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DEVELOPMENT OF METHODS AND TOOLS FOR TEXTILE PACKAGE STRUCTURE CONTROL

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ABSTRACT

There is a sufficient level of raw materials, material resources and material technical base, as well as human resources for the development of textile and light industry. The objective of the study is to increase the efficiency of textile production through the development of tools and methods for controlling the structure and properties of packages. The study considered the classification of these properties and their characterizing performance. A new classification of geometric, general and special properties is proposed that affect the design parameters of the winding mechanisms and the course of the production process. Existing methods and means of controlling the shape of textile packages are also considered. Mechanical, hydraulic and optical methods of *controlling the structure and shape of the package are analyzed. It is established that the structure of the winding affects the quality of the packages on subsequent process transitions. For this purpose, a winding structure analyzer is proposed for controlling the winding structure.*

Key words: hydraulic and optical, textile and light industry, production process, Mechanical.

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1. INTRODUCTION

The efficiency of textile production is largely determined by the quality of the semi-finished products formed at each stage of the production process. Phased quality control is one of the components of the ISO 9000 quality management system.

Yarn, threads, fabrics, knitted and non-woven fabrics and semi-finished textile products are long-length materials, wound from the input package at each transition and wound onto the output package. At the same time, the quality of package largely determines both the quality of wound material and the process efficiency at each process transition [1].

The influence of the winding parameters on the quality of the material being wound is related to a certain stress state the material experiences in the package body, caused by the winding tension and interaction with the working bodies of the machine. Under the action of this stress state, changes occur in the structure of the material, which may affect the quality of the finished product, for example, an increased unevenness of the yarn caused by the uncontrolled hood of the roving; barring of knitwear and fabrics made of chemical threads, caused by the relaxation of threads occurring in different layers of winding and having different initial tension, etc.

The quality of the winding depends on the efficiency of the process itself. This is due to the fact that winding defects often cause the breakage of a textile product. At the same time, to eliminate a break, either the machine or one workplace is stopped. In any case, the downtime of equipment increases [2].

In this regard, the present work aimed at analyzing, systematizing, modernizing the existing and developing new methods for controlling the structure, characterizing the production properties of textile packages seems to be relevant.

2. MAIN PART

We shall consider a theoretical analysis of the control profile of the forming windings of cross-winding by cross-section shadow projection. Fig. 1 shows a diagram of the formation of an image of a surface profile when illuminated with a parallel beam of light directed along the O_1 - O_1 axis at an angle α to the normal plane. Part of the beam of light is cut off by an opaque curtain C. As a result, a shadow is formed on the surface, repeating its profile. The image of the shadow is recorded by the observation device, the $O_2 – O_2$ optical axis of which is directed at an angle β to the normal plane [3].

The resulting shadow image is different from the real profile on the scale of the transformation, which can be calculated by the formula

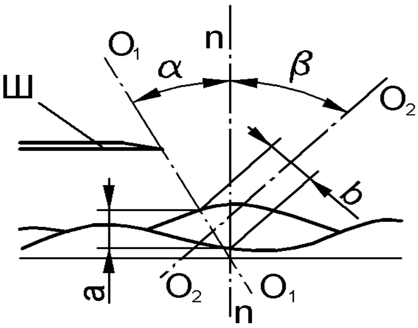

Figure. 1. Generation of a profile image using the shadow projection method

$$M = \sqrt{1 + \left(\frac{L}{H}\right)^2} \sin\left(\varphi + \arcsin \frac{1}{\sqrt{1 + \left(L/H\right)^2}}\right) \frac{\sin(\alpha + \beta)}{\cos \alpha}$$

Where φ – is the inclination angle of the plane passing through the lines $O_2 - O_2$ and $O_1 - O_1$ to the normal *n-n; H* is the highest observed height of profile; *L* is the width of the field of view of the observation device.

The dependence of the profile conversion scale on the design parameters of the device has been analyzed. The main errors that affect the process of retrieving the primary data using the shadow projection method are revealed: these are the errors caused by the curvature of the image of the shadow edge and the scale errors of the transformation; deviations caused by the linear offset of the illuminator; the deviation caused by the linear displacement of the reel; and deviations caused by turning the curtain [4].

