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SELECTION OF IMAGE PARAMETERS FOR AUTOMATED DETERMINATION OF TWIST INDICATORS OF SELF-TWISTED YARN

ВЫБОР ПАРАМЕТРОВ ИЗОБРАЖЕНИЯ ДЛЯ АВТОМАТИЗИРОВАННОГО ОПРЕДЕЛЕНИЯ ПОКАЗАТЕЛЕЙ СКРУЧЕННОСТИ САМОКРУЧЕНОЙ ПРЯЖИ

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It is shown that the known indicators used to assess the twist are not suitable for self-twisted yarn. This is due to the peculiarities of its structure. The presence in the yarn of zones with left and right twist, separated by a section of yarn that does not have a twist, requires the use of specific indicators. The following single indicators are proposed: twist unevenness, average length of transition sections, length of twist zones and maximum length of zones with zero twist, relative difference of twists in the zones. It is shown that the existing methods for determining the indicators of yarn twist are ineffective for determining the newly proposed indicators. It is possible to increase the efficiency of their determination by using computer vision methods. The substantiation of the computer analysis of the image has been carried out. An analysis of the structure of the image processing algorithm was carried out. The requirements for the original image and methods for obtaining it are formulated. The main parameters of the original image are resolution, background width, displayed yarn length.

Показано, что известные показатели, используемые для оценки скрученности, непригодны для самокрученой пряжи. Это связано с особенностями ее строения. Наличие в пряже зон с левой и правой круткой, разделенных участком пряжи, не имеющим крутки, требует использования специфических показателей. Предложены следующие одиночные показатели: неровнота по крутке, средняя длина переходных участков, длина зон кручения и максимальная длина зон с нулевой круткой, относительная разница круток в зонах. Показано, что существующие методы определения показателей скрученности пряжи неэффективны для определения вновь предложенных показателей. Повысить эффективность их определения можно за счет ис-

пользования методов компьютерного зрения. Дано обоснование компьютерного анализа изображения. Проведен анализ структуры алгоритма обработки изображения. Сформулированы требования к исходному изображению и методам его получения. Основными параметрами исходного изображения являются разрешение, ширина фона, отображаемая длина пряжи.

Keywords: self-twisted yarn, twist zone, zero zone, twist, twist index, image analysis, computer vision.

Ключевые слова: самокрученая пряжа, зона кручения, нулевая зона, крутка, показатель скрученности, анализ изображения, компьютерное зрение.

The main indicators of yarn twist are twist, twist coefficient and twist angle [1]. These indicators do not allow one to characterize the unevenness of the twist along the length of the yarn or its distribution.

Yarn obtained by self-twisting method differs from yarn of ring and rotor spinning. This difference is characterized by the presence of multidirectional twist zones separated by untwisted sections, zero zones [2, 3]. Therefore, these indicators are not enough to describe the twisting of such a yarn. Due to the fact that the twist zones in self-twisted yarn are separated in space, the twist flow over the length of the yarn is possible only within the lengths of the respective zones. To characterize the uniformity of such yarn, the unevenness of twist in the zones along the length of the yarn is essential - unevenness in twist, which can be characterized by the coefficient of variation

$$H_k = \frac{\sigma_к}{\overline{К}}, \quad (1)$$

where $\overline{K}$ - the average value of the twist in the sample, σk is the mean square deviation of the twist.

It is known that twist has a significant effect on yarn strength [4]. As the twist increases from zero to a certain value called the critical twist, the strength of the yarn increases. With a further increase in twist, the strength of the yarn decreases. The strength of the yarn in the twist zones must be ensured by the appropriate twist value. However, due to the fact that the twist changes continuously along the length of the yarn, it cannot be constant even over the respective zone. Transitional sections are observed at the beginning and end of the twist zone. At the beginning of the zone, the twist gradually increases to the nominal value, and at the end it also gradually decreases. The increase in the length of the transition sections leads to a decrease in the strength of the yarn. Therefore, one of the additional indicators of the twist of a self-twisted yarn should be the average length of the transition sections in which the twist changes.

