NEW DEVELOPMENTS IN SINGLE FIBER FINENESS & MATURITY MEASUREMENTS

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Abstract

New advances in AFIS optical technology and measurement algorithms have enabled the measurement of cotton fineness and maturity parameters and their associated distributions. General classifications of fineness, immature fiber content, and maturity ratio values have been established drawing on traditional research results and on new in-mill application studies. Application results for raw material, opening and cleaning lines, carding processes, and fabric analyses are presented which show the importance of knowing and being able to control not only the average maturity and fineness of a laydown of cotton but also the distribution of fineness and maturity throughout the spinning process.

Introduction

Cotton fiber fineness can be defined in various ways. Lord (1) lists five measures that may be used: perimeter, diameter, area of cross section, mass per unit length, and specific fiber surface. Cotton maturity is loosely defined by ASTM D-13 as the degree of fiber cell wall thickness. What constitutes an acceptable level of each is a matter of much debate. How to measure and report such level is a matter of additional debate.

Experience has shown that immature cotton contributes to poor spinning performance, nep formation, increased fly and waste, and yarn or fabric dye difficulty. Micronaire has been thought to be a measurement of fineness and a good indication of maturity. Experience has shown that for many cotton varieties the micronaire value may not be a good indicator of either property. Tight control of micronaire in the bale laydown has not eliminated the problem of barre in fabric.

Precise measurement and proper evaluation of cotton fineness and maturity would be valuable tools in making yarn and fabric. The attractiveness of an acceptable test method is confirmed by the extent of past and present research.

Modern measurements of fineness and maturity can be effective in producing average or bulk values for cotton samples, but do not address a problem most often associated with fineness and maturity by spinners, the distribution of these parameters. In fact, one of the most significant problems associated with the assessment of the quality of a sample of cotton fibers is an accurate and precise measure of the distribution of maturity and fineness in the sample.

The AFIS Fineness & Maturity measurements were developed to quickly and accurately determine not only the average values of maturity and fineness but to provide distributions as well. Maturity distributions will give spinning mills and cotton researchers the detailed information necessary for reducing and eliminating fabric finishing problems. The relationship between fineness and maturity for various varieties, processes, and applications may be examined to determine the interaction between the properties and to what extent each property affects dyeability.

The paper reports on the latest developments in measurement and application for the AFIS Maturity Module.

Methods

The AFIS Method for measuring fiber, nep, and trash "events" within a fiber sample is well documented. The Maturity Module uses these proven AFIS optical techniques and employs new expanded capabilities of the optical system which includes the analysis of multiple angles of scattered light from the sampling volume. These expanded capabilities (and enhanced algorithms) allow the determination of the individual fiber "shape" so that accurate measurements can be made of single fiber perimeter, area, surface area, diameter, and cross-section. The individual fiber information produces the traditional distribution information that is typical of AFIS data modules.

Definitions:

Image analysis techniques (2) have been chosen as the reference standard for the AFIS Fineness & Maturity measurements. Figure 1 illustrates a typical cross-section of a cotton fiber and provides definitions for "Circularity" and "Theta" which are the basic components of the AFIS measurement of F&M. According to Lord (1), the "degree of thickening" is the fundamental, unbiased maturity measurement.

Fineness is defined, and applied in AFIS measurements, as the average fiber fineness (weight per unit length) in millitex. One thousand (1000) meters of fibers with a mass of 1 milligram equals 1 millitex (Figure 2). Proprietary algorithms are used to produce the AFIS Fineness data.

Immature Fiber Content is defined as the percentage of fibers with less than 0.25 circularity. The lower the IFC%, the more suitable the fiber is for dyeing (Figure 3).

Maturity Ratio is the ratio of fibers with a 0.5 (or more) circularity ratio divided by the amount of fibers with a 0.25

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(or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing (Figure 4).

Data Presentation:

The AFIS Maturity Module is combined with the AFIS Length Module creating the "Length & Maturity" (L&M) Module. This new module became available in January 1996 as a standard module on all new AFIS instruments and as a retrofit module on all "Version 3" and "Version 4" instruments.

