I. Frydrych[1,2], M. Matusiak[1]

[1]**Institute of Textile Architecture**

ul. Piotrkowska 276, 90-950 Łódź, Poland
e-mail: iat@iat.formus.pl

[2]**Technical University of Łódź**

ul. Żeromskiego 116, 90-543 Łódź, Poland
e-mail: ifrydryc@ck-sg.p.lodz.pl

Trends of AFIS Application in Research and Industry

Abstract

One of the basic factors influencing the manufacture of good quality yarn is the correct blend composition to obtain the required yarn properties. Another important factor is a correct technological process (starting from the raw material, going through the processes of sliver preparation, and ending with the spinning and winding processes). A lack of precise checking procedure of the technological process can lead to negative changes of fibre parameters, such as fibre shortening or breaking, nep creation and so on. The development of modern measurement systems, which has been progressing for 30 years, has created new possibilities for assessing fibre properties as well as monitoring and optimising the manufacturing process. In this paper, some aspects are described of the AFIS (Zellweger Uster) application in the spinning process on the basis of data gathered by the Polish spinning mills and in the research activity of the Institute of Textile Architecture.

Key words: *AFIS, cotton fibres, spinning process.*

Introduction

The Advanced Fibre Information System (AFIS) by Zellweger Uster enables a fast and objective assessment of cotton raw material as well as spinning half-products [1-3]. It measures 21 different cotton parameters by individualising fibres in the air stream. It gives the mean value of a parameter and its distribution. Generally, information provided by the AFIS can be classified as follows:
a) that used for basic research,
b) that used for applied research.

Additionally, the second group can be divided into two sub-groups:
- direct information concerning fibre parameters in raw material and half-products,
- indirect information concerning the technological process.

The first kind of information is very valuable for trading purpose and optimal composition of the blend for production. It also allows the changes of particular parameters during processing to be followed. Indirect information consists of parameters which are not measured directly on the AFIS, but can be calculated on the basis of fibre parameters. Thanks to both kinds of information the AFIS can be used for:
- blend composition,
- analysis of changes in basic fibre properties during processing,
- optimisation of the spinning machinery operation and of the technological process,
- predicting the quality level of yarns produced.

The AFIS System in the IAT's Research

Research on cotton fibres, their properties, measurement methodology and spinning process has been carried out in the Institute of Textile Architecture for many yarns. Some research solutions have been introduced in the Polish spinning mills. The AFIS system has been used in our work since 1996.

Results from the AFIS system have been applied for a detailed assessment and comparison of the properties of cotton from different regions of cultivation [4], for analysis of fibre parameter changes during processing [5] and for predicting cotton yarn quality. Many papers on these topics have been published [6-8] and presented at international and domestic conferences.

We should point out here the research concerning cotton neppiness and the influence of nep number and size distribution on yarn faults. Kluka, Matusiak & Frydrych [7] performed a precise analysis of the nep number changes in cotton in the successive stages of the technological process, i.e., in the scutching room, during carding and during combing, with consideration of changes in nep size distribution during processing. They stated that the mean nep size changes during spinning. The reduction in the mean nep size occurs to only a small degree in the carding process, whereas this phenomenon is significant in the combing process. Neps in the raw material and half-products are characterised by the nep size from 650 to 1500 µm. Big neps (above 1250 µm) either do not appear or appear rarely in the sliver after combing. In our consideration, neps were divided into 4 groups:
- below 800 µm,
- 800 µm,
- 850 µm,
- above 850 µm.

We have found out that frequencies of neps of different size change during the technological process. The share of big neps (above 850 µm) decreased from 30% to 20% in the sliver after combing, whereas the share of the smallest neps (below 800 µm) increased from 40% in raw material to about 50% in the sliver after combing. Neps of external sizes are removed most efficiently in the carding process.

