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ANALYSIS OF CHANGES IN FIBER DENSITY DISTRIBUTION IN A COTTON COMBED SPINNING SYSTEM USING MODIFIED REGULATION OF THE SLIVER DRAFT

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Abstract:

Shortening the technological spinning processes, aiming at the reduction in production costs, causes problems with keeping up a high quality of yarn. Of great significance is the use of autolevellers that not only equalize the distribution of fiber linear density but also straighten the fibers and lay them parallel to the product axis. Consequently, they replace the machines eliminated from technological lines and contribute to the improvement in the quality of intermediate products and yarns. Using an example of the cotton combed spinning system, the article presents the analysis of the possibilities of using a short-term autoleveller with a modified operation algorithm that takes into account the phenomenon of sliver retardation after the process of short-term regulation. The regulation of draft was used before and after combing. The quality parameters of slivers used for feeding roving frames or rotor spinning machines were analyzed.

Keywords:

draft regulation, sliver, fiber combing.

Introduction

The aim of all the spinning systems is to produce yarn with the best possible quality parameters and the highest efficiency. In many cases, an increase in machine efficiency results in the deterioration in yarn quality. The yarns produced by conventional system, with the use of ring spinning frames, have mostly a better quality (especially with respect to strength parameters) [9] than that of rotor yarns produced on rotor spinning frames. Rotor spinning machines are characterized by a productivity that is more than 12 times higher than that of ring (classic) spinning frames and, therefore, their use in the industry is successively increasing. To improve the quality of rotor yarns, a stage of fiber combing is added to the technological spinning process, which so far was realized only in classic systems. The aspiration for reducing the price of the yarn made causes a gradual reduction in the number of machines in the technological process [1], which causes that the improvement in the evenness of intermediate product of spinning must be accomplished with the use of autolevellers. The regulators used in carded spinning systems can now be seen in most spinning mills, while the use of autolevellers in combed systems is not so obvious, especially if one use them before the combing process. Autoleveller constitutes an additional system for fiber straightening and should contribute to increasing the combing efficiency. Autoleveller used after combing exerts a considerably higher influence on the uniformity of the yarn linear density as the effect of its action is not any more eliminated by the fiber combing process. The algorithm of the autoleveller operation is also of great importance. It has been proved [2-6] that the most efficient is the regulation algorithm that takes into account the retardation of sliver leaving the zone of variable draft in time.

Aim and object of study

The aim of the study was to assess the effect of short-term regulation of the sliver linear density uniformity on the quality of slivers used for feeding roving frames and classic spinning frames or rotor spinning machines in the combed spinning systems. The study was carried out in the technological spinning laboratory of the Department of Material and Commodity Sciences and Textile Metrology of the Lodz Technical University.

The raw material used for the production of yarn consisted of medium staple cotton in the form of blend of three types:

1.	Turkish	Ex/I	3/32″	content:	32%
2.	Turkish	I/II	3/32″	content:	48%
3.	Greek	60x-41	3/32″	content:	20%

The following machine system was used: laboratory carding machine type 3K from Befama, laboratory drafting machine type SD (series N211) from Platt, sliver doubling frame type 1572/2 from Textima, combing machine type 1531 (series 005-PE2) from Textima, and laboratory drawing frame type SD (series N211) from Platt.

The machine system after drawing machines (before and after combing) consisted of short-term autoleveller in the following variants:

1. Regulation before combing (variant A)
2. Regulation after combing (variant B)
3. Regulation before combing and after combing (variant A + B)
4. No regulation (variant O), reference variant.

The analyzes of the operation of short-term regulation performed in previous studies [5, 6] have shown that the sliver linear density uniformity that is equalized by the short-term regulator is a function of time and only its direct measurement in on-line system allows one to immediately and reliably conclude about the efficiency of the regulation process. The test results have led to the construction of short-term autoleveller whose algorithm of operation takes into account the phenomenon of sliver retardation.

