

KNITTING TECHNOLOGY

A comprehensive handbook and practical guide

Third edition

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8

The various types of weft knitting machines

8.1 Fabric machines and garment-length machines

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

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

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

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

8.1.1 Fabric machines

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

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

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

8.1.2 Garment-length machines

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

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

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

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

8.2 Knitting welts and rib borders

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

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

Shaping of flat garment panels is either in the form of cut edges or in the form of knitted selvages (in the case of reciprocating knitting on a flat machine). The amount of shape introduced into the garment also varies; in some cases this is

achieved entirely by the cutting and making-up operation, in others it is by stitch shaping, stitch length variation, loop transfer and fashioning, held stitches or reciprocation.

8.3 Integral knitting

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

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

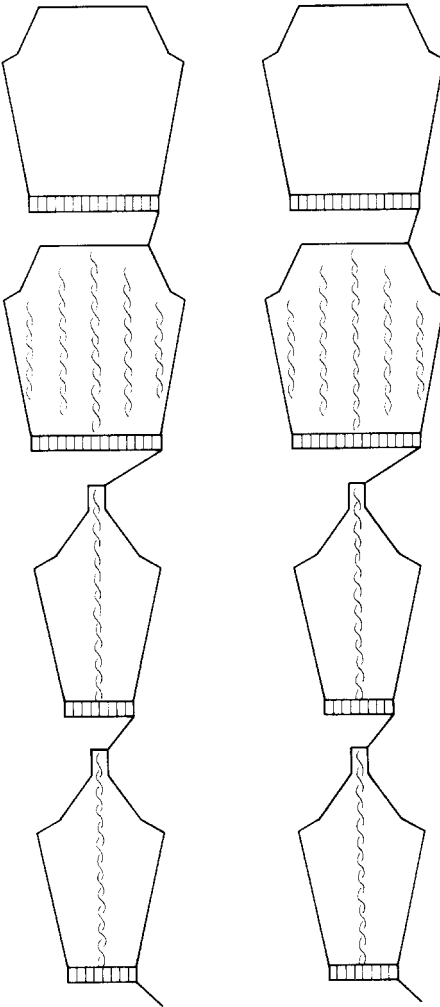


Fig. 8.1 Sequential knitting.

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

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

8.4 The three classes of weft knitting machines

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

8.4.1 Straight bar frame machines

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

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

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

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

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

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

Straight bar frames are long, capital-expensive machines that, because of their multi-sections and in spite of their intermittent knitting action, are highly productive in a very narrow sphere of garment manufacture. The knitting width is rather restricted

and fashion tends not to encourage full exploitation of the fashion shaping and stitch-transfer patterning potential of the machines.

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

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

8.4.2 Flat machines

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

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

The classes of flat machines are:

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



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

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

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

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

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

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

8.4.3 Circular machines

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

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

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



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

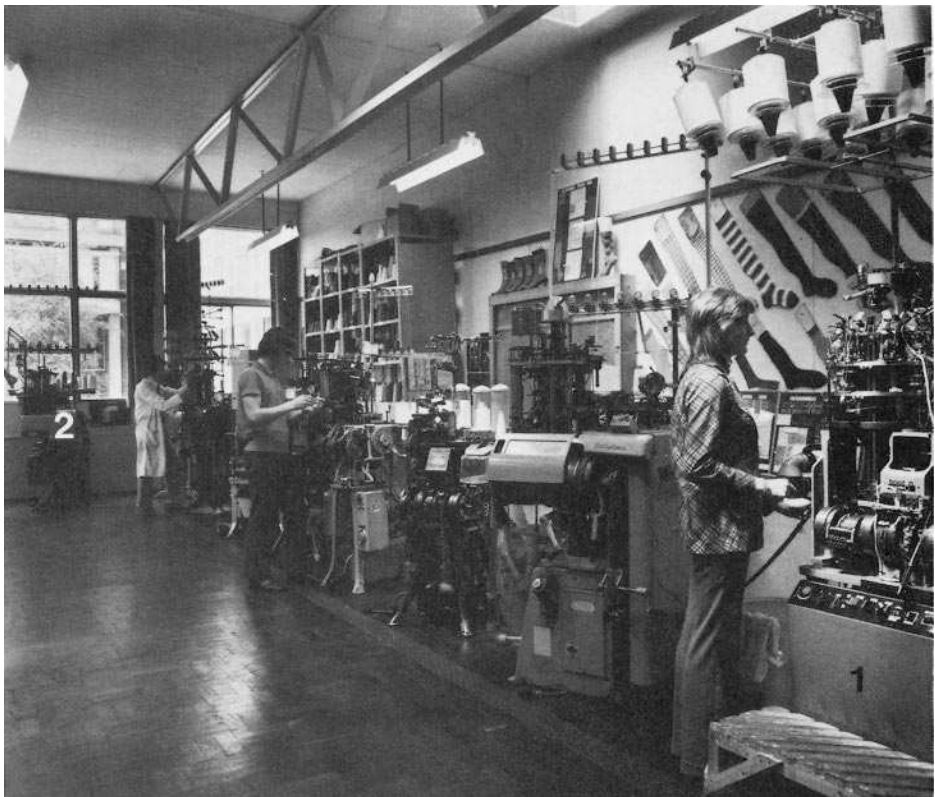


Fig. 8.4 Mechanically controlled hosiery machines. 1 = seamless hose machine; 2 = double cylinder half-hose machine.

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

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

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12

Electronics in knitting

12.1 The disadvantages of mechanical control

Knitting machines have developed with mechanically controlled and operated movements. The exacting requirements of modern knitting technology, however, emphasize the limitations of mechanical movements which are expensive to manufacture, slow and cumbersome in operation, difficult to adjust or alter, and subject to friction and wear.

12.2 The disadvantages of mechanical programming

Mechanical pattern and programming data for controlling knitting machines is stored in the form of punched cards, chains, rack-wheels, peg drums, and element butt arrangements. These are expensive in material, bulky in space on the machine or in storage, time-consuming to handle and alter, slow in operation, and provide restricted facilities.

Hydraulics, fluidics, and electronics provide alternative systems of power transmission and signal storage with the requisite speed and precision.

12.3 The advantages of electronic control and programming

Electronics offer the decisive advantages of convenient power-supply, compatibility with existing mechanical components, micro-miniaturisation of circuitry, and economical data storage. In addition, electronic systems do not require to be of a size proportionate to their task or to operate on a one-to-one relationship with it.

Electronic selection or machine control is compatible with higher running speeds and eliminates complex mechanical arrangements, thus reducing supervisory requirements. It provides greater versatility as regards design parameters, simplifies



Fig. 12.1 Electronic sampling machine [Monarch].

the modification of repeat sequences and size, style and pattern-changing operations, and, in some cases, enables changes to occur whilst the machine is knitting (Fig. 12.1).

12.4 The compatibility of electronic signals and knitting data

Electronic devices process information as binary digital logic signals that exist in two states, *ON* or *OFF*. This can be directly translated as *1* or *0*, *YES* or *NO*, *TRUE* or *FALSE*, or magnetic *ATTRACTION* or *REPULSION*.

This information can just as conveniently be translated into knitting states such as *KNIT* or *TUCK*, *TUCK* or *MISS*.

The binary digits can be arranged in the form of a programme where they can be encoded and converted into symbols to compose, for example, a knitting design or a machine programme.

12.5 Microprocessors and computers

The most important use of electronics is in microprocessor and computer systems. A computer can receive, store, retrieve, and communicate enormous quantities of information at phenomenal speeds. It can also manipulate, rearrange, select, and transform this information. It performs arithmetical or logical processes accurately at high speed after receiving the instructions (programme) and values (data) without the need for further intervention by the operator.

Flexibility in processing of data occurs because the system can be programmed to produce *YES* or *NO* decisions, based on the result of comparing and testing monitored data, that then determine the choice of two alternative courses of action in the program of the system. These alternative courses within the main program sequence may include counted loop sequences, branching or jumping out of the main sequence, and selection of stored sub-routines.

It is these facilities that give electronically-controlled knitting pattern preparation and needle selection their extensive capabilities as compared with previously available methods. Inputs include switches, sensors on knitting machines, keyboards, light pens, tapes and discs; and outputs include actuators on knitting machines, lights, digital and graphical displays, tapes, and printers. Outside the system, the digital impulses may be changed from parallel to serial, or even analogue, form, or may be converted into light, sound, radio or carrier waves, or mechanical movements.

Although it is possible to directly program a system using switches, a matrix board, a keyboard or another input device, the processor (and probably the knitting machine) will be held waiting during this time-consuming operation. It is therefore preferable to record the program and data in an auxiliary memory store such as a tape or disc. Its contents can be rapidly inputted electronically into internal memory, as required, whilst using a direct input keyboard or switches for minor amendments or alterations during the running of the programme.

Some systems are programmed to interact with the operative who is thus able, within specified and guided limits, to change values of data, with the effects of the amendments being visually indicated by the system.

12.6 The computerised knitting machine

Although knitting is still a mechanical action between the yarn and the knitting elements, the design of tomorrow's machines will be increasingly influenced by the facilities offered by electronics (Fig. 19.13). Thus, whereas on mechanically-controlled knitting machines nearly all the mechanical movements are linked to, and are triggered by, the revolution of the machine or traverse of the cam carriage, electronic controls can be dispersed and separately operated.

