CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Textile fabrics can be produced directly from webs of fibres by interlocking, bonding or fusing to make non-woven fabrics and felts, but their physical properties tend to restrict their potential end usage. The mechanical manipulation of yarn into fabric is the most versatile method of manufacturing textile fabric for a wide range of end uses. There are three principal methods of mechanically manipulating yarn into textile fabrics such as interweaving, intertwining and interlooping. Knitting is the most common method of interlooping and is second only to weaving as a method of manufacturing textile structures. There are various reasons behind the use of the knitted fabrics than woven fabrics.

Weft knitted fabrics are comfortable, easy-care properties, crease-resistant, higher air permeability and highly extensible. Some of the special problems related to weft knitted fabrics are shrinkage, snagging and handling difficulties. Shrinkage is one of the major causes of distortion and dimensional stability of the weft knitted fabric. Distortion of weft knitted fabrics is inherent in their manufacture. Dimensional stability means that the fabric maintains the dimensions with which it was manufactured, without changing with use. Dimensional stability of weft knitted fabrics is a serious problem in view of fabric quality control.
This chapter is concerned with the literature review on the dimensional properties of knitted fabrics. The extensive research work has been carried out on cotton and wool weft knitted fabrics. Much interest has been shown on contribution factors for the dimensional stability of knitted fabrics like stitch length, yarn variables, fabric construction, relaxation, finishing treatments and washing cycles. This chapter also reviews the viscose fibre properties and dimensional properties of viscose knitted fabrics.

2.2 KNITLOOP

![Diagram of an ideal knit loop](image)

- **ab** – Loop or stitch length
- **AC & BD** – Loop arms

**Figure 2.1 Ideal knit loop**

The structure of knitted fabric is a system of yarns, bent into stitches. Stitch length is the fundamental unit in any weft knitted structure. The loop length, width and height are considered to be the most significant dimensions of a loop. The loop length is mainly decided during knitting process of knitted fabrics and the other two during the relaxation process of knitted fabrics (Banerjee and Bhat 2006). Figure 2.1 shows the shape of an ideal knit loop for single jersey structure and Figure 2.2 shows the way in
which yarns interlock in a plain knitted structure. Where two loops interlock, there is a region of contact between the yarns. Reaction forces between the yarns are distributed over this contact region. Integrity and friction of a yarn bent into the stitch determine the form of a knitted fabric loop (Shanahan and Postle 1970).

Figure 2.2 Way in which yarns interlock in a plain knitted structure

Bhat (2006) stated that the uniformity in geometrical shape of the loop is another parameter, which affects the elegance of the fabric and its fluidity. In most of the structures, the loop is distorted during relaxation, chemical processing or during usage resulting in dullness, rough or ridged effect in the knitted fabric. The geometrical shape of a standard knitted loop should have same curvature for crown and sinker loop. Both the arms of the
knitted loop should be in the same plane. The bending of crown and sinker loop should be to an equal depth and without twisting or turning. The contact places of yarn in loop interlacement should be at the junction of loop arm and the crown/sinker loop, i.e., at points A, B, C and D in Figure 2.1.

The variation in this loop shape and the dimension should be minimum. Such structures can be more resilient because the mobility of loops or redistribution of yarn in loops during any deformation would be easier. This would improve the dimensional stability to the fabric. Figure 2.3 shows the shape of uniform and deformed loop for single jersey knitted structure. Because of the dimensional instability of knitted loop construction, single jersey weft knitted fabrics suffers from various forms of dimensional distortion (Tao et al 1997).

From a visual examination of the single jersey knitted structure, clearly it consists essentially of a repeating pattern or matrix in both length and width of interlocking loops, in which the repeating unit or cell is the single loop. The geometry of the weft knitted fabric, therefore, is basically a study of the geometry of the single knitted loop.

Figure 2.3 Uniform and deformed loop
2.2.1 Characteristics of Single Jersey Knitted Fabrics

The simplest and the most widely used weft knit fabric is jersey or plain knit fabric. It consists of face loop stitches only. The technical face and back sides of a jersey fabric are shown in Figures 2.4 and 2.5 respectively.

Figure 2.4 Technical face side of a single jersey knitted fabric

Figure 2.5 Technical back side of a single jersey knitted fabric
Figure 2.6  Symbolic representation of technical face and back sides of a single jersey knitted fabric

![Symbolic representation of technical face and back sides of a single jersey knitted fabric](image)

(a)  
(b)

Figure 2.7  Graphical representation of technical face (a) and back (b) sides of a single jersey knitted fabric

The main characteristic features and properties of this fabric are the loops have a V-shaped loop appearance on technical face side and show semi-circular loops on the technical back side. Because of the side limps of the loop to the face side, it feels smoother on the face side than on the back side. It is thus, not reversible from the feel and appearance point of view. The interlocking semi-circles at the technical back can be used to produce interesting effects if alternate courses are knitted in different coloured yarns.

