Developing and Comparing New Software Based on “Lord” and “Ramey” Equations to Calculate Fineness and Maturity Parameters Using “HVI” Output Data

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ABSTRACT

Background: Fineness and maturity are major quality characteristics of cotton fibers which are directly related to yarn and end product value. As a fact, fine and mature cotton fibers are the most and required by spinners. Thus, there is a need for an accurate and rapid method for measuring cotton fiber fineness and maturity characters. Objectives: This present study was conducted to explore the possibility of utilizing the data of “HVI” to estimate the fiber fineness and maturity parameters of Egyptian cotton, corresponding to the same parameters provided by both of “Micromat” instrument and Image Analyzer. Methodology: To achieve the objectives 15 of Egyptian genotypes produced by Cotton Research Institute, Giza, Egypt, as well as two of Upland cotton samples from Sudan were used in this study during 2012 season. The samples were tested using the HVI, Micromat and the Image Analyzer instruments. Results: Data of the degree of thickening, area of secondary cell wall and perimeter showed no significant difference between its means, excellent correlation and determining factor between both of the Image analysis data and the data extracted from the equation used for HVI software. Conclusion: Thus, it could be easy to add new characters to the HVI output data and simulate both of the Micromat and Image analyzer instruments successfully. These equations will save time, efforts, labors and testing costs.

Key words: Cotton, fiber, fineness, maturity, HVI, micromat

INTRODUCTION

Fineness is one of the important characters of cotton because yarn made from fine fiber is generally stronger and more uniform than yarn spun from coarse fibers. Also, fiber maturity is important because mature fibers having well developed cell walls, will absorb the dye better as well as less prone to cause defects of various sorts in the finished product.

Fineness and maturity can be measured in accurate way by using microscope or image analyzer. Cross sectional analysis of cotton fiber provides direct accurate measurements of fiber perimeter and maturity, which are often regarded as the reference data for validation or calibrating other indirect measurements of these important cotton fiber properties but it is time consuming.

Thus, there is a need for an accurate and rapid method for measuring cotton fiber fineness and maturity characteristics. Scientists have develop a lot of instruments for measuring fineness and maturity parameters, the most famous instrument is Micronaire instrument. Micronaire measures fineness and maturity in one reading called Micronaire reading. Micronaire reading is an indicator of air permeability, it's regarded as an indication of both fineness and maturity (degree of cell wall development) but in fact those Micronaire measurements are considerate to be a combination of fiber fineness and maturity.

Normal Micronaire reading does not tell us whether the fiber is coarse and immature or fine and mature. For a given type of cotton fineness is a genetic trait so, its variation is limited. A relatively low Micronaire reading has been used as a predictor of a low maturity when comparing the samples of the same genotype. Low Micronaire reading may also indicate fine fiber with adequate maturity. So, there was a need to develop new instrument for measuring fineness and maturity separately. The Micronaire tester (Shirley development LSD, stock port, England) is being used to measure fineness and maturity.
The Micromat is a current model of a series of instruments manufactured by the company to measure fineness and maturity and generally is referred to as the Fineness and Maturity Tester (FMT). This instrument has a double compression airflow device that measures the pressure drop of air drawn through a fixed mass that is compressed, during the test to two different densities. The initial and second stage pressure drops are referred to as PL and PH, respectively and are converted to fineness and maturity and perimeter by appropriate empirical equations\(^9,10\). The FMT equations were calibrated with the British Standard Methods and image analysis\(^11,12\).

Regarding fineness, Ramey and Lord’s equations could be successfully estimate all the image analyzer measurements which need time and effort\(^13-15\) these equations could be easily utilized using HVI data when it is converted to simple software. Therefore, the main objective of this study is to develop this simple software.

**MATERIALS AND METHODS**

To estimate fiber maturity, gravimetric and intrinsic fineness measurements, by using HVI data. Fifteen of Egyptian cotton genotypes namely, (Giza 88, Giza 92, Giza 93, [G.84 (G.70×G.51b)] defined as C1, Giza 45, Giza 87, Giza 80, Giza 90, 90xAus.-defined as C2, G.83×58×G.80 defined as C3 (10229×G86) defined as C4, Giza 86, green cotton, dark brown and light brown cotton) produced by Cotton Research Institute, Giza, Egypt. As well as two upland cotton samples from Sudan were used in this study during 2012 season.

