20. Formation and Properties of Knitted Structures

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Learning objectives

On completion of this lecture you should be able to:

- Describe, using simple diagrams, common knitted structures (eg, jersey stitch, rib stitch, purl stitch)
- Compare the features the of various types of stitch
- Explain how designs can be introduced into knit fabrics using the various types of stitches
- Discuss the factors that influence the cover factor of a woven fabric
- Describe the types of faults that can occur in knitwear, and their origin
- Compare the respective advantages and limitations of knitted and woven fabrics

Introduction

Knitted structures are progressively built up by converting newly fed yarn into new loops in the needle hooks. The needles then draw these new loops head first through the old loops which they have retained from the previous knitting cycle. The needles at the same time release ('cast off' or 'knock over') old loops so that they hang suspended by their heads from the feet of the new loops whose heads are still held in the hooks of the needles. A cohesive, flexible structure is thus produced by a combination of the intermeshed loops and the yarn joining those loops together.

The knitted loop structure may not always be noticeable because of the effect of structural fineness, fabric distortion, additional pattern threads or the masking effect of finishing processes. The properties of a knitted structure are largely determined by the interdependence of each stitch with its neighbours on either side and above and below it.

The lecture notes from the UMIST web site on the principles of knitted structures provide information relevant to this lecture.

Key terms and concepts

Jersey stitch, rib stitch, purl stitch, interlock stitch, face side, reverse side, welt stitch, tuck stitch, cardigan stitch, fabric density, stitch distortion, spirality, barré, easy-care.

Knitted structures

Four primary structures are the base structures from which all weft knitted fabrics are derived. They are:

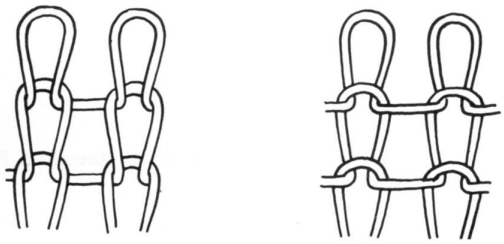
- Jersey (or plain)
- Rib
- Purl, and
- Interlock.

Each is composed of a different combination of face and reverse meshed stitches, which are knitted using a particular combination of needles.

Jersey stitch

The jersey stitch (or plain stitch) is the starting point for all knitted structures (Figure 20-1). The loops intermesh in one direction with the result that fabric has one appearance on the face side and a different appearance on the reverse side.

Figure 20.1 Jersey stitch. Source: Wood, 2006.



The jersey stitch is widely used in the knitting of sweaters, dresses, sport shirts and other items of sports wear.

The characteristic of a single jersey fabric are:

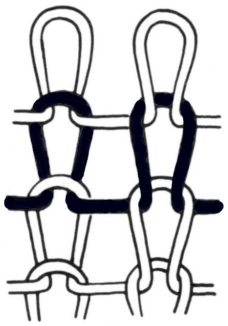
- single sided
- thin/light weight
- fast and efficient production
- edges curl, making it difficult to handle
- partially unstable, susceptible to stitch distortion

These fabrics tend to roll at their edges due to the tendency of the yarn distorted into loops to try to straighten from this configuration.
The jersey stitch structure is extensible in both the lateral and longitudinal directions; however the lateral extension is twice the longitudinal extension. This because the yarn loop pulled in the longitudinal direction can extend by only half its length while when pulled in the longitudinal direction can extend by its entire length.

Rib stitch

The rib stitch has the same appearance on both sides, resulting from the fact that the stitches intermesh alternately on the face and reverse sides of the fabric (Figure 20-2). Thus the rib stitch is actually a blend of the two sides of the jersey stitch. Fabrics using the rib stitch are also known as double jersey or double face fabrics.

Figure 20.2 Rib stitch. Source: Wood, 2006.



In the same course, the first wale would have the appearance of a jersey fabric, the next the reverse of jersey and so on across the fabric. The simplest form of rib stitch is a 1 x 1 rib. However, there are a variety of other rib stitch constructions such as 2 x 2, 2 x 1, 3 x 1, etc.

The rib stitch has excellent widthwise elasticity, especially fabric knitted in a 2 x 2 rib structure. Because of this inherent elasticity, yarn having a relatively low elasticity can be used. Consequently, the rib stitch is widely used in sleeve trims, sweater waistbands and collars. With rib structures, extensions of up to 140% can be achieved. However, as the number of wales in each rib increases the elasticity decreases, as the number of changeovers from reverse to front reduces.

An advantage of the rib stitch fabrics is that they do not curl at the edge and thus create no difficulty in cutting. The reason for the lack of curling is that the wales tend to counterbalance each other's effect.