Knitted loops in plain knit fabrics tend to distort easily under tension, which helps to give a form fitting and comfort due to property of elastic recovery. It has potential recovery of about 40 percent in width after stretching. Its width shortens if the length is extended by tensions while the
length shortens if width is stretched. Normally, width way extensibility is approximately twice the length way extensibility. The structures can be unrobed from the course knitted last by pulling the needle loops through from technical back or from the course knitted first by pulling the sinker loops through from the technical face side. If the unraveled plain knit fabric is kept flat on the surface, it curls upwards at the top and bottom and backwards at the sides. The fabric may appear thick or flimsy if the stitch length is reduced or increased (Ajgaonkar 1998).

2.3 GEOMETRY OF PLAIN KNITTED FABRICS

Doyle (1953) stated that the length of yarn per stitch is regarded as a factor of fundamental importance since it is independent of the fibres from which the yarn is spun. Song and Turner (1968) also mentioned that the loop length was the fundamental unit in any weft knitted structure. Stable loop shape depends on the type of yarn used and the relaxation treatment to which the fabric has been subjected. The relaxed dimensions of a fabric are determined by the relationship between loop length and loop shape. Two fundamental factors must be appreciated:

(i) The loop length, i.e., the length of yarn in the knitted loop, is the dominant factor for all structures.

(ii) There are several dimensionally stable states possible for a knitted structure.

Some of the terms used for the study of the knitted structure are given in Figure 2.8. The lines of loops across the fabric are known as courses and the lines down the fabric as wales (Booth 1977). One loop is referred to as a stitch.
Figure 2.8 Single jersey knitted structure

AB  =  Loop length
W  =  Wale spacing
C  =  Course Spacing
S  =  the number of stitches per square unit
C =  the number of courses per unit length
w  =  the number of wales per unit width
l  =  the stitch or loop length
1/W =  w  =  Wales/cm
1/C =  c  =  Courses/cm
S  =  Stitches/cm²
The result of research into knitted geometry has enabled some important relations:

(i) The number of stitches or loops per unit area is inversely proportional to the square of stitch length

\[ S_{\alpha} \frac{1}{l^2} \quad (2.1) \]

(or)

\[ S_{\alpha} \frac{K_s}{l^2} \quad (2.2) \]

(ii) The number of courses per unit length is inversely proportional to the stitch length

\[ c_{\alpha} \frac{1}{l} \quad (2.3) \]

(or)

\[ c_{\alpha} \frac{K_c}{l} \quad (2.4) \]

(iii) The number of wales per unit length is inversely proportional to the stitch length

\[ w_{\alpha} \frac{1}{l} \quad (2.5) \]

(or)

\[ w_{\alpha} \frac{K_w}{l} \quad (2.6) \]

(iv) Form the relations in (ii) and (iii)

\[ \frac{\text{Courses per unit length}}{\text{Wales per unit length}} = \frac{c}{w} = \frac{K_c}{K_w} \quad (2.7) \]
The relationships established experimentally in the work reported by Munden (1959). Relationship between loop length and wale and course spacing

\[
\begin{align*}
K_s &= S \times l^2 \quad (2.8) \\
K_c &= c \times l \quad (2.9) \\
K_w &= w \times l \quad (2.10) \\
K_s &= K_c \times K_w \quad (2.11) \\
K_l &= K_c / K_w \quad (2.12)
\end{align*}
\]

Where \(K_s\), \(K_c\) and \(K_w\) are dimensional constants, the numerical values of which depend on the actual configuration of the knitted loop.

\(K_l\) may be described as the loop shape factor as it is a measure of the ratio of width of the loop to the length of the loop. The loop model indicates that this ratio should be a constant for fabrics in the completely stable configuration. The ratio is, however, critically affected by any fabric distortion, since such distortion causes an increase in the one parameter together with a decrease in the other. \(K_s\), \(K_c\), \(K_w\) and \(K_l\) values of worsted plain knitted fabric obtained empirically by Munden (1959) are shown in Table 2.1.