The results from the AFIS Maturity Module are presented in two different ways. First, the data is summarized in a Summary Data Table as shown in Figure 5. The table shown in the figure is the standard or default printout for the AFIS L&M module. It is user configurable -- the user may select the various Length parameters which may be included in the printout; the Fineness and Maturity data consists of the *Fine, IFC,* and *Mature Ratio* values as listed in the default summary table. Second, the distribution information is detailed in the Fineness and Maturity histograms shown in Figure 6. The IFC is further annotated by the differently shaded bars in the Maturity histogram to give a quick visual impression of the distribution. The various Length histograms are also available and user selectable.

Applications of the New AFIS Maturity Module

The development of new measurements, ratios, and relationships for fiber properties is of little practical use if there are no relevant applications information associated with the new parameter. In order to relate the new AFIS information to the spinning mill, classifications were developed for the new parameters -- Fineness, IFC, and Maturity Ratio. These classifications are the result of traditional research theories and results and new application studies undertaken to validate the AFIS L&M Module. They are described in Figures 7, 8, and 9.

In-Mill studies were also conducted using each of the new parameters in the AFIS Maturity Module in order to develop the necessary applications data -- these studies looked at raw material, bale laydowns, opening and cleaning, and carding. Fabric samples were produced and analyzed as described below to verify the theories and application assumptions. These studies are described in Figures 10 through 17.

Property Classifications:

Cotton fiber samples with fineness readings below 125 millitex are considered to be *Very Fine* those with fineness reading above 250 millitex are considered to be *Very Coarse*. Fiber samples with *Average* fineness are in the 175 to 200 millitex range. See Figure 7.

Cotton samples with Immature Fiber Contents (IFC's) between 4% and 8% are considered to be *Low*, those with IFC's between 8% and 14% are considered *Average*, and those with IFC's 14% to 18% considered *High*. See Figure 8.

Maturity ratios of less than 0.7 are uncommon in practice; fiber samples with readings of 0.7 to 0.8 are considered to be *Immature* and fiber samples with readings between 0.8 and 1.0 are considered to be *Mature*. A maturity ratio of greater than one (1) is not uncommon and these fiber samples are said to be *Very Mature*. See Figure 9.

Application Studies:

Raw Cotton -- micronaire is one of the parameters traditionally used to sort bales used for laydown and it has traditionally been considered to be a good indicator of maturity. The following example is taken from an in-mill study conducted by Zellweger Uster and a cooperating mill partner who was having problems with fabric barre.

Raw cottons with similar (or the same) micronaire may have very different amounts of immature fibers. Three samples were pulled from a laydown of 32 bales averaging a 4.2 micronaire value. These samples were knitted from yarn processed from three samples of cotton of the same variety yet from different growing areas -- the visual results, shown in Figure 10, illustrate the potential dyeability problems that can occur. Figure 11 details the HVI values for these three samples; the similarities between the length, strength, and micronaire values are typical of bales in the laydown ... there is no indication of potential dyeability problems when these data alone are analyzed. The AFIS Maturity results (Figure 12) indicate a significant difference in the IFC for the first sample (3% lower IFC); which would predict and explain its difference in dyeability.

Process Improvement -- Zellweger Uster in-mill studies have shown that the maturity of a laydown is not significantly affected by the opening and cleaning process. Results show that the average maturity and general distribution of maturity at the card mat matches, with high correlation, the average maturity and general distribution in the laydown.

Detailed AFIS analysis of the carding process shows a very different result -- indicating that the card has a significant influence on fiber maturity and maturity distribution. First, the carding equipment itself and the speed of that equipment have an influence on the IFC (as well as short fiber content, SFC). The test results given in Figure 13 show a significant difference between older cards operating at slower throughput rates and new cards operating at high throughput rates. Second, supposedly "identical" cards served by the same opening and cleaning lines show very different level of IFC along the line of cards. Figure 14 shows a typical variation that has been found in carding lines. In this particular example, a variation of more than

3% is seen between cards from a single line, which as seen above can produce significant differences in dyeability.

