19. Principles of Yarn Requirements for Knitting

Errol Wood

Learning objectives

On completion of this lecture you should be able to:

- Describe the general methods of forming textile fabrics;
- Outline the fibre and yarn requirements for machine knitwear
- Describe the steps in manufacturing and preparing yarn for knitting

Key terms and concepts

Weft knitting, warp knitting, fibres, fibre diameter, worsted system, yarn count, steaming, clearing, winding, lubrication, needle loop, sinker loop, courses, wales, latch needle, bearded needle

Introduction

Knitting as a method of converting yarn into fabric begins with the bending of the yarn into either weft or warp loops. These loops are then intermeshed with other loops of the same open or closed configuration in either a horizontal or vertical direction. These directions correspond respectively to the two basic forms of knitting technology – weft and warp knitting.

In recent decades few sectors of the textile industry have grown as rapidly as the machine knitting industry. Advances in knitting technologies and fibres have led to a diverse range of products on the market, from high quality apparel to industrial textiles. The knitting industry can be divided into four groups – fully fashioned, flat knitting, circular knitting and warp knitting. Within the wool industry both fully fashioned and flat knitting are widely used. Circular knitting is limited to certain markets and warp knitting is seldom used for wool.

This lecture covers the fibre and yarn requirements for knitting, and explains the formation of knitted structures. A number of texts are useful as general references for this lecture; (Wignall, 1964), (Gohl and Vilensky, 1985) and (Spencer, 1986). The comprehensive lecture notes by Professor Kovar and published in Knitting Technology journal are also very informative. (Kovar, 2002).

The huge number of internet web sites on knitting are devoted mostly to hand-knitting and simple machine knitting as home crafts rather than high volume industrial production of knitwear. However, the UMIST lecture notes which are available on the internet are very informative.

Formation of textile fabrics

Textile fabrics can be produced by a number of processes: (a) directly from webs of fibres by bonding, fusing or entangling, or (b) by manipulating yarns. There are three principle methods of mechanically manipulating yarns into textile fabrics:

Weaving

This is the oldest and most common method of producing continuous lengths of straight-edged fabrics. It involves the intersection of straight threads (ie, the warp and the weft) which cross over each other at right angles.

Intertwining and twisting

Various techniques such as braiding, twisting and knotting involve threads intertwined with each other at right angles, or some other angle. This method of fabric formation is limited to specific product applications.

Interlooping

Knitting is the most common method of interlooping yarns, and is second only to weaving for manufacturing textile structures.

All three methods of fabric formation have evolved from hand manipulation techniques leading to the use of primitive equipment and finally the sophisticated manufacturing operations carried out today on highly automated machinery. Although the unique ability of knitting to make shape and form-fitted garments has been used for centuries, modern technology has enabled knitted constructions to expand into a wide range of apparel, domestic and industrial end-uses.

While the underlying principles of fabric formation are the same for both hand knitting and machine knitting, this lecture series will focus on the use of electrically-powered knitting machines and the knitted structures produced by these machines.

19.1 Introduction to knitting

It has not been possible to determine the historical origins of knitting. It is the youngest sector of textile production, with relics of hand-knitted products from the 6th century having been discovered. Nothing is known of the procedures first used to form stitches, but they probably involved a hook (like a crochet hook) or a knitting pin (or needle). Whereas the art of weaving was already mechanised before the birth of Christ, knitting remained a manual process until the end of the 16th century. However, since the knitting process was relatively simple, it actually lent itself to mechanisation more easily than weaving. A knitting frame machine invented by William Lee made mechanically all of the kinds of knitted structures that had previously been made by hand. The invention by Townsend of the latch needle in 1853 stimulated huge growth in machinery development and permitted simpler and more widely available technologies.

When knitting is performed by hand, each loop is made separately to form a row of stitches across the width of the cloth. This row of stitches is then connected to the next row as the knitter proceeds. However, in machine knitting, a complete row of loops is made at one time by having one needle for each loop being formed.

