SEM Studies on Changes in Tensile Properties and Abrasion Resistance of Sewing Threads during Chemical Processing Treatments

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Changes in the strength-elongation properties and abrasion resistance of three different sewing threads owing to chemical processing, viz., mercerization, kier-boiling and bleaching, as followed for the manufacture of sewing threads were studied. The nature and extent of damage to the surface structure of one of the samples (abraded and unabraded) at different stages of chemical treatments were examined by SEM, with a view to explaining the changes in tensile properties and abrasion resistance.

Keywords: Bleaching, Kier-boiling, Mercerization, Scanning electron microscopy, Sewing threads

For sewing threads, characteristics like tensile properties, abrasion resistance, seam efficiency, uniformity, hairiness, lustre, etc. assume great importance. The serviceability of a thread depends to a great extent on its strength, elongation properties and resistance to abrasion. In the present work, an attempt has been made to study extensively the changes in these properties of sewing threads owing to chemical processing treatments. Although some work has been reported on the effect of mercerization on tensile properties and abrasion resistance, no detailed work appears to have been done on sewing threads. Further, the nature and extent of damage to the surface structure of abraded samples of a typical sewing thread at different stages of chemical treatments have been examined with a scanning electron microscope (SEM), with a view to explaining the changes in strength-elongation parameters and abrasion resistance.

Materials and Methods

Materials—Three samples of sewing thread (30s/2, 60s/3 and 80s/2) differing in count and construction, representing coarse, medium and fine threads, were chosen for the study. Of the three samples, a typical (30s/2) sewing thread sample was taken up for SEM observations.

Methods—The samples were subjected to the chemical processing treatments, viz., mercerization (M), kier-boiling (K) and bleaching (B), sequentially, in the laboratory, as followed for the manufacture of sewing threads.

Mercerization was carried out with 25% caustic soda solution and 1% mercerin as wetting agent. A specially devised laboratory-model hank mercerizing machine was used. Skeins were allowed to run over two rollers, which were kept at a definite distance (136 cm) to give necessary tension so as to avoid shrinkage. The material was made to rotate with the help of rollers in the mercerizing solution for 5 min and then washed with hot water under the same stretched condition. Finally, it was washed with dilute acetic acid (1%) to neutralize the traces of alkali and then with cold water and dried.

Kier-boiling was done with 1% caustic soda solution by keeping a material-to-liquor ratio of 1:50. Samples were kept for 4 h in kier under 16 lb/in² pressure at 123°C. The samples were removed and dipped in 1% acetic acid to neutralize the excess of alkali for 30 min and finally washed with water and air-dried.

Sodium hypochlorite was used as bleaching agent (available chlorine, 2 g/litre). The samples were kept in the bleaching liquor (material-to-liquor ratio, 1:20) for 2 h and washed with water. The samples were scoured with 0.25% HCl for 30 min, washed with 1% sodium metabisulphate for 15 min and then with water and air-dried.

Samples collected at various stages of treatments were tested for breaking strength and elongation on a CRL-type Uster automatic single yarn strength tester. From 100 observations, average breaking strength (g), elongation %, tenacity (g/tex) and toughness index were computed.

The abrasion resistance was determined by using a Stoll quarter master universal wear tester by following the method standardized earlier at CTRL. In all, 20 specimens of each sample were tested and the average
number of rubs required to rupture and CV% were determined.

For taking SEM photomicrographs, the thread pieces were mounted on the specimen stub by using a conducting silver paint. To avoid the charging effect, the specimen was made conductive by depositing a thin layer of Au/Pd alloy on the surface of the specimen in a vacuum evaporator. A Cambridge Steroscan S-150 scanning electron microscope was used. The instrument was operated at 5 kV accelerating voltage, the specimen being tilted at 30°.

Results and Discussion

Effect of Chemical Processing Treatments on Tensile Properties and Abrasion Resistance of Sewing Threads

The results of the single thread strength and abrasion resistance (number of rubs to cause rupture) for the samples collected at different chemical processing treatments are given in Table I. The percentage change in breaking strength in comparison to grey (G) strength is also given. The percentage differences for abrasion resistance (number of rubs) over G and also over previous respective treatments are given in Table 2. The changes during different stages for breaking strength and abrasion resistance are shown in Figs 1 and 2 respectively.

