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A COMPARISON OF COTTON MATURITY BY DIFFERENT METHODS

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Abstract

Cotton maturity is one of the basic cotton properties. It influences fiber behavior during processing and also the quality of cotton yarns. There are a lot of methods of cotton maturity assessment. In the frame of this research there were performed cotton maturity assessments by three optical methods: - the microscopic observation of longitudinal fiber views in polarized light, - the assessment of fiber cross-sections under microscope with use of image analysis software LUCIA, - the AFIS system. Using the mentioned methods we obtained parameters characterizing the cotton maturity. The microscopic observation in a polarized light allows finding the maturity degree. Using the AFIS system we determined Maturity Ratio and circularity coefficient of cotton fiber cross-section; whereas using the image analysis of cotton fiber cross-sections the circularity coefficient, the area of cross-section as well as the thickness of the secondary wall were determined. The evaluated thickness of the secondary wall determines the calculation of maturity degree according to Raes. Basing on the obtained results the statistical analysis of agreement was carried out.

1. Introduction

Cotton fiber maturity is a very important parameter characterizing the quality of cotton raw material. It decides about physical and mechanical fiber properties, their behavior in processing, quality parameters of yarn produced from the given fibers as well as about a cotton fabric dyeability.

Cotton fiber maturity is defined as a degree of development of the secondary wall. When the secondary wall is getting thicker, the area of fiber cross - section increases and at the same time the fiber strength also increases [Watson 1992]. Therefore, with the growth of the area of fiber cross-section the fiber fineness also increases. Fibers of a low maturity are not so rigid, and they have an ability to create neps in the all production stages. Fiber maturity influences also their luster; non-mature fibers disperse the light in all directions due to the shape of a twisted tape [Urbańczyk 1978].

The mature fibers with the small number of twists reflect the light in determined direction, thanks to which they have a luster (the higher maturity, the higher luster). The color of fibers also deals with maturity. It was stated the relationship between a maturity degree and fiber strength, initial modulus and so on.

Special attention is paid on the fiber maturity during an assessment and classification of cotton from the Central Asia. According to GOST (Soviet Standards) [GOST] the fiber maturity was a basic criterion of soviet cotton classification. Actually, during the Uzbeck cotton assessment, according to the standard Uz RST 604-931, the maturity is one of the main assessment and classification criteria of cotton from the cultivation region. Taking it into account, the precise and objective cotton maturity assessment is very important.

There are many methods of measurement of this parameter. Except the traditional organoleptical methods based on the microscopic observations of longitudinal fiber views, the modern instrumental methods of cotton maturity assessment are developed, among the others, with the use of such systems as AFIS or Fiberlab.

Due to many methods of cotton maturity measurement, there is a need of assessment of result agreement. The aim of this research is the agreement assessment of cotton maturity results obtained by three optical methods:

- using AFIS,
- LUCIA computer analysis of images of cotton fiber cross-sections,
- microscopic assessment in the polarized light of the fiber longitudinal views.

2. Experimental

Thirteen lots of medium staple cottons from the Central Asia were measured by the mentioned above methods.

Method of microscopic observation of fiber longitudinal view in polarized light

Cotton fiber is characterized by an anisotropy of light transmission, which involves a double refraction of the light beam falling on a fiber. After transmission through the fiber, the beam is divided into two perpendicular beams. These beams are spread out with different speeds and they are in a different phase. If an analyzer, put in the path of the light ray going out from the fiber, conveys these two beams into one oscillation plane, the beams will interact with each other, yielding a color picture of the fibers. With the increase in fiber secondary wall thickness, i.e., with the increase in cotton fiber maturity, the optical length in a fiber also increases.

Moreover, layers of better macrofibril arrangement occur. Therefore, fiber maturity will determine the interference color of fiber observed in the polarized light [Frydrych, Zurek, Andrysiak, Trywiańska 1998]. According to the Soviet Standards (GOST) cotton fibers are classified into the following 4 color classes:

1. Mature – orange, yellow-gold, yellow-green;
2. Not fully mature-yellow green with blue parts, green, blue;
3. Immature-blue, blue-violet;
4. Dead-violet-purple or purple as a background.

