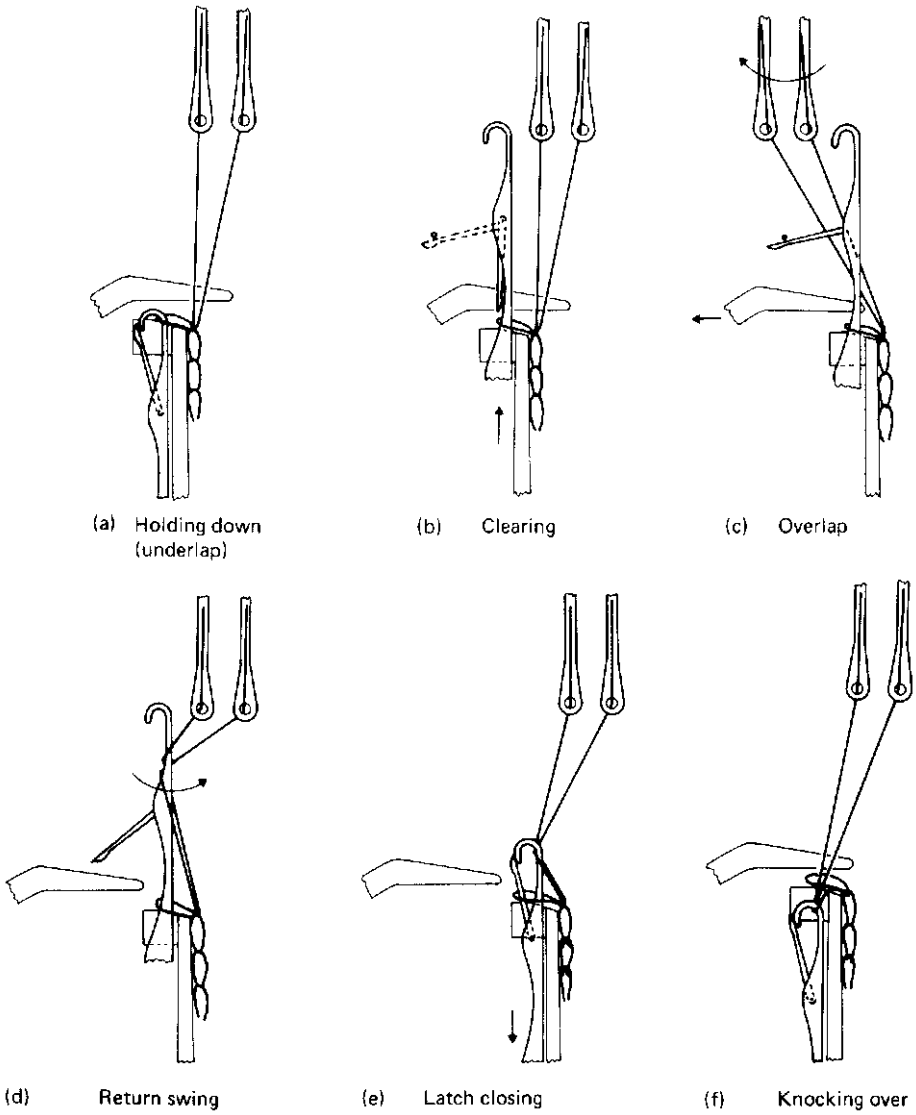


Fig. 24.6 Knitting action of a single needle bar latch needle raschel machine.

walls preserve the needle spacing and whose verge provides an edge for a clean knock-over. Holding-down sinkers that are thin blades, unleaded at their forward edges, move in a horizontal plain over the top of the trick-plate.

1 *Holding down*. The guide bars are at the front of the machine, completing their underlap shog. The sinker bar moves forward to hold the fabric down whilst the needle bar starts to rise from knock-over.
2 *Clearing*. As the needle bar rises to its full height, the old overlaps slip down onto the stems after opening the latches, which are prevented from flicking closed by latch wires. The sinker bar then starts to withdraw to allow the guide bars to overlap.

