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EVALUATION OF KEY HYPOTHESES ASSOCIATED WITH HVI AND AFIS FIBER QUALITY MEASURES

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Abstract

This paper revisits two existing fiber testing systems and questions the validity of some of the parameters they generate. These are the HVI system and the Advanced Fiber Information System. Both systems are commercially produced by Zellweger Uster of Knoxville, TN. Using correlation and cluster analyses, four hypotheses about cotton fiber characteristics produced by the HVI and AFIS were examined. A wide range of cotton and cotton waste categories was used. As a result of evaluating these hypotheses, the analysis concludes that Micronaire value reflects the fineness and maturity of cotton fibers when samples of low trash levels are tested. When samples of high trash levels are tested, the Micronaire reading becomes largely unreliable. Cotton maturity as estimated by the AFIS exhibits a significant correlation with short fiber content. This makes AFIS maturity measures largely in doubt when samples of high short fiber content are tested. The color Rd value produced by the HVI system typically reflects the cotton sample color, not the cotton inherent color. This is a result of the failure of the HVI system color meter to segregate between fiber color and trash color. HVI and AFIS measures of trash largely agree in trend. However, this agreement only holds up to a certain level of trash content beyond which the HVI trash measure becomes insensitive and fails to reflect the true trash content in the sample.

Introduction

Over the years, many studies of cotton quality have been largely based on performing correlation or association analysis between different fiber attributes (El Mogahzy *et a1*, 1995, 1998, 2000). The extent of these correlations often reveals important information regarding the interactive nature of cotton fiber properties. It's conceivable that a fiber attribute measured by one instrument may differ considerably from that measured by another instrument, even from the same make. So, to evaluate and to improve the accuracy and precision of the measurements, correlations between different testing methods and testing instruments should be carried out (Knowlton, 2004, Cui *et al*., 2003, Frydrych and Matusiak, 2000, 2005). This paper continues with this tradition but in a different manner in which correlation analysis is used to test a number of physically justifiable hypotheses that have hardly been questioned in past studies. These hypotheses are as follows:

- Hypothesis 1: Micronaire value fully reflects the fineness and maturity of cotton fibers
- Hypothesis 2: AFIS maturity ratio truly reflects the extent of maturity of cotton fibers
- Hypothesis 3: HVI color parameters, particularly Rd, fully reflects the inherent color of cotton fibers
- Hypothesis 4: HVI trash count truly reflects the percent of trash in a cotton bale

These hypotheses are tested in this paper using a very large set of data consisting of over 550 cotton samples covering the following fiber types:

1. Cotton linters- these are the short fibers left on the cotton seed after ginning and extracted at the oil mill using machines similar to gins, but with circular saws and finer teeth. First-cut linters are used in manufacturing absorbent cotton, medical pads, mop and carpet yarns or to produce felts or batting for use in mattresses, other bedding products, and in cushioning for furniture and automobiles
2. Comber noils- these are fibers that are extracted during the combing process in which the typical purpose is to remove short fibers and neps
3. Upland cotton samples- these represent most of the cotton samples used in this study. They include cotton samples obtained from different states and USDA calibration cottons with extreme levels of fiber length and fineness
4. Extra-Long Staple (ELS) cotton samples- this is a small number of samples representing cottons of extra long-staple fibers typically used for producing fine and extra fine yarns

Tables 1 and 2 provide summary statistics of the data of all the cotton samples tested in this study. HVI and AFIS were calibrated according their own procedures and passed the calibration as specified (Zellweger Uster 2004 and 1996).

Table 1. Summary Statistics of Fiber Samples used: HVI Data

Cotton		Mic	Mat	Len [in]	Unf %	SFI %	Str g/tex	Elong %	Rd	+b	Trash Cnt	Trash Area
Upland	min	4.01	0.87	1.04	79.5	7.6	24.2	6.4	7.0	5.5	2	0.04
	max	5.20	0.92	1.16	83.6	10.4	32.2	7.8	10.2	7.9	73	1.19
	Ave.	4.63	0.89	1.09	81.5	8.9	27.5	7.1	8.5	7.0	24	0.30
USDA cotton	min	2.53	0.77	0.93	77.1	6.8	23.4	5.8	9.5	6.5	5	0.01
	max	5.24	0.92	1.22	84.9	13.5	33.9	8.7	15.9	8.1	25	0.32
	Ave.	4.13	0.87	1.08	81.3	9.4	28.4	7.3	12.4	7.1	12	0.13
ELS	min	2.70	0.78	0.95	75.1	3.4	23.9	3.8	8.0	7.3	4	0.08
	max	5.50	0.93	1.44	89.5	17.4	44.0	5.5	14.3	8.3	24	0.57
	Ave.	4.03	0.88	1.23	83.6	8.2	34.0	4.7	10.5	7.8	14	0.21

Results and Discussions

Hypothesis 1: Micronaire Value Fully Reflect the Fineness and Maturity of Cotton Fibers

