EVALUATION OF ALTERNATIVE INSTRUMENT MEASUREMENTS FOR SELECTED COTTON FIBER PROPERTIES

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Abstract

Relationships among alternative cotton fiber property measurements are examined, their usefulness is evaluated, and suggestions for improving them are offered. Needed changes include wider strength ranges in calibration cottons, an adequate elongation measurement, more information on length distributions, an adequate high-volume trash measurement, a focus on reference cottons for determining fineness and maturity of fibers, and a focus on exploiting the distribution information on major fiber properties.

Introduction

This report derives from an Advanced Technology Program project funded by the Texas Higher Education Coordinating Board. The larger purpose of the project is to improve the objective selection and control of cotton for efficient textile manufacturing.

Biological and environmental variations in cotton fiber properties cause many problems in textile manufacturing. Measurements of these properties are used in models to achieve better processing efficiency and quality control in textile manufacturing (Yehia E. El Mogahzy & al., 1990). Improving these measures and the models based on them will improve cotton's competitiveness as an industrial raw material. Both existing measurements and (mostly linear) statistical models are inadequate to advance the processes of the cotton variety selection and textile quality control to the efficiency levels needed by state-of-the-art textile industries. Improvements based on nonlinear and adaptative models may overcome these limitations.

This report examines measurement results obtained from alternative instruments. The focus is on relationships between alternative measurements of selected cotton fiber properties and between distinct types of cottons (Upland versus ELS).

Material

One hundred ninety-one cotton samples were collected worldwide, representing a wide range of fiber characteristics. The fibers were analyzed as follows:

- Stelometer test - Two technicians executed this according to the ASTM D 1445-95 procedure and using the ICCS cotton C35 as a reference (pressley 1/8 reading level). A check using C35 was done each time the technician returned to his work station. A total of six breaks per sample was done.

- HVI test - The Spinlab 900B HVI machine was used and the ASTM D 4604-95 procedure was followed. Calibration was done using HVI cotton calibration standards (HVICCS) 29407 and 28181 for the first run. For the second run international cotton calibration standards (ICCS) D6 and G15 were used. Three replications were made with two combs per replication. Calibration checks were made periodically throughout the testing.

- AFIS - The first run of the 191 samples was done with an early version of the AFIS. The samples were tested using the Multi Data Mode. The Multi Data measured for length, short fiber content, fiber diameter, neps and trash. The second run was done with a new generation of AFIS instrument. The AFIS autojet length and maturity module was used. Measurements included length, short fiber content, maturity and fineness. For each sample, with both instruments, five replications of 3,000 fibers were made.

- FMT III - The SDL FMT III was used to measure fineness and maturity. Two ICCS cottons, H3 and C35, were used for the calibration of the instrument. Before testing, samples were run through a Fiber Blender to remove trash particles and produce a more uniform sample. Two replications were made for each sample. The ICCS cottons were used at the beginning of each work day to calibrate the instrument. Check tests were made periodically.

- Shirley analyzer - Tests were made using the ASTM D 2812-95 procedure. A sample weighing one hundred grams was divided into three equal parts and placed on the feed table one at a time. Lint that is not clean may be passed through the machine up to three times. All clean lint and all trash is then collected and weighed.

Results and Discussion

Fiber Bundle Strength

Testing was done an HVI 910B instrument with both calibration cottons, i.e., HVICCS and ICCS. For the calibration with the HVICCS, the weak cotton value was 23.8 g/tex and the strong cotton value 33.7 g/tex. The range of strength for the tested cottons with this calibration was from 24.3 g/tex to 44.4 g/tex. Measurement results revealed strength values higher than the value of the strong calibration cotton in 47.6% of the cases. Thus, the HVI

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software has to extrapolate these values, resulting in a large increase in measurement error. Most of the breeding programs in the world are working to develop new varieties with higher strength and it is quite common to get new lines with 35 g/tex or higher. Therefore, to get a reliable HVI strength value, a wider range of strength for the calibration cottons will be useful.