In typical regulators of sliver drafting, the proportional rule of regulation has been used [7, 8] according to the following relationship:

$$\mathbf{R}(\mathbf{t}) = \mathbf{R}\left[1 - \frac{\mathbf{1}}{\mathbf{A}} + \frac{\mathbf{m_1}[\mathbf{Q};(\mathbf{t}-\mathbf{t_z})]}{\mathbf{m_1} \cdot \mathbf{A}}\right] \tag{1}$$

where

$R(t)$ is the momentary draft in the regulator;

R is the nominal draft;

A is the amplitude of changes in the density of fiber front ends in measuring cross section Q;

m_1 is the nominal number of fibers in the sliver cross section;

$m_1[Q;(t - tz)]$ is the number of fibers in $t - t_z$ moment in measuring cross section Q;

t_z is the time of the regulating signal delay.

The analysis of silver retardation and the classic algorithm of the operation of short-term autoleveller led me to propose changes in the regulator controlling, which made it possible to achieve the lowest fluctuations of the sliver linear density before its insertion in subsequent machine in the technological process. The realization of variable algorithm was accomplished digitally based on the system of signal correction in the form of a computer set with appropriate software continually correcting the value of the controlling voltage signal.

The algorithm of regulator operation used has the following form:

$$R'(t) = \left\{1 + a \cdot [R(t) - k]^b \cdot e^{c \cdot [R(t)-k]}\right\} \cdot R(t) \tag{2}$$

where

R'(t) is the momentary draft in the regulator with the controlling signal correction;

R(t) is the momentary draft in classic regulator;

a, b, c are the coefficients of the sliver retardation equation;

k is the limiting draft, at which no sliver retardation occurs.

All the slivers (after carding, combing, and drafting machines) had, in all variants, the same linear density: 5 ktex. The slivers leaving the autoleveller, operating with a nominal draft of 1.4, had a linear density of 3.5 ktex. On account of the retardation of sliver under regulation, all the slivers after the short-term autoleveller, were sent to the next machine in the technological process not earlier than 4 h after regulation. The combing frames had 2 different lengths of sorting zones (E_1 = 6 mm and E_2 = 12 mm), which, with setting a proper feeding length, made it possible to obtain two different combing percentages: p = 10% and p = 20%. Between the tenacity of combed yarn, W_{cz}, and the combing percentage, p, there is a known relationship in the spinning branch:

$$W_{cz} = W_z \cdot (1.03 + 0.0052 \cdot p) \tag{3}$$

where

W_z is the tenacity of carded yarn (cN/tex).

Altogether eight variants of sliver were made—each sliver with the given percentage of combing was made in four variants (A, B, A + B, and O).

The following measurements were carried out to assess the technological parameters of the spinning process under analysis:

irregularity of sliver tenacity (Uster Tester 3);

sliver adhesion (Zwick tester, model 1120);

fiber length in the sliver combed (Almeter apparatus).

Measurement results

Irregularity of sliver tenacity

The analysis results of the sliver linear density irregularity, obtained by means of Uster Tester 3 (an electro-capacitive apparatus), are shown in Figures 1–8.

The following are the denotations in figures:

R1 represents sliver after drafting before combing;

R1R represents sliver after the regulation of uniformity by the draft regulator before combing;

CZ represents sliver after combing;

R2 represents sliver after drafting and combing;

R2R represents sliver after the uniformity regulation by the draft regulator after combing.

In the case of slivers leaving the zone of regulated draft in the short-term autoleveller, Figures 1–8 also show the coefficient of equalizing ability **η** of the draft regulator that assesses the efficiency of the autoleveller operation and is expressed by the formula

$$\eta = \left(1 - \frac{CV_R}{CV_N}\right) \cdot 100\% \tag{4}$$

where:

CV_R is the coefficient CV according to Uster for the sliver under regulation;

CV_N is the coefficient CV according to Uster for the sliver with no regulation.