In addition, their operation can be smoothly introduced in a series of gradual steps and not in a restricted number of large steps, as is the case with mechanical drive systems.

The electronically-controlled knitting machine can be part of a network of management communication links. A single control unit can control a complete bank of machines if necessary.

Unlike the mechanically-controlled machine, which is passively operated, stands alone and has no means of receiving and transmitting electronically generated data,



Fig. 12.2 Knitting patterns and programmes are quickly generated using automatic routines. These are checked and can be transmitted on-line to the CMS knitting machine. Simultaneous monitoring of production can also be achieved [Stoll SIRIX].

the increasing automatic monitoring and adjustment facilities provided by micro-processor control on modern machines obviates the need for continual manual attention (Fig. 12.2).

Perhaps electronics has had its greatest impact in V-bed flat knitting, as a major factor in the successful development of shaping techniques (Chapter 19).

Electronics is also increasingly being employed in 'intelligent' stop motions, yarn feed systems, the design and preparation of knitting patterns, machine function control, pattern selection and striping.

12.7 Computer graphics and pattern preparation

Of all knitting machines, the modern electronic V-bed flat machine, with its comprehensive patterning and garment shaping facilities, offers the greatest challenges as well as the greatest opportunities for the application of a CAD/CAM system (Fig. 12.3).

Interactive computer graphics enables a dialogue to occur between the operator terminal and the system, with the resulting development of the design being immediately visually represented on the screen. The position is defined and located by two numbers in the Cartesian co-ordinate system. On the horizontal (X) axis, the numbering increases positively from zero towards the right, whilst on the vertical (Y) axis, the numbering increases positively upwards from zero at any point on the design.



Fig. 12.3 The simulated knit package is mapped onto an image of a model to simulate the appearance of the final product. This image can also be used for evaluation and sales promotion purposes [Shima Seiki]. **lululemon Ex. 1014**
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Generally, an input device is employed that can be moved by hand in the direction of either axis, with its location and movement over the screen being indicated by a special character symbol termed a cursor. The physical movement of input devices such as digitizers, joysticks, and trackballs is converted by the system into the series of numbers, whereas a light pen detects the presence of light whose position is being generated on the screen.

Computer graphics provides a tool for the efficient creation and development of designs and overcomes tedious and repetitious aspects, enabling realistic representations of the knitted designs and garment shapes to be prepared, to be easily modified on the screen, and to be outputted as accurate, to-scale, coloured, hard-copy prints. It provides a much quicker response to customer requests than is possible with traditional knit sampling techniques whilst postponing the expensive knitting operation until such requirements have been fully identified. Recognised standards for these systems are now becoming established so that there will be greater compatibility in the future and choice of system will be less dependent upon the preference for a particular make of knitting machine.

The *Quantel Paintbox* has established the standard for an interactive computer graphic design system. It consists of a digitising table, a pressure-sensitive stylus, an interactive computer with integral software, a digital frame store, hard disc storage and a colour monitor that communicates commands via menus displayed on the screen.

Selections include colour, brush size, paint mode, and the automatic drawing of various shapes and structures. Enclosed areas of the design may be filled in with a colour (if this facility is available) and the locations of the colours may be exchanged. Stored sub-routines may also be recalled to assist with the development of the design.

By relating the co-ordinate points of the design to other co-ordinate points within the design area, the design can be rapidly modified, with motifs being multiplied in number or geometrically transformed. Each transformation may occur separately or as a combined effect: for example, a motif may be reflected (mirror imaged) across the width (the X axis) or the depth (Y axis) of the design area. It can be translated (moved in a straight line without altering its appearance), rotated (moved in a circular path around a centre of rotation), and scaled (increased or decreased in size along the X or Y axis or along both axes). Graphic capabilities are obviously dependent upon the type of system and its software. Electronic pattern preparation thus provides the designer with an immediate visual representation of the design as it is being conceived, amended, and edited, without recourse to the knitting of trial swatches (Figures 12.3 and 12.4). The grading of sizes [1] and the introduction, manipulation and placing of shapes and colours, is achieved with the minimum of effort and the elimination of all tedious and repetitious actions.

The program can be structured to guide and assist the designer and thus ensure that the resultant design is compatible with the knitting machine and the end-use requirements. Once a satisfactory design is achieved, a permanent record may be outputted onto hard copy and/or onto a carrier acceptable for controlling the knitting machine.

Not only is a programme required for knitting the fabric structure, one is also required for knitting the garment-length sequence, and a further programme is required for shaping. Many automatic modules are already installed that can be quickly recalled and 'seamlessly' co-operate with each other. The technician is

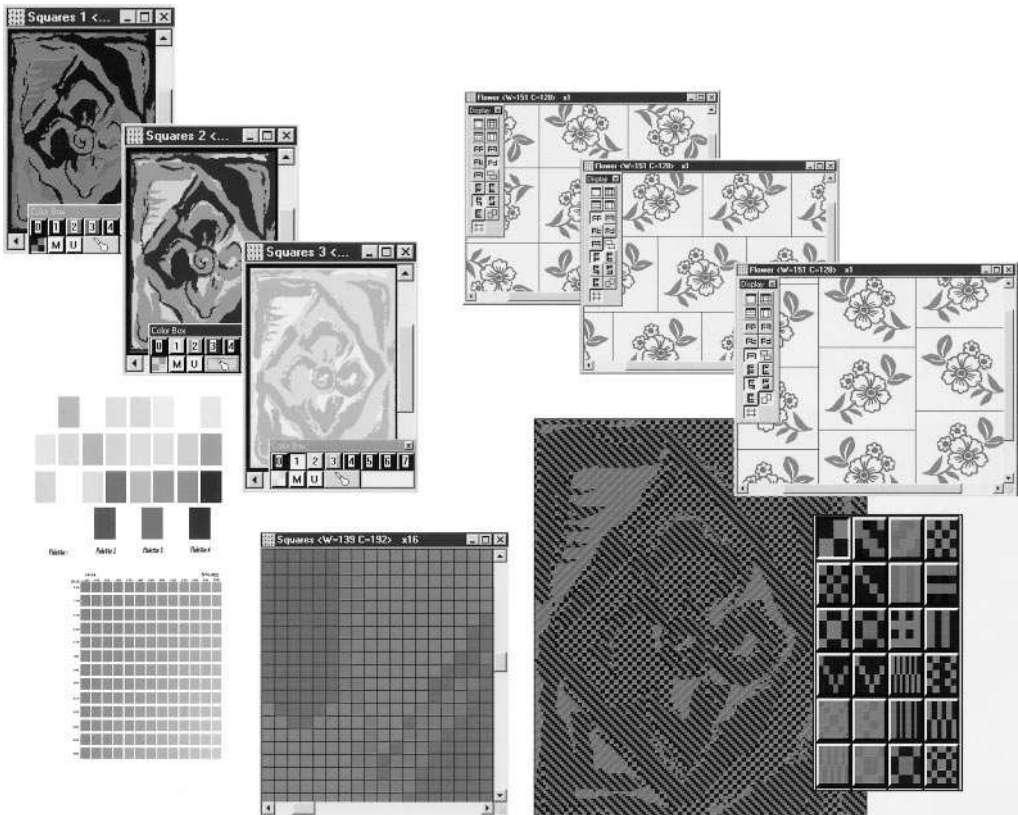


Fig. 12.4 MKS knitting system for Windows [Monarch].

guided throughout his programming by software that recognises the constraints imposed by the fabric and the technical specification of the knitting machine.

12.8 The Stoll CAD pattern preparation system

The *Stoll SIRIX* is a complete design, patterning and programming system originally specially developed from *Apple II* PC software. It caters for every application in V-bed flat knitting. It uses icons and windows to graphically support the generation and development of knitting programmes for *Stoll CMS* electronic flat machines. *SIRIX* has a hierarchy of files holding folders. These can be opened by a double click of the mouse on an icon. It simplifies pattern drafting and speeds-up the processes required in the production of knitted fabric and garments. Fabric depiction and programme drafting is carried out on-screen, without the need to interrupt production on the machine.

The multi-tasking facility permits simultaneous operation of a wide variety of programmes. These are controlled via the graphically-oriented user interface. Patterns can be designed using jacquard colours and the *Sintrial* programming language, or directly by defining stitches and modules. These can then be transformed automatically into a knitting programme simply by pressing a button. *Sintrial* is the text

editor, which facilitates the creation of knitting programmes using plain language instructions. Designs or programmes are analysed, processed and tested, then automatically translated into *Sintral*, then presented to the monitor or loaded into the machine.

The *design programme* is a 'Paint' programme that provides a palette of colours, shades, brush shapes and sizes, and design tools.

Using the *yarn programme*, yarn types, shades, and textures can be generated and stored to closely simulate knitted panels, in advance of the knitting process.

Sophisticated colour printers can produce realistic images of the garment which, it is hoped, will reduce the time-consuming process of swatching and sample development on the knitting machine. Once the design is completed, a model can be called-up onto the screen whose three-dimensional appearance simulates the wearing of a garment made from the design.