3 *Overlap*. The guide bars swing to the back of the machine and then shog for the overlap.
4 *Return swing*. As the guide bars swing to the front, the warp threads wrap into the needle hooks.
5 *Latch closing*. The needle bar descends so that the old overlaps contact and close the latches, trapping the new overlaps inside. The sinker bar now starts to move forward.
6 *Knocking-over and underlap*. As the needle bar continues to descend, its head passes below the surface of the trick-plate, drawing the new overlap through the old overlap which is cast-off and as the sinkers advance over the trick-plate, the underlap shog of the guide bar is commenced.

24.4 The compound-needle warp knitting machine

After its introduction in 1946, the two guide bar British-built FNF tricot machine with its tubular compound needles (Section 3.16) became, for 10 years, the pacemaker of the industry, with its speed of 1000 courses per minute being more than twice that of contemporary bearded needle machines. It also incorporated many new features such as double eccentric element drive, positive warp let-off, light spring warp tension rails, and carefully-balanced machine parts. However, it required precise setting-up, its pattern scope was limited, and needles and other parts were expensive.

In 1965 the *FNF Company* ceased production, having failed to improve their machine in the face of increasing competition from high-speed bearded needle tricots with single eccentric drives built by the West German companies of *Liba* and *Karl Mayer*. The East German *Kokett* concern, however, continued its production of compound needle tricot machines.

In 1967 *Liba*, in a bid to increase production speeds, introduced a new design open-stem compound needle into both raschel and tricot machinery and by the mid 1970s *Karl Mayer* was pursuing a similar policy.

Now, the compound needle is employed in most high-speed warp knitting machines, excluding double needle bar raschels. Its short, simple action enables 3300 cpm to be achieved without the problems of metal fatigue and loop distortion associated with latch and bearded needles.

The open stem needle is simpler, cheaper and more adaptable than the FNF tube needle, having individually replaceable hook members and a wider open hook.

The designs of the other elements are similar to those in conventional machines except that the tricot sinkers have flat bellies because the compound needle does not require assistance in landing the old overlap.

The hook members are individually mounted in their bar whilst the tongues are set in leads that are mounted in the tongue bar.

24.4.1 The knitting action of the compound needle warp knitting machine

Figure 24.7 illustrates the knitting action of a compound needle warp knitting machine:

1 *Needle rise and guide bar swing.* With the sinkers forward holding down the fabric, the hooks and tongues rise, with the hook rising faster, until the head of

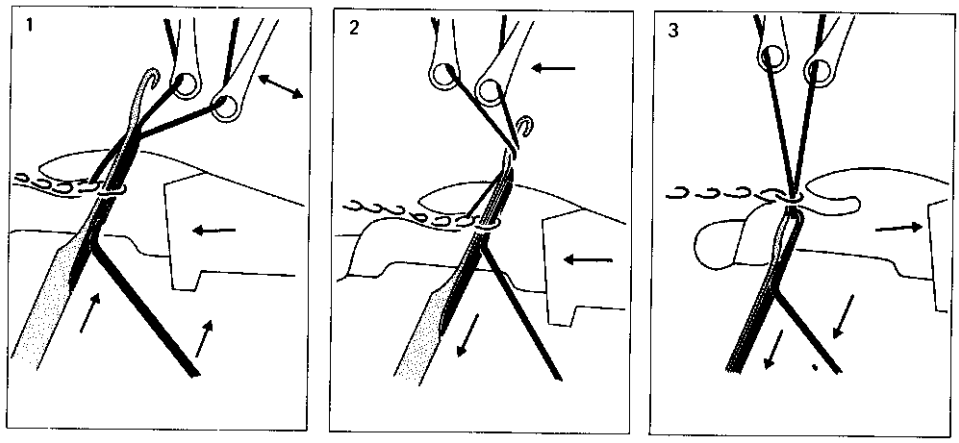


Fig. 24.7 Knitting action of a compound needle tricot machine.

the latter is level with the guide holes and is open. The guides then swing through to the back of the machine.

