2007 Beltwide Cotton Conferences, New Orleans, Louisiana, January 9-12, 2007

COTTON/SYNTHETIC FIBER BLENDING - THE THEORY & THE PRACTICE: COTTON/MODAL BLENDING

Ramsis Farag
Yehia El Mogahzy
Alaa Araf Badr
Department of Polymer and Fiber Engineering - Auburn University
Auburn, AL

Abstract

When cotton fibers are blended with synthetic fibers, a great deal of compatibility must be achieved to realize the benefits of this fiber mixture. This compatibility stems from three basic interaction modes: structural compatibility, attributive compatibility, and appearance compatibility. These modes collectively make up for a homogenous and predictable fiber mixture. In this paper, the focus will be on characteristic compatibility. Of particular emphasis, a key question will be how fibers of different components assist each others in meeting the desired performance of yarn. In this regard, critical attributes such as fiber dimensions, bulk density, and fiber strength will be analyzed. In addition, the concept of length utilization efficiency presented by El Mogahzy and Kirifa will be implemented for the mixtures of this study. Fiber blends considered will include: cotton/polyester and cotton/micro-denier modal fibers.

Introduction

This paper represents a continuation of a long study that began in the year 2000 by the first two authors in which an integrated approach was established to evaluate the theory and the practice of multi-component fiber blending (El Mogahzy, TRJ, 2004, and El Mogahzy, et al, TRJ, 2004, 2005). The result of the study was an analytical approach aiming at more general evaluation of fiber blending as it relates to its critical practical objectives. In this regard, the outcome of fiber blending was classified into four basic modes:

1. Structural blending-This implies the extent of geometrical allocation of different fiber segments within the structural boundaries of the fiber strand.
2. Attributive blending-This indicates the extent of interaction of different fiber attributes within the characteristic boundaries of the fibrous assembly.
3. Appearance blending-This describes the extent of homogenization of color or component apparent intensity in the fiber assembly.
4. Interactive blending-This implies the interaction between different fiber components during the blending process.

The importance of the above classification stems from the fact that each represents a different technological focus in the process of making textile products. Structural blending represents the foundation of any blending process since fibers of different types should be blended together according to some structural or geometrical criteria. In other words, understanding structural blending is a basic technological requirement. This is the reason for the great deal of attention given to this mode of blending in previous blending studies.

Attributive blending has always been considered as a by-product of structural blending. In other words, if different fiber types are blended on the basis of the structural or geometrical criteria, attributive blending is assumed to be simultaneously achieved. One exception to this assumption that was realized by some investigators is the case of blending fibers of different strength properties (Hearle, et al, 1969, and Zurek, 1975). In today's technology, there is an increasing trend toward technical textiles in which fibers are blended not only with substantially different fibers but also with different non-fibrous materials. This makes attributive blending a key issue that should be addressed with great deal of attention.

Appearance blending represents a uniquely different and challenging problem. It can be independent of structural blending in many situations. In other words, meeting the structural criteria may not necessarily yield the anticipated appearance of a blended fiber strand (El Mogahzy, 2004).

Interactive blending is primarily a technological issue. Different fibers will have different processing behavior depending on a number of factors including surface morphology and fiber resilience. When two or more fiber types exhibiting substantially different surface or resiliency characteristics are blended together, potential processing problems can occur. In addition to the impact of these problems on processing efficiency, they are likely to influence the other modes of blending.

In our previous work, the emphasis was on cotton/cotton and cotton/polyester blending. In this phase of work, the emphasis is on cotton/modal blending. This has become a common blend particularly in the area of high-fashion and soft hand clothing. The focus of this paper will only be on the attributive and interactive aspects of blending.

Why Cotton/ Modal Blend?