A recognition that designers and technicians require different information as the sample is developed has led to the provision of two separate but linked and constantly up-dated screen windows. The *technical window* presents the developing design in the form of running thread notations and technical data, whereas the *design window* shows the design as a knitted structure. Each can be displayed as and when required, and changes on one are automatically up-dated on the other (Fig. 12.5).

The *grid or raster programme* works with peripheral input devices including scanners and cameras, or any programme containing an image. It adjusts images to the correct size for the number of wales and courses in the required design. An automatic *colour reduction programme* reduces the number of shades to the number of yarn colours to be used in the jacquard design.

The *jacquard programme* takes over after the grid programme, and has an extensive tool and colour palette (Fig. 12.6). The pattern field and stitch size are selected and the pattern motif is drawn onto a grid. Patterns can be depicted in the form of colours, stitch icons, or *Sintral* symbols. Stored designs can be called up. Shapes and areas can be re-scaled, manipulated, rotated, flipped, multiplied, deleted, or interchanged. Whilst a motif is being moved, it becomes transparent, so that the background can be seen through it, thus making it easier to accurately position.

Structure patterns are drawn using stitch icons that graphically depict stitch appearance. Pattern elements, such as cables, Aran and lace, are available in modules to build into the programme. The computer translates into machine language other relevant information that can be inputted by the designer, such as *yarn carrier allocation* and *knitted stitch sizes*.

The *intarsia programme* enables complex programmes for the production of intarsia designs to be generated almost completely automatically, based on following the rules of intarsia knitting. The pattern sketch is converted into an intarsia design in several stages. Intarsia designs are drawn using intarsia stitch icons for colours, structure and, if required, ladder backing. From the intarsia motifs on the screen, the *SIRIX* generates individual colour fields that are allocated to individual yarn feeders. The programme step '*Yarn Feeder*' works out the best starting point for the yarn feeder and inserts the lines necessary to position it. From the intarsia pattern needle selection, feeder paths and, if required, ladder backing on the rear bed is generated.

In the *shaping (fully-fashioned) programme*, the shape of the panel, e.g. sleeve, back, or front with a V-neck, is superimposed graphically over the ground pattern.

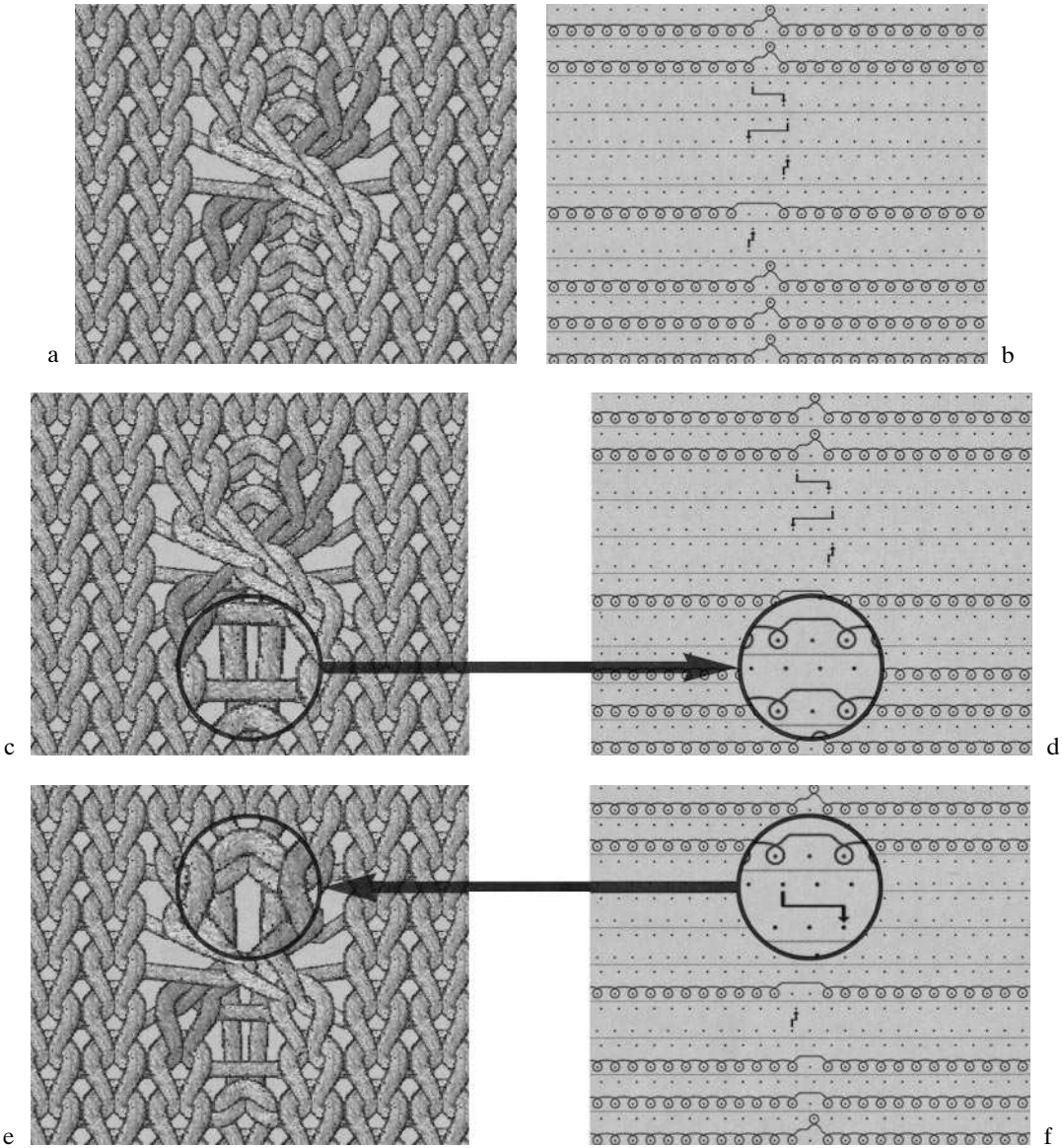


Fig. 12.5 Linked windows options of fabric view and technical view [Stoll].

Cables and Aran motifs are automatically faded-out at the selvages. A complete automatic-knitting programme is generated from a drawn shape (Fig. 12.6).

A garment shape is selected from the file, inserted in the form of an area over the jacquard, and positioned where required. The width of the selvedge area can be varied and different stitch structures selected. The shape is cut out of the jacquard.

Narrowing modules are automatically inserted to give the required shape. The *FF programme* generates the *Sintral* programme that contains all the necessary data



Fig. 12.6 The FF programme inserts the control columns and, using the existing jacquard, generates the Sintral programme, which contains all the necessary data for machine control [Stoll].

for machine control. The *module programme* breaks the modules down into complete knitting sequences. Stitch transfers can be programmed automatically.

The programme *Sirix Auto-Sintral* automatically generates the complete *Sintral* knitting programme. Starts and repeats for size changes can be selected. Once one size has been knitted, the CMS machine automatically changes-over to producing the next size.

The *analyse programme* tests the knitting programme, line-by-line, using an internal analysis routine, simulating without involving the knitting machine. Knitting information such as needle selection, yarn feeders, racking, etc. are carried in a programme log and can be assessed at any time. The *selection programme* presents the *analyse* data, course by course, in notation form, permitting rapid checking of pattern accuracy.

The *DIM 3 programme* permits the three-dimensional representation of knitted fabric on the screen. This can be enlarged, rotated and manipulated, from the face or reverse, at any angle. The fabric can be appraised as a whole or in fine detail.

On-line generates a direct connection to all the machines in the plant. Knitting programmes are transferred, on-line, to and from the knitting machines on the network, and production sequences are centrally controlled. Data on machine stoppages and reasons, as well as on production progress can be collected.

Tele-Service provides long-distance data transmission of knitting programmes as well as remote diagnosis of CMS flat knitting machines and *SIRIX* pattern-preparation systems.

On the CMS machine, the touch control screen displays pictogram symbols providing information on the progress of knitting production such as knitting speeds, settings of cams, yarn feeders and fabric take-down. Patterns and garment programme sequences can be read into the machine memory, either from floppy discs or directly on-line from the pattern-preparation unit.

12.9 The Shima total design system

Since developing the *Micro SDS* pattern preparation system, *Shima* have introduced a series of systems with improved hardware and software according to industry's needs.

The *Shima Total Design System* is a totally-integrated knit production system that allows all stages – planning, design, evaluation, production, and sales promotion – to be integrated into a smooth work-flow:

- 1 The designer, using computer-graphic paint software and a pressure-sensitive airbrush, creates concept drawings. Scanned-in images can be used to create storyboards.
- 2 A fully-fashioned pattern for shaping is created, using a pattern CAD program for knitting. The working pattern is then displayed using *KnitPaint* software. Courses and wales are converted into numbers of loops. Jacquard, intarsia and structure patterns can be created separately.
- 3 When each pattern is complete, *KnitPaint* automatically combines all patterns into usable knitting data, customised to the required *Shima* machine. Machine data is converted for intarsia using the *auto yarn carrier selection function*.
- 4 The *loop simulation programme* uses yarns either scanned or painted or created by the *yarn creation programme*.
- 5 The resulting simulated knit pattern can then be draped onto models using the *mesh-mapping function*. A mesh grid is created to conform to each fully-fashioned piece, such as the front body, back body, and sleeves, and the simulated knit pattern is draped directly over that piece. The *mesh mapping* allows shadows and wrinkles to be maintained from the original image.
- 6 A database of models wearing various types of knitwear (V-neck, crew neck, cardigan, etc) for which the mesh grids are ready-made is available.

