Effect of Crimp on the Tensile and Compressive Properties of Polyester Fibers

INTRODUCTION

Excessive crimping of a polyester fiber can lead to premature failure. Qualitative analysis of the mechanism of strength loss with the scanning electron microscope indicates that the fiber breaks primarily through the compressive mode. Thus, even though overcrimping of the fiber will increase overall yarn bulkiness, a sacrifice of the strength of the fiber or yarn is obtained as a secondary consequence.

DISCUSSION

Fibers are crimped to increase yarn bulkiness, a desirable characteristic of carpet yarns. The crimp is a measure of the difference between the length of straightened fiber and that of the unstraightened fiber. This effect of increased bulk is shown in Figure 1, where the

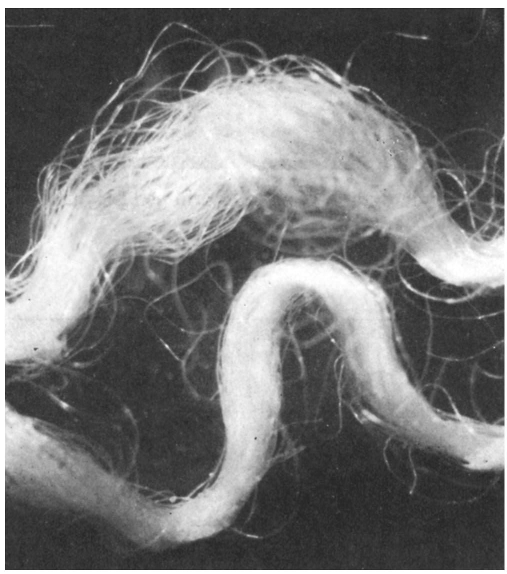
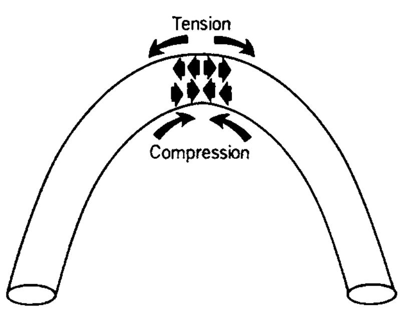


Fig. 1. Photomicrograph of crimped and uncrimped polyester fiber, 40×.



Fi.. 2. Sketch showing tension and compression areas due to bend in individual fiber.

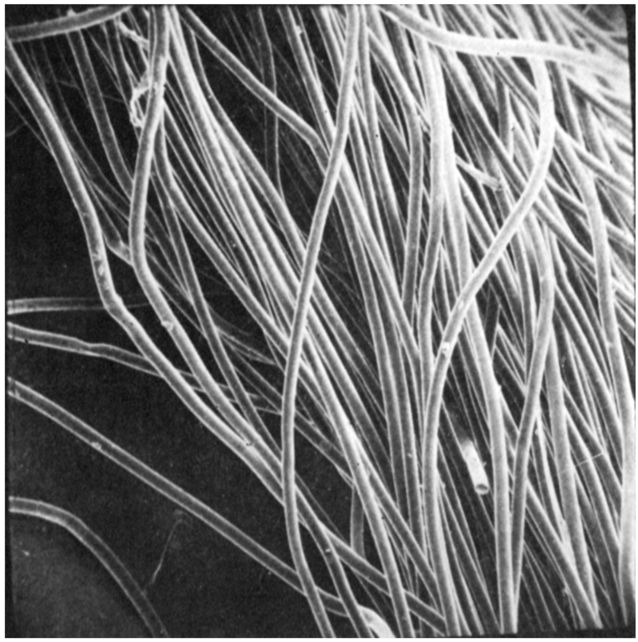


Fig. 3. SEM micrograph of slightly crimped polyester fiber, 47×.