Modal is a generic name of a modified rayon fiber that has high tenacity and high wet modulus, made by spinning of regenerated cellulose. Thus, cellulose is the common blood between cotton and modal fibers. However, the type of cellulose used for modal fibers can be obtained from pure beech wood (e.g. Lenzing Modal®). Modal fibers were initially developed in the 1930's for industrial uses in tires, conveyor belts and hose pipes. It is an independent fiber type defined by BISFA (The International Bureau for the Standardization of Man-Made Fibers.) and ISO 2076. Basically the definition contains minimum values with regard to the wet modulus and fiber breaking resistance in a conditioned state. It has a tenacity ranging from 3 to 5 g/denier; elongation from 6 to 14% (dry) and 8 to 20 % (wet); and a stiffness or modulus of 0.5 g/denier in the wet state.

Together, cotton and modal fibers represent a perfect marriage in the world of softness, sensual feeling, and body conscious attributes. Modal provides the necessary dimensional stability and the unique cross section with its serrated edges and cotton provides the natural feel enhanced by the convolutionary surface morphology (see Figure 1). When cotton and modal fibers are successfully blended together, mercerizable and more uniform yarns can be produced and compatible dyeing can be achieved. As a result, this unique blend is used for making a wide range of products from intimate apparel to terry products.

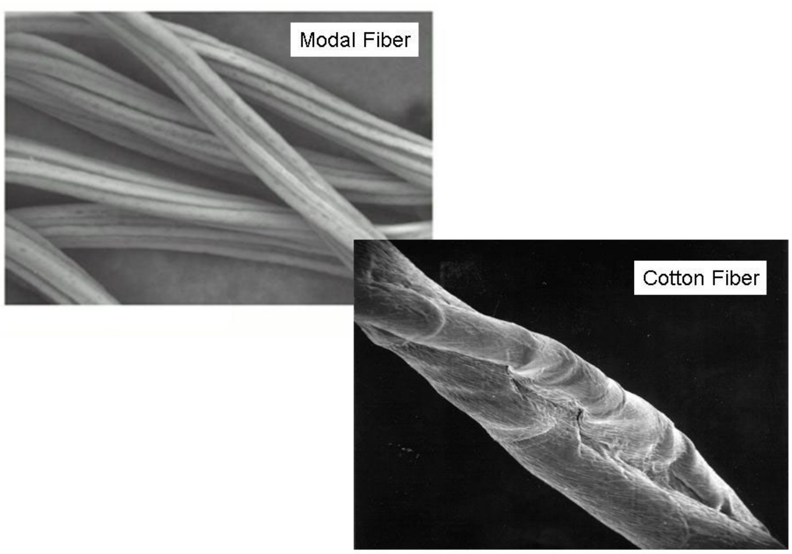

Figure 1. Modal & Cotton Fiber Surface Morphologies

2007 Beltwide Cotton Conferences, New Orleans, Louisiana, January 9-12, 2007

Experiments & Results

The cotton blend used in this study consists of extra long staple (ELS) pima cotton and Modal staple fibers. Pima Cotton has L(w), 33mm and 160 mtex (1.45 denier) measured on AFIS®). Modal has 34 mm length, and 0.90 denier nominal values. In this paper, we report results for 100 % pima cotton, 100% modal and 50%/50% cotton/modal blend. Fibers were blended on a modified Rotor-ring machine (Fig. 2). Rotor-ring settings were: 4 rpm feed roller speed, 3000 rpm opening roller speed and 10000 rpm rotor speed. Only the average net opening torque data were collected in addition to the rotor-ring band width for each run of the fibers on the machine. Consecutive runs expected to do more opening, more fiber alignment and add more projected fiber surface. The results of opening torque and band width are given in Figures 3 and 4.

