Morphological changes in Tencel through crosslinking

by Iram Abdullah, Department of Polymer Engineering, National Textile University, Faisalabad, Pakistan.

The crosslinking agents which impart crease resistance to cellulosic fabrics bring morphological changes to fibres. In this case the fibrillation tendency of tencel fibres is greatly modified. Fibrillation not only brings undesirable difficulties during wet processing it also affects the wear life of tencel fabric. During washing, the fibrillation process causes greying and creasing of the fabric, resulting from the joint action of the washing liquor and abrasion against the walls of rotating washing drum. Therefore, abrasion is important consideration in wear life of the tencel fabrics, and thus tencel garment useful life is affected in two ways.

- It renders the fabric so hairy/fuzzy that it becomes unbearably unsightly;
- It produces a progressive deterioration in strength until a level is reached at which the fabric is no longer able to withstand the stress of usage without rupture.

The mode of fracture of tencel fibres in abrasion was observed using scanning electron microscopy (SEM). The fibres rupture by multiple splitting revealing the internal fibrillar structure of tencel fibres as shown in Figure 1. This rupture resulted from the tensile stress due to frictional forces. The particular length of fibres that raised the surface of the fabric after breakage of individual fibres was much more vulnerable to further attack by repeated abrasion action. Multiple cracks along raised fibres indicated the repeated bending and flexing of fibres, shown Figure 1. Further abrasion results in rounded fibre ends produced from the multiple split ends and axially split rounded ends.

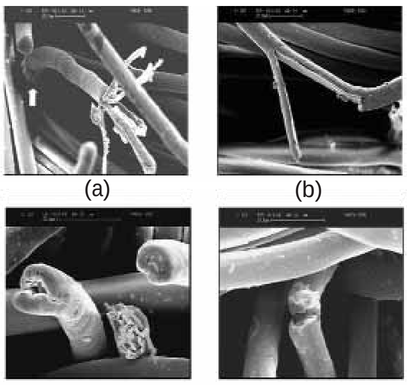

Figure 1: Dry abrasion morphology of untreated sample: (a) multiple split fibre end; (b) transversely and axially fractured; (c) rounded and axially split ends; (d) propagation of transverse fracture.

There is also some evidence of transverse crack linked by axial split as shown in Figure 1b. There are usually three possible combinations of transverse and axial crack as shown in Figure 2. Axial cracks appear first and thus divide the fibre into two parts, which break independently, giving the form of break shown in Figure 2a. Transverse cracks form first and then join with an axial split (Figure 2b), which then breaks independently giving form shown in Figure 2c. The propagation of breaks shown in Figure 1e, and continuation of split suggest that axial split occurs first.

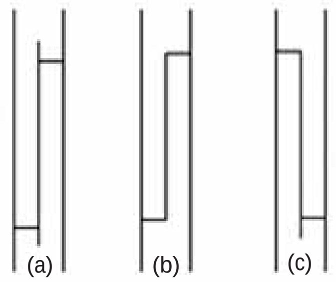

Figure 2. Three possible combinations of transverse and axial cracks.

Morphology of fabric at the breakage point is shown in Figure 3. As fibres in the crowns were broken down in succession, this not only caused reduction in yarn strength, but also the frictional forces holding the rest of the fibres together were reduced; the plucking action pulled the more loosely held end of the fibre from the yarn body and raised it to the surface of the fabric. This particular raised length of the fibre was no longer an effective component of the fabric and was, additionally, more vulnerable to further abrasive attack. Towards the end point, the whole yarn structure was pulled out (Figure 3a) and fibre ends at break appeared mangled, twisted and mashed as shown in Figure 3b and Figure 3c.

During laundering i.e. in wet state it was observed that fibrillation starts from minor cracks (Figure 4a), which with further abrasion caused the complete disintegration of fibre structure (Figure 4b). Macro-fibrils were liberated individually or in groups held in fibre structure by relatively weak hydrogen bonding and van der Waals forces. Considerable damage to the fabric also resulted from creasing. Maximum stresses developed at the outer curvature of the crease, which rubbed against the fabric and inner surface of washing drum, caused successive localized fibrillation as shown in Figure 4d. The fibres which were pulled out due to the abrasive action of washing drum were massively fibrillated. The fibre ends also appeared stepped broke and rounded off as shown in Figure 4e and Figure 4f.

