CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

Amongst the man-made fibres, microfibres are those which can claim to have opened up new and previously unexplored outlets in the apparel sector. They possess novel physiological properties and impart to the textiles produced with them entirely new characteristics such as handle, softness, drape, cover and lusture. In blends with other fibres, new unusual cloths can be produced which are of indisputable top quality in appearance and comfort.

Microfibre properties are influenced in many interesting ways, as denier per filament (denier per filament) is reduced. These changes of properties may affect both processing conditions and potential end uses. A reduction in denier per filament has an immediate impact on fibre flexibility which in turn increases difficulties in processing as there are more chances of nep formation and fibre breakage at each stage where fibres are manipulated and requires a reduction in number of steps in processing. This increase in flexibility due to the reduction of denier per filament is related to the reduction of bending rigidity. The reduced bending rigidity of microfibres might allow fibres to be easily damaged in carding process. The bending rigidity of the fibre considerably decreases as the fibre denier is reduced. There are several advantages of producing fabrics from microdenier fabrics as far as fabric properties are concerned, but due to extra fineness of fibres, critical problems are faced during processing of these fibres.
End products incorporating microfibres must satisfy functional requirements like windproofness, water repellency apart from fashion attributes like drape, soft handle and appearance. Accordingly, microfibre yarns have found applications in sportswear, women and men’s fashion outer layer and household fabrics. The great majority of these end products are made from continuous filament though microfibres are also available as cut staple fibre with lengths between 30 and 40 mm.

Karolia and Paradkar (2005) report from their study that fabrics made out of microdenier fibres are superior in many cases as compared to fabrics produced by conventional fibres. It has been seen from researches that microdenier yarn improves draping properties. Garment physiology and environmental behaviour, comfort and lifestyles have become the components of modern fabric creations. In the first half of the 20th century, active wear was not scientifically designed as few appropriate natural and man-made fibres were available. But the microfibres of today make all of it possible. Microfilaments due to their special textile properties and their distinctive hand, when made in to woven and knitted fabrics, offer the industry a multitude of new possibilities for fashion apparel applications as observed by Vidur (1997). Purane and Panigrahi (2007) report that microdenier yarns have varied simulations of natural fibres such as silk, however, the industry has to gear up to handle these delicate yarns in the downstream processes.

2.2 MICROSCOPIC IMAGES OF MICROFIBRES

Figures 2.1 to 2.3 show the longitudinal view of various types of microfibres. Figures 2.4 and 2.5 show the cross sectional views of modal fibres. Source: Fig 2.1-2.5-www.lenzing.com  Scale: 100x
Figure 2.1 Longitudinal view of 1.3 dtex-modal fibre

Figure 2.2 Longitudinal view of 1.0 dtex-micromodal fibre

Figure 2.3 Longitudinal view of 1.3 dtex-lyocell fibre
2.3 PROPERTIES OF MICROFIBRES

As we go to micro level in terms of fineness (denier), the immediate dimensional change that can be foreseen is a reduction in diameter. Due to the reduction in diameter, the following properties get affected significantly.

- Flexural rigidity
- Tensile strength
- Surface friction
Figures 2.6 and 2.7 shows the strength–elongation curve of 0.8 dtex microdenier and 1.3 dtex normal denier polyester fibre for the difference in strength and elongation properties. Microdenier fibres have higher strength and elongation compared to normal denier fibres.

**Figure 2.6 Stress strain curves of 0.8 dtex micropolyester fibre**

**Figure 2.7 Stress strain curves of 1.3 dtex normal polyester**

From Figure 2.8, it is clearly seen to what extent it gets affected, if the diameter is plotted as a function of decitex, ranging from micro to normal level. The diameter-decitex relationship, assuming circular cross-section is given in equation 2.1. **Source:** Basu (2000).
Diameter $d$ (cm) = \[
\frac{11.8929 \times 10^{-4} \times \text{denier}}{\sqrt{\text{Fibre density}}}
\] (2.1)

**Figure 2.8 Relation between fibre diameter and fibre fineness**

Figure 2.9 explains the relationship between fibre fineness and fibre cross sectional area. The area is linearly dependent on the fibre fineness. Figure 2.10 gives the relation between the fibre fineness and moment of resistance and figure 2.11 gives relation between the fibre fineness and moment of inertia.

**Figure 2.9 Relation between fibre cross-section and fibre fineness**
The moment of resistance takes to square and the moment of inertia to cubic with the fibre fineness. Higher the value in the shown figures the better the effect of values on deformation and tension. This means, for example, higher moments of inertia give lower values of deformation. The low values of fine fibres, therefore, lead to unfavorable high tensions and deformations. All these properties are extremely important since flexural
rigidity relates to easiness with which deformation may lead to nep generation or incidence of lapping. Tensile strength resists damage that may accrue to the fibre during processing and surface friction influences cohesion. The fibre bending properties will be governed by the shape and size of fibre. The bending resistance is proportional to the $D^4$ (diameter to the power 4) and the effect of this can be seen from a given volume of polymer. For this volume of polymer, one can make any number of fibres.

The surface area of these fibres is related to the square root of the number of fibres. This means that if the number of fibres is increased from one to four, the surface area doubles; and if the number of fibres is multiplied by 100, the surface area increases by 10 times. As reported by Behery (2005), the fibre resistance to bending is proportional to the fibre radius to the fourth power. Therefore, if the radius is decreased by a factor of 2, the bending resistance decreases by a factor of 16. The developments of microfibres have enabled the development of fabrics with desired flexibility and are soft. Hence, a small reduction in diameter through changing denier will cause a fine fibre to get deformed easily, leading to nep formation. If the tenacity value remains same, the absolute tensile strength will be lower for microdenier fibre and the actual tenacities are sometimes lower than normal (probably due to manufacturing difficulties) fibres. This compounds the problems of processing microfibres. Table 2.1 gives important physical properties of polyester and acrylic microdenier fibres. **Source:** Basu A (2000)

**Table 2.1 Physical properties of polyester and acrylic microdenier fibres**

<table>
<thead>
<tr>
<th>Type of fibre</th>
<th>Polyester</th>
<th>Acrylic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denier</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>38</td>
<td>32</td>
</tr>
<tr>
<td>Tenacity(g/d)</td>
<td>6.32</td>
<td>5.53</td>
</tr>
<tr>
<td>Elongation %</td>
<td>19.5</td>
<td>24.9</td>
</tr>
</tbody>
</table>
From the above Table 2.1, it is observed that the actual tenacities of microfibres are lower than normal denier fibres. Also, it has to be taken into account that increasing fineness of fibre count is associated with

- Greater efforts in opening the fibre stock
- Lower carding performance
- Higher sensitivity to unfavorable spinning conditions

The mechanical stresses and in the deformation of fibres in the manufacturing process as observed by Leifield (1992) are shown in Figure 2.12. They are the diameter D, the length of fibre L, its tensile strength and modulus of elasticity E as well as the magnitude of applied force K. The modulus of elasticity E and the tensile strength of the basic raw materials are allowable in comparison between coarse or fine fibres from the same raw material.

![Figure 2.12 Mechanical stresses and the deformation of fibres](image)

**Source:** Leifield (1992)
The length and the effective force are placed as equals. Accordingly the diameter of the fibre is then the greatest determining factor. During the processing, the fibres are pressed, compressed, rubbed, drawn and bent. Pressing, compressing and rubbing are not accessible for numerical estimation. There are higher loadings which create stresses in the fibres and this can be numerically estimated, if one simply understands a circular fibre cross section at hand. One can go from the point that in the manufacturing process, the tensile and bending strength make decisive stresses in the fibres. This leads to the formation of tensile and bending stresses and results in tensile and bending deformations. As far as pulling and bending, the tension and deformations are dealt with, so long as they are influenced by diameter of the fibre. With the tension, it is described how a force influences the cross section. Therefore in case of equal pulling forces, the smaller cross sections are subject to higher stresses than the higher cross sections. The deformation in case of pulling force is the elongation. With the bending deformations, one gets the information of the form of the fibre in the length wise direction. For the given example, one can derive the formula, for the pull given by

\[
\text{Pulling Tension} = \sigma_t = K/F
\]  \hspace{1cm} (2.2)

\[
\text{Pulling Deformation (Elongation)} = \Delta \ell / \ell = K/EF
\]  \hspace{1cm} (2.3)

\[
\text{Area } F = \frac{1}{4} \pi D^2
\]  \hspace{1cm} (2.4)

The pulling tension and the pulling deformation are dependent on the fibre cross section F, therefore, of the square of the fibre diameter. As per this, pulling tension and pulling deformation are inversely proportional to \(D^2\).

The formula for bending is given by

\[
\text{Bending stress } \sigma_s = M/W
\]  \hspace{1cm} (2.5)
Bending deformation $f_{\text{max}} = \frac{L^3 K}{48EJ}$ \hspace{1cm} (2.6)

Moment of Resistance $W = \frac{D^3}{10}$ \hspace{1cm} (2.7)

Moment of Inertia $J = \frac{D^4}{20}$ \hspace{1cm} (2.8)

In the case of bending for the stresses due to the force, the bending stresses, and the moment of resistance $W$ are responsible. For the bending deformation, the moment of inertia $J$ is to be determined.

Leifeld (1992) has reported in a study that of the two fibres having 0.5 and 1.7 decitex, the former reacted in a significantly different manner than the latter in connection with the stresses and deformations.

Table 2.2 shows the different stresses possible while treatment is given in the header row, the last row elucidates the possible results from such stresses. The factor shows the ratio of the sensitivity of the 1.7 dtex fibre to the 0.5 dtex fibre. In the middle line the factor taken from the graph between the values for 1.7 decitex to 0.5 decitex are given. From the result, one can see that 0.5 decitex fibre with reference to the fibre damage due to tensile stresses and deformation reacts three times more sensitively. As lesser values of bending deformation leads to nep formation, the fine fibre reacts 10 times more sensitively with reference to nep formation than 1.7 decitex fibres.

Table 2.2 Source: Leifeld F (1992)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pulling Stress</th>
<th>Pulling deformation</th>
<th>Bending Stress</th>
<th>Bending deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Effect</td>
<td>Fibre damage</td>
<td>Fibre damage</td>
<td>Fibre damage</td>
<td>Nepes</td>
</tr>
</tbody>
</table>
2.4 SPINNING OF MICROFIBRES

In recent years, fine denier fibres have been developed by man-made fibre manufacturers for use in apparel and higher quality consumer products. However, when such fine fibres are subjected to a series of machines employed in spinning, they experience various types of stresses and strains of different magnitude. Unfortunately the properties of microfibres that make them attractive for fabrics are also the same properties that lead to difficulties in mechanical processing as observed by Hwang et al (2001).

