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DEVELOPMENT OF THE METHOD OF CONSTRUCTING THE GRAPHIC MODEL OF TEXTILE PACKAGES BY EXPERIMENTAL DATA

Об'єктом дослідження є методи аналізу геометричних параметрів текстильних пакувань, що форматуються на машинах з роздільними процесами формування пряжі і її намотування. Одним з найбільш проблемних місць аналізу відхилень форми пакувань від необхідної є великий обсяг інформації про координати точок поверхні пакування, одержуваних в результаті вимірів. Усунення зазначеної проблеми можливе за рахунок створення об'ємної моделі пакування, що дозволяє попередньо візуально оцінити наявність дефектів на поверхні пакування та провести наступний кількісний їх аналіз.

В ході дослідження запропоновано експериментальний метод отримання первинних даних, що характеризують форму окремих меридіональних перерізів пакування. Розроблено експериментальну установку, що дозволяє отримувати дані і зберігати їх в оцифрованному вигляді, і метод перетворення отриманих даних в об'ємну геометричну модель текстильного пакування.

Встановлено, що розроблена модель дозволяє отримати ряд одиничних показників відхилення форми бобін від заданої і надалі поводити роботу по формуванню комплексного показника для оцінки якості форми бобін. Комплексна оцінка якості форми пакування може бути отримана методом середньозваженого показника. Середній зважений показник будується як залежність, аргументами якої є одиничні показники якості і параметри їх вагомості.

Проведено оцінку застосовності розробленого комплексного показника для аналізу форми пакувань. Для цього проведено аналіз партії пакувань, який підтвердив відтворюваність процесу аналізу форми пакування за допомогою запропонованого комплексного показника, а також відповідність оцінок, отриманих за запропонованою методикою, візуальним оцінкам.

Метод комплексної кількісної оцінки форми пакувань, викладений в цій роботі, дозволяє проводити оптимізаційні експерименти і на їх основі призначати такі регульовані параметри мотальних механізмів, які дозволять отримувати пакування необхідної якості. При розробці нового мотального обладнання можна буде закласти необхідні механізми регулювання процесу намотування.

Ключові слова: *зображення тіньової проекції, форми бобіни, перетину на торцях, розпізнавання зразка.*

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 stages of textile production. One of the significant stages of textile production is the formation of cross-wound bobbins, which are obtained either on spineless winders or by rewinding cobs obtained on circular spinning machines. The quality of the packages of cross winding is determined by a whole set of parameters, which includes:

- density of winding and its uniformity in radius and generatrix;
- the form of the package and its deviation from the required one;
- the presence of structure defects in the form of compacted sections, bundle and tape winding, etc.

At present, there are no proven effective methods for controlling all parameters of the packages of cross-winding that affect their quality. Systematically, only the diameter of the bobbins and their average density, which is estimated by the weight of the wound yarn at a known diameter of the winding, are controlled in the preparatory department of weaving.

The second important component of the quality of packages is the winding structure, with which the form of the package is closely related. The presence of defects in the winding structure leads to an increase in discontinuity during winding, which leads to a decrease in the efficiency of warping and weaving. Timely detection of such defects will eliminate the causes of their appearance by appropriate adjustment of equipment, and bobbins with defects sent to re-rewind. At the same time, the costs associated with additional rewinding are much lower than the costs associated with the elimination of cliffs in walking and weaving.

Thus, the creation of a method for automated control of the winding structure and its introduction in production will increase the efficiency of the processes of knitting and weaving and improve the quality of the fabric by eliminating the defects that accompany the elimination of breakages.

In this regard, the research aimed at developing a method for constructing a graphic model of textile packages based on experimental data seems to be relevant.

2. The object of research and its technological audit

The object of research are textile packages, formed on machines with separated processes of obtaining yarn and its winding, which are the most common spinning equipment to date. For the formation of packages on such machines, as a rule, winding mechanisms with a frictional drive of packages are used.

Due to a number of objective reasons related to the peculiarities of the operation of such devices, in certain packages specific characteristics of the structure may appear in the packages, which are accompanied by a distortion of the specified shape of the packages. It is possible to evaluate the quality of the packages and the work of the winding mechanism on which they are obtained, on the basis of an analysis of the deviation of the shape of the packages from the specified one.

