CHAPTER 5

SILK COVERED CORE-SPUN
YARNS AND FABRICS.
5.1 INTRODUCTION

Core-spun yarn is a structure, essentially consisting of two components, one of which is constrained to lie at the central axis of the yarn, termed as core, while the other component acts as covering fibre, termed as sheath. Core-spun yarns are generally produced to improve the strength, durability and functional properties. The concept of core-spun yarns in silk industry is in its infant stage and its introduction may have far reaching benefits.

Although pure silk fabrics are excellent in terms of appearance, glossiness, wear-comfort but 100% silk fabrics are very costly. Coarser silk yarns are required to produce medium and heavy weight knitted silk fabrics for outerwear purpose. These kinds of fabrics sell well at the international market. Therefore, if these medium and heavy silk fabrics are developed replacing part of the silk by filament in the core, it may be cost effective.

A special feature of this kind of core-spun yarn would be the different properties in its core and sheath regions. The continuous filament incorporated at the central axis of the yarn will contribute mainly towards the strength, while the surface characteristics of the composite yarn will almost remain same as silk yarn.

Polyester filament has good strength and breaking elongation. So new type of silk covered yarn having polyester filament in the center can be produced. This kind of yarn will have positive attributes of silk, which is present on the surface and strength, elasticity of the polyester filament present in the core. Silk covered yarns have many economical and social benefits. It will offer a lower material cost for fabric manufacture because polyester filament is obviously cheaper than mulberry silk. These kinds of fabrics are still possible to be exported as silk goods if silk content is properly adjusted according to the end-use requirements of different countries. The material cost reduction will be significant in case of medium and heavyweight fabrics. Silk covered yarns can afford lower prices than pure silk, yet with almost same gloss, style and comfort.

If instead of hydrophobic filament yarn as a core material, a hygroscopic filament is used as a core, then we can expect better properties of yarns as well as fabrics. If we use viscose filament as core and silk as sheath fibre, then positive attributes of both the components can be utilised. The fabric made out of
this yarn can be claimed to be made of 100% hygroscopic components. Silk yarn having viscose filament in the core might be even more comfortable as both the components are hygroscopic. The introduction of viscose filament will reduce cost of fabric as well.

Hence silk covered yarns are an excellent new type of material for knitting. In this study, the properties of silk covered polyester and viscose filament core-spun yarns and single jersey knitted outerwear fabric made out of them have been explored. The properties of these new kinds of yarns and fabrics have been compared with 100% silk and cotton yarns and fabrics under identical conditions.
5.2 EXPERIMENTAL PLAN

5.2.1 Properties of the Raw-material

Mulberry silk in hank form (denier 24-26) was procured. The hanks of mulberry silk were then cut to a length of 51 mm staple by scissor. Degumming was carried out by boiling off in soap solution as per following conditions

- Soap : 6 g/litre
- Sodium carbonate : 1 g/litre
- Temperature 90°C
- Time : 90 minutes
- Material: Liquor ratio 1:40.

After degumming, the fibres were washed in soft water and dried at room temperature for 48 hours. The conversion of silk hanks to fibres has already been described in detail in section 3.2.

For the core, the polyester multi-filament yarn of 50 denier having 34 mono-filaments and viscose multi-filament yarn of 50 denier having 12 mono filaments were procured. There was no choice of raw material specifications and only these types of filaments were only available commercially.

Silk covered polyester and viscose filament core yarn of 30\textdegree{} N\textsubscript{e} (19.7 tex) each were prepared. The core:sheath ratio was 28:72 in both the cases. These kinds of core-spun yarn and corresponding fabrics are denoted as SPF and SVF respectively, in this study. The properties of the polyester filament, viscose filament, silk fibre and cotton fibre are shown in Table 5.1.

Table 5.1 Properties of polyester, viscose filament, silk fibre and cotton fibre.

<table>
<thead>
<tr>
<th></th>
<th>Polyester Filament</th>
<th>Viscose Filament</th>
<th>Silk Fibre</th>
<th>H-4 Cotton Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenacity (g/den)</td>
<td>4.6</td>
<td>3.4</td>
<td>4.1</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>(4.4)</td>
<td>(8.6)</td>
<td>(12.0)</td>
<td>(12.4)</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>22.2</td>
<td>16.7</td>
<td>30.8</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>(10.4)</td>
<td>(16.1)</td>
<td>(13.3)</td>
<td>(15.4)</td>
</tr>
<tr>
<td>Staple length (mm/2.5% span length)</td>
<td>—</td>
<td>—</td>
<td>51</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>(28.5)</td>
<td>(28.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fineness (den/micronaire)</td>
<td>50</td>
<td>50</td>
<td>1.2</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>(10.4)</td>
<td>(12.4)</td>
<td>(17.4)</td>
<td>(20.4)</td>
</tr>
</tbody>
</table>

Figure in parenthesis represents C.V. %
The stress-strain curves of polyester and viscose filament yarn are shown in Fig. 5.1 and 5.2 respectively.

