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Technical and Technological Aspects of Assessing the Quality Characteristics of Thread Compounds in Products from Fibrous Materials

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Abstract. The object of the study is thread connections of garments parts, and the subject is an express instrumental method and technical support for determining damage to threads by the needle of a sewing machine when sewing garments. The purpose of study is to develop technological and technical support for the process of researching the quality of the sewing stitch based on the development of an express method for determining damage to threads in a material when a needle is punctured during sewing, which increases the objectivity and accuracy of the estimated information. As a result of the study, a method for assessing the damage to a material by a needle during sewing was developed and a patentable technical device for its implementation is proposed. The developed method is based on the use of neural networks elements and provides for the control of visible and invisible needle cut in the process of sewing the product. The technical solution of the device provides the ability to visualize the sewing stitch through the use of optoelectronic means and the formation of an electronic database of material properties on-line. The developed method belongs to the class of express methods, provides new technological possibilities for studying the quality of thread compounds and increasing the objectivity of evaluating the characteristics under study. Testing of the proposed technological and technical solutions showed the necessary efficiency and the possibility of practical application of the developed method.

1. Introduction

Conducting operational quality control of technological operations directly in the process of their implementation provides the opportunity to take timely corrective actions, including those of a technical nature, which ensure the prevention of defects in the product. This approach is consistent with the basic principles of quality management. However, the implementation of this approach is possible only with the appropriate technical and technological support of the control procedure directly in the process of performing technological operations. All of the above is true in relation to the production of any type of product, including clothing manufacture. In modern practice of sewing production, the quality of sewing operations is evaluated only at the stages of inter-operational or final technological control [1-3]. This is primarily due to the fact that there are no necessary methods and



technical means for intraoperative quality control of the resulting sewing stitch. In this regard, corrective measures aimed at improving the operation of technological equipment and preventing the appearance of unwanted defects in sewing stitches are carried out only after defects on the products occur. This leads to additional costs of all types of production resources, as it requires either rework of products or their recognition as inappropriate technical requirements.

2. Relevance and scientific significance of the issue

As known, the quality of the sewing stitch is assessed by the compliance of the parameters of the stitch with the established requirements and the degree of damage to the threads of the material when punched with a needle, i.e. needle cutting. At the same time, one of the main indicators of the quality of sewing seams is the needle cutting the material, the indicators of which are visible and invisible needle cut. In the manufacture of garments, primarily from knitted fabrics, an assessment of needle cutting degree during sewing is important from two points of view: assessing the quality of the stitch and the product service life.

In addition, in the process of sewing products, due to deficiencies in the adjustment of equipment, other defects in sewing stitches may occur, for example skipping stitches or distorting the stitch line, which, like cutting, reduces the quality of the finished product.

The analysis of methods and technical means [4-6] showed that at present, mainly visual assessment is used to assess the quality of stitches. From the practice of studying the properties of materials it is known that visual assessment is characterized by a high level of subjectivity and, as a rule, a low level of accuracy. During the analysis, some disadvantages of methods and devices for assessing the quality of stitches used in the practical activities of Russian sewing enterprises were identified. Among these shortcomings, the following should be noted: according to technological characteristics, they cannot be attributed to the class of express methods; the test methodology requires a significant number of additional devices to visualize the quality parameters of the stitch; methods are characterized by low technological productivity of the procedure and subjectivity of the assessment; the methods do not allow to control the quality of the stitch directly during sewing and to form an electronic database in an automated mode. The need to address the aforementioned shortcomings of the practiced methods determines the relevance and scientific value of developing a new instrumental express method for evaluating the quality of a stitch that meets the requirements of manufacturability, objectivity, and, as a result, the accuracy of the assessment.

The purpose of the research is to develop technological and technical support for the process of researching the quality of the sewing stitch based on the development of an express method for determining damage to threads in the material when a needle is punctured during sewing, which improves the objectivity and accuracy of the estimated information. The object of the study is thread compounds of parts of garments, and the subject is an express instrumental method and technical support for the process of studying damage to threads by a needle of a sewing machine when sewing garments. To achieve this goal, elements of the theory of neural networks and traditional approaches to the development of methods and devices for studying the properties of materials were used. Testing of the developed express method and technical device was carried out on the basis of comparing the results of assessing the quality of thread stitching when sewing products from fibrous materials using the research methods developed and practiced now.