Święch [8] predicted the nep number per 1000 m of OE yarn on the basis of the nep number in the sliver feeding the rotor frame. In her considerations she applied the equation on the coefficient of the nep and trash transfer φ proposed by Färber [9]:

$$\varphi = \frac{\dfrac{Nep\ number}{gram\ of\ yarn}}{\dfrac{Nep\ number}{gram\ of\ sliver} + \dfrac{trash\ number}{gram\ of\ sliver}} \qquad (1)$$

She determined the value of φ coefficient for the rotor yarn 30 tex and obtained a wide variation in particular φ values: CV - 45.5%. Additionally, she calculated values of the nep and trash transfer coefficient for neps of the following size:
- above 800 µm,
- above 900 µm,
- above 1000 µm.

Taking only neps and trash of large size into consideration during calculation of φ coefficient caused an increase in the φ value, but it did not significantly diminish the variation in the samples analysed.

Frydrych & Matusiak [10] carried out investigations aimed at identifying the factors influencing the value of the nep and trash transfer coefficient. They stated that, besides the yarn linear density, the following factors influence the value of the φ coefficient:
- the nep and trash content in the sliver feeding the rotor frame,
- the manner of sliver preparation,
- the technical shape of the spinning points.

They additionally proposed a new coefficient of the nep transfer φ_1 only:

$$\varphi_1 = \frac{Nep\ number\ /\ gram\ of\ yarn}{Nep\ number\ /\ gram\ of\ sliver} \qquad (2)$$

There is a strong correlation (R_{xy}=0.9984) between both coefficients: φ and $φ_1$. The proposed coefficient of the nep transfer $φ_1$ facilitates the prediction of the nep number in the yarn. Additionally, it enables the prediction of quality in a situation when the spinning mill has only one AFIS module (AFIS-N).

Frydrych & Matusiak [11] derived a theoretical relationship on the minimal inertia radius of a cotton fibre cross-section in the function of cotton maturity as expressed by the circularity coefficient determined on the AFIS system. Considerations were made on the assumption that the cotton fibre cross-section has an ellipse shape and the shape of a flattened ring. They obtained the following relationships:

$$i_e = \frac{D}{4}\left(1-\sqrt{1-\theta}\right) \qquad (3)$$

$$i_r = \frac{D}{2}\cdot(1-\sqrt{1-\theta})\cdot\sqrt{\frac{\frac{1}{4}+\frac{5}{12}\sqrt{1-\theta}}{1+\sqrt{1-\theta}}} \qquad (4)$$

where:
- i_e - minimal inertia radius of cotton fibre cross-section on the ellipse assumption,
- i_r - minimal inertia radius of cotton fibre cross-section on the flattened ring assumption,
- θ - circularity coefficient of cotton fibre cross-section,
- D - cotton fibre diameter.

The relationships extrapolated allow cotton fibre slenderness (and in the same way their ability of nep creation to be linked) with fibre maturity as expressed by the AFIS system.

AFIS Application for Blend Composing

As mentioned before, AFIS can precisely characterise the cotton raw material. Nevertheless, the obtained results cannot be used for cotton classification and assessment if the tested raw material lot corresponds to the declared quality. Cottons from Central Asia, which are those most often processed in Polish spinning mills, together with cottons from the other cultivation regions, are classified based on a different methodology including organoleptical measurements. So far, AFIS results have not been used for cotton classification in any country. Nevertheless, the precise characteristics of raw material from the AFIS system can be used for a comparison of cotton lot quality, and principally for composing the blends.

Blend composing is one of the basic phases of the spinning process, due to the high cost of imported raw material, as well as the influence of fibre parameters on the quality of produced yarn [12-14]. While composing the blend, some rules should be observed. First of all, the appropriate choice of raw material length is very important. The difference in length of particular blend components should not be greater than 1-2 mm. A higher difference is admitted only when the difference of length variation coefficients is higher than ±1.9% [15].

The next important parameter is fineness. This decides the number of fibres in the yarn cross-section. In order to assure the appropriate yarn evenness, the number of fibres should not be less than 100-200 in the case of OE yarn, 50-60 in the ring-spun carded yarn, >30 in the ring-spun combed yarn. Fibre maturity and strength also decide about the yarn quality. The levels of these parameters are determined for a particular grade of cotton from Central Asia. The fibres of the same or neighbouring grades are admitted for the blending purposes.

Trash content and structure in cotton also play an important role [16,17]. All the mentioned fibre parameters considered during the blend composition (apart from fibre strength) can be determined by the AFIS system.