![Stress-strain curves of polyester filament](image1)

![Stress-strain curves of viscose filament](image2)

The stress-strain curves of the silk and cotton fibres have been shown in section 3.2.1.

### 5.2.2 Preparation of yarn samples

Three mixings of 100% silk (700 gm each) were prepared and three rovings of 100% silk were prepared. The detail is given in section 3.2.2. From these rovings silk covered polyester filament core-spun yarn (SPF), silk covered viscose filament core-spun yarn (SVF) and all silk ring spun yarn were prepared. All the process parameters were same as described earlier in Section 3.2.2. All spinning parameters like spindle speed, traveller number, break draft etc. were kept unchanged for these SPF, SVF and silk yarn.
The method of production of core-spun yarn has been depicted in Fig. 5.3. For pre-tensioning of filament Gate type (multiplicative) tensioner was used, so as to compensate any fluctuation in unwinding tension. The Twist Multiplier (T.M.) chosen was 2.7 as the yarn was intended for knitting purpose only.

![Diagram of core-spun yarn production](image)

Fig. 5.3 Method of production of core-spun yarn.

The position of the filament with respect to the roving during spinning plays an important role in coverage of the filament by sheath fibres. The improper positioning of core and roving can lead to poor covering of the core filament by the sheath fibres due to formation of a large V between core and roving under the front rolls. Proper positioning of the filament with respect to roving can effectively control this. For single end roving feed, the core yarn should be placed at the edge of the roving and opposite the direction of twist. The core must be positioned to take advantage of the natural fold of the roving as twist is inserted. For instance, as in this case, with a Z twist, the fibres fold to the left as they emerge from the nip of front roll. Therefore the core should be placed just to the left side of the roving as shown in Fig. 5.4. The result is a shift
in the center of twist for the aggregate structure, which favours covering the core.

For Z Twist

For S Twist

Fig. 5.4 Position of core filament with respect to roving.

The pre-tension constrains the filament to lie close to the core of the yarn. During optimisation of pre-tension of filament, to ensure that core is perfectly buried inside sheath fibres, the use of coloured filament has been suggested [154]. Hence the filament was temporarily coloured with ink. After optimization of tension, normal filament was used during the production of core-spun yarn.

Initially the coloured filament was placed to the left edge of the roving. Then the pre-tension was gradually raised, until the filament started to become buried in the yarn. The polyester and viscose coloured filaments were least visible at a pre-tension of 28 gm. At this position and pre-tension of the filament, the core-spun yarn production was continued. The traverse bar was kept stationary during the production of core-spun yarn so as to avoid disturbance in the relative position of core filament and roving. The samples of the silk covered core-spun having coloured viscose filament in the core yarn before and after optimisation of the pre-tension are attached herewith. The photograph of these yarns is also shown below after magnification through pick glass.

100% cotton yarn was prepared from separate roving with the same twist multiplier (2.7). The roller settings were fixed according to fibre length.
5.2.3 Preparation of Fabric Samples

Four types of fabric samples (SPF, SVF, silk and cotton) were prepared. The fabric samples were knitted on single Jersey, 24 feeder circular knitting machine (Make: Sant knitting works, Ludhiana) having 12 inches dia., total number of needles 886 and 24 gauge. All the four fabric samples were knitted at the same time with same cam settings.

Knitted fabrics made of cotton are commercially very successful. The tightness factor of these fabrics is generally around 15. Hence cam setting in
knitting machine was done in such a way so that a tightness factor of 15 is achieved for cotton fabric. Now on the same cam setting, other three fabrics SPF, SVF and silk were knitted. This was done to observe the change in properties of fabrics (knitted under identical conditions) from different yarns (spun under identical condition, same count, twist etc.).

5.3 TEST METHODS

The samples were conditioned for 48 hours in the standard atmosphere of 65% RH and 27°C and then tested according to ASTM or British standards. The tensile properties of the yarns and filaments were tested on Instron tensile tester 4465. The core sheath ratio was determined by an electronic balance after separating the core filament and sheath fibres on electronic twist tester.

All other methods of testing core-spun yarn and fabrics are same as normal ring spun yarn and fabrics as described earlier in Section 3.3. The fabrics were tested in dry relaxed state.
5.4 RESULT AND DISCUSSION

5.4.1 Yarn properties

The properties of all the four yarns, silk covered polyester filament core-spun yarn SPF, silk covered viscose filament core-spun yarn SVF, 100% silk and 100% cotton yarns are shown in Table 5.2 in the appendix. Stress strain curves of these yarns are shown in Fig. 5.6 and Fig.5.7. The values of tenacity and elongation percentage at break of these yarns have also been plotted in Fig.5.8 and Fig.5.9 respectively.