Techniques and equipment for instrumental control of the form of textile packages are practically absent at present.

To obtain complete information on the shape of the bobbins, it is necessary to have profile images along the sections at the ends and the generatrix. The most promising for obtaining such images is the shadow projection method in combination with the means of automated pattern recognition. The implementation of this method is based on the use of a device for obtaining a shadow projection image and a device for recording this image and digitizing it. In turn, to work the last of them, special software is needed to recognize the image of the bobbins on the image and build a three-dimensional model of the package [1, 2].

Device has been designed and manufactured for receiving primary data on the package shape [3, 4]. The basis of its work is based on the method of shadow projection. The scheme of the device is shown in Fig. 1. The device consists of a frame 1, on which the bracket 2 and the tripod 3 are fixed. On the bracket 2, the drive 4 of the bobbin holder 5 is rotatably mounted about the axis 6. The drive is a synchronous motor-reducer RD-09 (RF production) with a speed of the output shaft, equal to 7.8 min^{-1}, on which the bobbin holder is located.

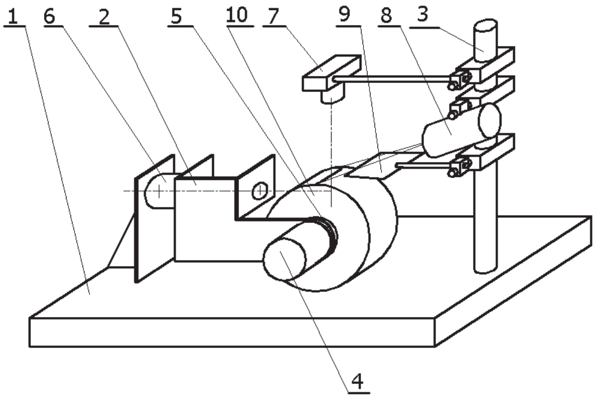

Fig. 1. The scheme of the device for the receiving the primary data on the shape and dimensions of the package

The bracket 2 after the rotation can be fixed in one of the positions located at an angle of 90° to each other. On the tripod are fixed: digital camera 7, illuminator 8 with halogen lamp and shutter 9. The design provides for adjusting the mutual position of the digital camera, curtain and illuminator in relation to each other and to the bobbin 10 installed on the bobbin holder 5.

With the help of adjustments, the optical axis of the camera is aligned with the axis of symmetry of the package. The digital camera 7 is connected to the computer via a USB port. The general view of the device is shown in the photo (Fig. 2).

Fig. 2. Type of device for the receiving the primary data on the shape and dimensions of the package

The device also includes a control unit for the electric motor and illuminator (not shown in Fig. 1). To accurately determine the conversion scale near the controlled surface of the profile, in the field of view of the digital camera, there is a measuring label with a width of 1 cm.

The device works as follows. The package 10 is mounted on the bobbin holder 5, which is in an upright position (Fig. 2). On the package at an angle of 45° to the analyzed surface a parallel beam of light is directed from the illuminator 8. A curtain 9 with a straight edge is installed in the path of light. The shade from the curtain is located on the controlled surface of the package. Its length depends on the height of the relief on the profile of the package. The shape of the shadow on the scale reproduces the section of the package at the point where the shadow falls. The shadow image is fixed by a digital camera and transmitted to the computer for further processing. During the receiving primary data, the bobbin installed on the bobbin holder receives a continuous rotation from the drive. Receiving data on the surface profile is continuous, while the digital camera is operating in the video mode. The duration of the shooting process is equal to the duration of one revolution of the package. The beginning and the end of the process of removing primary data is determined by the image of the label printed on the package surface. Upon completion of the receiving primary data of the end surface of the storage of the bobbins, the holder 5 rotates around the axis 6 by 90° and the data is taken from the side surface of the package. The duration of the process is also equal to the duration of one revolution of the package. At the end of the process, the bobbin holder is set to its original position, the bobbin is turned 180° relative to the axis of rotation, after which the data from the opposite end of the package are taken. After completion of the process of receiving primary data, they are transferred to a computer for further processing, construction of a three-dimensional model and calculation of indicators characterizing the form of the package.

