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DEVELOPMENT OF AN ALGORITHM FOR RECOGNIZING THE SURFACE OF TEXTILE PACKAGES

РАЗРАБОТКА АЛГОРИТМА РАСПОЗНАВАНИЯ ПОВЕРХНОСТИ ТЕКСТИЛЬНЫХ ПАКОВОК

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The issues of creating a method for controlling the shape of cross-wound packages based on the shadow projection of the section are considered.

As a result of the analysis of technological processes of textile production, it was found that control methods at each technological transition are essential to ensure high product quality and labor productivity. In the spinning and rewinding phase of the formation of textile packages, their shape is an important parameter. The shape of the package and its deviations from the given one can be used as a complex indicator that characterizes the quality of the product of the corresponding technological transition, but also as a characteristic of the technical level and condition of the equipment used and the optimality of technological production modes.

To obtain complete information about the shape of the package, it is necessary to have cross-sectional profile images at the ends and generatrix. An analysis of the methods for controlling the shape of technical objects showed that a promising direction for controlling the shape of cross-wound packages in the textile industry is the shadow projection method in combination with automated pattern recognition tools. For the successful implementation of the method, a theoretical analysis of the influence of the design parameters of the transducer on measurement errors was carried out. Reasonable requirements for the mutual arrangement of the elements of the transducer relative to the controlled object are established. Relationships are obtained that allow predicting the parameters of the device, in particular, the scale of the transformation.

The substantiation of the choice of means for digitizing the resulting images for subsequent automated pattern recognition has been carried out.

Рассмотрены вопросы создания метода управления формой паковок с крестовой намоткой на основе теневой проекции сечения.

В результате анализа технологических процессов текстильного производства установлено, что методы контроля на каждом технологическом переходе имеют важное значение для обеспечения высокого качества продукции и производительности труда. На этапе прядения и перемотки текстильных паковок важным параметром является их форма. Форма паковки и ее отклонения от заданной могут быть использованы как комплексный показатель, характеризующий качество продукта соответствующего технологического перехода, а также технический уровень и состояние используемого оборудования и оптимальность технологических режимов производства.

Для получения полной информации о форме паковки необходимо иметь изображения профиля поперечного сечения на концах образующей. Анализ методов контроля формы технических объектов показал, что перспективным направлением контроля намотанных паковок крестовой формы в текстильной промышленности является метод теневой проекции в сочетании с автоматизированными средствами распознавания образов. Для успешной реализации метода проведен теоретический анализ влияния конструктивных параметров преобразователя на погрешности измерений. Установлены обоснованные требования к взаимному расположению элементов преобразователя относительно контролируемого объекта. Получены соотношения, позволяющие прогнозировать параметры устройства, в частности масштаб преобразования.

Проведено обоснование выбора средств оцифровки полученных изображений для последующего автоматизированного распознавания образов.

Keywords: packaging, cross winding, shape control, section shadow projection, transformations, automated recognition.

Ключевые слова: паковка, крестовая намотка, контроль формы, теневое проецирование сечения, преобразования, автоматизированное распознавание.

1. Introduction

The mass nature of the use of packages in modern high-speed technologies for the production of yarn at domestic and foreign enterprises of the textile industry determines the relevance of the chosen topic and subject of research.

One of the most common types of

textile packages are cross-wound packages [1]. This is due to the fact that they meet a wide range of requirements that are placed on them by technologists. These requirements include: compactness, free descent of the thread during processing at subsequent transitions, uniform permeability during processing with solutions, suitability for long-term storage and transportation without loss of quality. The fulfillment of these requirements is ensured by the corresponding properties of cross-wound packages: its shape, structure and stress-strain state of the winding body. The properties of the packages that ensure the fulfillment of technological requirements can be considered the main ones. Maintaining them at the required level is a criterion for choosing rational design parameters of winding mechanisms and winding technological modes. The indicators characterizing these properties are subject to regulation in accordance with the requirements for a particular package.

In this regard, a study aimed at developing a method for controlling the shape of cross-wound packages based on the shadow projection of the section seems relevant.

Optical methods and devices implemented on their basis are non-contact, therefore they do not introduce distortions into the shape of the controlled winding body during measurements. The absence of mechanical contact with the measured body allows measurements to be made on a moving object, which, at a sufficiently high reading and processing speed, allows obtaining high resolution, which means detecting the smallest defects on the winding body.

