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Research Article

RESEARCH OF THE UNEVENNESS OF THE SPINNING PRODUCTION'S SEMI-FINISHED PRODUCTS BY THE METHOD OF SPECTRAL ANALYSIS

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ABSTRACT

The article describes the characteristics and types of unevenness of semi-finished products of spinning production, as well as their influence on the quality of the finished product. A technique for performing spectral analysis of semi-finished products and calculating the wavelengths of the spectrogram is described. A spectral analysis of such semi-finished products as carding sliver and sliver from the first and second stages of draw frames with a linear density of 4.9 Ktex with a coefficient of variation (CVm) equal to 3.29%, 3.71% and 2.97%, respectively, was performed. Their wavelength was calculated taking into account the filling parameters of the studied machines. The reasons and places of formation of unevenness of semi-finished products are revealed and their assessment was given.

KEYWORDS

Unevenness, semi-finished product, spectrogram, the coefficient of variation, sliver, peak, amplitude, wave, yarn, fiber

INTRODUCTION

One of the main tasks of the modern textile industry is to identify and analyze the factors that determine the quality of products, as well as the reasons for the decline in its performance. The solution to this problem is the provision, regulation and quality management at all stages of product formation.

The production of high-quality textile products largely depends on the choice of raw materials and the organization of technological processes. However, it is not always possible to increase or ensure the required quality of products by selecting the appropriate raw materials. [1, 2]. This is due to the fact that there are not always raw materials of the required quality in production, and sometimes textile workers have to use the raw materials that they have. Also, high-quality raw materials have a high cost, which negatively affects the cost of manufactured products. Therefore, in order to achieve the expected quality of spinning products, they often resort to methods for studying the unevenness of finished products and semi-finished products, the reasons for its formation and the flow of technological processes.

The main part

The unevenness of spinning products is a complex phenomenon. For spinning products, there are several types of unevenness, such as: unevenness in linear density, unevenness in breaking load, quadratic unevenness, etc.

The unevenness that occurs in the first stages of the spinning process can affect the flow of the processes of subsequent stages of production, as well as the quality indicators of the finished product. The unevenness of spinning products in linear density in many cases is one of its main types. With the above complex change in the properties of the product, no numerical values of the unevenness can fully take into account and evaluate its nature. So, for example: two products can have the same numerical values of the quadratic unevenness in linear density, but one of them will have a periodic unevenness, and the other will have an unevenness with a one-sided increase in deviations or random. The reasons for the formation of unevenness of these types are different.

The use of such characteristics as amplitude spectrum, unevenness gradient, correlation function, and others makes it possible to reveal the nature of the unevenness and its structure. Quantitative assessment of the nature of the unevenness, i.e., determination of the amplitude and wavelengths found in the unevenness of the product under study, the repeatability of wavelengths, as well as the determination of other characteristics, will help to better reveal the phenomena that occur during the production of semi-finished products and finished products [3].

The problem of studying the causes of unevenness, as well as the influence of the unevenness of spinning products on the course of further technological processes, has been dealt with by many scientists. So, for example, in his works, A. N. Soloviev studied statistical methods for monitoring and analyzing product quality using continuous monitoring and analysis of the studied material properties using control-scatter charts, as well as using graphs of the autocorrelation function [4]. A. G. Sevostyanov, on the other hand, studied the methods and means of studying the unevenness of spinning products, fabrics, knitted and non-woven fabrics, revealing the essence of the unevenness and its types, based on the correlation and spectral analysis of the unevenness [5].

In the study of any one indicator of unevenness, it turns out that the indicator of this unevenness consists of a number of elementary unevenness. Since the unevenness that occurs at the initial stages of production changes in the subsequent ones and, in addition, the unevenness of new types is formed, and different types of unevenness are interdependent [6]. Studies have shown that all semi-finished products and the yarn itself have unevenness, for example, in thickness, which consists of several irregularities that differ in length, waveform and vibration amplitudes. Having arisen, any unevenness does not disappear, it passes from one semi-finished product to another and finally to yarn. Since the product is folded and thinned in spinning machines, its length increases in accordance with the drawing, then various kinds of fluctuations in thickness along the length of the incoming product pass into the outgoing product, and the wavelength of these oscillations increases in proportion to the drawing, and the resulting unevenness with shorter waves is superimposed on longer waves of fluctuations in the thickness of the incoming product [7]. The earlier unevenness occurs in the course of the spinning process, the longer the oscillation waves will be for the corresponding component of unevenness in the yarn. To a greater extent, this refers to unevenness in the thickness of the product.

