CHAPTER 4

BULK SILK

YARNS AND FABRICS.
4.1 INTRODUCTION

Silk is the most tenacious, continuous, natural textile fibre. Coupled with high strength, silk fabrics have exceptional natural lusture, soft handle and good comfort properties. Since the yarn possesses low bulk, more number of threads (lengthwise and widthwise) are required for producing better cover. Because of high density of threads, the silk fabric tears off like a paper very easily. A high bulk silk yarn can not only give a new texture with better cover but also warmth. The fabric also will be light.

Some research work has been carried out to improve the quality of silk fabric by increasing the bulk of silk filament by texturisation process [50]. A composite yarn of silk and acrylic filament yarn was also developed in Japan [51]. This yarn was produced by mixing silk and acrylic filaments in the raw silk reeling process. In China, bulk stretch silk has also been developed from raw silk by reprocessing the silk filaments [53]. Compared to normal silk it has excellent bulkiness, softness with remarkable elasticity and recovery.

In the case of acrylic bulk yarn, fibres of different shrinkable properties are mixed together and then steam relaxed in hank form after spinning operation. Bulk generates due to shrinkage or contraction of shrinkable fibre in the yarn which causes the non-shrinkable component to form numerous loops. Following the same principle bulk silk yarn can also be produced by blending silk with shrinkable acrylic fibre. The acrylic fibre after shrinking will go in to core leaving the silk on the surface. The fabrics made from silk-acrylic yarns can find suitable place in outerwear fabrics, jerseys and sweaters also. These kinds of fabrics would have outstanding characteristics of acrylic fibre like excellent resistance to atmospheric conditions, dimensional stability, heat settable, handling, easy care properties as well as elegant lusture, moisture absorption, permeating features of silk.

Blending of such fibres is relatively new to the industry and the properties of such blends are little known, hence for comparison purpose cotton yarn and fabric was also prepared at the same time.
The objective of the work is
- To explore possibility of producing silk acrylic bulky yarn.
- To find blend ratio for producing maximum bulk in the yarn.
- To assess the properties of such yarn.
- To assess the properties of fabric made from such bulky yarn.
4.2 EXPERIMENTAL PLAN

4.2.1 Properties of Raw-material

The silk hanks were cut to a staple length of 64mm with a scissors and then degummed using soap and soda method. The process has been already described in Section 3.2. The degummed silk was opened manually. Shrinkable acrylic fibre of 64mm staple length and fineness 2.0 denier was selected for blending with silk as fine denier shrinkable acrylic fibre are not manufactured commercially.

The properties of silk and acrylic fibres (before and after steaming) are shown in Table 4.1. The properties of acrylic fibre have changed after steaming.

Table 4.1 Properties of acrylic, silk and cotton fibre.

<table>
<thead>
<tr>
<th></th>
<th>Acrylic (Before steaming)</th>
<th>Acrylic (After steaming)</th>
<th>Silk</th>
<th>H-4 Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenacity (g/den)</td>
<td>3.5</td>
<td>2.7</td>
<td>4.1</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>(17.9)</td>
<td>(19.0)</td>
<td>(12.0)</td>
<td>(12.4)</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>24.2</td>
<td>41.4</td>
<td>30.8</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>(18.8)</td>
<td>(22.7)</td>
<td>(13.3)</td>
<td>(15.4)</td>
</tr>
<tr>
<td>Staple length (mm/2.5% span length)</td>
<td>64.1</td>
<td>51.1</td>
<td>64</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>(18.5)</td>
<td>(20.8)</td>
<td>(28.5)</td>
<td>(28.4)</td>
</tr>
<tr>
<td>Fineness (den/micronaire)</td>
<td>2.0</td>
<td>2.38</td>
<td>1.2</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>(14.8)</td>
<td>(17.0)</td>
<td>(17.4)</td>
<td>(20.4)</td>
</tr>
</tbody>
</table>

(Figures in parenthesis represent CV %)

The stress-strain diagram of these fibres are shown in Fig.4.1.
4.2.2 Preparation of yarn samples

Silk and acrylic fibres were blended in various proportions. These were 0:100, 20:80, 40:60, 50:50, 60:40, 80:20 and 100:0 (denoted as Acrylic, S2A8, S4A6 S5A5, S6A4, S8A2 and Silk respectively). In this study, an additional blend of silk-acrylic 50/50 (S5A5) was also prepared.