Modern knitted products are many and varied, and even difficult three-dimensional shapes can be produced without waste. As well as apparel, knitted products are also available as interior textiles, reinforcements for composite materials, medical implants, packaging etc. Large-diameter circular knitting machines knit 120 courses simultaneously at speeds of 1.5 m/s or more. Modern warp knitting machines are capable of 3000 rpm.

Fibre requirements for knitting

Knitted fabrics, like woven fabrics, can be made from a wide range of fibres and can have many textures (soft or firm, loose or tight, stiff or elastic and rough or smooth).

Yarns used in knitting should be strong, resilient, bulky, have good elasticity and the ability to absorb moisture. These properties depend mostly on the characteristics of the fibres used, as well as the construction of the yarn (ie, twist, count, etc.).

Knitting has traditionally uses a wide range of natural textile fibres such as wool, silk, cotton and flax. During the 20th century the advent of man-made fibres (regenerated and synthetic) has added greatly to the list of fibres used.

The current list of widely used fibres in knitwear is:

1. Animal fibres: wool, mohair, angora, silk, cashmere, alpaca, vicuna
2. Vegetable fibres: cotton, linen ramie
3. Manmade fibres: rayon, nylon, polyester, acrylic

The dominant fibres for knitted apparel are nylon, polyester, the acrylics and wool.

Wool in knitwear

Wool yarns from the traditional fibre are ideal for most types of knitted fabrics and have the appropriate properties for efficient knitting. Wool accepts dye well, is naturally flame-retardant, remains warm even when wet and sheds water better than other yarns. It can be given a shrink-resist treatment to make it easy care in washing, however if a wool garment is agitated in water that is too hot it will shrink.

However, wool has always been considered a problem yarn for machine knitting because numerous difficulties are encountered in converting it into fabric. Slow machine speeds, low knitting efficiencies, high costs of manufacture and lack of versatility in cloth design have tended to exclude wool from certain modern trends in knitting product development. Basically, the problems of knitting wool yarns are mainly due to its relative weakness, especially in relation to continuous filament synthetics. Consequently, if, during the knitting cycle large stresses are experienced by the yarn, fabric faults such as holes will readily occur. Yarn faults such as unevenness, thick and thin places all contribute to knitting inefficiencies. Hence, with wool it is obvious that the quality of the yarn for knitting must be high.

Despite these limitations, its exceptional aesthetic and comfort properties have ensured a strong, consistent demand for knitted wool products.

Because of its influence on the bending properties of yarns (as well as the relationship with fibre crimp), the fibre diameter is generally of more importance than fibre length. In general, the finer the mean fibre diameter (micron) of the wool, the softer the handle of the fabric and the greater the bulk (arising from fibre crimp).

The form of the fibre diameter distribution must also be considered. In the case of fine machine knitting yarns used for underwear in particular, the probability of any constituent fibres producing unpleasant prickle sensations when protruding from the fabric surface must be reduced to a minimum. For this reason tops finer than 20 microns are used for such products in order to guarantee that the percentage of prickle-causing fibres (ie, those coarser than 30 microns) will be negligible.

The colour of the wool is also important, but this is not often an issue with fine merino fleece wools which are generally very white in comparison with coarser wool types. Fibre length affects processing efficiency in yarn manufacture as well as having an influence on the appearance and wear performance of knitted fabrics.

Wool yarns for weaving spun on the worsted system, are spun near the count limits (ie, approximately 40 fibres per singles in the cross-section). The formula for the approximate yarn count for a given micron is:

$$\text{Yarn count (tex)} = 0.0436 \times \text{micron}^2$$

Machine knitting yarns are generally spun to meet a specific set of product requirements such as handle, softness and appearance. Therefore the above formula does not necessarily apply although it does indicate the finest yarn that may be spun from a given micron. Table 19-1 shows the average fibre diameter of tops commonly used for producing two-fold machine knitting yarns. It is clear that most often machine knitting yarns, especially medium to coarse counts, are not spun at the limit.