A study on spinning microfibre yarns on the MJS system by Murata Machinery Limited (1994) reports that carding becomes more difficult in the manufacturing process for fine denier yarn, and drafting becomes more difficult in ring spinning process. Also, as the yarn spins around the traveller, the tension increases leading to more end breaks if spindle speed is increased. The fibres are easily damaged and this needs a reduction in spindle speeds and hence paves way for lower productivity. Therefore, at every stage of processing microfibres, care must be taken to maintain quality of yarns so as to produce value added fabrics.

2.4.1 Blow Room

The large numbers of fibres call for intensive tuft opening. Consequently the blow room line must be equipped with two opening points. There are new series of openers and cleaners like the one shown in Figures 2.13 and 2.14, namely, TUFTOMAT TFV1 which treats the fibres very gently. These openers are placed in the first position where from the clamped feed it is plucked out by a full pin or needle roller.
The follower rollers should be preferably fitted with saw tooth wire. Being sensitive fibres, the microfibres must be treated gently. Short machines, short pipe connections, short air transport and less number of machines rightly selected show the way for the solution to the problem. Since a self controlled stroke is necessary for a good opening, the components which pull out the fibres from the fibre tuft must be so shaped that the load on fibre is minimum. The ideal components may be pins and needles on the pin
roller and needle on the licker-in. There is no other gentler component as the needles which because of their fine points penetrate practically with no resistance in the lap. The round needle obstructs the sharp cutting on the edges and or bending of the fibre. Properly selected and properly processed saw tooth are harmless, especially when they only convey or take over fibres in an opened condition. Figures 2.15 and 2.16 show examples of pin and needle type rollers for opening and cleaning functions.

Figure 2.15  Pin cylinders

Figure 2.16 Needle cylinders
From Figure 2.17, it is seen that a pure microfibre installation is quite short and comprises small number of machines. For opening, a BLENDOMAT BDTO13 specially developed for chemical fibres is provided. Bales are fed, processed and mixed in multimixer (Blender) MM4. The waste feeder AS allows the feeding of soft waste. Through the multiple blenders MM4 the differences are levelled in which individual flocks from different bales on the production belt under the mixer can be brought together. After the multiple mixer, the flock feed formed on the horizontal held under the multiple mixer is led to single roller opener TUFTOMAT TFV1 through the inclined belt. This is the most gentle and economical transfer from one machine to the following machine.

![Diagram](image)

**Figure 2.17 Blow room line for processing pure microfibres**

Figure 2.18 shows the blow room line for processing cotton with microfibres. The microfibres and cotton processed in rotation with BLENDOMAT BDT019. The cotton is fed to the four rollers cleaner CLEANOMAT CVT4 over multiple mixers MM4. The new cleaner CVT4 replaces a complete cleaning line of conventional design with a high cleaning efficiency. The material then reaches the dusting machine DUSTEX DX in the pneumatic weighing feeder PWSE. The microfibres are transported after the BLENDOMAT BDT 019 direct to the weighing bale opener BOVA. After
the mixing, it is sandwiched, processed and opened. The flocks are sent to multiple mixer MM6. As described in first installation, the flock feed lead to single roller opener TFV1 over an inclined belt and over the air distributor LT and flock feed EXACTAFEED FBK the mixture is sent to card EXACTACARD DK760.

Figure 2.18 Blow room Line for processing cotton with microfibres

Source: Fig.2.13 -2.18 Leifeld (1992)

2.4.2 Carding

In carding technology, the parameters that may be used as performance indicators with regard to sliver quality are the mean length after carding, amount of neps, short fibre content resulting from fibre breakage, and the level of irregularity of sliver and the trash and dust content. The degree of fibre individualization and the types and distribution of fibre hooks play a vital role in deciding sliver quality but since they are not easily measured characteristics they are seldom used in monitoring sliver quality. The quality of yarn is determined primarily by the processes prior to spinning, and the card quality parameters are of fundamental importance to the resultant yarn quality as reported by Lawrence (2000).

The bending rigidity of the fibre considerably decreases as the fibre denier is reduced. The fibre properties likely to affect the degree of fibre entanglement in a tuft and therefore nep formation are fineness or aspect ratio,
crimp level and elastic modulus. Propensity for fibres to form neps is related to buckling coefficient (fibre diameter and elastic modulus) and this is evident from the linearity between measured neps/gram in slivers and buckling coefficient as observed by Alon and Alexander (1978). Blending with higher micronaire cottons can reduce nep levels in man made fibres with respect to fineness. Frictional characteristics of fibres have a strong influence on the disentanglement of neps in carding. The production rate employed in carding has a negative effect on nep removal for fine dtex man made and low micronaire cottons and fibre breakage is dependent on the interaction of roller speed and production rate as reported by Lawrence (2000). The settings and surface speeds associated with the flat-cylinder-doffer actions on short staple cards have a significant effect on the nep level as observed by Harrison and Bargeron (1986).

Li et al (1996) showed fibre withdrawal forces needed to separate entangled fibre mass were largely dependent on density of the mass and the contact angle fibres made with wire clothing. The number of fibres per unit mass increases significantly as denier per filament decreases. From the view of this change, a given card should accommodate the increase in the number of fibres. As the number of fibres increase, the openness of feed stock should be improved as the lack of openness of fibres deteriorates the web quality with an increase of nep count and fibre breakage. In order to efficiently handle the increase in the number of fibres in the card, wires with high point density, high speed of card elements and proper settings becomes a necessity. Over the last 30 years, numerous developments have taken place with the cotton card. The production rate has risen by a factor of 5 with the main rotating components running at significantly higher speeds. Triple taker-in rollers and modified feed systems are in use. Additional carding segments are fitted for more effective fibre opening, and improved wire clothing profiles have been developed for a better carding action. Advances in electronics have
provided much improved monitoring and process control as reported by Lawrence et al (2000). Most modern cards (Trutzschler DK 760, Rieter C4 etc) with presently available facilities are capable of handling microdenier fibres. In 1980s, it was possible to produce 30 – 40 kgs/hr. The success can be shared by the fibre and machinery manufacturers. The new and accurate machines, which have the modern metallic clothing, have a remarkable share in this development.

According to Bock (1993), spinners are familiar with the saying, that the card performance is not measured in kg/hr, but in fibres/ hr., and that every fibre must be carded by a minimum number of carding points. The inference from this is that, with a 1.7 decitex fiber, the card throughput needs to be cut down by 50% compared with a 0.85 decitex fiber or at least the number of carding points in the card clothing needs to be significantly increased. The two postulations are based on the experience in the processing of cotton where the removal of neps is an essential task of the card. Conversely with polyester fibres generally being produced, free from nepes, the formation of nepes in carding must be prevented and at the same time any fibre breakage and damage must be avoided by gentle treatment. This is certainly more difficult with very fine fibres the ends of which tend to curl up than with coarse ones.

Hwang et al (2001) report that the number of fibres per unit mass increases significantly as denier per filament decreases. From the view of this change, a given card should accommodate the increase in the number of fibres. As the number of fibres increases, the openness of feed stock should be improved as the lack of openness of fibres deteriorates the web quality with an increase of nep count and fibre breakage. The number of points per fiber (ppf), which reflects the level of fiber opening, is useful in evaluating the effects of spinning parameters on yarn uniformity as observed by Kong LX et
al (1996). In order to efficiently handle the increase in the number of fibres in the card, wires with high point density, high speed of card elements and proper settings become necessary. As denier per filament decreases, the fibre surface area per unit mass increases enormously. This in turn causes fibre to fibre and fibre to wire friction to increase, and it leads to difficulty in the fibre transfer from one element to another during carding. To avoid or reduce this problem, it was suggested that certain critical processing parameters be controlled such as the use of low throughput, wires with high point density and/or high speeds of elements. Hwang et al (2001) determine the cardability of polyester microfibre through optimization of fibre parameters, carding processing variables and their interactions. The cardability is judged by the fibre web quality in terms of nep count and fibre breakage.

Tables 2.3 and 2.4 give experimental data used namely parameters of flat top card and levels of fibres and carding parameters of the experimental design. A polyester fibre of 0.9 denier per filament and a meter wide flat top card was used. An experimental design was structured to reveal the influence of fibre length, processing variables and their interactions on the cardability of microfibres. The levels of these independent parameters represented $2 \times 2 \times 3 \times 4$ full factorial design. Nep counting was done using manual template method. For each experimental run, an average of the nep count was calculated from sum of left, middle and side sections. The average of nep count was expressed in neps/gm. For estimation of fibre breakage and short fibre content, AFIS was used. The investigation of fibre loading distribution in machine and cross card direction an IR based device was used. ANOVA were performed to test the main effects and their first order interactions. Multiple regression analysis was performed to smooth out the data and obtain predicted equations of nep count and fibre breakage in terms of independent parameters and their interactions. Residual analysis was performed to examine the fitness of the regression model of the data.
Table 2.3 Parameters of flat top card. Source: Hwang et al (2001)

<table>
<thead>
<tr>
<th>Elements</th>
<th>Speed (rpm)</th>
<th>Diameter (mm)</th>
<th>Wire point/sq inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed roller</td>
<td>0 - 6</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>Licker in</td>
<td>510, 930</td>
<td>254</td>
<td>40</td>
</tr>
<tr>
<td>Cylinder</td>
<td>190, 338</td>
<td>1270</td>
<td>684</td>
</tr>
<tr>
<td>Doffer</td>
<td>0-20</td>
<td>653</td>
<td>378</td>
</tr>
</tbody>
</table>

Table 2.4  Levels of fibres and carding parameters of the experimental design. Source: Hwang et al (2001)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre length</td>
<td>mm</td>
<td>31.8, 38.1</td>
</tr>
<tr>
<td>Feed roller speed</td>
<td>m/min</td>
<td>0.63, 0.94, 1.26.</td>
</tr>
<tr>
<td>Draft</td>
<td></td>
<td>12.7, 19, 25.3, 31.7</td>
</tr>
<tr>
<td>Cylinder to doffer</td>
<td>mm</td>
<td>0.15, 0.30</td>
</tr>
</tbody>
</table>

2.4.2.1 Effect of fibre length, feed roller speed, draft and settings on nep content for polyester microfibres

Figure 2.19 reveals the influence of fibre length on neps for different setting of cylinder to doffer. Higher the length of fibres, more the chance of nep formation due to lower bending rigidity. Figure 2.20 indicates the influence of feed roller speed on nep generation at different settings. As cylinder to doffer setting gets wider, the nep count increases. Figure 2.21 gives the effect of draft on neps. The nep count becomes less as draft gets higher. This is true at different fibre lengths also.
Figure 2.19 Effect of fibre length and settings on Nep content

Figure 2.20 Effect of feed roller speed and settings on nep content

Figure 2.21 Effect of draft and settings on nep content

Source: Hwang et al (2001)
2.4.2.2 Effect of fibre length, feed roller speed, draft and settings on short fibre content for polyester microfibres

From Figure 2.22, one can understand that longer fibres cause an increase of SFC% (short fibre content) as longer fibres have more point of contact with fibres and wires than short fibres. This causes long fibres to entangle and break. Figure 2.23 gives the effect of feed roller speed on SFC% which indicates a rise in SFC% as feed roller speed increases. The influence of cylinder to doffer setting on SFC% shows that as setting gets wider, SFC% increases. The SFC% shows a declining trend as draft increases and is consistently true for different fibre lengths as observed as shown in Figure 2.24.