A mixture of 5% water and LV-40, P-2152 (0.5% each) on the weight of fibres, was sprayed on the mixing to avoid static related problems during processing. The mix was dried at room temperature. Then the mixing was fed to the cards. The feed plate-licker in, cylinder-flats and cylinder-doffer settings were widened from 18, 15 and 6 thou, to 22, 18 and 8 thou, respectively, due to longer length and bulky nature of acrylic fibre. The carded sliver of 0.1 hank was produced by maintaining cylinder speed of 250 rpm and production rate of 10 Kg/hr.

Then card slivers were given two passages on drawframe. The roller setting was 68/72 in front/back zone and a trumpet of 4 mm dia. was used. From the drawn sliver a roving of 1.2 hank was prepared by keeping front roll speed 200rpm and spindle speed 900rpm on speed frame. From this roving, yarn was spun on ring frame. The as spun count and twist levels were decided following the procedure stated below.
The bulk yarn count was fixed at 30s Ne with a twist multiplier of 2.7. The twist level in the yarn would be 14.8 twist per inch. After steaming shrinkage of 20% was observed in case of acrylic fibre. So to produce 30s acrylic yarn after steaming, 37.5s acrylic yarn should be spun at ring frame. It was calculated as given below

\[
\text{Actual count to be spun} = \frac{30 \times 100}{100 - \text{shrinkage \%}} = \frac{30 \times 100}{80} = 37.5s
\]

Similarly if 14.8 twist per inch (30s count and 2.7 TM) is required after steaming, then 12.3 TPI should be set on ring frame so that 14.8 TPI is achieved after steaming.

\[
\text{Twist level in the yarn} = \frac{14.8 \times 100}{100 + \text{shrinkage}} = \frac{14.8 \times 100}{120} = 12.3
\]

For acrylic-silk 80/20 (A8S2), value of count and twist was calculated by putting shrinkage value equal to 16% in the formula. Similarly for A6S4, A5S5, A4S6 and A2S8, a shrinkage value of 12%, 10%, 8% and 4% was taken respectively. All acrylic-silk blended yarns were produced with different values of count and twist, so that after steaming and shrinkage, same count 30s and 14.8 TPI (TM 2.7) may be achieved for all the yarns. After producing yarn on ring frame the other operations followed in sequence were

1. Ring frame (Bobbin)
2. Winding and Clearing (Cone)
3. Hank Winding (Hank)
4. Steaming
5. Hank Rewinding (Cone)
6. Winding and Clearing (Cone)
7. Knitting
The ring frame bobbins were wound to cones on a winding machine having electronic yarn clearer. Then hanks were prepared on hank winding machine. Hanks of about 20 g were prepared which were properly crossed and laced in at two or three points so as to avoid entanglements during and after steaming. The lacing was kept completely loose so as not to hinder the bulking process during shrinking. Then the hanks were hung in the autoclave. Any direct contact of the yarn with hot metal surface was avoided because it might cause formation of non-bulked areas in the yarns. Steaming of the hanks was done for 20 minutes at a temperature of 100°C and pressure of 1.0 Kg/cm².

After steaming the hanks were rewound on to cones on hank rewinding machine. It was followed by one more winding operation equipped with electronic yarn clearer, because during hank rewinding there often occurs impacts due to incorrect yarn crossings in the hanks which result in uneven extension of the yarn of the bobbin. The second rewinding operation is, therefore, incorporated to smooth the tension variations in the yarn package and to ensure a uniform unwinding during knitting.

4.2.3 Preparation of fabric samples

All acrylic-silk blended fabrics, silk and cotton fabrics were knitted on single jersey, 24 feeder circular knitting machine (Make : Sant knitting works, Ludhiana) having 12 inches diameter, total numbers of needles 886 and 24 gauge. All the fabric samples were knitted at the same time with same cam setting.