Research and analysis of the unevenness of spinning products in order to evaluate the operation of individual machines must be accompanied by the determination of indicators of changes in unevenness and the conditions for their operation. [8,9].

Today, in modern spinning mills, the definition of unevenness, as well as the analysis and nature of its origin, is determined by the method of spectral analysis. The essence of spectral analysis lies in the study of fluctuations in the thickness of the product, including waves (thickening and thickening) of various lengths and amplitudes, which are mutually combined and superimposed on one another. Using this method, waves of the same length, but different amplitudes, and vice versa can occur. The task of this method is to decompose complex fluctuations in the thickness of the product into the simplest components (harmonics) with the subsequent construction of a spectrum of wavelengths of various amplitudes. To construct a spectrogram, the amplitude corresponding to the wavelength is plotted along the ordinate axis, and the wavelength is plotted along the abscissa axis. [10, 11]

Some modern devices, such as Uster Tester or Evenness Tester, have special modules that allow you to carry out harmonic analysis and obtain the spectrum of waves of the unevenness of the product under study by recording them in the form of a spectrogram shown in Figure 1.

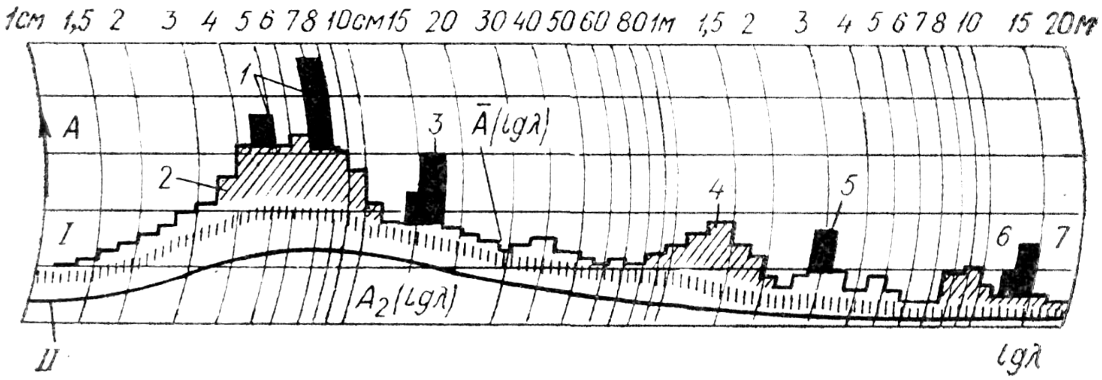

Figure 1. Spectrogram

On the spectrogram shown in Figure 1, we can see the logarithmic scale of the wavelength lgλ along the abscissa and the mean amplitude A along the ordinate. The figure also shows the curve of product I, which has an unevenness formed due to defects in the working parts or incorrect optimization of the technological parameters of machines, which are expressed in the spectrogram as peaks (1,2,3,4,5,7). Each of the peaks has a certain length, and by their size it is possible to determine in which machine node the unevenness of the product has formed by calculating the wavelength responsible for one or another working part of the machine. Under the Roman numeral II on the spectrogram is shown a curve of a perfectly flat product, for a visual representation of deviations in the unevenness of a real spinning product [12, 13]. In the production of yarn in a spinning system consisting of six stages, the spectrum of all waves that make up the unevenness of the yarn can be divided into four main groups:

1) 1) The widest waves (up to Zsm.) - they are formed by a slight curvature of the cylinders of spinning machines.

2) The short waves (from 3sm. to 50sm.) - are caused by the eccentric rotation of the rollers and cylinders of the spinning machine drafting system, which create uneven yarns due to the formation of freely moving (floating) fibers.

3) The medium waves (from 50sm. to 5m.) - are formed due to the presence of defects in the drafting system of the draw frame;

4) The longest waves (more than 5m.) - indicate a defect in the drafting system of draw

frame (rollers, cylinders rotate eccentrically, i.e., crookedly).

5) indicate a defect in the drafting system of tape machines (rollers, cylinders rotate eccentrically,).

Unevenness analysis by spectral analysis can be carried out both for all stages of spinning, and for semi-finished products separately. In production, spectral analysis of yarn is most often performed from a ring spinning and winding machine, analysis of semi-finished products such as sliver or roving is performed much less frequently. The data of these laboratory studies of finished products and semi-finished products allow technologists to identify process failures and show at what stage of production the quality of the product is deteriorating.