For the HVI calibration using the ICCS cottons, we have made the choice of the G15 and D6 cottons with a strength value respectively of 20.6 g/tex and 33.3 g/tex. The range of the measurements obtained was from 19.5 g/tex to 34.6 g/tex. Seven strength measurements (3.7% of the tested cottons) were lower than the weak cotton, but just one strength measurement (0.5%) was higher than the strong calibration cotton.

The HVI results, calibrated with both the HVICCS and the ICCS cottons, were compared with those obtained using the Stelometer calibrated at the Pressley 1/8 level. With the HVICCS cottons, regressing HVI strength on Stelometer strength resulted in a coefficient of determination (R2) of 0.87 (Figure 1).Using ICCS cottons, the resulting R2 when regressed on the Stelometer strength measurements increase to 0.91 (Figure 2). Regressing HVI strength with HVICCS calibration on HVI strength with ICCS calibration resulted in a R2 value intermediate between these, at 0.89 (Figure 3).

For the HVI tests using the HVICCS cottons, the total population was divided into two sub- populations; i.e., 137 upland types and 54 ELS types. The linear regressions with the Stelometer results show (Figure 4) that the slope for the upland cottons is very close to one (0.97), but the slope decreases to only 0.49 for the ELS; furthermore, the R2 value drops substantially (from 0.79 to 0.44).

At this time, it is not possible to say whether the foregoing results are from an instrument bias or a calibration bias. If the same procedure is done using ICCS cottons, the two slopes are not statistically different. Further examination of these results will be necessary.

For the period 1987 to 1996 (Hunter, 1997) the average inter-laboratory variation (CV's) using stand-alone instruments for the strength tests was 6.4%, but only 4.9% for the HVI. On our 191 samples the intra-sample distributions of CVs (Figure 5) reveal lower CVs using HVI (ICCS calibration). Therefore, with HVI you can lower both intra-sample variability and inter-laboratory variability. Nevertheless, this higher reproducibility could probably be improved using a better calibration procedure for HVI and a wider range of fiber characteristics for the calibration cottons.

The bundle strength of fibers is related to the strength of the individual fibers (Sasser, 1991)and to the number of fibers within the bundle. The higher the number of fibers or the lower the fiber fineness for a constant bundle weight, the higher is the bundle strength. We can get an estimate of the fiber fineness using FMT micronaire, FMT fineness, AFIS diameter, and AFIS fineness. The correlations between these parameters and the stelometer strength are respectively -0.10, -0.44, -0.83, and -0.61. The AFIS diameter is a direct measurement and, as shown in Figure 6, seems to be a very good indicator of fiber fineness.

Fiber Bundle Elongation

For the cotton population studied, the bundle elongation for the Stelometer is in the range 4.50% to 8.75%. For the HVI the range is narrower, going from 4.8% to 7.9%. The correlation between the two instruments is very poor (r = 0.35).

Fiber Length Distribution

A very strong relationship was evident between the HVI 2.5% SL (span length) and the HVI UHML (upper half mean length); the R^2 value is 0.96 (Figure 7). Using both generations of AFIS instruments the agreement is also very good with the HVI UHML (Figure 8). However, the new generation of AFIS gives a longer length than the old generation (0.03 inch on the average) and the coefficient of determination with the HVI UHML is slightly lower (0.93 vs 0.96). This behavior stayed consistent with the HVI 2.5% SL.

For the Mean Length (Figure 9), the agreement between the AFIS ML and the HVI ML is good (R^2 = 0.93) for the old generation of AFIS instrument, but deteriorates with the new generation (R^2 = 0.86). In both cases the AFIS Mean Lengths are slightly higher than those obtained with the HVI (0.01 to 0.02 inch on the average). The Mean Lengths obtained with the two AFIS instruments are very close (0.01 inch of difference in average).

In general, the higher the fiber length, the lower the short fiber content (SFC) by weight in the fiber population. Figure 10 shows the relation between the AFIS SFC and the HVI UHML. The coefficient of determination is quite good for the old generation AFIS, but much lower for the new generation of AFIS instrument.