Reference

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Further information

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18

Flat knitting, basic principles and structures

18.1 History

The first *flat bar machine* (Section 8.4.2) was demonstrated in 1862 and patented in 1865 by the Rev. Isaac Wixom Lamb, an American clergyman. He later changed the arrangement to the inverted V-bed shape patented by *Eisenstuck*.

18.2 The two types of flat machine

Two types of flat machine evolved. The widely used *V-bed rib* machine and the slower, more specialised *flat bed purl* or *links-links machine*.

V-bed machines have two rib gated, diagonally-approaching needle beds, set at between 90 and 104 degrees to each other, giving an inverted V-shape appearance.

Flat bed purl (links-links) machines have horizontal needle beds. They have been employed mainly in knitting simulated hand-knitted constructions of a speciality type, such as cable stitch, basket purl, and lace patterning. They use *double-headed latch needles* that are transferred to knit in either of two directly opposed needle beds. The non-knitting hook is controlled in the manner of a needle butt by a *slider* that hooks onto it. There is a set of sliders in each needle bed whose butts are controlled by the traversing cam-carriage to produce knitting or transfer of the needles (see Section 7.5).

These complex and slow machines are no longer built because the modern electronic V-bed machines can knit all the links-links designs using the facilities of rib loop transfer and needle bed racking.

Early *intarsia* machines employed a different approach, using only one needle bed to knit solid colour designs. Now, however, many modern V-bed machines have intarsia-patterning facilities and are no longer restricted to geometrical designs because the mechanically-controlled carrier stops have been replaced by more versatile electronic controls.

18.3 Flat machine gauges

Flat machines (Fig. 8.2) are normally gauged on the *English system* (*E*) of *needles per inch* (npi). The *Metric system*, which is based on the distance in tenths of a millimetre from the centre of one needle to the next, is rarely used. The latter is a direct system, with a higher gauge number indicating a coarser gauge – the opposite of the English system.

Generally, flat machine gauges range from E 5 to E 14, with the main gauges being 5, 7 and 10, but there are machines as coarse as E $2\frac{1}{2}$ and as fine as E 18 or even finer now being built.

NB: All flat machines can be *half-gauged* by removing every alternate needle; thus, an E 10 gauge machine will become an E 5 gauge. Also, different needle hook sizes are available, and gauge conversion by changing needle beds is possible.

18.4 Conversion from Cottons Patent to V-bed gauge

To convert from Cottons Patent gauge (G^* , needles per $1\frac{1}{2}$ inch) to V-bed gauge (*E*, needles per inch)

- 1 Convert from $1\frac{1}{2}$ inches to 1 inch needle bed width.
- 2 In the gauge range G9 and below, reduce the resultant *E* gauge by 1. Above G 9 reduce the resultant *E* gauge by 2. This is to fit commercial practice in flat knitting, where a slightly coarser gauge is preferred.

Example: Convert G9 and G21 fully-fashioned (needles per $1\frac{1}{2}$ inches) to V-bed flat *E* gauge (npi)

$$G9 \times 2/3 = 6$$

$$6 - 1 = E5$$

$$G21 \times 2/3 = 14$$

$$14 - 2 = E12$$

18.5 Knitting widths

Strapping machine needle bed widths tend to range from about 14 to 50 cm (5.5–20 inches); hand-operated garment-width machines range from about 80 to 120 cm (31–47 inches); power-driven automatic garment length machines range approximately in width from about 66 cm to 240 cm (26–95 inches).

Wider '*blanket width*' machines are approximately 244 cm (96 inches) wide, to knit unshaped garment pieces for cut-and-sew knitwear.

Narrow bed '*compact*' machines are approximately 127 cm (50 inches) wide for fashion shaped knitwear.

For *integral garment* knitting, the approximate width is 183 cm (72 inches).

* '*G*' is sometimes expressed as '*gge*'. For example, G 9 = 9gge.

18.6 Yarn counts

An indication of an approximately suitable count for a flat machine may be calculated using the formula:

$$\text{worsted count (NeK)} = \text{gauge}^2 / 9$$

The following are typical NeK count ranges for particular E gauges:

12npi – 2/26's to 2/42's

8npi – 2/14's to 2/22's

5npi – 6/14's to 6/18's

2npi – 8/7's to 8/9's

It can be seen that a characteristic of the flat machine is the large number of ends of yarn that may be knitted at the same time. However, if light-weight structures are required, the number of ends may be much fewer (See multi gauges, Chapter 19).

18.7 Simple hand-manipulated V-bed rib flat machines

Figure 18.1 shows a cross-section of a simple hand-powered and manipulated V-bed rib flat machine. The trick walls are replaced at the needle bed verges by fixed, thinner, polished and specially shaped *knock-over bit edges*. In rib gating, a knock-over bit in one bed will be aligned opposite to a needle trick in the other bed. During knitting, the edges of the knock-over bits restrain the sinker loops as they pass between the needles and thus assist in the knocking-over of the old loops and in the formation of the new loops. The takedown tension and the needles in the other bed help to hold the old loops down on the needle stems as the needles rise to clear. Many modern electronic flat machines have movable knock-over and holding-down elements, which assists in the knitting of shaped and single-bed structures.

On hand flat machines, after the first or *set-up course* of rib is taken by the needles, a *fabric comb* is hand-inserted into it, upwards from under the needle beds, so that the eyelet holes of the comb protrude above the course. The comb wire is then inserted through the eyelets, over the set-up course, so that the comb is suspended from the course, and a takedown weight is attached to it.

The *cover plate* is a thin metal blade, located in a slot across the top of the needle bed tricks. It prevents the stems of the needles from pivoting upwards out of the tricks as a result of the fabric take-down tension drawing the needle hooks downwards, whilst allowing the needles to slide freely in their tricks. The plate can be withdrawn sideways out of the needle bed to allow damaged needles to be replaced.

Supporting the tail of each needle is a *security spring* that fits over the lower edge of the needle bed. When the spring is pushed fully into position, it locates into a groove on the under-surface of the needle bed. The butt of the needle that it supports is then aligned with the knitting cam track on the under-surface of the traversing cam-carriage. When a needle is not required to be in action, its security spring is not located in the groove, so that the needle is nearer to the lower edge of the needle bed and its butt misses the traversing cam-carriage.

On machines employing jacquard selection, the function of the security spring is replaced either by the thrust of a jacquard steel onto the tails of the elements or by

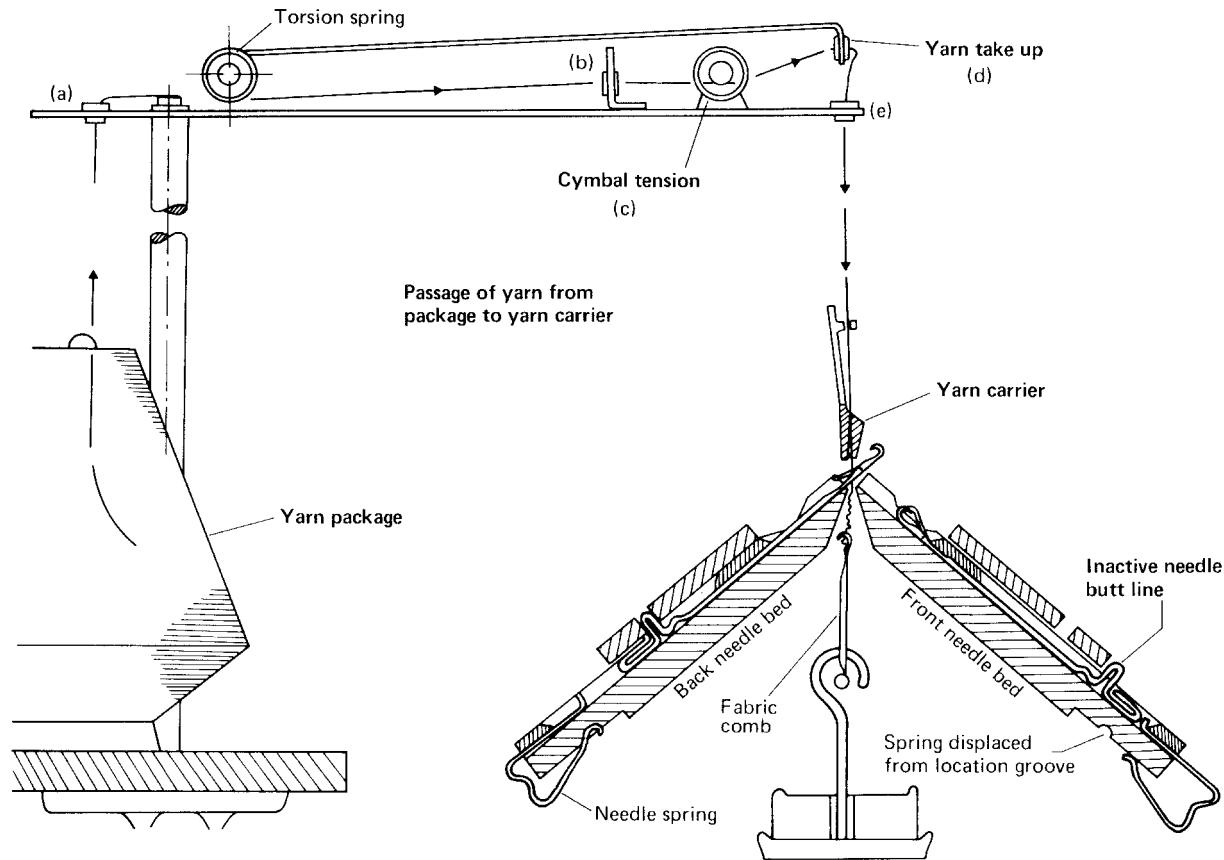


Fig. 18.1 Passage of yarn from package to yarn carrier.

the raising or depressing of the knitting butts into the tricks, in order to position the needle butts for each carriage traverse.