![Figure 2.22 Effect of fibre length and settings on SFC%](image1)

![Figure 2.23 Effect of feed roller speed and settings on SFC%](image2)
Nep formation and fibre breakage were influenced by all main independent parameters and their interactions. The increase of draft (increase of doffer speed) led to a reduction of nep and fibre breakage while the increase of throughput led to an increase of nep count and fibre breakage. Increasing doffer speed reduced recycled fibres on cylinder and contributed to less nep and fibre damage after carding. However, the increase of throughput results in reduction of openness of fibres and an increase of nep formation and fibre breakage. The increase of cylinder to doffer settings resulted in more nep formation and fibre breakage due to increase of recycled fibres on the cylinders. Longer fibres had higher fibre breakage and neps than shorter fibres. The shorter fibres possessed higher bending rigidity leading to less fibre breakage and neps.

It was found that there was a strong correlation between fibre breakage and nep formation. The study of nep localization in terms of fibre load uniformity across card showed that less total neps could be produced if the fibre load uniformity in cross machine direction is high.
Schenek and Schwippl (2005) report that card parameters are key elements for boosting performance in the spinning process with minimum fibre loading and good carding quality. In order to keep forces as small as possible cylinder clothing, featuring, 640 teeth/square inch and a 30 degree front angle was used. It became apparent that the transfer of fibre from cylinder to doffer was not ideal and that the fine fibres were accumulating between the teeth of clothing. Increasing the number of teeth to 720 resulted in good running properties. The influence of fibre spinning process was also clearly demonstrated visually with gentle fibre preparation at a carding output of 30kg/hour.

A study on carding of microfibres by Leifeld (1992) reveals that cards with needles on the licker-in can be used for opening microfibres. However, the conventional saw tooth licker-in can also be used for processing microfibres. Further, the shape of saw tooth plays an important role and function. The experience shows that properly dimensioned and properly processed saw tooth can go a long way with the fibre. With the cleaners as well as with the cards the stresses in the fibres can be influenced through the setting. In openers and cards, the machine and settings are selected as used in the case of finest cotton. For fine cotton, cylinders of 865 teeth per sq inch are selected. For processing microfibres, either the above or cylinders with 1080 teeth per sq inch can be used. The wire breast angle 25 degrees may be used for fibres with less number of neps. The flat wire density would be 450-500 PPSI. As far as the card cylinder speed is concerned, it must be assumed that, because of the lower centrifugal force of the microfibres the speed should be somewhat higher in order to prevent the fibres from lodging at the base of the clothing. In this case, the number of carding points on the card cylinder should not be excessive if fibre damage is to be kept within reasonable limits.
The new EXACTACARD DK-760 allows exact and closer settings through use of more modern aluminium extrusion press profiles for working components and coverings around the licker-in and drums. This helps in processing of microfibres and gives safe working conditions in production of, for example 30kg/hour. Also at 50kg/hour it still gives good operating characteristics. Microfibres of varying fineness (in dtex) which included polyester fibres of 0.7, 0.8 and 0.85 dtex and fibre length of 32, 38 and 40 mm were used for various experiments on the carding of microfibres for which the production levels varied from 30 to 40 kg per hour. Assessment of the card sliver quality was done by estimating the neps per gram, fibre damage and the average fibre length before and after carding which are shown in Table 2.5 [Source: Leifeld (1992)] along with the weight CV% and USTER CV% for each selected card production.

**Table 2.5 Carding results of different microfibres. Source: Leifeld (1992)**

<table>
<thead>
<tr>
<th>Type of fibre</th>
<th>Fineness (dtex)</th>
<th>Length (mm)</th>
<th>Card production Kg/hour</th>
<th>Neps/g</th>
<th>Average fibre length (mm) Before-After</th>
<th>Weight CV%</th>
<th>Uster CV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acryl Bayer Darlon</td>
<td>0.6</td>
<td>32</td>
<td>35</td>
<td>4</td>
<td>28-27.9</td>
<td>1.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Polyester Diolen 44</td>
<td>0.8</td>
<td>40</td>
<td>30</td>
<td>1</td>
<td>34-32</td>
<td>1.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Polyester NN</td>
<td>0.7</td>
<td>38</td>
<td>35</td>
<td>3</td>
<td>32-29</td>
<td>1.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Polyester Skyron</td>
<td>0.8</td>
<td>38</td>
<td>40</td>
<td>1</td>
<td>33-31</td>
<td>1.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Polyester Montefibre</td>
<td>0.85</td>
<td>38</td>
<td>35</td>
<td>3</td>
<td>29-28</td>
<td>1.5</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Figure 2.25 Neps Vs Card production.

From Figure 2.25 one can realize that from 24 kg/hour to 44 kg/hour the nep count per gram falls from 7 to 3. On increasing the production to 53 kg/hour, it remains still the working conditions and the other results hardly influenced, but the nep count increases to 10 neps per gram. This can be related to loading on the cylinder and on the previously mentioned narrow space in the intermediate of the metallic clothing. Figures 2.26 and 2.27 show that there is no significant influence of production on reduction of variation in Uster CV values and fibre length.
Figure 2.26 Card production Vs USTER CV%.

Figure 2.27 Card production Vs Average fibre length

Source: Fig 2.5-2.7 Leifield (1992)
The results from the experiments carried out jointly by Bayer, Schlafhorst and Trutzschler, and reported by Leifeld (1992), show that the performance of cards (Exacta card DK760) improved with the increase in production up to a certain level and then deteriorated for 0.6 denier and 32 mm Bayer Acryl fibre Dralon. At a production rate of 24 kg/hr, the nep count of card sliver was 7 per gram, which became 3 per gram at 44 kg/hr production. On increasing the production to 53 kg/hr, the nep count increased to 10 per gram. However, it still remained in good working condition.

Ernst (1993), from his study reveals that carding performance must match to the fibre fineness. Throughput rates on the C4 card ranged from 25 to 30 kg/hr depending on the fibre type and using cylinder clothing with 600 to 700 points per sq inch. With polyester fibres, production can be increased to 40 kg/hr and with acrylic upto50 kg/hr. when using cylinder clothing with 1000 points/sq inch. On account of large number of fibres in the card sliver, it is advisable not to exceed sliver weights of 4.5 kilotex. Coarser card sliver may cause significant drafting difficulties in subsequent draw frame operations.

Bock (1993), in a test on a Rieter C4 card, demonstrated that using card cylinder clothing, with 860 points per sq inch and a breast angle of 25° the number of neps in the card sliver was distinctly lower than with 640 points per square inch and a breast angle of 9°. On the other hand, the fibre breakage increased with higher number of carding points. It was found that best results were achieved with a production rate of 45 kg per hour keeping the number of carding points and the breast angle between the above two set of values studied. Card clothing meeting the specification of 720 points/square inch and with a breast angle of 20 degree was investigated on a Trutzschler DK 715 card. At a production rate between 20 and 50 kg/hr, a decline in the mean fibre length about 1 mm was recorded in the card sliver but the difference no longer occurred in fibres sampled from the rotor of the spinning head. A drop
in the cohesion length of the card sliver was significant caused by the fibre crimp being drawn out at higher rates of through put. Since no significant difference in the yarn property was revealed in results of spinning the card sliver, rates of card through put between 40 and 45kg/hr may be regarded as fully practicable. As far as the card cylinder speed is concerned, it must be assumed that because of the lower centrifugal force of the microfibres, the speed should be somewhat higher in order to prevent the fibres, lodging at the base of the clothing. In this case the number of carding points adopted on the carding cylinder should not be excessive, if fibre damage is to be kept within reasonable limits.

In case of fine thick and thin places, the C60 card system displays the same yarn values as the C51 with an 80% increase in output. At the same card output of 35kg/hr, the imperfection index values on the C60 system are approximately 20% lower. The carding forces are therefore directly related to carding quality especially when using man made microfibres. When processing microfibres where carding output has been limited to a maximum of approximately 35 kg/hr the new C60 carding system enables increased production. Output of up to 63 kg per hour is possible and this considerably increases the attraction of processing microfibres and sets new standards in card output. In the study with microfibres, carding becomes more difficult as the denier of polyester becomes finer, because nep generation during carding increases. An extremely effective means of dealing with this problem is to reduce the fibre length. By making polyester denier finer, and using the MJS system the following benefits are obtained.

- Spinning speed increases by 20%
- Increased yarn strength
- Improved yarn evenness
- Softer fabric hand
2.5 SLIVER COHESION

Sliver cohesion tests were carried out by Scardino and Lyons (1970), who investigated the effect of surface roughness of polyester fibres on their spinning performance. These tests can be conveniently carried out on an Instron tensile tester. Cohesion refers to attraction between fibre assemblies and also can provide information on drafting force, hooks, spin finish and inter-fibre friction. Higher cohesion may imply the nature of fibres their contacts and number fibres. Grosberg (1963) and Grosberg and Smith (1966) have investigated the strength of slivers with and without twist. Geometrically smoother fibres made out of polyester have led to higher cohesion. Such information may be useful to decide the draft which is required. Carding variables such as doffer speed are likely to affect sliver cohesion. Also, finishes which are applied on fibres during processing are likely to affect sliver cohesion.

2.6 FIBRE CONFIGURATION IN CARD SLIVER

Knowledge about fibre configuration is extremely important as it influences the performance of the material in down stream processing. To find the fibre configuration, tracer fibre technique, which is a very tedious process, was employed. Taylor (1954) reports on the use of radioactive rays in the study of fibre configuration. Fibres in card sliver have hooks and their effect on the performance of yarn has been well established by these techniques.

Lindsley (1951) developed a simple technique for studying fibre configuration and many research workers have employed his method for investigating the effect of carding variables on sliver quality and the effect of comber noil on the quality of yarns. ATIRA (Ahmedabad Textile Industry’s Research Association) during the early 60s conducted a great deal of work on fibre configuration of card sliver. Wakankar et al (1961) have pioneered in
research on hooks. Briefly, the technique involves the measurement of combing ratio, cutting ratio and fibre orientation. Recently Ishtiaque et al (2007) have studied the effect of carding and draw frame, variables on hooks using the technique. Simpson (1967) found that cutting ratio was a sensitive indicator of hooks than combing ratio and used this for studying the effect of carding variables on sliver quality and yarn characteristics. Thus Lindsley’s (1951) technique of studying fibre configuration became very popular due to its simplicity and was exploited by researchers.