2 *The overlap and return swing.* The guides shog for the overlap and swing to the front of the machine; immediately, the hooks and the tongues start to descend with the tongues descending more slowly, thus closing the hooks.

3 *Landing and knock-over.* The sinkers start to withdraw as the needles descend so that the old loop is landed onto the closed hook and then knocked-over as it descends below the sinker belly. At this point the underlap occurs before the needles begin their upward rise and the sinkers move forward to hold down the fabric.

The *Karl Mayer* tricot model HKS 2–3 E is designed to knit elastic fabrics and has a maximum speed of 3300 cpm with reduced noise levels and energy consumption. The vertical staggered arrangement of the guide bars enables the stroke to be reduced. The bars are hollow section which reduces their weight and expansion due to heat.

24.5 The crochet machine

In hand crocheting, a hook is used to draw a new loop through the old loop with the chains of loops being joined together at intervals.

On crochet machines, the warp chains are separate from the weft inlay and it is the latter threads that join the chaining wales to each other. The *crochet galloon* machine, as developed by *Sander and Graff* and popularised by *Kholer*, is essentially a highly versatile raschel with the following unique features (Figures 24.8 and 24.9):

- A *single horizontal needle bar* whose simple reciprocating action can be used to operate individually-tricked latch, carbine or embroidery needles.

  The *patent* or *carbine bearded needle* is used for fine structures and has a sideways crimped beard placed in a permanently-pressed position. Although warp threads can only be fed into the beard from the left (necessitating a unidirec-

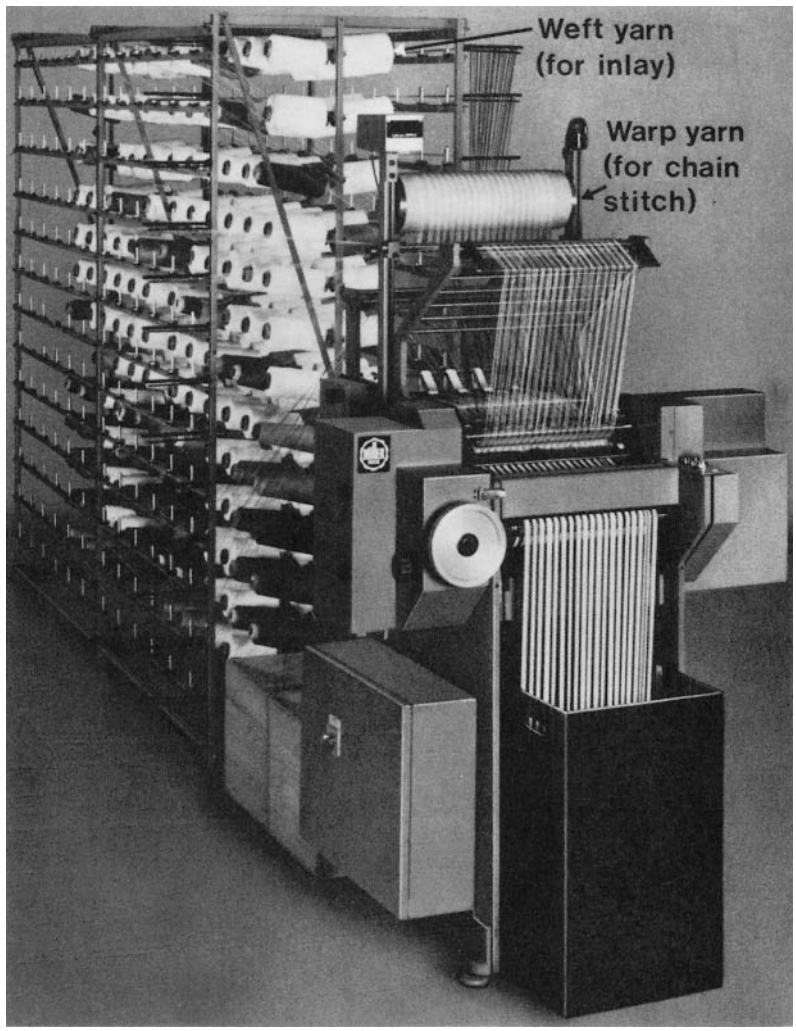


Fig. 24.8 The crochet machine. Knitting narrow width elastic trimmings [Jacob Muller].