The simplest of the optical methods is the photographic or shadow method for controlling the geometric dimensions of packages [2, 3], in which, after winding the package, it is photographed together with a scale bar or a shadow silhouette is recorded on the screen. Based on the dimensions on the photograph or screen, taking into account the scale, the actual dimensions are calculated. This method is only suitable for packages that do not have recesses on the end surface, such as roving. Cross coil bobbins, both conical and cylindrical, usually have a smaller width near the cartridge than in the middle part.

To control the non-circularity of the bobbin, Japanese authors proposed a device [4, 5], which projects its image onto a screen, at certain points of which photocells are installed. The signals from the photocells are processed on an electronic computer (computer). As follows from the description, the control of the geometric dimensions in this device is carried out only at some points in this case, since the projection of the bobbin image on the screen is analyzed, information about the shaded areas of the bobbin is lost.

Some better results can be achieved when scanning the investigated area of the winding body with a laser beam, as is done by the bobbin winding control device [6, 7]. The device is designed for non-contact determination of the angle of elevation of the coil. Also, this device, based on the measurements of the angle, can correct it in a given range, which allows you to wind the bobbins of the correct shape. The main disadvantage of the device is that it does not allow to determine winding defects on the formed bobbin, and is designed to control only one parameter-the angle of the turn.

The next stage in the development of devices based on bobbin image scanning is the Beltro-Lis [8, 9] automatic thread package control system, which is manufactured by Barmag AG (Germany). The system detects the presence of broken filaments, stains and dirt, and also controls the contours of the packages. Systems based on scanning the package area under investigation with a laser beam are quite complex and, as a result, expensive, requiring specially trained personnel for their operation.

In the device [10, 11] controlled bobbins move through a control chamber equipped with optical devices for bobbins control. As a result of checking each reel, they are sorted. At the same time, full-fledged reels continue to move on the conveyor carrying them to the place of removal. Reels that have defects are transferred to another conveyor, from which they are removed at a different location. The device allows you to fully and quickly evaluate the quality of packages. However, the principles of image filtering, its transformation and defect detection are not disclosed by the authors.

Traditionally, optical methods are used to control micro-roughness of surfaces in mechanical engineering. The most common are the methods of light section and shadow projection.

2. Materials and methods

The essence of the first method is that a slit in the form of a narrow light strip is projected onto the surface under study at an angle, the image of which is observed through a microscope located at the same angle. This method is applicable for measuring roughness in the range from 0.5 to 50 μm [12]. The unevenness of the profile of the end surfaces of the bobbin and its generatrix are large. Therefore, this method is not suitable for measuring the irregularities of a textile package.

The shadow projection method is designed to measure the roughness of a weakly reflective surface over 40 μm [13, 14]. When measuring by this method, a shutter (Sh) is installed above the controlled surface. At the same time, it cuts off part of the light beam, which is directed to the controlled surface from the illuminator, the optical axis of which is inclined at an angle α to the normal of the controlled surface. The shadow from the curtain, falling on the surface, repeats its profile. The shape and dimensions of the section are judged by the visible image of the shadow in the observation device, the optical axis of which is directed at an angle β to the normal of the controlled surface. Unlike methods that use surface scanning, the shadow projection method does not require a long time to capture the primary image.

3. Results and discussion of the study.

To control package shape defects by the shadow projection method, it is required to determine the height of the profile H of the controlled package section in the normal section (Fig. 1 – the position in space of objects of the surveillance camera of the profile formed by the projection of the edge of the curtain onto a stepped surface). However, when using the section shadow projection method, the camera fixes the profile height h in some inclined section.

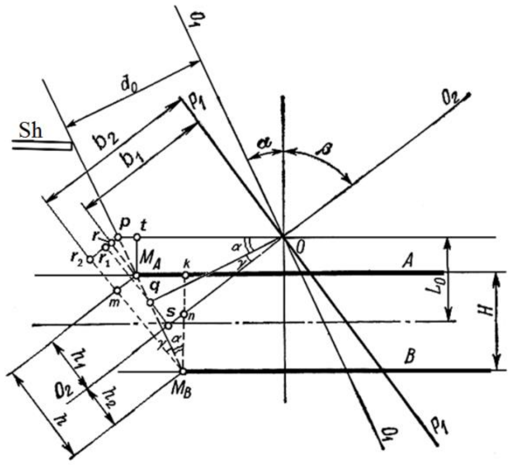

Fig. 1

Between these quantities there is a directly proportional relationship:

$$H = Mh\,, \qquad (1)$$

where M is the profile transformation scale.