The data obtained as a result of the operation of the device contains sufficiently complete information about the actual shape of the bobbin. After appropriate processing, they can be used to obtain quantitative estimates of various winding defects and to visualize the bobbin in the form of a three-dimensional model. Enlarged scheme of the algorithm for acquiring initial data and their processing in order to obtain a visual model and quality indicators, characterizing the shape of a bobbin, is shown in Fig. 3.

The primary information received by the software and hardware complex is video clips captured with a digital camera. The clips are recorded in QuickTime format with the .mov extension, which is determined by the software of the digital camera. This format is the standard for working with video images on MacOS operating systems on Macintosh computers [5].

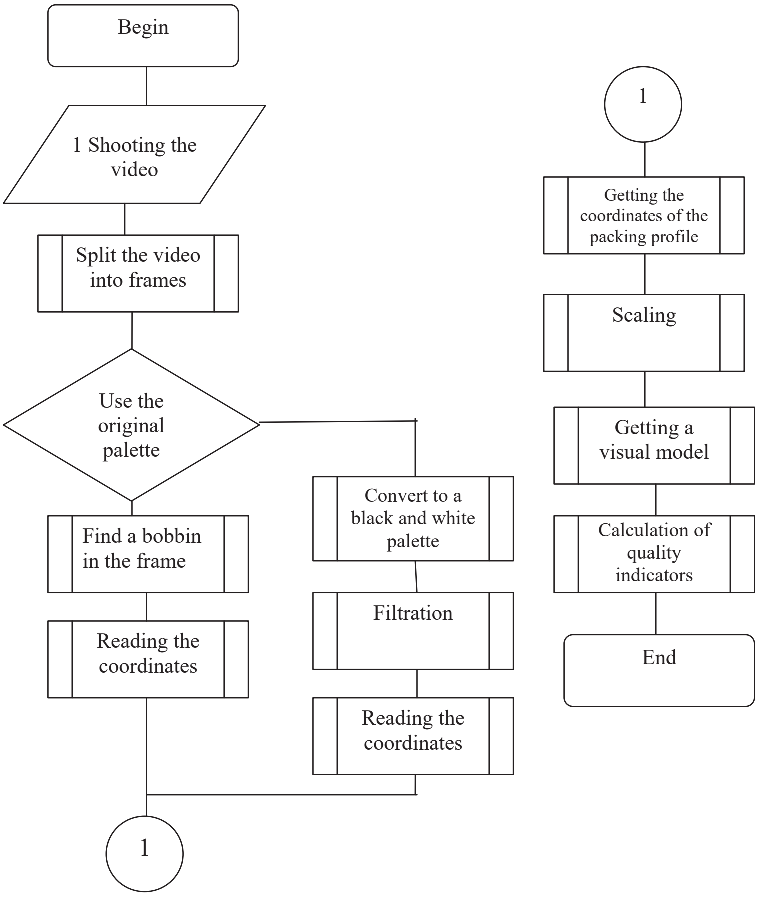

Fig. 3. The enlarged scheme of the algorithm for receiving the initial data and their processing for obtaining a visual model and quality indicators

For the construction of a three-dimensional model, the profiles of the package surface must be located in certain planes, and the plane count must coincide when constructing the lateral and end surfaces. To do this, a mark is placed on the bobbin, positioned so that it can be seen both when shooting both ends of the package, and when shooting the side surface of the bobbin. For the construction of the model, the resulting section profiles of the package are located in the planes obtained by rotating each subsequent plane, relative to the previous one.

To create a graphical model of bobbins, it is necessary to obtain information on the shape of a series of its meridional sections. Analysis of technical solutions shows that the most promising for obtaining information on the shape of individual sections is the shadow projection method in combination with the means for automated pattern recognition.

3. The aim and objectives of research

The aim of research is ensuring the quality of textile packages due to timely and objective control of their shape.

To achieve the aim, the following tasks are set:

1. To develop a device based on the method of shadow section for automated reading of data on the form of packages.

2. Development of a graphical model that allows processing the results of controlling the form of the package in real time.

