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Методы снижения уровня шума и вибрации в швейных машинах

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Аннотация. В данной статье проанализированы силы, действующие на звенья швейной машины, и, следовательно, вибрации, возникающие в швейной машине, отказы, возникающие в результате этих вибраций, а также неисправности и влияние этих неисправностей на качество шитья. Разработана динамическая модель механизма упругого элемента скользящего амортизатора и решены теоретические задачи анализа характера и параметров напряжений механизма упругого элемента скользящего амортизатора на основе экспериментального метода.

Ключевые слова: швейная машина, вибрация, эластичная подушка, амортизатор, пружина, частота, пневмоцилиндр, скорость, платформа, звено, кинематическая пара.

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Methods of reducing the vibration and noise level in sewing machines

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Abstract. The article covers the forces acting on the sewing machine links and the vibrations in the sewing machine caused by these forces, the failures and the faults caused by these vibrations, and the impact of these faults on the sewing quality. A dynamic model of the flexible shock absorber mechanism with elastic elements has been developed and theoretical problems have been solved, the nature and parameters of the stresses of the flexible shock absorber mechanism with elastic elements have been determined.

Keywords: sewing machine, vibration, elastic cushion, shock absorber, spring, frequency, pneumatic cylinder, speed, platform, link, kinematic pair.

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INTRODUCTION

Scientific research aimed at the production of science-based methods and technologies aimed at identifying important factors influencing technological processes in the production of garments in the world are carried out. In this regard, particular attention is paid to the creation of new types of garments, a rational design of sewing machines, taking into account high-quality competitive, ergonomic requirements, the development of interrelationships of technological parameters, multiplication and development of types of sewing machines, maintaining a state of stability based on scientific laws improvement of the system of quality indicators for the manufacturing sector.

At present, machines and mechanisms consisting of advanced rotating, vibrating and complex moving parts are widely used in the light industry. Such mechanisms are widely used in periodic and continuous motion machines, and require the use of vibration dampers, as they are mainly considered vibration-active. However, while vibration dampers protect the machine from dynamic stresses acting on the foundation, they do not change the nature and value of the stresses in the machine itself. This has a negative impact on the technological process. Increasing the speed of the mechanism and working parts to increase the productivity of the machine leads to an increase in the dynamic and inertial stresses in the links. Such stresses have a negative impact on the reduction of service life of the engine links and kinematic pairs, the volume and quality of the product. If the reduction of inertial stresses in the kinematic pairs of the mechanism is achieved, it is possible to increase the speed of the mechanism, as well as reduce operating costs. Based on the above, one of the urgent tasks is to create new designs of machines and mechanisms of the garment industry, which will increase the speed of machines and reduce dynamic stresses.

In recent years, scientists and designers have developed new efficient technologies for sewing materials of various characteristics, new types of shuttles and chain saws, as well as high-efficiency equipment for sewing production. V.N. Gorbaruk, S.I. Rusakov, A.I. Komissarov, N.M. Archilov, V.L. Polukhin, L.B. Reybach, O. Suziki, V.B. Sherbekov and other foreign scientists made research on improvement of sewing machines.

Z. Tadjibaev, K. Djemanikulov, A. Juraev, S. Baubekov, K.T. Olimov, S.Sh. Tashpulatov, D.S. Mansurova, I.M. Rakhmonov, Sh.H. Behbudov and others made a huge contribution for the development of sewing production methods and technology in Central Asia. However, research in the field of creating new mechanisms with elastic elements that provide high-quality sewing, reduce stresses in links and kinematic pairs, and high-efficiency working bodies are not enough.

MATRIALS AND METHODS

The vibration and noise reduction device on the sewing machine is located between the machine table and the platform and consists of flexible elements. One is firmly attached to the table and platform (Figure 1) and the others are attached to the platform. However, the stable operation of this device is not enough and it is not possible to automatically adjust the stiffness of the shock absorbers, depending on the process of switching the machine from one mode to another and the operation of the main shaft. The purpose of the invention is to increase the stable operation of the machine. The intended purpose is that the device on which the machine is placed is located between the table and the platform and consists of flexible elements, one of which is connected to the table and platform and the other is connected to the platform, the machine head the shaft has a speed sensor, power cylinders and a signal amplifier, in which the sensor is directly connected to the power cylinder rods and signal amplifiers, self-adjusting flexible shock absorbers platform. The flexible shock absorber is a pneumatic cylinder in the form of a rotating coil or plate spring, made of rubber-like material, like an inflatable cushion [1].