The twist zones in self-twisted yarns are separated by zones that do not have twist. It is known that the strength of the yarn is formed due to the friction forces that arise between the fibers due to the mutual pressure caused by the twist [4]. Under the action of a tensile load on the yarn, sliding and tearing fibers are distinguished in it. With a decrease in twist, the number of sliding fibers increases and, in fact, not a break occurs, but a pulling apart of the product, which occurs at forces much smaller than the maximum breaking load that occurs during critical twist. The presence of zero twist zones in a self-twisted yarn poses a risk of strength reduction, which can occur when the length of the zero zone approaches a quarter of the average length of the fibers used to make the yarn. To control structural disturbances of this type, it is suggested to introduce an indicator - the length of the twist zones and the maximum length of zones with zero twist.

Self-twisted yarn is formed from two strands, which, during the spinning process, must receive the same twist for equal periods of time. However, due to a malfunction in the operation of one of the twisting devices (clogging of the channel, failure in the air distribution system), one of the strands may receive less twist. This will lead to corkscrew of the yarn in the corresponding area and a decrease in its strength, i.e. to the formation of a defect. A direct consequence of such a defect is a decrease in the strength of the formed yarn and increased breakage. The presence of such yarn defects can be determined by comparing the average twist in the S-twist and Z-twist zones. For such a comparison, you can use the indicator of the relative difference in twists, which is calculated by the formula

$$\Delta_K = \frac{|K_s - K_z|}{K_s + K_z}, \qquad (2)$$

where K_s and K_z–are twist in zones with zones with S- and Z-twist, respectively.

The suggested twist values for self-twisted yarns are specific and cannot be used for yarns and threads of traditional structures. Some of these can be determined using existing methods such as twist measurement with a twist meter or direct visual counting of the number of twists in an area. A ruler can be used to determine the maximum length of twist zones and zero twist zones. The resulting data can be recalculated into the corresponding indicators using formulas (1), (2) or well-known formulas of mathematical statistics. The use of existing methods for determining the newly proposed indicators of yarn twist is laborious and has low accuracy. To determine the “average length of transition sections” indicator, special equipment is needed that will allow you to measure the distance between adjacent turns of strands on yarn. Currently, such equipment is not produced. Thus, the analysis of the existing methods for determining twist indexes showed their unsuitability for determining the indexes proposed for self-twisted yarns.

All the proposed indicators can be obtained by computer processing of the image of self-twisted yarn.

Methods based on computer image processing are widely used for yarn quality analysis [5-9].

The development of a method for computer analysis of the image of self-twisted yarn in order to determine its indicators of twisting refers to the "Computer Vision" technology. Computer vision makes it possible to detect and classify objects. One of the most frequently solved tasks with the help of computer vision is recognition. Recognition includes search and identification of characteristic objects in an image or video stream [5, 6]. An enlarged algorithm for computer image analysis is shown in fig. 1.

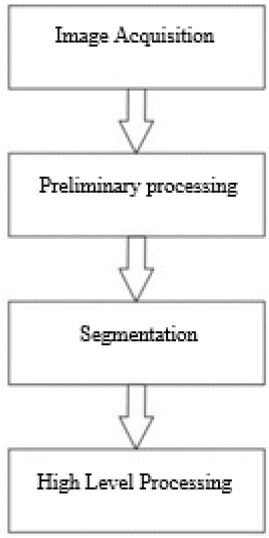

Fig. 1

Let us consider in more detail the content of each of the blocks of this algorithm.

Getting images. The initial data include various types of digital images or a sequence of digital images [7]. Pixel color values can make it possible to determine various physical characteristics of the object under study. Depending on the features of the analyzed object, different requirements are set to its image. These requirements usually include primarily the size and color mode of the image. In some cases, special requirements set to the matrices of the input device.

Preliminary processing. Depending on the method of image analysis, it is necessary to first achieve conformity of the digital image to certain parameters. Spatial noise reduction is most often used as preliminary processing. Its purpose is to remove uninformative pixel color values or improve image clarity [8]. The most common noise reduction methods are: adaptive filtering, methods based on wavelet transforms, principal component analysis, anisotropic diffusion. Preliminary processing also includes image contrast enhancement and scaling.

Segmentation (Identification of details) This stage is the search and selection of certain objects that may contain important information for further analysis [9].

