Development of a Device for Continuous Monitoring Parameters of the Winding Structure of Textile Bobbins

Desarrollo de un dispositivo para el seguimiento continuo de los parámetros de la estructura de bobinado de las bobinas textiles

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Abstract

Introduction: The research "Improving the control methods for winding structure at friction drive machines" was conducted at Azerbaijan State Economic University in 2017.

Methods: To assess the efficiency of the proposed technique for processing signals, a model of a winding analyzer (WA) device, which allows the unwinding of the package, was designed and manufactured.

Results: The authors developed a methodology and a corresponding device to quantitatively assess the parameters of the winding structure by the light-section method.

Conclusions: The dimensions adopted while designing the device make it possible to exclude the influence of the non-roundness of the bobbin on the measurement results.

Originality: The equipment advancement and quality control improvement are the most urgent issues in textile industry. The quality requirements for package is constantly growing, while this research contributes to maintain it at a corresponding level, which ensures further development of textile industry as a whole.

Limitations: The research results can be practically implemented in new winding motion designs for spinning frames with cross-winding bobbin.

Keywords: Bundle structure, cross winding, packgage, textile bobbin, threader, winding mechanism.

Desarrollo de un dispositivo para el seguimiento continuo de los parámetros de la estructura de bobinado de las bobinas textiles

Resumen

Introducción: la investigación "Mejoramiento de los métodos de control para la estructura de bobinado en máquinas de fricción" se llevó a cabo en la Universidad Estatal de Economía de Azerbaiyán en el 2017.

Métodos: para evaluar la eficiencia de la técnica propuesta para el procesamiento de señales, se diseñó y se fabricó un modelo de dispositivo de análisis de bobinado (AB), el cual permite desenrollar el paquete.

Resultados: los autores desarrollaron una metodología y el dispositivo correspondiente para realizar la evaluación cuantitativa de los parámetros de la estructura de bobinado mediante el método de sección luminosa.

Conclusiones: las dimensiones adoptadas al diseñar el dispositivo permiten excluir la influencia de la ausencia de redondez de la bobina en los resultados de la medición.

Originalidad: el avance del equipo y la mejora del control de calidad son los temas más urgentes en la industria textil. Los requisitos de calidad para el paquete están en constante crecimiento, en tanto que esta investigación contribuye a mantenerlo en el nivel correspondiente, lo cual garantiza un mayor desarrollo de la industria textil en su conjunto.

Limitaciones: los resultados de la investigación se pueden implementar de manera práctica en nuevos diseños de movimiento de enrollamiento para marcos giratorios con bobina de bobinado cruzado.

Palabras clave: estructura del fardo, bobinado cruzado, paquete, bobina textil, enhebrador, mecanismo de bobinado.

Desenvolvimento de um dispositivo para o seguimento contínuo dos parâmetros da estrutura de enrolamento das bobinas têxteis

Resumo

Introdução: a pesquisa "Aperfeiçoamento dos métodos de controle para a estrutura de enrolamento em máquinas de fricção" foi realizada na Universidad Estatal de Economía de Azerbaiyán, em 2017.

Métodos: para avaliar a eficiência da técnica proposta para o processamento de sinais, foi desenhado e fabricado um modelo de dispositivo de análise de enrolamento, o qual permite 2, desenrolar a embalagem.

Resultados: os autores desenvolveram uma metodologia e o dispositivo correspondente para realizar a avaliação quantitativa dos parâmetros da estrutura de enrolamento mediante o método de seção luminosa.

Conclusões: as dimensões adotadas ao desenhar o dispositivo permitem excluir a influência da ausência de redondeza da bobina nos resultados da medição.

Originalidade: o avanço da equipe e a melhoria do controle de qualidade são os temas mais urgentes na indústria têxtil. Os requisitos de qualidade para a embalagem estão em constante crescimento, razão pela qual esta pesquisa contribui para mantê-lo no nível correspondente, o que garante maior desenvolvimento da indústria têxtil em seu *conjunto.*

Limitações: os resultados da pesquisa podem ser implementados de maneira prática em novos desenhos de movimento de enrolamento para molduras giratórias com bobina de enrolamento cruzado.

Palavras-chave: estrutura do fardo, enrolamento cruzado, embalagem, bobina têxtil, passa fio, mecanismo de enrolamento.

1. Introduction

Improving the quality and competitiveness of the finished products of textile enterprises directly depends on the systematic and effective quality control of semi-finished products and raw materials at all the stages of textile production. One of the most significant stages of textile production is the formation of cross-wind bobbins. Cross-wind bobbins are formed either on spineless spinning machines or by rewinding cobs on circular spinning machines.