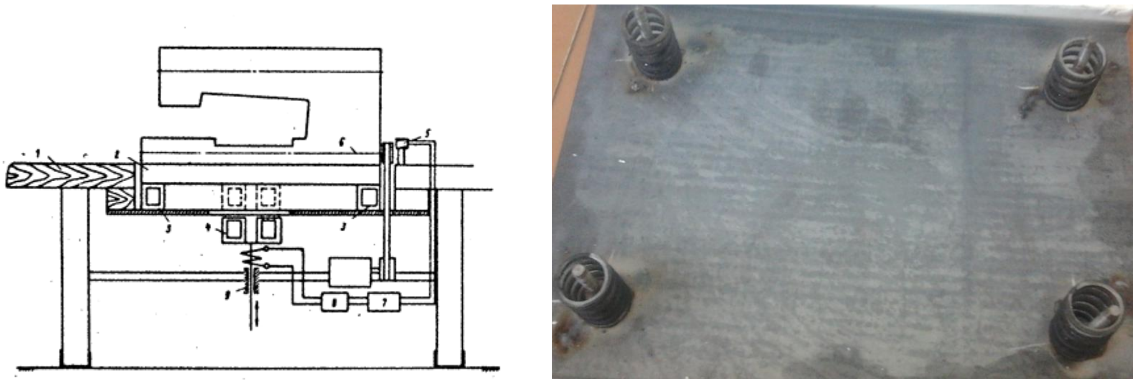

Figure 1. The general view of the equipment.

The device is connected to the sewing machine located between table 1 and platform 2, with flexible shock absorbers 3 and 4, shock absorbers 3 to table 1 and platform 2 and shock absorber 4 to platform 2. Device machine shaft 6 mounted speed sensor 5, platform 2 amplifier 7 and executive element 8, 5 power cylinders 9 transmitting amplified signals from the sensor 9, where the sensor 5 direct signal amplifier 7, power cylinders 9 their corresponding elastic shock absorber 4, which in turn is connected to platform 2. The shock absorbers 3 and 4 are made in the form of inflatable pads 10 (Figure 4) and are made of rubber-like material. Shock absorbers 3 and 4 can be made in the form of rotating spiral windings or plate springs 12, connecting curved support surface 13 (Figure 3). The device can contain a number of flexible elements (Figure 2, positions 3 and 4) and power cylinders 9. The device works as follows: The sewing machine head shaft 6 has its own number of revolutions, the sewing machine unit at the value of the intermediate resonant frequency, the sensor 5 rotates, the amplifier 7 enters, the actuator 8 is activated, which pneumatic cylinders 9 in turn are intermediate flexible shock absorbers interacting with the sewing machine adopts the hardness value given to the platform support. When switching to resonant frequency, when the sensor 5 rotates, the power cylinders 9, the shock absorber 3 and 4 come out of contact. The machine relies on a shock absorber with a stiffness of 0.6-10 Nm, which ensures that 5 times the minimum voltage is transmitted to the 1V table, the elements are mounted on a support on a 4-line surface 13, the plate spring 12 2a bends due to the force applied from the platform 2 to the cantilever part. In this case, the profile of the curved surface 13 is chosen so that the sum of the stiffness of the shock absorbers, according to the nonlinear law, must change according to the change in frequency resonance of the sewing machine unit. At that time, the shock absorbers 4 were made in the form of rubber-like pads, and when the interaction with the power cylinders 9 reached the intermediate frequency resonance, the hardness of the cushion 10 caused by rubbery or elastic materials changed, ie inflatable pads the system eliminates the connection between the power cylinders, pads 10 and the table, due to the elimination of the resonance phenomenon. If, when the pneumatic cylinders of the flexible elements (Figure 5) reach an intermediate frequency resonance of 9, the platform 2 after the interaction of the pneumatic cylinders, the sensor 5, the head shaft 6 rotates, and the actuating element 8 to the pneumatic cylinders 9, the pneumatic cylinder 11 to the platform separates the connection from 2. Therefore, the invention allows significantly reducing the vibration and noise level on sewing machines in the danger zone for operators. The vibrating speed of the sewing machine industrial table is reduced in 10-12 times, while the working speed of the main shaft is reduced in all ranges [2].

