RELATIONSHIPS AMONG INDIVIDUAL FIBER TENSILE PROPERTIES AND FIBER BUNDLE TENSILE PROPERTIES

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Abstract

This study was performed on the 104 reference cottons for maturity described by Hequet et al. (2006). The samples were tested with the FAVIMAT (gauge length = 10 mm, pre-tension = 0.2 cN/tex, and testing speed = 20 mm/min) with three replications of 150 fibers. Fibers were randomly picked. Data set was inspected for outliers. For most samples, one or two fibers showed discrepancies between the maximal elongation and the elongation-at-break. This revealed fiber slippage and possibly instrument malfunction. These fibers were removed from the data set. Then, the examination of the linear density data revealed a few fibers very high linear densities. This is likely due to breaking two fibers rather than one. These data were also removed from the data set. A total of 46,950 fibers were tested with the FAVIMAT. Among those, 342 fibers were removed from the data set (outliers), corresponding to 0.73% of the population.

The results obtained show an excellent linear relationship between elongation-at-break and work-to-break (r^2 = 0.804) and a relatively poor linear relationship between force-to-break and work-to-break (r^2 = 0.399). It seems that, for this set of samples, the main contributor of the work-to-break is the elongation-at-break. For elongation-at-break, the range of variation among samples is quite large (from 6.1% to 12.7%) while it is narrower for force-to-break (from 3.6 to 6.1 g). It confirms that there is a wide range of variability available in the current cotton germplasm for fiber elongation (the 104 were commercial cotton bales). Unfortunately, at this time, most of the cotton breeders concentrate their effort on improving strength and ignore elongation. The relationship between force-to-break and elongation-at-break is quite weak (r^2 = 0.162) and positive. It is well documented (Benzina et al., 2008) that with bundle tests the same relationship is weak and negative (also true for this set of samples r^2 = 0.126). This negative relationship is one of the reason why the cotton breeders do not work on elongation. They are concerned that improving elongation will result in lower tenacity and possibly discounts.

The relationships between average FAVIMAT tensile properties and HVI bundle properties are all linear with a positive slope and a rather good coefficient of determination. Why do we have a positive relationship among samples with the FAVIMAT (arithmetic average of all fibers tested) and a negative one with the HVI (bundle test)? The main differences between a tensile bundle test and the arithmetic average of individual fibers tensile tests are:

- For the average of individual fibers tensile tests there is no interaction effect among fibers.
- For a bundle test, we have to take into account the possible interactions among fibers during the test that leads to the breakage of the bundle.
    - Among the main effects are:
        - tenacity,
        - elongation,
        - work-to-break of the individual fibers,
        - friction among the fibers in the bundle (related to the number of fibers in the bundle, the residual crimp, and the wax content),
        - and the standard deviation of each of these factors.

Intuitively we understand that a bundle with a large variation in elongation from fiber to fiber will not behave the same as a perfect bundle where all fibers are identical even if the elongation averages are identical (all other fiber properties being constant). The bundle with a large variability in elongation may be weaker because the stress applied to the bundle is exerted first on the low elongation fibers instead of being shared by all fibers equally. The low elongation fibers break first, then the full force is applied to the remaining fibers and due to a cascading effect the whole bundle breaks. Therefore, the relationships between average FAVIMAT tensile properties and their standard deviations were determined. All are linear with a positive slope and a high coefficient of determination. As a result, cottons with high elongation and high standard deviation may tend to have lower bundle tenacity. During

fiber processing the mechanical stress is not applied to bundle of fibers but to individual fibers or small tufts of fibers. Consequently, the individual fiber's work-to-break is extremely important to prevent fiber breakage. Stronger fibers tend to have higher elongation which results in better work-to-break. This could lead to lower fiber breakage during processing.

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References

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