With the HVI instruments two length parameters are available for each type of calibration: (1) the UHML and the Uniformity Index (UI), when calibrated with theHVICCS, and (2) the 2.5% SL and the Uniformity ratio (UR), when calibrated with the ICCS. Given that the agreement between HVI and AFIS is good for the UHML and 2.5% SL, the other question is: Are the uniformity parameters given by the HVI representative of a fiber distribution parameter such as the SFC?. The comparisons shown in Figures 12 and 13 are not very encouraging. The coefficient of determination between SFC and UI% is not too bad for the old generation of AFIS (R^2 = 0.54), but rather low for the new generation (R^2 = 0.39). There is a complete lack of correlation between SFC and UR%. For the CV of the length by weight, the correlations are -0.39 and -0.36 with UI% and UR% respectively.

One of the most widely accepted generalizations regarding relationships among fiber properties is that fiber length is positively related to fiber strength and fiber fineness. Alternative estimates of fiber fineness are available from the micronaire, FMT fineness, AFIS diameter and AFIS fineness. The correlations between these parameters and the HVI UHML are, respectively, -0.14, -0.44, -0.88, -0.65. As shown in Figure 14, the AFIS diameter is highly correlated with length ($R^2 = 0.75$ with HVI UHML and $R^2 = 0.78$ with HVI 2.5% SL). This indicates that exclusion of fiber diameter from output of the new generation of AFIS has resulted in the loss of valuable information.

Trash Content

The ITC uses the Shirley Analyzer as the reference test for trash content. It is logical to expect that the HVI Leaf grade will be positively correlated with trash content measured with the Shirley Analyzer. However, our results clearly showed that there is no correlation between these two measurements (Figure 15).

Among the 191 cottons tested, the percentage of trash using the Shirley Analyser ranges from 0.6% to 19.4%. The number of foreign particles using the AFIS ranges from 24 to 12,539. To better discriminate between the cottons, a log transformation was applied to the AFIS trash (Figure 16). This revealed that a fraction of the Upland population is distinctly different from the rest of the Upland and ELS groups. These cottons seem cleaner than the others with the AFIS but not with the Shirley Analyzer. The reason for this difference is unknown.

The correlation between AFIS trash (done by counting) and Shirley Analyzer trash (done by weight) is good for the Upland cottons (both groups) but rather poor for the ELS types. This may be due to the differences in the ginning processes-saw ginning versus roller ginning. For example, the size of trash particles may be more variable in ELS than in Upland cottons, so that the number of particles does not reflect the trash weight in the same way.

Fiber Fineness and Maturity

The relation between the HVI micronaire and the FMT micronaire is very good. The $R^2 = 0.93$, the slope of the regression line is very close to one and the intercept very close to zero. However, agreement between the FMT III and the AFIS (Figures 17 and 18) is quite poor for both fineness ($R^2 = 0.54$) and maturity ($R^2 = 0.49$).

The range of fineness for these cottons was 106 to 217 mtex for the FMT III versus 128 to 175 for the AFIS. Knowing the very broad types of cottons collected all around the world for this research project, it must be concluded the AFIS results are errorenous. Examination of the maturity measurements shows the same tendency, with the maturity ratio ranging from 0.54 to 1.13 with the FMT III versus 0.73 to 0.96 for the AFIS.

The unacceptable fact is that we do not have any calibration cottons for fineness and maturity that are recognized internationally. A set of calibration cottons using the accepted reference method--image analysis of the cross section of the fibers-must be established for use in calibrating laboratory instruments.

Conclusions

The fiber database used in this report will be enlarged substantially. Around 200 additional cottons are currently under evaluation. All of these will be evaluated for spinning performance (for both ring and rotor spinning). Depending on the fiber properties, both carded and combed yarns will be included.

