Effect of Wet Processing on the Tearing Strength of Polyester/Viscose Rayon Blended Fabrics

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The effect of different wet-processing stages, viz. grey polyester stage, tint washing, scouring, heat-setting, polyester dyeing, viscose dyeing, singeing and finishing, on the tearing strength of plain woven polyester/viscose (65:35) blended fabrics has been studied. The effect of change in single-thread strength, yarn pull-out force, yarn crimp and extension at break due to wet-processing on tearing strength has also been studied. The causes for change in tearing strength after different processing stages are discussed. The relationship between the ratio of single-thread strength to the yarn pull-out force of opposite set of threads and tearing strength has been examined. When the fabric was finished with a softening agent there was a considerable increase in tearing strength.

In practice, a fabric fails more often because of poor tearing strength than because of poor tensile strength. The tearing strength is one of the most important mechanical characteristics of a fabric and while assessing the fabric quality, emphasis should be laid on this characteristic as it directly affects the serviceability of a fabric and also takes into account almost all the important factors entering into the service conditions.

Tearing strength is highly sensitive to slight variations in finishing-filling and lubrication. There is little published work on such finishing processes like scouring, bleaching and dyeing with the exception of that done by Huebner. Different finishing processes can affect tearing strength by altering the single-thread strength, thread slippage, and possibly by influencing other properties. Changes in such structural properties as thread spacing and crimp may also occur in the finishing process and lead to changes in tearing strength. The thread slippage may be affected by (i) increased friction, which, in turn, is caused by scouring, (ii) a reduction in friction due to lubrication, and (iii) sticking and filling-up of the threads. In the course of the present work, the effect of different wet-processing stages, such as grey-stage, tint-washing, scouring, heat-setting, polyester-dyeing, viscose-dyeing, singeing and finishing, on tearing strength of plain-woven polyester/viscose (65:35) fabric has been studied. The effect on tearing strength of changes in different parameters, such as single-thread strength, yarn withdrawal force, crimp and extension at break, because of wet-processing, has also been studied.

Materials and Methods

Preparation of fabric sample—The fabric sample was prepared from 65/35 polyester-viscose blend in plain weave with 60 ends/in and 52 picks/in. Yarn of 2/34s count was used in both warp and weft directions. The grey width of cloth was 147 cm, while the required finished width was 137-140 cm.

Tint-washing—The fabric was moved 4 times from one end to the other end of the jigger, water being used at normal temperature without the addition of chemicals and auxiliaries.

Scouring—During scouring, the fabric was moved 8 times from one end to the other end of the jigger at 85°C using soda ash (5.0 g/litre) and an anionic detergent (0.5 g/litre). The fabric was washed with hot water and later with cold water, and dried on a pin stenter at 150-160°C.

Heat-setting—The cloth was heat-set on a pin stenter at 205°C, keeping dwell period at 40 s and the overfeed at about 4%.

Polyester-dyeing—The polyester component of the fabric was dyed with a disperse dye in a high-temperature and high-pressure beam dyeing machine at a material-to-liquor ratio of 1:15 for 60 min at 130°C. The dye concentration, on the weight of the fabric, was 3.8%, the concentrations of other chemicals used being: acetic acid, 1.2 g/litre; carrier, 1.0 g/litre; and dispersing agent, 0.5 g/litre. The pH was kept at 5.5.

Viscose-dyeing—The viscose component of fabric was vat-dyed on a jigger dyeing machine with 2.3% (separately vatted) vat dyes on the weight of fabric at a material: liquor ratio of 1:3. The dyeing temperature was kept at 80°C for first three ends and dyeing was continued for three ends more, keeping steam supply off. The chemicals added were caustic soda (15 g/litre)
and sodium hydrosulphite (15 g/litre). After dyeing, the fabric was dried on a pin stenter.

**Singeing**—Both sides of the fabric were singed at a speed of 90 mm/min.

**Finishing**—The fabric was given a silicone finish on a pin stenter with silicone emulsion (20 g/litre), cationic softener (20 g/litre) and catalyst (4 g/litre) at about 160°C with required dimensions and overfeed.

Before testing, all the fabric samples obtained at different processing stages were conditioned in standard atmosphere (RH 65%; 27 ± 2°C) for 48 hr. Standard test methods as laid down in the B.S. Handbook were adopted to determine the yarn and fabric characteristics.

The yarn crimp in both warp and weft directions was measured on a Eureka crimp tester (Type FY-07) by taking 0.5 ± 0.05 g/tex tension and a 20 cm test length. The single-thread strength and extension at break of all the samples in warp and weft directions were measured on an Instron tensile tester, by taking 1000 g full-scale load and 500 ± 1 mm clamping length. Both the cross-head and chart speeds were kept at 100 mm/min. Twenty observations, 10 for warp and 10 for weft, were made for each sample.

