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DETERMINATION OF THE TEXTILE BOBBINS STRUCTURAL PARAMETERS

ОСОБЕННОСТИ ОПРЕДЕЛЕНИЯ СТРУКТУРНЫХ ПАРАМЕТРОВ ТЕКСТИЛЬНЫХ БОБИН

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The objective of this research paper is to determine the structural parameters of textile bobbins to ensure the proper provision of quality and competitive products. Breakage caused by defects in winding mechanisms is on average 22 %, so a theoretical analysis of the braid structure formation process in terms of the force interactions between threads was performed. An instrumental procedure for quantifying the winding structure parameters will improve production, so this study has investigated methods for its registration. The estimation method used to analyse the wind-

ing structure, generated without dispersing the braid structures, allowed the comparison of winding at different machines under varying conditions. The limitation of the study is its lack of applicability in computer applications to determine the lifting angle and coil difference. This is the first temporal and spatial study, which includes a holistic view of the structural parameters of textile bobbins.

Целью данной научной работы является определение конструктивных параметров текстильных бобин для обеспечения надлежащего обеспечения качественной и конкурентоспособной продукции. Поломка, вызванная дефектами намоточных механизмов, составляет в среднем 22 %, поэтому проведен теоретический анализ процесса формирования структуры плетения, в условиях силового взаимодействия между нитями. Инструментальная процедура количественной оценки параметров структуры намотки улучшит производство, поэтому в данном исследовании изучались методы ее регистрации. Метод оценки, использованный для анализа структуры обмотки, полученной без рассредоточения плетеных структур, позволил сравнить обмотку на разных машинах в различных условиях. Ограничением исследования является его неприменимость в компьютерных приложениях для определения угла подъема и разности катушек. Это первое временное и пространственное исследование, которое включает целостное представление о структурных параметрах текстильных бобин.

Keywords: defects of winding, defects of structure, tape winding, braid winding, shear of turns, turn reversal point.

Ключевые слова: дефекты обмотки, дефекты строения, ленточная обмотка, плетеная обмотка, сдвиг витков, поворотная точка разворота.

1. *Introduction*

In developing competitive and quality products within textile enterprises, it is critical to ensure that systematic and quality control processes are effective. This will guarantee the proper application of raw materials into textile production and develop a quality product. In particular, the development of the crosswound bobbin is a crucial stage in textile production to support competitiveness. This can be achieved through the application of spineless spinning machines that have a particular structural design like cobs in circular spinning machines. The quality provided by the cross-winding machine is influenced by other parameters like the density involved in the winding process and provision of uniformity in the generatrix radius. Other important parameters that will influence the quality of textile products include, the amount of deviation from the expected form, structural defects in compacted sections, and tape winding.

The process of developing bundle structures requires threads to be laid beforehand so that they play the role of a spreader to ensure that it does not violate the control of the yarn feeder. By increasing the number of coils, a resultant force returns the coil to the normal position effectively. As such, the structural design ensures that the thread can slip out from its position, which is detected by the bundle created by the yarn feeder. Provided the lifting angle created by the coil within the turnover remains at zero, it is important that the structural design maintains the remaining area with a non-zero value (β*)*. This will allow for changes in the yarn which will influence the quality of the fabric.

There is a correlation between the side surface relief provided in the package and the winding structure determined by the corresponding diameter. This is an important conclusion that this paper seeks to prove through mathematical calculation. For instance, the bundle structure should have its coils placed in succession which allows for the profile height to be increased to the packing density. Prior studies have indicated a possibility of determining the winding structure by considering distribution shadows created by the lateral illumination from the package surface.

The primary objective of this research paper is to determine the structural parameters of textile bobbins to ensure the proper provision of quality and competitive products. Therefore, the specific objectives of the study include the following.

The development of quality control methods to estimate the structure of cross-wound packages would ensure qualitative winding at spinning machines.