It was shown in [1] that the formation of an image in the space of objects of a recording camera occurs in different ways, depending on whether the surface under study is reflective or scattering light. The surface of the winding body is formed by textile threads and their constituent fibers and therefore represents a surface that scatters light.

Let us determine the scale of the profile transformation and the position of the profile image in the space of objects of the recording camera for surfaces that scatter light.

A step height H is shown in fig. 1, formed by scattering surfaces A and B. Points M_A and M_B are located on the border of the intermediate image of the edge of the curtain W projected onto these surfaces. O_1–O_1 and O_2–O_2 optical axes of the illuminator and recording camera. L_0 is the distance of the object point O to the middle line of the profile, P_1 is the object plane of the recording camera.

The distances from the points M_A and M_B to the optical axis O_2-O_2 of the camera are denoted by h_1 and h_2, and the distances from these points to the object plane P_1-P_1 by b_1 and b_2. Let us determine the profile height h recorded by the camera. From the triangle kM_AM_B we have M_AM_B=H/cosα, and from the triangle mM_BM_A we have $h=mM_B=M_AM_B\sin\gamma$, i.e.

$$h = H\frac{\sin\gamma}{\cos\alpha}. \quad (2)$$

Let the angle snM_B=β, then the angle nM_B=900-β. As can be seen from fig. one, $\gamma = mM_Bn - \alpha = 90^0 - \beta - \alpha$.

Then

$$h=H\frac{\sin(\alpha+\beta)}{\cos\alpha}, \quad (3)$$

those the conversion scale without taking into account the optical and digital zoom of the camera is equal to

$$M=\frac{H}{h}=\frac{\cos\alpha}{\sin(\alpha+\beta)}. \quad (4)$$

The position of the shadow image in the camera's field of view is determined by the values h_1 and h_2. They essentially depend on the position of the shutter, which is determined by the value of d0, and the position of the object point O, which is determined by the size of L_0. Figure 1 shows that

$$h_1=sq+qr_1-M_Ar, \quad (5)$$

$$h_2=M_Br_2-sq-qr_1. \quad (6)$$

Let us determine the values of the segments included in (4) and (5)

$$M_At=L_0-\frac{H}{2}. \quad (7)$$

From triangle M_Apt

$$M_Ap=\left(L_0-\frac{H}{2}\right)\frac{1}{\cos\alpha}. \quad (8)$$

From triangle M_Arp

$$M_Ar=\left(L_0-\frac{H}{2}\right)\frac{\cos\gamma}{\cos\alpha}=\left(L_0-\frac{H}{2}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha}. \quad (9)$$

Arguing similarly, we obtain an expression for determining

$$M_Br_2=\left(L_0+\frac{H}{2}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha}. \quad (10)$$

From the triangle qOp $pq=d_0\mathrm{tg}\alpha$,

$$qr_1=pq\cos\gamma=pq\sin(\alpha+\beta). \quad (11)$$

Substituting (11) into the last expression, we obtain

$$qr_1=d_0\mathrm{tg}\alpha\sin(\alpha+\beta). \quad (12)$$

From the triangle qsO

$$qs = d_0\sin\gamma = d_0\cos(\alpha+\beta). \quad (13)$$

Let us substitute the values of segments from (8), (12) and (13) into (5) and obtain an expression for calculating h_1:

$$h_1 = d_0\cos(\alpha+\beta) + d_0 \operatorname{tg}\alpha \sin(\alpha+\beta) - \left(L_0 - \frac{H}{2}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha}. \quad (14)$$

Similarly, after substituting (10), (12), and (13) into (6), we obtain

$$h_2 = \left(L_0 + \frac{H}{2}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha} - d_0 \operatorname{tg}\alpha \sin(\alpha+\beta) - d_0\cos(\alpha+\beta). \quad (15)$$

The value $b=b_2-b_1$ determines the required depth of field of the recording camera. Segments b and h are legs in a trianglemM_B-M_A, therefore, taking into account (3), we can write

$$b = H\frac{\cos(\alpha+\beta)}{\cos\alpha}. \quad (16)$$

The depth of field for lenses used in digital cameras, when shooting from a distance of 0.4 m, is about 10 cm, i.e. much larger than b. Thus, obtaining a sharp image is always guaranteed.

It follows from (3) and (16) that the transformation scale depends on the projection angle α and on the angle α+β between the optical axes of the illuminator and the camera, which is equal. At a constant value of the viewing angle β, the transformation scale increases with the projection angle α. If the projection angles α and observation β are not equal, then the scale of the profile transformation and the segments h_1 and h_2, which determine the position of the profile in the camera's field of view, are different even at $L_0=0$ and $d_0=0$.