The theory of Micronaire device is based on measuring the air flow through a sample constituted of randomly oriented fibers. AFIS calculates the fiber fineness in millitex from measured fiber diameter and assumed density. Figure 1 shows the value of Micronaire reading and AFIS fineness (millitex) for the different cotton samples tested in this study. As can be seen in this Figure, cotton linters exhibit exceptionally high Micronaire values. These high values were not fully supported by AFIS fineness values; instead the AFIS fineness values were in the middle to high range. Another noticeable observation of this Figure is the leveling-off of AFIS fineness values associated with an increase in Micronaire over some of the Upland cotton samples. This observation is further illustrated in Figure 2, which shows a wide scatter of finesses over a certain level of Micronaire reading. Generally, a lack of good correlation between fineness and Micronaire is attributed to the well-known fact that Micronaire is a combined index of both fineness and maturity. However, a closer look at some of the samples that exhibited approximately the same Micronaire, yet a wide range of AFIS fineness (e.g. points A, B, and C, Figure 3) reveals interesting results. These three samples exhibited approximately the same Micronaire values, also the same maturity, yet a wide range (34 points) of millitex. As can be seen in the data listed with the Figure, the key difference was in the trash levels of these samples. The Micronaire-Fineness relationship was corrected by removing of trash-biased points in the data. The correlation coefficient r was increase to be 0.844.

Table 2. Summary Statistics of Fiber Samples used: AFIS Data

Cotton		L(w) [in]	SFC (w) %	L(n) [in]	SFC (n)%	Fin. mTx	MR	Nep Cnt/g	SCN Cnt/g	Dust Cnt/g	Trash Cnt/g	VFM [%]
LINTERS	min	0.50	43.0	0.27	76.4	168	0.69	1188	399	3266	447	15.90
	max	0.63	57.1	0.34	85.3	176	0.74	1476	533	6011	824	23.66
	ave.	0.56	49.8	0.30	80.9	172	0.71	1327	470	4210	555	18.49
COMBERS	min	0.43	17.0	0.33	39.1	135	0.73	235	3	88	1	0.07

	max	0.82	72.1	0.63	86.2	177	0.86	1242	134	799	94	1.91
	ave.	0.61	47.1	0.42	71.0	147	0.76	678	27	237	19	0.35
REGINS	min	0.75	11.4	0.50	29.4	153	0.73	571	29	255	61	1.44
	max	0.91	26.1	0.72	58.4	184	0.88	1741	134	1600	279	6.64
	ave.	0.82	18.5	0.62	41.8	170	0.81	972	69	545	134	3.54
Upland	min	0.90	6.7	0.74	19.3	154	0.82	144	8	63	9	0.27
	max	0.99	10.8	0.84	27.5	182	0.88	367	38	1495	202	5.38
	ave.	0.95	8.4	0.79	22.9	168	0.85	237	20	500	70	1.90
USDA cotton	min	0.75	5.2	0.60	16.7	147	0.77	152	6	56	23	0.55
	max	1.07	19.2	0.91	39.9	191	0.93	1160	42	755	96	2.20
	ave.	0.92	10.8	0.75	26.9	168	0.86	404	20	317	51	1.25
ELS	min	0.82	1.8	0.66	11.7	135	0.76	77	1	188	26	0.66
	max	1.24	14.5	1.05	34.3	198	0.95	800	25	1151	144	3.17
	ave.	1.06	6.6	0.88	19.7	159	0.87	271	12	571	60	1.45