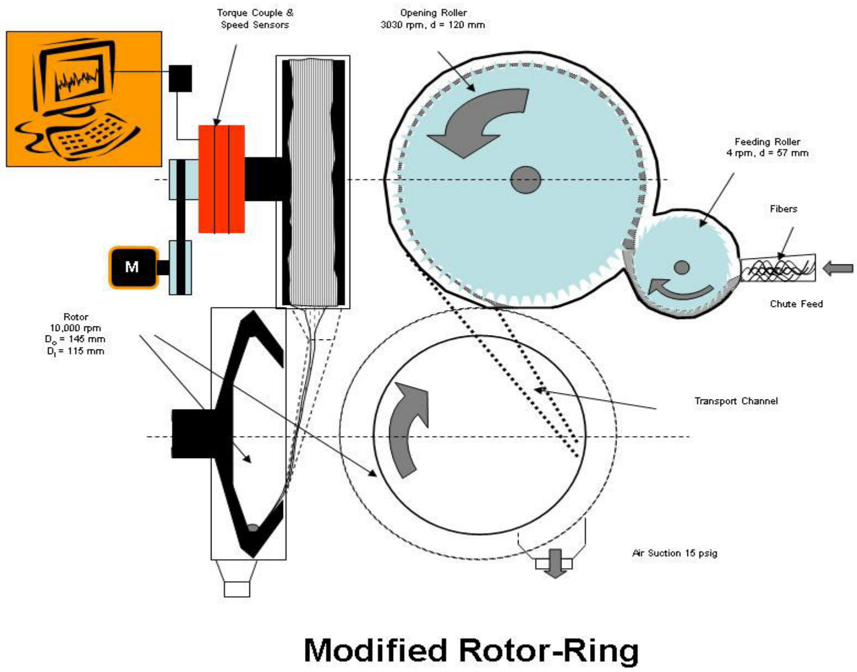

Fig. (2) Modified Rotor-ring Machine

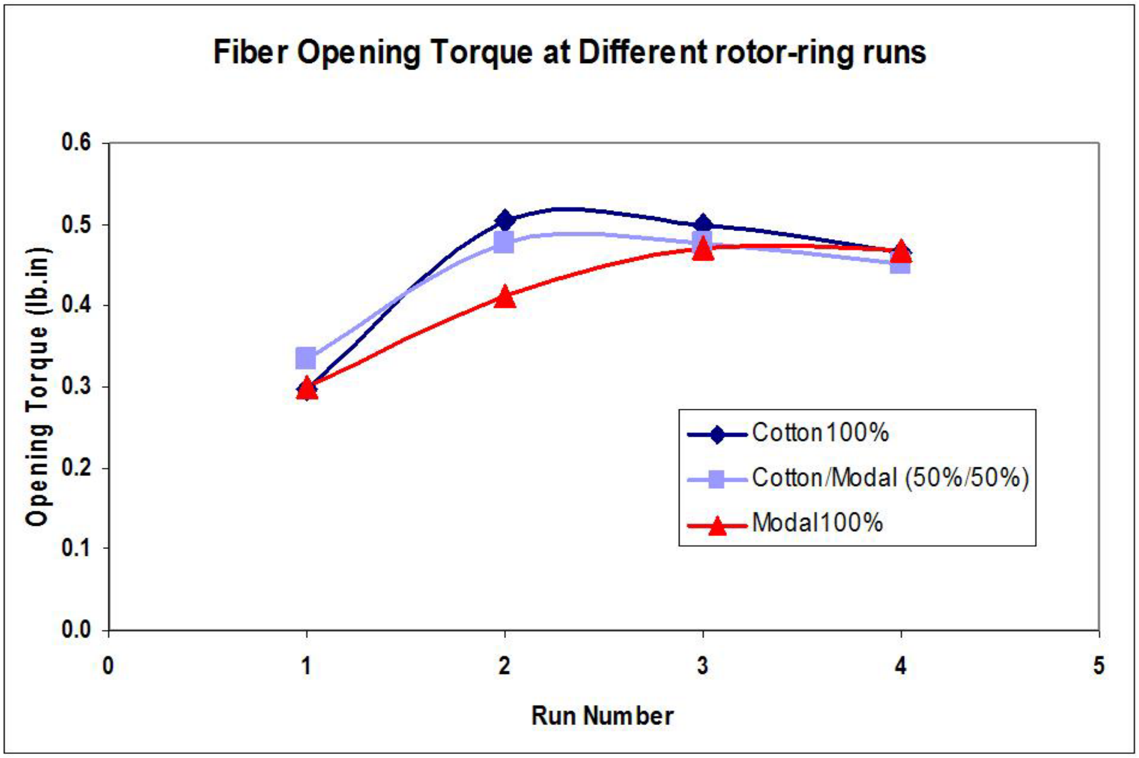

Fig. (3): Average net opening torque measured at the modified Rotor-ring at consecutive runs