![Stress-strain curves of polyester filament yarn, silk covered polyester filament core-spun yarn (SPF), 100% silk yarn and 100% cotton yarn.](image)

It is revealed from Fig.5.6 that tenacity of silk covered polyester filament core-spun yarn (SPF) is greater than 100% silk yarn whereas silk covered viscose filament core-spun yarn (SVF) is lesser than 100% silk yarn (Fig.5.7). The tenacity of the filament in comparison to silk fibre has an important role in deciding the tenacity of the core-spun yarn. It has been already observed from Table 5.1 that tenacity of polyester filament is greater than silk fibre, but tenacity of viscose filament is lesser than silk fibre. Hence tenacity of the polyester
filament core-spun yarn SPF is greater than 100% silk yarn whereas lesser in case of viscose filament core-spun yarn SVF.

Fig. 5.7 Stress-strain curve of viscose filament yarn, 100% silk yarn, silk covered viscose filament core-spun yarn (SVF) and 100% cotton yarn.

Fig. 5.9 shows that the elongation percentage at break value of core-spun yarn SPF and SVF is greater than silk yarn. It is clear from Fig.5.6 and 5.7 that 100% silk yarn has elongation % at break of 13.1% whereas polyester and viscose filament has 22.2 and 16.7% respectively. Hence an improvement in elongation percentage at break is observed after introduction of filament in the silk yarn. The coefficient of variation (CV%) of tenacity of SPF yarn was at a low level, indicating that the strength uniformity of the core yarn is also excellent as shown in Table 5.2 in the appendix.
U% value of core-spun yarn is same as pure silk yarn as shown in Fig. 5.10. Fig. 5.11 shows that total imperfections of pure silk yarn are lesser than core-spun yarns. These results indicate good quality of core-spun yarns.

The results of yarn hairiness show that the number of protruding fibres per unit length in case of core-spun yarn SPF and SVF are slightly greater than silk yarn as shown in Fig. 5.12.

Flexural rigidity or the stiffness of core-spun yarn depends upon the nature of the filament introduced. It is clear from Fig.5.13 that introduction of the polyester filament has increased the stiffness of core-spun yarn whereas viscose filament has reduced the stiffness of silk yarn since viscose has lower bending rigidity than polyester.
The numbers of strokes (rubs) required to rupture the yarn are plotted in Fig. 5.14. The abrasion resistance of core-spun yarn SPF is greater than silk yarn but SVF yarn exhibits lesser abrasion resistance than silk yarn. The toughness index which takes into account both the strength and extensibility of the yarn, has maximum influences on abrasion resistance, because both the factors in combination play a part, when the yarn is abraded. The tenacity and elongation of core-spun yarn SPF is greater than silk yarn, which finally improves toughness index of the SPF yarn and in turn the abrasion resistance is improved. As both tenacity and elongation has reduced after introduction of the viscose filament, hence SVF yarn exhibits lesser abrasion resistance than silk yarn.

Yarn diameter values are plotted in Fig. 5.15. The slight variation in the diameter of the yarns is due to count variation. The results of the appearance
grading are given in Table 5.2 in the appendix. A close comparison of the four types of yarns reveals that the core-spun yarns SPF and SVF are at par with equivalent 100% silk yarn in appearance grading.

5.4.2. Yarn Properties for Knitting

The properties of the yarn, which are important to be analyzed from knitting point of view, are shown in Table 5.3 in the appendix. It is clear from Fig. 5.16 that yarn metal friction of silk covered viscose filament core-spun yarn SVF is same as silk yarn whereas this value has reduced slightly for silk covered polyester core yarn SPF. The yarn metal friction is measured by wrapping the yarn on two steel pulleys, withdrawn at constant speed and difference in tension in yarn between two pulleys is measured. On the surface of core-spun yarn the core filament is present at random intervals. The smooth surface of the polyester filament, which may be present randomly on the surface of core-spun yarn, may be the reason of lower value of yarn metal friction for SPF yarn.

Fig.5.16 Yarn metal friction of yarns.

The loop strength and knot strength are measured to measure the brittleness of the yarn. The loop-breaking load of core-spun yarn SPF is slightly greater than silk yarn whereas reduced in case of SVF yarn as shown in Fig.5.17. The same trend was observed in yarn tenacity also.

Fig.5.17 Loop breaking load of yarns.
The loop breaking extension values are shown in Fig. 5.18. The loop breaking extension of SVF yarn is lesser than SPF yarn. This may be ascribed to lower value of elongation % at break of viscose filament in comparison to polyester filament. From Fig. 5.19 it is clear that the loop strength ratio of SVF core-spun yarn is least among four yarns and it is even lesser than cotton yarn. This is due to lower loop breaking load value of SVF yarn.

It is evident from Fig. 5.20 that knot breaking load of core-spun yarn SVF has reduced slightly due to comparatively lesser strength of the viscose filament. Knot breaking extension values are shown in Fig. 5.21. A lower value of knot breaking extension is observed for core-spun yarn SVF in comparison to SPF. This trend accords with the values of elongation at break of the polyester and viscose filament used for production of core-spun yarns.
The knot strength ratio of the core-spun yarns is greater than 75% (Fig. 5.22). The knot strength ratio of core-spun yarn SPF and SVF is lesser than silk yarn but still it is much greater than cotton yarn. Hence these core-spun yarns are expected to perform well during knitting.