Assessment of Changes in Basic Properties of Fibre Stream During Processing

Testing fibre stream half-products using the AFIS system (starting from raw material and finishing with the fibre stream from the rotor) permits an assessment of tendencies in property changes in the fibre stream during processing. In Figure 1, the changes in chosen fibre parameters during the OE spinning are presented.

On the basis of the results presented we can assess not only how the fibre stream properties change during processing, but we can first of all find out which properties characterise the fibres taken from rotor, and in the same way which ones characterise the OE yarn. Additionally, on the basis of the above results we can assess which relations between properties of the fibres from rotor (or rotor yarn) and the fibres from raw material are applied for production. The relationships obtained should be used for predicting the quality of produced yarns based on the fibre parameters.

Particular changes in fibre parameters characterising a length should be pointed out. The mean length of fibre stream from the rotor, as in the rotor yarn, is lower than raw material fibre length, but the SFC and variation coefficient of long fibre length registered for fibres taken from the rotor are much higher than the analogous parameters for raw material.

AFIS Application for Optimising Spinning Machinery Operation

The correctness of action of spinning machinery can be checked on the basis of a comparison of fibre quality parameters in the fibre stream feeding, and delivered

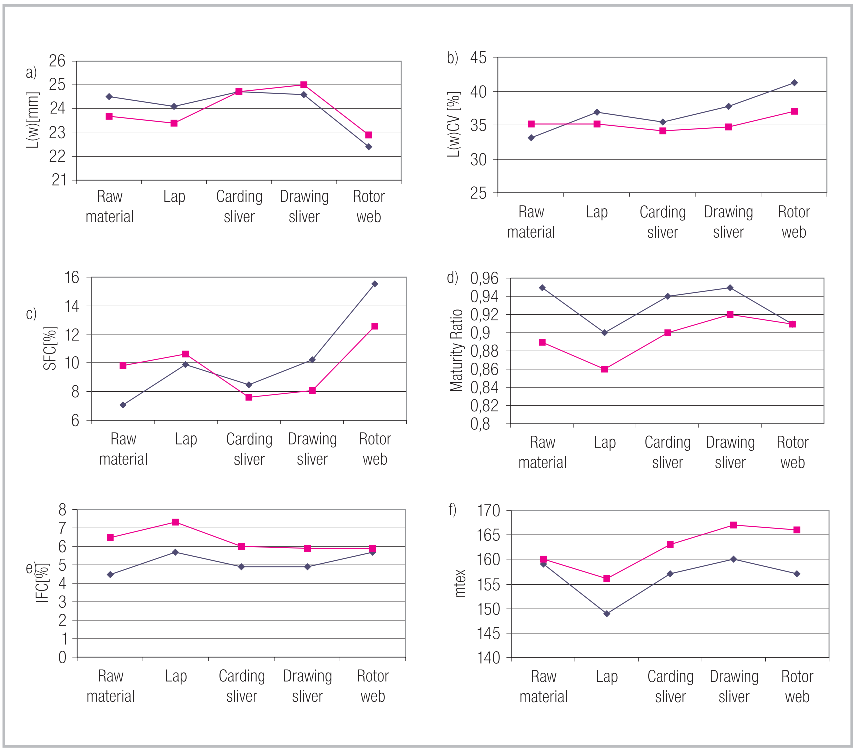

Figure. 1. Changes in chosen fibre parameters during the OE spinning; —◆— cotton from Egypt; —■— cotton from Central Asia.

as well as on an analysis of machine efficiency. Commonly known and used is an equation on the cleaning efficiency calculation [3]:

$$CE\,(\%) = \frac{TC_{feed} - TC_{del}}{TC_{feed}} \qquad (5)$$

where:
TC_{feed} - trash content in the feeding web,
TC_{del} - trash content in the delivered web.

This parameter is used for assessment of the scutching room, carding and combing machines. The other parameter for assessing of machine work is the fibre destruction index FDI (%) [6]:

$$FDI\,(\%) = \frac{SFC_{del} - SFC_{feed}}{SFC_{feed}} \cdot 100\% + CF \qquad (6)$$

where:
SFC_{feed} - short fibre content in the feeding web,
SFC_{del} - short fibre content on the output,
CF - correction coefficient taking into consideration SFC in machine wastes.