Latch opening brushes are attached to the cam-plates of both needle beds to ensure that the needle latches are fully opened. The supports of the brushes are adjustable to ensure precise setting of the bristles relative to the needles.

The cam-carriage either slides, or runs on ball-bearings or wheels, along *guide rails*, one of which is fixed over the lower end of each needle bed. It is propelled either by hand or from a motor-driven continuous roller chain or rubber belt.

Each *yarn carrier* is attached to a block which slides along a bar, which, like the carriage guide rails, passes across the full width of the machine. The carrier bar may be of the double prism type so that yarn carriers may be attached to slide along both the front and the back surfaces. The yarn carriers are picked up or left behind by the carriage, as required, by means of driving bolts or pistons that are attached to, and controlled either manually or automatically from, the carriage bow. There is a bolt for each carrier bar track that, when lowered, entrains with a groove in the shoulder of a yarn carrier block. Stop plates having inclined edges are positioned on the carrier bars at the knitting selvages. On contact with a stop plate, the base of the bolt rises and is lifted out and disconnected from the groove of the carrier block so that the carriage continues its traverse without that carrier.

Two levers are usually provided, one at each end of the needle bed. One is for *racking the back needle bed*, to change the gating of the needle beds for changes of rib set-out or rib loop transfer. The other is to *open the gap* between the needle beds for easier access to the knitted fabric hanging from the needles.

18.7.1 The cam system of the V-bed hand flat machine

Figure 18.2 illustrates the knitting action of a V-bed hand flat machine and Fig. 18.3 shows the underside of the cam-carriage and the cams forming the tracks that guide the needle butts through the knitting system. The single knitting system cam-box is symmetrically designed for knitting a course of loops on both the front bed and back bed needles during a right-to-left traverse and a second course during the return left-to-right cam box traverse.

The needle butts will enter the traversing cam system from the right during a left-to-right carriage traverse and from the left during a right-to-left traverse. For each needle bed there are two raising cams (R), two cardigan cams (C) and two stitch cams (S).

In the direction of traverse, the leading raising cam is responsible for knitting and the trailing raising cam acts as a guard cam. The leading stitch cam is raised out of action and the trailing stitch cam is in operation. In the reverse direction of traverse, the roles of the two raising cams and of the two stitch cams are reversed.

A raising cam lifts the needle to tuck height, but if the cardigan cam above it is in action the needle is lifted to full clearing height. Thus, the cardigan cam is taken out of action if a tuck stitch is required. To produce a miss stitch, both the raising cam and the cardigan cam are out of action. To produce a course of tubular plain knitting, a pair of raising cams that are diagonally opposite each other in each bed (RL and RR) are out of action.

The arrangement as shown in Fig. 18.3 is referred to as a *knitting system*. A *single system* machine will knit one course of rib in one traverse whereas a *double system* machine will knit two courses of rib per traverse. Sometimes a set of cams in one bed is referred to as a *lock*.

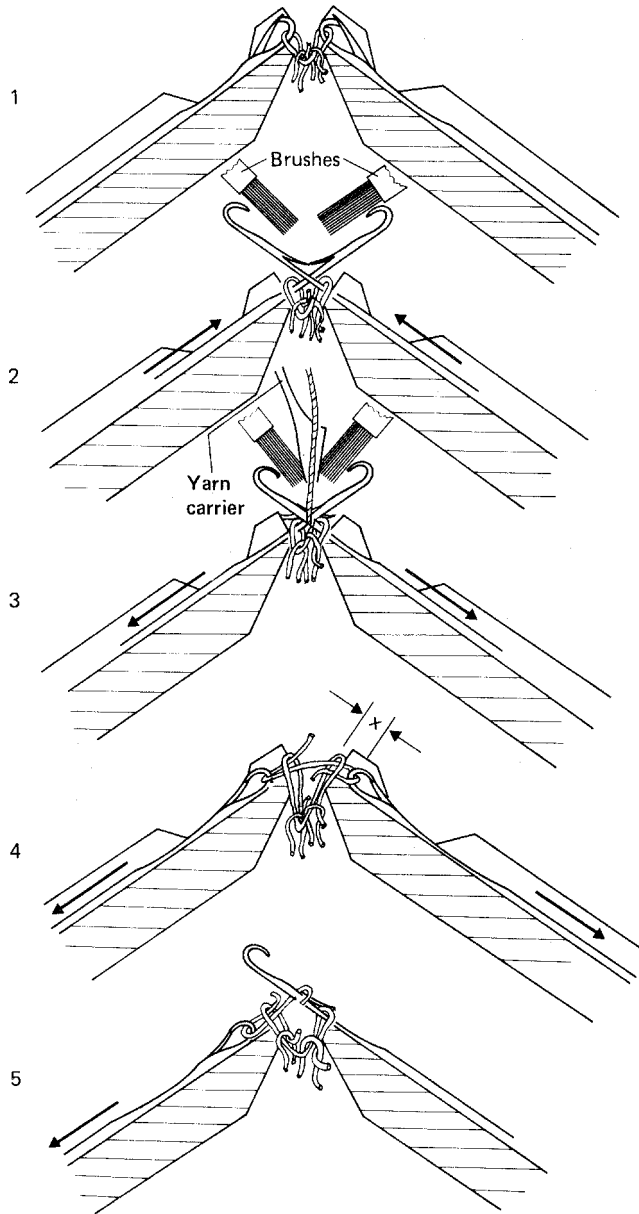


Fig. 18.2 Knitting action of V-bed flat machine.

18.7.2 The knitting action of the V-bed hand flat machine

Numbers 1 to 4 below correspond to the numbers in the knitting action illustrations (Fig. 18.2), assuming a carriage traverse from left-to-right. Similar positions may be plotted for the return traverse, using the cams given an (L) designation to provide the positive movements.

- 1 *The rest position.* The tops of the heads of the needles are level with the edge of the knock-over bits. The butts of the needles assume a straight line until