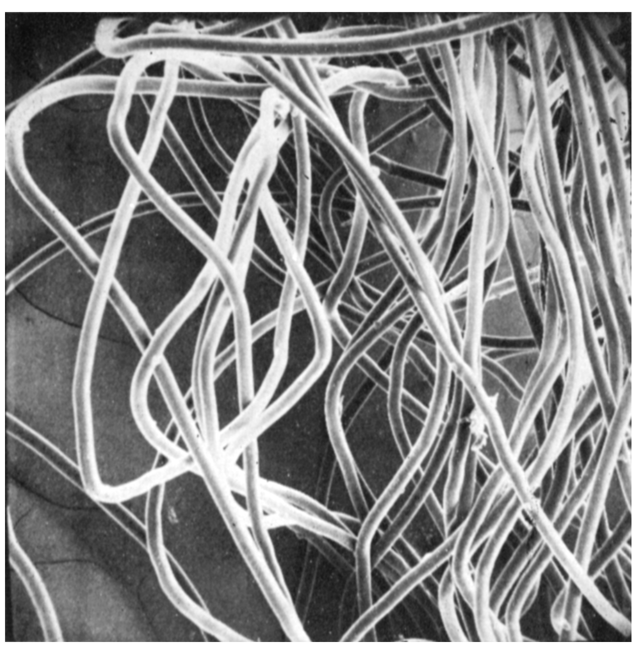


Fig. 4. SEM micrograph of highly crimped fiber, 47×.

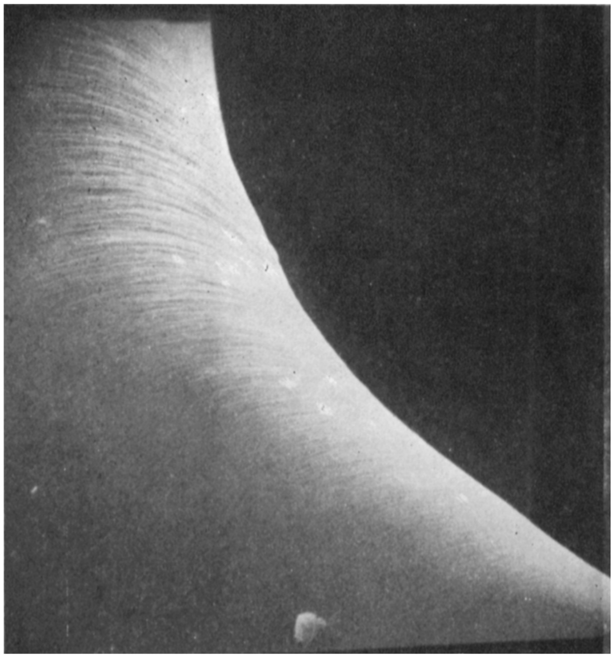


Fig. 5. SEM micrograph of the underside of a slightly crimped fiber showing effect of compression, 1870×.

Fig. 6. SEM micrograph of the compression damage in moderately crimped polyester fiber, 470×.

higher crimped fibers produce the bulkier yarn. However, crimped polyester fibers have been found to have a lower tensile strength when compared to uncrimped fibers. Ordinary microscopy did not reveal significant information concerning the cause of the loss, and it was necessary to turn to the scanning electron microscope for an explanation.

Crimp in man-made fibers is produced by the application of heat and pressure or by rolling the fibers between fluted rolls. The crimp or the number of crimp amplitudes (distance from one crest or valley to the next) per inch should not vary greatly. Crimping can be the cause for damaged fiber. Sharp angles or bends will normally give a larger crimp length; hence, a measure of the crimp can provide an index to fiber quality. A

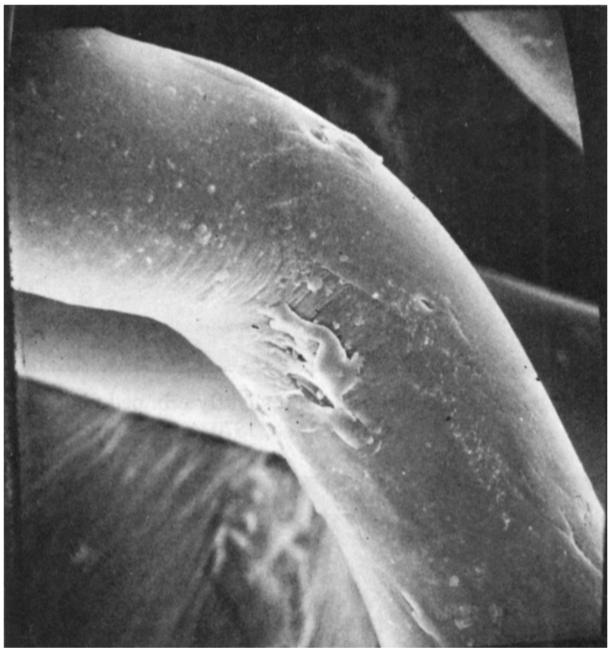


Fig. 7. SEM micrograph of the tensile and compression damage in a highly crimped polyester fiber, 935×.