In the spectral analysis of one semi-finished product, it is first checked on a test device, and then the wavelength is calculated, which is responsible for the correct operation of one or another element of the machine during the production of the semi-finished product.

Results and Discussions

In our study, we present a spectral analysis of semi-finished products using the Uster Tester laboratory device, and also describe a method for calculating wavelengths for analyzing the resulting spectrogram of semi-finished products (Tables 1,2 and 3), which gives us an idea of the operation of the working parts of machines and their malfunctions.

Table 1. Calculation of the waves of the card sliver

Machine name	*Areas that create unevenness*	*Wavelength calculation*
Carding machine	Taker-in	$\lambda_1 = V_p / n_1 = 72/600 = 0{,}12$ m.
	Cylinder	$\lambda_2 = V_p / n_2 = 72/360 = 0{,}2$ m.
	Doffer	$\lambda_3 = V_p / n_3 = 72/10 = 7{,}2$ m.
	Flats	$\lambda_4 = V_p / n_4 = 72/2{,}1 = 34{,}3$ m.
	Stripping roller	$\lambda_5 = d_5 \cdot \pi = 6{,}8 \cdot 3{,}14 = 21{,}3$ sm.

To determine the reasons for the formation of unevenness in semi-finished products, as well as to determine and control the operation of the working parts of machines, we compared the calculated wavelength data obtained by us with the spectrogram. If sharply prominent peaks were present on the spectrogram along the ordinate axis, then we, having determined on the abscissa axis to which wavelength they belong, determined the place of formation of product unevenness, i.e., malfunction of any working part or incorrect filling parameters of the machine we are studying.

Figure 2 shows the spectrogram of a carding sliver with a linear density of 4.9 ktex, which has a coefficient of variation (CVm) of 3.29%, which corresponds to the Uster Statistic 2018 standard of 95%. The spectrogram shows that on the logarithmic wavelength plotted along the abscissa axis, which is slightly more than one meter, there is a sharply prominent peak. Comparing this with our calculations presented in table 1, we came to the conclusion that the deterioration of the coefficient of variation of the card sliver is due to a slight fault in the area of the cylinder of the carding machine.

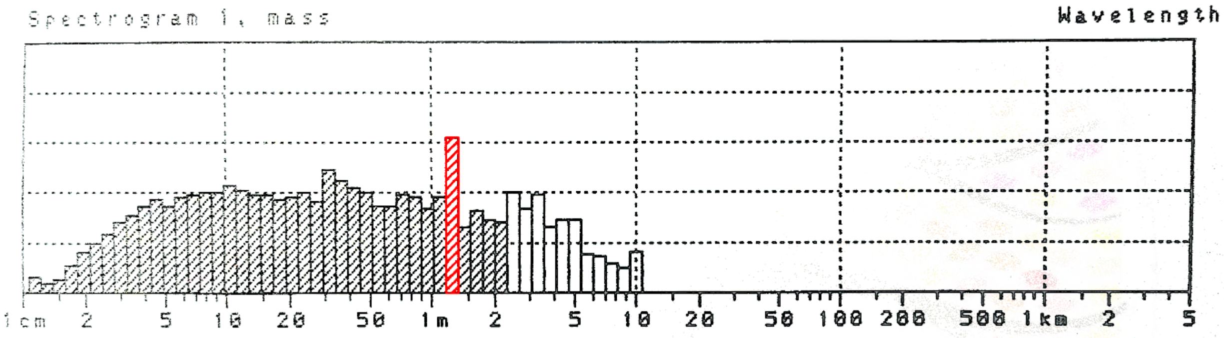

Figure 2. Spectrogram of card sliver 4.9 ktex

Table 2. Calculation of the wavelength of the sliver of the 1-st stage

Machine name	*Areas that create unevenness*	*Wavelength calculation*
Draw frame	Front roller	$\lambda_1 = d_1 \cdot \pi = 4{,}4 \cdot 3{,}14 = 14$ sm.
	Front cylinder	$\lambda_2 = d_2 \cdot \pi = 4 \cdot 3{,}14 = 13$ sm.
	Middle roller	$\lambda_3 = d_3 \cdot \pi \cdot D_1 = 5{,}08 \cdot 3{,}14 \cdot 7{,}2 = 115$ sm.
	Middle cylinder	$\lambda_{4,5} = d_{4,5} \cdot \pi \cdot D_1 = 2 \cdot 3{,}14 \cdot 7{,}2 = 45$ sm.
	Back roller	$\lambda_6 = d_6 \cdot \pi \cdot D_{um} = 4{,}4 \cdot 3{,}14 \cdot 7{,}56 = 104$ sm.