In summary, the characteristics of a 1x1 rib fabric are:

- doubled sided
- thick/medium weight
- excellent width stretch/recovery
- balanced structure/fairly stable

Interlock stitch

The interlock stitch (Figure 20-3) is not actually a basic stitch but a variation of the rib stitch.

In construction it resembles two separate 1 x 1 rib fabrics that are interknitted, ie, it is knitted alternately on opposite needle beds, but on alternate needles. It requires two opposing knitted courses or traverses to complete one row. Thus the interlock stitch is thicker and heavier than rib stitch fabric of the same gauge. It has the same appearance on both sides, has good width stretch/recovery and is a stable, balanced structure.

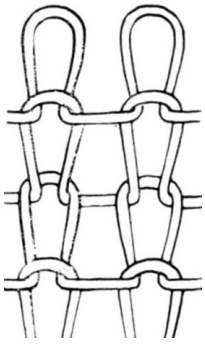
The interlock stitch produces a fabric with an extremely soft handle, a high degree of fabric firmness and good moisture absorption. It is easy to handle in cutting and like all rib structures does not curl at the edges.

Figure 20.3 Interlock stitch. Source: Wood, 2006.

Purl stitch

The purl stitch is a combination of the reverse and face of the jersey stitch, but in a different way from the basic rib structure. Unlike the rib stitch, which has alternate wales of the face and reverse of jersey, the purl stitch produces alternate courses of the reverse and face of jersey (Figure 20-4).

Figure 20.4 Purl stitch. Source: Wood, 2006.



The purl stitch is widely used in the manufacture of sweaters. From a design point of view it is probably the most versatile. Almost any design or stitch structure produced by hand knitting can be duplicated. Because the fabric has the same appearance on both sides, no problem of a face side occurs. A purl stitch fabric has excellent lengthwise elasticity, which is the reason for its extensive use in children's wear.

Variations in stitch structure

Design can be introduced into knit fabrics using these basic stitches in various ways. The simplest method is to knit different coloured yarns at pre-determined intervals to produce stripe effects or to utilise fancy yarns such as a boucle or slub yarn. No change in the basic stitch structure occurs when these are introduced; the design is achieved solely by the constituent yarns.

Several methods are available to introduce design into knitting, such as

- Causing needles to produce a welt stitch (miss) or a tuck stitch;
- Varying or combining the three primary stitches.
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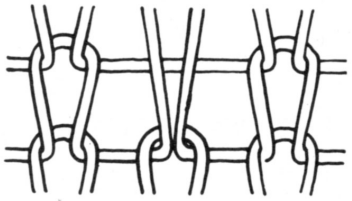
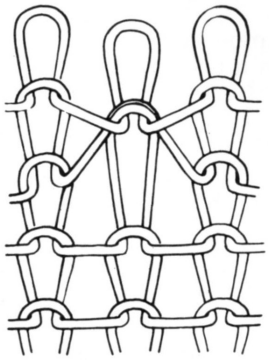
The ***welt*** stitch is not actually a stitch. It is produced when a needle fails to capture the yarn as it is fed and the new yarn passes behind a previously held loop. The missed yarn thus floats on the reverse side of the fabric in unlooped form, as shown in Figure 20-5.

Figure 20.5 Welt stitch. Source: Wood, 2006.



The ***tuck*** stitch also produces a float but does not involve mis-knitting as in the case of the welt stitch. It is produced by accumulating two or more loops on a needle during the knitting cycle. A tuck loop occurs when the needle casts off the accumulated loops as one stitch. Next to the welt stitch it is the simplest and perhaps most widely used variation of the basic stitch formation. The result is a loop distortion as shown in Figure 20-6.

Figure 20.6 Tuck stitch. Source: Wood, 2006.

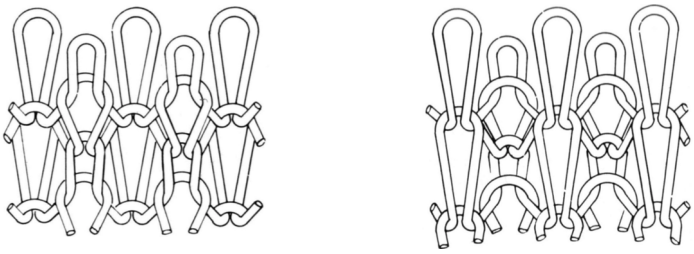


The distorted loop structure is different from that produced by the welt stitch because of the pile-up of loops. The tuck stitch is used in the knitting of jersey, purl and rib fabrics.