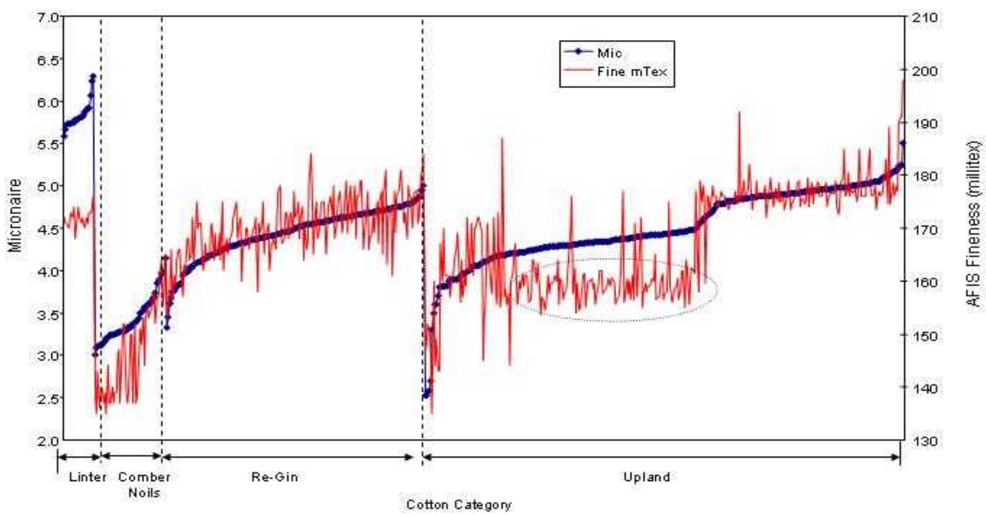


Figure 1. HVI Micronaire and AFIS Fineness of Different Cotton Types

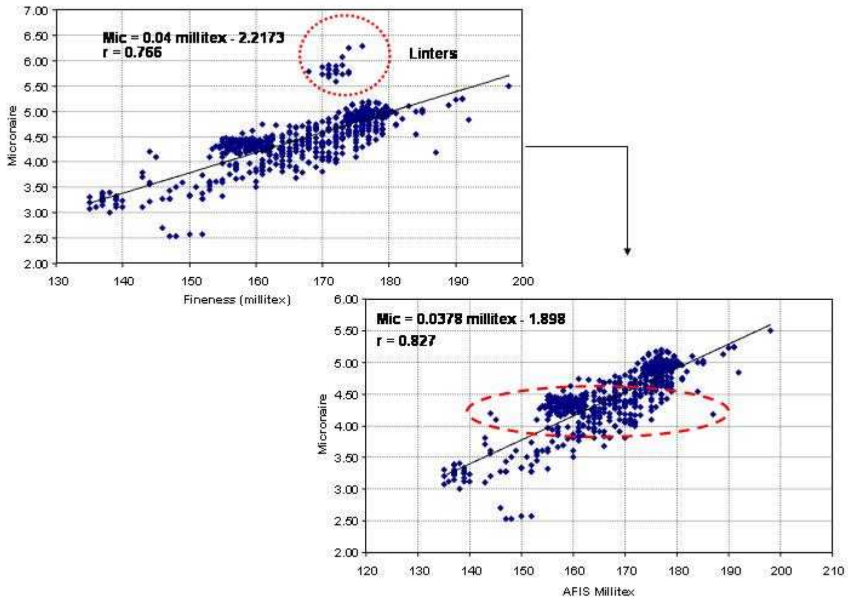
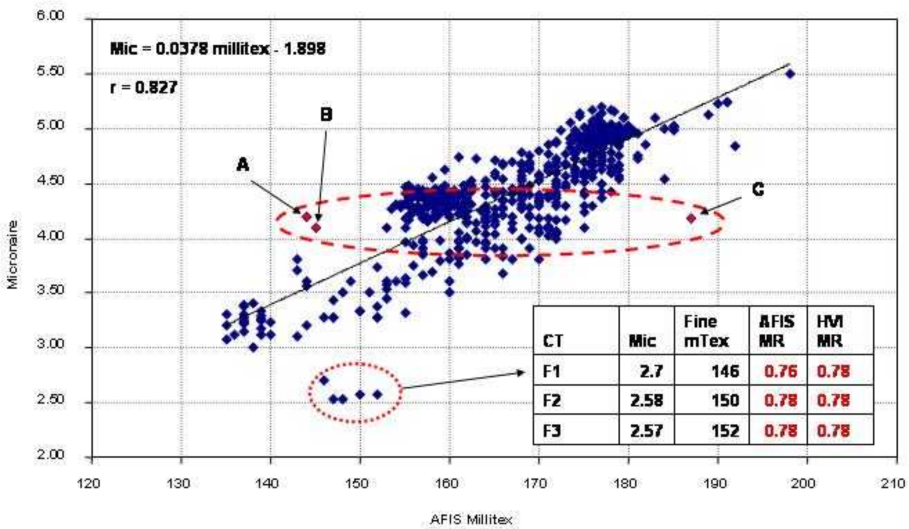


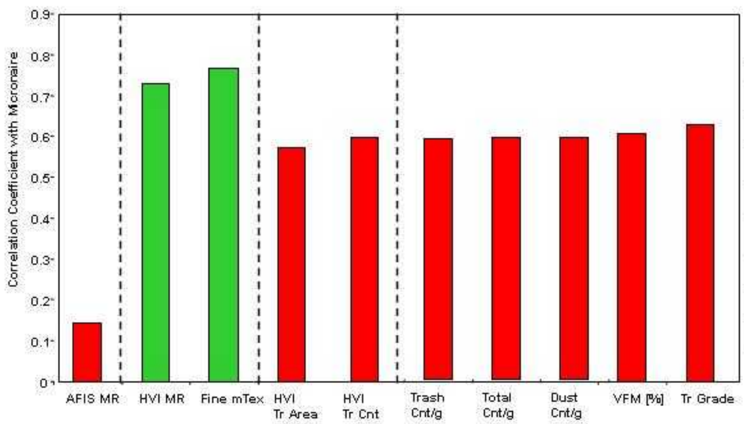
Figure 2. HVI Micronaire vs. AFIS Fineness



CT	Mic	Fine millitex	AFIS MR	HVI MR	AFIS T/g	AFIS Dust/g	AFIS Total/g	HVI TG	HVI TC	VFM [%]
A	4.2	144	0.88	0.92	1148	144	1292	4	24	3.17
B	4.1	145	0.88	0.92	1151	73	1224	4	20	2.08
C	4.18	187	0.9	0.89	339	43	383	2	12	1.04

Figure 3. Specific HVI Micronaire and AFIS Fineness Values

In light of the above results, the hypothesis that Micronaire value fully reflects the fineness and maturity of cotton fibers can be in doubt when samples of high trash levels are tested. Figure 4 shows the correlation coefficients between Micronaire and other fiber properties such as fineness, maturity, and trash parameters. As can be seen in this Figure, there is a good positive correlation between Micronaire reading and all trash parameters measured by the AFIS and the HVI system. Note that these correlations were obtained after excluding the cotton linter data. It is important therefore that the Micronaire reading be corrected for the impact of trash content on its reliability.