Fabric Barre -- the major cause of finishing problems in cotton fabrics are due to changes in fiber maturity, followed by fiber fineness, Yarn Count variations, twist variation, and hairiness of the yarn. When spinning mills use a single variety of cotton in a laydown, micronaire is a good way to control fabric finish. However, most mills must draw on fibers of different variety as a matter of practice and a recent Zellweger trail indicates that additional controls may be necessary. The knitted fabric in Figure 15 was produced from three different cotton varieties with the same micronaire, from the same growing area (the pattern is repeated ... i.e. the figure shows fabric from Bale 1, Bale 2, Bale 3, Bale 1, Bale 2, and Bale 3). The AFIS Maturity Module results are shown in Figure 16.. They indicate that Bale 3 had a significantly lower IFC -- and, thus the darker band in the knitted fabric.

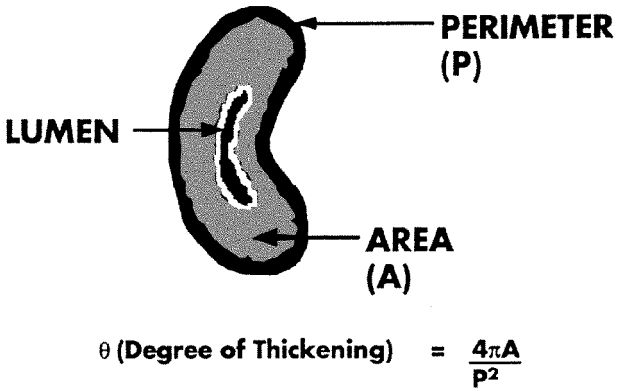
Summary

The fineness and maturity of cotton are important parameters in producing high quality yarns and fabrics. The measurement of average fineness and maturity are sometimes not adequate to describe the fiber properties which influence dyeing. Advances in AFIS optical measurement techniques and algorithms allow the AFIS to measure the maturity and fineness distributions in cotton. Using Image Analysis techniques as the reference method, Fineness, Immature Fiber Content, and Maturity Ratio values have been classified for use by spinning mills to compare and optimize their processes and laydowns. AFIS data distributions and selectable data reporting allow customized output of the fineness and maturity parameters of particular interest to individual mills. Spinning mills may now optimize the carding process to improve sliver consistency by analyzing carding elements and settings for their affects on fiber maturity distribution. Bale laydowns may be tested to check for unusually high or low IFC values and thus "smooth out" any deviations from the desired norms. The ability to optimize process machinery and to detect unusually high or low levels of fineness or maturity will allow spinners to become more competitive and to continue to provide higher quality cotton products to consumers.

References

1. Lord, E. and S. A. Heap. 1988. The Origin and Assessment of Cotton Fibre Maturity. 3rd Edition. International Institute for Cotton, Manchester, England.

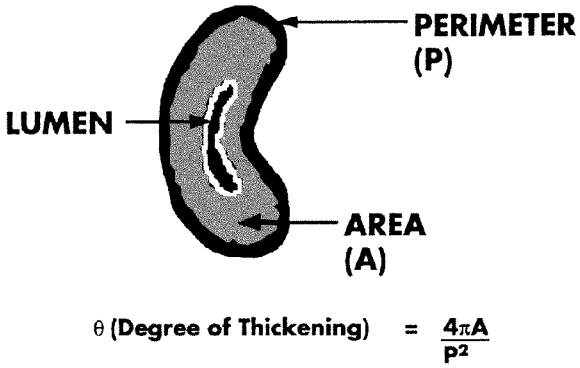
2. Thibodeaux, D. P. and J. P. Evans. 1986. Cotton Fiber Maturity by Image Analysis. Textile Research Journal 56.



Circularity The degree of thickening which is calculated by the cross sectional area of the fiber wall divided by the area of a circle of the same perimeter.

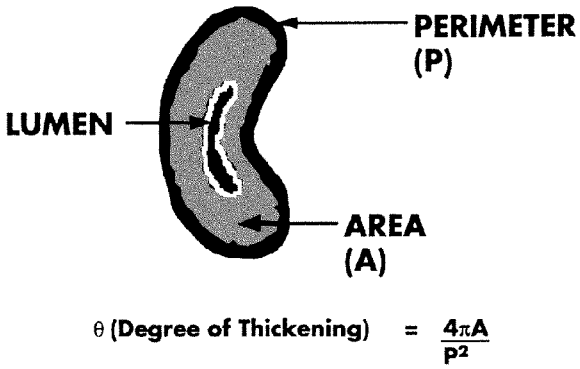
Theta Average circularity of the measured fibers also described as the degree of thickening.