The ***cardigan*** stitch is produced on machines with two sets of angularly opposed needles – the needles knitting and tucking and then tucking and knitting on alternate courses. In other words, while one set of needles knit, the other set tucks. At the next course the reverse occurs, the plain needles tucking and the rib needles knitting. The fabric structure produced by the full cardigan stitch is shown in Figure x-x. The fabric has the same appearance on both sides, with an equal number of loops on the face and reverse sides of the fabric.

The **half-cardigan** stitch is a variation of the full cardigan stitch. It is produced when one set of needles knit on all courses while the opposed set of needles alternately knit and tuck on successive courses. The face side and reverse side of the fabric produced by a half-cardigan stitch are shown in Figure 20-7.

Figure 20.7 Half-cardigan stitch: face side (left), reverse side (right). Source: Wood, 2006.



Jacquard fabrics

The origin of the term "jacquard" is in weaving rather than knitting. It came into use in 1804 to describe a technique developed by Joseph Marie Jacquard of controlling the feeding of warp yarns in weaving using perforated cards. The term was not applied until much later when a similar perforated card system was devised as an attachment to V-bed flat knitting machines.

A knitted Jacquard fabric is one produced on a rib or purl machine in which the coloured pattern has been produced by knitting and welting (miss-knitting) selected needles. While perforated cards and pattern wheels are other mechanical devices have been used to control needle actions, modern machines are invariably computer controlled.

Knitted fabric quality

Fabric quality in wool knitwear may refer to the fabric density or to the incidence of faults. The paper by Wiume provides an extensive list of the faults in knitwear, grouped according to whether they originate from the yarn, production, finishing or making-up.

Fabric density (or cover factor)

The stitch density is related to the length of yarn in a knitted loop. The factors that are affected when the loop length is changed are:

- Stitch density
- Fabric weight and cost
- Fabric dimensions and panel size (shaped knitwear)
- Dimensional stability
- Relaxation shrinkage
- Pilling propensity
- Burst strength.

The count of a wool yarn and the loop length of a knitted fabric should be linked by the cover factor CF:

$$CF = \frac{1}{\sqrt{R} \times LL}$$

where: R = resultant count of yarn (metric count)
LL = loop length

The cover factor is chosen to achieve the best possible compromise between (a) fabric performance and (b) softness/drape. The yarn count must also be matched to the type of gauge of the spinning machine.

The cover factor is also an indication of the relative tightness or looseness of the knitting.

Fabric faults

The most common faults associated with wool knitwear are:

- Stitch distortion
- Fabric spirality
- Yarn irregularity (thick and thin places) and neps
- Barré (horizontal stripes and bands)

Stitch distortion and fabric cockling tend to be associated with plain knit shaped garments.

Yarn irregularities or yarn faults can produce intermittent thick/thin horizontal stripes across the fabric.

Fabric **spirality** is a deformation (skewing) of the knit structure which arises when singles yarns or unbalanced two-fold yarns are knitted into single bed structures. The fabric twists on steaming or wetting, leading to garment seams that are no longer vertical. In a circular knitted fabric the wales follow a spiral path around the axis of the tube.

Barré can be caused by incorrectly set knitting equipment, or variations in lustre, yarn spacing or loop length.

A useful bulletin (AWI, 2005) provides good information on faults that detract from the appearance of a knitted garment.

The advantages and disadvantages of knitted fabrics

The major advantages of knitted garment to the wearer are comfort and retention of appearance. The loop structure provides the fabric with outstanding elasticity (ie, stretch and recovery), quite distinct from the elastic properties of the constituent fibres and yarns. Warmth and coolness are also important factors relating to comfort.

Because there is no single straight line of yarn anywhere in the pattern, a knitted fabric will be stretchy in all directions (some more than others, depending on the yarn fiber and the specific pattern used). This stretchiness, unavailable from woven fabrics (which only stretch along the bias), is what originally made knitting so suitable for stockings. Many modern stretchy garments, even as they rely on elastic synthetic materials (eg, elastane fibres such as Lycra) for some stretch, also achieve at least some of their stretch through the knit structure.

Appearance retention means lack of wrinkling during wear, garment care, packaging or storage. Good recovery from crushing relies on the loop structure, but is also influenced by the fibre content and the type of yarn. Knitted products generally require no ironing.

The thickness of a knitted structure is three yarn diameters, compared with two yarn diameters for woven. This creates many dead air spaces and results in knitted garments with excellent insulating qualities in still air. However, in moving air (wind), the insulating effects are nullified because of the openness of the loop structure.