**Data collection and sampling:** Two maturity ratio levels were used as possible for most genotype under this study. These genotypes were used to cover the different levels for Micronaire levels and diameter values (different genotypes) to be tested for Micronaire and maturity by HVI instrument. The same specimens were tested by Micro-mat to get the Micronaire value (Mic), Maturity Ratio (MR), fineness in millitex (Fin), Ph and PL values (which refer to low and high pressure). The cross sections and the images for the same samples were tested at the labs of Textile Consolidation Fund, Alexandria, Egypt. While, the Image Analyzer, of the Fiber Structural and Microscopic Unit Lab, Cotton Research Institute, Giza, Egypt, was used to test and analyze the images to calculate the fiber perimeter ($\mu$), Area of Secondary Cell Wall (ASCW) ($\mu^2$) and degree of thickness ($\beta$) (Table 1).

### Table 1: Means values of fiber fineness and maturity parameters measured by Micromat and Image analysis system

| Sample                  | Mic-mat measurement | Image analyzer measurement |
|-------------------------|---------------------|----------------------------|
|                         | Mic  | MR  | Fineness | 0   | ASCW ($\mu^2$) | P($\mu$)  |
| G88 low maturity        | 2.8  | 0.79| 111.62   | 0.47| 73.01          | 49.01     |
| G 88 normal             | 3.7  | 0.95| 137.59   | 0.58| 98.56          | 49.45     |
| G92 low maturity        | 2.8  | 0.87| 105.90   | 0.53| 73.00          | 47.30     |
| G 92 normal             | 4.0  | 0.99| 148.89   | 0.60| 109.62         | 49.32     |
| G 93 low maturity       | 2.2  | 0.75| 93.00    | 0.48| 58.28          | 43.00     |
| G 93 normal             | 3.2  | 0.95| 114.22   | 0.57| 83.86          | 44.55     |
| C1 normal               | 4.2  | 0.98| 160.57   | 0.57| 116.21         | 51.05     |
| C1 low maturity         | 3.3  | 0.90| 127.74   | 0.53| 88.14          | 49.11     |
| G 45                    | 3.2  | 0.92| 120.26   | 0.53| 85.27          | 43.12     |
| G 87                    | 3.0  | 0.99| 103.25   | 0.58| 79.70          | 42.00     |
| G 80 low                | 3.2  | 0.74| 146.63   | 0.44| 83.86          | 56.00     |
| G 80 normal             | 4.4  | 0.95| 173.72   | 0.56| 121.30         | 57.00     |
| G 90 low                | 3.2  | 0.87| 127.17   | 0.49| 85.27          | 54.00     |
| G 90 normal             | 3.8  | 0.94| 144.02   | 0.54| 101.66         | 55.05     |
| C 2                     | 5.0  | 0.92| 217.72   | 0.54| 144.65         | 56.94     |
| C3                      | 4.4  | 0.95| 176.46   | 0.55| 123.02         | 56.02     |
| G 86 low maturity       | 3.9  | 0.93| 153.26   | 0.55| 106.39         | 52.00     |
| G 86                    | 4.5  | 1.02| 169.50   | 0.59| 126.49         | 52.70     |
| C4                      | 3.9  | 0.92| 152.32   | 0.54| 104.80         | 52.41     |
| Green                   | 2.8  | 0.86| 107.13   | 0.50| 73.01          | 49.50     |
| Dark brown              | 3.7  | 0.99| 134.38   | 0.58| 100.10         | 49.19     |
| Light brown             | 3.0  | 0.80| 127.78   | 0.47| 79.69          | 48.00     |
| Upland Sudan fine       | 3.0  | 0.80| 127.78   | 0.47| 79.70          | 55.03     |
| Upland Sudan coarse     | 4.9  | 0.84| 231.74   | 0.48| 140.92         | 67.20     |
Sampling and testing were done according to ASTM\textsuperscript{16} and ITMF\textsuperscript{17}.