4. Research of existing solutions of the problem

It is known that if the conditions for the formation of bobbins violate, a number of defects arise that complicate its processing at subsequent technological transitions. One of the important components of the quality of the bobbins of the cross winding is its shape, for example:

1. *Maximum deviation of the butt end from straightness.* The surface of the butt ends of the package is never flat, and its generatrix is straight. The reason for the non-flatness of the butt ends of the package is the extrusion of coiling layers located closer to the cartridge by layers wound above them [6–8].

2. *Edges at the butt ends of the package* are formed when the bobbin holder is not rigid enough, when it is possible to shift it during the winding of the bobbin. When winding chemical filaments that have a high stress relaxation, the cause of the formation of ledges at the ends can be interruptions during the winding process.

3. Edges on the bobbin generatrix arise for two reasons. The first reason is that in the reverse direction of the yarn feeder (near the ends of the pack), more material is being stacked in the body of the winding than in the middle [7–10]. As a result of this, edges are formed near the ends, on the lateral surface of the bobbins. Because of the roll-out of the side surface of the bobbin, the winding shaft (or drum) compact these projections and locally increases the winding density.

The second reason for the formation of the edges on the generatrix is a violation of the yarn layout, its repeated flight from the groove of the slotted drum or the loss of the yarn of the yarn guide.

4. *The filament winding.* It occurs when the movement period of the yarn feeder is a multiple of the period of the bobbin movement [7, 11–13], that is, the gear ratio between them is expressed by an irreducible fraction *m/n*. In this case, the yarn is placed in the same place until the diameter of the winding is increased so that the value of the gear ratio changes. As a rule, the yarns are laid on the same place with a periodicity equal to the denominator n in the ratio between the bobbin and the yarn feeder. It is shown in [14–16] that the larger *n*, the fewer threads in the bundle and the lesser danger it presents for the appearance of breaks when the bobbin is unwound. Externally, the bundle winding is manifested in the form of protrusions on the side surface of the package, located at an elevation angle – a turn to the axis of the package.

5. *Corrugations on the ends of the package* are formed near the cartridge, and are small loops of threads that have lost tension. The reason for their occurrence is the loss of tension in the yarns located in the inner layers of the winding body, under the influence of the pressure of the overlying layers.

6. *Deflection of the bobbin from taper.* The change in the taper of the bobbin occurs when the chuck axis is skewed relative to the axis of the winding shaft. The actual taper is determined by the formula:

$$C = \frac{r_{\max av} - r_{\min av}}{l_{av}},$$

where $r_{min\,av}$ and $r_{max\,av}$ – the average values of the minimum and maximum radius of the package; l_{av} – the average value of the length of the package generatrix.

To assess the correctness of the shape of the bobbins, a number of instruments based on contact methods have been developed, but they have limited application, mainly for scientific research. Recently, foreign firms [17–19] have proposed instruments and control and sorting complexes, which work is based on the removal of primary information on the shape of the bobbins by methods of technical vision, followed by processing it on a computer with the help of special software. At the moment, work is under way to create such complex. Let's consider in general the range of problems, which solution is required in this case.

5. Methods of research

The essence of the method of shadow projection in combination with the means of automated pattern recognition is that knife 1 is installed above the measured surface (Fig. 4) [11, 20]. Parallel beam O_1–O_1 of light is directed at an angle α to the normal *n–n*. The shadow from knife *b*, falling to the surface, repeats its profile *a*. The shape and dimensions of the section are judged from the apparent shadow image in the observation device, which optical axis O_2–O_2 is inclined at an angle β to the normal *n–n*.