The usefulness of cotton fiber property measurements--to achieve better processing efficiency and quality control in textile manufacturing-depends on the quality of the measurements. Clearly, fiber measurement techniques need to be improved if we are to reach higher levels of success. These include the following:

- For HVI strength calibration, current HVICCS cottons do not provide a wide enough range of strength values. Furthermore, the linearity of the machine data for a wider range must be checked.

- The elongation measurements from current HVI machines are not consistent.

- More information is needed on properties of length distributions than is currently provided by the HVI. This information is available with AFIS instruments, but calibration problems must be solved.

- Trash measurements from the HVI are clearly inadequate. The AFIS provides much better data, but it will probably be necessary to combine the total number of trash particles with the size distribution to achieve a useful measure of trash content.

- The evidence indicates that AFIS measurements of fineness and the maturity are inferior to FMT measurements. It remains to be determined whether the ITC's new generation AFIS machine is not functioning as well as others. Moreover, until authoritative reference cottons are available it will be necessary to rely on analysis of yarn data to determine which estimates are better.

- A diameter measurement, which was provided by the old generation of AFIS but not by the new generation, appears to be a fundamentally important measurement.

- It is increasingly feasible for instruments like the HVI and the AFIS to provide a wealth of information on distributions of fiber properties. Currently the AFIS provides only the mean value of maturity and a measure of the IFC (immature fiber content). But much more information on the moments of the maturity distribution could be collected and provided as output. The statistical techniques currently used by the textile industry would have to adjust in order to use the additional information. For example, the focus has been limited to making multiple comparisons among means, rather than comparisons among both means and variances. This will be necessary if we are to use more of the available information on fiber properties to improve efficiency of textile manufacturing.

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El Mogahzy Yehia E. & al. 1990. A statistical approach for determining the technological value of cotton using HVI fiber properties. Textile Research Journal, Vol. 60, N 9.

Sasser Preston E. 1991. Interpretations of single fiber, bundle, and yarn tenacity data. Textile research Journal, Vol. 61, N11.

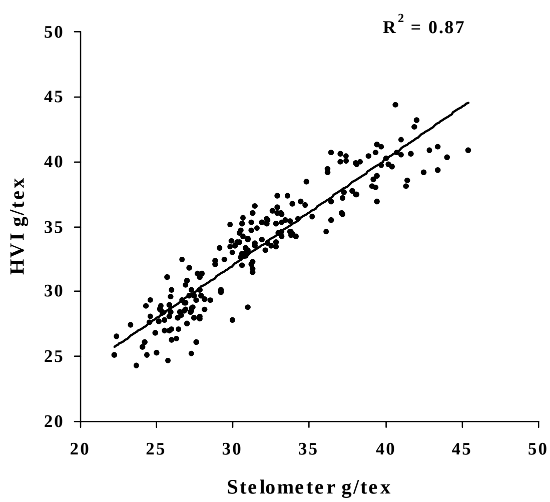

Figure 1. HVI Strength (HVICCS calibration) vs Stelometer strength.

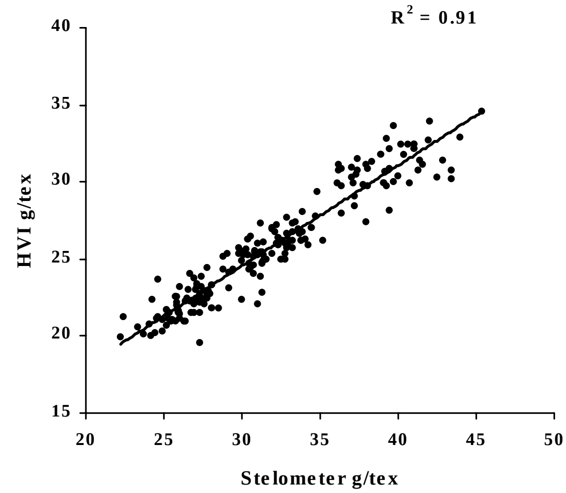

Figure 2. HVI strength (ICCS calibration) vs Stelometer strength.