2.7 DRAW FRAME

For processing microfibres on modern draw frame, it may be necessary to reduce the delivery speed to 400m/min in order to reduce the incidence of roller lapping which is likely to be more because of larger area of contact with the rollers and its low bending rigidity. Higher top roller load may be used (around 20-25%). More frequent grinding or buffing is required. Whenever the draw frames are stopped, the pressure on the top rollers should be in released condition. Prolonged holding of fibres under pressure may cause thermal damage. The draw frames SB 851 and RSB851 can be used. Delivery speeds between 400 and 600 m/min are possible depending on the fibre type.

From the study by Su and Lo (2000) on optimum drafting conditions of fine denier polyester spun yarns for the production of high quality microdenier polyester spun yarn, the ring spinning conditions have to be changed according to the twist factor and count of the roving. When the break draft is too low, the twisted roving cannot be sufficiently drafted in the back roller zone resulting in thick places in the spun yarn. Too great an increase in the break draft and the back roller gauge will frequently cause a drafting wave in the drafted roving and consequently influence the quality of spun yarn. Also it is better to increase the roller pressure 30 to 40% to control
the fibres to yield a normal drafting behaviour. Grishin (1954) developed a theoretical equation for dividing the total draft in the roller drafting system based on the total draft, roller gauge, setting and fibre length and its variation. Martindale (1947) set up an apparatus for measuring the drafting force of cotton slivers, and the technique of drafting force applications has been used to choose a suitable draft ratio. The investigation of the spinning conditions of fine denier polyester fibres in actual spinning to determine their effect on yarn quality such as U%, strength, thick and thin places and nepes has been undertaken by Su and Lo (2000). As the inter fibre cohesive force of microdenier polyester fibre is much greater than regular polyester, resulting in greater drafting force and since a lighter roving weight will decrease force and maintain the normal drafting behaviour a roving of 0.354 g/m, a softer roll hardness of 75 degree for the top front rollers was adopted for the study. Experimental data revealed the pressure of roll was set at 14 kgf which is higher than the normal roller pressure and 8 different draft ratios from 1.1 to 1.8 with 2 roller gauges 56 & 62 mm were used. The roller pressure was brought down to 10kgf to investigate the effect of yarn quality. Polyester fibres had a specification of 0.89 decitex *38 mm roving of 0.354 gm/m, with twist multipliers of 0.5, 0.6 & 0.7

To establish the relationship between yarn properties and spinning conditions on the break draft, a 13.1 tex yarn was spun on a laboratory spinning frame with SKF drafting system and with following parameters as shown in Table 2.6.
Table 2.6 Details of spun yarn. Source: Su and Lo (2000)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Process Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yarn Count (tex)</td>
<td>13.1</td>
</tr>
<tr>
<td>2</td>
<td>Break Draft</td>
<td>1.1 to 1.8</td>
</tr>
<tr>
<td>3</td>
<td>Roller gauge (mm)</td>
<td>44/56 and 44/62</td>
</tr>
<tr>
<td>4</td>
<td>Front top roller pressures (kgf)</td>
<td>14 &amp; 10</td>
</tr>
<tr>
<td>5</td>
<td>Total Draft</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>Traveller</td>
<td>6/0</td>
</tr>
<tr>
<td>7</td>
<td>Twist Multiplier</td>
<td>3.53</td>
</tr>
<tr>
<td>8</td>
<td>Spinning Speed (rpm)</td>
<td>12000</td>
</tr>
</tbody>
</table>

The yarns were tested for U%, IPI index and breaking strength with an Uster tester III and an Uster single tester. The results are tabulated in Table 2.7. Source: Su and Lo (2000). For high quality spun yarn, the ring spinning conditions of the back roller gauge and break draft must be changed to match according to the twist factor of roving. In addition, it is better to increase the roller pressure 30 to 40% when spinning fine denier polyester fibres. Neps do not seem to be influenced by the break draft ratio and back roller gauge and are evidently more likely to be influenced by the spinning preparatory processes. The results on the above investigations reveal that break draft ratios of 1.3 and 56 mm roller gauge in conjunction with a higher roller pressure of 14 kgf are optimum spinning conditions for 0.8 denier polyester fibre roving of 0.6 TM and 0.354g/m linear density.
Table 2.7 Comparison of fine denier polyester yarn qualities

<table>
<thead>
<tr>
<th>Yarn quality</th>
<th>Roller Gauge (mm)</th>
<th>Roller Gauge (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>56</td>
<td>62</td>
</tr>
<tr>
<td>Tex</td>
<td>13.1</td>
<td>13.1</td>
</tr>
<tr>
<td>U%</td>
<td>9.5</td>
<td>9.6</td>
</tr>
<tr>
<td>Thick Place</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thin Place</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Neps</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Breaking Strength (mN/tex)</td>
<td>336</td>
<td>331</td>
</tr>
<tr>
<td>Lea strength (N/tex)</td>
<td>41.15</td>
<td>40.15</td>
</tr>
<tr>
<td>Yarn quality index</td>
<td>1455.4</td>
<td>1384.3</td>
</tr>
</tbody>
</table>

Korkmaz and Behery (2004) studied the interaction between specific fibre fineness values and the drawing machine in their study on drafting dynamics of fine denier yarns.

It is important to understand the role of fibre properties in drafting process. Finer denier fibres may have different drafting behaviour than average denier fibres such as drafting force, required roller settings, draft distribution and velocity change zone. Fineness changes the drafting behaviour by introducing fibre clusters and fibre contact points. The acceleration process depends on the interaction of static and dynamic friction forces at the fibre contact points. Therefore, the fibre movement in the drafting zone is not a continuous process i.e. it consists of local acceleration and slowing down of segment of fibres.

Different methods have been used to observe fibre drafting behaviour. Raes and Taylor (1955) used radio activated wool fibres to determine the proportion of fibres that accelerate to the front roller speed at
any given time. Over a large part of the drafting zone, floating fibres achieve speeds greater than back roller speed for a limited time and they have only two speeds during the transfer through their drafting zones. High speed photography used by Taylor (1954) confirmed that floating fibres achieve speed between those of back and front rollers. McVittie and DeBarr (1961) observed the movement of colored fibres in an apron drafting system with a microscope. It was found that the motion of the floating fibres was determined by frictional contact points with neighbouring fibres and the coefficient of friction between materials varied with speed. In recent years, Laser Doppler Anemometer (LDA) has been used to measure fibre speed on different drafting systems with more accuracy. Polyester fibres were used in the experiment with different deniers 0.8, 1 and 1.2 all with the same length of 38 mm. The fibres were in card sliver form and the sliver weight was 5 kilotex. The experiment was run at the main drafting zone of a two zone drafting systems with three top rollers and three bottom rollers. Table 2.8 shows the experimental design which consisted of three different denier of fibres, three roller settings with 6 draft combinations (3 total draft ratios with two break draft ratios).

**Table 2.8 Experimental design. Source:** Korkmaz and Behery (2004)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fibre fineness (denier)</td>
<td>0.8, 1, 1.2</td>
</tr>
<tr>
<td>2</td>
<td>Roller Settings (mm)</td>
<td>43.7, 45, 47</td>
</tr>
</tbody>
</table>

At the break drafting zone, the roller setting was 46mm and the break drafting ratios were 1.47 and 1.76 with a constant 1.80 m/min incoming speed. The three total draft used in this study were 6.07, 6.8 and 7.73. An Olympus encore 2000 model high speed camera with a motion analyzer was
used to record fibre movement along the drafting zone. The data collected were tested by analysis of variance (ANOVA), and the mean separation was performed by the least significance difference at $P = 0.05$, if the F test was significant at the same level. The results are tabulated in Table 2.9.

The analysis of results from Table 2.9 reveals that the average fibre speed in the main drafting zone depends significantly on fibre fineness which accounted for 22% of total variation in fibre speed. The average fibre speed increased with increasing fibre fineness. The microfibre had a speed of 9.95m/min while 1.2 denier fibres had 7.6m/min as an average. The draft combination had a significant influence on fibre speed accounting for 18% of total variation in average speed. The interaction of setting and draft ratio was a significant factor and accounted for 7% of the total variation. Fibre fineness and draft ratio significantly affected the CV percentage of speed, accounting for 10% and 9% of the total variation respectively.

Table 2.9  
Sources of variation in the analysis of variance (ANOVA) for the effect of fibre fineness, draft ratio, and setting on the speed and CV% at the main drafting zone

<table>
<thead>
<tr>
<th>Source</th>
<th>Speed m/min</th>
<th>CV% of speed</th>
<th>P Value</th>
<th>Contribution %</th>
<th>Contribution %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness(F)</td>
<td>&lt;0.001</td>
<td>22</td>
<td>&lt;0.001</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Draft Ratio(DR)</td>
<td>&lt;0.001</td>
<td>18</td>
<td>&lt;0.001</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>F*DR</td>
<td>&lt;0.001</td>
<td>16</td>
<td>&lt;0.001</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Setting(S)</td>
<td>NS</td>
<td>&lt;1</td>
<td>0.049</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>F*S</td>
<td>NS</td>
<td>&lt;1</td>
<td>NS</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>DR*S</td>
<td>0.004</td>
<td>7</td>
<td>NS</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>F<em>DR</em>S</td>
<td>NS</td>
<td>5</td>
<td>NS</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>_</td>
<td>31</td>
<td>-</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>_</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
The statistical analysis revealed that fineness has a significant effect on average fibre speed and introduces the clustering effect and different numbers of fibre contact points. The number of fibres in the cross section of microfibre cross sliver was 50% more than that of a 1.2denier card sliver. Hence the crowded structure of the microfibre sliver obviously increased the number of contact points. The more direct effect of fibre fineness on the cluster structure is bending rigidity which depends on the shape factor of the fibres and proportional to the fourth power of diameter for round fibres. Microfibres have a lower bending rigidity which allows them to bend or wrap more easily than coarser fibres. Thus the clusters formed by microfibres are more compact than coarser fibre cluster due to higher compression forces created by flexible fibres.

The closer packing of microfibres results in high number of contact points. Each fibre contact point is exposed to a different magnitude of friction force; the forces determine the local fibre acceleration and the drafting force. In the experiment, microfibres have the highest average speed which decreased with increasing fibre denier. The drafting combination had a significant speed on fibre speed. Increasing the drafting ratio from 6.07 to 7.73 resulted in higher fibre speed. The draft combinations with a break drafting ratio of 1.47 had relatively lower average speed but higher variation values compared to 1.76 break drafting ratio. From the statistical analysis, 43.7mm setting had the lowest average speed whereas 47mm showed highest speed. Even though the difference between fibre fineness levels were small, the interaction of fineness with drafting conditions was highly important. It was found that microfibres had the highest speed but the lowest variation compared to other fineness level. This change in denier was enough to change to fibres drafting behaviour. Therefore, machine adjustments should be carefully made especially when working with fine denier fibres to spin high quality yarns.
Korkmaz (2004) made a thorough investigation on the effect of fine denier polyester fibre fineness on dynamic cohesion force and report that one of the most important parameters regarding the processability of synthetic fibre is the level of inter fibre friction which determines the drafting force or cohesive force dependent on such factors as surface condition, crimping and lubricant deposit on the fibre. Staple length and crimp are highly significant factors affecting the cohesion values.