FP	Mic
AFIS MR	0.1444
HVI MR	0.7301
Fine mTex	0.7657
Tr Area	0.5713
Total Cnt/g	0.5938
Tr Cnt	0.5973
VFM [%]	0.6058
Tr Grade	0.6278

Figure4. Correlation Coefficients Between Micronaire Reading and Other Fiber Attributes

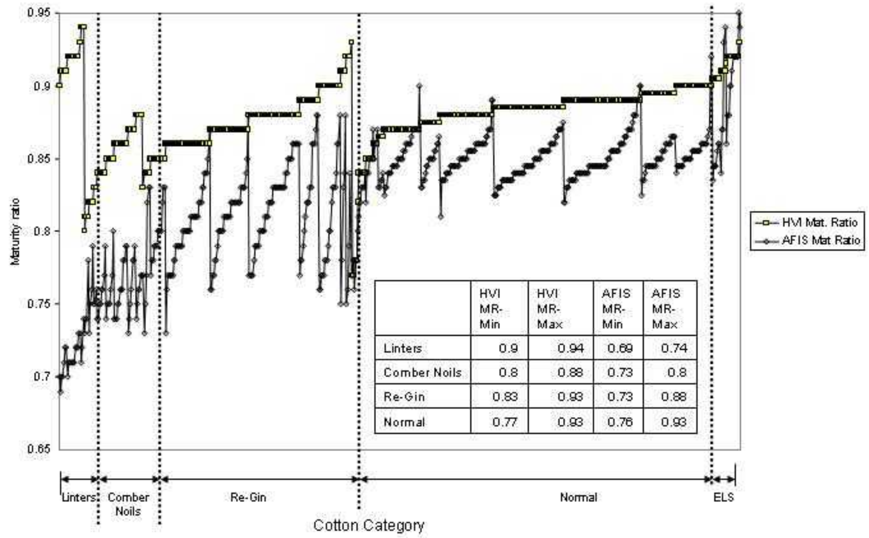
The presence of excessive trash particles in the sample is likely leads to an easier flow of air through the cotton sample during Micronaire testing and results in apparent higher values. Also, trash particles may create voids by virtue of their obstructing size. This is particularly true for large trash particles. As a result the density and the specific surface of a high trash sample will be different than that of a low trash sample. Figure 4 also shows that the relationship between HVI Micronaire and AFIS maturity ratio was not significant. This point will be discussed in the next hypothesis.

Hypothesis 2: AFIS Maturity Ratio Truly Reflects the Extent of Maturity of Cotton Fibers

AFIS maturity ratio is measured optically as a reflection of the extent of roundness of the fiber. The maturity ratio is also estimated in the HVI using data of fiber Micronaire, fiber length, and fiber strength. Figure 5 shows the value of HVI maturity ratio and AFIS maturity ratio for the different cotton samples tested in this study. As can be seen in this Figure, cotton linters exhibit exceptionally high maturity ratio by the HVI estimation equation, and exceptionally low maturity ratio measured by the AFIS. In addition, maturity ratio estimated by the HVI is consistently higher than that measured by the AFIS for all cotton samples. More importantly, one can see that the HVI maturity ratio does not follow the incremental trends of the AFIS maturity ratio, which was induced by sorting the maturity ratio within each cotton type.

The above observations yielded a poor correlation between the measured AFIS maturity ratio and the estimated HVI maturity ratio as shown in Figure 6. This is despite that fact that the HVI maturity ratio was estimated in reference to the AFIS maturity ratio. It is also important to point out that the difference between the HVI maturity ratio and the AFIS maturity ratio is highly negatively correlated with the AFIS maturity ratio as shown in Figure 7. This means that as the AFIS maturity ratio increases, the difference between the two parameters decreases in a linear fashion. This is an indication of a systematic error of the estimation of maturity ratio by the HVI system.

Close examination of the AFIS maturity ratio revealed even more stunning results. As can be seen in Figures 8 and 9, there is a negative correlation between the AFIS maturity ratio and short fiber content.



	HVI MR-Min	HVI MR-Max	AFIS MR-Min	AFIS MR-Max
Linters	0.9	0.94	0.69	0.74
Comber Noils	0.8	0.88	0.73	0.8
Re-Gin	0.83	0.93	0.73	0.88
Normal	0.77	0.93	0.76	0.93

