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TENSILE BEHAVIORS OF SINGLE COTTON FIBERS UNRAVELED FROM WORN GARMENTS

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Abstract

The mode and extent of damages inflicted upon cotton fibers by the mechanical actions during cotton ginning and the subsequent textile manufacturing processes have not been carefully studied in the past.

Preliminary tests have been performed in order to analyze the feasibility of testing tensile properties of single cotton fibers unraveled from worn garments and examine the changes in the tensile properties due to processing and repeated wash/drying. Single cotton fibers were unraveled from a worn T-shirt and a pair of worn blue jean as testing materials and tested through MANTIS®. The tensile properties of fibers from worn garments were compared with that of raw cotton. Fibers unraveled from a worn T-shirt have shown significantly lower mean breaking strength, breaking elongation and work-to-break values than that of raw cotton. Fibers unraveled from a worn blue jean have shown almost the same mean breaking strength, but significantly lower mean breaking elongation (with a large CV% and range) and a smaller work-to-break than a raw cotton. For the T-shirt, the distributions of the tensile properties were all positively skewed relative to that of raw cotton. Above results suggest that damages inflicted on cotton fibers by processing and wash/dry seem permanent and irreversible. The results shown in this study, however, are all preliminary. The observations will lead to an expanded study on the subject.

Introduction

While the tensile properties of cotton fibers in the bundle forms have been studied extensively in the past several years, little research has been performed with the single cotton fibers. It is natural to expect that the changes in the mechanical properties of cotton fibers brought about by the machine actions during the manufacturing processes would exert indelible effects on the characteristics of the resulting textile products, e.g., fabrics and garments. The modes and extents of machine actions or damages inflicted upon cotton fibers during the ginning and the subsequent processes, however, are too numerous, complex and indeterminate, to be quantified or identified. Investigations on this important issue have not been successful due to lack of means for testing the tensile properties of a large number of cotton fibers before and after each stage of processing. Yet, it is readily conceivable that the rapid and repeated loading of cotton fibers may leave irreversible effects on cotton fibers.

Loss of the fiber's "liveliness" for instance, through impairment of its elasticity, may be reflected in terms of certain latent changes in the stress-strain behaviors of fibers, yarns and fabrics. More importantly, how these changes are manifested during the lifetime of a product is of great significance. In this paper, we examined the feasibility of testing tensile properties of single cotton fibers unraveled from worn garments. In addition, observations have been made on their tensile properties relative to a known type of raw cotton.

Methods and Materials

Two worn garments were selected; a worn T-shirt and a pair of worn blue jean trousers. The yarns were removed from the fabrics and the fibers were carefully unraveled gently from the yarns, one at a time, without subjecting them to much pulling force. These single fiber test results were compared to that of "Memphis cotton" we stored in our *MANTIS Cotton Fiber Information System*. Possible differences in the features of statistical distributions were checked. While the origins of the cotton fibers are unknown for the two garments chosen, the purpose was to examine only the variation features apart from their average breaking strengths and average breaking elongations. Any peculiarity in the tensile test data could be assumed to have come from the process-induced stresses and strains as well as from the repeated wear, washing and drying. The number of fibers obtained from the worn T-shirt was 200 due to the difficulty in unraveling fibers from the knitted fabric while that from the jean fabric was 1400.

Results and Discussion

The results of MANTIS® single fiber tests are summarized in Table 1. The average breaking strength, breaking elongation, and work to break are shown along with their standard deviations and ranges. For the T-shirt, the average breaking strength was only 2.58 gf whereas the breaking elongation was 7.6%. Unquestionably, the average strength is very low compared to any other cotton type we have tested in the past. This suggests that the tensile strength losses are perhaps due to ginning, carding and other textile processes as well as the repeated wash and wear cycles. They appear to be permanent and irreversible. The results from jean fabric, however, are somewhat different. The average strength of 6.42 gf is quite comparable to that of Memphis cotton. Whether there was a loss of strength could not be determined as we have no reference value for the same cotton before processing.

The average breaking elongation for the T-shirt fibers is also low (7.6%) compared to that of Memphis cotton (15.7%), whereas the standard deviation (18.2%) is much higher than the Memphis cotton (6.5%). This perhaps demonstrates the existence of a differential effect of textile processing and effects of repeated wash-and-wear cycles on the cotton fibers, all contributing to a large standard deviation of breaking elongation. That is, not all fibers might have been affected by the stresses and strains of textile processing although the wash and wear cycles imparted more or less the same degree of adverse effects to all fibers.

For the cotton fibers obtained from the jean, the average breaking elongation was somewhat low (10.2%). However, unlike the case for T-shirt fibers, the standard deviation also remained low.

In Figures 4 and 5, the breaking strength (y) and breaking elongation (x) are plotted for the fibers from T-shirt and blue jean fabrics, respectively. In Figure 4, we can see clearly the large standard deviation of breaking elongation for the fibers from T-shirt.