2.8 ROVING FRAME

Due to higher cohesive force between the fibres the twist level used may be a little less as compared to normal denier fibre (i.e. TM 0.85-0.9). Higher top roller pressure should be used. The top rollers need to be buffed more frequently. Flyer with highly polished surface may lead to more fly generation and hence a matt finish would be preferable. Fly top with more number of ribs may be more advantageous.

2.9 RING FRAME

The sliver and drafted fibre web being very thin care has to be taken so that proper drafting takes place. Use of softer cots may be useful as the fibres will be gripped better, thereby reducing slippages. Higher break draft or wider setting (back zone) may be required due to higher cohesiveness of roving. For fibres finer than 0.5denier, very high spindle speed may be avoided as it is likely to damage the fibre. The traveler speed should be restricted to 30 – 35 m/sec along with smaller ring and shorter lift. For 0.8 denier polyester fibre, experience shows that the yarns can be spun at same spindle speed as conventional fibres. In addition, it is possible to reduce twist of the yarn due to presence of higher number of fibres per cross-section.

The results of micro modal yarn spun on a ring spinning system show very good properties as compared to normal viscose fibre yarn. The
CSP and RKM are higher and a lower count CV% as observed by Basu (2005).

2.10 OPEN-END ROTOR SPINNING OF POLYESTER MICROFIBRES

Microfibres are available between 0.6 to 1 decitex. Arithmetically this should allow spinning yarns down to 8 tex \((N_m 125 / N_e 70)\) with 100 to 125 fibres in the cross section. For rotor spinning, microfibres based on polyester, viscose/modal and poly acrylic are used while poly propylene and polyamide are less commonly used. The commercial availability of these fibres and the interest shown in them prompted to investigate their suitability for rotor spinning as well as their processing behaviour at high rotor speeds, spinning limits and the end products made from the yarns. Apart from the above, the objective was to find appropriate finished articles for the extremely fine rotor yarns spun from microfibres. The results obtained in both yarn and end products show that the use of microfibre in either 100% or blended forms opens up opportunity to spin finer yarns which were not able to achieve in rotor spinning with standard fibres. Outstanding yarn quality, soft handle in the finished product and superior aesthetics can thus open up new applications for rotor yarns as reported by Ernst (1993) in the study on open end spinning of microfibres. Systematic experiments with linear densities of 1.1 and 1.6 decitex revealed increasing fibre damage in a relatively large of fibres in the draw frame sliver. This knowledge may be extended to microfibres as quoted by Bock (1993), especially at a relatively higher rotor speed; a noticeable feature of heavy feed sliver is a high fibre length variation index. If the fibres in the rotor groove are inspected, in the heavier slivers an increasing proportion of short fibres are found.

The risk of fibre damage may therefore be mitigated by fine slivers. With the industrial standard draft of up to 200, in to rotor machine, the feed
sliver would have to be very fine. For example with 10tex yarn \((N_m 100/ne 60)\) spun with a draft of 200 a sliver of 2 kilotex is required. By optimizing the sliver speed and pneumatic fibre transport in the Ri-Q-Box spinning unit of the Ru14-A machine, much higher drafts are possible. A standard draft range up to 300 is available with this machine. During trials, drafts up to 400 were used.

Bock (1993) reports that in case of open end rotor spinning, microfibre plays an important role as more number of fibres are required in the cross section because of the inferior material strength utilization. In case of conventional ring spun yarns, 53 fibres are required in the yarn cross section, whereas open end rotor yarn needs 90 fibres. The microdenier polyester fibres fulfill the following aspects:

- To spin very fine open end rotor yarns, i.e. finer than 10 tex in 100% polyester and finer than 12.5 tex in blends with cotton.
- To produce yarns with special characteristics.

In industrial trials, an open end rotor yarn of fineness 7 tex has been successfully spun with 0.85 decitex “trevira” at a rotor speed of 90,000 rpm with relatively few problems. The yarn tenacity attained was higher at 19 cN/tex than those, for e.g., of a polyester/ cotton combed system ring spun yarn. Despite the higher rotor speed of 90,000rpm used for 100% polyester fibres, there was little fibre damage. The evenness of the yarns from the fine fibre was also found to be more uniform. However, there is a sharp rise in the number of neps in yarns spun from such fine fibres (0.8 decitex) which indicates that there are technological constraints in processing such fine fibres.
2.11 SPINNING MICROFIBRE YARNS ON THE MJS SYSTEM

The trials with microfibres on MJS system by Murata machinery limited (1994) explore the advantages of using fine denier fibres over the conventional ring and open end spinning systems to produce air-jet yarns with higher strength and better evenness and to increase spinning speed to the extent of 10-20%. Hairiness decreases as fibre becomes finer. In recent years, fine denier acrylic, rayon and polyester have been developed by man made fibre manufacturers for use in apparel high quality consumer products. However, carding is more difficult in the manufacturing process for fine denier yarn and drafting become more difficult in the ring spinning process. Also if the spindle speed is increased, fibres are easily damaged and owing to this reason, the productivity is lower. As denier becomes finer, in case of Murata jet spinning, the spinning speed increases and more number of fibres are found in the cross section with increased contact area between them. The twist propagation of false twist generated by the spinning nozzle becomes faster. All these factors promote a faster spinning. The spinning tension in MJS system can be controlled less than 30 grams preventing damage to the microfibres even at higher speeds. On the other hand when processing microfibres on ring spinning, yarn spins the traveller and the tension increases with spindle rotation resulting in fibre damage. With open end spinning machines, the draft is performed by combing and this combing can also damage the microfibres. For these reasons MJS system is best suited to spin microfibres. Artzt (1993) reported that for processing 100% polyester through air-jet spinning 1.3 dtex is optimum fineness for good spinning stability.

2.12 YARN QUALITY

Denier value becomes smaller, yarn strength increases but the fibre itself becomes weaker. The yarn evenness generally improves, the number of thin places decreases whereas neps and thick places increases. To improve the
same, the static and dynamic coefficient must be reduced. Hairiness decreases as the denier becomes finer. Considering the important yarn strength, yarn evenness and yarn hairiness becomes clear that the yarn quality improves.

2.13 BENDING OF YARNS

Bending of yarns has been studied using different methods in view of its importance. Carlene (1950) employed the loop test for investigating the flexural rigidity of yarns, and many have used his technique. The bending properties of ring, rotor, friction, air jet and blend yarns have been studied in depth as they are related to such important fabric properties as drape and handle. The Kawabata bending instrument also can be used for testing the flexural rigidity of yarns with some modifications. Data on the flexural rigidity of yarns have been provided by Owen (1968), Dhingra and Postle (1976), Subramanian et al (1990), and Thierron (1985).

2.14 FABRIC QUALITY

As the denier of the fibre becomes finer, the cloth becomes softer and smoother. The cloth bulkiness in case of knitting fabrics increases as denier becomes finer but with woven fabrics vice versa. In general, finer denier means more trouble with pilling. However, generation of pilling varies greatly depending on the composition of the yarn. It was found that with ring spun and MJS yarns, the finer the denier, the worse the pilling. In case of open end spun yarn, regardless of weather the denier is fine or coarse, pilling is much worse than ring spun or MJS yarn. For products where pilling is an important factor, OE spun yarn cannot be used.
2.15 AIR JET SPINNING OF MICROFIBRES

In a experimental work on air jet spinning(a type of open-end spinning), as reported by Rajamanickam et al (1998), microdenier polyester/cotton blended yarns were spun to study the interaction of first and second nozzle pressures on the properties of spun yarn. The results show that the first and second nozzle pressures interact with each other to determine yarn strength. This is because both the number of wrapper fibres and the length of wrappings formed at a particular first nozzle pressure depend on the level of second nozzle pressure and vice versa. There are an optimum number of wrapper fibres and wrapping lengths that yields the maximum yarn strength and this optimum level can be obtained at several different nozzle pressure combinations because the first and second nozzles interact with each other. However, it would be advantageous to use the lowest of these nozzle pressure combinations because of significant savings in energy costs. In a yet another study as reported by Rajamanickam et al (1998), investigates the effect of yarn delivery speed, first nozzle pressure, and blend ratio on the hairiness profile microdenier polyester/cotton blended air-jet spun yarns. The results show that yarn hairiness increased with increased yarn delivery speed and first nozzle pressure, but decreased with increasing amounts of polyester in the yarn. Also the three factors (yarn delivery speed, first nozzle pressure and blend ratio) interact with one another in determining yarn hairiness.

2.16 COMPACT SPINNING OF MICROFIBRES

In spite of modernization and rapid technological development in the field of ring spinning, the mechanism of ring-traveller spindle has remained almost the same until now. A new impulse in the field of ring spinning technology is offered by compact-condensed spinning. The spinning triangle that occurs while the yarn is formed is the cause of many fibres leaving the drafted roving, or being partly spun into the yarn with one end
only. This causes greater waste of fibres, low exploitation of fibre tenacity in yarn, poorer appearance and greater hairiness in spun yarn. The newest research in the field of ring spinning has shown that modification of 3 cylinder drafting equipment with two aprons in a region after front drafting rollers enables ring spinning to proceed with a minimized spinning triangle or even without it all. This is called as compact or condensed spinning. The distinguishing features of microfibres are a silky appearance and drape with a soft handle. These fibres are used in ladies outerwear and in the lingerie sector. However, these fibres display different processing properties in the spinning mill. Much attention has been given to their behaviour of knots, their tendency to nep and their high drafting forces. On the other hand the use of microfibres enables finer yarns to be produced. Higher yarn strength is possible with good running properties due to higher number of fibres in yarn cross section. In the context of the cooperative relationship between Rieter machine works limited, Switzerland and Reliance industries limited, India the processing properties of a Reliance micro polyester quality has been examined in a joint research project with Reutlingen technical college. Schenek et al (2005) report on the trials on compact spinning of micro polyester fibres in RIETER COM4 machines that COM4 yarn display better yarn uniformity indicating the necessity of fibre compacting which has a positive influence on fibre orientation. This is shown in Figure 2.28. Source: Schenek et al (2005). Fibre compacting thus has a positive influence on fibre orientation. The number of fibres in cross section or the twist factor should therefore be reduced to meet high quality standards.
As regards the imperfections, compacting reduced thin and thick places in the yarn by up to 20%. No differences were apparent due to compacting with regarding to nep-s. The COM4 spinning system with good drafting behaviour and fibre integration in the spinning integration offers interesting potential for the end product. Despite large number of fibres in the fibre cross sections, increases in tenacity of 1 cN/tex compared with conventional ring spun yarn were achieved as a result of better fibre integration in the COM4 spinning system. COM4 yarns display no reduction in mean tenacity as a result of reducing the twist factor of $\alpha_m$ 108 or $\alpha_m$ 97 respectively. This would, therefore, be an option for increasing output without loss of quality.