Table 19.1 Common top diameter for machine knitting yarn counts. Source: IWS, 1998.

Yarn count		Top mean fibre diameter (micron)
Nm	tex	
20/2	R 100/2	<25
28/2	R 70/2	<23.5
36/2	R 56/2	<22
48/2	R 42/2	<21.5
60/2	R 33/2	<19.5

Other fibres

Cotton has also been used in knitting since 1730, being able to be spun economically to fine yarn counts. Cotton is a heavy, dense, inelastic fibre which gradually loses its ability to retain its shape after washing. It is comfortable to wear cotton knitwear in a cool climate but not a warm climate (opposite to wool), and is slow to dry once wetted.

The development of synthetic fibres and their texturing processes to provide bulk has proved very beneficial to the knitting industry. Staple fibre yarns are used for many applications. Continuous filament is used for hosiery and some fabrics and is also used for reinforcement, for example, in socks. Very extensible elastane fibres such as Lycra are used as a minority component in stretch fabrics to provide high elasticity.

Acrylic fibres are the most widely used synthetic fibres in knitting yarns. They are resilient, moderately strong, somewhat inelastic, feel good to the hand and are light in weight. They are easily made to imitate natural fibres and so they provide an alternative to wool. However, acrylic knitwear fabrics cannot wick away moisture from the body so their warmth diminishes when they get wet. Acrylics are often used to produce novel textures not possible with natural fibres.

Nylon knitwear is lightweight, strong, elastic, resists abrasion and is easy to wash. Nylon is usually blended with wool to impart its strength to the wool, or used to strengthen section of garments that will encounter wear such as sock heels.

Both singles and folded yarns are used in knitting, but the best results are obtained with folded yarns.

The length and quality of the fibre in a yarn determines the texture, lustre, strength and handle of a knitted fabric. Yarns made from longer fibres will have a lower propensity for pilling, be smoother, stronger, more lustrous and more elastic. Tightly twisted yarns display the texture of a knitted pattern to its best advantage. Low twist, more fuzzy yarns obscure a stitch pattern but produce knitwear with a more bulky appearance, softer handle and which is warmer.

Yarn manufacture

Machine knitting requires relatively fine, smooth, strong yarns which have good elastic properties. Therefore the worsted system is the preferred yarn manufacturing route, although woollen-spun yarns also have their uses in knitwear, especially where a bulky, hairy yarn is required.

Knitting yarns tend to be of lower twist than weaving yarns, and may be textured to produce a fabric that is softer, more bulky and porous than woven apparel fabrics.

The worsted system is the most complex of all yarn manufacturing routes for wool. It involves an integrated series of steps, as shown in Figure 19-1.

An IWS publication (IWS, 1998) covers the topic of yarn quality requirements for knitwear in detail.

Topmaking

A major step is the removal of grease and dirt from the wool by scouring. After blending wool from different sources, cleaning is achieved by scouring, carding and backwashing. Scouring is carried out on the loose wool, then carding opens the wool and aids the mixing process. The sliver (a continuous rope of wool) produced by the card is subjected to gentle washing and drying (ie, a backwashing treatment) The sliver is then fed to a series of gill boxes to straighten, mix and parallelize the fibres. In combing the short fibres are removed from the sliver as noils and after two or three further gillings the top is obtained. This is a very even, parallel rope of fibres which is the starting point for worsted spinning.

Various chemical treatments such as dyeing or shrink-resist resin application may be carried out in topmaking. The latter treatment modifies the surface scales of the fibres so that they can readily slip past each other and not undergo felting. Both processes have the ability to impair knitting performance if not carried out carefully.

Spinning

Recombing and gilling prior to spinning restores the parallel arrangement of fibres so essential for producing a fine, even worsted yarn. Drawing reduces the linear density (ie, count) of the final gilled sliver to a thin strand, a roving, which is suitable for spinning. Knitting yarns are spun on ring frames to a wide range of counts. Here the roving is drawn out to the final count and sufficient twist is inserted to cause the fibres to bind together and impart strength to the yarn.