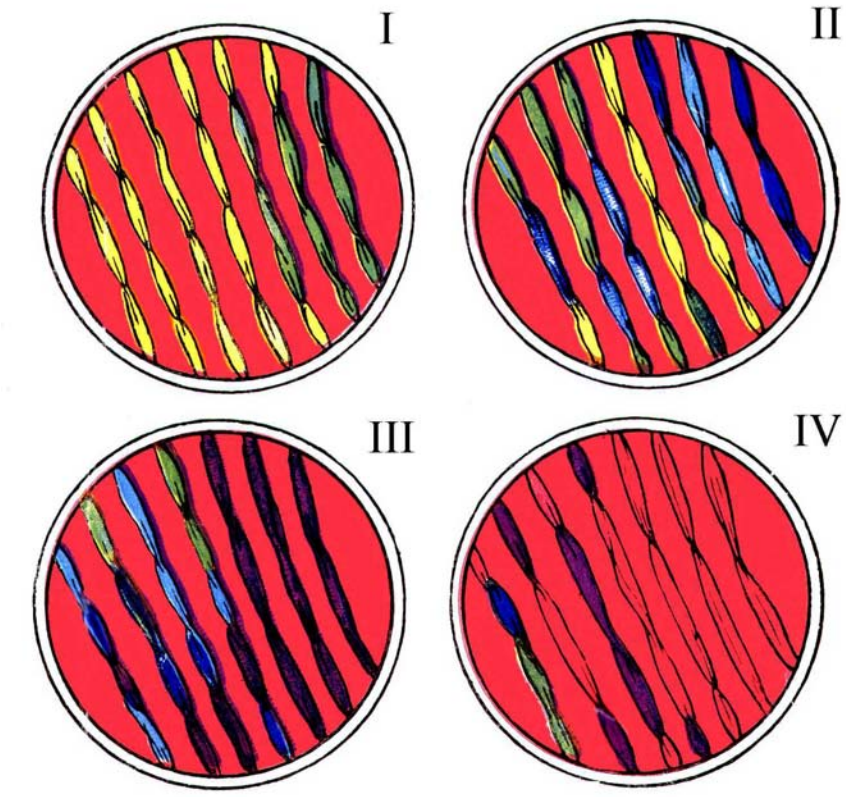


Figure 1. Color patterns in the particular maturity classes

The color patterns for cotton maturity assessment according to PN-72/P-04675 are presented in Fig. 1.

The mean maturity degree is calculated on the basis of the percentage of fibers in the successive classes according to the equation:

$$z = \sum a_i p_i / 100 \quad (1)$$

where:

z – maturity degree;

a_i – coefficients characteristic for the given cotton maturity class and a type of different origin set forth in Table;

p_i – fiber share in successive maturity classes [%].

Measurements on the AFIS system

AFIS enables the assessment of cotton fiber cross-section circularity coefficient. The coefficient of circularity is defined as a ratio of area of fiber wall and the area of a circle of the same perimeter as a fiber:

$$\Theta = \frac{4\pi A}{P^2} \tag{2}$$

where:

P – perimeter of a given fiber cross-section,
A – the area of the secondary wall of fiber.

Basing on the results of single fiber circularity coefficient the Maturity Ratio defined by Lord [Watson 1992] is calculated.

$$MR = 0.7 + (N - D)/200 \tag{3}$$

where:

N – mature fiber content, ie., the fibers of $\theta > 0.5$,
D – dead fiber content, for which $\theta < 0.25$.

Measurements of cotton fiber cross-section using the computer image analysis program LUCIA

Using the computer image analysis system LUCIA the measurements of parameters characterizing the shape and size of cotton fiber cross-section (Fig. 2) were performed. 100 measurements of individual fiber cross-sections were done for each fiber lot. The following parameters were measured:

- circularity coefficient of fiber cross-section θ,
- the thickness of the secondary wall e,
- equivalent diameter of the fiber cross-section *D*.