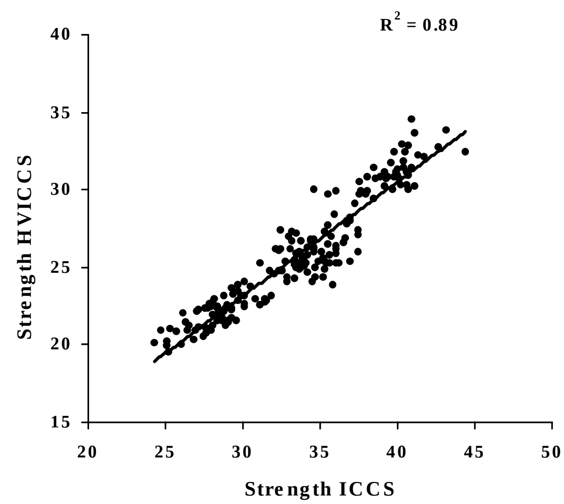

Figure 3. HVI strength (ICCS calibration) vs HVI strength (HVICCS calibration).

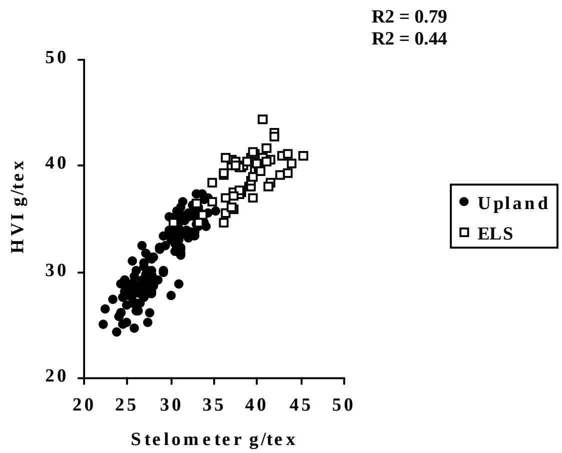

Figure 4. HVI strength (HVI CCS calibration) vs Stelometer strength.

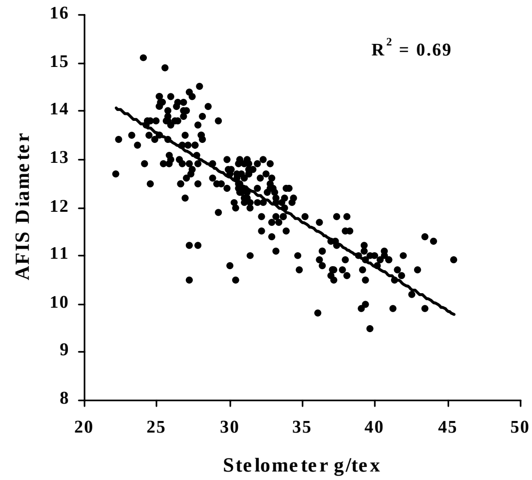

Figure 6. AFIS Diameter vs Stelometer strength.

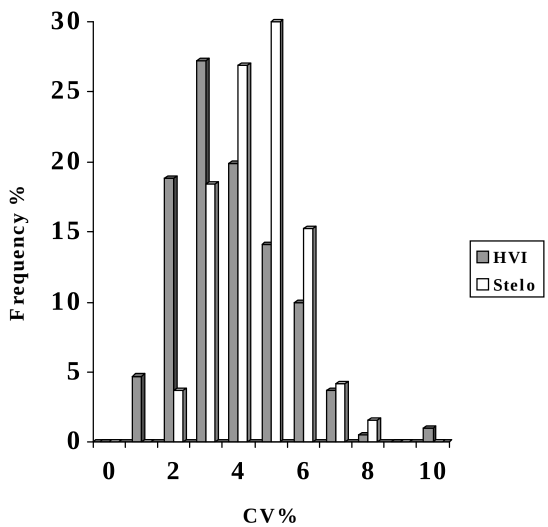

Figure 5. Intra-sample CV's distribution for strength.