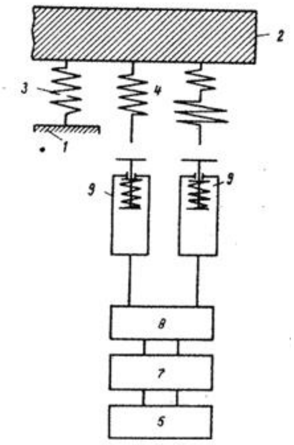

Figure 2. The scheme of rectification the stiffness of the shock absorbers.

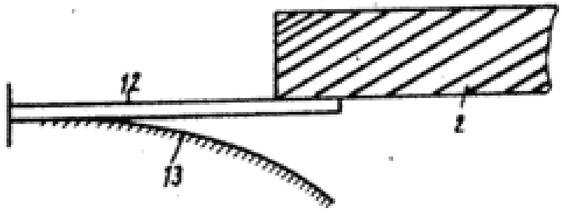

Figure 3. Machine mounting on non-linear flexible shock absorbers.

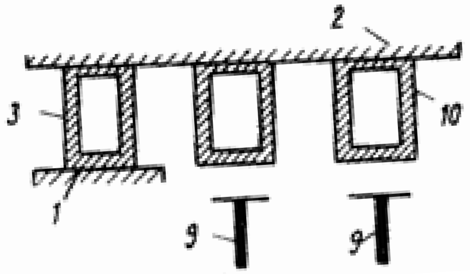

Figure 4. Machine mounting on elastic cushions.

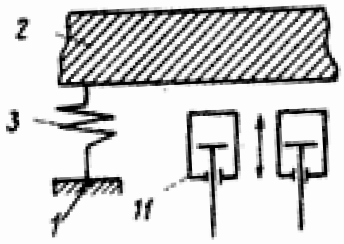

Figure 5. Machine mounting on pneumatic cylinders.

The vibration and noise reduction device on the sewing machine is located between the machine table and the platform and consists of flexible elements. One of them is rigidly connected to the table and platform, and the other is attached to the platform, which differs in that in order to increase the stability of the machine, the speed shaft of the machine is mounted on platform with a speed sensor; the sensor is directly connected to the platform 2 via a mutually compatible flexible shock absorber with signal amplifiers and power cylinders.

RESULTS

We find the number of experiments using the following formula.

$$N = Pk,$$

where N is the number of experiments; R is the number of equations, k is the number of factors. Coefficients k = 3, R = 2.

In the planning matrix, two levels (+1; -1) for the factor change show only the characters, i.e. the coded values of the factors. The process of factor coding is carried out by moving the coordinate head to the zero point with a linear change in the spatial factor coordinates, and the selection of the scale of the factor change on the axis of the unit axis using these ratios [3,4]:

$$X_i = \frac{C_i - C_{oi}}{\varepsilon}$$

where, Xi are coded factors (unlimited value); Si, Coi are natural values of factors (its corresponding value in the plan at zero); ε is natural value of the factor change interval.

We consider the mathematical effect of the object under investigation as a linear model. It is used to calculate the total motion by the vertical ascent method. The validity of the model is checked by statistical analysis of the experimental results.

We approximate the unknown response function equal to the first degree, the coefficient of which is evaluated by the results of the experiment:

$$Y = \beta_0 + \sum_{i}^{k} \beta_i x_i + \sum_{i,j=1}^{k} \beta_{ij} X_i X_j$$

When constructing a linear model, we find the numerical value of the regression equation and the linear coefficient.

$$Y = b_0 + \sum_{1}^{k} b_i x_i + \sum_{1}^{n} X_i X_j$$

According to the planning matrix, eight tests on the triple surface were performed (Table 1).

The conduct of the experiment depends on the precise control of all received incoming and outgoing and parameters and their consistency. Failure to follow these specifications can lead to major errors in modeling. Therefore, preliminary experiments were performed to detect changes in the degree of reinforcement of the factors and to assess the stability of the processes in the test.

Table 1. Matrix plan.