Correction coefficient can be calculated in the following way:

$$CF\,(\%) = W\,(\%) \cdot \frac{SF_{CW} - SFC_{del}}{SFC_{feed}} \cdot 100\% \qquad (7)$$

where:
$W(\%)$ - percentage of wastes from machine,
SFC_W - SFC in wastes.

Additionally, the efficiency of nep removal is calculated for carding and combing frames as follows:

$$NRE(\%) = \frac{N_{feed} - N_{del}}{N_{feed}} \cdot 100\% \qquad (8)$$

where:
N_{feed} - the nep number in the feeding web,
N_{del} - the nep number in the delivered web.

In spite of the parameters mentioned above, results from the AFIS system are used in Polish spinning mills for calculating the additional parameters characterising the work of particular machines, and a more precise assessment of the correctness of the technological process.

Assessment of effectiveness of the scutching room

Apart cleaning efficiency, a dust removing efficiency DRE (%) can be calculated according to the formula proposed by IAT:

$$DRE(\%) = \frac{Dust\ \ Cnt/g_{feed} - Dust\ \ Cnt/g_{del}}{Dust\ \ Cnt/g_{feed}} \qquad (9)$$

where:
$Dust\ Cnt/g_{feed}$ - the number of dust particles in the feeding fibre stream,
$Dust\ Cnt/g_{del}$ - the number of dust particles in the delivered fibre stream.

Moreover, the efficiency of nep removal NRE (%) is calculated according to equation (4). Since an increase in the nep number in the scutching room is observed, the obtained values of NRE% took the negative value. The higher the absolute value of NRE%, the greater the increase in the nep number, which indicates the worse work of the scutching room.

All the parameters characterising the technological process are calculated for particular opening machines working in the technological order. This allows, among other things, an identification of the place where the highest increase in nep number occurs.

Assessment of carding machine work

The following parameters characterising work quality can be calculated:
- cleaning efficiency CE %,
- nep removing efficiency NRE %,
- dust removing efficiency DRE %.

Moreover, an additional parameter was proposed for this production stage, i.e. SCN removal efficiency, according to the formula:

$$SCN\ \ RE\% = \frac{SCN\ \ Cnt/g_{del} - SCNCnt/g_{feed}}{SCN\ \ Cnt/g_{feed}} \cdot 100\% \qquad (10)$$

In Figure 2, the results are presented of work assessment of 9 carding frames carried out in one of the Polish spinning mills during processing. On the basis of the results presented it can be stated that these machines were characterised by different work efficiency. Trash particles are removed in the best way by the carding frame No 2 (CE=90.9%), then carding frames No 1 and 40. The worst carding frames were No 3 and 38. The highest dust removing efficiency was recorded for carding frames of No 1, 2 and 40, and the lowest for carding frame No 5.

It was also stated that high cleaning efficiency as calculated based on the changes of hard trash particles is not accompanied by high dust removing efficiency. It proves the need to calculate an additional parameter of DRE % proposed by IAT.

Regarding nep removal efficiency, it can be stated that the assessed carding frames work in a uniform way. NRE ranges from 51.5 to 79.1%, at the mean value for the whole machine group of NRE=68.2%. The assessment of SCN removal efficiency for some of the machines (carding frame No 1, 2, 3, 37, 40) is in agreement with the cleaning efficiency of these machines.

Fibre destruction index FDI % is not usually calculated. Calculation of this parameter is difficult in daily practice, because it requires knowledge of the waste percentage from the machine and the percentage of SFC in wastes. For carding frames fed by a fibre assembly working in the one technological scutching-carding order, it is difficult to separate wastes created on the particular carding frames because they are pneumatically conveyed to the common waste chamber.

In the case of carding frames fed by laps, where the waste is picked by hand, there is a problem with determining SFC in wastes. The laboratory staff are unwilling to test wastes of known trash content, such as for example husk taken from the lower part of the carding frame, because they are afraid of destroying the AFIS.