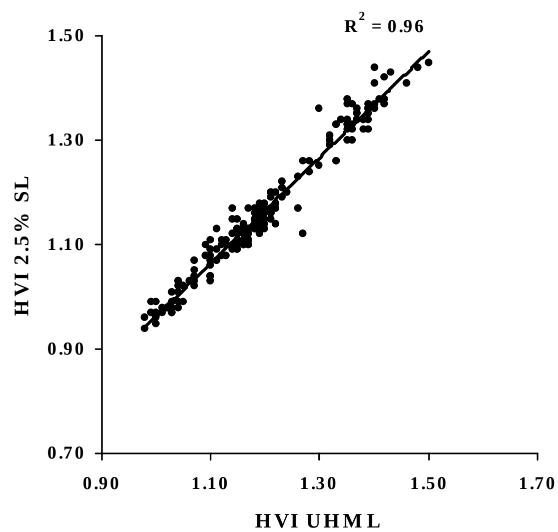

Figure 7. HVI 2.5% Span Length vs HVI Upper Half Mean Length.

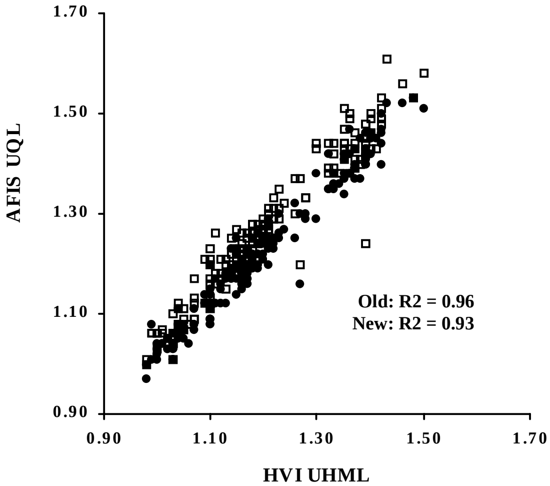

Figure 8. Upper Quartile Length old and new AFIS vs HVI Upper Half Mean Length.

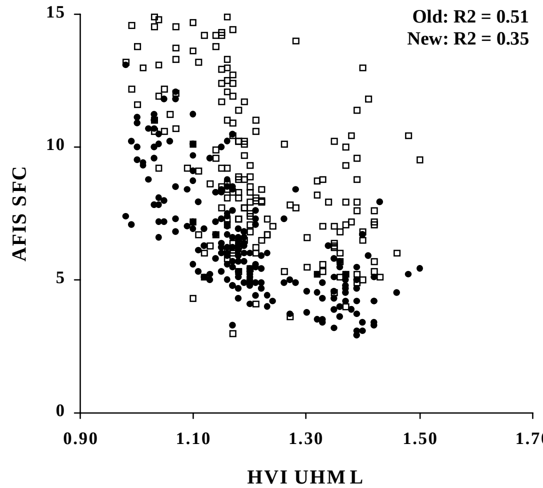

Figure 10. Short Fiber Content old and new AFIS vs HVI Upper Half Mean Length.

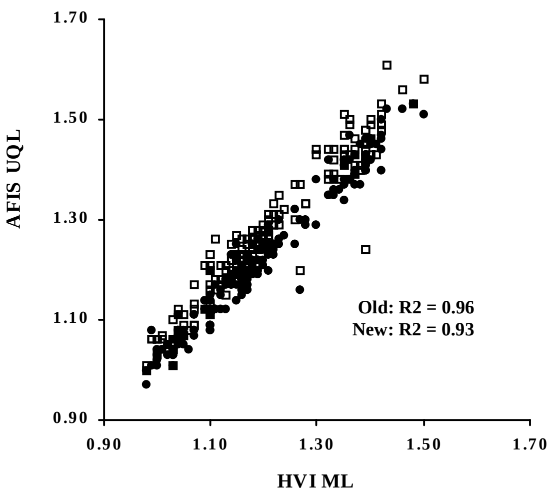

Figure 9. Mean Length old and new AFIS vs HVI Mean Length.