Experiment No.	X_0	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$X_1X_2X_3$	$\overline{Y}_1$
1	+	+	–	–	+	–	–	+	6.6333
2	+	–	–	–	–	+	–	–	7.6
3	+	+	+	–	–	–	+	–	5.8333
4	+	–	+	–	+	+	+	+	7.7667
5	+	+	–	+	+	+	+	–	5.9333
6	+	–	–	+	–	–	+	+	8.5667
7	+	+	+	+	–	+	–	+	7.0333
8	+	–	+	+	+	–	–	–	8.2

After the experiment, the numerical value of the linear coefficient of the regression equation is found [5].

Optimization criteria:

$\overline{Y}_1$ is productivity of the sewing machine.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{23}X_2X_3 + b_{123}X_1X_2X_3$$

where, bi is regression coefficient; Xiu is the factor value in u – N test; Yu is the arithmetic mean of the tests; N is the number of tests in the matrix. As a result of the experiment, the tests found 8 values of the optimization criterion, each of which has three surfaces.   is the arithmetic mean productivity of the sewing machine.

$$\overline{Y'}_1 = 7.19 - 0.82X_1 + 0.008X_2 + 0.248X_3 - 0.066X_1X_2 - 0.093X_1X_3 -$$
$$- 0.176\,X_2X_3 + 0.298X_1\,X_2\,X_3.$$

The derived equation is not the final version of the mathematical model, and it has been tested for the correctness of the model and the correctness of the regression coefficients according to the Student and Fisher criteria.

In order to estimate that the optimization parameters exceed the average value, the processing variance should be calculated by the following formula:

$$\overline{Y'}_1 = 7.19 - 0.82X_1 + 0.008X_2 + 0.248X_3 - 0.066X_1X_2 - 0.093X_1X_3 -$$

$$- 0.176\, X_2X_3 + 0.298X_1\, X_2\, X_3;$$

$$S^2_{\{y\}} = \frac{\sum_1^N (Y_{uj} - \overline{Y}_u)^2}{N},$$

where, N is the number of tests; Yuj is the result of a separate observation; Yu is the arithmetic mean of the criterion (test result). For all values in the matrix, the value is added to the given numbers. The value of the maximum variance is determined, based on the law of distribution of the ratio of the required maximum variance to the sum of all variances. The Cochrane criterion is used to ensure uniformity of variance, i.e.

$$G_P = \frac{S^2_{y\max}}{\sum_1^N S^2_y}$$

where, GP is Cochrane criterion, Symax is the largest variance; $\sum_1^N S^2_y$ is the sum of all variances.

For this, the equation q = 5 must be given; determining the numbers of freeness V1.B = n-5 and V1.B = N=8, and then calculated according to the above formula for the freeness. The values of the Cochrane criterion should be compared with those in the table. At GP< GCR, the variance is the same and the process is reversible.

The values of the regression coefficients are determined by the following formula according to the Student's criterion [6]:

$$t_i = \frac{|b_i|}{S_i\{b_i\}}$$

where, ti is Student's criterion; |bi| are calculated regression coefficients; $S_i\{b_i\}$ is standard deviation of the variance of the regression coefficient.

The standard deviation of the variance of the regression coefficient is determined by the following formula:

$$S\{b_i\} = \sqrt{\frac{S^2\{Y\}}{N \cdot n}}$$

where, S2(Y) is variance of optimization parameters; N is the total number of different points in the planning matrix; n is the number of parallel observations at each point.

The variance of the optimization parameters is determined by the following formula:

$$S^2(Y) = \sum_{u=1}^{N} S_u^2$$

where: $\sum_{u=1}^{N} S_u^2$ is the sum of all variances.

The hypothesis of the significance of the coefficient is then tested. In this case, the equation with the value g = 5 is given and the number of freeness is determined:

V3.N = N(n-1) = 8(3-1) = 16. Then the critical value of tkr found in the table according to the degrees of freedom is compared with the calculated values of the Student's criterion.

If ti> tkr, then the coefficient bi is significant, otherwise bi is not statistically significant, i.e. b = 0.