Figure 5. Maturity Ratio of Different Cotton Types

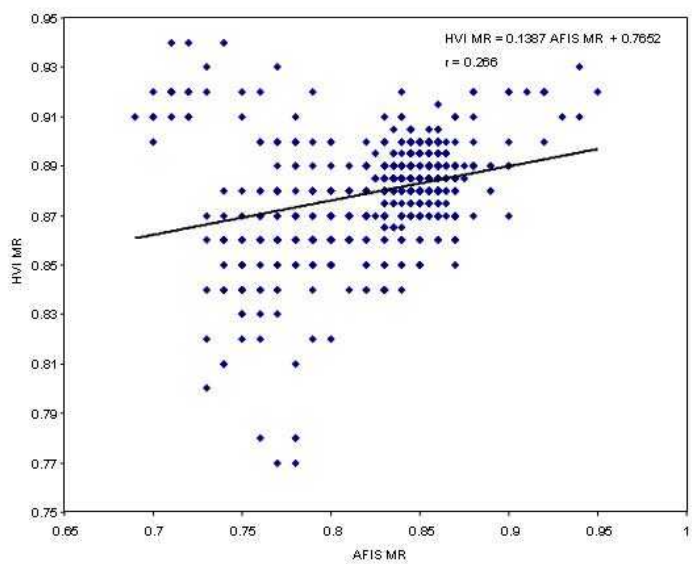


Figure 6. HVI MR-AFIS MR Relationship

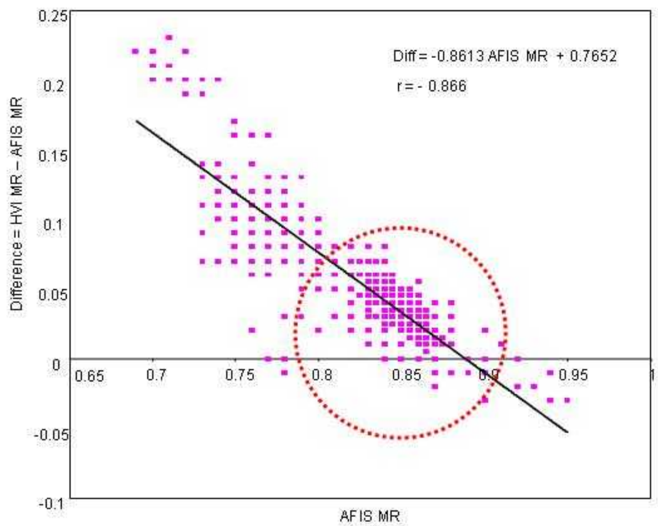


Figure 7. Relationship Between the Difference Between HVI and AFIS Maturity Ratio and AFIS MR (Cotton Linters excluded)

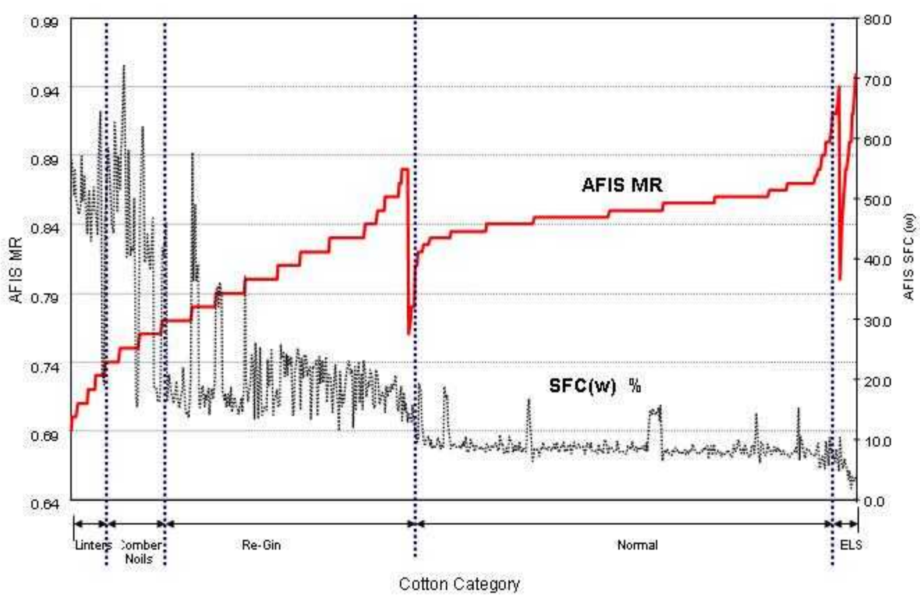


Figure 8. AFIS Maturity Ratio and AFIS SFC of Different Cotton Types

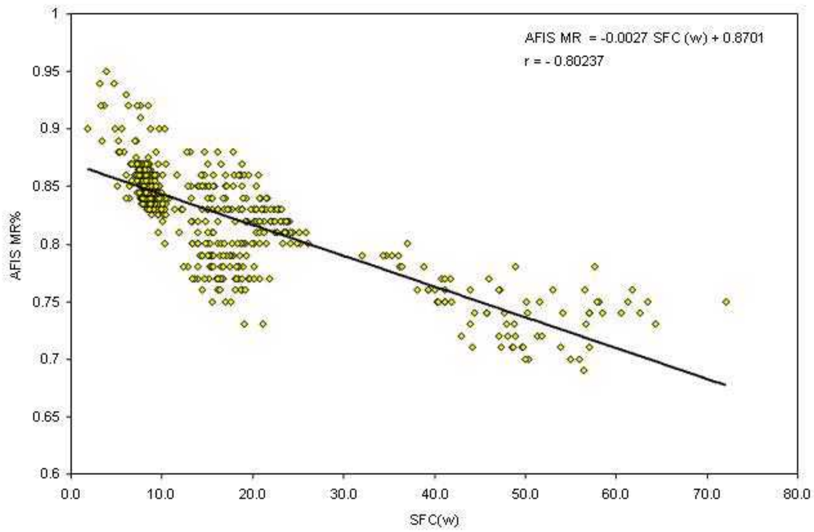


Figure 9. AFIS MR-AFIS SFC Relationship (All Cotton Samples)

This negative correlation was exaggerated by the use of waste samples such as linters, comber noils, and reginned fibers. However, even with normal cottons, the linear negative correlation between the AFIS maturity ratio and short fiber content still persist even with wider scatter.

In view of the above results the hypothesis that the AFIS maturity ratio truly reflects the extent of maturity of cotton fibers is now in doubt. It seems that the capability of the AFIS to reliably measure fiber maturity is limited by the extent of fiber length passing through the AFIS sensor.