Some information about the phenomenon of fibre destruction in the carding process can be obtained by comparing parameters characterising fibre length in the web feeding the carding frame and in the delivered sliver.

In Table 1, the values are presented of 4 parameters for 9 examined carding frames:

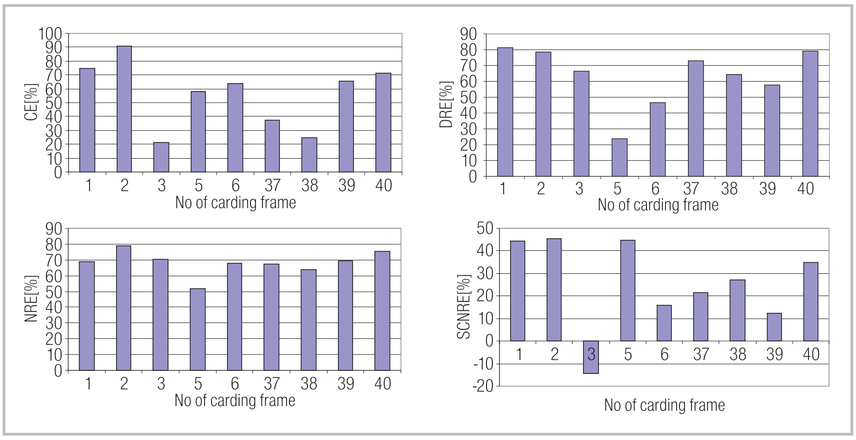

Figure 2. Assessment of carding frame work.

$$\Delta L(w) = L(w)_{sl} - L(w)_{fw} \quad (11)$$

$$\Delta L(w)CV = L(w)CV_{fw} - L(w)CV_{sl} \quad (12)$$

$$\Delta UQL(w) = UQL(w)_{sl} - UQL(w)_{fw} \quad (13)$$

$$\Delta SFC(w) = SFC(w)_{sl} - SFC(w)_{fw} \quad (14)$$

Where:
sl - sliwer
fw - feeding web

As a result of the carding process, an increase in mean fibre length by weight L(w) of 0.5 mm, and in mean value of UQL(w) of about 0.3 mm was observed. Simultaneously, a drop was observed in length variation coefficient of about 0.4%, and in SFC(w) of about 1%. Intensification of the fibre destruction process in the carding process was noted for carding frame No 39 and 5.

Assessment of combing frame work
The assessment of combing frame work is based on the parameters mentioned above characterising machine efficiency, i.e., CE%, DRE%, NRE%, SCN RE%. Since one of the tasks of the combing process is removing the shortest fibres and increasing fibre length uniformity, the length parameter changes in the fibre stream were analysed precisely. In Table 2, results are presented of the assessment of combing frame work in the one technological order with carding frames described earlier.

We analysed the individual heads of both combing frames. On the basis of the data presented earlier, it can be stated that the work of both combing frames is of a similar level regarding nep and trash removing efficiency. We noted an identical increase in mean fibre length after combing about 1.1 mm for both combing frames. A slightly higher reduction of SFC and fibre length uniformity for the combing frame No 6 was established. For both combing frames, we observed work variation of particular heads (especially in the aspect of nep removal efficiency):

- combing frame No 5 - NRE % in the range 36.6-69.0%,
- combing frame No 6 - NRE % in the range 39.0-63.3%.

Assessment of BD 200 rotor spinning frames
In the Institute of Textile Architecture, we use the AFIS for assessing spinning point work of the BD 200 RCE rotor spinning frame. These spinning frames are installed in a majority of Polish spinning mills, and a large proportion of cotton yarns are still produced on them, although a new generation of spinning frames has been introduced onto the market.

The assessment procedure is as follows: while processing OE yarns the fibre web is taken from the rotor. Before being in the rotor these fibres were transformed by an opening roller action. The sliver feeding the OE spinning frame and the fibre samples from the rotor were tested on the AFIS. A comparison of fibre properties in the feeding sliver and fibre web from the rotor enables assessment of the quality of particular spinning point work.

In Figure 3, the changes are presented in chosen parameters of the cotton fibre stream after passing through the zone of the opening roller, registered at 5 randomly chosen spinning points of the BD 200 RCE OE spinning frame while manufacturing the yarn of linear density 25 tex.