We will analyze the individual components of the error scale conversion, caused by linear and angular displacements of the individual components of the device to control the shape of the package. It is established that the error caused by the curvature of the image of the shadow edge is systematic. The law of its formation was established. This error is taken into account in the development of software.

The basic requirements were formulated that must be met by the monitoring device, which is included in the composition of the package shape control hardware. As a result, a digital video-recording camera was selected as a surveillance device.

A software and hardware complex has been developed to control the geometric parameters of textile packages. Diagram of the device for obtaining primary data on the package shape is shown in Fig. 2

The device consists of a bobbin holder with a bobbin drive 1, rotatable on a rack 2 and fixed in two positions to control the side and end surfaces of the bobbin, as well as the illuminator 3, the digital camera 4 and the shutter 5. The registration of the primary information about the profile of each bobbin is carried out in the video recording mode three times: for two end and one side surfaces during one turn of the bobbin. The received videos are transferred via USB port to a computer and saved on the hard disk in MOV format [5].

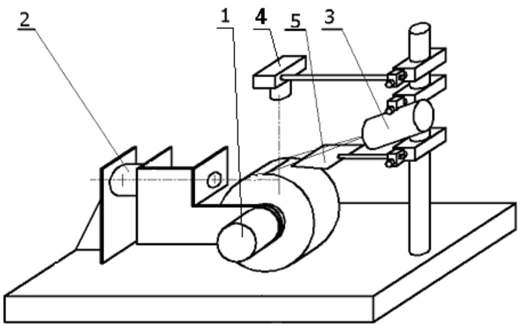

Figure. 2. Diagram of the primary data recording device

Their further processing is carried out using special software that implements the following algorithms: image scaling; video framing; package image search in the frame; image noise filtering; generation of package profile coordinates; building of a three-dimensional model of the package; calculation of single and complex indicators of the quality of the package by its shape.

To build a graphical model, the obtained profiles of the package sections are located in the planes obtained by rotating each subsequent plane, with respect to the previous one, at an angle

$$\psi = \frac{360^o}{n}$$

where n is the number of frames captured for one revolution of the package.

The visual construction of the model is implemented using the OpenGL library. A three-dimensional visual model of the package obtained with the developed software is shown in Fig. 4 and 5.

Figure. 4. A three-dimensional package model from Rieter R-40 pneumomechanical machine

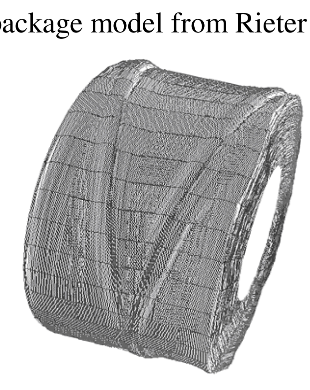

Figure. 5. A three-dimensional package model from PPM-120 pneumomechanical machine with a harness diameter

This paper developed a method for assessing the quality of the shape of cross winding packages. To this end, the method of expert survey conducted a ranking of defects in the shape of the packages according to the degree of their influence on the suitability of packages for processing at subsequent technological transitions. Six major defects were detected in the shape of the packages: the deviation of the end from straightness, benches at the end of the bobbin, compactions and benches on the lateral surface of the bobbin, harness winding, corrugations at the ends near the cartridge, deviation from the taper. For a quantitative assessment of each of these defects in the shape of a bobbin, single indicators have been determined, rules and algorithms have been developed for their calculation based on the previously received data array on the coordinates of points of the bobbin surface [6].

Based on the expert survey, a scoring system was established for the effect of each of the individual indicators characterizing winding defects on the suitability of packages to

Processing at subsequent process transitions.

Approximations of the dependences are given in Table 1.