tional closed overlap), the old overlaps are automatically cleared and landed by the movement of the needle. It is still the most frequently used needle, achieving speeds up to 2500 rpm. Reduced machine speed and high needle wear make its use uneconomical for knitting single end cotton yarns.

Embroidery or *lace needles* are carbine needles with pointed heads that can penetrate pre-woven structures to produce embroidery effects. The needles can be arranged for coarser gauges or for fancy set-outs, when the floating inlay threads may be cut to produce separated fringed edgings.

The *compound needle* patented by *Müller* produces less stress on the yarn during loop formation so a wider range of yarns can be used, and compound needles last up to six times longer than bearded needles.

Latch needles operate at uneconomic speeds and have a short life due to latch breakage.

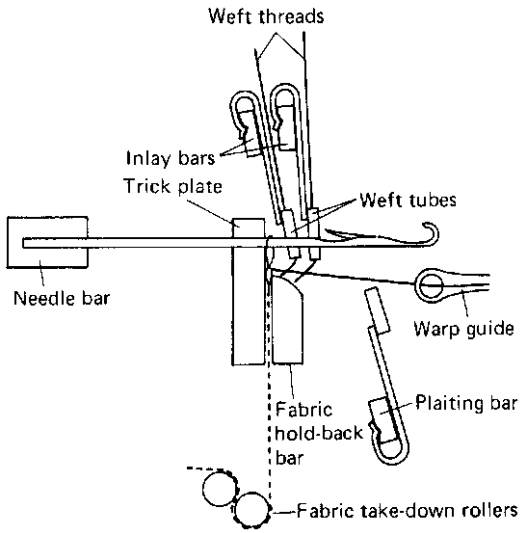


Fig. 24.9 Knitting elements in a crochet machine [*Knitting International*].

- *No sinkers*; instead a fixed hold-back bar is fitted in front of the knock-over verge to prevent the fabric moving out with the needles.
- *Closed lap pillar stitches and inlay threads controlled and supplied as separate warp and weft respectively*. Each needle is lapped from below by its own warp guide, which is clipped to a bar whose automatic one-needle overlap and return and underlap shog is fixed and is controlled from an eccentric cam whilst its upwards and downwards swing is derived from a rocker-shaft. The warp yarn is often placed low at the front of the machine.
- *The weft yarn, often placed above and towards the back of the machine, supplying the carrier tubes, which are clipped to the spring-loaded inlay bars*. These bars are fitted above the needle bar and are shogged at the rate of one link per course, from pattern chains around a drum at one end of the machine. There are usually up to two warp guide bars and up to 16 weft inlay bars, which may be electronically controlled.
- *Special attachments* are available for producing fancy effects such as cut or uncut fringe edges, pile, braiding (equivalent to fall-plate) and snail shell designs.

Crochet machines, with their simple construction, ease of pattern and width changing, and use of individual yarn packages or beams provide the opportunity for short runs on coarse- or fine-gauge fancy and open-work structures and edgings, as well as the specialist production of wide fancy fabrics or narrow elastic laces.

The weft inlay bars may either be electronically-driven or mechanically-controlled in the traditional manner by chain links or levers. The choice is governed by the requirements either of long complex pattern repeats and quick pattern changes as in sampling, or for simple structures and long production runs [4].

Very approximately, the knitting widths of crochet machines may vary between 16 and 122 inches (400 and 3100 mm). Gauges, often expressed in needles per centimetre, are between 2 and 10 (E 5 to E 24).