Histograms for breaking strength, breaking elongation, and work-to-break are shown in Figures 6, 7, and 8, respectively, for the two fibers obtained from worn fabrics along with that from Memphis cotton. These are to observe possible changes in the distributions of tensile properties that might have resulted from textile processing and wash-and-wear cycles. In Figure 6, we can see a large difference in the distribution of breaking strength for the fibers obtained from the T-shirt; the distribution is highly positively skewed unlike other fibers. The low average breaking strength is also well exhibited.

In Figure 7, we can also see a large difference between the T-shirt fibers and other fibers; the histogram for the T-shirt fibers is skewed positively compared to the other two types. This clearly shows that the fibers unraveled from the worn T-shirt were left with limited extensibility.

Examining Figure 8, we can see quite easily the large difference in the T-shirt fibers; the low average and relatively high standard deviation provided the distinct features in the histogram. For the jean fibers, the differences from Memphis cotton are shown to be minimal.

In summary, the above results indicate that positive skewness prevailed in the distributions of breaking strength, breaking elongation, and work-to-break for the fibers obtained from the T-shirt , whereas the distribution features for the fibers from jean fabric were quite similar to that of Memphis cotton.

Summary

The test results in this study suggest that cotton fibers within worn garments can be unraveled and tested for their tensile properties. Fibers unraveled from a worn T-shirt showed significantly inferior tensile properties than that of raw cotton. While the breaking strengths of fibers unraveled from worn blue-jean fabric was similar to that of raw cotton, the breaking elongation and work-to-break averages were significantly smaller than that of raw cotton. These results suggest that damages inflicted on cotton fibers by processing and wash/wear seem permanent and irreversible.

The foregoing test results came from fabric samples obtained under no known scheme. For this reason, we cannot generalize the observed phenomena without a designed experiment. It is quite encouraging, however, to find some distinct differences in the tensile properties of the fibers unraveled from worn garments.

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Table 1. Summary Statistics of Tensile Properties for 3 Fiber Types.

		Cotton Fibers from T-shirt	**Cotton Fibers from Blue Jean**	**Memphis Cotton**
Sample Size		200	1374	4002
Breaking Strength (gf)	Mean	2.58	6.42	6.23
	Std. Dev	1.37	2.64	2.51
	Min.	0.51	0.46	0.26
	Max.	7.58	15.46	15.71
Breaking Elongation (%)	Mean	7.69	10.21	15.66
	Std. Dev	18.06	4.47	6.50
	Min.	0	0.18	0.21
	Max.	66	31.99	49.19
Work done during tensile test (μJ)	Mean	3.85	10.99	16.19
	Std. Dev	9.03	6.85	9.64
	Min.	0	0.01	0.01
	Max.	33	48.23	82.13

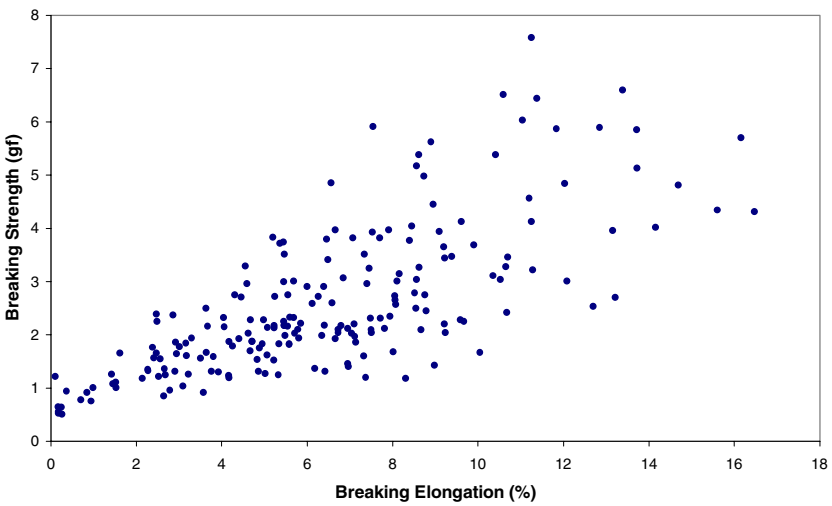

Figure 1. Breaking strength vs. breaking elongation of single fibers from a worn T-shirt.

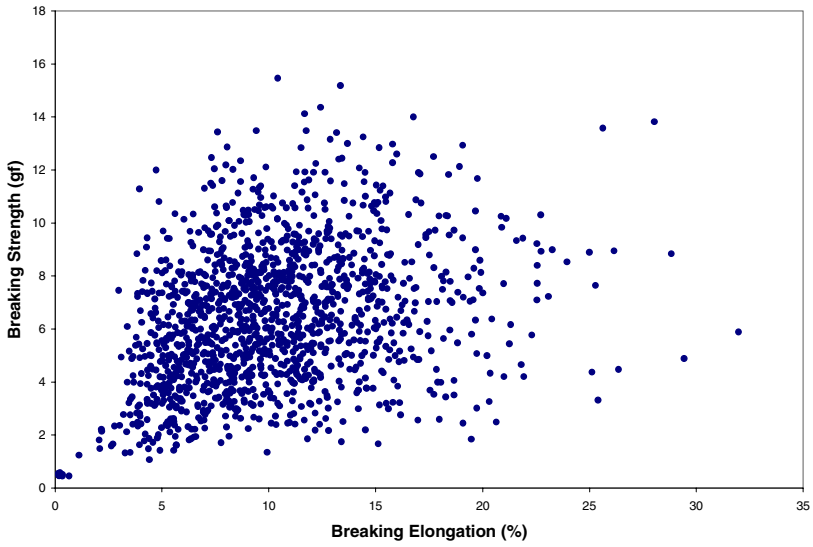

Figure 2. Breaking strength vs. breaking elongation of single fibers from a worn blue jean.