Table 1. Dependencies of scores on single indicators

No.	Single indicator	Score Y_i to single indicator X_i equation
1	Maximum straightness deviation of the end, mm	$Y_1 = 0{,}83 \cdot X_1 + 0{,}34$
2	The bench height on the bobbin end, mm	$Y_2 = 2{,}92 \cdot X_2 - 0{,}48$
3	Width of compacted points on the bobbin ends, mm	$Y_3 = 0{,}59 \cdot X_3 - 0{,}05$
4	Harness winding, number of threads	$Y_4 = 0{,}23 \cdot X_4 + 4{,}28$
5	Width of corrugations at the ends near the cartridge, mm	$Y_5 = 0{,}35 \cdot X_5 + 1{,}78$
6	Tapered deviation of the bobbin, degr.	$Y_6 = 3{,}38 \cdot X_6 - 0{,}56$

A comprehensive assessment of the quality of the package shape can be obtained using the weighted average method. The weighted average indicator is built as a dependency, the arguments of which are single indicators of quality and their weight parameters.

The developed device opens up wide possibilities for analyzing the operation of the scattering mechanisms of various designs. As an example, the structure of the winding formed on the spinning-twisting machine PK-100MZ during the production of cotton yarn with a linear density of 25×2 tex was analyzed. To compare the structure of the winding of the packages obtained on the experimental winding mechanisms, with the structure of the winding formed on the serial machine, control packages were produced. After their formation, unwinding was performed in order to study the structure of the winding and visually determine its characteristics (harness, tape), as well as unwinding on the ACH device with the corresponding diagram produced, which allows evaluating the adequacy of the control results. For visual assessment, the intensity of the harness winding was used as a quantitative parameter characterizing the winding structure. One of the diagrams obtained during the unwinding of the control reels formed on the serial winding mechanism of the PK-100MZ machine without a scattering mechanism with the elevation angle β=13 20' is shown in Fig. 7. The strongest bundle in this case is formed when $m/n=2/3$. The dissertation provides an analysis of the structure of the winding of the most common spindleless winder with various designs of dispersion mechanisms [7].

The ACG machine is specialized, non-commercial and therefore unavailable to most organizations involved in the development of textile equipment.

With the development of computer technology, it became possible to use a digitized image of the body surface and the methods of automated pattern recognition for analyzing the winding structure [8].

To determine the reproducibility of the process of determining the index of the quality level of winding using a software-hardware complex in the same conditions, two batches of packages were accumulated. The F-test-based analysis of sample dispersions showed that the difference between dispersions is statistically insignificant. Analysis of the average difference using the Student's t-test showed reproducibility of the process.

When setting up the process equipment installed, and especially when creating new designs, the problem arises of a reasonable choice of process parameters ensuring the formation of bobbins of a required quality [9].

The developed software and hardware allows us to solve this problem.

Analysis of the model showed that the greatest effect on eliminating defects in the winding structure is achieved when the values of the factors close to the center of the plan, i.e. with the following values of the controlled parameters: Δd_B = 1 mm and T=22.5 twists of a yarn guide. The total value of the negative impact of winding defects in this case is reduced by 3.5 times [10].

5. SUMMARY

1.Based on a systematic approach, a classification of the properties of cross winding packages has been developed, taking into account the requirements from technologists and textile equipment developers, and relationships have been established between the indicators characterizing the basic, additional and combination properties of packages.

2. It has been established that the existing methods of package shape control do not allow obtaining sufficiently complete information about the shape of the package and automating the process of control. The combination of the shadow projection method and automated pattern recognition tools allows us to create a package shape control system that can be used for a comprehensive assessment of its geometric parameters.

3. A software and hardware complex has been developed, including a device for obtaining initial data in the form of videos with a package image, and software for obtaining data on the shape of a package and building its three-dimensional model.

4. Based on the theoretical analysis, the reasons for the formation of harness and band winding structure defects were clarified, a generalized criterion for calculating the type of winding was formulated. Computational methods have been developed for analyzing the structure of the winding formed with and without bundle structures scattering, allowing to quantify the effectiveness of dispersion and to search for process regimes using multi-criteria optimization methods.

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