Various features like the winding analyzer provide an important point of focus because they allow continuous evaluation of the structural parameters of the textile bobbin. As a strategy to achieve the objectives of this research paper, the surface that has the ability to eliminate the impact of non-roundness of the bobbin will lead to a proper winding structure all the way starting from photo-detector. Increased requirements to develop the quality of packages are related to improving cross-wound packages for spinning machines. This is especially true for packages formed in machines that implement new spinning techniques, such as rotor and pneumatic, as well as spinning-torsional and torsional ringless machines. To accomplish the research aim, the following tasks have been set:

1. Clarify the reasons for the formation of defects in the winding structure in braid and tape winding;

2. Investigate experimentally the impact of the winding structure defects on the suitability of packages for processing during subsequent operations;

3. State the generalised criteria for the determination of the winding type.

2. *Literature review and problem statement*

The specific parameters involved in developing the winding structure are: the layout width, coil lifting angle, and coil distance. The structural design will have a major impact on the quality of the textile bobbin winding mechanism. Identification of these important parameters has a major influence on the technological features of the package in delivering a high-quality process. When the machine is in stationary mode, the winding bobbin will share a kinetic relationships created by the number of moves of the yarn feeder and the rate of turnover provided by the bobbin distance (Pracek et al., 2015).

Rudovsky (1995) established that coil distance provided by the circumferential direction of subsequent coils provides an important basis for analysing the winding structure of the textile bobbin. As such, the coil distance difference is obtained by calculation of the non-stationary movement of the textile bobbin. It is important for the distance difference to have a transfer ratio of i ~ 1 between the bobbin and coil. However, this mathematical approach is limited in its assessment of the winding structure overall. In common cases, structural parameters are influenced by the kinetic relationships within the winding machine. Consequently, it is important to undertake an analysis of the winding parameters using the calculative approach suggested by Rudovsky. In his work, he described a simpler technique for determining the angular and linear distance of the coils provided by the kinetic scheme in the winding mechanism and diameter. Also, the linear distance existing between adjacent coils will be used to determine the existence of defects like bundle winding, especially where the adjacent coils have been stacked together. The main limitation of this methodology is that it does not offer a solution based around computer technologies. Thus, it limits the control of forming bundle winding at any selected diameter.

Jianhui et al. (2015) proposed another technique in the assessment of the winding structure that is aided by a computer application. This is done in bundle winding by strictly following a two-step criterion. Firstly, the fixation angle in the coil and unequal distribution of the turnover points will be observed on the total circumference of the bobbin. In this case, the winding structure's parameters are the following quantities: thread turn lifting angle β; central angle j between the points of reversal of turns; a distance between thread turns Δ in the direction perpendicular to the turn; a distance between the turns of thread Δ_θ in the radial direction. Thus, the filament winding is the point at which the distance between the turns of a thread is smaller than its diameter d_t, that is:

$$\Delta \leq d_t \, . \quad (1)$$

The tape winding is the point at which the distance between the turns of a thread is less than three diameters of the thread:

$$\Delta \leq 3d_t \, . \quad (2)$$

In terms of reasoning, we assume that the defective winding structures are formed when:

$$\Delta \leq kd_t \, . \quad (3)$$

Where k is the number from 0 to 3, denoting the requirements to the winding structure. At $0 < k < 1$, the winding is the filament, and at $1 < k < 3$, this is the tape winding.

Cylindrical cross-wound packages, produced by spinning machines of type PPM-120, are used in the weaving or knitting industries. Depending on the purpose of the yarn, packages are delivered as a weft or a base for textile production after preliminary rewinding or directly from the above-specified machines. The quality of package winding significantly affects thread breakage during the specified operations in textile production.

To determine the reasons for yarn breakages categorised in technological practice as those due to a violation in the shape of a bobbin and the fly offs at turns, we additionally monitored the breakage in warping machines. In this case, we controlled the diameter of the winding experiencing breakage. Control was executed after eight rollers worked 330 threads each. To verify this provision, we monitored the percentage of breakage during bobbin winding obtained on a spinning-torsional machine PK-100M3. Based on these data, the breakage of thread due to defects in the winding mechanism was 58% on average. In this case, the main winding defect in the PK-100M3 is the fly offs at turns that typically accompany braid winding.