As shown in Fig. 3, consecutive runs through the rotor-ring resulted in an increase in the opening torque of cotton fibers to a certain point then it deceased as more opening took place. This phenomenon was also observed in our early studies with many other different cotton fibers, from short to extra long. In case of modal fibers, the opening torque increased with progressive opening then leveled off. The 50/50 cotton/modal blend followed the behavior of cotton fibers.

Figure 4 shows the effect of consecutive runs on the band width. In general, larger band width indicates better openability or lower resistance to opening. As can be seen in Figure 4, band width increased with progressive runs through the rotor-ring. 100% modal fibers had larger band widths than 100% cotton. The 50/50 cotton/modal blend resulted in larger band widths in consecutive runs than the individual fiber components. This indicates that the two fibers in their blended form exhibited better openability.

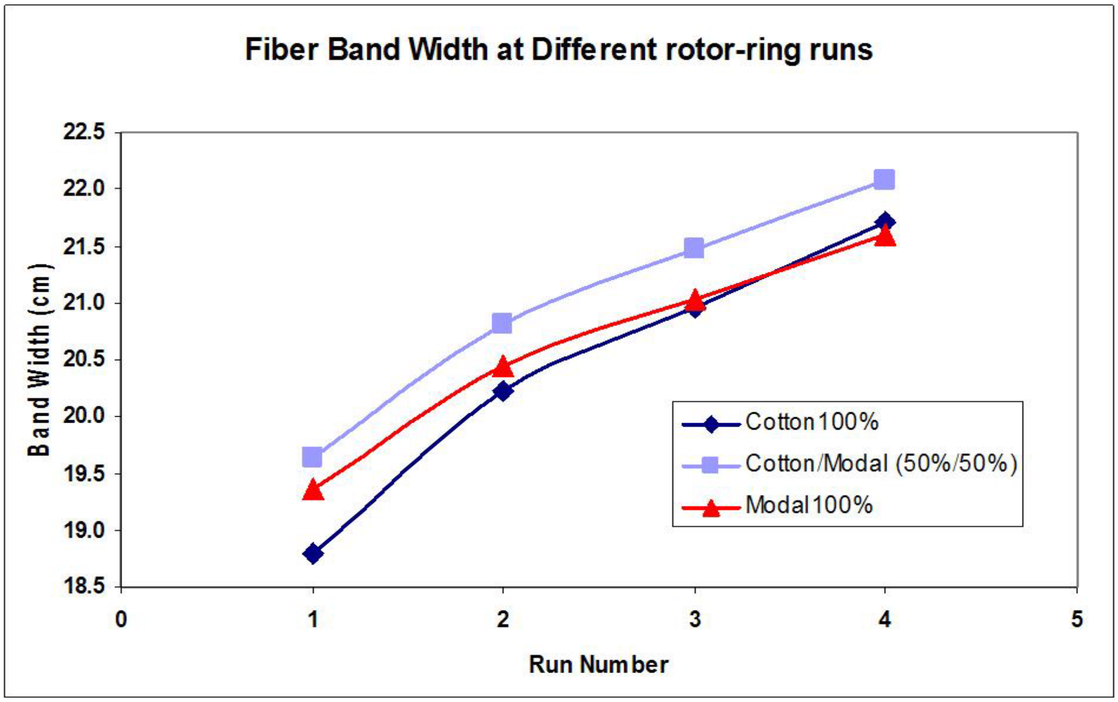

Fig. (4): Average fiber band width measured after consecutive runs on the modified Rotor-ring

Attributive blending was analyzed through evaluation of fiber length distributions of the individual components and the 50/50 blend. As shown in Fig. 5, the 50/50 cotton modal blend followed an intermediate distribution between those of the individual components, however, it was biased to modal fibers as a result of its significant fineness.

