CHAPTER 5

LOW STRESS MECHANICAL PROPERTIES OF A SERIES OF LABORATORY WOVEN CREPE-DE-CHINE SAMPLES BY CYCLIC HYSTERESIS BENDING TESTER

5.1 INTRODUCTION

Silk fabrics have unique characteristics viz., softness, lustrous appearance, handle and draping quality. A study of the processing of raw silk yarns show that the silk yarns have to be necessarily twisted to get the desirable surface texture in the woven fabric. Silk fabrics are woven with different denier yarns, construction particulars, and finishing treatments. As such no standard procedure is set by the silk manufacturers. Keeping this in view since twist in yarn plays a dominant role in processing of the yarn, and controls the various mechanical properties of the silk fabrics, a study of the effect of twist in the weft yarn on the geometrical and physical properties of the yarn and in turn on the fabric quality has been carried out.

This chapter deals with an experimental investigation of the low stress mechanical properties of the Crepe-de-chine Group 1 and Group 2 fabrics. These fabrics were woven with various levels of twist in the yarn ranging from 240 tpcm to 340 tpcm. A detailed investigation of the bending parameters obtained by the cyclic hysteresis bending has been done. This study also covers a comparative assessment of the experimental and theoretical models suggested by Livesey and Owen (1964) and Abbott et al., (1971).
5.2 MATERIALS

Details of materials employed are given in Chapter 4. Laboratory woven Crepe-de-chine Group 1 and Group 2 fabrics were selected for performing all the tests.

5.3 METHODS

An experimental investigation of the low stress-mechanical properties of the laboratory woven Crepe-de-chine samples has been carried out by the use of cyclic hysteresis bending tester, an apparatus described by Livesey and Owen (1964). The constructional particulars and method of testing have been described in the chapter 4 (Table 4.1).

5.4 RESULTS AND DISCUSSION

The results obtained for the two types of Crepe-de-chine fabrics are tabulated and discussed. Here, the effect of change in the amount of twist in the weft yarn on the mechanical properties was examined for both for light, and medium weight Group 1 and Group 2 fabrics.

5.4.1 Yarn characteristics

Table 5.1 shows the yarn characteristics namely tenacity, and elongation of the twisted raw silk yarns varying in the amount of twist from zero turns to 340 turns per cm (tpcm) for two ply 20/22 denier and two ply 26/28 denier yarns respectively. It is clearly shown in Figure 5.1 that with increase in the amount of twist, there is an increase in the tenacity of the yarn upto the twist level of 40 to 60 tpcm and thereafter there is a significant fall. The loss in tenacity is almost 50% in the raw silk yarn due to the process of twisting alone to produce the desired surface texture on the Crepe-de-chine fabrics. Thus, bending elasticity of the yarn which is directly correlated to the tensile modulus of the fibre is adversely affected by the twisting of the silk filament fibroin (Fig.5.2).
### TABLE 5.1 EFFECT OF TWIST ON THE RAW SILK YARN

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Raw silk yarn Characteristic</th>
<th>Turns per cm (tpcm)</th>
<th>Raw Zero</th>
<th>60</th>
<th>250</th>
<th>270</th>
<th>290</th>
<th>310</th>
<th>330</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 : 2 ply 20/22 denier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tenacity (g/denier)</td>
<td></td>
<td></td>
<td>3.16</td>
<td>4.70</td>
<td>4.50</td>
<td>4.36</td>
<td>3.20</td>
<td>3.10</td>
<td>2.90</td>
</tr>
<tr>
<td>2. Elongation (%)</td>
<td></td>
<td></td>
<td>20.00</td>
<td>16.20</td>
<td>22.30</td>
<td>22.50</td>
<td>22.80</td>
<td>23.50</td>
<td>24.50</td>
</tr>
<tr>
<td>Group 2 : 2 ply 20/22 denier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tenacity (g/denier)</td>
<td></td>
<td></td>
<td>3.00</td>
<td>3.15</td>
<td>2.50</td>
<td>2.40</td>
<td>2.26</td>
<td>2.10</td>
<td>1.90</td>
</tr>
<tr>
<td>2. Elongation (%)</td>
<td></td>
<td></td>
<td>27.00</td>
<td>27.00</td>
<td>27.50</td>
<td>28.30</td>
<td>28.70</td>
<td>29.30</td>
<td>29.80</td>
</tr>
</tbody>
</table>

### TABLE 5.2 EFFECT OF TWIST ON DEGREE OF SET \( \Phi \), AND \( n_1 \times N_1 \), AND \( n_2 \times N_2 \)

<table>
<thead>
<tr>
<th>Fabric Sample</th>
<th>Crimp (%) by Instron</th>
<th>Crimp (%) IS3442-1966</th>
<th>Degree of set ( \Phi )</th>
<th>( n_1 \times N_1 )</th>
<th>( n_2 \times N_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warp</td>
<td>Weft</td>
<td>Warp</td>
<td>Weft</td>
<td>Warp</td>
</tr>
<tr>
<td>I Group 1 : Light weight Crepe-de-chine samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample A, 1</td>
<td>13.68</td>
<td>7.70</td>
<td>13.13</td>
<td>6.74</td>
<td>0.98</td>
</tr>
<tr>
<td>Sample B, 1</td>
<td>15.60</td>
<td>9.20</td>
<td>14.08</td>
<td>6.80</td>
<td>0.95</td>
</tr>
<tr>
<td>Sample C, 1</td>
<td>15.63</td>
<td>14.32</td>
<td>12.94</td>
<td>11.86</td>
<td>0.91</td>
</tr>
<tr>
<td>Sample D, 1</td>
<td>15.72</td>
<td>21.80</td>
<td>13.31</td>
<td>18.05</td>
<td>0.92</td>
</tr>
<tr>
<td>Sample E, 1</td>
<td>16.40</td>
<td>22.64</td>
<td>13.58</td>
<td>18.75</td>
<td>0.91</td>
</tr>
<tr>
<td>II Group 2 : Medium weight Crepe-de-chine samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample A, 2</td>
<td>12.80</td>
<td>7.70</td>
<td>11.55</td>
<td>6.52</td>
<td>0.95</td>
</tr>
<tr>
<td>Sample B, 2</td>
<td>13.30</td>
<td>8.90</td>
<td>11.01</td>
<td>7.21</td>
<td>0.91</td>
</tr>
<tr>
<td>Sample C, 2</td>
<td>14.80</td>
<td>11.10</td>
<td>10.07</td>
<td>8.99</td>
<td>0.94</td>
</tr>
<tr>
<td>Sample D, 2</td>
<td>14.80</td>
<td>11.20</td>
<td>12.53</td>
<td>8.48</td>
<td>0.92</td>
</tr>
<tr>
<td>Sample E, 2</td>
<td>14.80</td>
<td>11.30</td>
<td>12.25</td>
<td>8.55</td>
<td>0.91</td>
</tr>
</tbody>
</table>
5.4.2 Effect of twist on the degree of set (Φ)