Müller quote gauges in needle pitch; this means that the lower the number, the

finer the gauge. For example, '10' means that the distance between one needle centre and the next is 10 mm; therefore in one inch (25.4 mm) there will be 2.5 needles (E 2.5).

Machines run at speeds between 200 and 350 courses per minute (or much more on simple structures). Crochet machines can process a range of filament yarns from 20 dtex to 1000 dtex.

24.5.1 The knitting action of the crochet machine

Figure 24.10 illustrates the knitting action of a crochet machine:

1 *The inlay.* Whilst the needle is withdrawn into its trick during knock-over of the previous warp overlap, the weft inlay tube is lowered. As it traverses in an underlap shog, the weft is laid below the level of the needle and on top of the warp thread that extends from its head to the warp guide.
2 *Clearing the warp overlap.* The weft tube rises slightly on completion of its traverse movement to allow the needle to move out of its trick to clear its old warp overlap.
3 *The warp overlap wrap.* The warp guide rises between the needles and

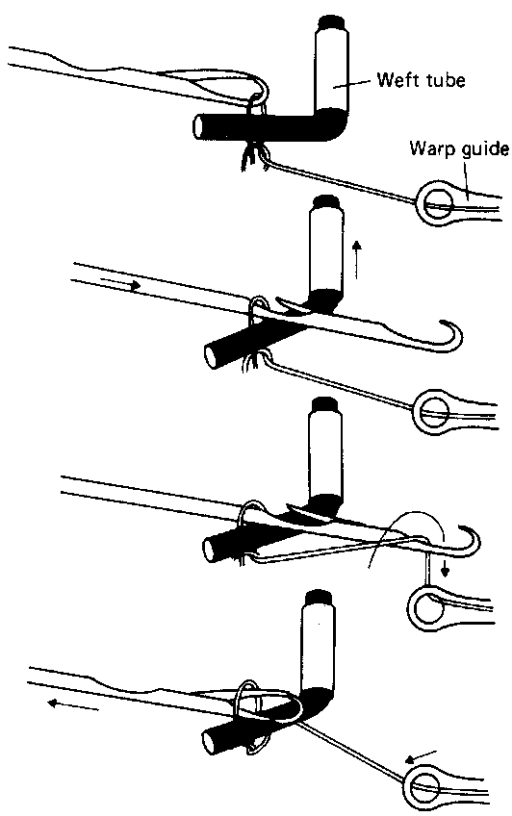


Fig. 24.10 Knitting action of a crochet machine [*Knitting International*].