Table 2.1 K values of worsted plain knitted fabric

<table>
<thead>
<tr>
<th>Constants</th>
<th>Dry relaxed</th>
<th>Wet relaxed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K_s)</td>
<td>19</td>
<td>21.6</td>
</tr>
<tr>
<td>(K_c)</td>
<td>5</td>
<td>5.3</td>
</tr>
<tr>
<td>(K_w)</td>
<td>3.8</td>
<td>4.1</td>
</tr>
<tr>
<td>(K_l)</td>
<td>1.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Knapton et al (1968) suggested new parameter K5 as dimensional parameter specifying fabric thickness.

\[
K5 = \frac{t}{d}
\]  

Where,

\[ t = \text{Fabric thickness in mm} \]

\[ d = \text{Yarn diameter in mm} \]

Shanahan and Postle (1970) predicted that both Kc and Kw will be functions of l/d, where d is the yarn diameter and their analysis shows the existence of a minimum energy state for a plain fabric.

### 2.4 RELAXATION OF SINGLE JERSEY KNITTED FABRICS

Changes in dimensions after knitting can create major problems in garments and fabrics, especially those produced from hydrophilic fibres such as wool and cotton. As synthetic thermoplastic fibres can be heat set, their shape or dimensions are least affected. The changes of dimensions with wool fibres are magnified by felting shrinkage, however, with shrink resist finish in wool yarns, the problem can be much reduced. During knitting, the loop structure is subjected to tension from sources such as yarn feeding and fabrics take down mechanism. In order to avoid further dimensional changes as the fabric is taken out of the machine, the knitted fabric should attain a stable state of equilibrium. A number of stable states are suggested by various research workers by which relaxation conditions are possible so that the yarn and structure can create high internal restrictive forces and thus inhibit recovery (Anbumani 2007). The three important dimensionally stable states are:
(i) Dry relaxed state

(ii) Wet relaxed state

(iii) Finished relaxed state

2.4.1 Dry Relaxation

The fabric has been taken off the knitting machine and allowed to lie freely for a sufficient length of time. Eventually the fabric attains dimensionally stable condition, called the dry relaxed state. In this state, the natural configuration of yarn is almost straight so that when it is unroved, the yarn takes up an approximately straight form. A plain fabric knitted from worsted yarn will recover from a 60-80% extension in length to its natural length after 48 hours if allowed to relax freely in the dry state, whereas a cotton fabric will retain permanently 10-20% of the extension in length. In the dry state, therefore plain knit wool fabrics may be expected to return their strain free conditions more freely than the cotton fabrics.

2.4.2 Wet Relaxation

If the fabric is soaked in water and allowed to dry flat, the wet relaxed state is attained, again a dimensionally stable condition. The equilibrium is reached after static relaxation in water and subsequent drying. In this state, the natural configuration of yarn is not straight but is set into a form approximately the loop shape in the fabric. Wet relaxation is carried out in water at 30ºC containing 0.1% wetting agent, allowed to lay for 24 hours, hydro extracted and dried naturally for at least three days.

2.4.3 Finished Relaxation

In order to reach this stable condition, the fabric is subjected to agitation in water or stream, and a denser fabric results. The fully relaxed
condition is obtained by subjecting the samples into gentle agitation at 80°C for 2 hours, tumbles dried at 80°C for 2 hours in a domestic top loading washing machine, and finally conditioned in the standard atmosphere for at least 24 hours. A satisfactory relaxation technique applied during the finishing of cotton fabric in the continuous length form is the compacting or compressive shrinkage technique.

Hearle et al (1969) mentioned that difference between the dry relaxed and the wet relaxed condition is most probably due to a certain amount of frictional resistance to the structure of the relaxation forces. This exists both at the crossover points between the yarns and in the yarns themselves, which will exhibit a resistance to being bent which is of a frictional nature. However, it is obvious from the small difference between the dry relaxed and wet relaxed condition that friction plays only a small part in the properties of the plain knitted loop.

2.5 DIMENSIONAL PROPERTIES OF KNITTED FABRICS

The textile material properties may be classified into three main groups, as suggested by Hearle et al (1969). These are bulk properties, surface properties and transfer properties. Dimensional stability or shrinkage resistance is one of bulk properties of the textile structures. Knitted fabrics are similar to woven fabrics in that they are subject to relaxation shrinkage and also to felting shrinkage if they are made of wool. However, it has been found difficult experimentally to determine when a fabric has reached a total relaxed state in which it is in a stable state with the minimum energy. This is because the stable state of a knitted fabric is controlled by the interplay of forces required to shape the interlocking loops of yarn, whereas the stable state of a woven fabric is controlled by the balance of forces required to crimp the yarns. The resistance provided by inter-yarn friction prevents the yarn taking up its lowest energy state and the magnitude of the restoring forces in a
knitted fabric is not great enough to overcome this. Because of this difficulty a number of relaxed states like dry relaxed state, wet relaxed state, finished relaxed state and fully relaxed state have been suggested. Gowers and Hurt (1978) mentioned that the most commonly used relaxation processes involves a combination of wet treatment, hydro extraction and tumble drying.