The quality of cross-winding packages is determined by many parameters, including the density of the winding and its uniformity along the radius and generatrix, the form of the package and its deviation from the required form, the presence of structural defects in the form of compacted sections, bundle and tape winding, etc.

When forming bundle structures, the threads laid earlier act as a spreader by laying the thread that has violated the law dictated by the movement of the yarn feeder. At the same time, as the number of coils laid in the above-mentioned way increases, the forces that strive to return the coil to its normal position increases. As a result, the thread eventually slips out of the position determined by the bundle into a position determined by the yarn feeder. Since the lifting angle of the coil in the turnover area is zero, while the remaining area of the package acquires a non-zero value of β, there can be changes in the behavior of the yarn in these sections.

Based on calculations, it is possible to draw a conclusion about the relationship between the relief of the side surface of the package and the winding structure at a corresponding diameter. Indeed, in bundle structures, the packing of coils takes place in succession, while the height of the profile increases in the places of packing. Studies have shown that it is possible to determine the winding structure by the nature of the distribution of shadows in the lateral illumination of the package surface.

The aim of this work is to determine the basic parameters of the structure of the winding analyzer (wa): a device, which provides continuous monitoring of the structure parameters as the bobbin is unwound and the parameters are quantitatively assessed.

To achieve the aim of the research, the following tasks were set:

- Determine the mutual position of the photo-detector and illuminator in relation to the package surface, which eliminates the influence of the non-roundness of the bobbin on the analysis results of the winding structure.
- Establish the order of processing signals coming from the photo-detector, which allows to determine the presence of defects in the winding structure.
- Develop a structure of a winding analyzer (wa).

2. Literature Review

The parameters of the winding structure: the width of the layout, the lifting angle of a coil and the distance between the coils Δ, depend on the structure of the winding mechanism. These parameters influence a number of technological properties of the package and its ability to process. In the stationary movement of the "winding shaft-bobbin" system, the kinematic relations between the number of moves performed by the yarn feeder and the number of turnovers of the bobbin at a distance of $\Delta = 0$, are described in the works by Praček et al. [1], Liangxue [2] , Shams Nateri et al.[3].

In Rudovsky's work [4], the distance $\Delta\theta$ in the circumferential direction between subsequent coils is used to assess the winding structure. The distance $\Delta\theta$ is identified by the calculation method under conditions of a non-stationary movement of the "winding shaft-bobbin" system only with a transfer ratio of $i \approx 1$ between the bobbin and the winding shaft. Undoubtedly, this method cannot be used to assess the winding structure of the entire package.

In many cases, the above-mentioned parameters are determined by the kinematic relationships in the winding machine. Therefore, the analysis of these parameters is done with the calculation methods described by Rudovsky [4]. The work describes a technique for calculating the angular and linear distance between the coils according to the kinematic scheme of the winding mechanism, depending on the winding diameter. The linear distance between adjacent coils determines the defects, such as bundle winding, when adjacent coils are stacked on top of each other. One shortcoming of the described methodology is the lack of orientation regarding the use of computer technology, which makes it impossible to control the formation of bundle winding at all diameters.

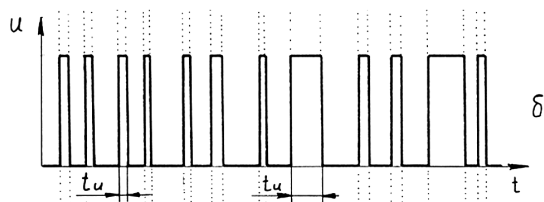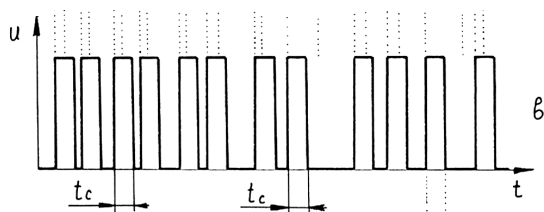
Figure 1a

Figure 1b

Figure 1c

Figure 1 (a-c). Procedure for processing the pulses coming from the photo-detector.
Source: own work

In the process of the research, the thread is constantly unwound from the package, and its diameter decreases. Meanwhile, the defects of the structure are also unwound and the diameter at which no defects are observed gets closer. Obviously, by counting the number of pulses that succeed a certain number of turns of the package (Nuriyev and Imanova [15]); it is possible to quantitatively assess the quality of the package. When observing the entire package while it is unwound, it is possible to get an objective understanding of its quality.