It was stated that during processing on the OE spinning frame, changes were observed in the parameters characterising fibre length. Mean length by mass is diminished after passing the zone of opening roller action, but the SFC increased significantly. The magnitude of changes in the parameters mentioned above is different at the particular spinning points tested. We also noted a reduction in the amount of trash, dust and neps, but particular spinning points have a different removing efficiency. Particular parameters characterising work efficiency of the spinning points can be calculated in an analogous way as in the case of the carding and combing spinning frames.

Assessment of the whole technological process
On the basis of the AFIS measurements of raw material and half-products arising from the different stages of processing, we can assess the quality of the spinning process by comparison of the experimental data with the data contained in the Uster Statistics`97 [18].

Figure 4 presents the changes in nep, trash and dust amount, as well as the SFC registered in the tested spinning mill, in comparison with the Uster

Table 1. *The set of parameters characterising the changes of fibre length properties.*

No of carding frame	ΔL(w)	ΔL(w)CV	ΔUQL(w)	ΔSFC(w)
1	0.5	0.4	0.4	1.0
2	0.6	1.1	0.6	1.2
3	0.7	0.9	0.4	1.5
5	0.2	0.2	-0.1	0.7
6	0.4	-0.4	0.4	0.6
37	1.1	2.3	0.7	2.6
38	0.4	0.2	0.4	0.8
39	-0.1	-1.3	-0.1	-0.2
40	0.6	-0.2	0.4	0.9
Mean value	0.5	0.4	0.3	1.0

Table 2. *Assessment of work of combing frames.*

Combing frame	No of head	CE %	DRE %	NRE %	SCNRE %	ΔL(w)	ΔL(w)CV	ΔSFC(w)
No 5	1	81.8	70.7	50.6	80.0	1.5	3.9	4.2
	2	81.8	63.8	36.6	50.0	1.0	3.2	3.6
	3	90.9	73.9	69.0	92.6	1.5	5.5	5.1
	4	55.6	41.7	48.9	68.4	0.6	2.0	2.6
	5	71.4	35.6	43.0	55.6	1.4	3.6	4.0
	6	63.6	72.4	55.2	66.7	0.8	3.6	3.7
	7	81.8	59.2	55.2	70.0	1.3	4.0	3.9
	8	58.3	42.6	38.3	46.7	0.7	3.3	2.8
	Mean value	73.2	57.5	49.6	66.2	1.1	3.6	3.7
No 6	1	54.5	16.4	39.0	53.3	1.2	3.0	3.5
	2	72.7	-25.0	61.5	81.8	0.7	3.4	3.3
	3	70.0	59.7	45.3	80.0	1.2	3.5	4.1
	4	76.5	45.5	60.2	76.2	0.8	3.4	3.8
	5	90.0	8.5	56.5	81.8	0.9	3.5	3.6
	6	83.3	53.8	63.3	83.3	1.3	4.1	4.3
	7	76.9	62.6	48.3	86.4	1.2	4.5	4.9
	8	72.7	35.2	57.0	71.4	1.4	5.7	4.9
	Mean value	74.6	32.1	53.9	76.8	1.1	3.9	4.1

Statistics lines corresponding to 25% and 50% of the world production.

In relation to the nep and trash content, the initial stages of processing (i.e., the applied raw material and the quality of web feeding the carding frame) are close to the 25% line, whereas further stages are closer to the 50% line, which is a result of the lower work efficiency of carding and combing frames. Changes in the SFC in the spinning mill mentioned above ideally cover the 50% line according to the Uster Statistics'97. Changes in the dust amount are also close to the mean world level. We should pay special attention to the good work of the scutching room, thanks to which trash and dust are removed with high efficiency. In that way the quality of applied raw material is improved from the level close to 50% to the level of 25%. This causes a low increase of the nep amount in comparison with the world tendency.