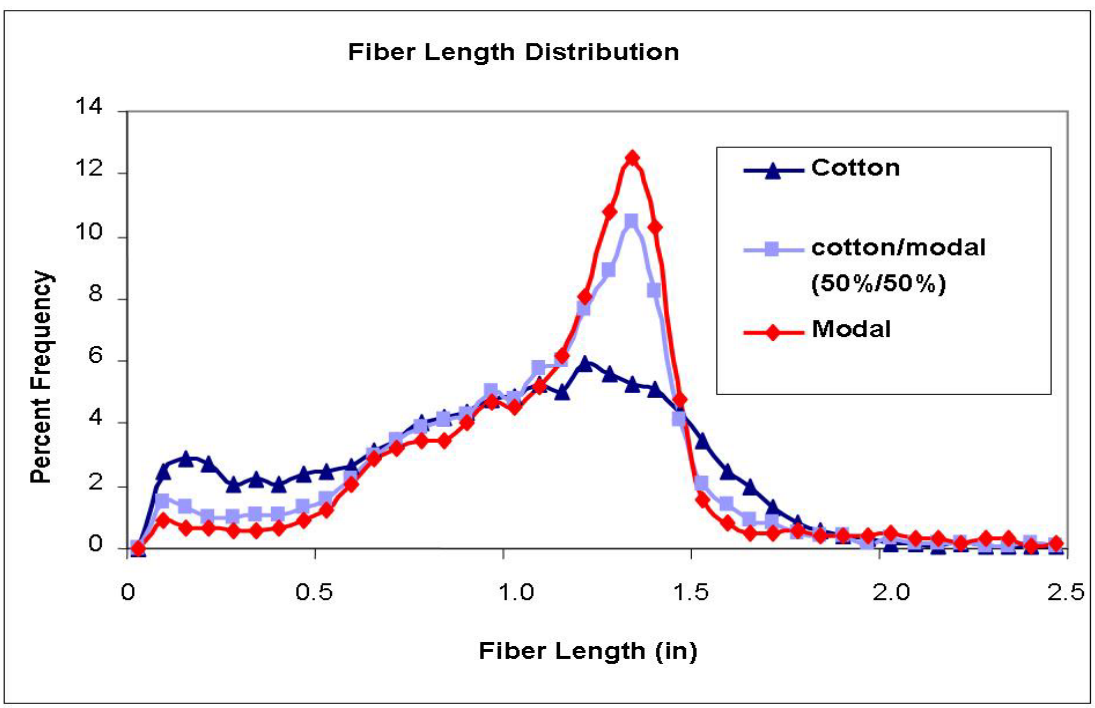

Fig. (5): Fiber Length Distributions of the Single components and the Blend

Attributive blending was also analyzed using cohesion tests. The fiber web (band) resulted from the Rotor-ring after the fifth run was rolled into a sliver. The total weight of the fibers in this sliver was 3 grams and the sliver length was slightly larger than the circumference of the rotor (38 cm). The sliver count was about 8 ktex (110 grains per yard). Sliver cohesion (the force developed during the separation of fiber bundles) was measured on the INSTRON according to the ASTM D2612 “Test Method for Fiber Cohesion in Sliver and Top in Static Tests.” Gauge lengths selected for this study were: 1.00, 1.25, 1.50, 2.00, and 3.00 inches. 6 breaks were carried out for each combination of material and setting.

Figure 6 shows the maximum developed cohesion force at different gauge lengths. At less than 1.5 inch gauge length, a great deal of fiber breakage. These results indicate that the 50/50 cotton/modal blend has lower cohesion force than the individual components. Different ways to illustrate the cohesion behavior of the individual components and the fiber blend are shown in Figure 7 for slivers at 2 inch gauge length, for example. The graphs show the build up of cohesion force with the continuous separation of fibers. The first part of the curve (rising) represents the fiber alignment, disentanglement, and breakage. The second part of the curve (dwelling) represents mostly the fiber to fiber friction. These results indicate that the 50/50 cotton/modal blend has lower cohesion force than the individual components.