Snarling tendency of the yarns has been shown in Fig. 5.23. The snarling tendency of SPF, SVF and silk yarn is lesser than cotton yarn. All the yarns were given steaming treatment before knitting. As silk and polyester filament can be steam set, hence lower values of snarling tendency are observed in case of SPF and silk yarn. Cotton yarn and viscose filament can't be steam set, hence higher values of snarling tendency is observed in SVF and cotton yarn.

### 5.4.3 Fabric properties

Table 5.4 shows the properties of knitted fabric made from silk covered polyester, viscose filament core-spun yarn SPF and SVF. It is evident from Fig. 5.24 that bursting strength of core-spun fabrics is much greater than cotton fabric. Bursting strength of SPF fabric is better than 100% silk fabric whereas bursting strength of SVF fabric is lesser than silk fabric. Bursting strength of a fabric depends upon structure of the fabric, elongation, tenacity of the yarn. As structure of the fabrics is same, hence these trends accord with the values of tenacity and elongation of the respective yarns.
The abrasion resistance of the core-spun fabric SPF and SVF is lesser than silk fabric but still it is greater than cotton fabric (Fig. 5.25). The fabrics made from core-spun yarns are exhibiting lower abrasion resistance. The filament is present at random intervals on the surface of yarn, so at these places it is comparatively easier to abrade the fabric. On the other hand in case of 100% silk ring-spun yarn the fibres are more firmly bound in the body of the yarn.

Fig. 5.26 reveals that there is not much difference in air-permeability of the core-spun fabrics SPF, SVF and silk fabric, but it is much greater than cotton fabric. This may be due to more diameter and higher hairiness value of the cotton yarn as shown in Table. 5.2 in the appendix.

The moisture regain of the SPF fabric has reduced due to presence of hydrophobic filament as shown in Fig. 5.27. The moisture regain values of SVF,
100% silk and cotton fabric is good because of hygroscopic nature of constituent fibres.

The pilling tendency of the fabrics is shown in Table 5.4 in the appendix. It indicates that SPF, SVF and silk fabrics have more tendencies to form pills as compared to cotton fabric.

Fig. 5.28 Thermal resistance of fabrics.

Thermal resistance of the core-spun fabrics is same as silk fabric, but thermal resistance of cotton fabric, is greater than other three fabrics, as shown in Fig. 5.28. Better thermal resistance of the cotton fabric may be due to higher value of the yarn diameter (Table 5.2) and fabric thickness as compared to other fabrics (Table. 5.5).

5.4.4 Relaxation Treatment

5.4.4.1 Dry Relaxed Fabric

Fig. 5.29 Courses/cm of core-spun fabrics.
Table 5.5 in the appendix shows the properties of dry relaxed SPF and SVF knitted fabrics in comparison to silk and cotton fabrics.

Fig.5.30 Wales/cm of core-spun fabrics.

It is clear from Fig. 5.29 and 5.30 that SPF, silk and cotton fabrics are exhibiting similar values of courses/cm and wales/cm whereas SVF fabric exhibits slightly higher value of courses/cm and lower value of wales/cm. From Fig. 5.31 not much difference is observed in the values of stitch density of all the four fabrics SPF, SVF, silk and cotton. It implies that silk-covered core-spun yarns and silk yarn behaves in a similar way as cotton yarn during knitting operation, resulting in almost same construction of the knitted fabric. This is further confirmed from the values of stitch density.

Fig.5.31 Stitch density of core-spun fabrics.
The stitch length of SVF yarn is slightly lesser than other yarns as shown in Fig. 5.32. This trend can be explained on the basis of flexural rigidity of SVF yarn. A lower value of yarn flexural rigidity (as shown in Fig. 5.13) in comparison to silk and cotton yarn implies that SVF yarn can be bent to a unit curvature with lesser force. As discussed earlier, the softer yarn follows a shorter path to form a loop, resulting in lesser loop length. This implies that height of loop will decrease and it can accommodate more number of courses but less number of wales in same unit area of fabric. Hence incorporation of viscose filament has reduced the stiffness of silk yarn resulting in lesser loop length, lesser height of loop, more course/cm and slightly less wales/cm in the SVF fabric. Increase in course/cm is accompanied by decrease in wales/cm for SVF fabric, hence no specific trend in stitch density is observed for dry relaxed SVF fabric as shown in Fig. 5.31.