In the device for obtaining a primary image, β=0, taking this into account, (3), (14) and (15) will be rewritten in the form

$$h = H \operatorname{tg}\alpha, \quad (17)$$

$$h_1 = d_0\cos\alpha + d_0\operatorname{tg}\alpha\sin\alpha - \left(L_0 - \frac{H}{2}\right)\operatorname{tg}\alpha, \quad (18)$$

$$h_2 = \left(L_0 + \frac{H}{2}\right)\operatorname{tg}\alpha - d_0\operatorname{tg}\alpha\sin\alpha - d_0\cos\alpha. \quad (19)$$

Let us consider the case when the normal to the surface does not lie in the plane passing through the optical axes of the illuminator and camera, but is deflected by an angle φ (Fig. 2 – the position in space of objects of the observation camera of the profile formed by the projection of the edge of the shutter onto a stepped surface inclined to the O_1OO_2 plane). In the field of view of the camera, the image of the surface in the form of a border between light and shadow will be tilted relative to the horizontal position by an angle φ.

Figure 2 shows an image of the boundary between light and shadow in the object plane of the recording camera, formed by scattering surfaces A and B, forming a step of height H. The optical axes of the illuminator and the camera lie in the NN plane. After the planes A and B are rotated by the angle φ, they will take the position A' and B', while the angle between the normal to the surfaces A' and B' and the plane NN will also be equal to φ.

The height of the step now depends on the width of the observed object, in.

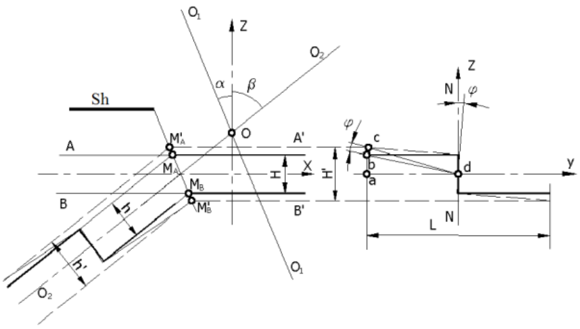

Fig. 2

In our case, on the width of the reel or the thickness of the winding. Let's denote this value as L. Points M_A and M_B, which were at the edges of the observed image of the shadow before the rotation of the object, will move to points M'_A and M'_B, respectively.

The height of the observed shadow will be H'. When the normal to the surfaces A and B is rotated through the angle φ, the point b on the border of the shadow will go to the point c along the circle with the radius bd=cd. Angle bdc=φ and angle

$$bda=\arcsin\frac{H}{\sqrt{H^2+L^2}}. \qquad (20)$$

The distance from point c to the x-axis can be calculated using the formula H'/2=bdsin(adc). Considering that the angle adc=bda+bdc, and the segment bd=$\sqrt{H^2-L^2}$,- after obvious transformations, we finally get:

$$H'=\sqrt{H^2+L^2}\sin\left(\varphi+\arcsin\frac{H}{\sqrt{H^2+L^2}}\right). \qquad (21)$$

Correspondingly, from h to h', the observed magnitude of the shadow will also change. Since the angles α and β remain unchanged, the value of H’ can be converted to h’ using a formula similar to (3):

$$h'=H'\frac{\sin(\alpha+\beta)}{\cos\alpha}. \qquad (22)$$

Substituting the value of H' from (21) we finally obtain

$$h'=\sqrt{H^2+L^2}\sin\left(\phi+\arcsin\frac{H}{\sqrt{H^2+L^2}}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha}. \qquad (23)$$

The formula for calculating the transformation scale will look like:

$$M=\frac{h'}{H}=\sqrt{1+\left(\frac{L}{H}\right)^2}\sin\left(\phi+\arcsin\frac{1}{\sqrt{1+\left(\frac{L}{H}\right)^2}}\right)\frac{\sin(\alpha+\beta)}{\cos\alpha}. \qquad (24)$$

There is a fairly wide range of devices used for image registration. Let us formulate the main requirements that must be met by the recording device, which is part of the hardware complex for controlling the shape of packages:

- the resolution of the device should allow to register individual threads of the most common assortment on the surface of the package;

- the device must have a system for digitizing the image and its direct transmission for processing in a computer;

− the device must provide for the possibility of prompt, sequential shooting of images on a rotating package.

Let's analyze devices that meet these requirements.