The following criteria are used for assessment:

$\eta \geq 50\%$—good regulation,

$25 \leq \eta < 50\%$—satisfactory regulation,

$0 < \eta < 25\%$—insufficient regulation,

$\eta = 0$—no regulation,

$\eta < 0$—deteriorating regulation.

Analyzing the diagrams in Figures 1–8, one can easily notice that the advantageous effect of autoleveller on the linear density uniformity of sliver before combing is eliminated by the process of sliver doubling and combing. The regulated sliver

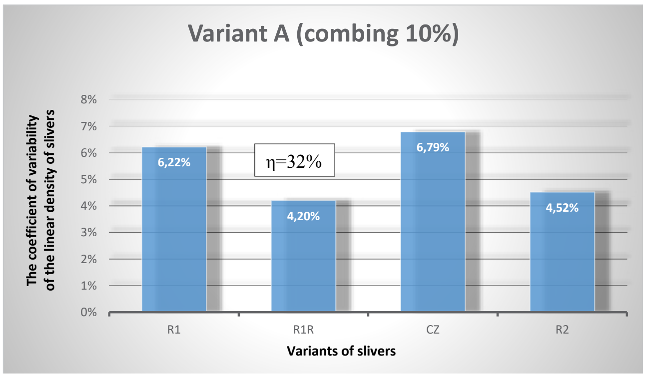

Fig. 1. Variant A—value of the coefficient of variability of the linear density of particular slivers measured on short sections (combing 10%).

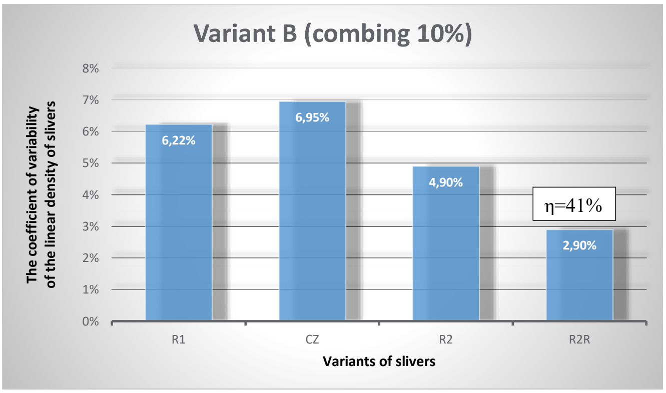

Fig. 2. Variant B—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 10%).

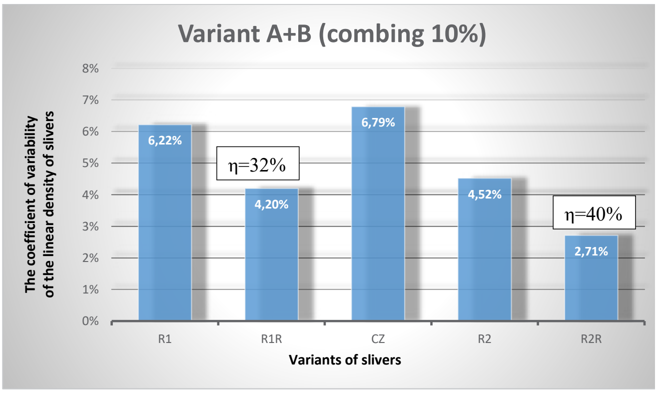

Fig. 3. Variant A + B—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 10%).

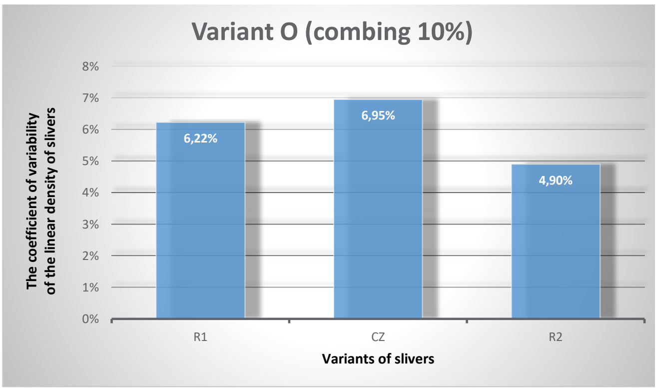

Fig. 4. Variant O—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 10%).