The winding structure's parameters depend on the design of the winding mechanism and affect many of the package's technological properties and its capability in processing. In the case of stationary motion of the system (winding shaft—bobbin), the kinematic ratios between the number of runs of the thread guide and the number of rotations of the bobbin, at adistance where A=0 are stated in papers by (Jianhui et al., 2015; Patent, 2015). Pracek et al. (2015) reported results on the simulation of the yam unwinding process from the package and the influence of these defects on its quality.

Ashhepkova (2015), in order to assess the structure of the winding process, applies distance Ae in the circumferential direction between successive turns. This is determined by calculation under conditions of the non-stationary motion of the system (winding shaft—bobbin), only when the gear ratio between the bobbin and the winding shaft is $i \approx 1$. This method certainly cannot be employed to estimate the winding structure of the entire package. In many cases, these parameters are determined by the kinematical ratios in the winding mechanism, which is why their analysis requires calculation methods. One drawback of the described procedure is its limited use in computational equipment, which makes it impossible to check the formation of braid winding for all diameters.

Patent (2015) gives dependence graphs of these factors based on the diameter of the winding, as different thread guide motions disturb the laws that apply to disperse winding defects. Using the described procedure, the authors analysed the efficiency of different techniques for dispersing defects in the structure. An analysis of one of the dispersion techniques is given in Nuriyev et al. (2017).

To assess the negative effects of braid winding, it is necessary to analyse the structure of winding mechanisms in order to determine the best possible diameters to use for braid formation, to define the volume or the thickness that would be acquired. In addition, it is desirable that such a method should make it possible to compare the winding structures obtained using different winding mechanisms or the same winding mechanisms in different modes of operation.

3. *Research methodology*

To solve the set problem, we shall solve inequality $|(mL - \pi Dn)\sin\beta| \le kd_t$ relative to:

Parameter D:

$$\frac{m}{\pi n}L - \frac{kd_t}{\pi n \sin\beta} \le D \le \frac{m}{\pi n}L + \frac{kd_t}{\pi n \sin\beta}. \qquad (4)$$

If one requires, when solving (4), an exact match between positions of the successive and preceding turns, that is, k=0, we obtain values for braid diameters:

$$D = \frac{m}{\pi n}L. \qquad (5)$$

Subtracting from the right side of expression (4) to its left side, we obtain a range of diameters where the inequalities are satisfied:

$$\Delta D = \frac{2kd_t}{\pi n \sin\beta}. \qquad (6)$$

Structural defects arise when the ratio of the layout wavelength L to the length of the bobbin's circumference nD is an irreducible fraction.

At a constant turn lifting angle P, this ratio depends only on the diameter of the winding D. In the L-πD coordinate system, each ratio L/πD will be matched by a beam passing through the coordinate origin (Fig. 1).

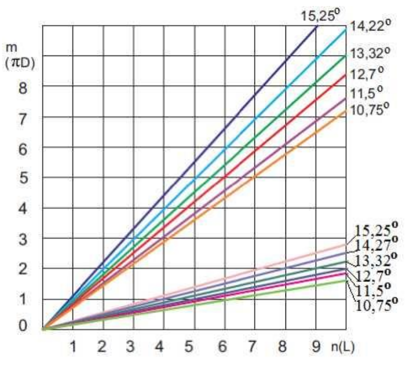

Fig. 1

By analysing the diagram, one can also estimate the strength of the defect. To this end, consider expression (4), from which it follows that the intensity decreases in proportion to the number n. Hence, Figure 1 shows that the strongest braid m/n=1 under specified conditions, forms close to the maximum diameter of the package. Defects that are generated at large values for n are of smaller thickness. The observations found that the defects generated when n > 6 do not affect the quality of the winding, and at n > 10, they cannot be detected visually.