The stitch length of SPF fabric is more than other three fabrics (Fig. 5.32). This is due to higher value of flexural rigidity of SPF yarn as shown already in Fig. 5.13 and hence it is supposed to follow a longer path to form a loop, resulting in higher value of loop length. The values of the knitting constants Kc, Kw and Ks have also been shown in Table. 5.5 in the appendix. The higher value of the loop length is the main cause of the higher value of the knitting constants for SPF fabric.
Loop shape factor depends upon shape of the loop in case of knitted fabrics. Higher value of loop shape factor is observed for SVF fabric in Fig. 5.33. This trend may be due to higher value of course/cm and lower value of wales/cm in SVF fabric.

The tightness factor for core-spun fabric SPF is least among the four fabrics (Fig. 5.34). As yarn linear density of all four yarns is equal, the slight variation in the values of stitch length has changed the values of tightness factor. Lowest tightness factor is observed due to higher value of loop length for SPF fabric.

Thickness of dry relaxed core-spun fabric SPF, SVF and silk fabric is almost same (Fig. 5.35).
The skewness of core-spun fabric SPF and silk fabric is much lower than SVF and cotton fabric (Fig. 5.36). Higher value of snarling tendency for cotton and SVF yarn in comparison to SPF and silk yarn was also observed in Table 5.3. The same trend is again shown in the skewness of fabric. It implies that good quality knitted fabrics can be commercially manufactured from silk covered polyester filament core yarns with ease.
Weight per square meter of the fabrics has been plotted in Fig. 5.37. The variation in weight/m² of knitted fabric is a combined effect of stitch length, stitch density and yarn linear density.

Fig. 5.38 shows that fabric bulk of core-spun fabrics SPF and SVF is same as silk fabric.

Table 5.6 reveals that area wise fabric shrinkage is maximum in case of cotton fabric, followed by SVF, silk and SPF fabrics. Shrinkage in SPF fabric is lesser than silk fabric. Due to presence of hydrophobic filament in the yarn, SPF fabric shrinks lesser than silk fabric. Lengthwise shrinkage is greater than...
widthwise shrinkage in all the cases. Shrinkage of fabric is dependent on processing and knitting variables and in particular take down tension. During knitting operation, the tension in lengthwise direction was greater than widthwise direction. Hence lengthwise shrinkage is greater than widthwise direction. The values of courses/cm, wales/cm and stitch density have changed according to the shrinkage in the fabric, as shown in Fig. 5.29, 5.30 and 5.31.

Reduction in values of stitch length is observed due to change in the shape of the loop after shrinkage (Fig. 5.32).

Due to increase in values of courses/cm and wales/cm, the value of loop shape factor has increased after wet relaxation (Fig. 5.33). The reduction in values of stitch length has caused an increase in value of tightness factor as displayed in Fig. 5.34. Thickness of all the four fabrics has increased after wet relaxation (Fig. 5.35). The pronounced increase in thickness of the fabric after wet relaxation is caused by several factors namely yarn swelling and increase in curvature of knitted loop out of the plane of the fabric.

Skewness of the fabric has increased after wet relaxation in all three fabrics (Fig. 5.36). This is due to penetration of water molecules in the inter-yarn stices, resulting in reduction of yarn to yarn friction. Hence the higher value of skewness is observed after wet relaxation.

Increase in weight/m² of wet relaxed fabric is due to shrinkage of the fabrics (Fig. 5.37). After wet relaxation bulk of the fabrics display an increasing trend, due to change in values of thickness as shown in Fig. 5.38.

5.4.4.3 Fully Relaxed Fabric

Properties of the fully relaxed fabric have been shown in Table. 5.7 in the appendix. Maximum value of shrinkage is observed in case of cotton fabric, followed by SVF, silk and SPF fabric. Shrinkage takes place as the tension in the fabric imparted before knitting is being relieved and molecular chains tend to orient themselves to a state of minimum energy level.

It is observed that shrinkage after full relaxation is greater than after wet relaxation as the reduction in tension is tremendous during full relaxation. The same trend is observed in both the directions of the fabric. At the same tightness factor, the shrinkage along as well as across the fabric was higher after full relaxation. This is due to vigorous thermal vibrations of water molecules at 70°C, which attack the inter-yarn friction in a more pronounced way. Hence the
tensions in the fabric are more relaxed, giving higher values of shrinkage in length and width direction of the fabric as well in area shrinkage. The shrinkage in the fabric has caused an increase in values of course/cm, wales/cm and stitch density as shown in Fig. 5.29, 5.30 and 5.31.

In comparison to dry relaxed fabric, an increase in thickness of fully relaxed fabric is observed (Fig. 5.35). This is due to yarn swelling and change in curvature of the loop after full relaxation. The reduction in skewness is observed after full relaxation due to inter-yarn lubrication during full relaxation (Fig.5.36). Weight of the fabric has increased after full relaxation due to shrinkage in the fabric (Fig. 5.37). The fabric bulk after full relaxation is also greater in comparison to dry relaxed fabric (Fig.5.38).