In some cases two or more yarns may be twisted together to form a plied yarn. Two-fold twisting may be carried out using two-for-one twisters, two-stage up-twisters and conventional ring twisters.

The finished yarn will be wound on a suitable package for dispatch to the knitwear manufacturer.

The yarn twist has an influence on its strength and extensibility. High twist results in a firmer, leaner yarn and can give a high level of stitch clarity in knitwear. The fabric will also tend to be somewhat thinner (ie, lower bulk), more permeable to air and possible feel a little harsher to the touch.

However, knitting yarns are not subjected to the same high abrasion forces as weaving yarns. They tend to be of lower twist than weaving yarns, and may be textured to produce a fabric that is softer, more bulky and porous than woven apparel fabrics.

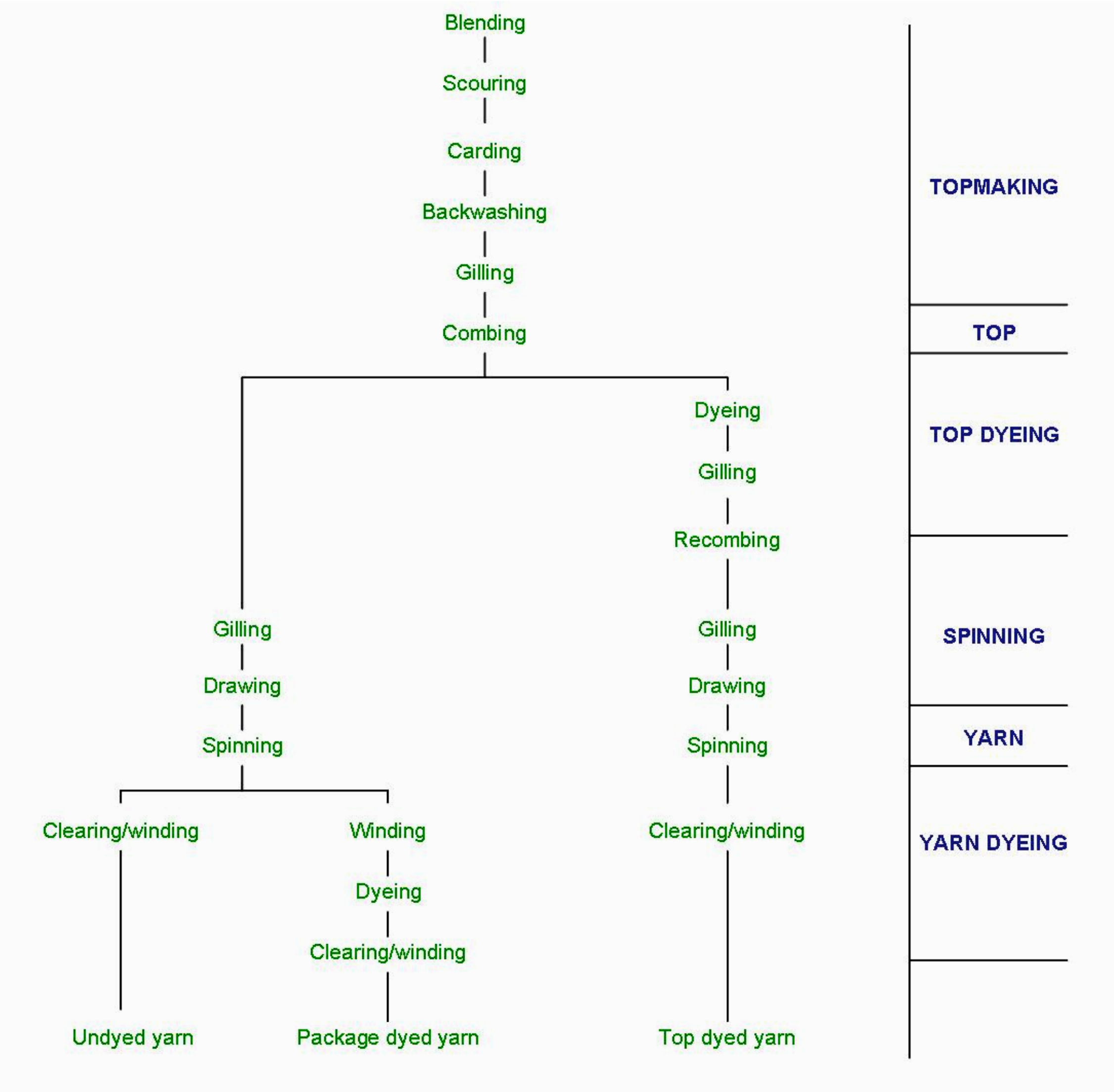
Machine knitting yarns for single jersey fabrics are usually spun with a metric factor of around 70-80. To calculate the actual turns per metre in the yarn the following formula is used:

$$\text{Yarn twist (turns per metre)} = \text{Metric twist factor} \times \sqrt{\text{(Resultant Count (Nm))}}$$

The recommended folding twist to singles twist ratio is about 60%.

For double jersey knitting, higher twist levels are used than for other types of knitting yarns. The metric twist factor for these yarns are usually in the range 90-105.

Figure 19.1 The worsted route. Source: Wood, 2006.



Yarn treatments

A number of treatments may be carried out to prepare a wool yarn for knitwear. These include steaming, package dyeing, clearing and winding, and lubrication.

Steaming

It is common to steam yarns in order to reduce the twist liveliness so that the yarn can be wound and knitted in a satisfactory manner. However, some decrease in knitting performance inevitably occurs in steaming so the severity of the treatment conditions needs to be kept to a minimum while ensuring that the steam penetrates throughout the package.

Steaming is not recommended for single jersey yarns to reduce the risk of loop distortion. The risk of spirality in the finished garment does not exist so long as the folding twist balances out the singles twist. On the other hand, yarns for double jersey knitting are mostly used in singles form and steaming is usually necessary, especially in view of their higher twist levels.

Clearing and winding

This is an important stage as it provides an opportunity to remove yarn defects and also is an ideal stage for the addition of knitting lubricants.

Knitting efficiency can be affected by the incidence of faults in the yarn. For medium to coarse counts, knitting faults are mainly a result of thick places in the yarn (eg, slubs, knots). Finer yarns, however, mostly break at the thin places and are rarely affected by knots. A clearing device automatically detects thickness faults, removes the section of yarn by cutting and rejoins the yarn.

The winding of the cleared yarn onto a cone is carried out under even tension. Excessive winding tension must be avoided as this can lead to flattening and distortion of the yarn, adversely affecting fabric appearance. Because of the unwinding conditions on the knitting machine, a knitting yarn package needs to have a greater taper to prevent the unwinding yarn fouling the edge of the package.

Wool knitting yarn packages should be soft wound to a packing density of less than 400 g/l and preferably weigh no more than 1 kg.

Lubrication

In knitting, the yarns are threaded around numerous guides and into the needles and tension builds up in the yarn due to friction between the yarn and the guides and needles. Frictional forces opposing yarn motion can cause excessive yarn breakage in knitting. Yarn lubrication to reduce these forces is an important part of the preparation of knitting yarns. Paraffin wax is often used for this purpose and is normally applied by means of wax rings during the winding process. Proper waxing ensures that a constant yarn tension is maintained throughout the knitting process. It is recommended that the average wax take-up should be around 2 grams per kilometer of yarn

The final yarn packages are now ready to be loaded onto the knitting machine. Unlike the time-consuming and labour intensive steps involved in bringing the warp yarns into a weaving loom, the loading process for knitting is relatively simple and quick.