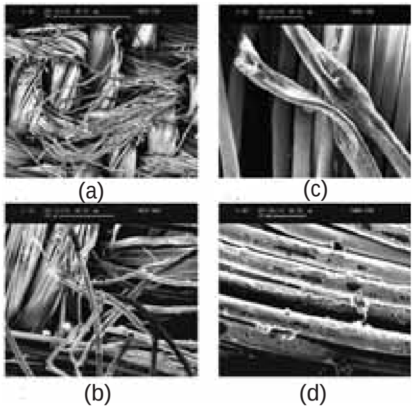

Figure 3. Morphology of fabric at the breakage point: (a) breakage of yarn; (b) detail of (a) mangled and axially split fibres; (c) detail of (a) crushed fibres; (d) smeared fibres at the yarn crown.

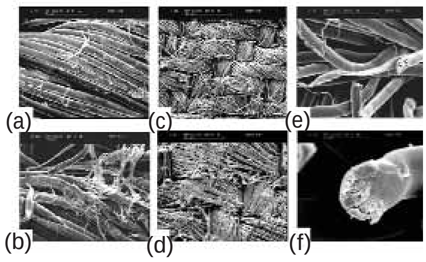

Figure 4. Fibrillation observed in untreated sample: (a) start of the fibrillation after first wash; (b) extensive fibrillation; (c) inner side of the crease; (d) outer side of the crease; (e) stepped break; (f) rounded fibre end.

Change in morphology through crosslinking

Two different resin treated fabrics were examined to see the effect of crosslinking on morphological behaviour of fibres. Scanning electron microscopic studies on Fabric A; treated with 50g dm-3 Reaktant DH indicated that the mode of fracture was not distinctly different from untreated fabric as shown in Figure 5. The main mode of fracture is multiple splitting of fibres due to tensile fatigue. However, the surface damage was less pronounced as the surface resin protected the fibre surface from abrasive action. Step breakage was also observed as shown in Figure 5b. According to two possible mechanisms of stepped break, it is not clear whether two breaks formed and then joined up by an axial split, or whether the fibre was already split axially into two parts, which then broke. Further abrasion rounded off the fibre ends and caused axial splitting as shown in Figure 5c.

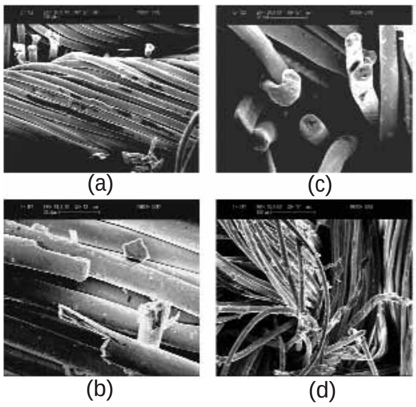

Figure 5. Dry abrasion morphology of Reaktant DH treated sample (a) surface damage and multi-ply splitted fibre ends, (b) stepped break, (c) rounded off and axially splitted fibre ends, (d) detail of fibres at the breaking point of yarn; mashed, mangled and twisted.

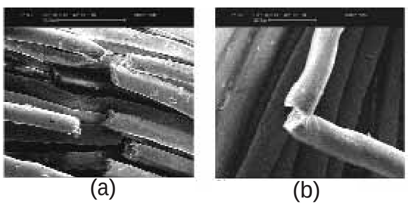

Figure 6. Fibre fracture observed in Reaktant FC treated samples: (a) brittle fractures at the crown; (b) brittle fracture through bending.