Because the L-πD diagram can be built in the dimensionless magnitudes m-n, it can be used to compare the structure of the winding packages generated at different machines or at the same machine at different settings of the bobbin winder.

Rudovsky (1995) shows the relationship between the fly off turns to the end of the package and the structural winding defects. According to Maag (1985), the experimentally established fact of the emergence of fly offs at the ends, could be partially eliminated by selecting the crossing angle of the turns. This is consistent with the result obtained; however, Maag (1985) fails to provide a theoretical explanation of this phenomenon. We estimate a range of diametersΔD, at which a defective winding forms, for example, in machine PK-100M3. In this case, we assume n=1 and k=3. The required estimated diameter of the thread can be obtained by employing the known formula:

$$d_t = 0.00357\sqrt{T/\delta}. \qquad (7)$$

Dispersion mechanisms introduce disturbances to the motion of a thread guide or bobbin, which disrupts the process of forming the braid structures and improves the quality of winding in general. However, it is not possible to analyse the winding structure of a dispersion mechanism for braid winding by applying the described method. That requires a method that takes into consideration the arrangement of reversal points of turns at the end of the package, as well as the actual change in the winding thickness over time.

As shown above, in order to describe the winding structure in general, using dispersion mechanisms, it is convenient to adopt, as a criterion, the distance between turns. In this case, to assess the thickness of the winding defect, one must have an actual dependence characterising the growth in the winding diameter due to the number of double runs by a thread guide. Applying time as an argument (Nuriyev & Musayeva, 2016; Nuraddin-Nuriyev et al., 2018) is not advisable in this case. It is much more convenient to use the number of double runs by a thread guide (Rudovsky, 1995; Nuriyev, 2016).

Let a bobbin be rotated at some elementary angle d_t, then the thread of the following weight will be wound around it:

$$dm = \frac{TDd\varphi}{2000\cos\beta}. \qquad (8)$$

Where T is the linear density of the wound thread, tex.; D is the current diameter of a winding body, m; β is the lifting angle of a turn averaged over a cycle of the dispersing mechanism. In this case, we assume that the thread weight is in the cylindrical layer of thickness d D/2 at the surface of the package, then:

$$dm = \frac{\pi\gamma(D)HDdD}{2}. \qquad (9)$$

Where *y* is the winding density, g/m^3; H is the width of a package, m.

Equating the right sides of (17) and (18) below, we obtain an equation to determine the new value for the diameter of the package:

$$\int_{D_I}^{D_{I+!}} \pi\gamma(D)HDdD = \int_{\varphi_i}^{\varphi_{i+1}} \frac{TDd\varphi}{1000\cos\beta}. \qquad (10)$$

The dependence γ = γ(D) is determined by many factors, both structural and technological. The physical processes by which these factors affect the winding density have not yet been fully revealed. Therefore, we assume that the dependence y=y(D) was obtained empirically and represents the polynomial:

$$\gamma = AD^2 + BD + C. \qquad (11)$$

Where A, B, and C are the empirical coefficients.

This kind of dependence has been defined by many authors in equations (13) and (14) for all types of winding mechanisms currently used in the textile industry. Not a single analytical dependence between the density of winding and the package structure, which could specify the law of change in the density of winding due to an increase in its diameter, has been found so far.