For testing the fabric tear strength, single rip test was adopted. From each sample obtained at different processing stages, 10 strips were cut, 5 in warp direction and 5 in weft direction, so that no two strips contained, as far as possible, the same warp yarn for the strip of warp tear test or the same weft yarn for the strip of weft tear test. The tests were performed on an Instron tensile testing machine, by keeping both the cross-head and chart speeds at 100 mm/min, and using a clamping length of 100 mm and the full-scale load at 10 kg.

The yarn pull-out force was measured by taking a 5 in long and 3 in wide fabric strip. Leaving 2 inches from one end of the longer sides, to allow the specimen to be gripped by the fabric jaws, and another 0.5 in for a clearance from the jaw line, a transverse cut was made across the width of the specimen. The specimen was marked across its width at a distance of 1 in from the transverse cut and all the crossing threads in the remaining portion of the specimen were unravelled so that the length of each of the freed longitudinal yarns from the marked line was 1.5 in. The rear end of the specimen in the fabric form being already gripped by a pair of fabric jaws. The yarn clamp, initially being separated from the jaws by a distance of 2 in, was then moved apart until the yarn was completely withdrawn from the strip, the force required to remove it being recorded in an autographic device. Five observations each for warp and weft directions were made and the average was calculated. Both the cross-head and chart speeds were kept at 100 mm/min, the full-scale load being 1000 g and clamping length, 50 mm.

**Results and Discussion**

The values of tearing strength, single-thread strength, thread pull-out force, crimp and extension at break for warp and weft directions of all the fabric samples are given in Table 1. Before performing the test, each sample was examined by a magnifying glass to check that the weave pattern (plain) remained free of any weaving defect throughout the fabric sample so that the results are not affected by any kind of weaving defect.

The data given in Table 1 show the tearing strength as influenced by single-thread strength, thread pull-out force, crimp and extension at break. The effect of different wet-processing stages, viz. grey stage, tint washing, scouring, heat-setting, polyester-dyeing, vat-dyeing, singeing and finishing, on the tearing strength of the fabric is also shown in Table 1.

**Effect of single-thread strength**—Table 1 shows that the tearing strength of fabric increases with increase in single-thread strength—a characteristic which has a direct effect on the fabric tear behaviour. With a higher yarn strength, the complete del assembly in the tear region supports a higher load, resulting in increase in the fabric tearing strength. This is in agreement with the observation of O'Brien and Weiner that the tearing strength increases with increase in the thread strength if other parameters like weave and fabric count are kept the same. It has also been observed by other workers that increase in single-thread strength, usually brought about by the use of coarse yarn, leads to increase in tearing strength.

**Effect of crimp**—Fig. 1 shows that the tearing strength of the fabric reduces with increase in total crimp, the correlation coefficient between these two being about -0.37. This is in agreement with Williams finding that with a lower crimp, the area of contact between the threads is smaller and the frictional resistance to the movement of threads is less. Because of this, the del area is more, and a greater number of cross yarns are brought into action during tear, leading to increased supporting capacity of del assembly and a higher tearing strength. Harrison pointed out that the higher crimp of the threads in the cloth causes a reduction in the ease of slippage because the yarns are bent to a greater extent and hence less tearing strength is recorded.

**Effect of yarn extensibility**—Table 1 shows that the extensibility of the yarns being ruptured plays an important role. Although after heat-setting the ratio decreased considerably, the tearing strength remained unaffected, or was lowered only a little. This is because of increase in the extension at break of yarn
Table 1—Tearing Strength, Single-Thread Strength, Thread Pull-out Force, Crimp and Extension at Break of Fabric Samples at Different Wet-Processing Stages