Figure 2. An example of microscopic picture of cotton fiber cross-sections

On the basis of results of the secondary wall thickness the degree coefficient k defined by Raes was calculated [Raes, Verschraegel 1991]:

$$k = \frac{e}{D} \tag{4}$$

where:

e – the secondary wall thickness,
D – equivalent fiber cross-section diameter, ie., diameter of a circle of a perimeter equal to the perimeter of fiber cross-section.

3. Results and their analysis

The results of parameters characterizing cotton maturity assessed by three described above methods are presented in Table 1.

Table 1. Results of cotton maturity by three methods

		Area	eqD	Perim	Theta Lucia	e	k	Theta AFIS	Z	**Mat**
089-053	1	130.26	12.738	57.38	0.5225	2.2222	0.3489088	0.429	1.16	0.81
303	2	139.36	13.159	55.86	0.5767	2.4409	0.3709856	0.428	1.3	0.81
25	3	140.5	13.216	53.79	0.6195	2.5831	0.390905	0.447	1.56	0.84
24	4	155.67	13.955	57.792	0.6051	2.8251	0.4048871	0.465	1.53	0.87
302	5	147.1	13.576	53.684	0.6551	2.6354	0.388244	0.473	1.54	0.89
094-003	6	138.12	13.112	49.799	0.7128	2.8975	0.4419616	0.484	2.01	0.9
042-169	7	140.84	13.161	52.33	0.6509	2.5469	0.3870375	0.48	1.53	0.91
JM02501	8	147.46	13.607	51.765	0.7056	3.0206	0.4439774	0.505	1.74	0.94
031-023	9	175.14	14.843	54.549	0.7479	4.1753	0.5625952	0.524	1.88	0.96
393-021	10	148.12	13.494	49.177	0.7694	3.2007	0.4743886	0.528	1.95	0.97
028-402	11	148.12	13.600	51.029	0.7175	3.2078	0.4717353	0.534	1.57	0.98
070-012	12	161.63	14.259	53.021	0.7346	3.3802	0.4741146	0.533	1.75	0.98
030-041	13	190.58	15.461	56.883	0.7439	4.0448	0.5232262	0.539	1.74	0.99

On the basis of results obtained by three different methods the assessment agreement was analyzed.

In Fig. 3., there is presented the comparison of fiber cross-section circularity coefficients determined using the AFIS and image analysis program LUCIA. For all assessed cotton lots the results from the AFIS system are lower than these obtained by the computer image analysis program. It can result from a fact that the specimens for microscopic measurements by the computer image analysis system were prepared by hand. Therefore, there is a probability that a part of the shortest and thinnest fibers, which are difficult to assess were not confined in the prepared by hand specimens.

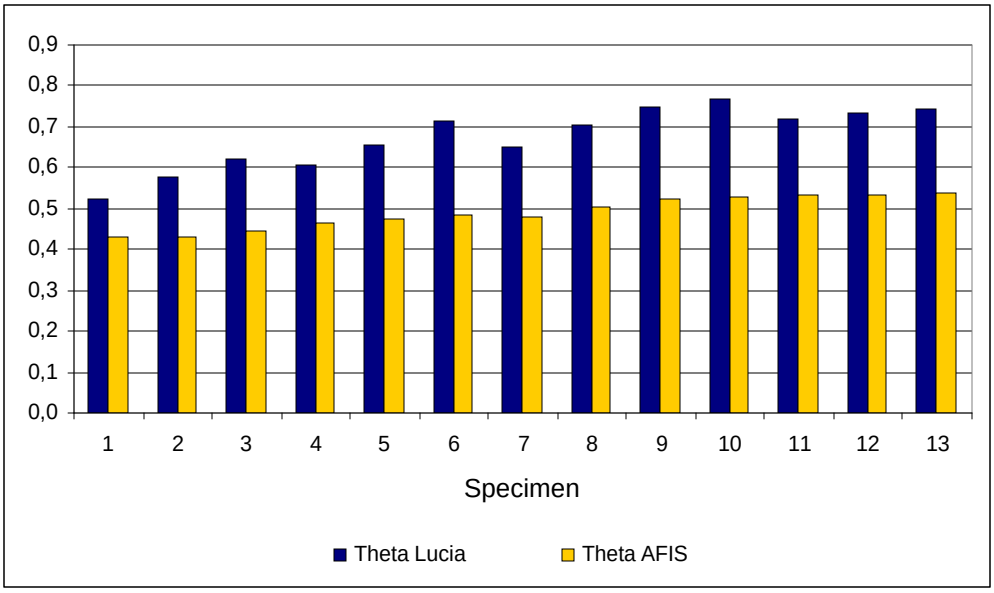


Figure 3. The comparison of mean values of circularity coefficients of cotton fiber cross-sections

Nevertheless, it was stated that there is a strong linear correlation relationship between the results of circularity coefficient of cotton fiber cross-sections obtained on the AFIS and computer image analysis system (Fig. 4).