Degree of set (Φ) is a measure of the dimensional stability of the fabric, and it is related to the inter and intra yarn frictional and geometrical restraints in the fabric. It is measured by the ratio of root of C/C. Where C_r and C refer to the crimp of the yarn outside and within fabrics respectively. Correlation between the twist and degree of set is negative and significant for both Group 1 and Group 2 fabrics. Hence, higher the twist in the yarn, poorer is the dimensional stability. Thus, optimum twist has to be fixed considering these fundamental properties of the fabrics (Table 5.2).

5.4.3 Effect of twist on the product n_xN_1 and n_xN_2

This is the product of warp sett and linear density of warp and; weft sett and linear density of the weft yarn. The correlation between twist and this product is positive and significant for both Groups 1 and 2 fabrics. Correlation coefficient obtained is 0.95. This is a measure of the geometrical restraints on the fabrics which show that higher the value, higher is the inter and intra yarn pressure which indicates that fabric is less stable. This is negatively correlated to the degree of sett which is clearly shown in the Table 5.2. Lower the geometrical restraints, higher is the degree of sett.

5.4.4 Geometrical properties of the Crepe-de-chine samples

Details of the constructional particulars the laboratory made Crepe-de-chine properties like fabric sett, weight per square metre; and thickness of the fabric are shown in Table 4.1.

Crepe-de-chine fabrics are light weight and medium weight fabrics which are characterised by uniformly distributed grains throughout the body of the fabric, forming a crinkled surface. This effect is popularly called as crepe effect. The "crinkles" or "grains" are produced by the contraction of the
EFFECT OF TWIST ON TENACITY OF THE WEFT YARN

![Graph 5.1](image1.png)

**Fig. 5.1**

EFFECT OF TWIST ON ELONGATION OF THE WEFT YARN

![Graph 5.2](image2.png)

**Fig. 5.2**
contraction of the highly twisted weft yarn when the fabric is subjected to
the degumming process. The untwisted or soft twisted warp yarns which are
tightly held are kicked up by the contraction of the weft yarns producing a
uniform pattern of surface irregularities. The most important aspect of
Crepe-de-chine is undoubtedly the twist contained in the weft yarn. It has
been observed during the extensive survey that various manufacturers of
Crepe-de-chine fabrics used different levels of twist in the weft yarn ranging
from 200 tpcm to 360 tpcm. The optimum twist level to be used to get the
desirable characteristics on the fabrics has not been standardised. Further,
the practical implication of imparting various levels of twist to various
qualities of yarns, and use of these yarns in Crepe-de-chine fabrics has not
been studied and analysed.

Although a considerable amount of similar studies has been
reported in the case of nylon and polyester filament yarns, it is felt that
such studies are warranted for silk yarns, and their fabrics to improve their
quality of Crepe-de-chine. There is a need to standardise the optimum level
of twist in the weft yarn in respect of Crepe-de-chine fabrics, so that this
could be woven without much problems. These highly twisted yarns, during
the preparatory processes and weaving need proper handling and care.

In this study, fabric quality evaluation has been undertaken to
study the effect of the amount of twist in the weft yarn on the geometrical
properties of the Crepe-de-chine samples. This study covers the bending
behaviour of the finished Crepe-de-chine samples, and thereby help to
establish a relationship between geometrical properties and low stress
mechanical properties.

5.4.4.1 Effect of the amount of twist in the weft yarn on the
geometrical properties of the Group 1 and Group 2 fabrics

Table 5.3 gives the geometrical properties of the Crepe-de-chine
Group 1 and Group 2 fabrics. Following observations could be made.
TABLE 5.3 EFFECT OF TWIST ON THE GEOMETRICAL PROPERTIES OF THE FINISHED CROPE-DE-CHINE FABRICS