During knitting of high bulk yarns, it is important to maintain constant yarn tension and yarn consumption per stitch on the knitting machine. For this, a mark, at equal distance from needle was applied on the yarns of each feeder which were about to enter the needles. Then knitting machine was run for a while and position of the mark was observed in the fabric. If the yarn tension and yarn consumption per stitch is same on all the feeders, then the marks will form a circle in the fabric. If they do not form a circle, cam setting on each feeder was adjusted until the ideal condition was achieved. After ensuring this, all types of acrylic-silk blended fabrics, cotton and silk fabrics were prepared on the knitting machine one after another.
4.3 TEST METHODS

All the test methods for yarns and fabrics were same as described already in section 3.3. In this section an additional test to ascertain yarn bulk was performed.

The bulk of the yarn can be assessed by comparing yarn diameter and thickness of the plain knitted fabric [148]. It can also assessed by preparing equal volume package from parent and bulk yarn and comparing their weight [149, 150]. It is fairly difficult to wind packages of same volume hence a modified method using the same principle is used [151]. In this method the parent and the bulk yarn are wound on a package for equal time at same tension and speed. Then package density of these two packages is compared [152]. While building packages either based on equal winding time or equal diameter, package size should be reasonably large for correct estimation of parent and bulked yarn package densities [153].

The package density method, yarn diameter and fabric thickness are the basis for finding out the maximum yarn bulk.

For assessing package density, all silk-acrylic yarns (before and after steaming) were wound on to a cheese for 20 minutes at same tension of 15 g and speed 600 m/min. The package density was calculated using the formula as given below

\[
\text{Package density (g/cm}^3\text{)} = \frac{M_{c+y} - M_c}{3.14 \times (R_{c+y}^2 - R_c^2) \times L}
\]

where 
- \(M_{c+y}\) = Total weight of cheese and yarn
- \(M_c\) = Weight of cheese alone
- \(L\) = Traverse length on the cheese
- \(R_{c+y}\) = Overall radius of the cheese with yarn on it and
- \(R_c\) = Radius of the cheese alone
Fig. 4.2 Dimensions of a cheese for measuring yarn bulk.
4.4 RESULT AND DISCUSSION

4.4.1 Yarn properties

The properties of silk-acrylic blended yarns at various blend levels before steaming are shown in Table 4.2 in the appendix. The properties of all these yarns after steaming are shown in Table 4.3 in the appendix. The stress strain curves at various blend levels of silk/acrylic yarns before steaming are shown in Fig. 4.3. The change in shape of the curves after steaming treatment is shown in Fig. 4.4.

The stress strain curves of 100% cotton, silk and acrylic yarn (before and after steaming) are shown in Fig. 4.5. No change was observed in the stress-strain curves of the silk and cotton yarn whereas shape of the acrylic yarn has changed. This can be ascribed to the change in properties of the shrinkable acrylic fibre after steaming. The stress strain curves of silk, cotton and acrylic fibre (before and after steaming) have already been shown in Fig. 4.1 and properties of these fibres in Table 4.1 in section 4.2.1. It is revealed from Table 4.1 that tenacity of shrinkable acrylic fibres reduces whereas marginal increase in elongation % at break is observed after steaming.
treatment. The change in acrylic fibre properties is due to its shrinkage during steaming. At the same time the denier has increased due to swelling of the shrinkable fibres. Length of the shrinkable acrylic fibre has reduced by 20% (64 to 51.12 mm) and denier has increased from 2.01 to 2.38. The properties of shrinkable fibre have changed after steaming treatment, hence a change in the properties of acrylic blended yarns is observed after steaming treatment.

![Stress-strain curves of 100% silk, cotton, and acrylic yarns (before and after steaming).](image)

The stress strain curves of each silk-acrylic blended yarn before and after steaming is shown separately in Fig. 4.6, 4.7, 4.8, 4.9, 4.10 and 4.11 respectively. The properties of silk-acrylic blended yarns (before and after steaming) have been plotted in respective figures simultaneously, so as to observe the changes in yarn properties after steaming clearly.
Stress-strain curves of silk-acrylic yarns (before and after steaming).

Fig. 4.6 - Acrylic/silk 20/80

Fig. 4.7 - Acrylic/silk 40/60

Fig. 4.8 - Acrylic/silk 50/50

Fig. 4.9 - Acrylic/silk 60/40
All the curves incline towards strain axis after steaming. There is a reduction in tenacity and increase in elongation % at break after steaming for all the yarns.