	Back cylinder	$\lambda_7 = d_7 \cdot \pi \cdot D_{um} = 4 \cdot 3{,}14 \cdot 7{,}56 = 104$ sm.
	Drawbox drive	$\lambda_8 < \lambda_6$
	Drafting waves	$\lambda_9 \sim 4.1 \approx 10$ sm.

The spectrogram of the sliver from the first stage draw frame with a linear density of 4.9 ktex having a coefficient of variation (CVm) equal to 3.71%, which corresponds to the Uster Statistic 2018 standard of 95%, is shown in Figure 3. It can be seen from the spectrogram that the nature of the peaks on the logarithmic wavelength plotted along the abscissa axis differs significantly, i.e., in the length interval from 5 sm. to 10 sm., we can notice a sharp increase in peaks. But this amplitude jump is acceptable for this stage, as the initial addition and drafting of several slivers is performed here. But the prominent peak at a wavelength equal to more than 25 sm., comparing with the calculation values from table 2, tells us that there is a small malfunction on the machine in the pre-drawing zone of the drafting system.

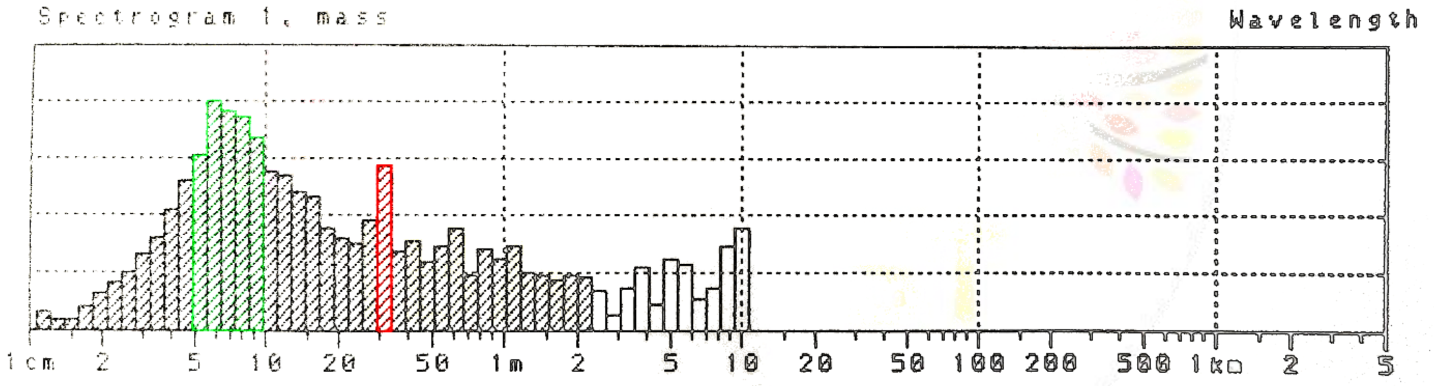

Figure 3. Spectrogram of the sliver of the 1-st stage 4.9 ktex.

Таблица 3. Calculation of the wavelength of the sliver of the 2-nd stage

Machine name	*Areas that create unevenness*	*Wavelength calculation*
Draw frame	Front roller	$\lambda_1 = d_1 \cdot \pi = 3{,}4 \cdot 3{,}14 = 10$ sm.
	Front cylinder	$\lambda_2 = d_2 \cdot \pi = 3{,}5 \cdot 3{,}14 = 11$ sm.
	Middle roller	$\lambda_3 = d_3 \cdot \pi \cdot D_1 = 3{,}4 \cdot 3{,}14 \cdot 7{,}2 = 78$ sm.
	Middle cylinder	$\lambda_{4,5} = d_{4,5} \cdot \pi \cdot D_1 = 3{,}5 \cdot 3{,}14 \cdot 7{,}2 = 79$ sm.
	Back roller	$\lambda_6 = d_6 \cdot \pi \cdot D_{um} = 3{,}4 \cdot 3{,}14 \cdot 7{,}56 = 80$ sm
	Back cylinder	$\lambda_7 = d_7 \cdot \pi \cdot D_{um} = 4 \cdot 3{,}14 \cdot 7{,}56 = 95$ sm.
	Drawbox drive	$\lambda_8 < \lambda_6$
	Drafting waves	$\lambda_9 \sim 4.1 \approx 10$ sm.