major factor which accounts for the tensile loss is the damage incurred by the fiber substrate during crimping. An analysis of Figure 2 indicates that during bending, two types of stress modes operate simultaneously on the fiber. There is a tensile stress along the outer curvature of the fiber, while a compressive stress is acting along the inner portion of the bend.

The results of the study are summarized in Figures 3 to 8. Since ordinary microscopy would not yield sufficient information concerning possible fiber damage during crimping, various types of polyester were subjected to an analysis with the scanning electron microscope.

The difference in bulk obtained between slightly crimped and highly crimped fiber is shown quite vividly in Figures 3 and 4. When the slightly crimped fiber is observed at high magnification, the outer surface will appear smooth and uniform. On the inner portion of the bend, however, small ridges are observed, as in Figure 5. This would imply that even at low bending, tensile stresses can be accommodated much better by the fiber than can compressive stresses. With increased bending, Figure 6, the compressive damage increases. A further increase will begin to affect the outer surface and fiber damage can become quite severe, leading to breaks and rupture of the outer portion of the fiber surface. Such damage is shown in Figures 6 and 7. Rupture of the surface allows easier penetration of dye molecules into the fiber substrate and leads to uneven dyeing characteristics.

It is also very probable that the increased compressive forces lead to extensive submicroscopic damage to the fiber substrate. For example, increased disorder within the fiber from compressive damage would increase the solubility of dye and could easily result in not only an increased rate of dyeing but also a higher saturation value. Severe

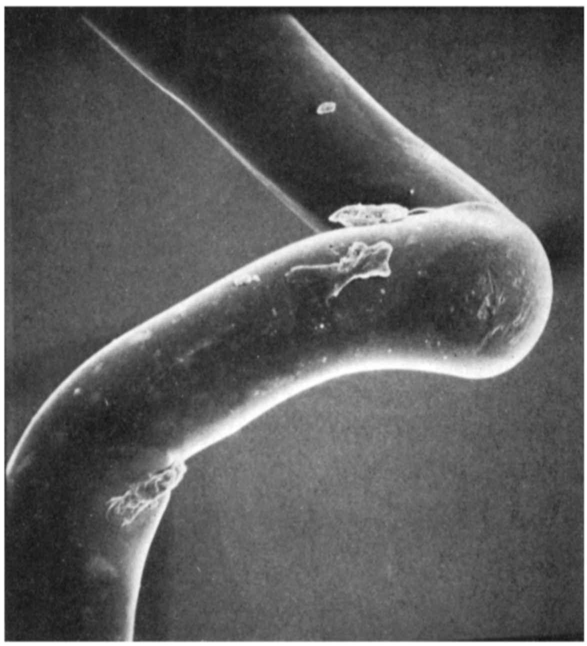


Fig. 8. SEM micrograph of an overcrimped polyester fiber, 470×. Failure is due to both tension and compression.

bending involves not only compression damage, but some tensile damage, as shown in Figure 8. Any attempt to straighten the fiber, which occurs when the fibers are stressed, would tend to reverse the radius of curvature. Cyclic loading during use would naturally increase the propensity for fatigue failure of the already highly crimped and damaged fibers.

CONCLUSIONS

An increase of the crimp applied to a fiber will increase the bulk properties of the resultant yarn. However, excessive crimp will lead to surface damage of the fiber. This damage is primarily a result of the fiber's apparent inability to accommodate the compressive stresses occurring during crimping. The increased damage, whether it causes more chain breaks or increased strain on individual chain bonds, will decrease the overall tensile strength of the fiber.

DAVID M. HALL
GORDON H. NIX*
R. I. VACHON

Textile Engineering Department
Auburn University
Auburn, Alabama 36830

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* Present address: Optimal Systems Incorporated, Atlanta, Georgia 30301.