The adequacy of the model is determined by the following formula:

$$S_{a\partial}^2 = \frac{n}{N-M} \cdot \sum_{u=1}^{N} \{\overline{Y}_u - Y_u\}^2 .$$

In addition to the known: is mathematical expectation of optimization parameters calculated by the regression equation; M is the number of significant coefficients. For all points in the matrix plan, it is determined by the regression equation. This difference $\{\overline{Y}_u - Y_u\}$ is squared for all points of the plan and the results are added.

To test the hypothesis of model adequacy, it is necessary to know the significance of the equation g = 5% by determining the numbers of freeness $V_{1ad}=N(n-1)$ and $V_{2ad} = N(n-1)$, then according to the formula chosen according to the freeness generated, calculated F_{cr} should be compared with the value of the with Fisher criterion Fr in the table. When $Fr< F_{cr}$, the model is considered adequate.

The results of testing the adequacy of the model to study the calculated values and optimization parameters for all points in the matrix plan are given in table 2.

The verification of the calculated value ti of the matrix plan for all points and the significance of the regression coefficient for the optimized parameters under test is given in table 2.

Table 2. Verification the significance of the bi regression coefficient.

t_i	$t_{(b_0)}$	$t_{(b_1)}$	$t_{(b_2)}$	$t_{(b_3)}$	$t_{(b_{1,2})}$	$t_{(b_{1,3})}$
Y_1	7.1958	0.826	0.0075	0.248	0.066	0.0937
$t_{(b_{2,3})}$	$t_{(1,2,3)}$	$S^2_{\{\overline{Y}\}}$	$S^2_{\{b_i\}}$	$S_{\{b_i\}}$	t_{kr}	Significant coefficients
0.176	0.298	0.028	0.0012	0.034	3.84	$b_0 \cdot b_2 \cdot b_3 \cdot b_1 b_2 b_3$

The mathematical model of the tested parameters, taking into account the significant coefficients, can be expressed in accordance with the methodology as follows [7].

$$\overline{Y'}_1 = 7.9 – 0.82X_1 + 0.008X_2 + 0.248X_3 – 0.066X_1X_2 – 0.093X_1X_3 – 0.176X_2X_3 + 0.298X_1X_2X_3$$

The exact assessment of the adequacy of the equation is determined using the Fisher criterion [8]:

$$F_r = \frac{S^2_{a\partial}}{S^2_{\{Y\}}} = \frac{0.028}{0.012} = 2.3$$

where, F_r is Fisher criterion; $S^2_{a\partial}$ is adequacy variance estimate; $S^2_{\{Y\}}$ is variance of optimization parameters.

According to table 3, the calculated value of the Fisher criterion is smaller than the value in the table, $F_r<F_{cr}$, so the hypothesis of the adequacy of the model is accepted.

Table 3. The calculated value of the Fisher criterion.

$S_{a\partial}^{2}$	$S_{\{Y\}}^{2}$	F_r	F_{cr}	F_r-F_{cr}	Verification result
0.028	0.012	2.3	3.01	-0.71	Adequacy model

According to the results of the experiment, a high-efficiency, elastic element with a hardness of Nm/rad was installed, the main shaft was created by sewing a fabric with a speed of 4500 min and a thickness of 4.5 mm. In this case, the elastic energy-saving fabric push mechanism provides a reduction of dynamic loads on the kinematic pairs, which increases the strength of the sewing machine. Therefore, the use of an elastic energy-saving fabric push mechanism in sewing machines ensures high-speed operation, which helps to increase the efficiency of the sewing machine [9].

CONCLUSION

Because of the research, the law of motion of the elastic element elastic shock absorber at different speed modes of the sewing machine was analyzed. A dynamic model of an elastic element flexible shock absorber mechanism was developed and the equation of motion of a dynamic system was derived. A mathematical model of a needle-driven machine under the influence of elastic elements of different hardness was developed and analyzed. The change in the interdependence of the parameters of the elastic element with different coefficients of resistance and strength of the material was studied. Research using the method of mathematical planning showed that the number of revolutions of the main shaft is 4500 rpm, the thickness of the sewn material is 4.5 mm, the coefficient of rigidity of the elastic element is 12.5 N/mm. increase the efficiency of the sewing machine and improve the quality of sewing. The results of the experiment showed that the reaction forces acting on the sewing machine are reduced by 2-2.5 times when the elastic element is used with a flexible shock absorber mechanism.

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