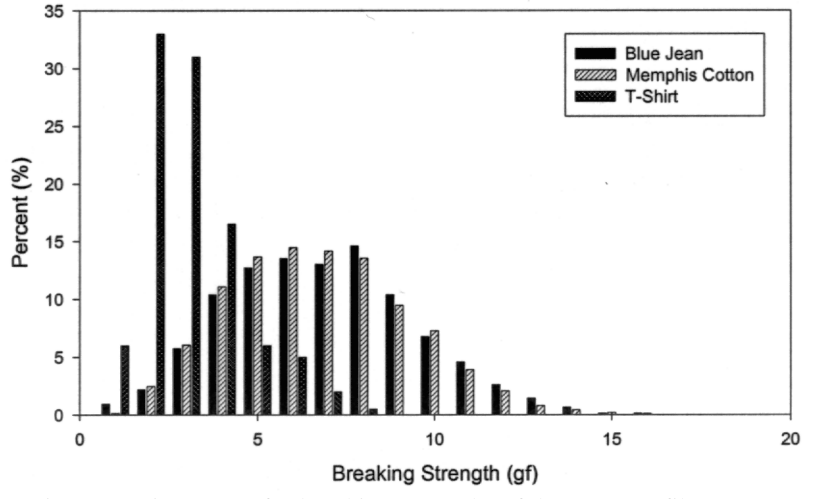

Figure 3. Histograms for breaking strengths of three cotton fiber types.

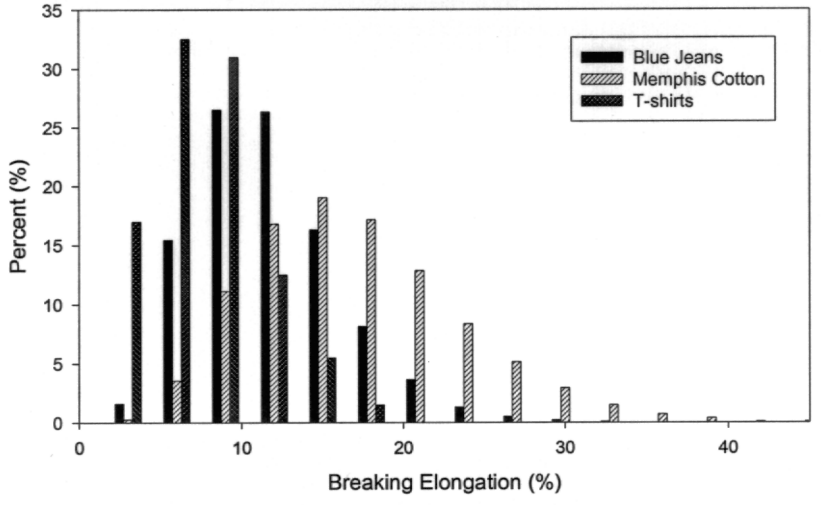

Figure 4. Histograms for breaking elongations of three cotton fiber types

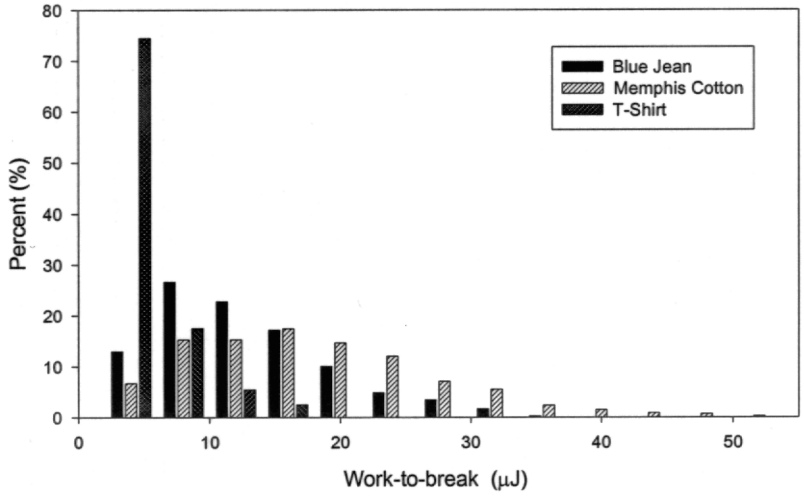

Figure 5. Histograms for work-to-break of three cotton fiber types