As a recording device, a digital camera with a CCD array (short of a «charge-coupled device») or a CCD-matrix (abbreviated from English CCD, «charge-coupled device») is used. Such matrix with a small resolution consists of 2 million pixels – 1600×1200 pixels. This number of elements allows to obtain an image with a resolution of 10 lines/mm. The apparent diameter of the cotton yarn with a linear density of 50 tex is 0.25 mm. Thus, the resolution of inexpensive digital cameras is small for fixing individual filaments. Currently, almost all digital cameras have the ability to shoot video. As a rule, the recording is made first into the internal memory, and then transferred to the installed memory module. The duration of such record is 20 seconds, although this figure may vary depending on the amount of internal memory. The shooting takes place with a resolution of 320×240 pixels. The experimental data show that at this resolution a scale of 1 mm 2 pixels is obtained. It is obvious that with such scale it is impossible to distinguish a single string, but this is quite enough to determine the presence of defects in the shape of the package.

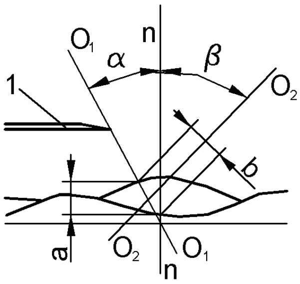

Fig. 4. Scheme for receiving information on the shape of individual sections

Using the video recording of a rotating bobbin, one can obtain a meridian cross-sectional image of one of its surfaces at different angles of rotation. To obtain complete information on the shape of the meridian section of the bobbins, the survey is performed three times, for each end and for the side bobbin. Based on these data, a three-dimensional model of bobbins is constructed.

Further processing of the image is carried out by means of special software [21, 22], which provides the solution of the following tasks:

- definition of the scale of the image;
- division of the video into frames;
- training for processing;
- determination of the package contour on the sectional image;
- building a 3D model;
- reading of single error parameters of the bobbin shape;
- formation of a complex quality index of the bobbin shape.

Let's consider in more detail the methods for solving some of them. To determine the scale, the user enters the coordinates of the beginning and the end of a 1 cm long measuring section along the image. For this, when shooting a video clip, a ruler with a standard measuring segment is installed on a bobbin level. As a result, the program receives the coordinates of two points on the image and calculates the number of pixels between them. The scale is defined as the number of pixels in one centimeter. The scale is saved after processing the package in the program settings, and the user can't override the value until processing of another bobbin begins.

At the second stage there is a process of splitting the videos into frames. To do this, let's use a set of control commands from the library QuickTime, which is designed to work with video images stored in the format MOV. Each video is divided into frames, which are stored in a graphic file with a standard BMP extension.

At the third stage, the process of preparing the received frames for reading the profile coordinates takes place. This process consists in removing from the frame an image that is not related to the package, which makes it possible to speed up the process of obtaining coordinates. The process of clipping image elements that are not related to the package can be carried out in two ways. The first works on the basis of standard functions for processing files of type BMP and selects the working area of the image automatically. In the second way, the user must define the boundaries of the workspace for each clip.

The solution of the task of determining the package contour is isolation of the package area in the image that is brighter than the background. In order for the software product to correctly determine the margin of the bobbin profile, it is necessary to specify the color that the bobbins will determine. The user must determine the point with the darkest color belonging to the package. This is done by specifying the image of the bobbin with the mouse. This parameter is also necessary to determine the start point of the bobbin image on the frames. All pixels that are darker than the specified color will not belong to the area of the bobbins. Search for the boundaries of the profile is done by scanning the image on the columns, starting with the top points, which always belong to the background, until the first point belonging to the bobbin is detected. The coordinate of this point is taken as the coordinate of the bobbin section profile.

6. Research results

The background image can contain defects in the form of separate points of bobbins that are close in color to the color, which can be taken by the program for the point of the profile of the package. To exclude them, a special parameter is entered at the image processing stage – the maximum gap. It determines the maximum possible deviation of the read coordinate from the previous one, in centimeters. If the current point has a gap greater than the specified, it does not belong to the bobbin and the search for the profile point in the current column will continue until the correct coordinate is found. The resulting profile coordinates are stored as a vector.

After reading the coordinates and writing them into memory, the stage of constructing the three-dimensional model follows. When building a model, it is necessary to ensure that the images of the butt ends and the side surface of the package match. To do this, when shooting on the bobbin surface, a mark is placed, which is visible on each of the original rollers. The frame count is made from this label. The angle between adjacent sections in the construction of the model is determined by the formula:

$$\psi = 360°/n,$$

where n – the number of frames per one revolution of the package.