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grey cloth</th>
<th>Tint washed</th>
<th>Scoured</th>
<th>Heat-set Polyester dyed</th>
<th>Viscose dyed</th>
<th>Singed</th>
<th>Finished</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tearing strength, kg</td>
<td>4.035</td>
<td>4.043</td>
<td>3.882</td>
<td>3.990</td>
<td>3.240</td>
<td>2.675</td>
<td>2.672</td>
</tr>
<tr>
<td>(0.198)*</td>
<td>(3.8)</td>
<td>(11.1)</td>
<td>(19.7)</td>
<td>(33.7)</td>
<td>(33.78)</td>
<td>H3</td>
<td>(4.43)</td>
</tr>
<tr>
<td>Single thread strength (f), g</td>
<td>580.0</td>
<td>582.0</td>
<td>552.0</td>
<td>525.0</td>
<td>210.0</td>
<td>480.0</td>
<td>476.0</td>
</tr>
<tr>
<td>(0.345)</td>
<td>(4.8)</td>
<td>(9.45)</td>
<td>(63.79)</td>
<td>(17.24)</td>
<td>(17.93)</td>
<td>(16.38)</td>
<td></td>
</tr>
<tr>
<td>Thread pull-out force (fJ, g)</td>
<td>269.5</td>
<td>262.0</td>
<td>280.0</td>
<td>376.0</td>
<td>378.0</td>
<td>431.5</td>
<td>428.0</td>
</tr>
<tr>
<td>(2.78)</td>
<td>(3.896)</td>
<td>(39.52)</td>
<td>(40.26)</td>
<td>(60.11)</td>
<td>(58.81)</td>
<td>(15.29)</td>
<td></td>
</tr>
<tr>
<td>Ends/in</td>
<td>64.00</td>
<td>65.33</td>
<td>66.00</td>
<td>65.00</td>
<td>67.66</td>
<td>67.00</td>
<td>67.33</td>
</tr>
<tr>
<td>Crimp, %</td>
<td>15.5</td>
<td>16.0</td>
<td>12.5</td>
<td>20.0</td>
<td>20.0</td>
<td>17.0</td>
<td>17.0</td>
</tr>
<tr>
<td>(f_s/f_r)</td>
<td>2.710</td>
<td>2.812</td>
<td>2.432</td>
<td>1.888</td>
<td>1.868</td>
<td>1.477</td>
<td>1.469</td>
</tr>
<tr>
<td>(0.376)</td>
<td>(10.26)</td>
<td>(30.33)</td>
<td>(31.25)</td>
<td>(45.498)</td>
<td>(45.79)</td>
<td>(3.24)</td>
<td></td>
</tr>
</tbody>
</table>

*Values in parentheses show percentage variation with respect to grey-stage characteristics. Negative values show increase and positive values, decrease.

Fig. 1—Relationship between crimp and tearing strength after heat-setting. The tear mechanism of the single-rip tear test reveals that the number of yarns in the ladder of a del at the tear locus depends upon the amount of yarn slippage and yarn extension. With a more extensible yarn, the number of active threads in the del increases and hence contributes more to the system in supporting a higher load. The results are in agreement with those of Harrison⁹ who found that a more extensible yarn leads to a more extensible fabric, which allows a wider distribution of the stresses about the point of application of the tear, and hence to a higher tearing strength.

Effect of yarn pull-out force—Data on tearing strength and yarn pull-out force (Table 1) show that the tearing strength increases with decrease in the yarn pull-out force for the opposite sets of yarns, i.e. the higher tearing strength is the result of easy slippage of cross-threads. This is in agreement with the finding of Taylor⁶ that the tearing strength increases with decrease in resistance to slippage of the cross-threads. This is because the resistance to slippage of the cross-yarn or the yarn pull-out force for the opposite set of yarns plays an important role in determining the tearing strength of the fabric. With increase in yarn pull-out force, the del limits itself within a smaller area and depth, bringing fewer yarns into action, which results in reduced supporting capacity of the del system and hence a lower tear strength.

Effect of the ratio single-thread strength/yarn pull-out force—Fig. 2 shows that the tearing strength and the ratio \(f_s/f_r\) have a linear relationship, the coefficient of
correlation between two being +0.86 and +0.95 for warp and weft tears respectively. O'Brien and Weiner also observed that the single-thread strength divided by the pull-out force for the opposite set of threads is directly related to tearing strength. They further observed that in addition to being a measure of thread slippage, as governed by the inter-thread friction, the yarn pull-out force reflects the crimp balance (defined as the ratio of the smaller to the larger crimp) and weave factor (defined as the ratio of the number of threads per repeat to the number of interlacements in the same repeat) and hence could be used to determine the deformability of a fabric, which is related to its tearing strength.

**Tearing strength at grey stage**—Table 1 shows that the warp tearing strength (4.0 kg) is higher than the weft tearing strength (3.6 kg). This is due to the higher \( f/f_s \) ratio for warp tear, which is obviously the result of low force required to withdraw a weft yarn, although the single-thread strength for warp (580 g) is less than that for weft (645 g), which, in turn, is the result of low weft crimp. The low single-thread strength for warp is because of subjecting the warp yarns to repeated stresses and strains, and continual abrasion with heald eyes, reed, race board, etc., during weaving.

It is observed that warp tear strength is higher than the weft tear strength at the other stages of processing also, although at all the stages the single-thread strength of warp is lesser.

**Effect of tint washing**—Data presented in Table 1 show that tint washing has no significant effect on the tearing strength of the fabric. This is as expected, for during tint washing, only the tinting material is removed by the use of water at normal temperature without any addition of chemicals and auxiliaries.