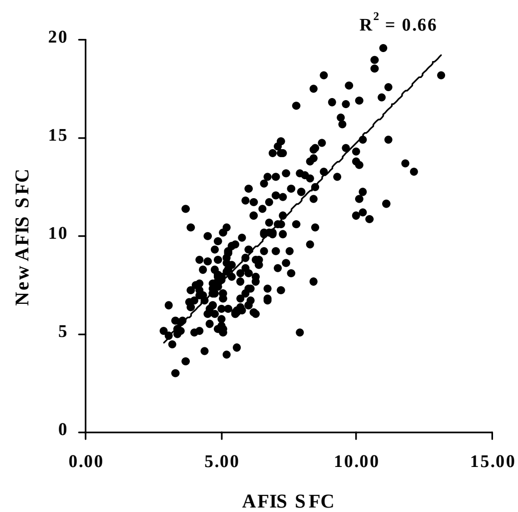

Figure 11. New AFIS Short Fiber Content vs Old AFIS Short Fiber Content.

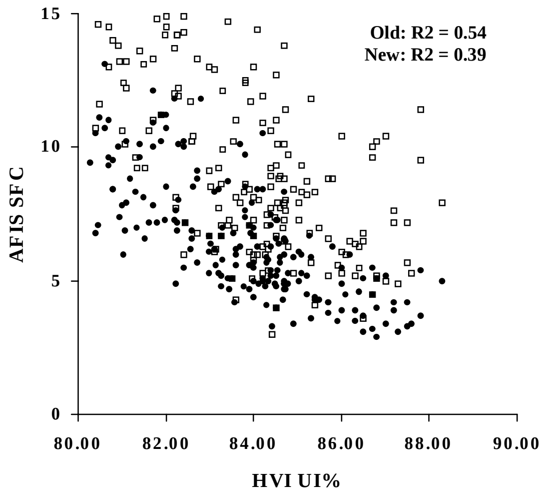

Figure 12. Short Fiber Content old and new AFIS vs HVI Uniformity Index.

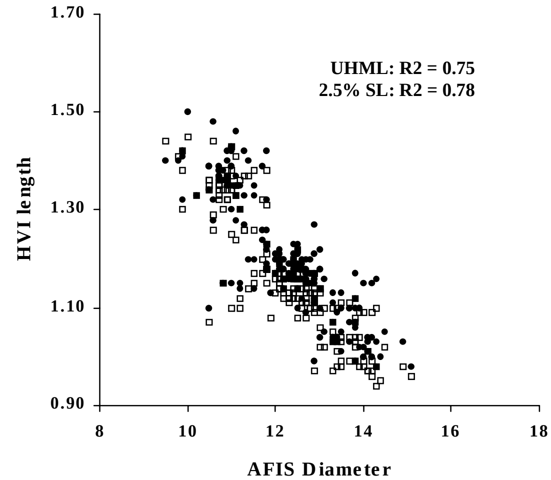

Figure 14. HVI lengths (Upper Half Mean Length and 2.5% Span Length) vs AFIS Diameter.

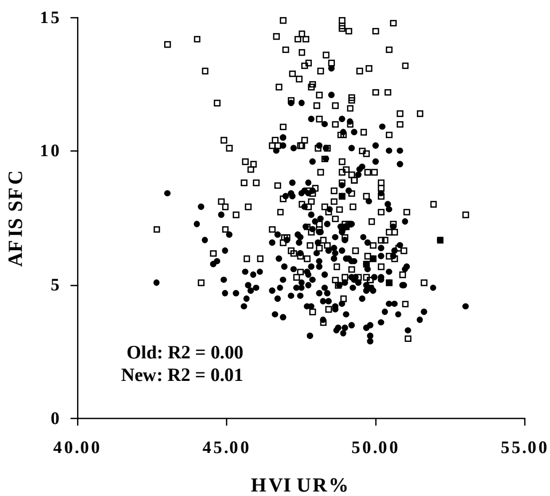

Figure 13. Short Fiber Content old and new AFIS vs HVI Uniformity Ratio.