3. Methods

To assess the efficiency of the proposed technique for processing signals, a model of a WA device, which allowed the unwinding of the package, was designed and manufactured. The scheme of the device is shown in Figure 2. It consists of an illuminator, which includes a lamp 1 and lenses 2 and 3 installed in a single body 4. The body of the illuminator has a ledge, which is placed in a way that, by supporting the surface of the package 5, the illuminator directs a light beam, always tangential to the surface of the bobbin. Above the contact point of the light beam and the bobbin surface, a photo-detector is installed. The photo-detector includes a focusing lens 6 and a photodiode 7 [16]. The bobbin receives the rotations of the electric motor at an angular frequency of 0.03 C-1.

The signal coming from the photo-detector is limited in amplitude to the processing unit 8 and can be fixed with the help of a high-speed recorder 9. The observations involved packages and their models, made of wood and pasted with white paper to ensure uniform optical properties of the surface. To identify the correspondence between the nature of the filament, the distribution and parameters of the signals, individual threads or groups of threads were glued onto such models. After this, the corresponding signal was recorded. The results of these tests revealed the presence of a significant influence of the non-roundness of the bobbin on the output signal of the device, which can lead to significant errors. To eliminate this phenomenon, it is necessary to place the light source in a certain way in relation to the bobbin.
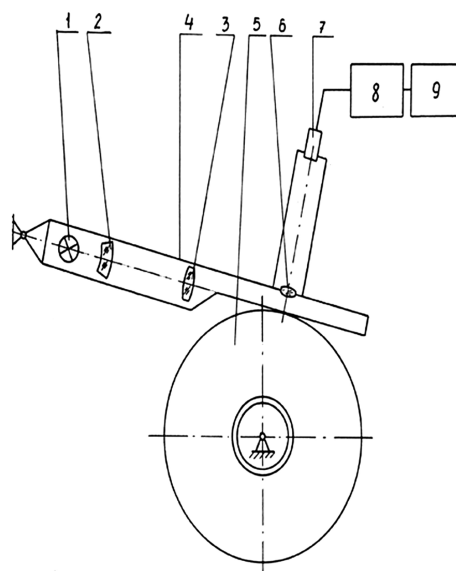
Figure 2. Scheme of the device for the continuous monitoring of the winding structure
Source: own work

4. Results

Generally, the actual package of a cross-wind bobbin has a deviation from an ideally circular shape. Therefore, when the package is illuminated by light directed along its tangent to its lateral surface, and the photo-detector is placed above the contact point of the light beam and the surface, one can observe a blackout of the photo-detector caused by these deviations. Figure 3a shows the registration process in the absence of non-roundness of the package, while Figure 3b illustrates the process in case of roundness of the package.

Furthermore, the conditions under which the deviation from the round shape of the package will not significantly affect the signal coming from the photo-detector should be defined [4]. This is possible provided that any possible deviation from the round shape of the package does not form a shadow on the side surface of the package under illumination.

Suppose that there is a dent CBE (Figure 4a) in the form of a triangular groove on the surface of the package, it runs along the generatrix of the bobbin and has a vertex angle equal to 2φ.

The position of the light source and the photo-detector is determined by the coordinates shown in the same figure. When the bobbin rotates, the groove moves along its surface. If at the moment the groove passes under the photo-detector, the angle of inclination of the groove bottom to the horizontal $\varphi+\alpha$ is less than the angle of inclination of the light beam from the photo-detector passing through the same point, a shadow is formed on the bottom of the groove. This is recorded by the photo-detector.

The angle β of inclination of the light beam (passing through point C of the intersection of

Figure 3. Scheme for the registration of the bobbin profile in the presence of non-roundness
Source: own work