Predicting the Quality Level of Produced Yarns

The results of raw material and half-product parameters can be used for predicting the quality level of the produced yarns based on the Uster Statistics`97. The newest edition of Uster Statistics [18] contains "Fibre-Yarn" statistics elaborated for the ring and OE spinning processes. For the first, the values are given of the roving parameters determined on the AFIS in relation to the quality level of carded and combed yarns. For OE yarns, the statistics give the values of parameters of slivers after the finisher in relation to the quality level of OE yarn.

The nep amount in the yarn can be predicted based on the nep balance elaborated on the basis of a temporary diagnosis of the spinning process by the AFIS. A model of nep balance was proposed by the IAT.

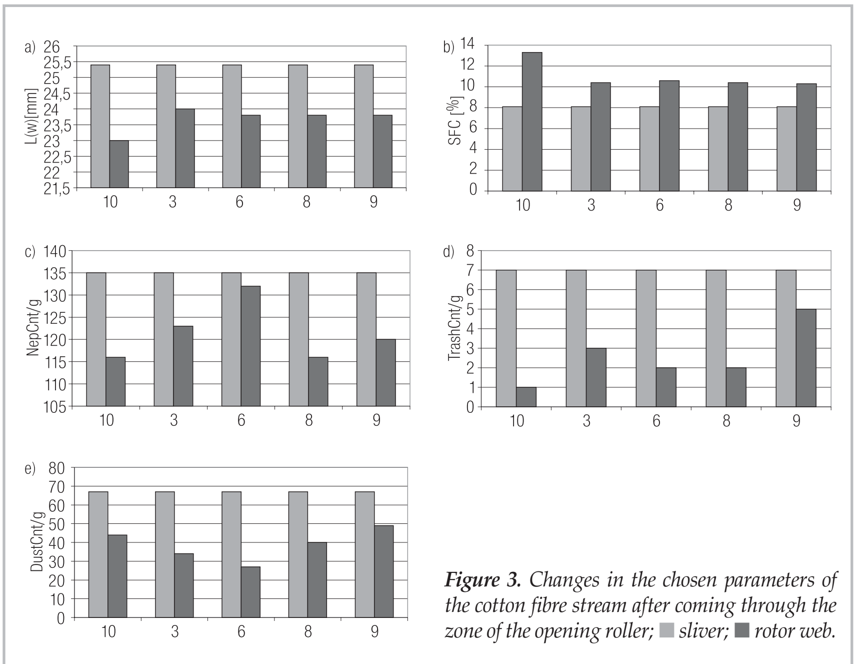

Figure 3. Changes in the chosen parameters of the cotton fibre stream after coming through the zone of the opening roller; ■ *sliver;* ■ *rotor web.*

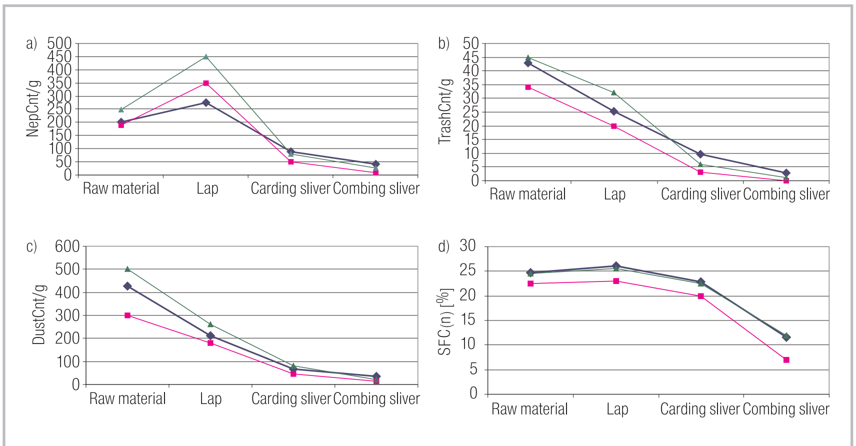

***Figure 4.** Assessment of the spinning process according to the Uster Statistics;* —◆— *spinning mill;* —■— *25% US;* —▲— *50% US.*

Summary

The AFIS system seems to be a very useful tool for the spinning industry. Although we are aware that it is not perfect, and sometimes the results of AFIS measurement are biased, it should still be worked on in order to become an indispensable tool in spinning mill work. Research should be carried out to extend the range of AFIS applications.

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