Following the substitution (11) in (10) and integration, we obtain equation:

$$\frac{D_{i+1}^3}{3} + \frac{BD_{i+1}^2}{2} + CD_{i+1} - \frac{AD_i^3}{3} - \frac{BD_i^2}{2} - CD_i - \frac{8T}{1000\pi(D_i + D_{i+1})\sin\beta} = 0. \qquad (12)$$

When estimating the structure of the generated layer, we assumed that the lifting angle of a turn over one double run by the thread guide remains constant, and its change is due to a jump to the beginning of a new double run. It is more convenient to adopt the reversal points of the turn at one of the package ends, as the points that defines the position of a turn. The criterion for estimating the structure of winding, in this case, is the distance between the points of turn reversal, measured along the arc of circumference of the bobbin A e. Inequality $|(mL - \pi Dn)\sin\beta| \le kd_t$, in this case, takes the form:

$$|\Delta_0| \le \frac{kd_t}{\sin\beta}. \qquad (13)$$

To calculate, we take a cylindrical coordinate system (r, y, φ) associated with the bobbin. Arc length L at the outer surface of the package with diameter D, upon which a thread is laid over one double run by a thread guide, is determined from:

$$L = \frac{2H}{tg\beta}. \qquad (14)$$

Where β is the current value of the layout angle, defined by the kinematic parameters of the braid winding dispersion mechanism.

This arc is matched by a central angle

$$\Delta\varphi_i = \frac{2L}{D}. \qquad (15)$$

Thus, following one double run by the thread guide, the reversal point of the turn will accept coordinate $\varphi_{i+1} = \varphi_i + \Delta\varphi$.

Subtract the part, multiple to 2π, from it:

$$\varphi_{(i+1)H} = \varphi_{i+1} - 2\pi \operatorname{int}\left(\frac{\varphi_{i+1}}{2\pi}\right). \qquad (16)$$

Where $\varphi_{(i+1)H}$ as the normalised angular coordinate of the reversal point.

The linear distance between two adjacent reversal points of the turn along the arc on the outer surface of the bobbin is:

$$\Delta_\theta = \frac{\varphi_{(i+1)H} - \varphi_{iH}}{D_i}. \qquad (17)$$

Because the formation of a defective winding may result in the fact that not only does each subsequent turn overlay the preceding one, but the following turns overlay each other in one, two, or more turns, Δ_θ should be determined repeatedly at each double run of the thread guide from the expression:

$$\Delta_{\theta m} = \frac{\varphi_{(i+1)H} - \varphi_{(i+1-m)H}}{D_i}. \qquad (18)$$

Where $\Delta_{\theta m}$ is the distance along the outer surface of the package between the newly laid turn and the turn laid earlier by m double runs.

When analysing the winding structure using the method described, we adopt $1 < m < 6$ because structures of higher multiplicity are of an insignificant thickness and thus do not affect the technological parameters of packages. Expressions (12) and (18) are, in essence, the algorithm for calculating the distance between the reversal points of turns, while expression (13) is a criterion for estimating the winding structure. They underlie the method for an analysis of the winding structure from a kinematic aspect.

The method implies the calculation of distances $\Delta_{\theta m}$ for each double run made by the thread guide when forming a winding. In this case, we determine preliminarily the turn lifting angle β, the layout width H, and other quantities that can vary by the dispersing mechanism in the package-forming process. Given a certain number of double runs by the thread guide, we calculate the number of instances for meeting condition (13), and we plot it as a coordinate in the diagram describing the winding structure (Figure 2). The abscissa is the winding diameter, determined from equation (12).

Condition (13) is checked not only for the two consecutively laid turns, but also for the following ones, laid in 1, 2...6 turns.

Comparative analysis of the calculation results shows that they agree well. Despite its complexity, the method is more informative. Indeed, the height of bars in the diagrams shows the number of threads, stacked sequentially, one next to another, while the width of these bars corresponds to the range of diameters over which such defects form. The proposed method enables the effectiveness of the dispersion mechanisms to be quantified. Such an evaluation can be based on the height of bars in the winding.

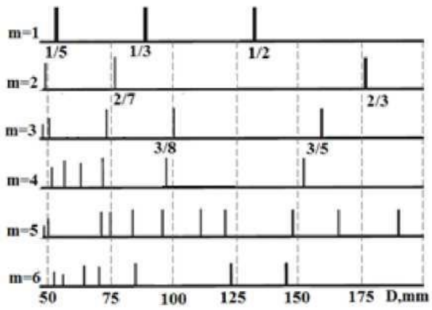

Fig. 2

However, the operation of the dispersing mechanism may have a different impact on the braid structures generated by different diameters of winding. Therefore, in order to clarify the technological modes in the formation of a package, it is necessary to apply methods of multicriteria optimisation.