Figure 1 Terms & Definitions



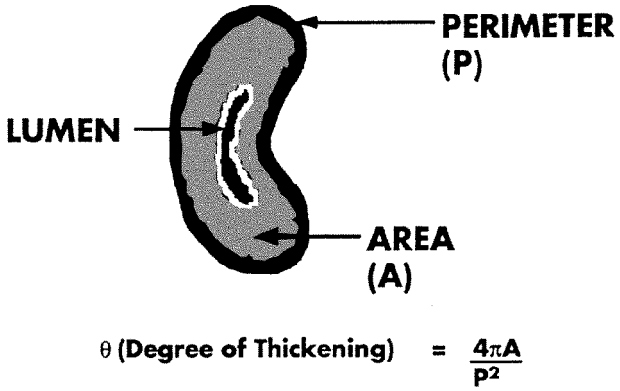
Fin (mtex) Average fiber fineness (weight per unit length) in millitex. 1000 meters of fibers with a mass of 1 milligram equals 1 millitex.

Figure 2 Terms & Definitions



IFC (%)) Immature fiber content in percent. Percentage of fibers with less than 0.25 circularity. The lower the IFC% the better the fiber is for dyeing.

Figure 3 Terms & Definitions



$$\theta \text{ (Degree of Thickening)} = \frac{4\pi A}{P^2}$$

Mature Maturity Ratio is the ratio of fibers with a 0.5 (or more)circularity ratio divided by the amount of fibers with a 0.25 (or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing.

Figure 4. Terms & Definitions

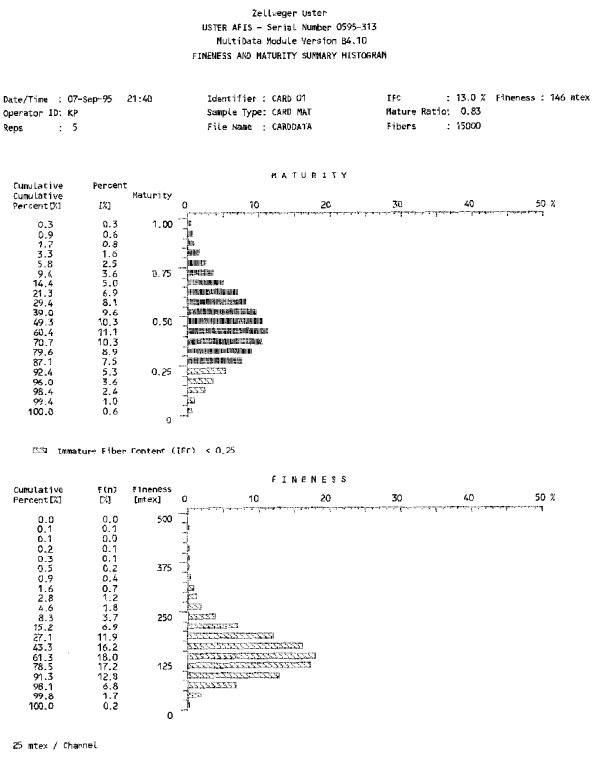
Zellweger Uster
USTER AFIS - Serial Number 0595-313
MultiData Module Version B4.10
Summary of Sample Analysis