Role of microfibres in compacting enhances evenness due to more number of fibres in cross section thereby reducing thick and thin places. Also the same yarn tenacity as obtained with ring spinning can be achieved in microfibres with less twist multipliers as we have a large surface area of fibres for better cohesion and higher number of fibres in cross section. The low hairiness of COM4 micro polyester yarns is clearly noticed compared with conventional ring spun yarn measured according to Uster H and Zweigle 1+2 mm. In this Zweigle S3 values a small number of hairs per meter of yarn.
are seen. In subsequent winding process lower hairiness has a generally positive effect on nep counts due to less fibre sloughing. The COM4 yarns also possess a better abrasion resistance. Micro lyocell is notably successful in compacting upto a yarn count finer than 30 tex. Hairiness was reduced substantially in comparison with conventional ring spinning technology with a very fine yarn of approximately 10 tex and increasing tenacity by up to 3.5 c N/tex.

Goktepe et al (2006) have made a comparative study of compact yarn properties produced on different systems and found that irrespective of the system, the compact yarns have superior yarn structure and quality, especially in terms of hairiness and strength. Basal and Oxenham (2006) have reported on a comparison of properties and structures of compact and conventional spun yarns produced at five different twist levels. The results of their studies show that high tenacity values of compact yarns can be attributed to the higher rate and amplitude of fibre migration in compact yarns. The superiority of compact yarns in terms of tensile properties is less noticeable at higher twist levels. Das et al (2007) from their studies on comfort characteristics of fabrics made of compact yarns report that the fabrics developed from the EliTe compact yarns are superior in comfort to fabrics made from normal yarns. Schwippl and Haubold (2003) observe from their study on processing properties of lyocell fibres in ring spinning, that clear differences in uniformity, imperfection index, values, hairiness, and abrasion behaviour are apparent between the two ring spinning systems comforspin and conventional.

2.17 WICKING

Patnaik et al (2006) quote that factors such as size, shape, alignment and distribution of fibres, fibre combinations, yarn structure, fabric construction parameters all affect the wicking property. Wicking is affected
by the morphology of fibre surface, and may be affected by the shape of the fibres as well. The shape of fibres in an assembly such as yarn or fabric affects the size and geometry of the capillary spaces between the fibres, and consequently the rate of wicking. Perssin et al (2002) found fibres with highest moisture sorption have the smallest contact angles. Contact angles of raw and pre treated regenerated fibres have shown that alkaline purification has the biggest influence on viscose fibres, in the case of lyocell and modal fibres influence of alkaline purification is smaller in comparison with viscose fibres and low essential reduction in compact angles can be seen. In the case of viscose fibres, after washing, the alkaline solution of the washing agent easily penetrates into less oriented amorphous regions and break down the interaction between the cellulose and macro molecules. The diameter of the fibre increases and the structure becomes loose leading to better accessibility of fibre interfaces to liquid. The result is smaller contact angle and wettability and sorptivity improvement of the viscose fibres. In comparison with the viscose fibres, modal and lyocell fibres have a higher degree of cristallinity and higher molecular orientation which means that only a small quantity of washing agent can penetrate into less-ordered amorphous region of the fibres.

Chattopadhyay and Chauhan (2005) studied the wicking behaviour of ring and compact spun yarns and found the rate of water rise was very fast at the beginning and slowed down gradually. The equilibrium wicking heights observed for ring yarns were higher than that of compact yarns. Ring yarns wicked faster than compact yarns. As the packing coefficient of compact spun yarns is greater than that of corresponding ring yarns, the average capillary size would be less in compact yarns than ring yarns. Smaller capillaries may create sufficient drag to slow down the rise in liquid height. Hence there must be an optimum capillary size that will cause fastest entry of water into the yarn pores.
Sengupta and Murthy (1985) found that wicking was highly sensitive to the twist and structure of ring and open-end spun yarns. For ring spun yarns, the wicking time increases steeply as twist increases. Yoon and Buckley (1984) reported the vertical wicking behaviour of various cotton knit fabrics. They found that wicking rate was higher in the wale direction than in the course direction. The liquid transport properties of a fabric as a whole are essentially determined by the energy between the fibre surface and liquid. According to Adler and Walsh (1984) in multilayer fabrics, the major mechanism of wicking between fabrics is by means of a vapor diffusion process. The amount of water that wicks from one layer to another depends on the sizes and volumes of the pores. Nyoni and Brook (2006) carried out an analysis of the wicking and liquid retention properties of nylon 6.6 continuous and textured filament yarns used for light weight high performance fabrics and found that wicking performance was significantly affected by the tension applied and twist inserted. Subramaniam et al (2007) from their study on wicking behaviour of regular ring, jet ring and compact yarns observe that compact yarns have lower wickability compared to regular ring yarns.

2.18 MIGRATION BEHAVIOUR OF FIBRE IN SHORT STAPLE SPUN YARNS

The structural study of spun yarns includes characterization of fibre migration, which has a decisive influence on the mechanical and physical properties of the yarns. Fibre migration apart from being influenced by constituent fibre properties, is also influenced by the spinning systems adopted with specific fibre accumulation mechanism and the process conditions in yarn formation. Among the modern techniques, open end rotor and friction spinning systems have drawn much attention. When migration is considered, ring spun yarn exhibits higher migration, followed by rotor spun yarn and friction spun yarn with least as observed by Huh et al (2002).
Migration and packing density are two independent factors that contribute to yarn strength. Higher the value of these corresponds with higher yarn breaking tenacity realization.

The recent development of compact spinning technology for staple yarns, in which the size of spinning triangle has significantly gone down, has reduced the migratory characteristics of fibres to certain extent in constituent yarns due to relative changes in the tension gradient of fibre strand at the point of yarn formation. In those yarns the strength gain in mainly obtained through the favourable change in the packing density of yarn. In general it could be concluded that the yarn structure depends one side on spinning technologies and the other side on processing conditions and this structural differences in staple yarn lead to different yarn properties. Thus it is very important to understand yarn structure and its effects on physical properties of yarn; because each kind of yarn manufactured by specific spinning system method exhibits unique properties. The relative fibre movement at the point of yarn formation and the resultant position of fibres in the yarn structure is described as fibre migration. The migration behaviour of a fibre is affected significantly by the inherent properties of constituent fibre like fibre length, fibre fineness, crimp and cross sectional shape and the inherent characteristics of adopted processing systems. Of the widely used system such as ring, rotor and friction, ring yarn exhibits highest fibre migration followed by rotor and friction spun yarns based on spinning tension and its variation. Pillay et al (1975) analysed the structure and properties of open – end rotor yarns and reported that higher rate of change of radial position of fibres in the rotor spun yarn may be attributed to relatively higher twist as compared to ring spun yarns.
2.19 KNITTING

The introduction of finer fibres less than one decitex (microfibres) by the man made fibre producer for use especially in apparel industry has created tremendous possibilities to achieve improved physical, mechanical and aesthetic properties of apparel fabrics. Fibre fineness represents an essential and significant influencing factor on the wear comfort of a textile fabric, claimed Umbach (1993). The lower denier fineness of microfibres proves to be physiologically advantageous especially in wear situation where heavy and copious perspiration exists. In these circumstances, the microfibre textiles show better moisture transport and ensure better moisture control than the other construction parameters of comparative textile from conventional fineness above 1 denier in the micro climate near the skin. The reason for the better physiological isolation of the microfibre textiles in these wear situations can be attributed to the higher absorption potential of the fibre surface enhanced by the fibre fineness as well as a better capillary effect during the transport of liquid perspiration. Thus microfibres are especially suited for inclusion clothing for bodily active people. Microfibres present the possibility of targeted textile constructions for sport and leisure wear as well as work or protective clothing by providing considerably a better wear comfort for the wearer than textiles made from conventional coarse fibres.

Knit fabrics are obviously different from their woven counterparts in their performance. When a sport or activity requires a wide range of body motion, highly elastic knits offer a number of practical benefits. Knitted fabric possesses stretch providing full freedom of movement and in particular has two important functions to perform namely to provide free movement and the transmission of body vapour to the next textile layer in the clothing system. Karolia and Paradkar (2004) observe, from their study on properties of knitted fabrics, report that on analyzing double jersey fabrics of polyester microfibre
and non-microfibre fabrics for growth and elastic recovery by load application, tensile strength and percent extension, flexing behaviour and abrasion resistance of fabrics revealed that microfibre fabrics were superior in physical comfort than non-microfibre fabrics. Microdenier fibres have excellent flexibility and yarns with better regularity and elongation contribute for perfect knittability ensuring knitted fabrics with better softness, drape, dimensional stability, and wicking, thus ensuring better mechanical and comfort properties. The hairiness of the microfibre yarns is very low and this in turn creates a low lint shedding propensity and it will generate lesser fly during knitting. These two aspects of lint shedding and fibre fly are very crucial for the improved efficiency of the knitting machine.

Leigh (1993) observed from his study on bi-layered knitted fabrics with polypropylene inner and cotton outer were seen to provide better comfort for an ideal sportswear. Microfibre polyester knitted fabrics have demonstrated superior growth and elastic recovery properties besides having a good tensile strength; extension, flexing behaviour and abrasion resistance. Microfibre blends with natural fibres were observed to enhance production speed in knitting besides improving softness, drape and better dimensional stability of knitted fabrics.

Sule et al (2004) from an investigation, describe the main pre requisites for sportswear for hot and humid climate conditions from heat and rapid dissipation of sweat. No sportswear made from any single fibre or blends of different fibres can make an ideal sportswear. It was recently recognized that it is necessary to have a multilayer sportswear. Such a sportswear should have an inner layer of a hydrophobic fabric that acts as a wicking layer transporting sweat to a hydrophilic outer layer of the sportswear that absorbs the sweat, spreads it rapidly to evaporate it producing a cooling effect and such a sportswear should also be soft to touch. Very often the
wicking action is faster than evaporation in which case the perspiration is transferred back accumulating around the skin making active sports man very uncomfortable. Hence a proper balance in function of the inner and outer layers is required in designing sportswear.