High level processing. This is the last stage in the algorithm, which is essentially image recognition. At this stage, the conditions determined at the stage of segmentation can be checked. Typically, conditions refer to the position, size, or shape of objects in an image. [10] Depending on the method, the found objects can be classified into different categories.

Thus, the following tasks can be identified that are necessary for the development of an automated method for determining the indicators of twisting of self-twisted yarn:

• definition of requirements for a digital image;

• choice of input devices required to obtain a digital image of self-twisted yarn;

• definition of a method for recognition of a digital image of self-twisted yarn;

• development of algorithms for primary processing of digital images;

• development of a segmentation algorithm;

• development of an algorithm for recognizing a digital image of self-twisted yarn;

• development of software for collection and processing of statistical data.

As shown in [11], as a non-destructive method for monitoring yarn twist indicators, the least laborious method is based on the analysis of a digital image of yarn, due to the availability and wide choice of technical means for image acquisition, as well as due to the abundance of tools and algorithms for image processing.

A digital image is a kind of data array obtained as a result of analog-to-digital conversion of the original. The transformation process is called discretization. As a result of encoding, a file is generated that is already directly used by the operating system of a personal computer.

According to the discretization method, digitized images are divided into: raster, vector [12].

A raster is called a matrix of elements, which is a two-dimensional array of data. Each element of the array is a section of the original with an average color index (pixel). The array contains for each pixel its coordinates on the plane and its color.

Raster images [12] are the most commonly used type of digital images. They are obtained either using a scanner or using digital cameras. As a sensitive element in these devices, a CCD matrix is used, which is an analog integrated circuit made of photodiodes. Unlike image scanning, where the original is read directly by the CCD, when shooting with a digital camera, the original is projected onto the CCD through the lens.

In discretization the amount of information about the original is averaged, so some of the information is lost. This is the main disadvantage of raster images and makes it impossible to scale them while maintaining the quality and volume of information. This is clearly seen in the enlarged image of the self-twisted yarn section shown in Fig. 2.

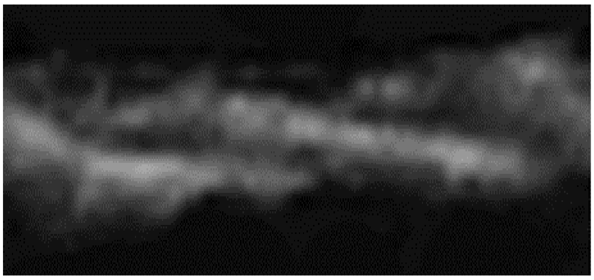

Fig. 2

The next type of digital images is called vector [12]. The vector image is based on the use of geometric objects and is essentially an image of mathematical functions. The most common and simplest vector image objects are the vector and the Bezier curve.

Compared to raster images, vector images have the following advantages:

• independence of the length of the descriptive part from the actual size of the object;

• the possibility of an infinite increase in the object;

• parameterization of objects. Any of the parameters of the object can be changed without loss of quality.

The use of vector images in non-destructive methods for controlling the geometric parameters of yarn could maximally simplify the algorithm of the method itself, since image, in fact, is a set of mathematical functions. However, along with the advantages, there are also disadvantages. The key disadvantage of a vector image is the complexity of obtaining it. A vector digital image is obtained either by manual or automatic tracing. Manual tracing consists in specifying by a person all the vector objects that make up the original image. In fact, the case is a stroke of the contours in the image using a set of tools. Automatic tracing implies software image processing by a number of algorithms. However, these algorithms are not perfect and their application leads to possible loss of information, as well as an unnecessarily large number of primitives and curves for describing any object (Fig. 3).

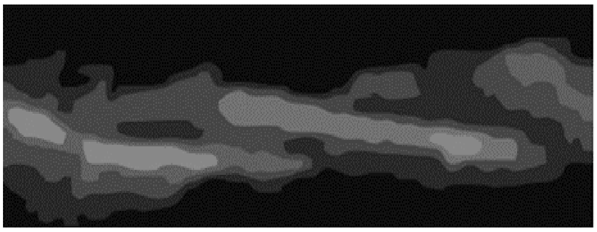

Fig.3

Despite a number of advantages of vector digital images, raster digital images are most suitable for automated methods of controlling the geometric parameters of yarn. This is due to the simplicity of their acquisition and the abundance of technical means for their generation. The disadvantages associated with the impossibility of scaling without loss of quality can be minimized by careful selection of technical means for obtaining an image.