3. Theoretical part

When assessing the quality of thread stitches, the sizes of the objects under study are in the millimeter range, and in the case of assessing the degree of damage to the threads when punctured with a needle, their size is about 0.1-0.2 mm or less, which requires additional visualization during the control procedure. Real-time monitoring of the damage to sewing thread assemblies is virtually impossible without the use of digital visual information processing methods. In the study of various approaches to the structure analysis of small research objects, methods for direct observations of the material microstructure by means of optoelectronic microscopy were of particular interest [7-12]. The

possibility of using these methods in the structural analysis of highly elastic textile materials was shown in [13]. However, the described technique involves obtaining optoelectronic images in manual mode, and it is proposed to use fairly sophisticated technological equipment to process the objects under study.

Thus, the analysis showed that the existing methods and methods for digital processing of visual information are not universal. They require fine-tuning of optical equipment and the development of complex processing algorithms. One of the objectives of this work is to show the possibility of using available equipment for these purposes that does not require precision settings and strict requirements for its installation. An analysis of the technical aspects of solving the problem made it possible to establish that the use of a web camera due to the high resolution of the image during photography makes it possible to achieve high resolution and quality of localized fragments. In addition, in each cycle of forming a sewing stitch and its element (stitch), it is possible to record an image with the required frequency.

However, a theoretically difficult question remains the solution to the problem of identifying the quality of the stitches to be laid by means of photography. When using digital photography as a tool for solving such a difficult formalized problem, a convolutional neural network (CNN) [14], trained accordingly, can be used in principle. The idea of using CNN is to alternate convolutional layers (C-layers), subsampling layers (S-layers) and the presence of fully connected (F-layers) layers at the output.

To train the neural network, that is, to determine the quality of damage recognition, we used the function of the mean square error [15] of the form:

$$E^p = \frac{1}{2} [D^p - O(I^p, W)]^2 \leq \varepsilon_{per} , \quad (1)$$

where E^p — recognition error for p - th learning couples, D^p — desired network output, $O(I^p, W)$ — network output depending on p -th input and weighting factors W , which includes convolution kernels, displacements, weighting factors S - and F - layers, ε_{per} - permissible display error.

The task of training a neural network is to configure the weights W so that for any training pair (I^p , D^p) they gave a minimum error E^p . To calculate the error for the entire training sample, their arithmetic average is taken.

To minimize the error function E^p it is advisable to use gradient methods with subsequent processing by a human-machine interface according to the Levenberg-Marquardt method[16].

Using the considered approach to assessing the quality of lines allows you to conduct research directly in the process of performing a technological operation with the processing of the estimated information in an automated mode.

4. Results of the study and their discussion

Based on the results of a theoretical study, an express method was developed and practically tested to assess the visible and invisible needle cut of materials as characteristics of the degree of damage to their structural elements when laying stitch of various kinds using elements of a neural network. In [17-19], the kinematic diagram of a device providing the implementation of the developed method is considered, and the principle of its operation is considered in detail.

The device is made in the form of a prefix to the sewing machine, which includes the optoelectronic module as the main element, including a web camera and designed to receive high quality optoelectronic images of control objects. Processing optoelectronic images of control objects, calculation of the desired characteristics and the formation of an electronic database is carried out through the system unit of a personal computer, through the interface unit connected to the webcam of the optoelectronic module. Synchronization of recording the formation of a stitch, and, accordingly, the puncture of materials with a needle at each working stroke of the thread feeder of the sewing machine, is provided by optoelectronic elements, which are also part of the optoelectronic module.

The basis of artificial intelligence is the symbiosis of a predetermined algorithm (the program itself with graphical interface elements) and a specially trained neural network. Figure 1 shows a block diagram of a sensible module designed for processing optoelectronic images of sewing stitch elements.

Fig. 2 gives an example of a shuttle stitch optoelectronic image obtained using the developed device and an analytical interface with image processing of sewing stitches in program mode.

The visibly damaged stitch element (Fig. 2) is circled by the operator on the monitor using the graphical interface. After selection, the type and color of damage are automatically recognized. Since a pixel is used as an informative parameter for displaying all objects of quality control of a sewing stitch, it is possible to identify a damaged area of material not only as a cut (a areas in which the thread is completely destroyed), but also as a partial (incomplete) damage to the material thread. Moreover, this procedure can be performed not only in the nominal, but also in a variable mode of materials stitching.