− The camera as an image recording device

The resolution of cameras depends on the quality of the photographic materials used. Typically, technical shooting of line art is done on high-resolution film, up to 600 lines/mm. However, the imaging process requires special equipment, consumables, and a wet chemical treatment of films and prints. To process an image on a computer, it must first be digitized using a scanner. Moreover, the quality of the resulting images depends on the quality of the scanner and the scanning mode. The higher the scan quality, the longer the scanning process will take. These features make the use of a camera as a recording device when evaluating the shape of packages impractical.

WEB camera as an image recording device

With the development of global communication channels, WEB-cameras are becoming widespread. The main task when creating these devices, developers put ease of installation and configuration, as well as the amount of information generated by the device. In this regard, any camera has a USB output that connects directly to the computer. It does not require device drivers or any mounting or interface boards. Thus, when using a WEB-camera, it is possible to provide the required direct connection of the recording device with the computer for the transfer of primary data.

The advantage of a WEB-camera is also that it allows you to control the shooting directly using software from a computer. However, the video resolution of such a camera, as a rule, does not exceed 640x480 pixels, which is not enough to display thin threads on the surface of the bobbin under study.

In addition, all USB cameras have a characteristic drawback - a relatively low frame rate associated with the limited data transfer rate via the USB bus (no more than 12 Mbps) [15]. Thus, the WEB-camera does not quite meet the requirements as an image recording device in a hardware complex for controlling the geometric parameters of the winding body.

–MiniDV –video camera as an image recording device.

Conventional analog camcorders have now been replaced by MiniDV standard digital camcorders. Video cameras of this format allow you to record on a special cassette with digital quality. They have many advantages over conventional analog cameras. Although the recording is also carried out on a cassette, but in digital form, this allows you to copy from the original without losing quality. The camera contains automatic white balance, digital effects, computer communication port, shooting resolution 720x576 pixels, frame rate 25 frames per second. Despite the higher resolution compared to WEB-cameras, it is still insufficient for registering individual threads on the surface of the package.

The disadvantage of MiniDV cameras is the connection to the computer via the IEEE 1394 port, which is almost exclusively found in laptops. There are separate expansion cards for the IEEE 1394 port. That is, to work with video, special equipment and software are required, which makes it difficult to use a MiniDV camera as a device for image registration in a device for controlling the geometric parameters of the winding body.

– Digital camera as an image recording device.

Digital cameras (digital cameras) are becoming more and more widespread. Unlike film cameras, digital cameras use a CCD-matrix (charge-coupled device), which consists of light-sensitive elements, to receive the image. Each of its elements is charged in proportion to the intensity of the part of the image that fell on it, and then converted into a digital RGB value. An RGB value is a composite of the levels of the three primary colors red, green, blue, and brightness. Their values vary within 0–255. For example, RGB values for white are 255,255,255 with a brightness value of 240.

The photographic resolution for digital cameras is determined by the resolution of the CCDs used.

The resolution of the matrix is characterized by the number of elements in millions of pixels. So matrices with low resolution consist of 2 million (1600x1200) pixels. With this number of elements, it is possible to obtain an imprint on paper of a standard size of 10x15 cm with a resolution of approximately 10 lines/mm. The visible diameter of cotton yarn with a linear density of 50 tex is 0.25 mm. Thus, the resolution of inexpensive digital cameras is quite sufficient for fixing individual threads on the surface of the package.

It should be noted that almost all digital cameras have the ability to shoot videos. Using the video recording mode of a rotating bobbin will make it possible to obtain an image of the meridional section of its surface at different angles of its rotation. Typically, digital cameras are equipped with a standard

USB port for connecting to a computer. This is a big plus when processing footage, because. will allow direct transfer of the received primary material to a computer for processing.

The obtained formula makes it possible to analyze the errors in the control of the bobbin surface profile by the shadow projection method. The main sources of systematic errors for the chosen measurement method are: the error of the transformation scale and the error caused by the curvature of the shadow edge image.

Thus, the most appropriate image recording device for controlling the geometric parameters of the winding body is a digital camera.

CONCLUSIONS

A formula is obtained for determining the transformation scale when controlling the bobbin shape by the method of shadow projection from the design parameters of the device.

It is shown that the transformation scale is affected not only by the angles between the normal to the bobbin surface and the optical axes of the illuminator and photodetector, but also by the width of the controlled bobbin.

It is substantiated that a digital camera has sufficient resolution, allows you to shoot videos at a frequency of up to 30 frames / s, transfer the footage to a computer via a USB port.

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