No all knitting yarns are waxed before leaving the spinning plant. This is because if the storage conditions are too warm, the wax can melt and penetrate into the yarn, thus significantly reducing its effectiveness.

Yarn quality

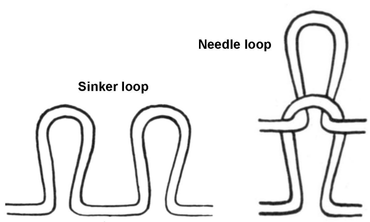
Some of the yarn quality parameters affecting ‘knittability’, such as tensile strength (or tenacity) and evenness have already been mentioned. Others, including extensibility, fibre-to-metal friction, twist, flexural and torsional rigidity and bulk also play their part. Of these extensibility and friction are of prime concern; extensibility is important because if a yarn has no ‘give’ it will be almost useless as a machine knitting yarn; excessive friction leads to the development of high tension in the yarn in the knitting zone.

Recommendations for wool yarns are available (IWS, 1998), for example the tenacity of two fold worsted yarns for machine knitting usually lies in the range 5 – 7 grams/tex, averaging around 6 – 6.5 g/tex. Singles yarns should be at least 5 g/tex to avoid downstream problems.

Formation of a knitted fabric

Knitted fabric manufacture begins with the conversion of a yarn into a series of loops. The loop is the fundamental element of all knitted fabrics, whatever the type of machine is used. The loops are of two kinds – the sinker loop and the needle loop (Figure 19-2).

Figure 19.2 The basic types of loops used in knitted structures. Source: Wood, 2006.



The sinker loop is the one that connects adjacent needle loops while the needle loop is one that has been drawn through a previously formed loop. The combination of a needle and sinker loop results in the formation of a stitch. The components of a stitch are

1. A complete needle loop
2. A sinker loop, and
3. Two connecting loop segments joining the needle loop to the one immediately preceding it.

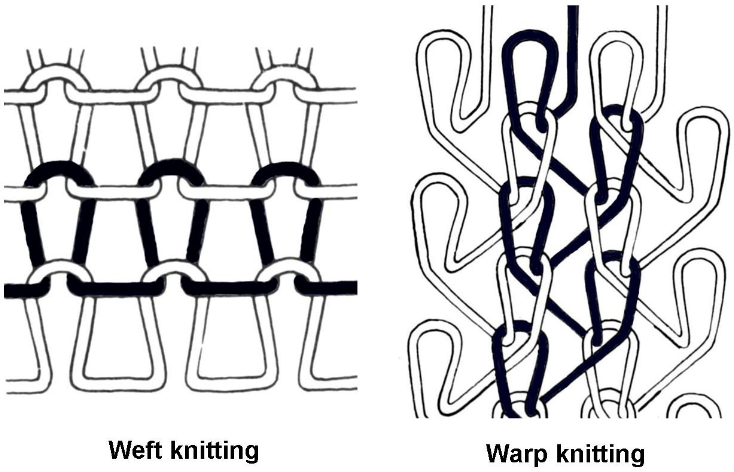
Thus, a knitted fabric is formed by a series of interconnecting loops arranged in succession such that each row of loops intermeshes with, and hangs from the row immediately preceding it, as shown in Figure 19-3 (left). The actual mechanisms involved in forming knitted structures, involving the actions of needles, sinkers and other devices, are outlined in the lecture "Machine Knitting Technologies"

A knitted fabric consists of a series of loops that intermesh both horizontally and vertically. The loops that are interconnected widthwise are called *courses*. The series of loops that intermesh in the vertical direction are called *wales*.