<table>
<thead>
<tr>
<th>Twist in weft tpcm</th>
<th>Yarn linear density dix</th>
<th>Threads per cm</th>
<th>Yarn crimp (%)</th>
<th>Modular length x 10^8 cm</th>
<th>Weave angle ϑ x 10^6 %</th>
<th>Yarn diameter x 10^8 cm</th>
<th>Fabric weight (g/m²)</th>
<th>Fabric thickness cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warp (N₁)</td>
<td>Weft (N₂)</td>
<td>Warp (n₁)</td>
<td>Weft (n₂)</td>
<td>Warp (c₁)</td>
<td>Weft (c₂)</td>
<td>Warp (l₁)</td>
<td>Weft (l₂)</td>
</tr>
<tr>
<td>I Group 1: Light weight crepe-de-chine fabrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 260 (A₁)</td>
<td>20</td>
<td>44</td>
<td>106.00</td>
<td>45</td>
<td>13.68</td>
<td>7.70</td>
<td>25.26</td>
<td>10.16</td>
</tr>
<tr>
<td>2. 280 (B₁)</td>
<td>20</td>
<td>46</td>
<td>112.00</td>
<td>45</td>
<td>15.60</td>
<td>9.20</td>
<td>25.70</td>
<td>9.75</td>
</tr>
<tr>
<td>3. 300 (C₁)</td>
<td>20</td>
<td>52</td>
<td>113.40</td>
<td>45</td>
<td>15.63</td>
<td>14.32</td>
<td>25.70</td>
<td>10.10</td>
</tr>
<tr>
<td>4. 320 (D₁)</td>
<td>20</td>
<td>56</td>
<td>115.40</td>
<td>45</td>
<td>15.72</td>
<td>21.80</td>
<td>25.72</td>
<td>10.55</td>
</tr>
<tr>
<td>5. 340 (E₁)</td>
<td>20</td>
<td>57</td>
<td>117.00</td>
<td>45</td>
<td>16.40</td>
<td>22.64</td>
<td>25.89</td>
<td>10.52</td>
</tr>
<tr>
<td>II Group 2: Medium weight crepe-de-chine fabrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 240 (A₂)</td>
<td>27</td>
<td>58</td>
<td>132.30</td>
<td>42</td>
<td>12.80</td>
<td>7.70</td>
<td>26.85</td>
<td>8.14</td>
</tr>
<tr>
<td>2. 260 (B₂)</td>
<td>27</td>
<td>65</td>
<td>134.30</td>
<td>42</td>
<td>13.30</td>
<td>8.90</td>
<td>26.97</td>
<td>8.11</td>
</tr>
<tr>
<td>3. 280 (C₂)</td>
<td>27</td>
<td>71</td>
<td>142.00</td>
<td>42</td>
<td>14.80</td>
<td>11.10</td>
<td>27.33</td>
<td>7.82</td>
</tr>
<tr>
<td>4. 300 (D₂)</td>
<td>27</td>
<td>82</td>
<td>148.00</td>
<td>42</td>
<td>14.80</td>
<td>11.20</td>
<td>27.33</td>
<td>7.51</td>
</tr>
<tr>
<td>5. 320 (E₂)</td>
<td>27</td>
<td>85</td>
<td>150.40</td>
<td>42</td>
<td>14.80</td>
<td>11.30</td>
<td>27.33</td>
<td>7.60</td>
</tr>
</tbody>
</table>
5.4.4.1.1 Effect of twist on the linear density of the weft yarn

An increase in the amount of twist has increased the linear density of the weft yarn. The correlation between twist and linear density of the weft yarn is positive and significant. The correlation coefficients are +0.95, +0.84 for Group 1 and Group 2 fabrics respectively. Fig.5.3 shows the relationship between the amount of twist and linear density of the weft yarn.

5.4.4.1.2 Effect of the amount of twist in the weft yarn on the fabric sett

Twist has no effect on the weft sett in the fabric. However, correlation between the twist and warp sett is positive and significant. Correlation coefficients are +0.96 and +0.9 for the Groups 1 and 2 fabrics respectively. This could be attributed to the widthwise contraction of the weft yarn during wet relaxation treatment during degumming, which removes the sericin present on the yarn leading to an increase in the warp sett. Also crimp interchanges which takes place, influences the warp sett. During degumming, since warp fibroins are separated out, they become flat and take up the residual torque in the weft yarn which has resulted in the haphazard distortion of the surface texture. Since warp fibroins are untwisted, lustre of the silk yarn is retained in these Crepe-de-chine fabrics. Thus the crepe effect and density of the packing of threads is a direct function of the degree of twist imparted to the weft yarn. It is appropriate to mention here that increased warp sett has contributed to the increase in the weight per unit area of the fabric (Table 4.1). In this experiment, eventhough degumming loss is approximately 30% the difference in weight per unit area of the fabric is very less, which has been compensated for the increase in warp sett (Table 5.3).
EFFECT OF TWIST ON LINEAR DENSITY OF THE WEFT YARN

Linear Density (dtex)

Turns per cm

Group 1 Fabrics |
Group 2 Fabrics

Fig. 5.3
5.4.4.1.3 Effect of twist in the weft yarn on the crimp

Table 5.3 shows that an increase in the amount of twist in the weft yarn has increased the crimp in both warp as well as in the weft directions. The effect is more pronounced in Group 1 fabrics, since finer denier yarns are used with wider sett in the fabric. Thus, there is more scope for yarn to contract in this group of fabric.

Correlation between twist and crimp is positive and significant for both warp as well as weft crimps. Correlation coefficients are 0.84 and 0.92 for warp and weft crimps respectively. The weave angle $\Theta$ which is related to the crimp shows a positive significant correlation with twist in the yarn. Here, widthwise contraction of the weft yarn during degumming has led to a significant increase in weft crimp. The extent of crimping is dependent on the warp sett. It is appropriate to mention that in the case of Group 1 fabrics, scope for the weft yarn to crimp is greater. The warp sett is wider and finer denier yarns are used (106 ends/cm to 117 ends/cm) in contrast to Group 2 fabrics where the warp sett ranges from 132 ends per cm to 150 ends per cm with coarser denier yarns and closer sett. Thus, in the case of Group 2 fabrics, there is a less scope for contraction to take place. This has been clearly shown by the Figures 5.4 and 5.5.

In case of Group 1 fabrics, crimp balance between warp and weft could be obtained at 300 tpcm, which is not at all possible in Group 2 fabrics. Thus there is a better scope for the uniform crinkles to be produced on the surface of the Group 1 fabrics, compared to Group 2 fabrics, hence better crinkled crepe effect is obtained in Group 1 fabrics.

5.4.4.1.4 Effect of twist on the diameter of weft yarn

The diameter of the weft yarn has increased with an increase of twist obviously due to contraction during twisting. The correlation between
EFFECT OF TWIST ON CRIMP
GROUP 1 Fabrics

Fig. 5.4

EFFECT OF TWIST ON CRIMP
GROUP 2 Fabrics

Fig. 5.5
twist and diameter is positive and significant ($r=0.88$); this is the reason for an increase of weight per unit area of the fabric (Table 5.3).