Bogaty et al (1951) concluded that knitting stiffness, and, to a much smaller extent, yarn twist, contribute to the felting behavior of knitted fabrics. Increase in the number of wales and courses per inch and in the twist can be used to effect appreciable improvement in the laundering stability of the knitted fabrics. Knapton et al (1968) observed that wool fabric dimensional properties are slightly influenced by wool fibre quality, twist level and yarn friction, also mentioned that majority of complex knit structures, particularly double knits, comprise plain knit and rib loops in various combinations (often with tuck stitches and floats), their dimensional behavior in relaxation is not so easily predictable. Each individual structure must be analyzed separately. Knapton et al (1975) mentioned that dimensional stability in cotton plain jersey fabrics can be attained by either mechanical relaxation techniques (consecutive laundering and tumble drying cycles) or chemical treatments (fabric mercerization without tension). Both treatments cause large linear dimensional changes leading to the same final stable condition. Allan Heap et al (1983) mentioned that the dimensions of knitted fabrics are strongly affected by the finishing process as well as by the yarn count and the stitch length.

Fletcher and Roberts (1952) found that the yarn in the finished cotton fabrics shrinks a negligible amount in laundering. Therefore, the shrinkage of the yarn contributed little to the dimensional change of the fabric. The fabrics having the greatest knitting stiffness shrink the most in the area. Banerjee and Alaiban (1988) concluded that for rotor spun cotton yarns,
the dimensional parameters $K_c$, $K_w$ and $K_s$ of fully relaxed single jersey fabrics depend on the tightness of construction. Ryuzo Oinuma (1989) reported that for coarse nylon plain jersey fabrics, the dimensional parameters are independent of the fabric tightness and the method of relaxation treatments used. Gulrajani et al (1998) stated that treatment of cotton knitted fabric with enzyme cellulose leads to various surface modifications and the surface smoothness is increased and consequently the bending rigidity and shear rigidity decreased. Jovancic et al (1998) stated that enzymatic treatment of wool by Bactosol SI has a positive influence on the degree of shrink resistance and whiteness.

Quaynor et al (1999) concluded that the dimensions of cotton knitted fabrics and their potential dimensional changes and shape retention properties are influenced by the knitting conditions and the state of fabric relaxation. Nuray Ucar and Seniz Ertugrul (2002) predicted the relationship between machine gauge and wale density, loop length, yarn twist and yarn count and mentioned that, from the partial correlation analysis, there is no direct relationship between machine gauge and loop length and yarn twist, but there is a direct relationship between machine gauge and wale density and yarn count. Mohamadi and Jeddi (2006) suggested that by using the ultrasonic method of relaxation, the fabric stabilization reaches to a higher degree than that by using the common mechanical relaxation treatment. It is observed that this method of relaxation has more effect on the fabric’s dimensional parameter than the conventional relaxation method.

Hearth et al (2007) concluded that dimensional behavior of 100% cotton and core spun cotton/spandex interlock fabrics are significantly different. Saravanan et al (2008) stated that the compacting process invariably changes the construction of the knitted fabrics by altering the courses and wales in unit area of the knitted fabrics. Mikucioniene and Laureckiene
(2009) mentioned that the shrinking potential of cotton weft knitted fabrics depends on the conditions of drying during the finishing process. Onal and Candan (2003) concluded that knit type and fabric tightness greatly influence cotton fabric shrinkage. Yarn type and fibre percentage contribute significantly to knit fabric shrinkage. Hurley (1966) pointed out that, width relaxation shrinkage of the acrylic plain knitted fabrics is occurring readily than length relaxation shrinkage. Hurley (1967) stated that the area shrinkage of acrylic knitted fabric increases with increase in tumble dryer temperature. Sharma et al (1984) found that acrylic fabrics made from different yarns and count the courses per inch and wales per inch vary inversely with the length of yarn knitted into the stitch. Stitch density or number of loops per unit area of fabric is inversely proportional to the square of stitch length. In dry relaxed state the values of Kc, Kw, Ks and Kl show dependence on cover factor, the values increase proportionally with the increase in the value of cover factor. Weight per unit area of acrylic fabrics varies inversely with the length of yarn knitted into the stitch.