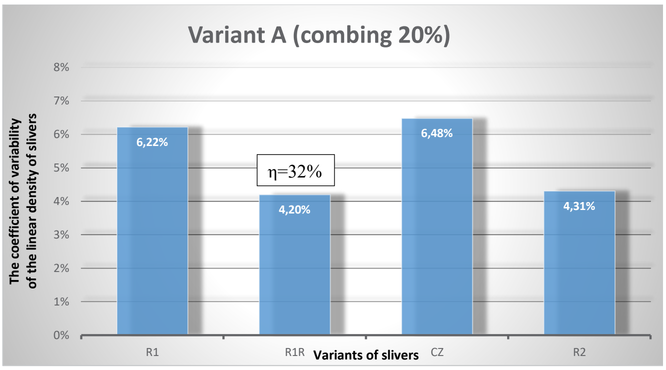

Fig. 5. Variant A—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 20%).

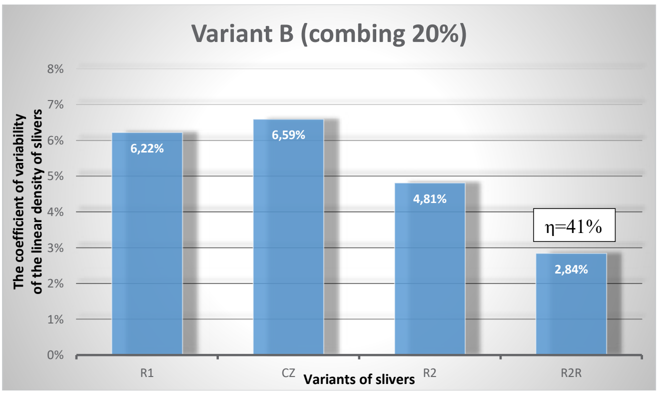

Fig. 6. Variant B—values of the variability coefficient of linear density of particular sections measured on short sections (combing 20%).

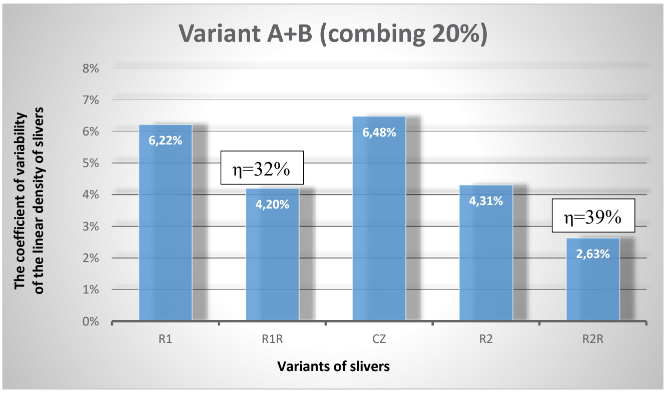

Fig. 7. Variant A + B—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 20%).

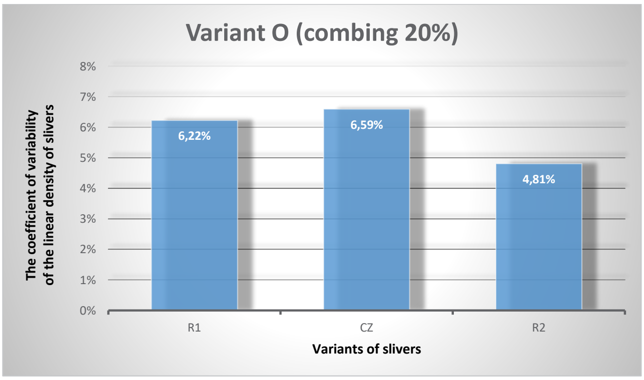

Fig. 8. Variant O—values of the variability coefficient of the linear density of particular slivers measured on short sections (combing 20%).