The tenacity of silk-acrylic blended yarns is also shown in Fig. 4.12. The tenacity increases with increases in stronger silk fibre component in the blend. The decrease in tenacity of the blended yarns after steaming is also apparent from Fig 4.12. This reduction in strength after steaming is mainly due to reduction in fibre strength of shrinkable acrylic and crimpy configuration of silk fibres.

An increase in yarn breaking elongation after steaming for all yarns containing shrinkable acrylic fibre (Fig 4.13) can also be observed. The increase in yarn elongation is maximum for acrylic-silk 50/50 blend. Higher breaking elongation value can be attributed to bending, buckling of silk fibres and increase in yarn bulk after steaming. As the buckling of fibres increases with increased quantity of acrylic content, the breaking elongation of the yarn also increases. It ultimately results in loosening of the yarn structure followed by reduction in tenacity and increase in elongation % at break.
Fig. 4.14 shows that U% of the yarns have increased after steaming marginally. This may be because of man handling of the yarns during reeling, steaming and hank rewinding operations. Uniformity improves with the addition of silk, as the number of fibres in the cross-section also increases. Total imperfections remain fairly same as shown in Fig 4.15.

A marginal increase in the hairiness of the yarns is observed in Fig. 4.16 due to repeatedly winding and rewinding as mentioned in section 4.2.2. Flexural rigidity of yarns has increased after steaming operation (Fig. 4.17). The silk-acrylic yarns have become coarser after steaming operation, hence coarser yarn is expected to exhibit more yarn flexural rigidity.
Fig. 4.17 Flexural rigidity of silk-acrylic yams.

Fig. 4.18 reveals poor values of abrasion resistance before steaming. The yarns were comparatively finer before steaming and hence are exhibiting lesser abrasion resistance. The diameter of the yarns as measured on the microscope is shown in Fig. 4.19. Each silk-acrylic blended yarn is showing an increasing trend in the yarn diameter after steaming operation, but increase in diameter of the yarn is found to be maximum in case of acrylic-silk 50:50 blend.

Fig. 4.19 Yam diameter of silk-acrylic yams.

It is clear from Fig. 4.20 that package density is minimum for silk-acrylic 50/50 blended yarn. It indicates that yarn bulk is maximum when silk-acrylic blend level is 50:50. This results accords with yarn diameter values also (Fig. 4.19).
A close comparison of all silk-acrylic blended yarns reveals that there is not much variation in appearance and grading of the various yarns as shown in Table 4.2 and 4.3 in the appendix.

4.4.2 Yarn Properties for Knitting

It is observed from Table 4.4 in the appendix Fig. 4.21 that yarn metal friction of 100% acrylic yarn is lesser than 100% silk and cotton yarn. The yarn metal friction shows an increasing trend with the increase in silk proportion in the blend. Fig.4.22 reveals that loop-breaking load of all silk-acrylic blends is greater than cotton yarn and it increases with increasing silk content. This trend matches with yarn tenacity values.

It may be seen from Fig.4.23 that loop-breaking extension of acrylic rich blends is considerably higher than silk rich blends. Such an increase is caused by higher
elongation % at break values of acrylic fibre. Fig.4.24 shows that loop strength ratio of all the yarns studied is greater than 95%.

The silk-acrylic blended yarns show an increasing trend in the knot-breaking load values with the increase in silk content in the blend (Fig. 4.25). This may be attributed to the higher tensile strength of silk fibre in comparison to acrylic fibre. From Fig.4.26, a decrease in the value of knot breaking extension is observed with increasing silk proportion. Higher value of breaking elongation of acrylic fibre may be ascribed to this trend.

In general all the silk-acrylic blended yarns have good knot-strength ratio values (more than 90%) as shown in Fig.4.27. The results of loop strength ratio and knot strength ratio indicate that these yarns are expected to perform well during knitting. After steam relaxation, acrylic rich blends show lower values of snarling
tendency in comparison to silk yarns (Fig.4.28). This may be due to good steam setting properties of acrylic fibre.