Hypothesis 3: HVI color parameters, particularly Rd, fully reflects the inherent color of cotton fibers

Figure 10 shows the values of HVI color Rd and color +b for the different cotton samples tested in this study. As can be seen in this Figure, cotton linters exhibit exceptionally low Rd value and exceptionally low +b values. The results of this figure also indicate that the color Rd and +b parameters may exhibit some correlations. Figure 11 shows the relationship between these two color parameters for Upland cottons. As can be seen in this Figure, the correlation between the two parameters depends largely on the level of +b. For low levels of +b (in the common practical range), there is a positive correlation between the parameters. At the very high levels of +b, the correlation tends to be negative.

One of the reasons for addressing the hypothesis above is the possibility of the influence of trash or off-white color particles on the values of the color reflectance of cotton. Figures 12 and 13 clearly address this point using the cottons tested in this study. As can be seen in these Figures, There is an obvious negative correlation between trash and color Rd. Referring to our hypothesis, one should expect that the presence of off-white particles such as trash content should influence the color reflectance of the cotton. However, this raises an important point that need to be clarified; that is whether the color Rd parameter is an index of the inherent whiteness of cotton or the whiteness of the cotton sample. It would seem logical that the interest of fiber color should be independent of the trash content of the sample since color reflects unique physical and growing characteristics of cotton. It is recommended that a better image analysis approach be taken to isolate the inherent color of the fiber from the trash-biased sample color.