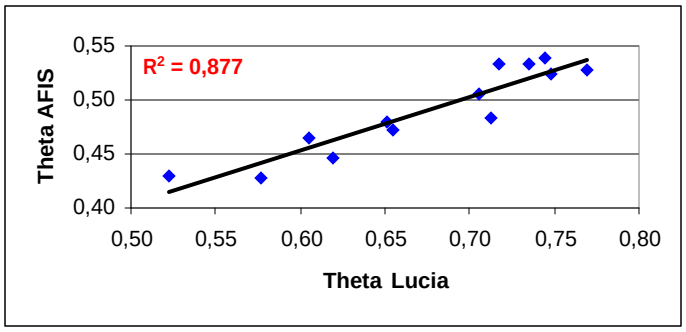


Figure 4. Correlation between the circularity coefficients obtained on the AFIS and by LUCIA

The absolute values of the rest of parameters cannot be compared directly, because each of them characterized a cotton maturity in a different way. Results from the AFIS system enable the cotton fiber classification according to Table 2.

Table 2. Assessment of cotton fiber maturity basing on the AFIS parameters

Fiber Maturity Assessment	Circularity coefficient	MR
Dead	0 < 0.25	
Thin walled	0.25 ÷ 0.50	0.7 ÷ 0.8
Mature	> 0.50	0.8 ÷ 1.0
Over mature		> 1.0

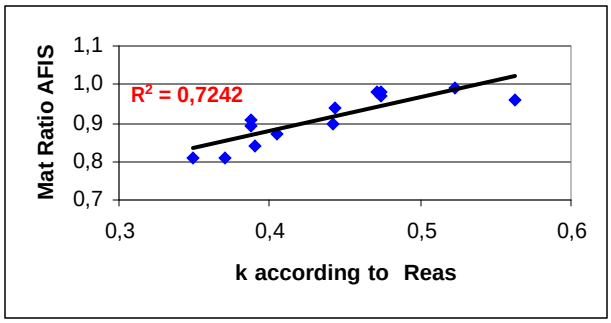
According to obtained by us results on the AFIS all the assessed cotton lots are mature.

According to GOST cotton can be assessed as mature (I), when the mean maturity degree *z* is *1.9*.

On the basis of our results only two cotton lots (sample 6 and 10) can be classified as a class I.

There are no classification rules on the basis of maturity coefficient k according to Raes. It can be only stated that the highest values of this parameter were obtained for lots No 9 and 13. The statistical analysis aimed at the assessment of correlation relationships between maturity results obtained by different measurement methods was performed.

In Fig. 5, there are presented the relationships between values of particular parameters determined by the applied measurement methods.