For an automated method of determining the indicators of twisting of self-twisted yarn, it is necessary to set a number of conditions that a digital raster image must meet.

The main conditions are the following:

- image resolution. The cross section of the yarn in the image must be described by at least 10 pixels. Description by a smaller number of pixels makes it impossible to recognize due to the small amount of information about the sample.

- to reduce the time for processing, it is necessary to reduce the proportion of the background in the image. The width of the background should not be more than 5 sections of the analyzed yarn. When developing the hardware-software system, it was accepted as 5 mm.

- the length of the sample displayed on the image should be at least 3 m. The latter is due to the fact that the analysis of geometric parameters is supposed to be carried out for self-twisted yarn, which has sections with twists of different directions, separated by untwisted sections. The maximum length of the twisting period for yarn formed on PC-225SHG machines can be up to 240 mm. Taking into account the fact that the software and hardware complex is supposed to be used, including for research purposes, the possible maximum length of the twist period was increased to 290 mm. To obtain reliable data, it is necessary to have at least 10 repetitions on one yarn sample, which means that the image length must be 2900 mm. Considering that imaging may not start from the beginning of the corresponding twist zone, 100 mm must be added, i.e. The length of the image must be 3 m.

Taking into account the above requirements for the digital image of self-twisted yarn, the problem arises of choosing a device for obtaining the image itself. The previously developed automated method for determining yarn twist [11] used a flatbed scanner.

To determine the twist, the thread under study was wound with a reel on a black-painted board. After that, the resulting sample was scanned by a flatbed scanner. As a result, the digital image presented many pieces of threads 25 cm long. Thus, the absence of a continuous image does not allow the use of this method for the analysis of self-twisted yarn [13 - 16].

The possibility of scanning the reel from both sides and then matching the corresponding areas of the yarn image is also not a solution to the problem. The process of combining image sections is quite laborious, in addition, it is practically not amenable to automation, which is associated with errors in the yarn laying step. In addition, even when combining images from two parts of the reel, it will not be possible to obtain a continuous image of the yarn, because sections of yarn laid on the side surfaces of the board do not participate in its formation. Thus, a flatbed scanner is not the best option when choosing a digital imaging device for the method being developed.

An acceptable solution to this problem is the use of a vision system using television cameras intended for scientific equipment. In particular, the VIDEOSCAN family of cameras [17]. The system should include a device for drawing the yarn under study, which will ensure its positioning in the transverse direction, which will reduce the field of view of the camera in the corresponding direction to the required value of 5 mm. The length of the frame in the longitudinal direction is theoretically unlimited.

The VIDEOSKAN-2-205 camera [18, 19] allows macro photography of objects with a resolution of 1390 × 1040 pixels at a pixel size of 4.65 × 4.65 μm. The camera is fully synchronized with a personal computer and is equipped with a USB interface. Image acquisition is in real time - the average frame rate is 7.7 frames / s. In this way, high-quality images of long yarn sections can be obtained. Image acquisition control can be hardware-synchronized upon receipt of an external pulse. For example, from an external drive. Includes program development kit (SDK) with descriptions. The SDK allows the user to develop their own image capture software.

The disadvantages of this equipment can be attributed only to its high cost.

The novelty of the results obtained on the basis of the performed work is the substantiation of requirements for the equipment for obtaining the primary image of yarn, allowing to provide its sufficient informativeness.

C O N C L U S I O N S

1. Indicators have been proposed that allow assessing the twist of a twisted yarn, such as unevenness in twist, the average length of the transition sections, the length of the twist zones and the maximum length of the zones with zero twist, the relative difference in twists in strands.

2. It has been established that the full range of proposed indicators can be obtained by analyzing the digitized image of yarn.

3. The parameters of the device for obtaining the primary image of the yarn, such as the minimum length and width of the frame, the camera resolution, the frequency of shooting, and the presentation of the image, are substantiated.

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