Date/Time : 07-Sep-95 21:40
File Name : CARDDATA
Operator ID: KP

Identifier : CARD 01
Sample Type: CARD MAT
Fibers : 15000

Rep	L(w) [in]	UQL(w) [in]	L(n) [in]	L(n) % CV	SFC(n) [%]	2.5%(n) [in]	Fine ntex	IFC [%]	Mature Ratio
1	0.89	1.11	0.70	51.7	32.1	1.38	148	13.4	0.83
2	0.91	1.12	0.74	48.7	28.0	1.37	147	13.0	0.83
3	0.90	1.12	0.71	50.4	29.0	1.34	145	13.0	0.82
4	0.92	1.12	0.75	48.0	27.0	1.37	147	11.2	0.85
5	0.90	1.10	0.73	48.2	27.8	1.36	144	14.2	0.82
Mean	0.90	1.11	0.73	49.4	28.8	1.36	146	13.0	0.83
S.D.	0.01	0.01	0.02	1.6	2.0	0.02	2	1.1	0.02
% CV	1.3	0.8	2.9	3.2	6.9	1.1	1.1	8.5	1.5

Figure 5Summary table for AFIS MultiData printout for Length and Maturity



Figures 6 Histograms of AFIS Fineness and Maturity

Fin (millitex)	Description
Below 125	Very Fine
125 to 175	Fine
175 to 200	Average
200 to 250	Coarse
Above 250	Very Coarse

Figure 7 Fineness

IFC (%)	Description	
4 to 8 %	Low	(very mature)
8 to 14 %	Average	(mature)
14 to 18 %	High	(immature)

Figure 8 Immature Fiber Content %

Maturity Ratio	Description
Below 0.7	Uncommon
0.7 to 0.8	Immature
0.8 to 1.0	Mature
Above 1.0	Very Mature

Figure 9 Maturity

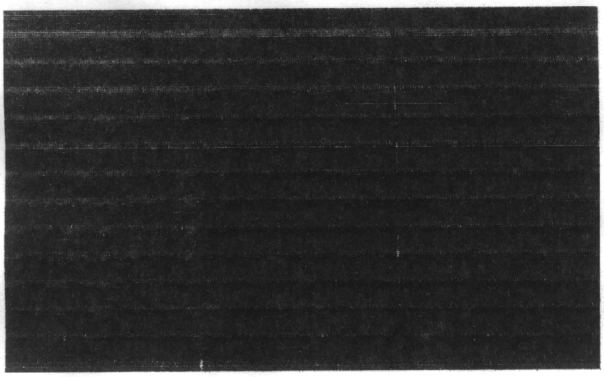


Figure 10. Fabric Analysis: Same variety, different Mic.