5.4.5 Comfort properties

5.4.5.1 Moisture transport properties

Moisture transport properties of the core-spun knitted fabrics in comparison to silk and cotton fabrics are shown in Table 5.8. It can be noticed that increase in height of water over surface of core-spun fabric is greater than silk and cotton fabric in first 30sec. It is further noticed that in first 30sec wicking height is maximum in case of core-spun fabric containing hydrophobic polyester filament in the SPF fabric. If the fabric contains hygroscopic fibre or filament, then increase in height of water is less in the start due to absorption of water but a fabric containing hydrophobic fibre or filament displays greater increase in height of water in the start.

Table 5.8 Moisture transport properties of silk covered polyester and viscose filament core-spun fabrics.

<table>
<thead>
<tr>
<th></th>
<th>SPF</th>
<th>SVF</th>
<th>Silk</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wicking test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Wicking height (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 sec.</td>
<td>1.1</td>
<td>0.9</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>5 min</td>
<td>1.9</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
</tr>
<tr>
<td>15 min</td>
<td>3.2</td>
<td>3.6</td>
<td>6.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Wickability</td>
<td>3.8</td>
<td>4.0</td>
<td>5.56</td>
<td>8.86</td>
</tr>
<tr>
<td>(b) Spot Test (sec)</td>
<td>20</td>
<td>55</td>
<td>44.5</td>
<td>160</td>
</tr>
<tr>
<td>2. Water vapour transfer (gm)</td>
<td>8.6</td>
<td>7.9</td>
<td>8.34</td>
<td>7.72</td>
</tr>
<tr>
<td>3. Total absorbency %</td>
<td>2.9</td>
<td>3.1</td>
<td>3.13</td>
<td>4.21</td>
</tr>
</tbody>
</table>

(Figures in parenthesis represent CV %)
Wickability of the fabric depends upon increase in height of water as well as increase in weight of the fabric due to absorption, hence wickability of silk and cotton fabric is greater than core-spun fabrics SPF and SVF.

Results of the spot test shows that SPF fabric transports the water in minimum time. Fabrics containing hydrophobic constituent takes less time to transport the moisture in comparison to hygroscopic constituents, as it takes time to absorb the water.

Cotton fabric exhibits minimum value of water vapour transferred among the four fabrics studied. This trend accords with the results of air permeability of the fabrics as shown previously in Table 5.4 in the appendix. It is clear from Table 5.8 that total absorbency of cotton fabric is maximum followed by silk, SVF and SPF fabrics.

5.4.5.2 Low Stress mechanical Properties

Low stress mechanical properties of knitted fabrics for outerwear purpose, made from SPF, SVF, silk and cotton yarn were evaluated in walewise and coursewise direction.

5.4.5.2.1 Tensile Properties

Table 5.9 shows that in comparison to silk fabric, low stress extensibility (EM) of the core-spun fabrics have not changed in walewise direction whereas EM has increased significantly in coursewise direction. It reflects comparatively more mobility of the threads within the fabric under low tensile load in coursewise direction. A fabric having large value of EM in walewise direction is not desirable as it causes distortion of fabric during fabric manufacture and sewing of the fabric. On the other hand, higher EM in weft direction provides weaving comfort.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Strain at 500 gf/cm²</th>
<th>Linearity of load extension curve</th>
<th>Tensile energy (WT) gfcn/cm²</th>
<th>Tensile resilience (RT) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wale</td>
<td>Course</td>
<td>Mean</td>
<td>Wale</td>
</tr>
<tr>
<td>SPF</td>
<td>20.5</td>
<td>45.3</td>
<td>32.9</td>
<td>0.76</td>
</tr>
<tr>
<td>SVF</td>
<td>19.6</td>
<td>32.7</td>
<td>26.1</td>
<td>0.80</td>
</tr>
<tr>
<td>Silk</td>
<td>21.5</td>
<td>33.8</td>
<td>27.6</td>
<td>0.67</td>
</tr>
<tr>
<td>Cotton</td>
<td>30.9</td>
<td>45.8</td>
<td>38.3</td>
<td>0.67</td>
</tr>
</tbody>
</table>
It can be noticed from Table 5.9 that the values of linearity of load elongation curve LT for core-spun fabrics SPF and SVF are greater than equivalent silk and cotton fabric in walewise as well as in coursewise direction. It implies that resistance offered by the core-spun fabric during tensile elongation at low stress levels, is more than cotton and silk fabric. LT represent linearity of load elongation curve, which further depends upon fabric extensibility in initial strain region.

Mean value of tensile energy (WT) for SPF and SVF fabric is greater than silk fabric (Table 5.9). It implies that in comparison to silk fabric, more energy is required for tensile deformation of SPF and SVF fabrics. WT represents the tensile energy per unit area i.e. the area under load elongation curve. WT exhibits the combined effect of LT and EM.

Table 5.9 reveals that tensile resilience (RT) of silk, SPF and SVF fabric is better than cotton fabric. Pure silk fabric exhibits maximum tensile resilience. RT represents elasticity of tensile deformation.