**Effect of scouring**—Table 1 also shows that after scouring the tearing strength reduces by 4-6% in both the directions from the grey stage of fabric. A similar trend of reduction is observed in ratio \( f/f_s \), which is due to the reduced single-thread strength \( f \) and increased yarn withdrawal force for the opposite set of threads \( f_s \).

The loss in single-thread strength after scouring is because of the alkaline action of caustic soda on both the polyester and viscose components of the blend. Shenai and Lokre reported that the polyester fibre undergoes alkaline hydrolysis in the presence of alkali, which results in loss of both strength and weight.

The surface ester groups of polyester fibres are first attacked, thereby removing shorter polymer chains. These are further hydrolyzed, the reaction then going to completion. The actual mechanism may involve the alkali attack on the electron-deficient carbonyl carbon atom, forming an intermediate.

Regenerated cellulosic fibres are highly susceptible to chemical attack. Viscose, being a regenerated cellulosic fibre, is largely a pure form of cellulose and, therefore, the strength loss is primarily due to the dissolution of low-molecular weight fractions of the cellulose polymer. Moreover, unlike cotton, viscose is made up of disoriented fibrils and hence is more prone to chemical attack.

During the spinning of polyester/viscose blended material, viscose has a tendency to come on to the surface of the resultant yarn and, therefore, the immediate action of alkali during scouring affects the viscose component preferentially. The increased yarn pull-out force after scouring may be due to the partial solubilizing action of alkali on the viscose, making it rough.

**Effect of heat-setting**—The data given in Table 1 show that after heat-setting, the warp tearing strength increases marginally from 3.882 to 3.990 kg, while the weft tearing strength decreases from 3.410 to 3.205 kg. The table also shows that the ratio \( f/f_s \) for both warp and weft is lowered considerably because of increased yarn withdrawal force and decreased single-thread strength.

The increase in yarn pull-out force is in agreement with the finding of Marvin, who observed that the setting of the polyester fabric is accompanied by a harshening or stiffening of the fabric, which detracts from its handle and draping qualities. The stiffening is due to the formation of a continuous film on the
eliminating the hairy appearance of fabric. The negligible change in the tearing strength of cloth after singeing is due to the fact that the process is carried out in such a way that its action is restricted to protruding fibres and that it in no way affects the other fabric characteristics.

Effect of singeing—The data given in Table 1 also show that after singeing there is no significant change in the tearing strength of cloth as well as in other properties of the fabric. The singeing process consists in burning out all the fibre ends that may be protruding from the fabric surface, which, in turn, helps in eliminating the hairy appearance of fabric. The negligible change in the tearing strength of cloth after singeing is due to the fact that the process is carried out in such a way that its action is restricted to protruding fibres and that it in no way affects the other fabric characteristics.

Effect of finishing—Table 1 shows that after finishing, the warp and weft tearing strengths increase by about 50% over that at the end of previous process. When compared with the strength at grey stage the finished fabric shows a decrease of 4.4% in the warp direction and an increase of 1.62% in the weft direction. The ratio $f/W$, also increased to almost twice that of its previous value in singed stage. This is mainly because of 40-45% decrease in yarn withdrawal force and also a slight increase in single-thread strength. The decrease in yarn withdrawal force is the result of finishing the fabric with 20% silicone finish, essentially a softening agent which also imparts water repellency to the cloth. The finish makes the surface of the fabric smoother. The increase in single-thread strength after finishing is due to the deposition of silicone finish in the form of a film on the surface of yarn.

Conclusions

(1) Increase in single-thread strength ($f$) for the set of threads being ruptured is accompanied by increase in tearing strength.
(2) Total crimp in the fabric has negative correlation with fabric tearing strength.
(3) The tearing strength of fabric increases with increase in the extensibility of crossing yarns.
(4) The fabric tear strength decreases with increase in yarn pull-out force ($f$) for the opposite set of threads.
(5) The ratio $f/W$, and the tearing strength of cloth have a linear relationship.
(6) Tint washing has no significant effect on the tearing strength of the fabric.
(7) Scouring reduces the tearing strength of fabric.
(8) The loss in tearing strength is expected after heat-setting, but this loss is compensated for by an increase in the extensibility of yarn, which depends upon the overfeed allowed.
(9) There is a significant decrease in tearing strength after polyester-dyeing.
(10) Tearing strength decreases considerably after vat-dyeing.
(11) Singeing has no significant effect on the tearing strength of fabric.
(12) Finishing of fabric with a softener increases its tearing strength considerably.

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References
1 Huebner J, J Text Inst, 12 (1921) 162.
7 Backer S & Tanenhaus, Text Res J, 21 (1951) 635.
8 Williams S, Text Inds, 117 (1953) 134.