On the spectrogram of the sliver of the second stage draw frame tape (Fig. 4.) with a linear density of 4.9 ktex, which has a coefficient of variation (CVm) equal to 2.97%, which corresponds to the Uster Statistic 2018 standard of 25%. We can notice that at the logarithmic wavelength plotted along the abscissa axis in the length interval from 5 sm. to 10 sm., compared with the spectrogram of the sliver of the first stage draw frame, the peaks are no longer sharply distinguished by their amplitude, but there is only one peak at a length after 10 sm., comparing this value with the value calculated by us from table 3, we can conclude that the load on the rollers of the drafting system of the draw frame of the second stage is applied unevenly, i.e. or it is low, or the load on the rollers is applied with periodic changes.

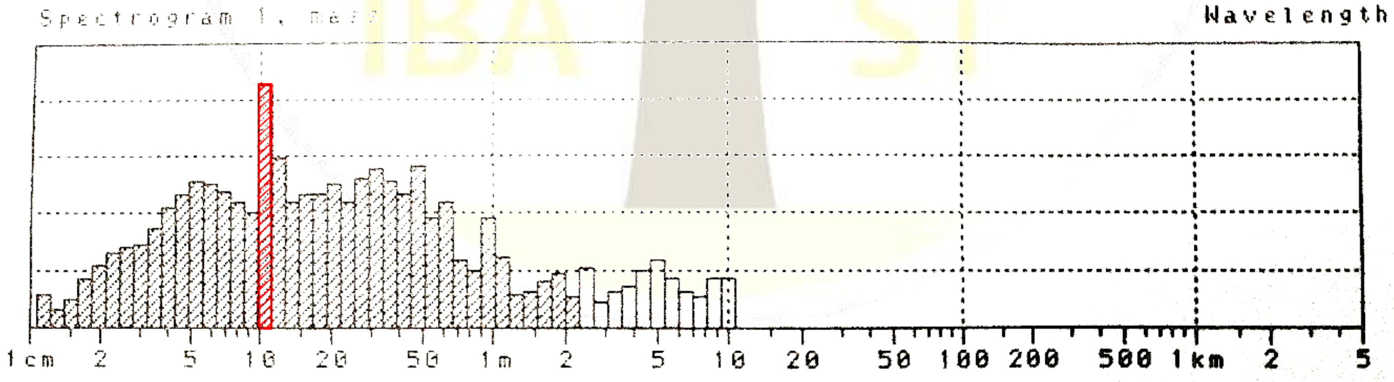

Figure 4. Spectrogram of the sliver of the 2-nd stage 4.9 ktex

Comparing all three spectrograms presented above, we can notice a decrease in the amplitude of the waves and peaks that determine the unevenness of the semi-finished products, and this tells us that the unevenness from stage to stage is decreasing. This reduction in unevenness occurs due to the addition and drafting of the product, but does not remove it completely. As mentioned above, «Having arisen, any unevenness does not disappear, it passes from one semi-finished product to another and finally to yarn. Since the product is folded and thinned in spinning machines, its length increases in accordance with the drawing, then various kinds of fluctuations in thickness along the length of the incoming product pass into the outgoing product, and the wavelength of these oscillations increases in proportion to the drawing, and the resulting unevenness with shorter waves is superimposed on longer waves of fluctuations in the thickness of the incoming product». Based on this, the coefficient of variation of the sliver of the second stage is only 2.97% which corresponds to 25% according to Uster Statistic 2018, and not 2.69% which corresponds to 5% according to Uster Statistic 2018. To achieve this improvement, the unevenness of the semi-finished products, i.e., decrease in the coefficient of variation and its value approaching 5% according to Uster Statistic 2018, it is necessary to correct the shortcomings of the processes identified by us through the analysis of spectrograms of semi-finished products of spinning production.

CONCLUSION

Thanks to our research, we studied such a factor as the unevenness of spinning products, its types and characteristics, as well as the principle of its determination by the method of spectral analysis. Which helped us understand the nature and causes of the formation of unevenness in the semi-finished products we studied.

Based on the results of our spectral analysis, we determined the causes of the unevenness of the products we studied, such as: carding sliver, sliver from the first and second stages. Summarizing all of the above, it can be noted that with the help of spectral analysis of semi-finished products, it is possible to identify and eliminate defects and malfunctions that affect the efficiency of spinning processes in the shortest possible time. Since, in comparison with other methods for determining unevenness, spectral analysis gives a more accurate result in determining the occurrence and cause of unevenness in the product.

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