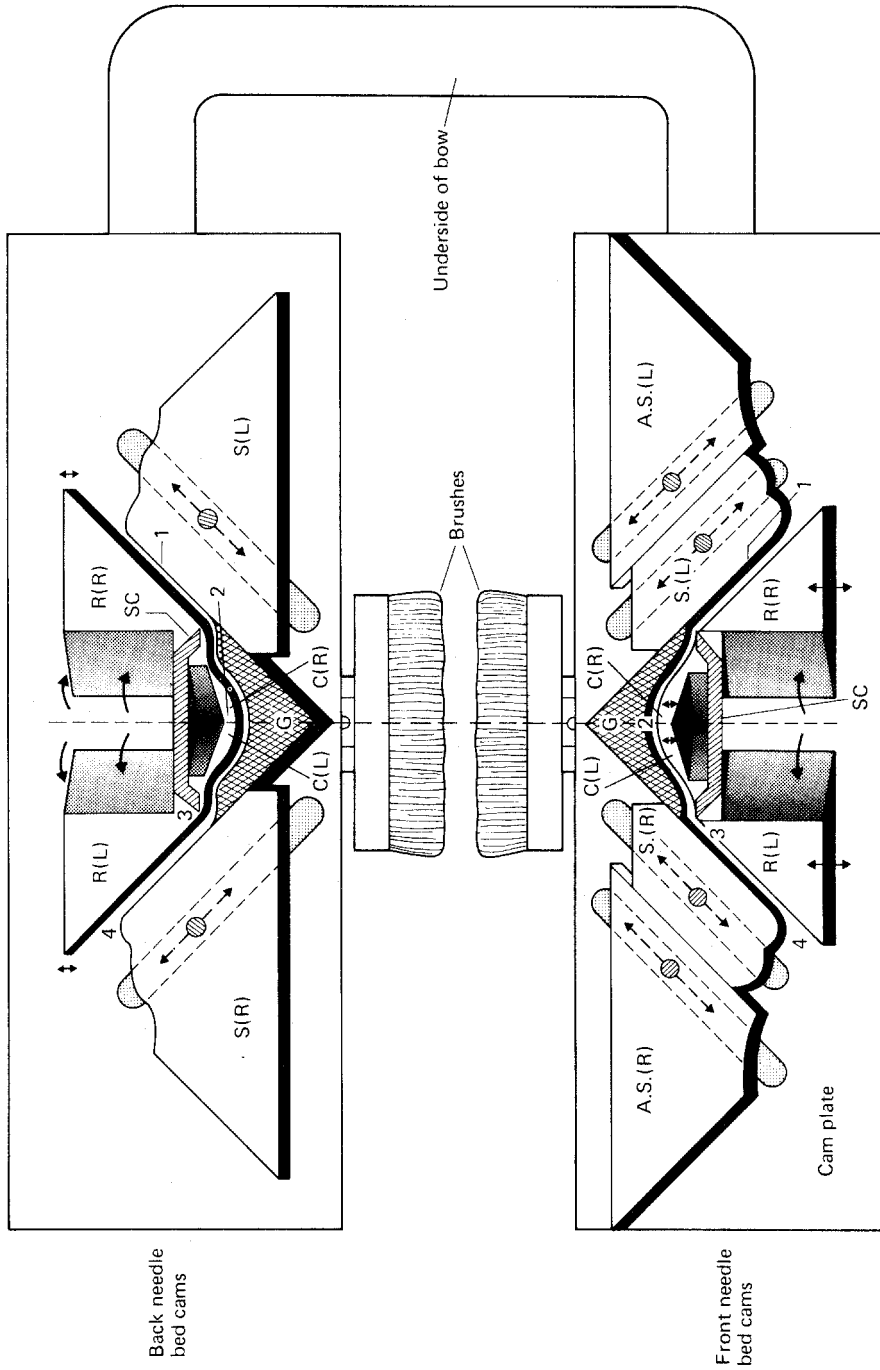


Fig. 18.3 Cam system of simple hand flat.

contacting the raising cams R (R) because the leading stitch cams S and AS (L) are lifted to an inactive position. The lifting action is an *alternating action* that always lowers the trailing stitch cams and raises the leading stitch cams in each system as the traverse commences. This action prevents needles from being unnecessarily lowered and a strain being placed on the old loops prior to the start-up of the knitting action.

- 2 *Clearing.* The needle butts are lifted as they contact the leading edge of cams R (R), which raises the needles to 'tucking in the hook' height with the under-surface of cams S (L) acting as guard cams. The needles are lifted to full clearing height as their butts pass over the top of cardigan cams C (R) and C (L).
- 3 *Yarn feeding.* The yarn is fed as the needles descend under the control of guard cam (G). The required loop length is drawn by each needle as it descends the stitch cam S (R).
- 4 *Knocking-over.* To produce *synchronised knocking-over* of both needle beds simultaneously, the stitch cam S (R) in the front system is set lower than the auxiliary stitch cam AS (R), so that the latter is rendered ineffective. If, however, *delayed timing of the knock-over* is employed, knock-over in the front bed will occur after knock-over in the back bed. In this case, stitch cam S (R) is not set as low as AS (R) (Number 5 in Fig. 18.2) so that the depth setting of the latter cam produces the knock-over action. Delayed timing is only normally used on gauges finer than 8npi and cannot be used for broad ribs.

18.8 Stitch cam settings

The stitch cams are located in slots by studs and they may be raised or lowered to a different setting position by moving the stud along the slot (Fig. 18.3). Unless the rate of yarn feed is controlled, the setting of the stitch cam at knock-over will determine the *stitch length* because it controls the distance the head of the needle descends below the knock-over bit edge from the rest position. The alternating stitch cam settings are indicated by pointers on a calibrated scale on the outside of the cam-plate.

On hand flats, the adjustment of the settings is obtained by hand controls, whilst on modern electronically-controlled flats, each stitch cam is raised and lowered by its own *step motor*, so a wide range of stitch lengths can be achieved during the knitting of a garment.

18.9 Spring-loaded cams

Raising cams (R) and cardigan cams (C) (Fig. 18.3) are of the spring-loaded type that can be depressed into the under-surface of the cam-plate against the action of a spring. The leading edge of a leading raising cam is straight so that it causes the butts to follow its profile. However, the trailing inner edge of the cam, which is the leading edge when that cam is trailing, has a gently sloping edge. Needle butts deliberately not raised by the leading cam thus ride up the trailing cam, depressing the cam into the cam-plate and then follow an undisturbed path across its face. After the butts have passed, the cam springs outwards from the cam-plate to resume its active position for the return traverse.

On hand flat machines, the cams are often of the sinkable setting type so that they can be set either:

- 1 *fully in action* out from the cam plate so that they act on every needle butt,
- 2 *partly withdrawn* into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface, or
- 3 *fully withdrawn* into the cam-plate so that all butts pass undisturbed across their surface.

The standard set-out when using different lengths of butts is two long and one short in each bed, with the short butt centred between the two long butts in the opposite bed. This enables changes from 1×1 to 2×2 rib knitting to occur.

Changes of cam settings are achieved by the movement of controls that are placed on the outside of the cam-plate. In the case of mechanical automatic power flats, these controls can consist of metal push slides, each corresponding to a different cam whose sideways movement produces the required change of cam setting. At each end of the machine is a contact post containing striking plates, aligned to contact the slides as the carriage reaches the end of its traverse so that the cams may be set for the return traverse. Control of the plates is achieved from the main garment (machine) control of the machine.

Electronic machines have continuous electronic contact with the cam carriage and therefore do not require the cam slide arrangement.

On hand flat machines it is useful to have split cardigan cams so that a different setting can be achieved in each direction without having to stop the carriage at the end of each traverse.

The automatic machine can change the cam settings for each traverse; split cardigan camming is unnecessary and these machines usually have a single cardigan cam for both traverse directions.

18.10 Two or more cam systems

Although hand flat machines have single cam system carriages, many automatic power flat machines have two, three or four cam systems, each with a complete set of knitting cams arranged side by side in the same cam-plate each working with a separate yarn carrier. Thus, in one cam carriage traverse, as many courses as there are cam systems can be knitted.

However, compared with a single system machine, the rate of carriage traverse is often reduced, firstly because of the heavier carriage, and secondly because it is longer and must traverse further, thus making the machine longer. There is also a problem of vertical floating threads at the selvedge edges of the fabric. Compact cam design and machine construction, together with the use of lightweight alloys and automatic thread cutters, have largely overcome these problems.

18.11 Split cam-carriages

Another useful development is the *split cam-carriage*. For example, a double system cam carriage operating across the full width might also be split into two single system (2×1) cam-carriages, each covering half the needle bed or both co-

operating in the knitting of wedge-shaped or other complex designs. Split cam-carriage machines have been built with a total of two (2×1), four (2×2), six (2×3), and even eight (2×4) systems.

18.12 Direct and indirect yarn feed

On mechanically-controlled flats, it is necessary to join the front and back needle bed cam-plates with a *bow* or *bridge* in order to drive the cam-carriage as a single unit. However, the traversing bow necessitates an unbalanced diversion of the yarn path down to the needles. This in turn produces unbalanced yarn tension, depending on whether the cam carriage is traversing towards or away from its yarn supply.

On some of the latest electronically-controlled power flats, the bow has been eliminated by driving the front and back needle bed cam-plates separately but in unison, thus giving the cam carriage an open construction. Additionally, the yarn carriers are no longer mechanically connected to the cam-carriage and are each individually driven. They need not be synchronised with the carriage traverse. A yarn carrier can be selected either for knitting, plating or laying-in. Precise placing is achieved both for selvedge shaping and intarsia, where swing yarn carriers are no longer needed (Chapter 19, *Tsudakoma*).

Direct yarn feed is often used on hand flat machines as it allows weak yarns to be knitted because the yarn is supplied directly down from the centrally-positioned yarn tensioner to the reciprocating yarn carrier, so that the tension is kept fairly constant at a minimum level. With this arrangement, the carrier must always remain on one side of the carriage bow, for example on the right, and not pass underneath it, as the yarn path would be disturbed. Yarn carriers can therefore only be collected and left by the carriage at the right side of the machine so that only double course striping can be produced. The pick-up device for the yarn carrier is located on the outside of the low bow.

Indirect yarn feed is used on power flat machines, and is characterised by a high carriage bow passing over the carrier bars, with the yarn path parallel to them, from guide eyes at the end of the machine to the yarn carriers. The yarn is deflected in its downward path from the yarn tensioners across to the guide eyes, thus increasing the tension on the yarn and tending to cause fluctuations depending upon whether the carrier is traversing away from, or towards, the yarn guide eye end of the machine. However, it does enable the yarn carrier to be picked up or left on either side of the machine, using plungers that operate down onto the carrier blocks from the underside of the carriage bow.

18.13 Yarn carrier arrangement

The yarn carriers are arranged to slide on both sides of double prismatic guiding bars and there are usually six or seven carriers operating on two or three double bars. When two carriers operate on the same track of the same bar, it is essential to arrange the sequence so that if the two carriers are deposited on the same side, the one nearest to the cam-carriage will be the one first required to traverse back in the opposite direction.

There are two methods of entraining carriers with cam systems on double system

machines: uncrossed and crossed. With the *uncrossed* arrangement, the same yarn carriers operate with the same cam systems in both directions of traverse. This simplifies the control and is essential when two carriers are on the same track, but it causes problems with vertical yarn floats at the selvages because the yarn with the leading cam system will finish the first course but will not knit the return traverse.