**Statistical analysis:** Firstly, data normalization test for all parameters under study were performed by SPSS software, before T-test, all data were subjected to statistical analysis by the technique of paired T-test\textsuperscript{18}. Differences were considered significant at \(p<0.05\). Correlation and regression analysis were computed according to Draper and Smith\textsuperscript{19}. The data were statistically analyzed by using the statistical software package SPSS V.17, Excel software was used, for drawing diagrams.

**RESULTS AND DISCUSSION**

Such that Micromat instrument software based on Lord’s formula to calculate Micronaire, fineness and maturity readings as follows:

\[
\text{Mic} = \frac{850}{\text{PL} + 40} + 0.6 \tag{1}
\]

\[
\text{MR} = 0.247^*\text{PL}^{0.125} (\text{PL}/\text{Ph})^2 \tag{2}
\]

\[
\text{Fin} = (60000/\text{PL})*(\text{Ph}/\text{PL})^{1.75} \tag{3}
\]

According to the previous study\textsuperscript{20} concerning producing calibration samples for micromat instrument using HVI micronaire and maturity ratio values to calculate back the PL, Ph values, which used principally to calibrate the micromat instrument.

The following two equations was formed by making the PL and Ph values the main subjects for the Eq. 1, 2 mentioned above:

\[
\text{PL} = \frac{1}{(\text{mic}-0.6)*850/1)-(40)} \tag{4}
\]

\[
\text{Ph} = \sqrt{0.247^*\text{PL}^{0.125}/\text{MR}} \tag{5}
\]

Thus it could be easy to calculate fineness when the third formula is applied. The pervious study\textsuperscript{20} indicated the congruency of the Micromat fineness and calculated fineness using HVI instrument. This because when we reversed the equations we have calculated a character from another accurate characters (mic, MR). Thus, we add new accurate character (Fin) not predictable. This described the congruency between the fineness readings according to the pervious study.

Maturity Ratio (MR)\textsuperscript{21} and fineness (H) were calculated from the following equation:

\[
\text{Maturity ratio (MR)} = \frac{0}{0.577}
\]

\[
\theta = \text{Maturity ratio} \times 0.577
\]

It could be calculated directly using HVI data. According to Ramey\textsuperscript{2}:

\[
\text{Fineness (Fin)} = \text{ASCW} \times \eta
\]

where, \( \eta = \text{cell wall density} = 1.52 \).

\[
\text{ASCW} = \text{Fin}/ \eta
\]

However, standard fineness (H\textsubscript{s}) was calculated from (Lord) equation\textsuperscript{22} as follows:

\[
\text{Standard fineness (Hs)} = \frac{\text{Fin}}{\text{MR}}
\]

According to Hequet and Wyatt\textsuperscript{13}:

\[
P = 3.7853 \sqrt{Hs}
\]

where, \( P = \text{perimeter} \).

With \( P = 2r \pi \) and \( 2r = \text{Diameter} (D) \). Where \( r = \text{radius} \). So:

\[
\pi \times D = 3.7853 \sqrt{Hs}
\]

\[
D = 3.7853 \sqrt{Hs} / \pi \text{ or } D = P / \pi
\]

where, \( \pi = 3.14 \).

According to Arafah et al.\textsuperscript{15}:

\[
\text{Diameter (D)} = 1.2055 \sqrt{Hs} \text{ or } \frac{\text{perimeter}}{3.14}
\]

These equations were used to develop a software for calculated fiber perimeter, (fineness), area of secondary cell wall from HVI data.

The obtained data were analyzed and summarized in Table 2 which indicated that no significant difference was observed between the means of theta obtained from image analyzer and their corresponding values calculated by HVI. Also, all the calculated data from HVI data are either equal or less than those measured by HVI by 0.01-0.03 units This results explained the very high correlation \( r = 0.98 \) and the excellent determination co-efficient \( R^2 = 0.96 \) shown in Fig. 1 and Table 2.
indicated that the area of secondary cell wall readings of image analyzer system were slightly higher than that of HVI instrument. Nevertheless, the correlation and the co-efficient of determination between them are high, \( r = 0.99 \) and \( R^2 = 0.99 \) as shown in Fig. 2. Furthermore, the difference between the two means is within the acceptable range. Data shown in Fig. 3, of perimeter explained no significant difference and good correlation \( r = 0.96, R^2 = 0.93 \) between both of the image analysis data and the data extracted from the equation used for HVI software Fig. 4 and 5. The software copy-write patent were registered at smart village, Egypt under the numbers (001761/2012 and 001762/2012).