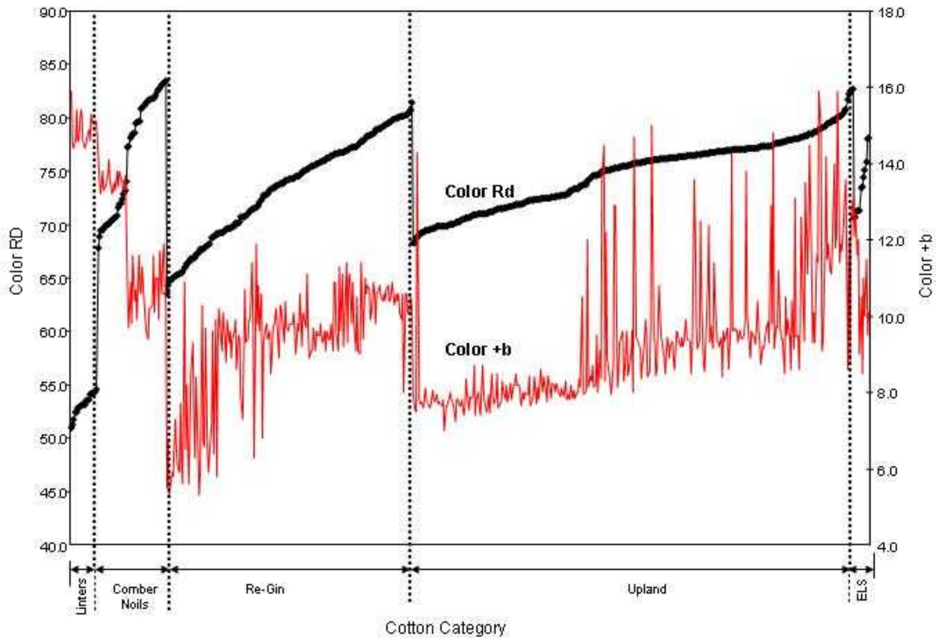


Figure 10. Color Rd and Color +b of Different Cotton Types

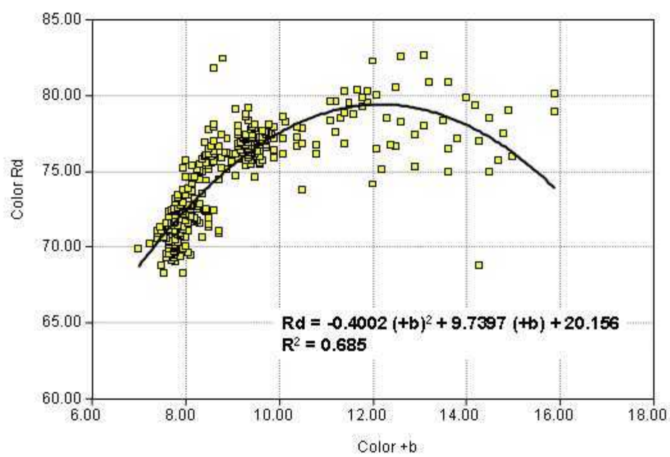


Figure 11. Color Rd-Color +b Relationship of Upland Cotton

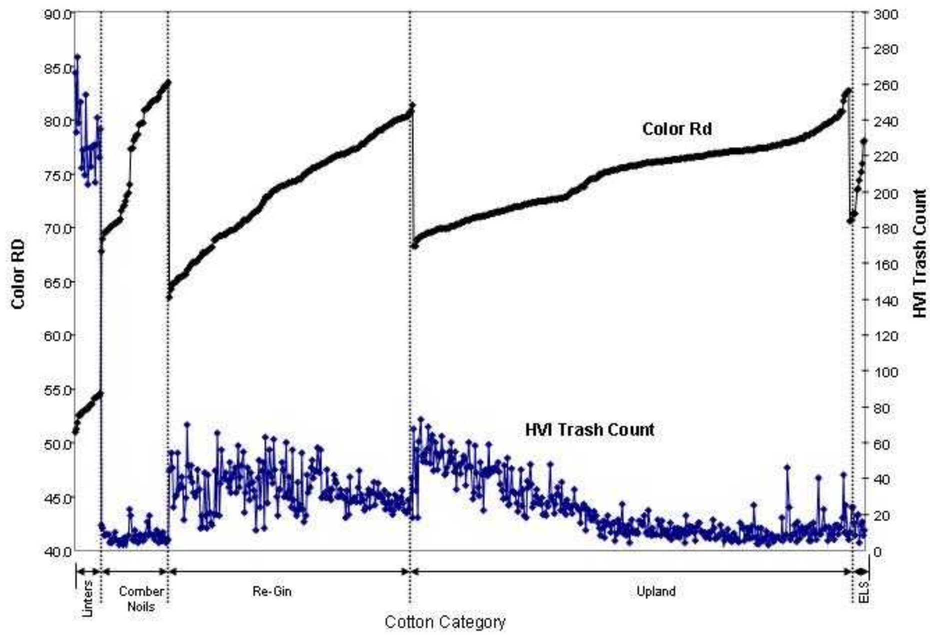


Figure 12. Color Rd and HVI Trash Count of all Cottons

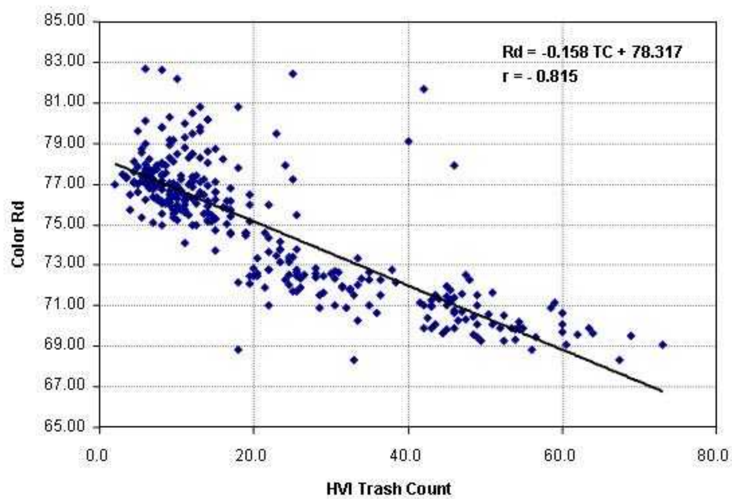


Figure 13. Color Rd-Trash Count Relationship of Upland Cottons

Hypothesis 4: HVI trash count truly reflects the percent of trash in a cotton bale

This hypothesis should be addressed with the full awareness of the purpose of measuring trash content on the HVI system. Typically, HVI trash measures are used to provide relative difference in trash content for normal cottons exhibiting low to medium levels of trash. When trash content exceeds certain limits one should not expect that HVI measures will be as effective as other weight-based trash measures. On that ground any analysis of this hypothesis should be based on normal cotton bales, not on waste bales.

Figure 14 shows the values of HVI trash count and AFIS visible foreign matter (VFM) for the different cotton samples tested in this study except cotton linters. Figure 15 shows the relationship between these two parameters. As can be seen in this Figure, both measures largely agree in trend. One can easily see that up to a certain level of HVI trash count (about 10) there is a corresponding scatter in AFIS VFM of up to about 1% difference. Beyond this point, the scatter increases as the trash content increases and it can be as high as 2.5% difference in AFIS VFM corresponding to the same level of HVI trash count. A high correlation (around 0.9) was found also between HVI trash count and AFIS trash parameters trash/gram and dust/gram. Figure 16 shows a very good correlation between HVI trash area and HVI trash count. The scatter increases as the trash level increases.

In light of the above results, the hypothesis that HVI trash count truly reflects the percent of trash in a cotton bale may be accurate up to a certain level of trash beyond which this hypothesis will become in doubt.