A schematic representation of the package model obtained from the program results is shown in Fig. 5. After processing the measurement results, the packing profiles are obtained in the YOZ coordinates. The three-dimensional model of the package is constructed in the coordinate system $OX'Y'Z'$. The axis OZ' coincides with the axis OZ. The plane YOZ for each section is obtained by turning the plane $Y'OZ'$ relative to the axis OZ' by the angle $n\psi$, where n – the profile number. Fig. 5 shows the construction of the second profile.

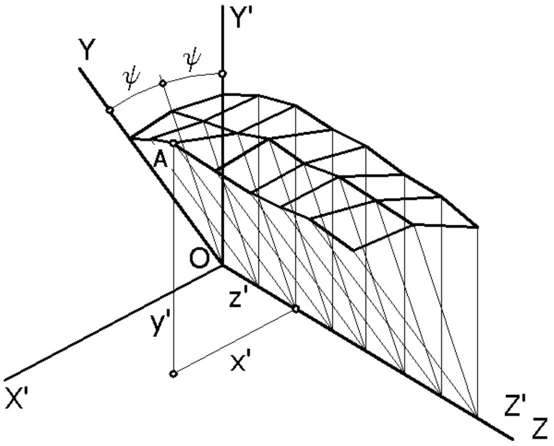

Fig. 5. The scheme for constructing a volumetric graphic model of the package

The point A having on the profile, that is, in the coordinate system YOZ, the coordinates y, z, in the coordinate system $OX'Y'Z'$ will have the coordinates x', y', z', which can be calculated by the formulas:

$$x' = y \sin n\psi,$$
$$y' = y \cos n\psi,$$
$$z' = z,$$

where x, y, z – the coordinates of the point of the bobbin surface in the coordinate system associated with the meridional section passing through this point; x', y', z' – the coordinates of the same point in the coordinate system in which the graphic model of the package is constructed.

The visual construction of the model is implemented using the OpenGL library [13, 23]. After the construction, the corresponding points of the profiles are joined together, forming a reticular surface consisting of quadrilaterals. When implementing the software, there are 3 ways to display a three-dimensional model of the package:

1) only profile points without connecting lines are displayed;

2) the profile points and their connecting lines are displayed;

3) the points and polygons connecting them are displayed.

According to the above algorithms, software is developed that allows to obtain graphic models of packages based on the control of their shape by the shadow projection method. To demonstrate the capabilities of the model to reflect the actual shape of the package with all its inherent defects, the samples are taken from packages of different machines, with defects and without them. In Fig. 6, and a model of the package produced on the R-40 pneumomechanical spinning machine from Rietter (Germany) is presented. The bobbin with a small taper (2°) has an almost perfect shape, without any defects at the ends and the lateral surface, and in Fig. 6, *b* is a graphic model of the package wound on the pneumomechanical spinning machine PPM-120 (Russia) to the bundle diameter. The model clearly shows the yarn formations and the convexity of the butt ends.

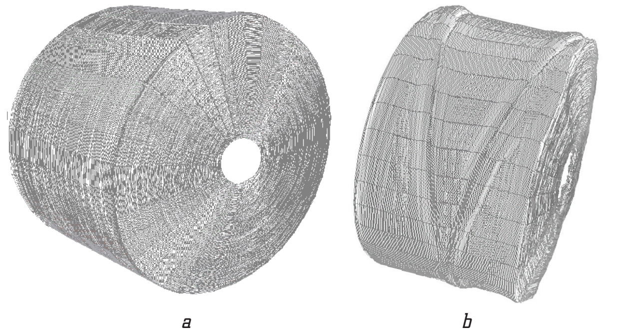

Fig. 6. Graphical model of the package wound on a pneumomechanical spinning machine: *a* – R-40 from Rieter (Germany); *b* – PPM-120 (Russia) with bundle winding

Graphic models have an auxiliary value when analyzing the quality of packages. The main evaluation of the availability of bobbins for further processing should be based on quantitative indicators characterizing individual defects in the shape of packages and the generalized index characterizing the shape of the bobbin as a whole.