5.4.4.1.5 Effect of twist in the weft yarn on the modular length

Values of the modular length of warp and weft yarns are dependent on the fabric sett and crimp in the yarns. Since there is positive correlation between twist, fabric sett and crimp, modular length are also correlated very well with the twist.

5.4.4.1.6 Effect of twist on the thickness of the fabric

An increase in twist has increased the thickness of the fabric; this is obviously due to the increase in the linear density of weft, crimp of the yarns, and warp sett. Weight per unit area also shows an increase. The correlation between twist and thickness is positive and significant in case of the Group 1 fabrics whereas in the case of Group 2 fabrics, it is not significant because coarser denier yarns have been used. Here, there is less scope for yarn to contract on degumming (Fig.5.7).

5.4.4.1.7 Effect of the twist in the weft yarn on the weight per unit area of the fabric

An increase in twist has increased the weight per unit area of the fabric; this is attributed to the increase in warp sett which is due to width wise contraction of weft yarn during degumming, leading to warp consolidation, which has led to an increase in weft crimp significantly. The draping quality of the fabrics, which is a function of the flexural rigidity and weight per unit area of the fabrics, is thus correlated to the amount of twist in the weft yarn. However, optimum twist in the yarn should be selected in such a way that it does not reduce the elastic recovery property of the fabric drastically. The correlation between the twist and weight per unit area is positive and significant. The correlation coefficients are $+0.94$ and $+0.87$ for Group 1 and Group 2 fabrics respectively (Figure 5.6).
EFFECT OF TWIST ON FABRIC WEIGHT

Weight (g/m²)

Fig. 5.6

EFFECT OF TWIST ON FABRIC THICKNESS

Thickness (cm)

Fig. 5.7
5.4.5 **Effect of the amount of twist in the weft yarn on the bending parameters obtained by the cyclic hysteresis bending tester**

The low stress mechanical properties of the Groups 1 and 2 fabrics with various levels of twist in the weft yarn, whose constructional details are given in Table 4.1, were tested on the cyclic hysteresis bending tester. Tables 5.4 and 5.5 give the bending properties namely, 1) calculated bending rigidity (Livesey and Owen 1964), 2) Actual bending rigidity of the yarns, 3) Coercive couple \((C_0)\), 4) Low curvature elastic flexural rigidity \((G_0)\), 5) The ratio \(C_0/G_0\) and Bending recovery \((RB\%)\). An Analysis of variance test was conducted to test the significance of the effect of the twist in the weft yarn on the bending parameters like, coercive Couple \((C_0)\), low curvature elastic flexural rigidity \((G_0)\), initial flexural rigidity \((G_i)\), and final flexural rigidity \((G_p)\).

5.4.5.1 **Effect of the amount of twist on the bending rigidity of the weft yarn**

An increase in the amount of twist in the yarn has led to a decrease in the bending rigidity, which is attributed to the freedom of movement of fibres. The correlation between twist and bending rigidity is negative and significant. Similar trend is followed in both Group 1 and Group 2 fabrics. The correlation coefficients are -0.85 and -0.90 for Group 1 and Group 2 fabrics respectively. This is in substantial agreement with the findings of Dhingra *et al.*, (1981). There is a good correlation between the experimental and calculated bending rigidity. The measured values are on the lower side which could be attributed the loss of elasticity of the weft yarn during degumming.
<table>
<thead>
<tr>
<th>Fabric sample</th>
<th>Twist in weft tpcm</th>
<th>Measured bending rigidity (mNmm²)</th>
<th>Calculated bending rigidity (mNmm²)</th>
<th>Coercive couple (C) x 10⁶ mNmm/mm</th>
<th>Low curvature elastic flexural rigidity G₀ (mNmm²/mm)</th>
<th>Initial flexural rigidity G₁ (mNmm²/mm)</th>
<th>C/G₁</th>
<th>Bending Recovery RB%</th>
<th>Specific flexural rigidity mNmm²/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warp b₁</td>
<td>Weft b₁</td>
<td>Warp b₁</td>
<td>Weft b₁</td>
<td>Warp (C₀)</td>
<td>Weft (C₀)</td>
<td>Warp (G₁)</td>
<td>Weft (G₁)</td>
<td>(1)</td>
</tr>
<tr>
<td>1 Group 1: Light weight crepe-de-chine fabrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 260 (A₁)</td>
<td>0.04</td>
<td>0.140</td>
<td>0.10</td>
<td>0.28</td>
<td>22.20</td>
<td>21.00</td>
<td>0.70</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>2. 280 (B₁)</td>
<td>0.04</td>
<td>0.140</td>
<td>0.10</td>
<td>0.27</td>
<td>23.60</td>
<td>17.50</td>
<td>0.72</td>
<td>0.77</td>
<td>1.30</td>
</tr>
<tr>
<td>3. 300 (C₁)</td>
<td>0.04</td>
<td>0.140</td>
<td>0.10</td>
<td>0.25</td>
<td>25.60</td>
<td>16.50</td>
<td>0.80</td>
<td>0.60</td>
<td>1.36</td>
</tr>
<tr>
<td>4. 320 (D₁)</td>
<td>0.04</td>
<td>0.140</td>
<td>0.10</td>
<td>0.26</td>
<td>26.80</td>
<td>14.30</td>
<td>0.90</td>
<td>0.46</td>
<td>1.37</td>
</tr>
<tr>
<td>5. 340 (E₁)</td>
<td>0.04</td>
<td>0.140</td>
<td>0.10</td>
<td>0.27</td>
<td>27.70</td>
<td>10.00</td>
<td>1.00</td>
<td>0.37</td>
<td>1.70</td>
</tr>
<tr>
<td>2 II. Group 2: Medium weight crepe-de-chine fabrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 240 (A₂)</td>
<td>0.045</td>
<td>0.123</td>
<td>0.14</td>
<td>0.31</td>
<td>22.80</td>
<td>21.00</td>
<td>0.80</td>
<td>0.77</td>
<td>1.82</td>
</tr>
<tr>
<td>2. 260 (B₂)</td>
<td>0.045</td>
<td>0.103</td>
<td>0.14</td>
<td>0.27</td>
<td>25.50</td>
<td>18.50</td>
<td>0.94</td>
<td>0.67</td>
<td>2.11</td>
</tr>
<tr>
<td>3. 280 (C₂)</td>
<td>0.045</td>
<td>0.080</td>
<td>0.14</td>
<td>0.27</td>
<td>28.70</td>
<td>15.90</td>
<td>1.07</td>
<td>0.55</td>
<td>2.23</td>
</tr>
<tr>
<td>4. 300 (D₂)</td>
<td>0.045</td>
<td>0.066</td>
<td>0.14</td>
<td>0.27</td>
<td>28.70</td>
<td>14.40</td>
<td>1.08</td>
<td>0.50</td>
<td>2.32</td>
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<td>5. 320 (E₂)</td>
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<td>0.050</td>
<td>0.14</td>
<td>0.26</td>
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<td>13.20</td>
<td>1.14</td>
<td>0.44</td>
<td>2.40</td>
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</tbody>
</table>