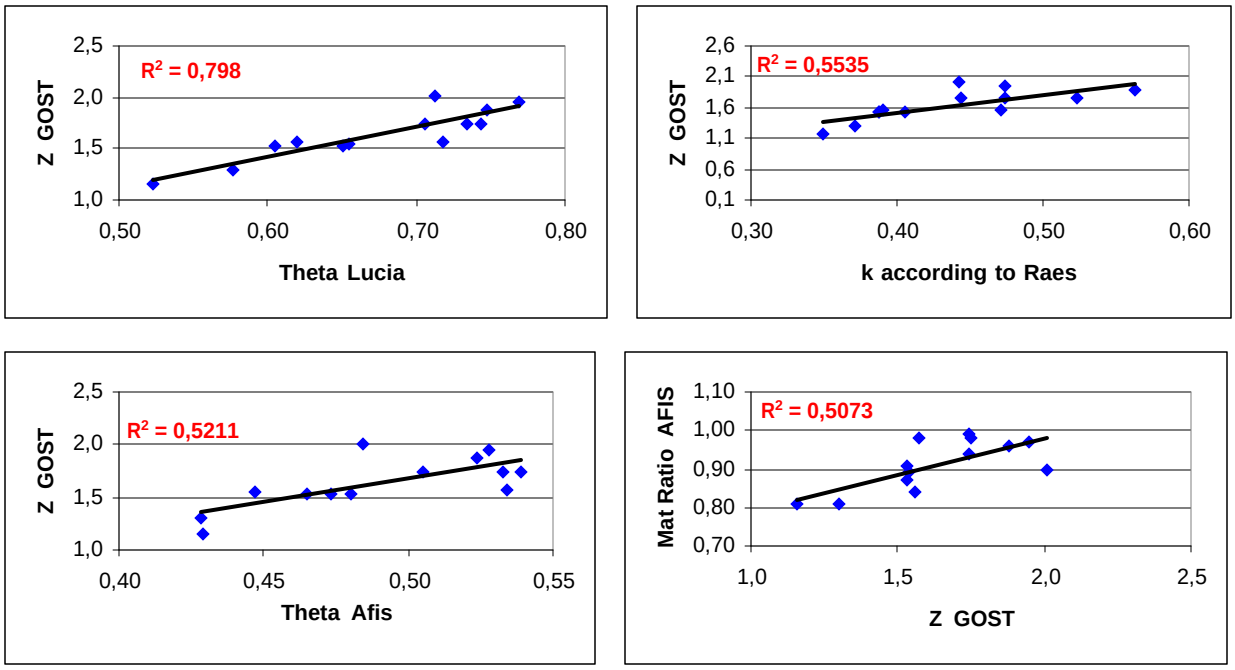


Figure 5. Correlation relationships between particular maturity parameters

It was stated a strong linear correlation relationship between the following parameters:

- fiber circularity coefficient θ obtained from the computer image analysis system and the maturity degree z according to GOST,
- Maturity Ratio from the AFIS and maturity coefficient k according to Raes.

The lower than previous values of correlation coefficients are noted between the value of maturity degree according to GOST and:

- Maturity Ratio from AFIS,
- maturity coefficient k according to Raes.
- fiber circularity coefficient θ from the AFIS.

Nevertheless, even in these cases the stated relationships are statistically significant. It should be noted that the number of measured sample lots are not big enough. This limitation results from the fact that maturity measurements using the computer image analysis system are not standard procedures. For our experiment purpose the own procedure of specimen cross-sections preparation and measurement was elaborated. The carried out measurements were very laborious, because for each single fiber the circularity coefficient θ, equivalent diameter *D* and the secondary wall thicknesses, were measured. The measured parameters were indicated on the computer screen manually.

The applied measurement procedure limited the number of samples. Such measurements will be continued.

Summing up

Summing up the carried out comparative measurements the following was stated:

- the strongest linear correlation relationship exists between the results of circularity coefficient θ from the AFIS and the computer image analysis system,
- there are strong correlation relationships between all parameters characterizing the cotton maturity assessed by three different methods: in polarized light according to GOST, AFIS and image analysis system,
- the simplest and less laborious method of maturity assessment is by using the AFIS,

- procedure of specimen preparation for image analysis system is very laborious and should be improved,
- there is a need of continuation of carried out measurements to conclude on the basis of bigger number of measurements.

Bibliography

Frydrych I., Zurek W., Andrysiak J., Trywiańska W., Comparative Analysis of Cotton Maturity Assessment Methods, Fibres &Textiles in Eastern Europe (1998).

Raes G. A. T. J., Verschraegel, Consideration of the Reel Maturity of Cotton Fibers, J. Tex. Inst. 72, 191-200 (1981).

Soviet standard, GOST 3274.2-72,.

Watson M. D., Measurement and Evaluation of Dye Resistant Neps and Immature Fibers, International Cotton Conference, Bremen (1992).

Urbańczyk G., Fibre science, TUL, Lodz (1978).

Uzbek standard Uz RST 604-93.