![Fig.4.27 Knot strength ratio of SA yarns.](image1)

![Fig.4.28 Snarling tendency of silk-acrylic yarns.](image2)

### 4.4.3 Fabric properties

Table 4.5 in the appendix and Fig. 4.29 indicates that bursting strength of the fabric improves with the addition of the silk in the blend. This trend accords with the tenacity of these yarns. During bursting of the fabric, tenacity in combination with elongation of the yarn play an important role. Silk yarn has maximum tenacity, hence it exhibits maximum bursting strength.

The abrasion resistance of the silk-acrylic knitted fabric shows an increasing trend with increasing proportion of silk in the fabric (Fig.4.30). Such a trend occurs because loose and bulky structure of 100% acrylic yarn can cause quick rupture of
sheath fibres in a bulky yarn in comparison to compact structure of all silk yarn during abrasion cycles.

Fig. 4.31 Air permeability of silk/acrylic fabrics.  
Fig. 4.32 Moisture regain of silk/acrylic fabrics.

It is observed from Fig. 4.31 that air permeability of silk/acrylic knitted fabrics shows a downward trend first and then increases slightly. We have already observed that with the increase in silk content in the blend, the yarn diameter and bulk increases and attains maximum value at 50/50 silk-acrylic level and then decreases. It results in higher cover factor and reduced air-permeability of the fabric.

Moisture regain is lower for fabrics having higher acrylic content (Fig. 4.32). This is due to hydrophobic nature of the acrylic fibre. Consistent increase in values of moisture regain is observed with increasing silk content. From Table 4.5 in the appendix severe pilling propensity is observed in case of acrylic majority fabrics.

Fig. 4.33 Thermal resistance of silk/acrylic fabrics.
Fig. 4.33 shows that thermal resistance of knitted fabrics first increases and then decreases with increase in silk proportion in the blend. The maximum value corresponds to silk-acrylic 50/50 (A5S5). This trend accords with the values of the yarn bulk. Fabric made from the yarn A5S5 having maximum bulk is exhibiting maximum thermal resistance.

4.4.4 Relaxation treatment

4.4.4.1 Dry relaxed fabric

Table 4.6 in the appendix shows properties of dry relaxed silk-acrylic blended fabrics. Courses/cm and wales/cm are shown in Fig. 4.34 and 4.35 respectively.

![Fig.4.34 Courses/cm of SA blended fabrics.](image1)

![Fig.4.35 Wales/cm of SA blended fabrics.](image2)

It is interesting to note that courses/cm first increase slightly and then decreases whereas wales/cm first decrease and then increase slightly. This trend accords with the change in bulk of the yarn with blend %. The bulk of the yarn first increases, reaches maximum value at 50/50 and then decreases. Due to bulky nature of the yarn, it is difficult to follow the looped path, hence the height of the loop has reduced, resulting in slightly more courses/cm and lesser wales/cm and lower value of the stitch length. Due to development of the bulk in the yarn, the value of the stitch length first reduces and then increases as shown in Fig. 4.37.

Stitch density has changed according to the change in the values of the courses/cm and wales/cm as displayed in Fig. 4.36. The values of knitting constants have also changed according to change in values of courses/cm, wales/cm and loop length as shown in Table 4.6 in the appendix.
Loop shape factor is a ratio of course/cm and wales/cm. Due to change in the values of courses/cm and wales/cm, loop shape factor first increases and then decreases with changing percentage of silk in the blend, as shown in Fig. 4.38.

The tightness factor of the fabric is inversely proportional to stitch length. Due to reduction in the values of stitch length with increasing proportion of silk, the tightness factor first increases to maximum value at silk/acrylic 50/50 and then reduces gradually (Fig. 4.39).

Thickness of fabric is largely dependent on the yarn diameter. The change in the values of the thickness of the fabric accords with the change in the values of yarn diameter and bulk as shown in Fig. 4.40. Thickness of the fabric is maximum at A5S5 due to maximum value of yarn diameter of A5S5 yarn (Table 4.3).
100% acrylic fabric displays minimum value of skewness in the fabric (Fig. 4.41). Snarling tendency was also minimum for acrylic yarn as already shown in Table 4.4. This is due to good steam setting properties of acrylic fibre.