sent to combing only insignificantly influences the improvement in uniformity of the sliver leaving combing frame regardless of the combing percentage used (variant A and B). The use of modified draft regulation after combing considerably improves the quality of the sliver intended for feeding roving frame or rotor spinning frame. When the regulator equalizing capability is at a level of about 40% (the zone of satisfactory regulation), the uniformity of the sliver linear density is decisively improved. The lowest value of the linear density irregularity (CV = 2.63%) was obtained for variant A + B (regulation before and after combing) and for 20% combing; however, the differences between the combing percentage variant used were small. Without the draft regulation after combing (variant A), the sliver feeding the spinning frame has a relatively high irregularity of linear density (CV = 4.52% for 10% combing and CV = 4.31% for 20% combing), which may result in a worse yarn quality. The reference variant (variant O), in which no regulation was used, made it possible to obtain the variability coefficient of linear density at a level slightly lower than 5%, which is the worst value of all the variants. The increase in the combing percentage from 10% to 20% contributed to about threefold decrease in the irregularity of linear density of the sliver combed on 1-m sections—a drop from 4.22% to 1.49%.

The autoleveller operating according to a modified algorithm achieved in all the variants the coefficient of equalizing capability in the zone of satisfactory regulation. Samples in laboratory amounts showed a relatively high irregularity of the sliver linear density after the first drafting machine after carding and combing. Thus, these did not allow one to reach the zone of good regulation (**η ≥ 50%)**, which come off already in previous experiments.

Sliver adhesion

This parameter was determined to assess the degree of fiber straightening in sliver. It is defined as a mean adhesion force related to the mean linear density of the sliver sections tested. The adhesion force is the highest value of the sliver tensile strength, resulting only from the abrasion resistance and adhesion between fibers that move relative to them without breaking inside the section under drafting. The adhesion of slivers was determined with the use of tensile tester Zwick, model zwicki 1120.

The criteria of breaking were as follows:

For slivers R1 and R1R— 75% of the maximal elongation strength;

For slivers CZ, R2, and R2R—65% of the maximal elongation strength.

The different criteria used for particular variants were conditioned by the fact that the process of fiber parting in the sliver drafted lasted sometimes for a long time and it was impossible to observe the end of breaking, despite the fact that the sliver sample has been already pulled apart. There was no distinct sliver “breaking.” These criteria, however, have no effect on the measurement of sliver adhesion.

The results of the measurement obtained are listed in Table 1.

An example of the sliver tensile forces diagram obtained by means of a tensile strength tester is shown in Figure 9 and the measurement and calculation results are shown in Figure 10.

As expected, the sliver obtained after the first drafting frame (R1) shows the highest adhesion (~19 cN/ktex), which results from the lowest parallelism of fibers—partly improved after the carding process. Not all the fibers have not been already straightened and arranged parallel along the product axis; therefore, they pose a greater resistance to tensile forces. Autoleveller (variant R1R) improves the sliver uniformity by simultaneously straightening fibers and arranging them along the product axis, which contributes to a decrease in adhesion by more than 50%.

Combing frames remove short fibers from slivers and considerably improve their straightening. A change in the