TABLE 5.4 EFFECT OF TWIST ON THE BENDING PARAMETERS
(Bending Rigidity b₁, Low curvature elastic flexural rigidity (G₀), Initial flexural rigidity (G₁), coercive couple, Specific flexural rigidity)
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Fabric Sample</th>
<th>Couple per turn x 1000</th>
<th>Final flexural rigidity (G_m) mN/mm²</th>
<th>Expt. (G_m) mN/mm²</th>
<th>(G_{p,m}) mN/mm²</th>
<th>(G_{p,m}) in, mN/mm²</th>
<th>(G_{p,m}) max, mN/mm²</th>
<th>Ext. (G_p) mN/mm²</th>
<th>(G_{p,m})</th>
<th>(G_p/G_{p,m})</th>
<th>(G_m/G_{p,m})</th>
<th>(G_p/G_0)</th>
<th>(G_m/G_{p,m})</th>
<th>(G_p/G_0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Group 1, Light weight crepe-de-chine fabrics</td>
<td>2.60 3.00</td>
<td>3.87 4.14</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Group 2, Medium weight crepe-de-chine fabrics</td>
<td>2.60 3.00</td>
<td>3.87 4.14</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
<td>3.97 4.15</td>
</tr>
</tbody>
</table>

**TABLE 5.5 EFFECT OF TWIST ON THE BENDING PARAMETERS**

(Bending rigidities \(G_p, G_m\), \(G_m\) in, \(G_m\) max, \(C_p\), \(C_m\), \(G_p/G_0\) and \(G_m/G_0\))
5.4.5.2 Effect of the twist in the weft yarn on Coercive couple \((C_o)\)

The Coercive couple \((C_o)\) is a measure of the frictional restraints in bending a unit width of the fabric. An increase in the amount of twist in the weft yarn has led to an increase in the coercive couple \((C_o)\) in the warp direction, whereas it is decreasing the coercive couple \((C_o)\) in the weft direction. This could be attributed to the increase in the geometrical restraints warp way; because, widthwise contraction of the weft yarn during degumming has led to an increase in the warp sett, thereby increasing the coercive couple \((C_o)\). The trend is reversed in the weft direction. Here, an increase in twist has led to a decrease in the elasticity of the yarn, thereby reducing the coercive couple \((C_o)\) in the weft direction (Table 5.4). The effect of twist is significant, and F value are shown in Table 57. The effect of twist in the weft yarn in both directions is significant for both group of fabrics considered this study (Fig.5.8 and 5.9).

5.4.5.3 Effect of the amount of twist in the weft yarn on the Low Curvature Elastic Flexural Rigidity \((G_o)\)

This represents purely the elastic component of the fabric stiffness in the low curvature region. From Table 5.4, it is very clear that \(G_o\) increases in the warp direction, whereas it is decreasing in the weft direction. Similar trends are shown in both Group 1 and Group 2 fabrics. This could be attributed to the increase of warp sett. The effect of twist is not significant. However, its effect on the \(G_o\), in both directions is significant in both Group 1 and Group 2 fabrics considered in the study. F values are shown in Table 5 which shows that, the effect of twist is significant at both 5% and 1% levels of significance (Fig.5.10 and 5.11).
EFFECT OF TWIST ON COERCIVE COUPLE

GROUP 1 Fabrics

Coercive Couple (10 mNmm)

Fig. 5.8

EFFECT OF TWIST ON COERCIVE COUPLE

GROUP 2 Fabrics

Coercive Couple (10 mNmm)

Fig. 5.9
EFFECT OF TWIST ON LOW CURVATURE
ELASTIC FLEXURAL RIGIDITY (Go)
GROUP 1 Fabrics

Fig. 5.10

EFFECT OF TWIST ON LOW CURVATURE
ELASTIC FLEXURAL RIGIDITY (Go)
GROUP 2 Fabrics

Fig. 5.11
5.4.5.4 Effect of the amount of twist in the weft yarn on the ratio \( C/G_0 \)

This ratio is related to the bending recovery of the fabric. Lower the value better is the handle of the fabric, whereas a high value indicates a poor handle, and creased appearance after the gentle crimping. Twist has a significant effect on the ratio of \( C/G_0 \) in both warp as well as in the weft direction. An increase in the amount of twist in the weft yarn has increased the ratio \( C_0/G_0 \) warp way and it has decreased in the weft direction. This could be attributed to the increase in the warp sett and a decrease in the bending rigidity values weft way due to the freedom of fibre motion. This has been clearly shown in Table 5.4. The correlation between the twist and ratio \( C/G_0 \) is negative in the warp direction whereas it shows a positive correlation in the weft direction. The effect is significant. The correlation coefficients are -0.90 and +0.88 for warp way and weft way respectively in Group 1 fabrics. Similar trend is noticed in Group 2 fabrics.