Weight/m² of fabric is shown in Fig. 4.42. It depends upon stitch density, loop length and tex of the yarn. As tex of yarn is same for all yarns, and loop length show a little variation, hence weight/m² of the knitted fabric varies according to the variation of the stitch density of the fabric studied.

Bulk of silk-acrylic blended fabrics first increases slightly and then decreases as shown in Fig. 4.43. This trend is a combined effect of changes in the values of the weight and thickness of the fabrics as fabric bulk is a ratio of the values of thickness and weight of the fabric.
4.4.4.2 Wet relaxed fabric

It has been noted from Table 4.7 in the appendix that shrinkage in acrylic rich blended knitted fabric is lesser than silk and cotton knitted fabrics of similar construction. Shrinkage has occurred as the fabric recovers from strains imposed by knitting machine in lengthwise and widthwise direction. During wet relaxation, water molecules penetrates the inter yarn spacings and behaves like a lubricant. The major part of the inter yarn friction is lost and yarn movement is eased. Thus yarn occupies a new configuration within the space available. Hence the values of courses/cm, wales/cm and stitch density have increased according to the shrinkage in the fabric.

Due to shrinkage in the fabric the shape of the loop has changed and the change in the shape of the loops is reflected from the values of loop shape factor. After wet relaxation the reduction in the values of stitch length has resulted in change in values of tightness factor. The tightness factor of A5S5 fabric is maximum due to minimum stitch length of this fabric. Due to yarn swelling after wet relaxation, the thickness of all silk-acrylic blended fabrics has increased.

From Table 4.7 it is clear that angle of spirality has increased in case of silk-acrylic blends. This is due to relieving of the torques imposed during spinning and knitting. Due to yarn swelling, the fabric bulk has increased.

4.4.4.3 Full Relaxation

It has been observed from Table 4.8 that shrinkage in the knitted fabrics after full relaxation is greater than after wet relaxation. This is due to the fact while tumble drying during full relaxation, the penetration of molecules of water in the inter-stices is further quickened and quantitative lubrication is also more, resulting in higher value of shrinkage as compared to wet relaxation treatment. The values of course/cm, wales/cm, and stitch density have increased after full relaxation whereas the values of stitch length have reduced. This is due to change in the shape of the loops as it is evident from Fig.4.38.

The increase in tightness factor of the knitted fabrics after full relaxation can be attributed to the reduction in value of loop length. It is evident from Fig.4.40 that increase in value of thickness after full relaxation
is lesser as compared to wet relaxation. This may be ascribed to tumble drying of the fabrics at 70°C.

The spirality of the silk rich knitted fabrics after full relaxation is greater than after wet relaxation (Fig.4.41). Due to tumble drying of the samples at an elevated temperature, the extent of inter-yarn lubrication is more which helps the fabric to shrink to a greater extent.

Weight/m² of the fabric has increased according to the amount of shrinkage in fabric. The fabric bulk depends upon thickness and weight/unit area of the fabric, hence the fabric bulk has changed according to the changes in the values of thickness and weight/unit area of the fabrics.

4.4.5 Comfort properties

4.4.5.1 Moisture Transfer Properties

The results of moisture transfer properties silk-acrylic blended knitted fabrics are shown in Table 4.9.

<table>
<thead>
<tr>
<th>Table 4.9 Moisture transport properties of silk-acrylic blended fabrics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>1. Wicking test</td>
</tr>
<tr>
<td>(a)Wicking height (cm)</td>
</tr>
<tr>
<td>30 sec.</td>
</tr>
<tr>
<td>5 min</td>
</tr>
<tr>
<td>15 min</td>
</tr>
<tr>
<td>Wickability</td>
</tr>
<tr>
<td>(b) Spot Test (sec)</td>
</tr>
<tr>
<td>2. Water vapour transfer (gm)</td>
</tr>
<tr>
<td>3. Total absorbency %</td>
</tr>
</tbody>
</table>

(Figures in parenthesis represent CV %)

From Table 4.9 it is clear that wicking height is maximum in case of 100% acrylic fabric. The rate of wicking is also fast in acrylic fabric in first 30 sec and 5 min. The results of spot test also indicate fastest transfer of moisture in acrylic fabric among all the fabrics studied. These results imply that wicking behaviour of acrylic majority blends in better than silk and cotton fabrics. This will ensure skin comfort to the wearer and lower static build-up of the fabric.
Table 4.9 indicates that water vapour transfer of silk/ acrylic knits first decreases and then increases. This trend accords with the results of air permeability. Lower water vapour transfer in case of A5S5 fabric is due to lower air permeability of the fabric as already observed in Table 4.5.