Table 2: Comparison between fineness and maturity readings obtained from image analysis system and their corresponding reading calculated from HVI data

| Sample                | 0 (Image) | 0 (HVI) | ASCW (\(\mu^2\)) (Image) | ASCW (\(\mu^2\)) (HVI) | P(\(\mu\)) (Image) | P(\(\mu\)) (HVI) |
|-----------------------|-----------|---------|--------------------------|------------------------|-------------------|------------------|
| G88 low maturity      | 0.47      | 0.46    | 73.010                   | 71.21                  | 49.01             | 45.91            |
| G88 normal            | 0.58      | 0.55    | 98.560                   | 96.36                  | 49.45             | 46.40            |
| G92 low maturity      | 0.53      | 0.50    | 73.000                   | 71.50                  | 47.30             | 45.00            |
| G92 normal            | 0.60      | 0.57    | 109.620                  | 106.62                 | 49.32             | 46.19            |
| G93 low maturity      | 0.45      | 0.43    | 58.280                   | 56.28                  | 43.00             | 40.54            |
| G93 normal            | 0.57      | 0.55    | 83.860                   | 81.36                  | 44.55             | 42.45            |
| C1 normal             | 0.57      | 0.57    | 116.210                  | 114.51                 | 51.05             | 49.97            |
| c1 low maturity       | 0.53      | 0.52    | 88.140                   | 86.44                  | 49.11             | 47.68            |
| G45                   | 0.53      | 0.53    | 85.270                   | 83.25                  | 43.12             | 41.51            |
| G87                   | 0.58      | 0.57    | 79.700                   | 78.50                  | 42.00             | 39.86            |
| G80 low               | 0.44      | 0.43    | 83.860                   | 81.36                  | 56.00             | 53.86            |
| G80 normal            | 0.56      | 0.55    | 121.300                  | 119.37                 | 57.00             | 55.89            |
| G90 low               | 0.49      | 0.50    | 85.270                   | 83.77                  | 54.00             | 52.67            |
| G90 normal            | 0.54      | 0.54    | 101.660                  | 99.66                  | 55.05             | 52.43            |
| C2                    | 0.54      | 0.53    | 142.650                  | 138.95                 | 56.94             | 54.85            |
| C3                    | 0.55      | 0.55    | 123.020                  | 121.42                 | 56.02             | 53.28            |
| G86 low maturity      | 0.55      | 0.54    | 106.390                  | 99.79                  | 52.00             | 49.86            |
| G86                   | 0.59      | 0.59    | 126.490                  | 124.41                 | 52.70             | 50.29            |
| C4                    | 0.54      | 0.53    | 104.800                  | 98.10                  | 52.41             | 49.72            |
| Green                 | 0.50      | 0.50    | 73.010                   | 71.01                  | 49.50             | 46.18            |
| Dark brown            | 0.58      | 0.57    | 100.100                  | 98.19                  | 49.19             | 47.88            |
| Light brown           | 0.47      | 0.46    | 79.690                   | 77.88                  | 48.00             | 45.79            |
| Upland Sudan fine     | 0.47      | 0.46    | 79.700                   | 77.78                  | 55.03             | 54.79            |
| Upland Sudan coarse   | 0.48      | 0.48    | 140.920                  | 138.62                 | 67.20             | 65.62            |
| Mean                  | 0.53      | 0.52    | 97.270                   | 95.22                  | 51.21             | 49.07            |
| p-value               | 0.665     | 0.233   | 0.275                    |                         |                   |                  |
| T-test                | n.s       | n.s     | n.s                      |                         |                   |                  |
Therefore, it could be successfully simulate both of the Micromat and image analyzer instruments and save the time, efforts, labors and energy by adding these new characters to the HVI output data as a form of sequence of equations converted to computer programs.
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