As initial data for the calculation of single indicators, data on the form of the package, obtained from the processing of video clips, can be used. The method of obtaining a three-dimensional graphic model of the package is described in [23, 24].

7. SWOT analysis of research results

Strengths. The constructed model can be saved in a database for accumulating statistics, as well as the subsequent restoration of the parameters of the bobbins for analysis by other methods. As the database core, Microsoft Jet is selected, which is used in Microsoft Access database management system (DBMS).

Weaknesses. A considerable amount of time is required to calculate the parameters using this technique.

Opportunities. According to the constructed model, it is possible to calculate a number of single indicators characterizing the deviation of the shape of the bobbins from the given one and on the basis of them in the future to form a complex index for evaluating the quality of the package shape. Comparing the values of the complex index with the given one, it is possible to produce automated bobbin sorting, similar to that performed by the device described in [10].

Threats. To implement the obtained research results, it is necessary to purchase licensed programs and train staff how to work on them.

8. Conclusions

1. On the basis of the shadow section method, a device for automated construction of a graphic model of bobbins has been developed, which makes it possible to analyze the package shape for the timely detection of winding defects. Its peculiarities are obtaining primary data in the form of video clips with the image of the butt end and side surfaces of the bobbin. Due to such features, it is possible to process an array of coordinates of points characterizing the bobbin shape.

2. Thanks to the development of the graphical model of the package form, it became possible to evaluate the results obtained in real time, providing operational functions of quality control of the technological process.

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INCREASING THE TECHNICAL LEVEL OF A TORQUE FLOW PUMP BY CHANGING THE GEOMETRY OF A FLOWING PART

Об'єктом дослідження є насос динамічного принципу дії, а саме вільновихровий насос типу «TURO» (Швейцарія).

Основним недоліком вільновихрових насосів є більш низьке значення коефіцієнту корисної дії порівняно з відцентровими насосами. Це пояснюється особливістю їх робочого процесу – утворення у вільній камері насоса поздовжнього вихору, на підтримання якого й витрачається частина споживаної насосом потужності.

Аналіз апріорної інформації свідчить про доцільність використання зміни геометрії проточної частини насоса як способу впливу на його напірну та енергетичну характеристику. Видовження частини лопатей робочого колеса у вільну камеру дозволяє використати у насосі комбінований робочий процес (лопатевий та вихровий), що дозволить підвищити економічність насоса без втрати ним істотних переваг, притаманним насосам даного типу.

Виготовлені експериментальні робочі колеса та проведене випробування на дослідному стенді. Отримані результати свідчать про можливість підвищення напору та коефіцієнту корисної дії насоса при збереженні місцезнаходження оптимального режиму.

Визначена номенклатура показників якості, за якими проводиться порівняння створеного насосу та насосу-аналогу. Обрано метод Харінгтона (метод «бажаної функції») для визначення базового показника якості. Визначено коефіцієнти вагомості для показників якості і розраховано інтегральний показник технічного рівня створеного насосу та насосу-аналогу.

Обгрунтовано використання SST-моделі турбулентності для проведення числового моделювання течії у проточній частині вільновихрового насоса. Проведено числовий розрахунок та отримано інтегральні показники насоса.

Запропонована конструкція дозволяє створити нове насосне обладнання з покращеними показниками та більш високим технологічним рівнем або підвищити відповідні показники існуючого обладнання шляхом внесення змін у конструкцію робочого колеса. Вказані зміни не вимагають значних витрат та не потребують використання складного обладнання і можуть бути реалізовані безпосередньо на місці експлуатації власними силами підприємства чи експлуатуючої організації.

Ключові слова: *вільновихровий насос, робоче колесо, технічний рівень, модель турбулентності.*

1. Introduction

Torque flow pumps (Fig. 1) is a type of pumping equipment with an easy-to-use design and provide high reliability, durability and economic efficiency when working on pumps. They are also used in the transport of various solids and products [1–3].

Analysis of the components of the pumping equipment and the main trends of the pump market development lifecycle point advantage torque flow pumps (TFP) [1] during transfer:

- liquids with a high content of abrasive particles;
- suspensions with a high solids content and fibrous impurities;