The correlation between twist and ratio \( C/G_0 \) in the warp direction is negative, but it is significant only at 5% level of significance. Whereas it shows a negative significant correlation at both 5% and 1% levels of significance. Correlation coefficients are -0.72 and +0.88 for warp way and weft way respectively in Groups 1 and 2 fabrics.

5.4.5.5 Effect of the amount of twist in the weft yarn on the Bending Recovery (RB %)

While the correlation between the twist in warp way bending recovery is positive, the opposite trend is noticed in the weft way.
5.4.5.6 Effect of the amount of twist in the weft yarn on the Specific Flexural Rigidity

This is a ratio of the flexural rigidity and weight per unit area of the fabric. Correlation between twist and specific flexural rigidity is negative, and significant in both Group 1 and Group 2 fabrics. Correlation coefficients are -0.94 and -0.88 for Group 1 and Group 2 fabric respectively. The fabric handle, which is a function of $C_0$, $G_0$, and weight per unit area of the fabric, is affected by the variation in these properties. These properties determine the ultimate specific flexural rigidity of the fabrics. An increase in twist has led to a decrease in the specific flexural rigidity. This is clearly shown in Fig. 5.12. Since this parameter reflects the handle of the fabric, this could be used in the objective assessment of the fabric.

5.4.5.7 Effect of the amount of twist in the weft yarn on the Initial Flexural Rigidity ($G_i$)

While correlation between twist and $G_i$ is positive in warp way, it shows a negative correlation weft way; the effect of twist is significant in each direction in both Group 1 and Group 2 fabrics considered in the study. F values are shown in Table 5.7. This is obvious due to the increase in warp sett, and decrease in the bending rigidity of the weft yarn.

5.4.5.8 Effect of the amount of twist in the weft yarn on Final Flexural Rigidity ($G_p$)

Twist has a significant effect on the final flexural rigidity ($G_p$) in both warp as well as weft directions in Groups 1 and 2 fabrics; it signifies the geometrical restraints. Since warp sett has increased, $G_p$ has increased warp way whereas it has decreased in weft way due to the fall in bending rigidity of the weft yarn.
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Degrees of freedom</th>
<th>Analysis of Variance Problem</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Twist</td>
<td>Direction</td>
<td>(T)(D)</td>
</tr>
<tr>
<td>Coercive Couple ($C_0$)</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Low curvature elastic flexural rigidity ($G_0$)</td>
<td>1.24</td>
<td>29.84</td>
<td>3.70</td>
</tr>
<tr>
<td>Initial flexural rigidity ($G_i$)</td>
<td>2.96</td>
<td>36.84</td>
<td>3.98</td>
</tr>
<tr>
<td>Final flexural rigidity ($G_f$)</td>
<td>4.60</td>
<td>39.41</td>
<td>3.69</td>
</tr>
<tr>
<td>F table at 5% level of significance</td>
<td>2.53</td>
<td>4.0</td>
<td>2.53</td>
</tr>
<tr>
<td>F table at 1% level of significance</td>
<td>3.65</td>
<td>7.06</td>
<td>3.65</td>
</tr>
<tr>
<td>Error Estimate</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

Remarks:
- Twist has a significant effect on the coercive couple ($C_0$). The difference of $C_0$ in both groups is significant in both warp as well as in weft direction.
- Twist has no significant effect on low curvature elastic flexural rigidity ($G_0$). Its effect on both Group 1 and Group 2 fabrics is significant in both warp as well as in weft direction.
- Twist has significant effect on $G_i$ at only 5% level of significance. Its effect is significant in both warp and weft direction in both Group 1 and Group 2 fabrics.
- Twist has significant effect on $G_f$ both at 5% and 1% levels of significance. Its effect is significant in both directions of warp and weft.

** Indicates significant at both 1% and 5% levels of significance
* Indicates significant at 5% level of significance
5.4.5.9 Effect of the amount of twist in the weft yarn on the ratio $G_i/G_o$

The initial flexural rigidity $G_i$ is greater than $G_o$, as a result of frictional interactions, the ratio is a measure of the non linearity in bending caused by these interactions. An increase in twist has increased $G_i/G_o$ upto 280 tpcm in Group 1 fabrics, where as it has increased upto 260 tpcm in Group 2 fabrics. An increase of twist beyond this level of twist has decreased this ratio indicating that fabric has become stiff and hard (Table 5.5).

5.4.5.10 Effect of the amount of twist in the weft yarn on the ratio $G_p/G_o$

It is often observed that the slope of the hysteresis loop increases as the curvature is increased beyond about 1.5 cm$^{-1}$; this implies an increase in the geometrical restraints. The effect is best shown by the ratio $G_p/G_o$. An increase in the twist has increased the ratio $G_p/G_o$ in both warp as well as weft directions in Group 1 and Group 2 fabrics considered in the study (Table 5.5). This clearly shows that geometrical restraints have increased with increase of twist in the weft due to the increase in the warp sett after degumming.

5.4.5.11 Effect of twist on $G_{min}$ and $G_{max}$

From the yarn bending rigidity $G_{min}$ and $G_{max}$ were calculated by the Owen’s (1964) equations given in chapter 4. (4.15 and 4.16). From the Table 5.5, it is very clear that an increase in twist has increased the $G_{min}$ warp way and shows marked fall in the $G_{min}$ weft way. Similar trend is followed in both Group 1 and 2 fabrics for $G_{max}$ also.
EFFECT OF TWIST ON SPECIFIC FLEXURAL RIGIDITY

Fig. 5.12

EFFECT OF TWIST ON THE FRICTIONAL COUPLE OF THE WEFT YARN

Fig. 5.13
5.4.5.12 Effect of twist on the theoretical $G_{\text{min}}$ and $G_{\text{max}}$

Theoretical $G_{\text{min}}$ and $G_{\text{max}}$ values were obtained by assuming the flexural rigidity of the silk filament (3.9 $\mu$Nm$^2$), and Torsional rigidity of the single silk filament (1.06 $\mu$Nm$^2$), which is given by Owen (1965). There is a large difference in the theoretical and experimental $G_{\text{min}}$ and $G_{\text{max}}$ values; this could be attributed to the assumptions made. Here it is shown clearly that there is a large difference in the flexural rigidity, which the filament under goes during each stage of processing. Hence there is a need to measure torsional rigidity at each stage of fabric production to obtain accurate information about the low stress mechanical properties of the fabric.