5.4.5.2.2 Bending Properties

From Table 5.10 it is evident that the mean value of bending stiffness (B) of core-spun fabrics is lesser than silk fabric. It implies that presence of filament has reduced the stiffness of silk fabric in both directions, walewise and coursewise.

Hysteresis of bending moment (2HB) also represents the same trend. It is related to recovery from bending deformation. A lower value of 2HB implies better recovery from bending. Table 5.10 indicates that recovery of SPF and SVF fabric is better than silk fabric.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Bending rigidity (B)</th>
<th>Hysteresis of bending moment (2HB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gpcm²/cm</td>
<td>gpcm</td>
</tr>
<tr>
<td>SPF</td>
<td>0.0550 0.0667 0.0609</td>
<td>0.1156 0.1524 0.1340</td>
</tr>
<tr>
<td>SVF</td>
<td>0.1290 0.0237 0.0764</td>
<td>0.2749 0.0882 0.1815</td>
</tr>
<tr>
<td>Silk</td>
<td>0.0693 0.0967 0.0830</td>
<td>0.2377 0.1697 0.2037</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.0998 0.0214 0.0606</td>
<td>0.1802 0.0471 0.1137</td>
</tr>
</tbody>
</table>
5.4.5.2.3 Shear Properties

It can be observed from Table 5.11 that shear stiffness (G) of the core-spun fabrics SPF and SVF is slightly greater than silk fabric. It implies that core-spun fabrics offer more resistance during shear deformation.

Table 5.11 - Shear properties

<table>
<thead>
<tr>
<th>Sample</th>
<th>Shear stiffness (G) gf/cm/deg</th>
<th>Hysteresis of shear force at 0.5° shear angle(2HG), gf/cm</th>
<th>Hysteresis of shear force at 5° shear angle(2HG5), gf/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF</td>
<td>0.6321 0.7546 0.6934</td>
<td>4.3659 4.7922 4.5791</td>
<td>4.5668 5.1303 4.8485</td>
</tr>
<tr>
<td>SVF</td>
<td>0.6492 0.8159 0.7326</td>
<td>3.6260 4.9784 4.3022</td>
<td>3.8514 5.2038 4.5276</td>
</tr>
<tr>
<td>Silk</td>
<td>0.6003 0.6934 0.6468</td>
<td>3.6652 4.6550 4.1601</td>
<td>3.9445 4.9196 4.4321</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.6542 0.6174 0.6358</td>
<td>2.2589 2.2540 2.2565</td>
<td>2.4892 2.4255 2.4573</td>
</tr>
</tbody>
</table>

Table 5.11 indicates that the mean values of hysteresis of shear force at 0.5° and 5° shear angle (2HG and 2HG5) for SPF and SVF fabrics are slightly greater than silk fabrics at both shear angles. Hysteresis losses are important from the dimensional stability standpoint, during the usage of fabric. Higher value of hysteresis losses (2HG and 2HG5) implies poorer recovery from shear deformation.

5.4.5.2.4 Surface Properties

Table 5.12 - Surface Properties

<table>
<thead>
<tr>
<th>Sample</th>
<th>Coefficient of friction (MIU)</th>
<th>Mean deviation of MIU (MMD)</th>
<th>Geometrical roughness (SMD), μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF</td>
<td>0.2220 0.2445 0.2333</td>
<td>0.0162 0.0155 0.0158</td>
<td>6.566 7.948 7.257</td>
</tr>
<tr>
<td>SVF</td>
<td>0.2107 0.2538 0.2323</td>
<td>0.0138 0.0166 0.0152</td>
<td>4.964 8.428 6.696</td>
</tr>
<tr>
<td>Silk</td>
<td>0.2220 0.2509 0.2364</td>
<td>0.0166 0.0154 0.0160</td>
<td>4.268 7.360 5.814</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.3685 0.2862 0.3274</td>
<td>0.0155 0.0174 0.0164</td>
<td>4.145 7.938 6.041</td>
</tr>
</tbody>
</table>

The values of coefficient of friction (MIU) for core-spun fabrics SPF and SVF is almost same as silk fabric as shown in Table 5.12. Similar value of MIU for core-spun and silk fabric indicates that surface properties of the silk fabric
haven't hampered even after introduction of the filaments. Mean deviation of MIU (MMD) for core-spun fabrics is also slightly less than both silk and cotton fabrics.

Table 5.12 shows that in comparison to silk and cotton fabrics, a higher value of geometrical roughness (SMD) is observed for core-spun fabrics.