Fletcher and Roberts (1952a) studied that shrinkage in area of all of the grey fabrics and of the finished viscose fabrics increased with knitting stiffness. Fletcher and Roberts (1953) concluded that changes in dimensions of viscose knit goods in laundering are due largely to a rearrangement of the fabric structure. The fabrics could be given a relaxing treatment to remove distortion so that the structure would exhibit little rearrangement after laundering and the area would remain nearly constant.

2.6 SPIRALITY OF WEFT KNITTED FABRICS

Single jersey knitted fabrics suffers from various forms of dimensional distortion due to the dimensional instability of knitted loop construction. One such distortion arises from the use of yarn that is twist liveliness resulting in wales that are not perpendicular to courses. Badr (2008)
mentioned that one of the key measures determining the dimensional stability of a knit fabric is course and wale alignment. Basically, it is necessary that the wale on the knitted fabric be perpendicular to the course. When this geometric feature is violated, the fabric will suffer a skew to the left or right. This phenomenon is called fabric spirality and it is often observed in cotton single jersey knits, where the fabric exhibits a tendency for the course and wale loops to skew when allowed to relax. Terms such as fabric skew or fabric torque are also used to describe fabric spirality.

The residual torque in the component yarn caused due to bending and twisting is the most important phenomenon contributing to spirality. The residual torque is shown by its twist liveliness. Hence the greater the twist liveliness, the greater is the spirality. Twist liveliness of yarn is affected by the twist factor or twist multiple. Besides the torque, spirality is also governed by fibre parameters, yarn formation system, yarn geometry, knit structure and fabric finishing. Machine parameters do contribute to spirality. For instance, with multi-feeder circular knitting machines, course inclination will be more, thus exhibit spirality.

Some of the practical problems arising from loop spirality encountered garments produced by knitted materials are displacement or shifting of seams, mismatched patterns and sewing difficulties. Badr (2008) reported that the various factors cause the spirality of weft knitted fabrics. Fibre causes are fibre type, torsion rigidity, flexural rigidity, fibre blend, fibre fineness and fibre length. Yarn causes are bulkiness, spinning system, fibre arrangement, twist level, mechanical properties, twist direction, yarn count and doubling. Knit causes are gauge, needles type, yarn input tension, fabric take down tension, tightness factor and fabric structure. Finishing causes are stentering, calendaring, softner, mercersing, resins and enzymes.
Arujo and Smith (1989) concluded that, the major causes of spirality are yarn twist instability and the number of feeds on the weft knitting machine. Primentas (2003, 2003a) reported that, the more slack the knitted fabric structure, the greater is the spirality. This slackness can be achieved by changing either the tightness factor or the linear density of the yarn. The direction of spirality in the fabrics knitted from single short stable ring spun yarns is determined by the yarn twist direction. Thus, the technical face of single jersey fabric exhibits spirality in the Z direction if a Z twisted yarn has been knitted (Primentas and Iype 2003, 2003a). As the measurement of the angle of spirality is concerned, either a protractor or a specially designed transparent plastic board can be used. As the level of acceptable spirality angle is concerned, the opinions are divided, indicating as maximum values five degrees or seven degrees and the percentage spirality of 8.

2.7 SHRINKAGE OF KNITTED FABRICS

Fabric shrinkage is a reduction in the physical dimensions of fabric because of relaxation or the application of water, heat, steam, laundry, or dry cleaning. It is caused by numerous factors, some of which are inherent in the structure, finishing, or handling of fabric. Fabric shrinkage problems may not be apparent until the fabric is cut or garments are finished. Differential shrinkage occurs when garment parts or different materials shrink unequal amounts (Glock and Kunz 2000).

Suh (1967) mentioned that shrinkage of a knitted fabric is determined by a number of factors, such as fibre characteristics, stitch length, machine gauge, yarn twist, knitting tension, and washing and drying methods. However, the factors most responsible for shrinkage are known to be the swelling of yarn and the relaxation of internal stress since these have been imposed on the yarn during the knitting process. The configuration change of loops due to yarn swelling is extremely complicated in a knitted structure,
compared to woven structure, because of the distinct three dimensional features of the knitted loop. Length shrinkage of a plain knitted cotton fabric depends upon two phenomena. Part of it’s due to loop migration and the rest is due to the change in course curvature. Width shrinkage of a plain knitted cotton fabric is affected by the void space in a wale after accommodating four yarn diameter. Herath and Kang (2008) indicated that the resiliency force and the yarn frictional force acting on interlacing points are major forces which affect the relaxation behavior of knitted fabrics.