Knitting systems

In the formation of a looped, knitted structure two different systems of knitting may be used – weft knitting and warp knitting (Figure 19-3, right):

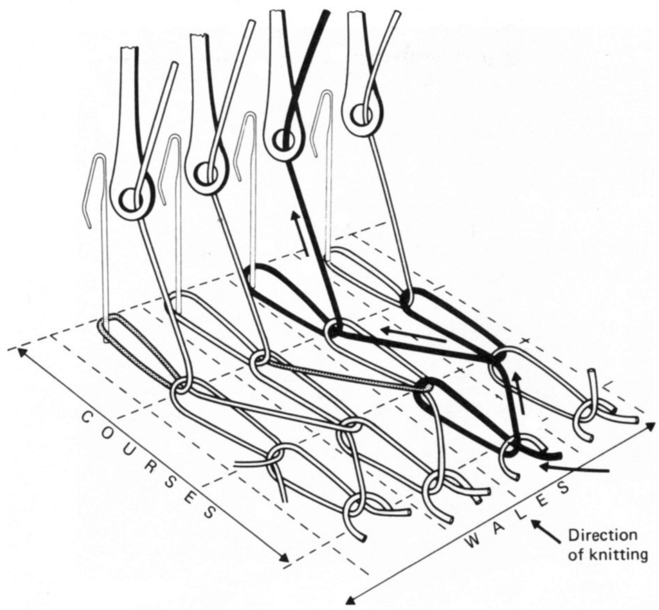
Figure 19.3 Yarn paths in weft and warp knitted structures. Source: Wood, 2006.



Warp knitting is a method of making a fabric where the loops made from each warp yarn are formed along the length of the fabric (Figure 19.4). Each warp yarn is fed more or less in line with the direction in which the fabric is produced. Each needle within the knitting width must be fed with at least one separate thread at each course. There is a simultaneous yarn feeding and loop forming action at each needle. In this case bearded needles are used.

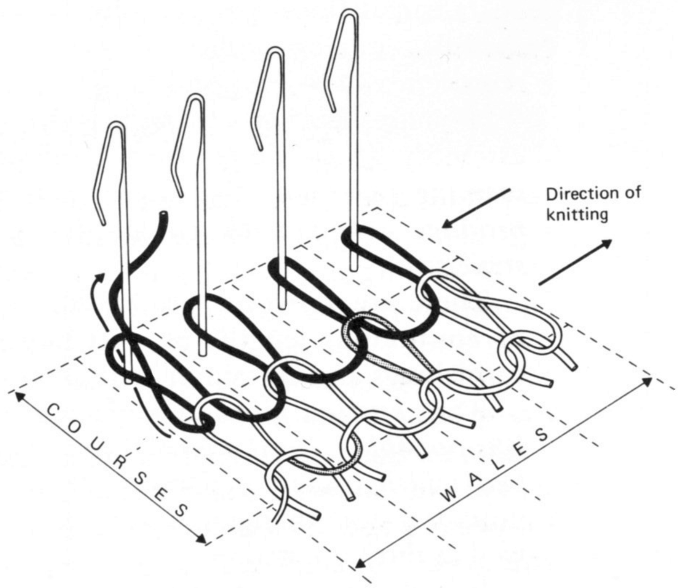
Warp knitting is the fastest method of converting yarn into fabric, when compared with weft knitting and weaving.

Figure 19.4 Warp knitting. Source: Spencer, 1986.



Weft knitting is a method of making a fabric where the loops made by each weft thread are formed across the width of the fabric (Figure 19.5). Each weft thread is fed at right angles to the direction in which the fabric is produced. Yarn feeding and loop formation occur at each needle in succession along the row of needles in a needle bed.

Figure 19.5 Weft knitting. Source: Spencer, 1986.



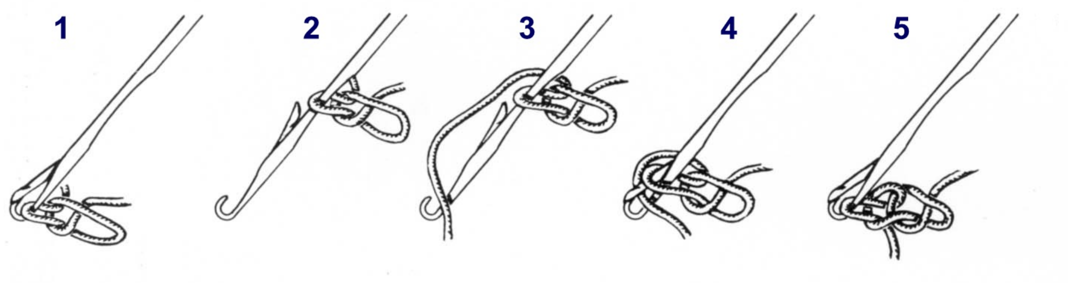
It is possible to knit one thread only, but up to 144 threads may be used on one machine. This method is the more versatile of the two in terms of the range of products made as well as the types of yarns that can be used.