With the *crossed* arrangement, one yarn carrier will always be entrained with the leading cam system and the other with the trailing cam system, so that if the carriers have different coloured yarns, each will knit alternate courses.

In carrier positioning and traversing for jacquard (Fig. 18.4), the yarn carriers

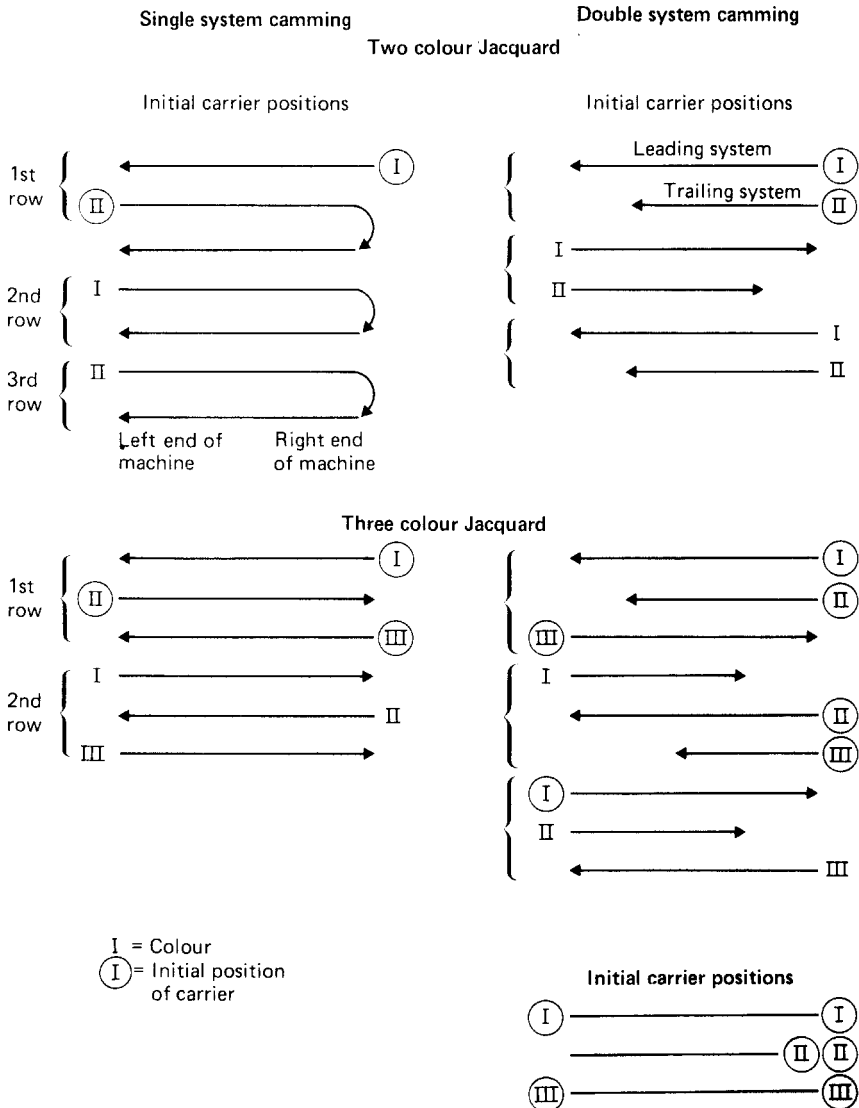


Fig. 18.4 Yarn carrier positioning.

must be carefully positioned initially in order to keep their number to a minimum whilst ensuring that empty traverses (without knitting a course) are avoided whenever possible, as they reduce productivity. By drawing a plan of traverses and colours, and indicating each time a new yarn is picked-up, the initial positions can soon be established. For double system knitting in two- or three-colour jacquard, each system will require as many carriers as there are colours, but two carriers of the same colour can use the same track. Only in the case of single-system two colour jacquard is it necessary to alter the sequence of coloured courses. This is because, after their first course, each colour is knitted at two consecutive courses.

18.14 Typical structures knitted on flat machines

Cardigan stitches are two-course repeat tuck rib knitwear structures, widely used in the body sections of heavy-weight stitch-shaped sweaters. The tuck stitches cause the rib wales to gape apart so that the body width spreads outwards to a greater extent than the rib border. The tuck loops increase the fabric thickness and make it heavier in weight and bulkier in handle, although the rate of production in rows of loops will be less than for normal 1×1 or 2×2 rib. The greater the proportion of tuck to cleared loops, the heavier and wider the finished relaxed structure (see Fig. 16.13).

In the production of a knitted stitch, the leading raising and cardigan cams for that bed and direction of traverse must be in action, whilst for a tuck stitch, the raising cams remain in action but the cardigan cam is taken out of action. It is important to arrange the camming for the needle beds so that, at the start of the traverse when tucking, the first needle is tucking and the last needle in action is in the opposite bed and is thus knitting. If the last needle is tucking, the selvedge tuck loop will withdraw from the needle hook as the reverse traverse commences.

Half-cardigan or *royal rib* (Fig. 18.5) is produced on a 1×1 rib base, having tuck loops on one bed only at alternate courses. It is therefore an unbalanced structure with a different appearance on each side and with twice as many cleared loop courses per unit length on the all-knit side as on the tuck loop side. On the all-knit

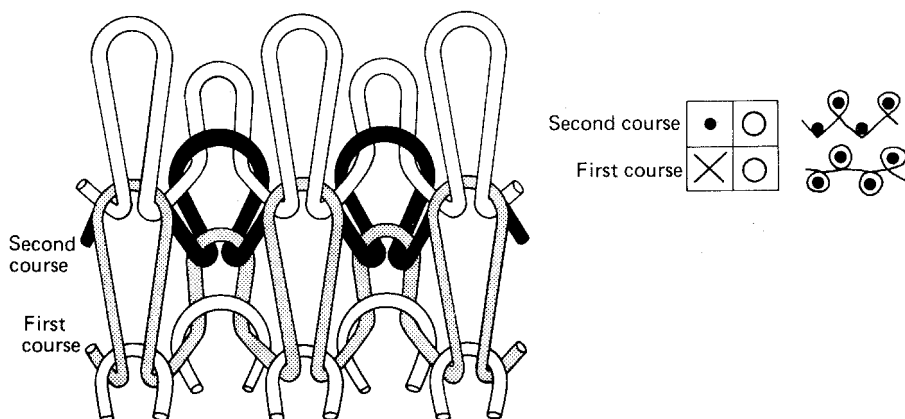


Fig. 18.5 Half-cardigan loop structure.

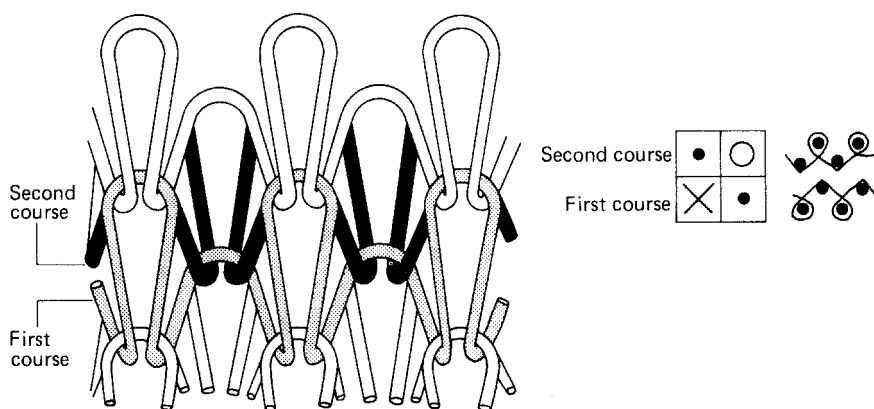


Fig. 18.6 Full cardigan.

side, one course of loops has very large and rounded loops. This is because they receive yarn from the tuck loops on the other side. The other course of loops on this side has, in contrast, extremely small and insignificant loops because they are robbed of yarn by the elongated held loops on the other side, which consists only of held loops as the tuck loops lie behind them.

A two-tuck variation of half-cardigan, based on a four course repeat with each repeat sequence repeated at two consecutive courses, is useful as it produces rounded loops on the knit side as a result of yarn passing into it from the second tuck course.

Full-cardigan or polka rib (Fig. 18.6) consists of one course of loops knitted on the front bed and tucks on the back, and the second course with the sequence reversed, thus producing a balanced 1×1 tuck rib structure with the same appearance on both sides. If different coloured yarns are knitted at alternate courses, a 'shot rib' will be produced which in the relaxed state will show one colour on one side and the second colour on the opposite side.

In open width, a 1×1 rib fabric will relax by about 30 per cent, half-cardigan by only 5 per cent, and full-cardigan will show no width shrinkage compared with its original knitting width.

To knit half-cardigan on a single-system hand-flat, one of the four cardigan cams is taken out of action so that in one direction of traverse a tuck stitch will be knitted on one needle bed only.

To knit full-cardigan, diagonally opposite pairs of cardigan cams are taken out of action so that in one direction of traverse the front needle bed will tuck and in the return traverse the back needle bed will tuck.