4. *Results and discussion*

To set the winding mechanisms, both under industrial conditions and when testing new equipment, the most acceptable ways are instrumental methods, based on an analysis of the package itself. The first step towards constructing such methods is to determine the actual curve of the turn arrangement on a winding body. We describe the procedure to register the position of the thread at the reversal site, which implies rolling the package over an adhesive tape; in this case, a thread is glued, from a bobbin to the tape, in line with the position at which it was laid in the winding. The distance from the point where a thread leaves the package to the tape, which fixes it, is zero. It should be noted that such a procedure is suitable only to analyse the violations of the turn arrangement at the reversal site and cannot be applied to analyse the dispersing mechanism due to considerable time cost and tape consumption. To quantify defects in the winding structures, we introduce the notion of the intensity of braid winding, that is, the number of threads per unit width of the defective structure.

Figure 3 shows the dependence chart of the intensity of braid winding q on a winding diameter for machine PSK-225 SHG. The dashed lines demonstrate diameters for the respective ratios m/n, according to the model for forming the braid winding. Figure 3 shows that the model quite accurately predicts the strongest formations observed at diameters of 60, 90, and 180 mm. Some differences can be attributed to the presence of slippage in the pair "bobbin-winding shaft" and to the subjectivity of the described experimental method. The formations that form when m=3 possess less intensity than that at m=2 and merge with the rest formed at larger multiplicities. The magnitude of the intensity of braid winding for them is q < 3 threads/mm; that is, a 1-mm width of the defective structure hosts less than 3 threads. That indicates that such a formation is unlikely to have a significant impact on breakage at winding, on the process of laying a thread, or other processes, which are negatively affected by braid winding.

Indeed, when unwinding the packages, the pattern of a winding structure at the package surface changes constantly, and a researcher is required to demonstrate a certain reaction to terminate the unwinding process. In this case, the researcher may miss some formations considering them not to be significant. In this sense, there is a need to develop a procedure that would make it possible to monitor the winding surface as it is continuously unwinding and to record indicators correlated with the number of threads in the braid. At the same time, the current package diameter must be measured and recorded.

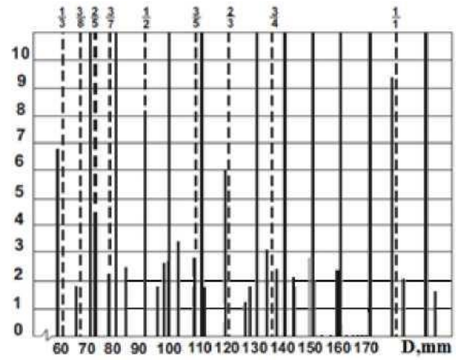

Fig. 3

CONCLUSIONS

It was established that the cause of defective formation in the winding structure in braid and tape winding is the multiplicity of thread guide motion periods and the bobbin rotation frequency, which make it possible to reasonably address the development of a method for estimating defects in winding. We have formulated a generalised criterion for this purpose, i.e. the number of turns stacked sequentially at a distance not exceeding the specified one, gives the estimated determination of defects in the winding structure and their impact on the quality of the package. We have experimentally confirmed the negative effect of structural winding defects on the suitability of packages for processing at subsequent operations. Thus, the breakage caused by defects in winding is up to 22 % of the total breakage, on average. We have constructed an estimation method to analyse the structure of winding that is generated without dispersing the braid structures, enabling the representation of results based on normalised dimensionless indicators. The research also compared the winding structure formed using different machines under varying conditions.

In addition, the proposed method makes it possible to choose rational structures for winding mechanisms and thereby reduce breakage.

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