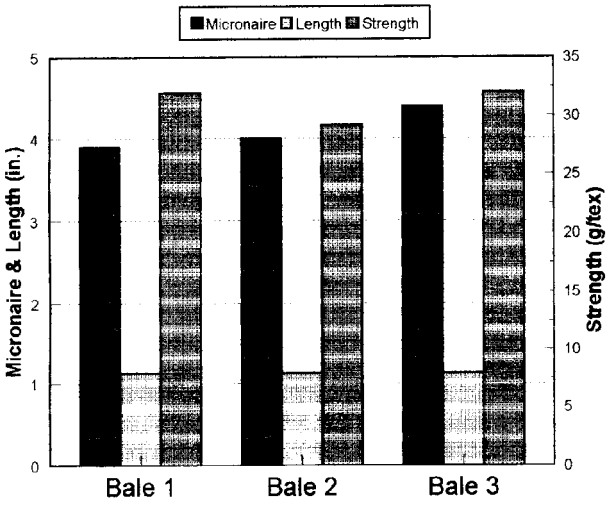


Figure 11. HVI bale data: length and micronaire analysis

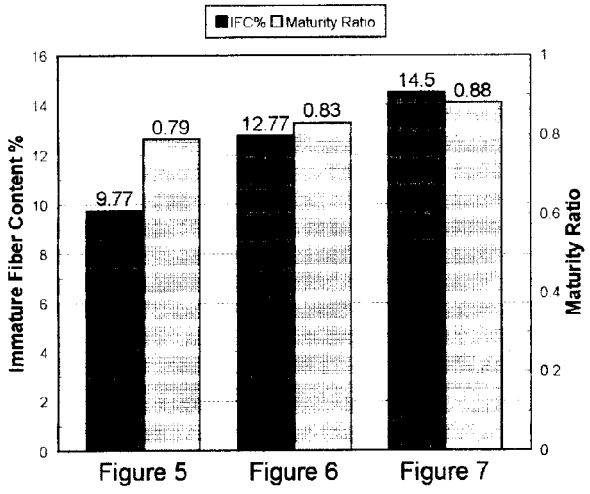


Figure 12. AFIS maturity analysis: fabric white speck defects

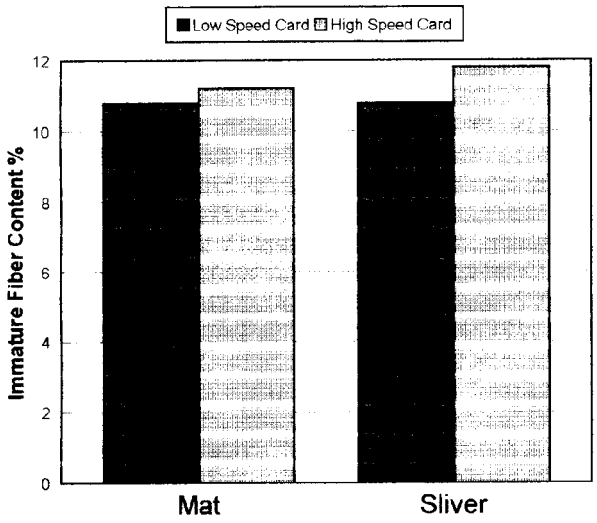


Figure 13. AFIS maturity analysis: flow versus high speed carding

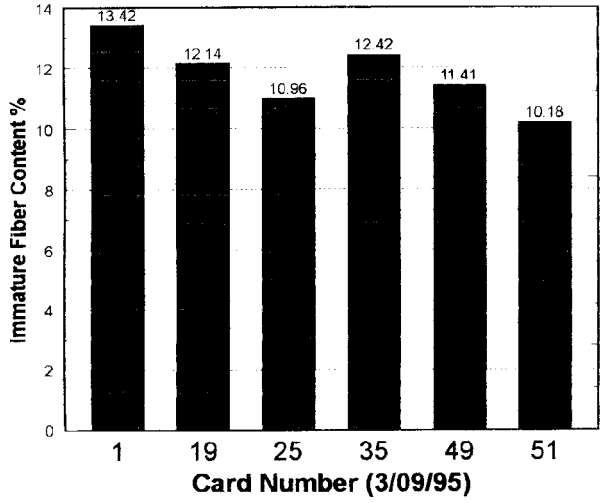


Figure 14. AFIS carding analysis: IFC variation in card sliver

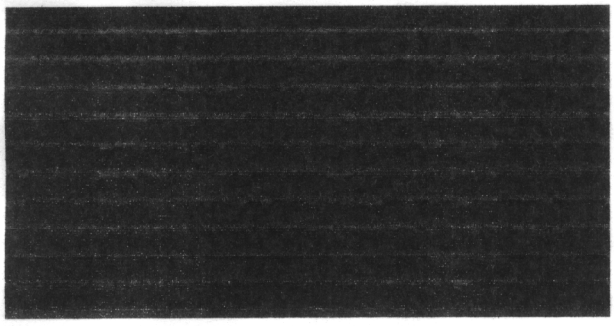


Figure 15. Knitted fabric samples: three varieties, same mic., same growing area

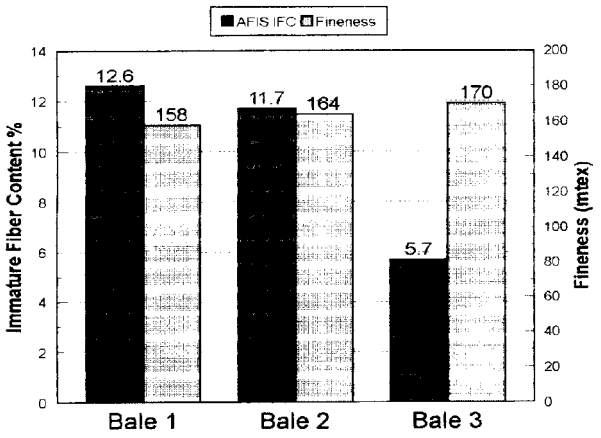


Figure 16. Maturity analysis: AFIS fineness and maturity