Table 1. Results of the measurements of silver adhesion

Sliver variant	**Real linear density of sliver (ktex)**		**Adhesion force F_{max} (cN)**		**Elongation at break (%)**		**Work to F_{max} (cN□m)**		**Mean sliver adhesion (cN/ktex)**	
% of combing	10%	20%	10%	20%	10%	20%	10%	20%	10%	20%
R1	**5.11**		**98.82**		**7.21**		**0.43**		**19.34**	
R1R	**3.55**		**32.64**		**7.00**		**0.17**		**9.19**	
CZ (sliver after R1)	**4.96**	**5.09**	**44.22**	**55.29**	**7.31**	**7.75**	**0.29**	**0.37**	**8.91**	**10.86**
CZ (sliver after R1R)	**5.08**	**5.14**	**47.25**	**59.33**	**7.72**	**7.97**	**0.33**	**0.41**	**9.30**	**11.54**
R2 (sliver after R1)	**4.92**	**4.88**	**27.19**	**39.24**	**7.54**	**7.89**	**0.22**	**0.33**	**5.52**	**8.04**
R2 (sliver after R1R)	**4.89**	**4.91**	**27.33**	**39.59**	**7.71**	**8.00**	**0.26**	**0.39**	**5.58**	**8.06**
R2R (sliver after R1)	**3.47**	**3.58**	**19.27**	**27.11**	**6.95**	**7.14**	**0.12**	**0.20**	**5.55**	**7.57**
R2R (sliver after R1R)	**3.59**	**3.44**	**20.11**	**28.21**	**7.01**	**7.46**	**0.15**	**0.24**	**5.60**	**8.20**

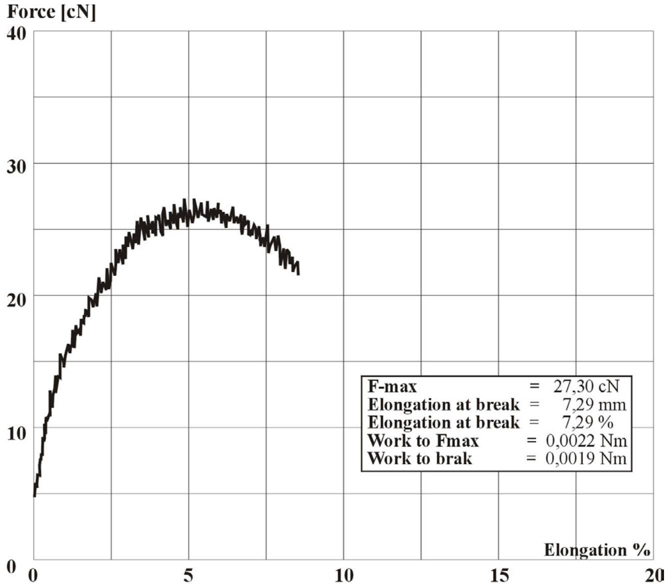

Fig. 9. Diagram of the tension of sliver R2R obtained after 20% combing.

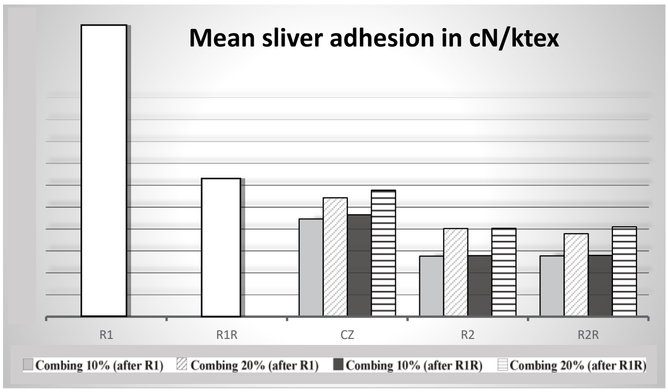

Fig. 10. Mean sliver adhesion in cN/ktex for various variants.

adhesion force is closely dependent on the sliver variant. Combing the sliver after draft frame (variant R1) leads to a decrease in its adhesion by about 50%, while combing the regulated sliver (variant R1R), thus that which was characterized by a low adhesion, slightly increases its adhesion value. In the first case, a serious influence on decreasing adhesion is exerted by straightening fibers during combing, whereas in the second case, a greater effect on the increase in adhesion comes from removing short fibers and consequently increasing the number of contact points between fibers in the sliver combed—this is more visible when the percentage of combing increases from 10% to 20%.