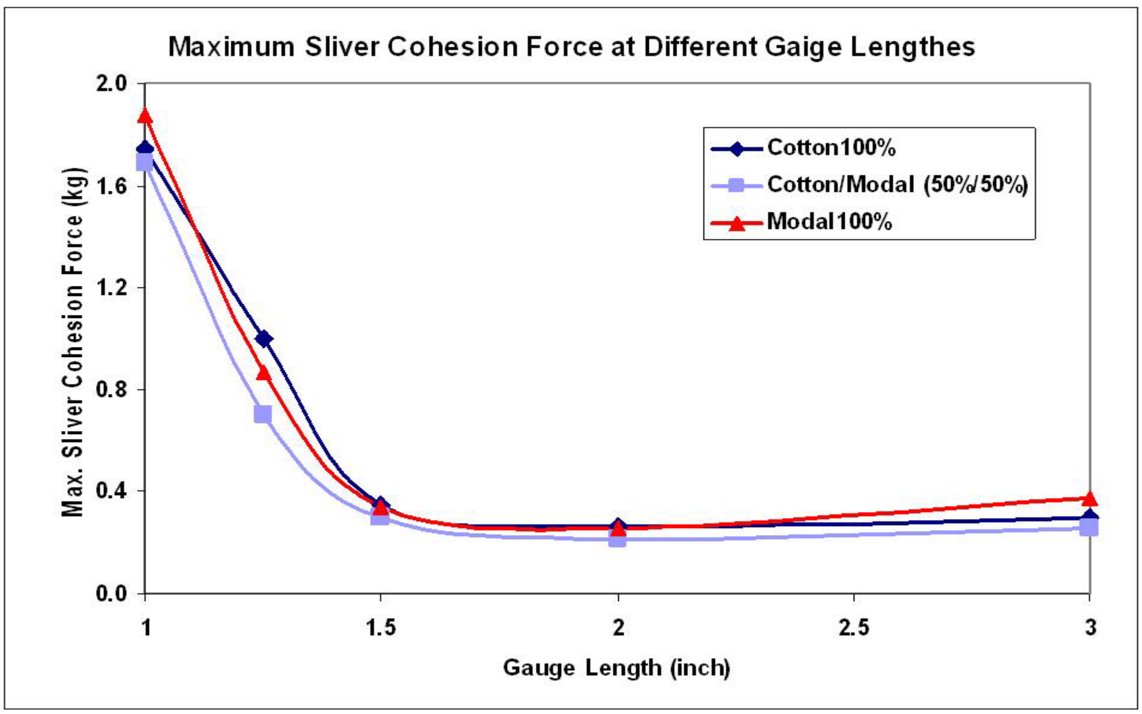

Fig. (6): Maximum Cohesion Force of the Single components and the Blend at Different Gauge Lengths