5.4.5.2.5 Compression Properties

Table 5.13 shows that in comparison to silk fabric, slightly higher value of linearity of compression (LC) is observed for core-spun fabrics SPF and SVF. Compressional energy (WC) is also greater for SPF and SVF fabrics than silk fabric. The value of LC depends upon shape of compression thickness curve and WC represents energy required to compress the fabric.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Linearity of compression (LC)</th>
<th>Compressional energy (WC) gfc/cm²</th>
<th>Compressional resilience (RC) %</th>
<th>Fabric thickness (T) mm</th>
<th>Fabric weight (W) mg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF</td>
<td>0.295</td>
<td>0.407</td>
<td>57.55</td>
<td>1.11</td>
<td>13.16</td>
</tr>
<tr>
<td>SVF</td>
<td>0.273</td>
<td>0.382</td>
<td>55.80</td>
<td>1.13</td>
<td>14.23</td>
</tr>
<tr>
<td>Silk</td>
<td>0.259</td>
<td>0.376</td>
<td>66.34</td>
<td>1.13</td>
<td>13.82</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.291</td>
<td>0.466</td>
<td>52.75</td>
<td>1.31</td>
<td>14.32</td>
</tr>
</tbody>
</table>

It may be observed from Table 5.13 that silk fabric shows maximum value of compressional resilience (RC) among the four fabrics studied. The resilience of SPF and SVF fabric is less than silk fabric but greater than cotton fabric. Compressional resilience (RC) of a fabric depends upon the compressional behavior of yarn. It indicates recovery from compressional deformation.

5.4.5.2.6 Weight and Thickness

Not much change is observed from the values of thickness of the core-spun and silk fabrics. The weight of SPF, SVF and silk fabrics doesn't show any trend.

5.4.5.2.7 Fabric Hand

Table 5.14 shows hand values of knitted outerwear fabrics made of SPF and SVF core-spun yarns in comparison to silk and cotton fabrics. For ease of comparison these values have also been plotted in Fig. 5.39. Such a
plot results in a property profile which can be easily visualised for comparison purposes.

Table 5.14 shows that value of Koshi for SPF and SVF fabric is lesser than silk fabric but greater than cotton fabric. It implies that addition of polyester and viscose filament in the silk yarn has resulted in reduction of bending stiffness of silk fabric. Koshi of the fabric is contributed by bending property and springiness.

Lower value of Numeri (smoothness) is observed for SPF and SVF fabric. It indicates slight reduction in smoothness of the core-spun fabric as compared to silk and cotton fabric.

Table 5.14 Total hand value of single jersey core-spun knitted outerwear fabric.

<table>
<thead>
<tr>
<th>Material</th>
<th>Koshi (Stiffness)</th>
<th>Numeri (Smoothness)</th>
<th>Fukurami (Fullness and softness)</th>
<th>Total Hand Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF</td>
<td>0.78</td>
<td>6.28</td>
<td>6.31</td>
<td>2.45</td>
</tr>
<tr>
<td>SVF</td>
<td>1.49</td>
<td>6.49</td>
<td>5.66</td>
<td>2.90</td>
</tr>
<tr>
<td>Silk</td>
<td>1.56</td>
<td>7.37</td>
<td>6.22</td>
<td>3.47</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.14</td>
<td>7.23</td>
<td>5.33</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Table 5.14 clearly shows that introduction of polyester filament has resulted in increase in fullness of the silk fabric whereas introduction of viscose filament has resulted in slight reduction in fullness of the fabric. In this respect SPF fabric is exhibiting highest value of fukurami in comparison of cotton and silk fabric. Fukurami (fullness and softness) is an important property for knitted outerwear fabrics. Fukurami is mainly affected by fabric bulk and compressional behaviour.
Fig. 5.39 Hand values of silk covered polyester filament core-spun (SPF), silk covered viscose filament core-spun (SVF), silk and cotton knitted fabrics.

Among the four fabrics studied silk fabric has highest THV (total hand value) followed by SVF, cotton and SPF fabrics. The degree of "good" hand is expressed by 'Total hand value (THV)'. Good hand is an evaluation of the primary quality of the fabrics.
5.5 CONCLUSION

Incorporation of a continuous polyester filament in the core of silk yarn has improved tensile strength, elongation, abrasion resistance of the core-spun yarn. The quality of the silk covered polyester and viscose filament core-spun yarns is good as they are having low U%, total imperfections and hairiness. Although the tenacity of silk yarn has reduced slightly after incorporation of viscose filament, but still both core-spun yarns didn't pause any problem in knitting.

The bursting strength, abrasion resistance and air-permeability of silk covered polyester filament core-spun knitted fabric is greater than cotton fabric. The properties of the viscose filament core-spun fabric like abrasion resistance, bursting strength are inferior than silk fabric but superior than cotton fabric. The results of moisture transport properties suggest the suitability of core-spun fabrics for apparel purpose.

The incorporation of the polyester and viscose filament in the core of silk yarn has resulted in reduction of Koshi (bending stiffness) of the knitted fabric. Although the total hand value of silk covered polyester filament core-spun fabric is lesser than silk and cotton fabric but total hand value of silk covered viscose filament core-spun knitted fabric is greater than cotton fabric.

Silk covered polyester and viscose filament core-spun, single jersey knitted fabric may be new materials for apparel purpose, upholstery, bedsheets etc. and can also serve as face yarns for tufted carpets.