Fabric shrinkage can cause problems in two main areas either during garment manufacture or during subsequent laundring by the ultimate customer. Laundering is a more vigorous process than pressing and it usually involves mechanical agitation, hot water and detergent. Tumble drying can also affect the shrinkage as the material is wet at the beginning of the drying process, the material being agitated while heating until it is dry. Dry cleaning involves appropriate solvents and agitation, the solvents are not absorbed by the fibres so they do not swell or affect the properties of the fibres. This reduces some of the problems that occur during wet cleaning processes. There are a number of different causes of dimensional change, some of which are connected to one another. Most mechanisms only operate with fibre types that absorb moisture, but relaxation shrinkage affects any fibre type.

Relaxation Shrinkage is the shrinkage measured when the fabric is wetted out. The changes in the dimensions of the fabric are measured after the wet relaxation. Relaxation shrinkage is the irreversible dimensional change accompanying the release of fibre strains imparted during manufacture which have been set by the combined effects of time, finishing treatments, and physical restraints within the structure (Abbott et al 1964). Hygral expansion is a property of fabrics made from fibres that absorb moisture, in particular fabrics made from wool. It is a reversible change in dimensions which takes
place when the moisture regain of a fabric is altered. Swelling shrinkage results from the swelling and de-swelling of the constituent fibres of a fabric due to the absorption and desorption of water. In a loosely knitted fabric, the effect of this swelling of the yarns is greater than in a tightly knitted fabric, since there is greater freedom of movement (Saville 2002).

2.8 EFFECT OF YARN PROPERTIES ON THE KNITTED FABRICS PROPERTIES

In a knitted fabric the yarn is in a sense, both raw material and the finished product. A knitted fabric may be regarded as a particular configuration of a yarn or yarns. The original raw material is not greatly altered in form. The more one knows about the properties of yarn the better will one be equipped for the efficient production of fabric having predetermined and desirable characters. Yarn properties such as count, twist, moisture conditions, quality and package hardness were found to affect the characteristics of knitted fabrics. Yarn shrinkage can be a significant factor in the relaxation shrinkage exhibited by knitted fabrics. Relaxation of the yarns is one factor which contributes to the dimensional stability. Yarn of low shrinkage knitted into a tight structure the contribution to overall dimensional change is negligible. At the other extreme, for yarns of high shrinkage used in an open structure, the contribution can be a major component of the overall changes (Baird 1975). The effects of yarn shrinkage were reflected directly in the dimensions of the relaxed fabrics. The amount of relaxation shrinkage occurring with open end spun yarn is greater than that occurring with ring spun yarn (Candan et al 2000).

Pillay and Ramani (1976) suggested that fabric defects can be considerably reduced and knitting efficiency improved by giving suitable chemical finishes to cotton yarns. The most useful type of finishing agents appears to be those that increase the fibre to fibre friction in yarns without
appreciably increasing the yarn to metal friction. Kaushik et al (1989) concluded that courses per cm, wales per cm and stitch density do not change with fibre composition or yarn twist but increase appreciably with the increasing tightness factor irrespective of the relaxing treatments for plain knitted fabrics made from acrylic / viscose rotor spun yarns. In fully relaxed state slack knits exhibit lower area shrinkage. However, an increase in yarn twist results in a decrease in shrinkage followed by an increase with further increase in twist. Fibre composition has no effect on fabric weight in the dry relaxed state. The fabric weight decreases initially and then increases with an increase either in yarn twist or tightness factor for dry and fully relaxed knitted fabrics.

Tao et al (1997) said that yarn twist and fabric tightness are the most predominant factors contributing to fabric spirality. It was clearly demonstrated that the problem of fabric spirality is much more serious for loosely knitted fabrics from highly twisted yarns. Tao et al (1997a) mentioned that, by modifying the rotor spun yarn structure by means of the untwisting process exerted significant influences on yarn and fabric performance. On the positive side, knitted fabric spirality was greatly reduced or completely eliminated after yarn modification. Residual torque or twist liveliness of a twisted yarn, among other factors, is the most prominent and fundamental factor contributing to the spirality of single jersey knitted fabrics. The yarn twist liveliness has a large influence on spirality. Bueno et al (2004) stated the influence of fibre fineness and the yarn spinning process (yarn structure) on 3D loop shape. Any modification of fibre fineness or yarn structure affects the yarn bending rigidity and therefore yarn behavior during fabric relaxation.