**Tensile strength parameters**—Table 1 shows that mercerization increases the breaking strength of all the samples irrespective of count and ply, the average increase being 9%. The increase in breaking strength is also reflected in tenacity and toughness values. The values of CV are almost the same after mercerization compared to G, indicating that chemical treatment does not lead to further variation. It was, however, expected that mercerization would have brought more uniformity of strength, lowering the CV values.

It is observed from the strength parameter values for K and B samples that kier-boiling and bleaching after mercerization had not caused any appreciable change in strength as well as elongation compared to M samples. CV values also did not change significantly after K or B, though it was expected that there would be significant changes in strength and strength variation, since both the treatments were rather severe. It could, therefore, be inferred that while mercerization increased the strength, subsequent processing did not have any effect. In addition, the elongation at break was also not affected adversely.

**Abrasion resistance**—From the values of the number of rubs required for yarn rupture given in Table 1, it is seen that the abrasion resistance decreases successively from grey(G) to mercerized(M), K and

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<th>Table 1—Effect of Chemical Treatments on Tensile Properties and Abrasion Resistance of Sewing Threads</th>
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<td>Property</td>
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<tr>
<td>Breaking strength, kg</td>
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<td>CV% of breaking strength</td>
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<td>Tenacity, g/tex</td>
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<td>Elongation, %</td>
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<td>Toughness index</td>
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<td>Number of rubs to cause rupture of yarn</td>
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<td>CV% of rubs</td>
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*Values in the parentheses indicate percentage change in breaking strength in comparison with grey strength.

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<th>Table 2—Percentage Differences in Abrasion Resistance on Chemical Treatments</th>
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<tr>
<td>Count</td>
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<tr>
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</tr>
<tr>
<td>30s/2</td>
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<tr>
<td>60s/3</td>
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<td>80s/2</td>
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G—grey; M—mercerized; K—kier-boiled; and B—bleached.
Fig. 1—Effect of chemical treatments on breaking strength of sewing threads

Fig. 2—Effect of chemical treatments on abrasion resistance of sewing threads

Plate 1—Grey thread showing hairy appearance (× 50)
Plate 2—Grey thread showing compact arrangement of fibres in the yarn (× 500)
Plate 3—Abraded grey thread showing a number of broken fibres separated out of yarn (× 50)
Plate 4—Abraded grey thread showing clustering of loose fibres, bruising effect and surface cracks (× 500)
B for all the samples. The trend is seen clearly in Fig. 2. Further, the percentage decrease from G to M was greater for finer threads. This higher reduction may be basically due to the lower strength of yarn. It was also observed from the 80s/2 sample that the percentage reduction from K to B was very high (34%). The percentage reduction was higher for 80s/2 at all the stages as compared to that for the other two samples. The difference in the number of rubs from M to K stage was almost the same for all the samples. The difference from G to B (77%) as well as from K to B (34%) for the 80s/2 thread were higher than for the other two threads. If the values for 30s/2 and 60s/3 (Table 2) are considered, it is seen that although the resultant count difference is not much, the extent of reduction in the number of rubs from G to M and M to K is considerable. This may be due to more number of plies for the 60s/3 sample. Practically no difference was observed in abrasion resistance at K and B stages.

It was rather interesting to observe that, in general, there was a considerable reduction in abrasion resistance in terms of the number of rubs on mercerization although yarn strength increased considerably. A similar observation was made by Gailey¹ for the yarns treated with NaOH as well as liquid ammonia. Studies carried out by one of us (S.D.P.)⁵ have shown that abrasion resistance and strength elongation parameters are related significantly, the highest toughness (γ) being +0.96 (a parameter taking into account both strength and elongation). The differences in the trends observed may be explained on the basis of surface structural characteristics which play important roles. The decrease in abrasion resistance may be due to the

Plate 5—Mercerized thread showing compact and nonhairy appearance (x 50)
Plate 6—Mercerized thread showing swollen cylindrical fibres (x 500)
Plate 7—Abraded mercerized thread showing distorted yarn geometry. Note the loose and hairy appearance of thread (x 100)
Plate 8—Abraded mercerized thread showing negligible surface damage (x 1000)
change in the surface characteristics of yarns caused by changes in the processing treatments, whereas the tensile properties are not much affected by surface structure but are more influenced by other factors such as the number of fibres, fibre strength, and fibre cohesion and twist in yarn. Surface characteristics might have changed further during subsequent processing treatments to cause the further changes observed in abrasion resistance due to these treatments.