2.20 PROPERTIES OF KNITTED FABRICS MADE FROM MICRODENIER FIBRES

Table 2.10 gives the comparative properties of fabrics made of different kinds of acrylic fibres. The fabrics made out of microdenier fibre are superior in many cases as compared to those of fabrics produced by conventional fibres. Source: Basu A. (2000)

Table 2.10 Properties of microdenier knitted fabrics

<table>
<thead>
<tr>
<th>Properties</th>
<th>Units</th>
<th>0.8 decitex</th>
<th>1.3 decitex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compactness</td>
<td>Tex/cm</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Weight</td>
<td>grams/sq metre</td>
<td>213</td>
<td>208</td>
</tr>
<tr>
<td>Thickness</td>
<td>mm</td>
<td>1.08</td>
<td>1.10</td>
</tr>
<tr>
<td>Voluminosity</td>
<td>cm/gm</td>
<td>6.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Flexural rigidity</td>
<td>mg.cm</td>
<td>26</td>
<td>2.6</td>
</tr>
<tr>
<td>Flexural length</td>
<td>cm</td>
<td>0.95</td>
<td>1.11</td>
</tr>
<tr>
<td>Compression recovery</td>
<td>%</td>
<td>49</td>
<td>45</td>
</tr>
<tr>
<td>Wear resistance</td>
<td>Cycles</td>
<td>6400</td>
<td>5000</td>
</tr>
<tr>
<td>Air permeability</td>
<td>Litre/cm/min</td>
<td>6.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Pilling</td>
<td>0-9</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Insulating capacity</td>
<td>min</td>
<td>26.9</td>
<td>28.1</td>
</tr>
<tr>
<td>Water absorption</td>
<td>%</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>Drying threshold</td>
<td>%</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>Speed of drying</td>
<td>1/t</td>
<td>5.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Speed of capillary rise</td>
<td>cm²/second</td>
<td>0.5</td>
<td>0.41</td>
</tr>
</tbody>
</table>
As can be seen from the results, the microdenier improves draping properties. The soft towel of microfibre is represented by the high value of the compression recovery test. This is confirmed by good air permeability measures. In this particular case it was observed that in spite of thin filaments, the pill formation resistance was substantially different from the standard acrylic. The original end use sector of microfibre was active sportswear. With a superfine microfibre yarns, it is possible to construct fabrics which are so fine that they are water and wind proof. For the knitting industry, the main end use sector should go for warp knitted and weft knitted fabrics which embrace both for traditional functional active sportswear and highly fashionable leisurewear as observed by Hauer (1990).

2.21 FRICTIONAL PROPERTIES OF FABRICS

The end and sales values of textile materials are dependent on their performance and aesthetic characteristics. Tactile property is an important and integral component of the aesthetic value and the marketability of fabrics and garments. The tactile property is commonly referred to as “hand” of fabrics. The hand of fabric is a complex and nebulous phenomenon that offers enormous challenge to quantify it objectively. Important mechanical properties that contribute to the hand of fabrics are tensile, shear, bending, compression and friction. The concepts and the evaluation of tensile, shear, bending and compression of fabrics are all well established and documented. However, the evaluation of the frictional property has offered significant challenges due to the complexity of the subject. The coefficient of friction, \( \mu \) is not a valid parameter to quantify the friction of textiles as the friction in textile materials deviates from the classical Amontons’ law of friction as reported by Howell and Mazur (1953). However, friction of fabrics contributes to the overall hand of fabrics as observed by Wilson (1963). Two prominent fabric quality evaluation systems such as the Kawabata Hand
Evaluation System KES-F (1975) and the Fabric Assurance by Simple Testing FAST (1989) are inadequate in quantifying the frictional characteristics of textiles. Therefore, it is of immense help to the textile community and the fabric and apparel industry to develop a simple friction evaluation method based on proven scientific concepts.

An upsurge in the objective quantification of the frictional property of textile materials has taken place in the recent past due to the necessity for a scientifically valid and simple method to determine the friction of fabrics as observed by Ramkumar et al (2003). These studies have resulted in a composite friction factor, “R” that takes into account the material and surface mechanical properties of fabrics. The first attempt to utilize this composite factor for the objective quantification of surface mechanical properties was undertaken using cellulase enzyme treated cotton fabrics. Surface etching by cellulase enzyme on cotton fabrics, which resulted in enhanced smoothness, was reflected in lower “R” values as reported by Ramkumar et al (2000). The “R” values correlated well with the perceived smoothness measured by people knowledgeable in the quality aspects of textiles. This composite friction factor “R” deviates from the Amontons’ coefficient of friction ‘μ’ and takes into account the effect of the apparent area of contact, different applied normal loads and the nature of the material. Recent studies have shown that this factor is logical and capable of quantifying the surface mechanical property/smoothness of a wide range of fabrics such as enzyme treated cotton fabrics; light weight needle punched nonwoven fabrics, leather and composite materials as observed by Ramkumar and Rodel (2003).

Handle of fabrics was measured by frictional properties. When a fabric slides on another surface, the resisting motion is called friction. Frictional properties of fabrics were measured by an attachment to Instron and the design is essentially based on Ajayi’s device (1992). The experimental
results obtained from the sledge method using the Instron tensile tester. Testing machine could be conveniently used to obtain the frictional constants “C” and “n”. The friction constants were derived from the basic equation \( F/A = C (N/A) n \) using regression analysis. Using C and n, R was calculated by taking the ratio of them. The new constant could be used as a measure of surface mechanical characteristics of fabrics.

Ram Kumar (2000) has studied the relation between fabric friction and fabric hand. Fabric weight and structure and the major effect on extraction force values. Heavier fabrics required a greater force to achieve extraction through the nozzle. The denim twill fabric showed the highest C value which is a measure of friction whilst a scoured, plains weave direct dyed sheeting fabric had the lowest C value.

2.22 MOISTURE COMFORT OF BILAYER FABRICS

The properties of any fabric produced depend on constituent materials, yarn type, fabric structure and how all these factors interact with each other. The ultimate aim of any apparel fabric is to satisfy the wearer and make him feel comfortable. Clothing comfort can be divided into tactile, psychological and thermo physiological comfort according to Yoon and Buckley (1984).

Bi-Layer knitted structures were produced using 100% polyester and 100% cotton spun yarn and were studied for transmission behaviour of air, water and heat. The statistical analysis revealed that many of the comfort characteristics have a high degree of correlation among themselves as reported by Behera et al (2002).
2.23 OBJECTIVE EVALUATIONS OF FABRIC HANDLE

Fabric handle is related to basic mechanical properties of fabrics, especially the initial low stress region of the fabrics. KES-F (Kawabata evaluation system for fabrics) has become popular among textile researchers for the evaluation of fabric hand value and assessing the suitability of fabric for the manufacture of clothing for specific end uses. Using the various fabric quality attributes like tensile, shear, bending, compression, surface friction and thickness, Kawabata established primary hand standards for different qualities of fabrics. The Total Hand Value (THV) is a single value that represents the overall handle or quality of a fabric and as such as a function of its primary hand values. The effect of yarn linear density on the hand value was reported by Dhingra et al (1983). They reported that both Numeri and Fukurami are increased considerably by spinning the same fibres into a finer count. Yarn produced on different spinning systems have different structure and hence differ in hand values due to fibre arrangement and twist distribution.

Radhakrishnaiah et al (2005) have demonstrated that tactile quality improvements occur after cellulase treatment for both cotton and polyester-cotton yarns and for the yarns representing all three commercial spinning systems. Gong and Mukhopadhyay (1993) made a comparative study on low stress mechanical properties of micro fibre fabrics with silk fabric as a reference and found that microfibre fabrics are soft and smooth but do not have the high kishimi hand which is typical of silk fabrics. Behera et al (1998) have made studies on handle of microdenier polyester filament dress materials and compared the same with fabrics produced from normal denier yarns. The study revealed sizing was the most important process for microdenier micro filament yarns to realize its speciality effect in the fabric made out of this yarn. Schacher et al (2000) reports from a comparative study on thermal
insulation and thermal properties of classical and micro fibre polyester fabrics and found that fabrics made of microfibres show lower heat conductance and therefore higher thermal insulation properties. Microfibre exhibits a warmer feeling than classical polyester fabrics depending on pressure, which may be due to the difference in fibre and fabric contacts with the human skin.

2.24 MICROFIBRE DYEING

Dyeing of microfibres is different from normal denier fibres due to the increased surface area of such fibres. The subsequent sections discuss the developments in research for microfibres and also some of the special considerations for microfibre dyeing.

Nakamura et al (1995) studied the sorption and diffusion behaviour of disperse dyes on microfibres. Sorption isotherms and dyeing rates of purified disperse dyes on polyester microfibres (fineness of 0.25-1.0 denier) from water have been measured at 95°C. The isotherms were curved and followed the dual-mode sorption model: Nernst’s-type partitioning and Langmuir sorption which were found to be concurrently operative. The effect of a diffusional boundary layer on the dyeing rate was found to be small under the conditions that the microfibres were dyed in the form of a bulky two-ply yarn in a well stirred bath. Dyeing rates of a commercial dye were also measured at 110 and 130°C. For dyeing of a 0.32d fibre at 130°C, the amount of dye sorbed by the fibres attains a maximum value at an early stage and then decreased gradually. This phenomenon is explained in terms of the aqueous solubility of very fine dye particles.

Burkinshaw et al (1996) reported the use of 13 acid dyes on conventional and microfibre knitted nylon 66 fabrics with four different dyeing methods. The dyes exhibited a faster rate of uptake, higher extent and rate of dye desorption, lower wash fastness and lower colour strength on
microfabric than on a conventional one. These findings were attributed to the greater surface area of the microfibres.

The effect of supercritical dyeing conditions on the morphology of polyester microfibres was studied by Drews and Jordan (1998). They have showed that supercritical dyeing has no adverse effect on the fibre structure.

Dyeing properties of a polyester taffeta made from ultrafine fibres (0.07 denier), made using sea-island-type conjugate spinning techniques, with disperse dyes were studied by Nakamura et al (2000) through an analysis of sorption isotherms and rate of dye sorption data. This was compared with data for microfibres (0.25, 0.32, and 0.44 denier) made by the conventional melt spinning method. Physical properties of the ultrafine fibres relating to the dyeing properties are also measured. They found that sorption and diffusion behavior of disperse dyes in polyester ultrafine fibres made by sea-island-type spinning techniques is almost same as that of polyester microfibres made by conventional melt spinning if the fibres contain no additives.

Dieval et al (2001) studied the polyester microfibre and fibre structure by critical dissolution time. The results showed that microfibre has a structure allowing good diffusion of the dye and showed that independent of the fineness; structural differences do exist between classic polyester and microfibres.

Chen et al (2002) studied the dyeing properties of polyester microfibres and regular polyester filaments. The dyeing rates were measured for four disperse dyes, the K/S values, and the colour properties of cross-sectional views of the dyed fibres. The research reveals that at 70°C, dye exhaustion of microfibres was very small; meaning that dyeing the fibres at a low initial dyeing temperature was less effective in achieving good colour effects, particularly with high energy disperse dyes. Also, when dyeing
microfibres, small disperse dyes were found to require a low dyeing temperature and bulky dyes require a higher dyeing temperature. Microfibres had a lower initial dye exhaustion temperature than regular fibres.