Banerjee and Bhat (2005) mentioned that during the process of loop formation on a knitting machine, the yarn undergoes tensile, bending and torsional deformations. The dynamic balance between the resulting yarn
tension in the knitting zone and other mechanical forces acting on the needles affect the loop forming point and hence the loop length. During the course of its relaxation in wet processing stage, the loop changes its shape and tends to assume the one corresponding to the minimum strain energy level. The torsional as well as tensile and bending stresses stored in the loop during its formation in the knitting machine play important roles in this relaxation process. As the yarn rigidities in tension, bending and torsion affects the loop length as also its relaxed shape, it becomes necessary to relate them to manufacturing knitted fabrics of stable and desirable dimensions.

Hepworth and Leaf (1976) stated that the length of yarn in loop contributes to the length, width and thickness of the knitted fabrics. Stankovic et al (2009) reported that the yarn twist level affects to a great extent the spacing of yarns in knitted fabrics. Chellamani and Vittopa (2009a) stated that the ability of the yarn to be guided easily through various elements of the knitting machine is important for a hosiery yarn and it is mostly depends on the friction of yarn to metal. Kariyappa et al (2012) concluded that the yarn shrinkage and fabric shrinkage of silk plain fabrics have highly correlated each other.

Banerjee and Bhat (2006) observed that the mean torsional rigidity of yarn plays a very important role in determining loop dimensions of rib fabrics, necessitating the testing and standardization of this property for improvement in quality of knit goods. Jaouadi et al (2009) mentioned that the dimensional and mechanical characteristics of fabrics are dependent on yarn diameter, courses per unit length, wales per unit length and stitch length in knitted fabrics and the yarn twist will have a significant effect on yarn diameter.

Banerjee and Alaiban (1988) mentioned that the changes in yarn count may be accompanied by changes in yarn diameter and yarn shrinkage
during full relaxation and it was necessary to determine each parameter separately. Asayesh and Mohammad (2007) studied the effect of yarn twist on wicking of cotton interlock weft knitted fabrics and concluded that the wicking rate decreases with an increase in the amount of yarn twist.

2.8.1 Effect of Yarn Twist on Shrinkage

When we consider normal shrinkage as opposed to felting shrinkage, we do not find that a high twist reduces the amount of the shrinkage. In fact a high twist will increase the shrinkage. This is the result of the swelling of the fibre when it is exposed to water or some other swelling agent. In the following discussion any shrinkage in length of the fibre has been ignored since for fibres like cotton and linen, it is so small as to be negligible and for other fibres like rayon it can be studied independently. However, the increase in diameter of a cotton fibre can be quite large when it is wet and from the bone dry to the completely wet state an increase in diameter of 20 percent is frequently encountered.

A very compact yarn made of such fibres would increase in diameter a similar amount when it was wet out. However, the outer fibres are wrapped around the yarn so that the swelling tends to lengthen their helical path. If the yarn is unrestrained, the fibres will not be stretched to accomplish this, but rather the yarn will shrink so that the lengths of the fibres are unchanged (Truslow 1957).

<table>
<thead>
<tr>
<th>S.No</th>
<th>Twist multiplier</th>
<th>% Yarn shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1.7</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>8.9</td>
</tr>
</tbody>
</table>
In addition to this effect is the effect on the yarn density. The tightly twisted yarns usually are more compact than the loosely compacted yarns. With repeated swelling and drying, it is possible for them to acquire a more open structure which can have the resulting effect of accenting the above shrinkage. It is therefore seen that twist can affect the shrinkage of yarns by a twofold mechanism due to the helical path of the fibres and due to the compactness of the yarn.

2.9 EFFECT OF WASHING ON THE DIMENSIONAL PROPERTIES OF KNITTED FABRICS

Excessive change, particularly shrinkage, in fabric dimensions can represent a serious problem in virtually all textile applications, more particularly in clothing. Dimensional stability to laundering (washing), including drying, therefore forms an important quality and test requirements. Dimensional change has been defined as a generic term for percentage changes in the length or width of a fabric specimen subjected to specific condition. Various test methods are used for testing the dimensional stability of fabrics, the choice of test method often depending upon the particular application of the fabric. Standardized washing machines and tests, to assess fabric or garment performance under repeated home laundering cycles, have been developed (e.g. AATCC 135). One example of a popular test method, which includes both washing and tumble drying (e.g. five cycles) are AATCC 135. An industry norm for such a test on cotton single jersey is, for example, no more than 8% shrinkage in either length (wale) or width (course) direction. The actual changes in fabric dimensions during a test depends upon a number of factors such as the test medium (liquor), liquor to goods ratio, type and severity of mechanical agitation, liquor temperature, number of cycles and method of drying.
Quaynor et al (1999) concluded that multiple washing and tumble dry cycles result in almost a complete relaxation state, especially for cotton. Onal and Candan (2003) stated that loops gradually relax from dry relaxation to further washing cycles, but the relaxation amount in each shrinkage direction change according to knit type.