The next drafting machine equalizes the distribution of linear density of the combed sliver and straightens fibers, which causes a further decrease in adhesion by about 25%. The use of the second autoleveller (variant R2R) does not cause significant changes in the sliver adhesion.

After the analysis of the sliver variants tested on tension tester, it may be concluded that the use of the short-term autoleveller with a corrected operation algorithm improves only the sliver uniformity but does not exert any influence on the final adhesion value of the slivers obtained after combing and sent to the next machine in the technological process. It is the combing percentage that exerts influence on the adhesion value. With increasing combing percentage in all the variants, the value of work that should be done to attenuate the sliver during drafting process in the next spinning frame increases. This can lead to impediments to the sliver attenuation in the draft apparatus of roving frame (disorder in fiber migration and an increase in irregularity of roving) or problems in sliver opening by the opening roller of rotor spinning machine.

Length of fibers in sliver and noils

Fiber length was determined by means of Almeter apparatus, using its version intended for the length determination of cotton fiber and staple chemical fibers. The fiber length measurement here is of indirect character and consists in determining changes in the electric capacity of capacitor generated by moving a specially prepared fiber sample between its plates. The analysis was carried out to assess the effect of the short-term regulation, used before combing, on the fiber parallelism in sliver and, consequently, on the fiber length in the sliver combed. Two mean fiber lengths were determined:

H, which is the mean length corrected in relation to the fiber cross-sectional area;

B, which is the mean length corrected in relation to fiber mass.

Both H and B are calculated as follows:

$$H = \frac{\sum_{i=1}^{n} l_i \cdot a_i}{\sum_{i=1}^{n} a_i} \qquad B = \frac{\sum_{i=1}^{n} l_i \cdot m_i}{\sum_{i=1}^{n} m_i}$$

where *l*, *a*, and *m* are the fiber length, cross-sectional area, and mass, respectively.

The limiting cotton fiber length, below which the content of short fibers was determined, was 12.5 mm. There was also determined the minimal length of the longest fibers for the level of 5%.

The measurement results obtained are listed in Table 2.

Examples of the diagrams from Almeter apparatus are shown in Figures 11 and 12. On the diagram was deposited a scale that is absent in the original printouts from the apparatus.

In all the sliver variants, regardless of the combing percentage, a positive effect of the short-term regulation, used before combing, on the degree of fiber straightening was observed, which resulted in an improvement in the fiber length parameters in the sliver combed. For each combing percentage, this sliver shows a higher mean of fiber length in the case of length H, which is corrected in relation to the fiber cross-sectional area, as well as in the case of length B, which is corrected in relation to fiber mass. At the same time, the coefficients of variation of both lengths (CV_H, CV_B), minimal length of 5% fibers, and the percentage of the shortest length below 12.5% are decreased.

Table 2. Measurement results of fiber length in the combed sliver

Sliver variant	**Length H (mm)**		**Length B (mm)**		**CV_H (%)**		**CV_B (%)**		**Minimal length 5% fibers (mm)**		**Percentage of fibers with a length below 12.5 mm**	
Combing percentage	10%	20%	10%	20%	10%	20%	10%	20%	10%	20%	10%	20%
CZ (sliver after R1)	23.11	24.71	24.49	25.11	29	24	17	15	35	33	17	12
CZ (sliver after R1R)	24.03	24.94	24.64	25.25	23	21	15	12	34	31	14	10

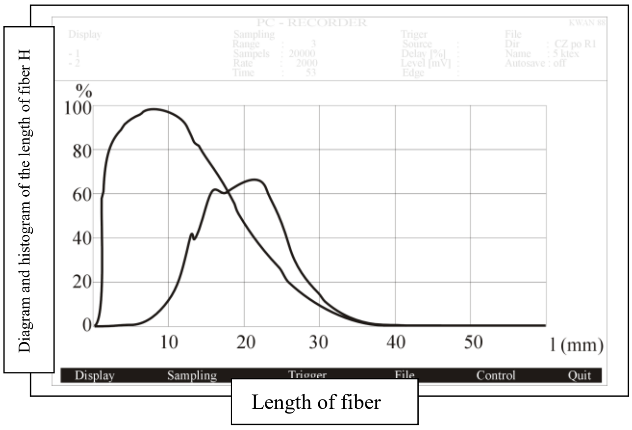

Fig.11. Diagram and histogram of the length of fiber H variant CZ (sliver after R1)—10% combing.