Figure 4. Determining the influence of non-roundness on the results of controlling the package profile.
Source: own work

photodetector axis with the bobbin surface) to the horizontal can be determined from Δ ABC by the following formula:
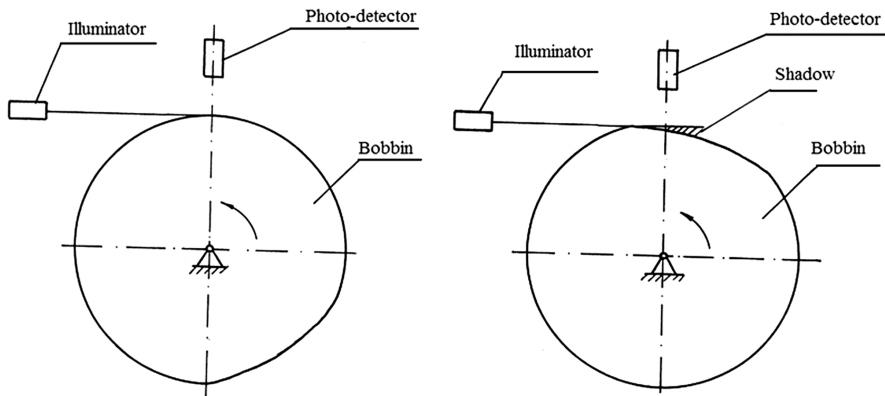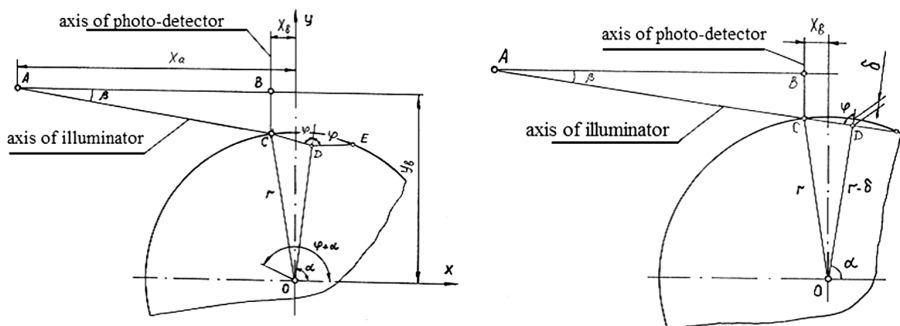
$$\beta = \pi - \text{arctg}\, \frac{AB}{BC} ,$$

or excluding the function arctgx, which has a discontinuity at x = $\frac{\pi}{x}$

$$\beta = \pi - \arcsin \frac{AB}{\sqrt{AB^2 + BC^2}} . \qquad (1)$$

To avoid the appearance of a shadow at the moment when the groove approaches point C, the following condition must be met:

$$\varphi + \alpha > \beta,$$

or

$$\varphi + \alpha > \pi - \arcsin \frac{AB}{\sqrt{AB^2 + BC^2}} . \qquad (2)$$

As Figure 4 shows, AB=b-c, while BC = $\alpha - \sqrt{r^2 - c^2}$

Substituting these expressions into (2), we eventually get

$$\varphi + \alpha > \pi - \arcsin \frac{b-c}{\sqrt{(b-c)^2 + (\alpha + \sqrt{r^2-c^2})^2}} . \qquad (3)$$

On the packages formed by the winding of the thread, we generally get

$$\Phi \geq \frac{\pi}{2}$$

In case of the equality $\Phi \geq \frac{\pi}{2}$, we get

$$\alpha > \frac{\pi}{2} \arcsin \frac{b-c}{\sqrt{(b-c)^2 + (\alpha + \sqrt{r^2-c^2})^2}} . \qquad (4)$$

α needs to be expressed in terms of dimensions that determine the position of the photo-detector in relation to the center of the package. As can be seen in Figure 4b,

$$\alpha = \frac{\pi}{2} + \arcsin \frac{c}{r} - \arccos \frac{r-\delta}{r} , \qquad (5)$$

where δ is the non-roundness of the package surface.

Equating (4) and (5), we get an inequality for determining the coordinates of the photodetector.

$$\frac{\pi}{2} + \arcsin \frac{c}{r} - \arccos \frac{r-\delta}{r} > \frac{\pi}{2} \cdot \frac{b-c}{\sqrt{(b-c)^2 + (\alpha + \sqrt{r^2-c^2})^2}} ,$$

$$\arccos \frac{r-\delta}{r} - \arcsin \frac{c}{r} < \arcsin \frac{b-c}{\sqrt{(b-c)^2 + (\alpha + \sqrt{r^2-c^2})^2}} . \qquad (6)$$

The resulting inequality is transcendental and can cause significant difficulty for full analysis. However, taking into account the practical inaccuracy of the inequality, we can proceed as follows. Given the values of α, r, δ and c, we can determine b in the extreme positions of the package, i.e. for r_{min} и r_{max}.