Although wicking properties of acrylic rich knitted fabrics are good but total absorbency of these fabrics is poorer in comparison to silk and cotton fabrics. This is due to hydrophobic nature of acrylic fibre.

4.4.5.2 Low stress mechanical properties

The experimental results discussed in the previous section have revealed that maximum bulk in yarn is observed in case of silk-acrylic 50/50 blend. Due to limited financial resources low stress mechanical properties and primary hand expressions of only four samples (100% acrylic, acrylic-silk 50/50, 100% silk and cotton) were evaluated on Kawabata system. The results are shown in Table 4.10.

4.4.5.2.1 Tensile properties

Table 4.10 shows comparatively lower values of elongation for 100% acrylic and acrylic-silk 50/50 blend (A5S5) in comparison to 100% silk and cotton fabric. This elongation represents mobility of the threads within the knitted fabric. Yarn diameter was found to be greater in case of A5S5 yarn and 100% acrylic yarn in comparison to silk and cotton yarn as observed in previous section (Fig.4.19). Due to higher value of yarn diameter, area of contact within the threads is higher which offers more resistance during tensile elongation resulting in lower value of EM in case of acrylic and A5S5 fabric.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Strain at 500 gf/cm</th>
<th>Linearity of load-extension curve (LT)</th>
<th>Tensile energy (WT)</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>Acrylic</td>
<td>18.4</td>
<td>22.4</td>
<td>20.4</td>
<td>0.73</td>
</tr>
<tr>
<td>A5S5</td>
<td>15.7</td>
<td>28.7</td>
<td>22.2</td>
<td>0.85</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>

Slightly higher values of linearity of load-extension curve (LT) are observed in case of acrylic and A5S5 fabric. This may be ascribed to more
resistance offered by these yarns due to greater diameter. Linearity of load-extension curve LT represents fabric extensibility in initial strain region. It depends upon slope of the load-extension curve of the fabric and resistance offered by the threads during elongation.

Lower values of tensile energy (WT) are observed in case of acrylic and A5S5 fabric. Maximum value of tensile resilience (RT) is observed in case of A5S5 fabric. It implies that recovery from tensile deformation of silk/acrylic 50/50 fabric is maximum among the fabrics studied.

4.4.5.2.2 Bending properties

Table 4.11 shows that bending stiffness (B) of acrylic fabric is maximum followed by A5S5, silk and cotton fabric. This is due to the fact that thickness of acrylic and A5S5 fabric is greater than silk and cotton fabric. Hence a higher value of bending stiffness is observed for acrylic and A5S5 fabric. The hysteresis of bending moment (2HB) is also maximum for acrylic fabric. It represents recovery from bending deformation.

<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>Wale</td>
<td>Course</td>
</tr>
<tr>
<td>Acrylic</td>
<td>0.1372</td>
<td>0.1122</td>
</tr>
<tr>
<td>A5S5</td>
<td>0.1434</td>
<td>0.0369</td>
</tr>
<tr>
<td>Silk</td>
<td>0.0693</td>
<td>0.0967</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.0998</td>
<td>0.0214</td>
</tr>
</tbody>
</table>

4.4.5.2.3 Shear properties

Table 4.12 – Shear properties

<table>
<thead>
<tr>
<th>Sample</th>
<th>Shear stiffness (G)</th>
<th>Hysteresis of shear force at 0.5° shear angle(2HG),</th>
<th>Hysteresis of shear force at 5° shear angle(2HG5),</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wale</td>
<td>Course</td>
<td>Mean</td>
</tr>
<tr>
<td>Acrylic</td>
<td>1.0070</td>
<td>0.9726</td>
<td>0.9898</td>
</tr>
<tr>
<td>Silk</td>
<td>0.6003</td>
<td>0.6934</td>
<td>0.6468</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.6542</td>
<td>0.6174</td>
<td>0.6358</td>
</tr>
</tbody>
</table>
Table 4.12 shows that shear stiffness (G) is maximum for A5S5 fabric followed by acrylic, silk and cotton. This may be due to more resistance offered by A5S5 fabric during shear deformation. The same trend is observed for hysteresis of shear force (at 0.5° angle and 5° angle). The hysteresis is higher in case of acrylic and A5S5 fabric.