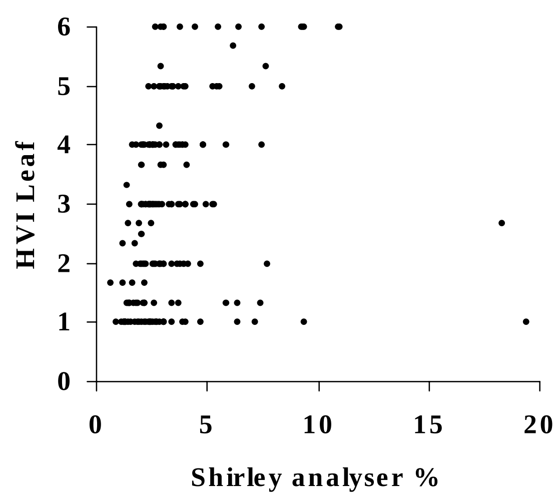

Figure 15. HVI Leaf vs Shirley Analyser %.

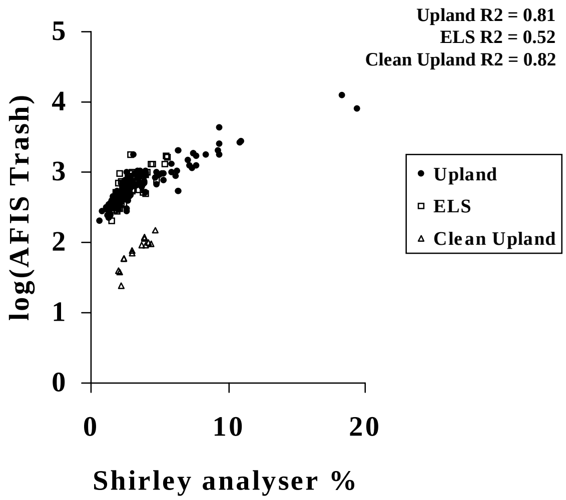

Figure 16. log (AFIS Trash) vs Shirley Analyser %.

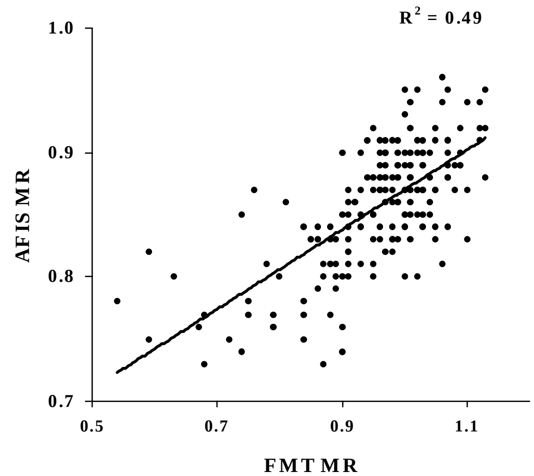

Figure 18. AFIS Maturity Ratio vs FMT Maturity Ratio.

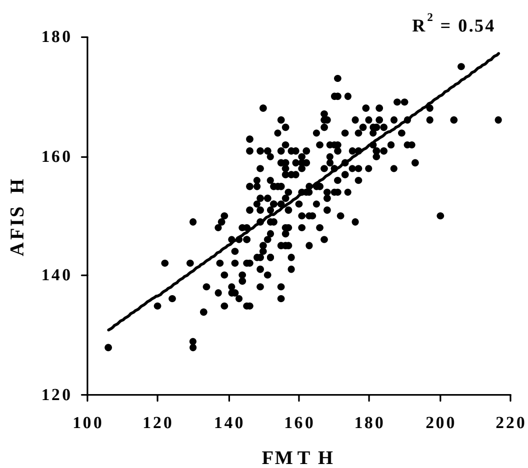

Figure 17. AFIS fineness vs FMT Fineness.