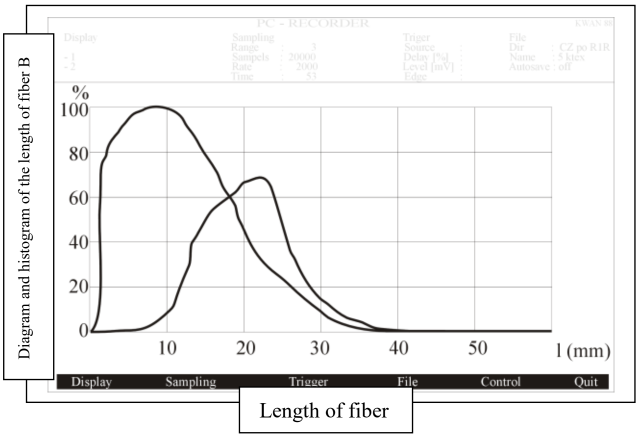

Fig.12. Diagram and histogram of the length of fiber B variant CZ (sliver after R1R)—10% combing.

Summary

The results obtained from the study justify the need for using autolevellers, operating based on a modified algorithm of operation, in the combed systems of fiber spinning. The sliver regulated before the combing process slightly improves the uniformity of sliver leaving the combing frame, while the use of a modified draft regulation after the combing process considerably improves the quality of sliver intended for feeding the roving frame or rotor spinning machine. Autolevellers improve the uniformity of slivers but have no effect on the final value of the adhesion of slivers obtained after the combing process and sent to the next machine in the technological process. First of all, it is the combing percentage that has an influence on the value of adhesion. However, a positive effect of the short-term regulation used before combing on the degree of fiber straightening has been observed, which results in an improvement in the fiber length parameters in the combed sliver and translates into an improvement in the quality parameters of yarns.

References

[1] *Taher Halimi M., Ben Hassen M., Azzouz B., Sakli F. – „Effect of Cotton Waste and Spinning Parameters on Rotor Yarn Quality”. Journal of the Textile Institute 2007 No. 5.*

[2] *Idzik M. – „Sposób i urządzenie do regulacji równomierności grubości taśmy przędzalniczej”. Patent Nr 212029 z dnia 01.08.2012 r.*

[3] *Idzik M. – „Sposób i urządzenie do wspomagania regulacji równomierności grubości taśmy przędzalniczej”. Zgłoszenie patentowe nr 405560 z dnia 7.10.2013 r.*

[4] *Idzik M. – „Optimization of Work Parameters of a Short-term Autoleveller”. Fibres & Textiles 2000 No. 4.*

[5] *Idzik M. – „Assumptions for Constructing an Autoleveller with a New Algorithm of Operation”. Fibres & Textiles in Eastern Europe 2006, No. 1, vol. 14.*

[6] *Idzik M. – „Analysis of Work of a Card Autoleveller with a New Algorithm of Operation”. Fibres & Textiles 2006 No. 2, vol. 14.*

[7] *Baumann M., Heitmann U., Planck H. – „Reduzierung der Faserbeanspruchung und Kardierkräfte beim Hochleistungskardieren”. Melliand Textilberichte 2008 No. 1-2.*

[8] *Qu Jian Zeng – „Effect Analysis of the Autoleveller in Finishing Drawing Frame”. Cotton Textile Technology. 1998, nr (26)3.*

[9] *Rutkowski J. – „Tenacity of Cotton Yarns Joined During the Rewinding Process”. Fibres & Textiles 2011, Vol. 19, No. 1 (84) pp. 34-36.*