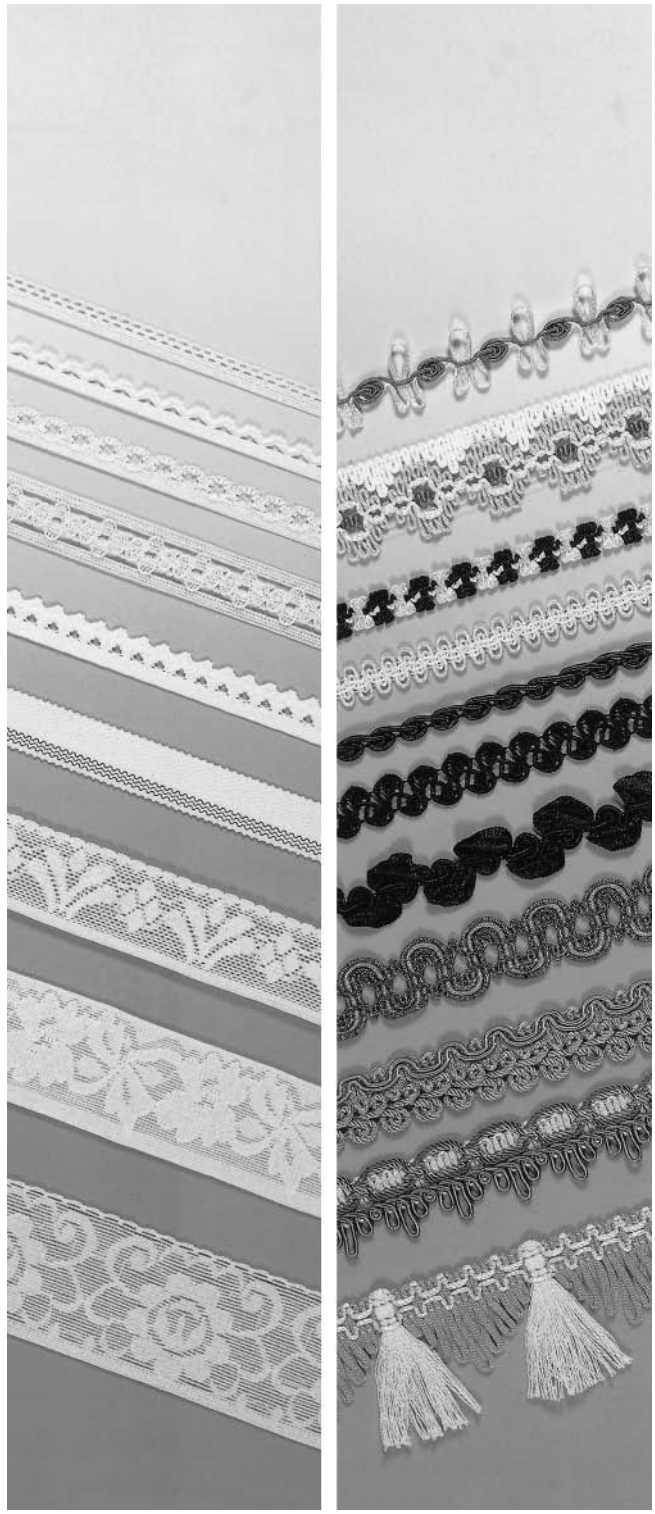


Fig. 24.11 A range of crochet fabrics [Comez].

automatically overlaps from the left, lowering itself again on the right side of its needle.

4 *Warp knock-over and underlap.* The needle now retires into its trick to knock-over the old overlap, whilst the warp guide is cammed under its needle to the start position for its next overlap, thus completing the closed lap pillar. NB: The closed lap is used for the carbine needle but the alternating overlap of the open lap pillar stitch used with the conventional latch and bearded needles gives a more balanced loop structure. Tricot lapping with two guide bars produces a secure fabric which does not unrove.

A range of crochet fabrics is illustrated in Fig. 24.11.

24.6 The Waltex machine

The Italian company *Caperdoni* build a unique type of warp knitting machine termed a *Waltex* machine [4]. Instead of needles, two sets of guide tubes threaded with warp yarn alternate in wrapping a loop around each other. The overlaps on one bar of guide tubes thus intermesh towards the face at their knitting cycle (course). At the next knitting cycle, the overlaps on the second bar of guide tubes intermesh towards the back. A type of 1×1 purl warp knitted fabric is thus produced.

The spacing between the guide tubes on the bar corresponds to the gauge, 3 mm being the finest and 14 mm being the coarsest.

24.7 Warping

Warp is normally prepared as an accumulation of ends wound parallel to each other on a beam. The warp must possess the correct number of ends, all of the same length and all wound at the same tension. The ends must be parallel to one another and evenly distributed throughout the width of the beam. The spacing must be suitable for the gauge, and the width of the warp often equals the width of the needle bar in use, although it may be composed of a number of sectional beams.

Generally, warping is carried out *directly* from the yarn packages placed on a creel to the driven knitting beam because this is the fastest method. For fancy warps and sampling purposes, *the indirect* method of building a warp in sections onto a mill and then off beaming the completed warp onto the knitters beam is generally preferred, as this involves less yarn packages.

The warping of synthetic yarns involves the need for static eliminators, whilst the warping of staple fibre yarns may require the use of lint-removal arrangements and possibly the application of a lubricant to the warp. Special warping machines with reciprocating guides are employed to warp the pattern beams of multi-guide bar machines where only a few warp ends are required.

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