The 2×2 rib version of half-cardigan is termed *fisherman's rib* and the full-cardigan version is termed the *sweater stitch*.

18.14.1 Racked rib structures

The V-bed flat machine is capable of knitting a unique range of racked rib structures (Fig. 18.7), based on the facility of racking one needle bed by one or more needle tricks past the other needle bed, either towards the right or the left as and when required. Usually, the needle set-out is 1×1 rib, or a modified version with

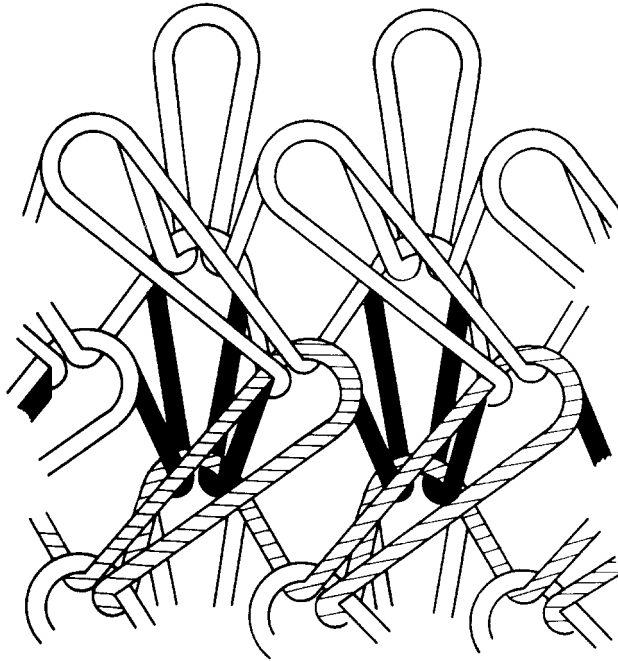


Fig. 18.7 Racked rib.

selected needles taken out of action, and a knitting sequence of half- or full-cardigan [1].

The *basic principles of racked rib structures* are as follows:

- 1 A loop on a needle in one bed must be racked past a loop from the same course on a needle in the other bed. The structure must therefore be rib based.
- 2 After an all-knit course of 1×1 rib, the 45 degree angle of inclination of a single needle rack would be shared by the loops in both beds and the appearance would be insignificant. A two-needle rack is thus required.
- 3 After a course with tucking on one bed and knitting on the other, a single-needle rack will produce a 45 degree inclination on the knitted loop side, irrespective of which needle bed was racked (Fig. 18.7). The open legs of the tuck loops resist the effect of racking so the tension only inclines the knitted loop side of the course. Half- or full-cardigan sequences (Figures 18.5 and 18.6), which consist of courses of knitted loops on one bed and tuck loops on the other, are thus an ideal base for racked structures.
- 4 With half-cardigan, racking can occur only after every alternate course of the two-course repeat – it cannot occur after the 1×1 rib knitting course. The racked effect will show only on one side of the fabric – the all knitted loop side – at every second row. In-between the racked loop courses, the 1×1 rib courses will appear as minute upright loops on the effect side.
- 5 In the full-cardigan sequence, every course has tucks on one bed and knitted loops on the other, so that racking can occur after every course. The racked loops will appear on one side of the fabric at the first rack and on the other side at the next, always on the side remote from the tuck loops of that course.

Racked loops can be produced at every row of knitted loops on each side of the fabric because the tuck loops are hidden inside the structure.

- 6 In a full-cardigan sequence, if racking occurs to the left at the first course and to the right at the second course, all loops will be racked in the same direction on both sides of the fabric. This is because racking knitted loops to the right produces the same direction of inclined loops as racking the tuck stitches to the left. If the colour of the yarn is changed at fixed intervals of courses and the fabric is cut in rectangular pieces at right angles to the inclined selvages, diagonal rather than horizontal stripes will be produced relative to the selvage.
- 7 If in a full-cardigan sequence racking occurs in the same direction at two successive courses and is followed by two racks in the opposite direction at successive courses, alternate courses on each side of the fabric will show loops inclined in opposite directions.
- 8 A *Vandyke* or *zigzag selvage edge* will be produced if the principles explained in 6 and 7 are combined. *Example*: 16 courses might be knitted with a rack to the right after every odd course and a rack to the left after every even course. This is then followed by a course without a rack so that the racking sequence recommences out of phase producing inclined loops in the opposite direction for a further 16 courses before the next no-rack course completes the repeat of the design. On each side of the fabric, courses will incline in one direction for 8 face rows before the inclination is reversed. Every 16 face rows there will be one row of small insignificant upright loops that alternates on one side and then on the other.
- 9 Racked loops are produced only if a needle in one bed racks past a needle in the other bed. If a needle racks past an empty trick (because the needle in the other bed has been removed or is out of action) there will be no inclined loop in that wale.
- 10 A pattern repeat of racked and straight wales can be produced across one side of a full-cardigan fabric. It is knitted with a needle-out sequence with racking to the right after every second course and to the left after the next two-course sequence. With this arrangement, a needle racked to the right and later to the left past a tuck loop on a needle in the other bed, will produce a wale of inclined loops whereas a needle racked to the right and left past an empty needle trick will produce a wale of upright loops. The sequence can be interrupted by making two successive racks in the same direction before continuing the previous sequence. The needle that was racked past the tuck will now be racking past an empty trick, so its wale changes from inclined to upright loops, whereas the needle previously racked past an empty needle is now racking past a tuck loop, so the loops in its wale are no longer upright but inclined. The changeover in either direction can be achieved whenever required.
- 11 The racked effect is more prominent if the wales are spaced further apart by *half-gauging*, i.e. removing every alternate needle from each bed before arranging the needle set-out.

18.14.2 Knop structures

Knop fabrics are relief structures in rib where successive tuck stitches on all the needles or certain needles of one bed produce a three-dimensional effect. Some-

times the all-knit courses are produced in a different colour and sometimes racking occurs after the knop sequence so that the next knop is off-set.

18.14.3 The cable stitch

Cable stitch is a traditional hand-knitted stitch pattern incorporated into fishermen's sweaters in the islands of Jersey, Guernsey and particularly Aran, where it is one of a range of stitch patterns (Fig. 18.8) that includes *ladder*, *blackberry stitch* and *honeycomb* [2]. Traditionally, the yarn is partly-scoured wool in its ecru (undyed and unbleached) colour. The cable stitch is a three-dimensional design of cords of face loop wales, centred in a panel of reverse loop stitches bordered on either side by rib wales of face stitches. Each cord is usually three wales wide; these move as a unit when they are crossed (twisted) over another cord. The direction of twist of the cords is always the same relative to the surface of the design.

Cables are normally either two-cord or three-cord. In machine knitting, the cords are knitted on one needle bed and the background panel on the other. The cable loops are longer to reduce the tension where cords twist. At this point, the loops of

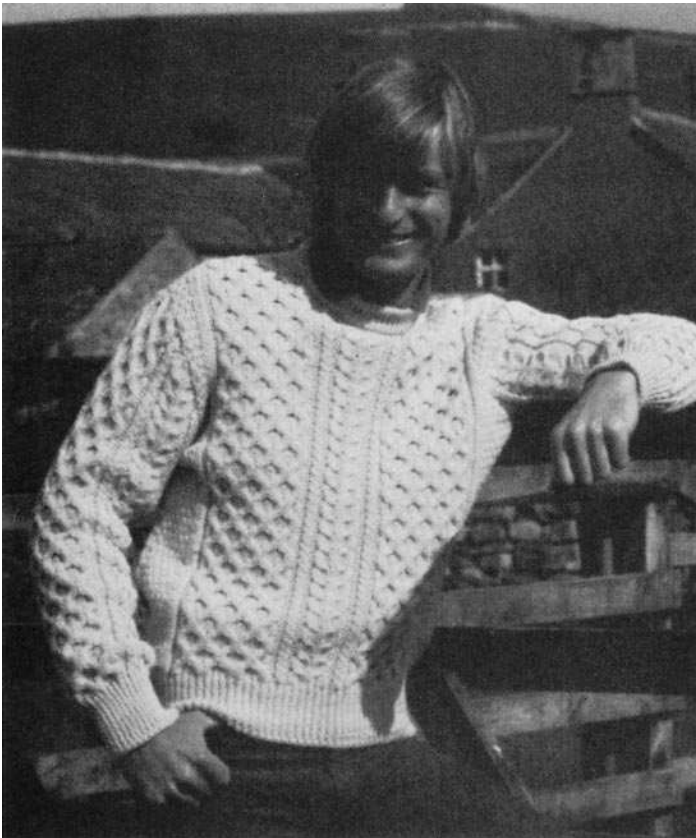


Fig. 18.8 Aran crew-neck pullover knitted by T W Kempton on a 5-gauge JDR flat machine from 2/6's worsted count woollen spun yarn [British Wool Marketing Board/Marks and Spencer].

one cord are transferred over to the other bed so that the two cords can be racked past each other before they are transferred back to recommence knitting. Cable stitches are knitted on some automatic flat rib and purl machines, as well as on a few double-cylinder machines with the facility for shogging the top cylinder. Generally, double-cylinder machines knit only mock cable effects using purl stitch designs.

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