5.4.5.13 Effect of the amount of twist on cloth stiffness ratio ($R_s$)

An increase in twist has increased the stiffness warp way and, it has decreased in the weft way. Similar trend is followed in both Group 1 and 2 fabrics. Hence, by measuring $G_0/G_{\text{min}}$, one could easily fix the optimum twist level required in the fabric to obtain desired stiffness, which shows the best handle.

5.4.6 Computation of the coercive couple of the yarns in Crepe-de-chine fabrics by various models

A comparative assessment of the experimental coercive couple and predicted coercive couple of yarns in the plain woven fabrics has been done (Table 5.6). Here, model given by Abbott et al. (1971) was used to compute theoretical couple which is shown as below.

$$m_{\text{ocal}} = \mu Vd \left[ 0.176(L/2l) + \frac{8l^2}{\pi^2 L \sqrt{4\pi^2 d^2 + 4l^2}} \right] + m_{\text{oy}} \quad ...(5.1)$$

where, $\mu = \text{Coefficient of friction between silk fibre}$ is given by Morton Hearle (1975)
TABLE 5.6 COMPUTATION OF THE COERCIVE COUPLE OF THE YARNS IN CREPE-DE-CHINE FABRICS BY VARIOUS MODELS

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Fabric sample</th>
<th>Twist in weft yarn</th>
<th>Diameter 10 mm</th>
<th>Modular length 10⁴ mm</th>
<th>Exptl. yarn flexural rigidity mNmm¹</th>
<th>Exptl. coercive couple per thread x 10¹² mNmm²</th>
<th>Exptl. coercive couple per thread x 10¹³ mNmm³</th>
<th>Ratio of crimps</th>
<th>Clustering ratio</th>
<th>Inter yarn pressure (V) mN</th>
<th>Abbots and Grosberg's model mvol</th>
<th>mmin/mmax</th>
<th>μVd</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Group 1: Light weight crepe-de-chine samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Sample Aₐ</td>
<td>260</td>
<td>5.50</td>
<td>8.10</td>
<td>25.26</td>
<td>10.16</td>
<td>0.04</td>
<td>0.140</td>
<td>3.20</td>
<td>3.10</td>
<td>6.60</td>
<td>20.00</td>
<td>2.09</td>
<td>4.66</td>
</tr>
<tr>
<td>2. Sample Bₐ</td>
<td>280</td>
<td>5.60</td>
<td>8.30</td>
<td>25.70</td>
<td>9.75</td>
<td>0.04</td>
<td>0.110</td>
<td>3.20</td>
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<td>6.40</td>
<td>17.10</td>
<td>2.13</td>
<td>3.88</td>
</tr>
<tr>
<td>3. Sample Cₐ</td>
<td>300</td>
<td>5.70</td>
<td>8.90</td>
<td>25.70</td>
<td>10.10</td>
<td>0.04</td>
<td>0.080</td>
<td>3.20</td>
<td>2.10</td>
<td>7.10</td>
<td>13.30</td>
<td>2.25</td>
<td>3.49</td>
</tr>
<tr>
<td>4. Sample Dₐ</td>
<td>320</td>
<td>5.70</td>
<td>9.30</td>
<td>25.72</td>
<td>10.55</td>
<td>0.04</td>
<td>0.058</td>
<td>3.20</td>
<td>1.90</td>
<td>7.80</td>
<td>10.20</td>
<td>2.31</td>
<td>3.18</td>
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<tr>
<td>5. Sample Eₐ</td>
<td>340</td>
<td>5.70</td>
<td>9.20</td>
<td>25.89</td>
<td>10.52</td>
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<td>0.040</td>
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<td>1.60</td>
<td>8.60</td>
<td>8.20</td>
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<td>2.22</td>
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<td>II. Group 2: Medium weight crepe-de-chine samples</td>
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<td></td>
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<td>1. Sample Aₐ</td>
<td>240</td>
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<td>26.85</td>
<td>8.14</td>
<td>0.045</td>
<td>0.123</td>
<td>3.40</td>
<td>3.60</td>
<td>6.00</td>
<td>18.30</td>
<td>1.72</td>
<td>5.00</td>
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<tr>
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<td>26.97</td>
<td>8.11</td>
<td>0.045</td>
<td>0.103</td>
<td>3.40</td>
<td>2.80</td>
<td>7.00</td>
<td>16.00</td>
<td>1.90</td>
<td>4.40</td>
</tr>
<tr>
<td>3. Sample Cₐ</td>
<td>280</td>
<td>6.60</td>
<td>10.40</td>
<td>27.33</td>
<td>7.82</td>
<td>0.045</td>
<td>0.090</td>
<td>3.40</td>
<td>2.20</td>
<td>7.50</td>
<td>13.10</td>
<td>1.88</td>
<td>3.67</td>
</tr>
<tr>
<td>4. Sample Dₐ</td>
<td>300</td>
<td>6.50</td>
<td>11.20</td>
<td>27.33</td>
<td>7.51</td>
<td>0.045</td>
<td>0.066</td>
<td>3.40</td>
<td>1.90</td>
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<td>12.00</td>
<td>1.94</td>
<td>3.43</td>
</tr>
<tr>
<td>5. Sample Eₐ</td>
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<td>6.50</td>
<td>11.40</td>
<td>27.33</td>
<td>7.60</td>
<td>0.045</td>
<td>0.050</td>
<td>3.40</td>
<td>1.50</td>
<td>7.60</td>
<td>10.50</td>
<td>1.94</td>
<td>3.14</td>
</tr>
</tbody>
</table>
Inter yarn pressure \( V \) mN

diameter of the yarn \( d \) mm

Twist repeat for two-fold yarn \( L \)

two fold yarn twist rate \( l \)