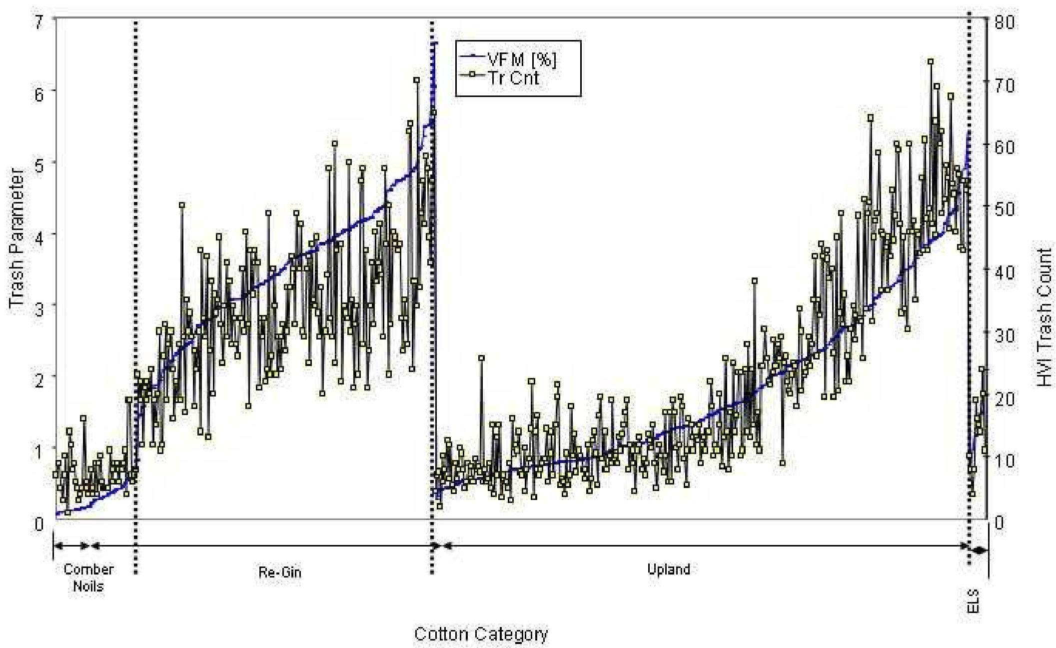


Figure 14. AFIS VFM and HVI Trash Count of all Cottons Excluding Linters

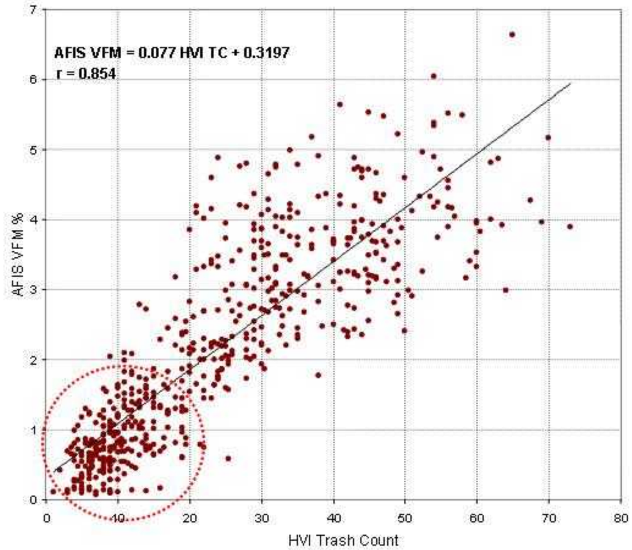


Figure 15. Relationship between AFIS VFM and HVI Trash Count of all Cottons Excluding linters

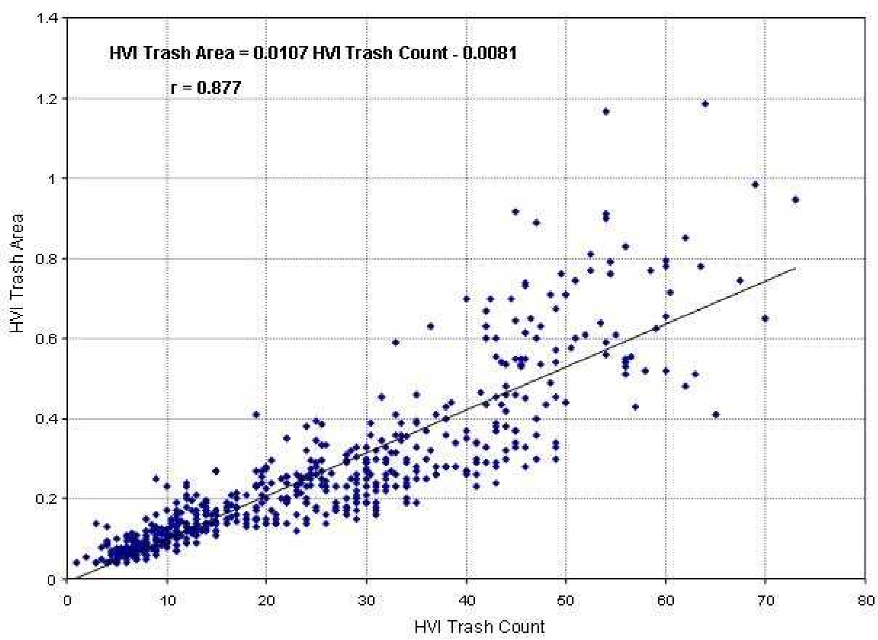


Figure 16. Relationship between HVI Trash Area and Trash Count of all Cottons Excluding linters

Conclusions

The purpose of this study was not to raise too many doubts about HVI and AFIS measurements. It was to pinpoint issues that deserve attention if forward progress is desired. With the current trends of International HVI testing and Cotton Classing, these issues will become more serious in years to come.

Summing up the above results, the following conclusions can be made:

- The hypothesis that Micronaire value fully reflects the fineness and maturity of cotton fibers can be in doubt when samples of high trash levels are tested. Also, the relationship between HVI Micronaire and AFIS maturity ratio was found to be non significant
- The hypothesis that the AFIS maturity ratio truly reflects the extent of maturity of cotton fibers is now in doubt. It seems that the capability of the AFIS to reliably measure fiber maturity is limited by the extent of fiber length passing through the AFIS sensor.
- The hypothesis that the HVI Rd color parameter fully reflects the inherent color of cotton is now in doubt. A better image analysis approach needs to be taken to isolate the inherent color of the fiber from the trash-biased sample color
- The hypothesis that HVI trash count truly reflects the percent of trash in a cotton bale may be accurate up to a certain level of trash beyond which this hypothesis will become in doubt.

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