In this case, we will need the value of the non-roundness of the package for further calculations. To determine the non-roundness of the package, a special device was designed and manufactured. The scheme of the device is shown in Figure 5. The device consists of a frame 1, on which the axis of the bobbin holder 2 and the watch-like indicator 3 with a flat support platform 4 are attached.
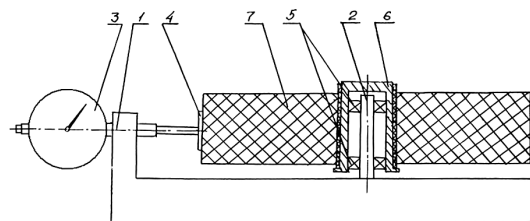

Figure 5. Scheme of the device for controlling the non-roundness of the packages
Source: own work

With the help of rolling bearings 2, the bobbin holder is placed on its own axis. The package 7 (produced on a spinning and twisting machine ПК-100М3) is installed on the bobbin holder touching the bobbin surface to the maximum diameter. After installation, the package is manually rotated to make a complete turn. At the same time, the maximum and minimum values of the indicator are recorded. In subsequent calculations, the difference δ between the maximum and minimum values is considered to be the non-roundness of the package. Table 1 shows the values of the measurements and their processing, according to [10], [17] and [18].

5. Discussion

The wA device was designed to analyze the entire complex of packages used in cotton spinning. It is required to check whether the ratio (4.6) is true for the packing of a ПК-100М3 machine under the proposed arrangement of the device.

Table 1. Values of the non-roundness of the packages

Measurement №	δ, mm	Measurement №	δ, mm
1	0.90	17	0.95
2	0.30	18	0.95
3	0.99	19	0.63
4	0.72	20	1.20
5	0.58	21	1.73
6	1.30	22	0.64
7	1.56	23	0.70
8	0.95	24	0.10
9	0.58	25	0.94
10	1.36	26	0.99
11	1.35	27	0.92
12	1.45	28	0.82
13	1.30	29	0.27
14	0.45	30	0.79
15	0.85		
16	1.03	average	0.97

Source: own work

The radius of the package varies from r = 22.5 mm for an empty cartridge to 100 mm for a full package. At the same time, α varies from 57.5 mm to 135 mm, as the device supports an invariable distance α - r from the surface of the package to the photo-detector. b and c are 210 mm and 2 mm respectively. According to the measurement results, the non-roundness of the bobbin δ is 0.97 mm.

Substitution of these data provides the following results.

For r = 22.5 mm,

$$\arccos \frac{22.5 - 0.97}{22.5} - \arcsin \frac{2}{22.5} < \arcsin \frac{210 - 2}{(210-2)+(57.5+\sqrt{22.5^2-2^2})^2}$$

$$11° - 2,54° < 59°$$

For r = 100 mm,

$$\arccos \frac{100 - 0.97}{100} - \arcsin \frac{2}{100} < \arcsin \frac{210 - 2}{\sqrt{(210-2)^2+(135+\sqrt{100^2-2^2})^2}}$$

$$7.96° - 1.14° < 41°$$

From results of the carried-out calculations it is visible that influence of non-roundness of a forging is absent.

Thus, the dimensions adopted while designing the device make it possible to exclude the influence of the non-roundness of the bobbin on the measurement results.

Thus, the sizes accepted at design of the device allow to exclude influence of not roundness of the reel on results of measurements. Besides, key parameters of a design of the device for continuous control of structure of winding are proved. Thereby the possibility of quantitative assessment of parameters of structure of winding is determined by a profile of a surface of a forging and the technique of her realization is developed.

In the course of carrying out researches mutual position of the photo detector and the lighter concerning a forging surface is defined. Such situation will exclude influence of non-roundness of the reel on results of the analysis of structure of winding. The offered order of processing signals from the photo detector allows to define existence of defects of structure of winding.

6. Conclusions

The basic parameters of the device, designed for the continuous monitoring of the winding structure, have been theoretically substantiated. In addition to establishing the possibility of identification and quantitative assessment of the winding structure along the surface of the package, the author of the research has developed a corresponding implementation methodology.

The author of the research has determined the mutual position of the photo-detector and illuminator in relation to the package surface, which eliminates the influence of the non-roundness of the bobbin on the analysis results of the winding structure.

The basic parameters of the wa structure have been determined and a corresponding device was developed to quantitatively assess the parameters of the winding structure by the light-section method.

The proposed wa device eliminates the influence of the non-roundness of the bobbin and provides continuous control of the structure parameters during the winding process, as well as the quantitative assessment of the parameters.

The proposed wa device can be used to analyze the entire complex of packages used in cotton spinning.

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