A unique advantage of the knitting industry is that it can produce a completed (ie, fully fashioned) garment on a knitting machine. In comparison with woven fabrics, less extensive fabric finishing treatments are required. Another advantage of knitting over weaving is the rate of production, but this is more than offset by the increased cost of yarn. There are two reasons for the higher cost:

1. Because the looped shape of the yarn imparts bulk, more yarn is required to produce a knit cloth of the same weight than a comparable woven cloth. As the yarn becomes finer the cost increases.
2. The looped structure is more porous and hence provides less cover than a woven fabric, so to achieve an equal amount of cover smaller stitches and finer yarns must be used.
3. Knitting yarns are expensive to make because they must be very uniform to prevent the formation of thick and thin places in the fabric.

Both knitted and woven fabrics can be produced in a multitude of designs. Multicoloured effects, textured designs, stripes and Jacquards are common to both types of structures. One area in which warp knits excel is the production of net fabrics. These are produced very economically and the structure is firmly locked in place.

Table 20-1 summarises the major differences between the processes of knitting and weaving, and the characteristics of the fabrics made by these processes.

Table 20.1 A comparison of knitting and weaving. Source: Wood, 2006.

	Knitting	Weaving
Comfort and appearance retention	Mobile elastic fabric, adapts easily to body movement, good recovery from wrinkling	Rigid to stress (unless made with stretch yarns), varies with the weave
Handle	Soft bulky handle	Firm, smooth handle
Cover	Porous, more open spaces between yarns permits wind to penetrate	Provides maximum cover per weight of yarn
Versatility	Design patterns can be changed quickly to meet fashion needs	Machinery less adaptable to rapid changes in fashion
Economics	Process is less expensive but is offset by more expensive raw material costs. Faster, regardless of fabric width	Most economical method of producing a unit of cover. Wider looms weave more slowly than narrow looms
Product areas	Sportswear, underwear, hosiery	Suits, shirts, furnishings

Performance issues

While knitted fabrics are inherent stretchy, and can therefore have dimensional stability problems, shrinkage control treatments, resin applications or heat setting (for synthetics can provide good dimensional stability to garments. Knits are regard as 'easy-care' fabrics and in many cases machine washing and tumbling drying approved treatments. However the dimensions will be retained best by dry cleaning, or drying a washed garment lying flat.

The loop structure of knitted fabrics makes them especially susceptible to snagging. If a loop catches on a sharp object it may be pulled from the fabric surface and a long snap or pull of yarn formed. If the yarn is not broken, it can be drawn back into the fabric. If the yarn breaks, a hole may be formed and hand-stitching will be required to secure the yarns.

Synthetic double knits or knits made from loosely twisted yarns may be subject to pilling. As the fabric is subjected to abrasion during wear, the short fibre ends that work their way to the fabric surface are rubbed into a small ball that becomes attached to the surface. When these fibres are weak, as in cotton, wool, rayon, etc. the pills generally break free of the fabric. Stronger fibres cling to the fabric, making an unsightly appearance. The use of textured yarns for knitting synthetics decreases the likelihood of pilling.

Applications

Knitted fabrics have a wide range of applications because of their mechanical properties and the characteristics acquired from the constituent yarns, or in finishing. The popular perception is that knitted fabrics are only appropriate to those end-uses where the properties of stretch, elastic recovery and air permeability are of primary importance. These end-uses include clothing worn next to the skin such as hosiery and underwear.

Knitted fabric need to be confined to these traditional applications. Its versatility enables it to be used across almost the entire field of textiles, from sheer hosiery, fines laces and hair nettings to heavy blanket, carpet and fur-like fabrics, and medical implants. (Kovar, 2002, pp 58-59) has a comprehensive list of knitted technical textiles.

Readings

The following readings are available on CD

1. Australian Wool Innovation Ltd, 2005. Fabric Appearance, from On The Wool Web - Technical Support for Wool Processors. Australian Wool Innovation, Sydney, Australia.
2. 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.

Glossary of terms

Barré	A fault in a weft-knitted fabric appearing as light or dark stripes in the course direction
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.
Jacquard	In a knitting machine, a mechanism for selecting individual knitting elements
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
Rib fabric	A weft-knitted fabric in which both back and face loops occur along the course, but in which all the loops in a single wale are of the same type (back or face)
Spirality	The deformation by skewing of a knitted structure due to the yarn twisting within the structure. The vertical lines of stitches (wales) are no longer at right angles to the horizontal lines of stitches (wales).
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.

References

Kovar, R., 2002. Flat knitting technology. Knitting Technology, March 2, 2002, pp58-59.

Australian Wool Innovation Ltd, 2005. Fabric Appearance, from On The Wool Web - Technical Support for Wool Processors. Australian Wool Innovation, Sydney, Australia.