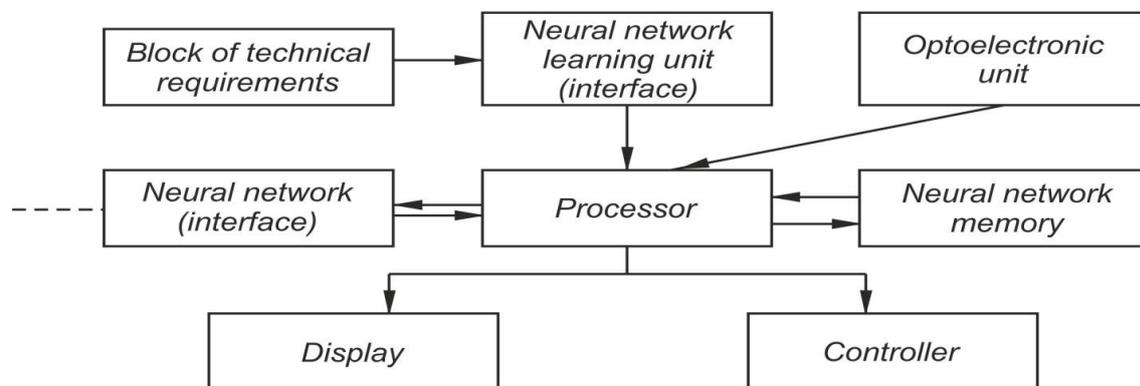


Figure 1. Block diagram of sensible module elements.

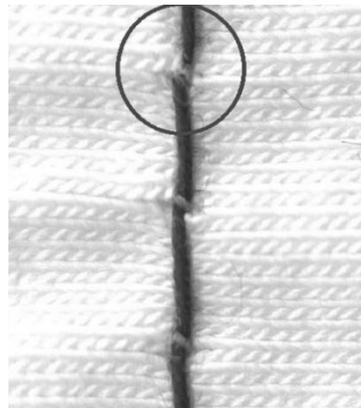


Figure 2. Optoelectronic image of the damage element to the threads during the formation of the stitch.

When assessing the penetrability of materials, the personal computer processor, using a special program, calculates the number of cuts and areas of partial damage to the material threads and determines the required parameters. At the same time, information about the cut or partial damage to the material threads is distributed into two information registers of the processor according to the conditions for recognizing damage nature displays when executing a stitch based on the algorithm of functioning of neural networks [14-16].

When a predetermined stitch length is reached, a command to disable the reception of information is generated and the processor calculates the visible and invisible needle cut of the material as an indicator for the degree of damage to its threads in a given area of the sewing stitch. Such a technique significantly reduces the time it takes to determine the required parameters for percussion, which allows us to attribute the developed research approach to the class of intelligent methods, and also increases the information content and productivity of the measuring procedure.

Due to the fact that the technical part of the device is designed as a separate and stand-alone module, in the practice of sewing production it can be used to study the quality of stitching and the degree of needle cut of textile materials when sewing products on various types of sewing machines.

In the course of research, a human-machine interface was developed for computer technology for assessing damage, a characteristic of which is given in [20]. Using the developed devices and information and software, an experimental research program was carried out, the results of which are shown in the table.

Table 1. The results of the materials needle cut experimental studies using elements of artificial intelligence (fragment).

Expe- rience number	Material	Number of stitches/ stitch length, [mm]	Weave, composition of raw materials	The linear density of the thread, tex	The surface density of the material, [g / m ²]	Material thickness, [mm]	The number of damages identified by the experimantally/ visually
1	The knit wear	100/2	Knitwear weave, Cotton 100%	22	140	0.7	1/1
2			Combined weave, Vis 97% PU 3%	34	120	0.6	1/1
4	The cloth	100/2	Linen weave, PE , 100%	26	210	0.9	1/0
5			Twill weave, Cotton 100%	21	150	1	1/1

Note. The following conventions are accepted in the table: Vis – viscose; PU – polyurethane; PE - polyester

5. Conclusion

Thus, the analysis of the data obtained during the testing of the express method, developed for assessing damage to threads when sewing stitches and devices for its implementation, allowed us to draw a number of important conclusions and determine areas for further research:

- firstly, real-time monitoring of the damage to the threads of stitches of the sewing stitch is practically difficult without the use of digital methods for processing visual information;

- secondly, according to the condition (criterion) of the contrast of the recognizable stitch display laid by a needle on a sample of material, there is a fundamental possibility of processing the identified information in program mode based on the use of technology for constructing neural circuits and

recording display in different electronic processor registers, which allows you to quickly generate electronic database of damage to the threads and make management decisions during the process;

- thirdly, the functioning of the principle of identification of damage to the thread at the stages of research requires technological adjustment according to the values of pixels received from the webcam;

- fourthly, the theoretical solution to the problem of transforming and identifying the quality of the stitches to be sewn using artificial intelligence elements and through photography, which requires additional research based on the use of a neural network system, remains a theoretically difficult question.

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