Twist correction factor in the equation 5.1.

\[
\frac{8l^2}{\pi^2 L \sqrt{4\pi^2 d^2 + 4l^2}} \quad \text{(5.2)}
\]

is very negligible. The following equation was used in our study to obtain \( m_{\text{ocal}} \) for twisted 2 fold silk yarns.

\[
m_{\text{ocal}} = \mu V d\{0.176 \frac{(L/2l)}{c}\} \quad \text{(5.3)}
\]

Inter yarn pressure \( V \) was calculated by Grosberg model (1966a)

\[
V = 16 b \sin \Theta / p^2 \quad \text{(5.4)}
\]

Where, \( b \) = bending rigidity of the yarn
\( \Theta \) = weave angle = 106° where \( c \) = crimp of yarn
\( p \) = Thread spacing

Since, the warp is untwisted yarn the following model suggested by Grosberg (1966) was used.

\[
m_{\text{ocal}} = \frac{1}{8} \mu V d \left\{ \frac{C_2}{C_1 + C_2} \right\} + m_{ey} \quad \text{(5.5)}
\]

where \( m_{ey} \) = frictional restraint couple of the yarn \( C_1 \) and \( C_2 \) warp and weft contact lengths

\[
C_1 + C_2 = \text{Pick (or end) spacing times one plus the fractional crimp} \quad \text{(5.6)}
\]
and we have \[ \frac{C_1 + C_2}{C_1} = \text{The ratio of initial bending rigidity to the final bending rigidity}. \] ... (5.7)

From the equations 5.6 and 5.7, value of the \( C_2 \) was computed and used in the equation 5.5, to obtain theoretical \( m_{\text{calc}} \) for warp yarns.

5.5 RESULTS AND DISCUSSION

5.5.1 Effect of twist on the frictional couple \( (m_o) \)

An increase in twist has decreased the frictional couple of the weft yarn. This has been clearly shown by the Fig. 5.13 for both Group 1 and Group 2 fabrics. This could be attributed to the fall in the flexural rigidity of the yarn, hence loss of elasticity of the weft yarn (Table 5.6).

5.5.2 Effect of twist on the inter yarn pressure \( (V) \)

An increase in twist in the weft yarn shows decrease in the inter yarn pressure in the weft yarns. This could be directly assigned to the fall of bending rigidity of the weft yarns. Similar trend is shown in both Group 1 and 2 fabrics (Figures 5.14 and 5.15). The increase in inter yarn pressure in warp way could be assigned to the increase in warp sett due to twist in weft yarn (Table 5.6).

5.5.3 Comparison of the theoretical and experimental frictional couple

Figures 5.16 and 5.17 show the predicted and measured values of the coercive couple by Abbott's model (1971) and Cyclic hysteresis bending tester (Livesey and Owen 1965). There is a good correlation between the values of the frictional couple obtained for both Group 1 and 2 fabrics (Table 5.6).
EFFECT OF TWIST ON THE INTER YARN PRESSURE (V)
GROUP 1 Fabrics

Fig. 5.14

EFFECT OF TWIST ON THE INTER YARN PRESSURE (V)
GROUP 2 Fabrics

Fig. 5.15
COMPARISON OF THEORETICAL AND EXPERIMENTAL FRICTIONAL COUPLE OF THE WEFT YARN (GROUP 1 Fabrics)

-3
mo-Theoretical (10 mNmm)

Fig. 5.16

COMPARISON OF THEORETICAL AND EXPERIMENTAL FRICTIONAL COUPLE OF THE WEFT YARN (GROUP 2 Fabrics)

-3
mo-Theoretical (10 mNmm)

Fig. 5.17
RATIO OF CLUSTERING IN WARP AND WEFT
Vs RATIO OF CRIMP IN WEFT AND WARP
GROUP 1 Fabrics

Clustering Ratio in Warp and Weft

Fig. 5.18

RATIO OF CLUSTERING IN WARP AND WEFT
Vs RATIO OF CRIMP IN WEFT AND WARP
GROUP 2 Fabrics

Clustering Ratio in Warp and Weft

Fig. 5.19
5.5.4 **Effect of twist on the ratio of clustering**

It is found that for set fabrics the bending rigidity of the cloth per unit yarn is greater than the bending rigidity of the yarns. The ratio of these two rigidities is clustering ratio, which is directly correlated to the inter yarn pressure. From the Table 5.6, it is very clear that with an increase in twist in the weft yarn inter yarn pressure has decreased, but the clustering ratio shows increase in both warp as well as in the weft direction in both Group 1 and Group 2 fabrics. This could be attributed to the large increase in the warp and weft crimps in the Crepe-de-chine fabrics.

Fig.5.18 clearly shows an increase in the clustering ratio with increase of crimp ratio $C_1/C_2$ for Group 1 fabrics where as in the case of the Group 2 fabrics clustering ratio increase only upto 280 tpcm in weft beyond this level of twist clustering ratio falls, which indicates that the warp and weft yarns are jammed. An increase in twist beyond this level of twist results in poor quality of the fabric (Fig.5.19).

5.6 **CONCLUSIONS**

An increase in the amount of twist in the yarn has led to a drop in tensile and bending modulus of the yarn. An increase in twist has consolidated the warp sett after the degumming, thereby improving the quality of the fabrics.

There is a good correlation between the frictional couple obtained by model of Abbott et al. (1971) and experimental values obtained by cyclic hysteresis bending tester. The model could be used in predicting the frictional couple of the silk fabrics.

An increase in twist has improved quality of the fabric upto a twist level of 300 tpcm in Group 1 fabrics, where as it has improved upto 280 tpcm in case of Group 2 fabrics. Thus, to obtain best crepe effect and better handle above mentioned twist levels will give a best results.