4.4.5.2.4 Surface properties

From Table 4.13 lower values of coefficient of friction (MIU) are observed for silk and silk/acrylic 50/50 blend. It indicates smoother surface of these fabrics. Mean deviation of MIU (MMD) is also lowest for A5S5 fabric. Geometrical roughness of acrylic and A5S5 fabric (SMD) is also lower than other fabrics studied.

<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></td>
<td>Wale Course Mean</td>
<td>Wale Course Mean</td>
<td>Wale Course Mean</td>
</tr>
<tr>
<td>Acrylic</td>
<td>0.2367 0.2847 0.2607</td>
<td>0.0200 0.0166 0.0183</td>
<td>4.234 5.307 4.771</td>
</tr>
<tr>
<td>A5S5</td>
<td>0.2352 0.2577 0.2656</td>
<td>0.0133 0.0183 0.0158</td>
<td>3.357 8.070 5.713</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>

4.4.5.2.5 Compression properties

Table 4.14 shows that linearity of compression (LC) for acrylic and A5S5 fabric is higher than silk and cotton fabric. This may be ascribed to higher resistance offered during shear deformation due to bulky nature of these fabrics.
fabrics. The same trend is also observed for compressional energy (WC). Compressional resilience (RC) is found to be highest in case of silk fabrics.

4.4.5.2.6 Thickness and Weight

From Table 4.14 thickness of A5S5 fabric is found to be maximum among all fabrics. This may be due to highest value of yarn diameter and yarn bulk observed in case of A5S5 yarn. The variation in weight/sq.m may be due to count variation.

4.4.5.2.7 Fabric hand

Primary hand expressions for knitted outerwear fabrics of acrylic, A5S5, silk and cotton are shown in Table 4.15. For comparison purpose, the values are plotted in Fig.4.44.

Table 4.15 Total Hand Value of single jersey knitted outerwear fabrics.

<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>Acrylic</td>
<td>3.21</td>
<td>6.64</td>
<td>6.27</td>
<td>3.66</td>
</tr>
<tr>
<td>A5S5</td>
<td>3.57</td>
<td>6.31</td>
<td>6.04</td>
<td>3.58</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 4.5 shows that Koshi value (bending stiffness) is maximum in case of A5S5 fabric. This may be due to maximum bulk and thickness observed in case of A5S5 fabric. Koshi depends upon bending properties of fabric. It is a stiff feeling promoted by springiness in the fabric. Higher value of Numeri (smoothness) is observed for silk fabric in comparison to other fabrics.
It is revealed from Table 4.15 that acrylic and A5S5 fabrics exhibit higher values of Fukurami as compared to cotton fabric. Higher values of fabric thickness and bulk in case of acrylic and A5S5 (as shown in Table 4.6 in the appendix) may be responsible for higher Fukurami values of these fabrics. Fukurami is a feeling which comes from bulky, rich and well formed feeling. It represents springy property in compression, thickness and warm nature of fabric. It depends upon bending and shear properties as well.

It is evident from Table 4.15 and Fig.4.44 that total hand values (THV) of acrylic and A5S5 fabric is greater than silk and cotton fabrics. Hence acrylic and A5S5 fabrics are more suitable for outerwear purpose.
4.5 CONCLUSION

It is possible to produce silk-acrylic blends on cotton spinning system. After steaming the bulk of the silk-acrylic blended yarns increases but at the same time tenacity reduces and elongation at break increases. Results of yarn diameter, package density and fabric thickness have revealed that silk-acrylic 50/50 blend has maximum bulk. Moisture transport properties of acrylic rich blends are also good. Total hand value of silk-acrylic 50/50 blend is also greater than cotton and silk knits of equivalent construction.