Generally in a weft knitted fabric all the stitches in a course are formed from the same yarn, thus the yarns are in the direction of the courses. To knit this fabric the yarn is laid onto the needles individually with a yarn feeder.

On the other hand, in a warp knitted fabric the stitches in a course are formed with different yarns, thus the yarns are in the direction of the wales. To knit this fabric every needle is provided with a yarn by a yarn guide.

The sequence in which a latch needle produces a knitted loop is shown in Figure 19-3.

Figure 19.6 Formation of a stitch with a latch needle. Source: Wood, 2006.



1. The stitch previously formed is in the hook. The latch is either open or closed.
2. The needle is raised until the stitch passes behind the latch on to the stem of the needle.
3. The yarn which will form the following stitch is laid in the hook. The latch is open.
4. The needle is drawn downwards. The preceding stitch closes the latch then falls beyond the hook over the new stitch.
5. The needle is ready to form the next stitch (as in step 1).

Readings

The following readings are available on CD

1. Knitting Together - History and evolution of knitting machinery. The Heritage of the East Midlands knitting industry, since the 1500s. Retrieved 19th April, 2006 from website http://www.knittingtogether.org.uk.

Activities

Available on WebCT

Multi-Choice Questions

Submit answers via WebCT

Useful Web Links

Available on WebCT

Assignment Questions

Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

Movie

A movie is available on CD.

References

Gohl, E.P.G. and Vilensky, L.D., 1985. Textiles for Modern Living, Longman Cheshire, ISBN 0 582 68831 0.

IWS, 1998, Quality requirements for machine knitting yarn manufacture, Process Development Bulletin No. 19, International Wool Secretariat, UK.

Kovar, R, 2002, Flat knitting Technology, Knitting Technology, March 2/2002, pp. 6-69.

Spencer, D.J., 1986, Knitting Technology, Pergamon Press, ISBN 0-08027463-6

Wignall, H., 1964, Knitting, Pitman, London.

Glossary of terms

Balanced yarn	A yarn which has no tendency to untwist or snarl when unconstrained
Barré	A fault in a weft-knitted fabric appearing as light or dark stripes in the course direction
Bulk	The space filling ability of a yarn or fabric; inversely related to its density
Course	A row of loops across the width of a knitted fabric
Cover factor	A number which indicates the extent to which the area of a knitted fabric is covered by the yarn.
Knit	To form a fabric by the intermeshing of loops of yarn
Knitted loop	The basic unit of weft-knitted fabrics, consisting of a loop of yarn meshed at its base with a previously formed loop
Knitwear	A term usually applied to all knitted outwear garments excluding socks and stockings
Topmaking	The first half of the route to manufacture worsted yarn, comprising blending, carding, gilling and combing steps. The product, a top, is the input material to worsted spinning
Wale	A column of loops along the length of a knitted fabric.
Warp knitting	A method of making a fabric in which the loops from each warp thread are formed along the length of the fabric. Each warp thread is fed more or less in line with the direction in which the fabric is produced.
Weft knitting	A method of making a fabric in which the loops made by each weft thread are formed across the width of the fabric. Each weft thread is fed more or less at right angles to the direction in which the fabric is produced.
Yarn count (or linear density	The mass of material in a standard length of yarn (eg, tex = grams per km) or the length of yarn having a standard mass (eg, metric count = metres per gram)