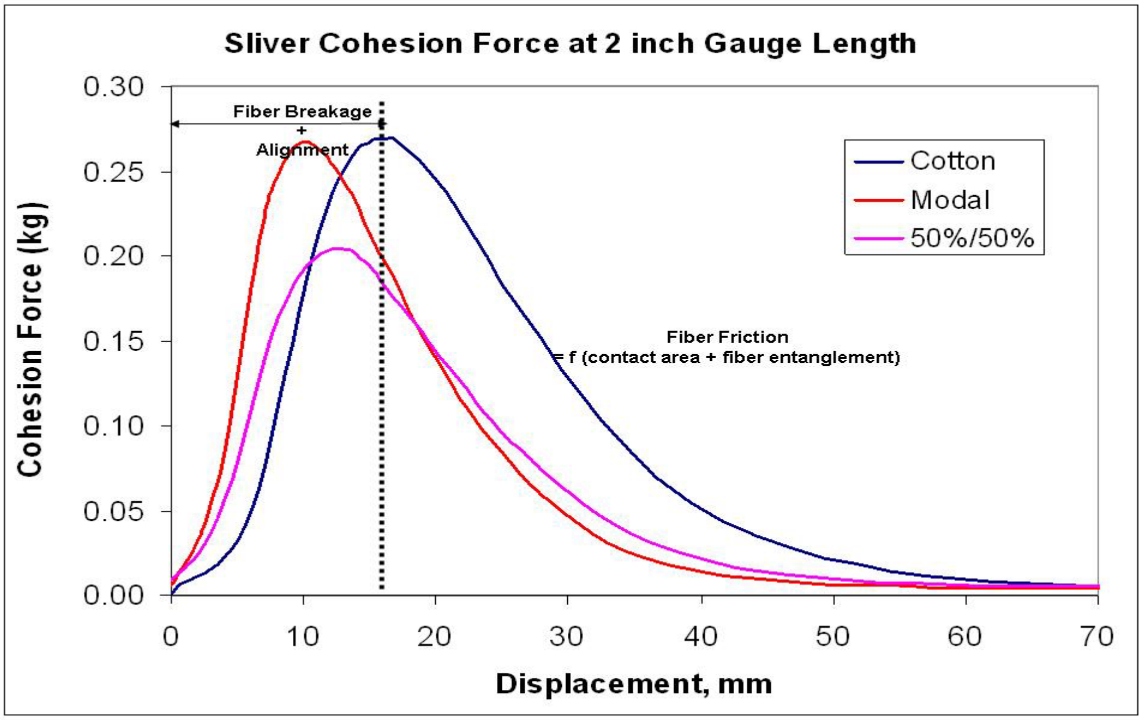

Fig. (7): Sliver Cohesion Force/Displacement of the components and the blend at 2 inch gauge Length

Conclusion

This paper covered a work in progress regarding cotton/modal fiber blends. In general, modal fiber seems to harmonize with cotton and add advantage to cotton in terms of processing propensity despite its superior fiber length and significant fineness. This was evident by the following key observations:

- Rotor-Ring Torque is lower for Modal than for cotton
- Rotor-ring band width for modal is larger than for cotton
- Modal slivers exhibit lower friction cohesion than cotton
- The 50/50 Modal/Cotton blend exhibit larger band width than both components and lower friction cohesion than cotton.

Further analysis and experimental work are performed to achieve in-depth evaluation of this important blend. This analysis will cover yarn and fabric samples to develop a realization of the effect of attributive blending on the quality of end products.

References

Yehia Elmogahzy, “An Integrated Approach to Analyzing the Nature of Multicomponent Fiber Blending;Part I: Analytical Aspects”, TRJ 74 (8), 701-712 (2004)

Yehia Elmogahzy, Ramsis Farag, Faissal Hady, Asaad Mohamed, “An Integrated Approach to Analyzing the Nature of Multicomponent Fiber Blending; Part II: Experimental Analysis of Structural and Attributive Blending”, TRJ 74 (9), 767-775 (2004)

Yehia Elmogahzy, Ramsis Farag, Faissal Hady, Asaad Mohamed, “An Integrated Approach to Analyzing the Nature of Multicomponent Fiber Blending; Part III: Experimental Analysis of Interactive Fiber Blending”, TRJ 75 (12), 833-845 (2005)

Hearle, J. W. S, Grosberg, P., and Backer, S., The Structural Mechanics of Fibers, Yarns, and Fabrics. Wiley-Interscience, NY, 1969.

Zurek, W., The Structure of Yarn, (translated from Polish), Foreign Scientific Publications Department, National Center for Scientific, Technical and Economic Information, Warsaw, Poland, 1975.

Tatjana Krese and Sonja Malej, "Structural characteristics of New and conventional Regenerated Cellolosic Fibers" TRJ 73 (8), 675-684 (2003)

Gordon Cook, "Handbook of Textile Fibres, Volume II: Man-Made Fibres," 5th ed., Merrow, Durham, U.K., 1984.

ASTM D2612 "Test Method for Fiber Cohesion in Sliver and Top in Static Tests"