The effective end dyeing temperature for polyester microfibres was found to be around 125°C for small molecular structures disperse dyes, but the effective dyeing temperature was around 130°C for large molecular structures disperse dyes. The heat setting temperature for the lowest dyeability of polyester microfibres was usually 15°C lower than that of the regular fibres in this experiment. The surface reflectivity of the microfibres was usually higher than the regular fibres and this led to lower K/S values than those of the regular fibres. A recent paper by Agudelo et.al. (2008) discusses the fabric colour changes in polyester micro-fibres caused by the multiple reuse of dispersed dyes dye baths.

2.24.1 Various Uses of Microfibres

Microfibres have been put to various uses. Two major advantages of microfibres lie in their cleaning and filtration applications. The principles behind these two are discussed. Mukhopadhyay (2002) gives an overview on some of the important developments that have taken place in the field of microfibres. Microfibre fabrics absorb all sound frequencies better than a conventional fabric because of their higher surface area as reported by Na et.al (2007).

2.24.2 Mechanism of Cleaning by Microfibres

The surface area of the microfibres is more than ten times of a normal fibre. The microfibre’s small diameter translates into a much larger surface area than that found in conventional fibres. The small diameter of the
fibres also provides a particularly powerful capillary action, which, in addition to pulling in liquid, also pulls in particulates and microbes contained within the liquid. Thus, the combination of the increased surface area and capillary action gives the ultra-microfibre cloth the ability to absorb vast amounts of liquid many times its own weight.

The ultra fineness of each fibre also allows more fibres to be packed per square centimeter. This results in a far greater quantity of fibres coming into contact with the surface to be cleaned. This gives a faster and more efficient result.

The cleaning properties of the ultra-microfibres are further enhanced because they have a cationic (positive) charge due to the presence of the polyamide in the ultra-microfibres. Most dirt and dust particles, bacteria, pollen, oxidation on metals, etc., have an anionic (negative) charge. Thus, the ultra-microfibres naturally attract negatively charged particles, bacteria, etc.

2.24.3 Mechanism of Filtration by Microfibres

Filtration applications rely on the dominant mechanisms like (1) interception, (2) Brownian motion, (3) coalescence, (4) electrostatic effects and (5) triboelectric effects discussed by Homonoff (2000).

2.24.4 Industrial

A novel product, disclosed in a patent, by Robeson et al (1992) uses microfibres for cleaning up oil spills. The product comprises ultra-fine polymeric fibres which are produced from various polymeric materials by mixing with thermoplastic poly (vinyl alcohol) and extruding the mixture through a die followed by further orientation. The poly (vinyl alcohol) is
extracted to yield liberated ultra-fine polymeric fibres. The fibres are ultimately processed into said product, such as a mat, which is placed directly on the oil spill to absorb the oil.

Waterproof, multilayered nonwovens fabric of reduced weight having good vapour permeability and the method for its production has been described by Corovin et al (1999).

2.24.5 Civil

Toughness and strength improvements in cement-based matrices due to micro-fibre reinforcement were investigated by Banthia and Shenj, (1996). Cement paste and cement mortar matrices were reinforced at 1, 2 and 3% by volume of different microfibres including polypropylene, and these composites were further characterized in the hardened state under an applied flexural load. Both notched and un-notched specimens were tested in four-point bending. Considerable strengthening, toughening and stiffening of the host matrix due to microfibre reinforcement were observed. The test data from the notched specimens was used to construct crack growth resistance and crack opening resistance curves for these composites and to identify the conditions necessary for failure. This paper recognized the potential of these composites in various applications and stresses the need for continued research.

2.24.6 Medical

Fabrics from Microfibres have excellent breathability and have been used for wound care. Ultra-microfibres are generally triangular in cross-section, have sharp edges, and have a diameter of approximately three microns. Because a bacterium typically has a diameter of two to five microns, the extremely small size and structure of the ultra-microfibre allows that fibre
to get beneath the bacteria or other small microbes and particles that are smaller than the fibre, and substantially remove them from a surface. Additionally, to improve performance, the ultra-microfibres are usually mixed with polyester fibres in a 50/50 ratio in the case of woven material, and a 70/30 ratio of polyester to ultra-microfibre in the case of knitted material.

**Polypropylene**

Polypropylene (PP) microfibre spun bonds have application in wound-care, where they are used as hydrophobic backings to prevent exudates strike-through for extra protection against contamination. At the same time, the air permeability and breathability of these nonwovens promote healing and their softness and flexibility allows excellent adaptation to the skin. In addition, polypropylene (PP) microfibre spun bonds have potential application in disposable surgical gowns and mask where spun laced fabrics are widely used. The barrier properties of these spun bonds are more than 25% better than the spun laced fabrics at about half their weight (35 grams per square meter). Their softness, high permeability and breathability guarantee a high level of comfort in wearing when used as surgical gowns, and for application as surgical face masks; the hydrophobic outer layer prevents fluid strike-through in case of splashes.

**Polyethylene**

A fabric sheet with a curable resin coated onto the fabric sheet and a plurality of microfibre fillers dispersed into the resin has been described. The incorporation of microfibre fillers into the casting materials adds substantially to the strength of the cured casting material, particularly when the fabric used therein is a non-fibre glass fabric.
2.24.7 Apparel

Evolon, Nonwovens, is made from continuous microfibres. The Evolon process has filament spinning and web formation after which high pressure water jets split the continuous filaments into 0.05-0.2 dtex microfibres. Fabrics intended for garments from Evolon have outstanding drape and handle, comfortable to wear, can be given hydrophobic or hydrophilic treatments and can be laundered easily.

Tanaka and Tanaka (2000), the market leader in the development of man-made leather, has introduced the new Amaretta JP man-made suede. The new product satisfies both aesthetic and physical properties criteria. The product is based on a polyester microfibre and a microporous polyurethane resin.

Various microfibre jackets are now in use. For example, a website (2008) advertises for a 100% polyester sueded microfibre body with water repellent finish, convertible collar with button-tab closure, full-zip front, slash front pockets with snap closure, locker loop, inside pen pocket, rib knit cuffs and waistband, polyester/cotton lined body. A reversible golf length jacket having 100% polyester sueded microfibre body with water repellent finish is also advertised.

Smith (2008) gives a good idea about the garments made from microfibres. They are usually labelled to identify their presence, for example, 100% polyester microfibre. Many fibre companies use trade names to identify their microfibre products. A few examples include:

- Trevira Finesse (polyester)
- Fortrel Microspun (polyester)
- DuPont Micromattique (polyester)
- Shingosen (polyester)
• Supplex Microfibre (nylon)
• Tactel Micro (nylon)
• Silky Touch (nylon)
• Microsupreme (acrylic)

Fabric manufacturers also use trade names for microfibre fabrics. They include:

• Logantex:
  • Charisma--dress weight with suede-like finish
  • Ultima--water repellent finish
  • Thompson of California:
  • Moonstruck--soft sueded finish, silk-like
  • Micromist--brushed finish
  • Regal--dry hand
  • Springs Mills:
  • Silkmore--sandwashed silk finish
  • Stanza--water repellent microtwill
  • Vanessa--reversible fabric for rainwear

2.24.8 Synthetic Leather

Natural leathers, e.g., chamois leather, with beautiful appearance, softness, and a porous structure that give them high water absorption and vapor permeability are popular in the market. However, these are less and less in markets because of their restricted source, exorbitant price, as well as more and more awareness of protecting animals. As an alternative, man-made leather based on nonwoven support material coated with polyvinylchloride or polyurethanes is usually used for habiliments and shoe upper materials.
2.24.9  Household

A super absorbent drying towel uses microfibre that eliminates the need to use any soap or detergent as claimed by the producer. The microfibres with their enhanced surface area grab the grease and dirt. It also gives much better cleaning results in less time.

2.24.10  Miscellaneous

Microfibres have limited tendency to lint. Microfibre towels last much longer than conventional towels. Microfibre is also extremely absorbent. One of the companies claims drying towels and ultimate microfibre chamois’ which can absorb 10 times their weight in water. The absorbent products comprise pressure-sensitive microfibres that provide good liquid transport properties and resiliency and mask the odours associated with bodily fluids.

The microfibres of less than 1 dtex are formed using molten spray technology and are used to form coatings on the substrate of 0.002 - 0.084 g/m². They are sprayed onto the absorbent core using a spray nozzle or a melt-blown technique. They can be used in sanitary napkins, incontinence garments and disposable diapers using less expensive techniques.

2.25  ECONOMICS OF MICROFIBRE PROCESSING

The price of microfibre is generally 5 to 10% higher than conventional fibres which will push up the yarn price by 4%. However the conversion of fibre to yarn will come down due to increased production per spindle at ring frame and fly frame owing to reduction in twist by 5 to 10%. Also due to better working of ring frame, the work assignment of the ring frame tenters can be increased to some extent. The final net increase in yarn cost will come
down to 2%. As against the 2% increase in yarn cost, there are many advantages. The products made out of microfibre yarns are more attractive due to their soft feel, greater absorbency etc. The fabrics fetch more prices due to their speciality nature. Besides it is possible to produce value added products using these fibres. It can be said that use of microfibres is economically attractive if the products have good marketability, by Basu (2000).

2.26 LIMITATIONS AND PRECAUTIONS

The most important limitation of microfibres is their heat sensitivity. Because the fibre strands are so fine, heat penetrates more quickly than with thicker conventional fibres. As a result, the microfibres are more heat sensitive and scorch or glaze if too much heat is applied or if it is applied for too long a period. Generally, the microfibres are wrinkle resistant, but if pressing is needed at home or by drycleaners, care should be taken to use lower temperatures.

Microfibres can generally be cared for in a manner similar to that of conventional fibres made from the same fibre type. For example, fabrics made from polyester and nylon microfibres can probably be machine washed and tumble dried similar to fabrics made from regular polyester and nylon fibres. Polynosic or high wet modulus rayons are machine washable while viscose rayons perform best when dry-cleaned. Rayon microfibre should be cared for depending on whether it is polynosic or viscose-type rayon. The fibre properties, not the fineness of the fibre, usually dictate recommended care. Always follow care labels on garments.

A few cautions should be noted regarding microfibres. Because they are very fine or small diameter, heat penetrates the fibres more quickly than thicker fibres. As a result, glazing, melting or scorching can occur
quickly. This is of particular concern with heat sensitive fibres such as polyester or nylon. It is preferable to use a cool iron, if pressing is necessary, and the iron should not be left on the fabric for too long. It is also advisable not to apply too much pressure, which can create shine and ridges on the surface.

Static may develop in fabrics from synthetic microfibres, especially during dry winter months when heating systems are turned on and the humidity is low. Fabric softeners in the rinse cycle of the washing machine may lessen the problem. Paper dryer sheets can be used; however, temporary spots from excessive heat in the dryer may form on the microfibre. The delicate finish of microfibre fabrics and the amount of fibre surface make the spots noticeable if they develop.