Mikucioniene and Laureckiene (2009) mentioned that the shrinkage potential of knitted fabrics depends on the conditions of drying during the finishing process and the shrinkage values of plain jersey knitted fabrics after three washings and drying cycles were considerably reduced.

2.10 PROPERTIES OF REGENERATED CELLULOSIC FIBRES

The fast growing capacities in fibre raw material worldwide, where viscose fibre is a part of it, are reflected by the international market in textile application and end users to an immense extend. Viscose rayon fibres are moisture absorbent and very amorphous, its filaments or stable fibres are weaker than cotton and have only a fair tenacity. The shorter polymer and very amorphous nature of the regenerated cellulose fibres are responsible for the much greater sensitivity of these fibres to acids, alkalis, bleaches, sunlight and weather when compared with cotton. The problems with viscose are sensitive against chemicals and shrinks easily when washed in the wrong way.

Lyocell is a new generic name given to cellulosic fibres produced using an environmental friendly process. Chavan and Patra (2004) concluded that lyocell has come up as a fibre for the future and has many advantages over other cellulosic fibres in respect of fibre properties as well as from fashion and aesthetic points of view. Table 2.3 shows the physical properties of regenerated cellulosic and cotton fibres.
Table 2.3 Physical properties of regenerated cellulosic and cotton fibres

<table>
<thead>
<tr>
<th>S.No</th>
<th>Property</th>
<th>Viscose</th>
<th>Modal</th>
<th>Lyocell</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Count dtex</td>
<td>1.7</td>
<td>1.7</td>
<td>1.4-1.7</td>
<td>1.5-1.8</td>
</tr>
<tr>
<td>2</td>
<td>Dry tensile strength, cN/tex</td>
<td>22-26</td>
<td>34-36</td>
<td>38-42</td>
<td>20-34</td>
</tr>
<tr>
<td>3</td>
<td>Wet tensile strength, cN/tex</td>
<td>10-15</td>
<td>19-24</td>
<td>34-38</td>
<td>25-30</td>
</tr>
<tr>
<td>4</td>
<td>Dry elongation %</td>
<td>17-25</td>
<td>13-15</td>
<td>14-16</td>
<td>7-11</td>
</tr>
<tr>
<td>5</td>
<td>Wet elongation %</td>
<td>21-30</td>
<td>13-15</td>
<td>16-18</td>
<td>11-14</td>
</tr>
<tr>
<td>6</td>
<td>Moisture uptake %</td>
<td>13</td>
<td>12.5</td>
<td>11.5</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Water retention capacity %</td>
<td>90-100</td>
<td>75-80</td>
<td>60-70</td>
<td>45-55</td>
</tr>
<tr>
<td>8</td>
<td>Initial wet modulus,5%</td>
<td>40-60</td>
<td>100-120</td>
<td>250-270</td>
<td>100-200</td>
</tr>
<tr>
<td>9</td>
<td>Degree of Polymerization Value</td>
<td>250-350</td>
<td>300-600</td>
<td>500-600</td>
<td>2300-3000</td>
</tr>
</tbody>
</table>

Source: Chavan and Patra (2004)

When fibres absorb water, they change in dimensions, swelling transversely and axially. This has technical consequences on the dimensional stability of the fabrics, the predominant transverse swelling usually resulting in shrinkage of twisted or interlaced structures. Table 2.4 lists the swelling properties of fibres when immersed in water. Upon wetting most hygroscopic textile fibres exhibit a slight increase in length and a considerable increase in diameter and cross sectional area (Sabit Adanur 1995).
Table 2.4 Swelling properties of viscose rayon

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Length increase (%</th>
<th>Diameter increase (%)</th>
<th>Cross-sectional area increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscose rayon</td>
<td>3-5</td>
<td>25-52</td>
<td>50-113</td>
</tr>
<tr>
<td>Cotton</td>
<td>1.2</td>
<td>14-30</td>
<td>40-42</td>
</tr>
</tbody>
</table>

2.11 SUMMARY

Based on the literature cited it is evident that the length of yarn in the knitted loop is the dominant factor for all structures and the knitted fabric characteristics are influenced by the constituent fibres, yarn properties, knitting machine variable, processing and finishing treatments. The thrust of this thesis is to study the effect of contributing factors like fibre type, stitch length, yarn twist, wet yarn shrinkage, fabric construction, relaxation and finishing treatments on the dimensional properties of knitted fabrics made from 100% viscose ring spun yarn.