It appears that the main mechanism of failure in Fabric B; treated with 50g dm-3 Reaktant FC was not rubbing off of the fibre surface or multiple splitting of fibres, but it was abrupt rupture of fibres under stress as shown in Figure 6a & 6b. Transverse fractures appeared to be brittle fractures; it was very difficult to draw any conclusion from the side view of broken fibre ends, but this may be granular fracture. Figure 7 shows an idealized view of granular fracture. When tension reaches a certain level, elements will begin to break (Figure 7b), but the discontinuity prevents the occurrence of a large enough stress concentration to cause the crack to continue propagating across the fibre. However, there is some cohesion between elements, and excess stress is transferred to neighbouring elements that are thus more likely to break at a nearby position. Eventually the failure becomes cumulative over a cross-section (Figure 7c), and the granular breaks results (Figure 7d).

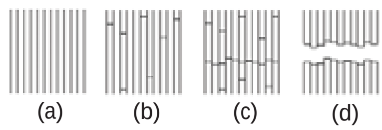

Figure 7. (a) Structure of separate elements, (b) Under tension, elements start to break. (c) Stress transfer causes cumulative break over a cross-section. (d) Granular break.

Figure 8 shows the wet mode of fibre fracture in Reaktant DH and Reaktant FC treated fabrics. Broken ends developed where fibres were pulled apart leaving frayed fibril bundles as shown in Figure 8a and Figure 8e. Such damage is typical of wet abrasion in tencel. Reaktant DH treated fabric showed some evidence of fibrillation presumably the cumulative swelling and tearing forces were great enough to tear fibrils and bonded sheets from the fibres, as shown in Figure 8b. However, the fibrillation is not strictly fibrillation as observed in untreated fabric. It seems like peeling away of thick slabs and ribbons of fibrils from the body of the fibre. Small wedges or notches at the surface of the fibres (marked by an arrow in Figure 8c and Figure 8f) indicated the cutting action by the drum liner. These are potentially the weak regions through which fibre fracture propagates. In Reaktant FC treated fabric, the cutting action was progressive and caused removal of fragments from the surface of the fibres as shown in Figure 8d. The propagation of fibre rupture by cutting action was also evident in Figure 10f. In some instances, large segments were peeled from the fibres revealing the inner fibril structure (Figure 8h), and also skin layer was flaked off showing the resin layer underneath (Figure 8g). There was no evidence of fibre fibrillation as observed in the fabric.

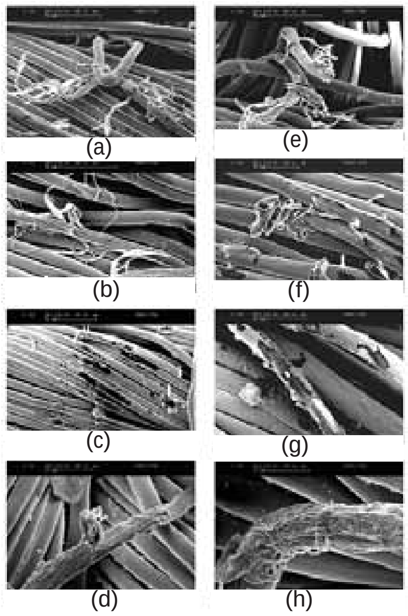

Figure 8. Fracture morphology of Reaktant DH treated fabric: (a) frayed fibril end; (b) Fibrillation; (c) surface damage through cutting action. Fracture morphology of Reaktant FC treated fabric: (d) gradual peeling of thick slab; (e) Frayed fibril end; (f) propagation of fracture through cutting action; (g) flaked off fibres; (h) Inner fibril structure of fibre.

Summary

The molecular structures introduced into the fibres affect the fibrillation tendency and mode of fracture of tencel fabric; however, it is greatly related to the molecular length and extensibility of the crosslinkages formed in the fibre. The mode of fracture of Reaktant DH treated fibres was similar to untreated Tencel fibres because either its monomers were not able to penetrate far into the fibre interior due to longer-chain molecule or it formed long-chain crosslinks which imparted less stiffness to the Tencel fibres compare to shorter-chain lengths of Reaktant FC crosslinks. When dry abraded, Reaktant DH treated fibres were multiply splitted, while Reaktant FC treated fibres were abruptly ruptured. When wet abraded, in both fabrics fibre ends were pulled apart leaving frayed fibril ends. However, cutting abrasion action was more progressive in Reaktant FC treated fabric.◆