SEM Studies on Abraded and Unabraded Sewing Threads after Chemical Treatments

The SEM photomicrographs of a typical 30s/2 thread at different stages of chemical treatments, viz. G, M, K and B, were taken before and after abrasion at low and high magnifications (Plates 1-17). A similar work on fabrics was carried out by Dweltz.

From the photomicrograph of G thread (Plate 1), it is seen that fibres are protruding considerably, causing hairy appearance to the yarn. The high-magnification photomicrograph (Plate 2) indicates compact arrangements of the fibres in the yarns. In contrast to this, the abraded thread (Plate 3) shows a number of broken fibres separated out of the yarn owing to more number of rubs to rupture the yarn (635), causing extensive hairy appearance. At high magnification (Plate 4), clustering of loose fibres, bruising effect and cracks developed on the surface of fibres are more pronounced. The photomicrograph of unabraded M thread (Plate 5) shows that fibres in thread appear to be more compact than in G thread without any hairy appearance. This may be because of the setting of fibres after caustic treatment. At high magnification (Plate 6), well-aligned cylindrical fibres in the yarn are seen which may contribute to more yarn strength as seen in Table 1. Since the fibres had become more circular, strong, rigid and less cohesive, because of swelling and changes in surface structure during chemical treatments, they offered less resistance to abrasion and ruptured quickly after a fewer number of rubs to rupture the yarn (620).

In the photomicrograph of abraded M thread (Plate 7), distorted yarn geometry is seen with some broken fibres protruding from the yarn surface, giving more loose and hairy appearance compared to that of unabraded yarn. However, there was negligible surface damage, as seen in high magnification photomicrograph (Plate 8), which may be due to the fewer number of rubs required for rupturing, compared to G. This trend of reduction in abrasion resistance was predominant in the case of finer threads, as seen from Tables 1 and 2.

In the photomicrograph of unabraded K yarn (Plate 9), the fibres are seen loosely packed and more hairy in
Plate 12—Abrasced kier-boiled thread showing surface peeling, and deposits of fibre debris (x 500)

Plate 13—Abrasced kier-boiled thread showing surface peeling, twisting of fibres and broken ends (x 500)

Plate 14—Bleached thread showing loose packing of component yarn (x 100)

Plate 15—Bleached thread showing less damage to the thread compared to that in plate 11 (x 500)

Plate 16—Abrasced bleached thread showing a large number of broken ends of the fibres, which give hairy and distorted appearance (x 50)

Plate 17—Abrasced bleached thread showing a large number of broken ends of the fibres, which give hairy and distorted appearance (x 500)
contrast to that seen in the case of M yarn. At high magnification (Plate 10), the fibre debris is seen on the surface; also, at the same places, surface damage is clearly seen. These surface disturbances may be due to the kiering treatment.

The photomicrograph of abraded K yarn (Plate 11) shows a completely disturbed structure in which most of the fibres from one of the components are entangled and the entire bunch protrudes out of the yarn. At high magnification (Plates 12 and 13), the surface peeling and deposits of fibre debris are seen.

In general, samples were severely affected by M, K and B treatments and as a result, they offered progressively less abrasion resistance as compared to grey yarns, although strength was not affected considerably (Table 1), owing to peeling and surface rupture.

In the photomicrograph of unabraded B thread (Plate 14), loose packing of fibres in the component yarns, compared to that in the case of M, is seen. The individual fibres appear to be without any damage (Plate 15). For abraded B thread (Plate 16), more broken fibres are seen to be protruding. This gives a hairy and distorted appearance. At high magnification (Plate 17), the twisting of fibres and the longitudinal cracks developed on the surface are seen. The abrasion resistance has decreased as a result of total changes in surface characteristics, the percentage decrease in abrasion resistance being 27.1 and 18.8 from G and K respectively.

Conclusions
The SEM photomicrographs give physical evidence of change in the structure of a sewing thread because of chemical treatments. The surface structure at M stage is more tidy and compact (Plates 5 and 6) as compared to that at G and B stages (Plates 1 and 14). It is completely distorted at K stage (Plates 9 and 10). Owing to the successive deterioration in yarn surface structure, the capacity to resist abrasion is lowered sequentially, causing also, to some extent, reduction in tenacity at B stage.

Chemical treatments modify the surface structure, and as a result, there is reduction in abrasion resistance but no improvement in tensile properties. Improvement in breaking strength may be attributed to such factors as the number of fibres, increase in fibre strength, and fibre cohesion twist.

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References