Scientific Research Publishing

Engineering, 2023, 15, 709-719
https://www.scirp.org/journal/eng
ISSN Online: 1947-394X
ISSN Print: 1947-3931

Analysis of Vibrations of Roller of the Polymer Composite Coating Equipment on Stitches of Tarpaulin Materials

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How to cite this paper: Behbudov, S., Djurayev, A., Kayumov, J., Kuryozov, U. and Samadova, M. (2023) Analysis of Vibrations of Roller of the Polymer Composite Coating Equipment on Stitches of Tarpaulin Materials. *Engineering*, **15**, 709-719.
https://doi.org/10.4236/eng.2023.1510048

Received: August 9, 2023
Accepted: October 28, 2023
Published: October 31, 2023

Abstract

The article presents a structural diagram and the principle of operation of the installation of a sewing machine for applying a polymer composition to the stitch lines of tarpaulin materials. The calculation schemes and the mathematical model of oscillations of the axis of the composite roller during the application of the polymer composition along the lines of tarpaulin materials are presented. Based on the numerical solution of the problem, the regularities of roller oscillations are presented. The main parameters of the system are substantiated.

Keywords

Sewing Machine, Device, Roller, Polymer Composition, Vibration, Rigidity

1. Introduction

To increase the strength of the seams of garments, a device for applying various coatings is used.

Known design for applying a polymer composition, which is installed on the needle bar machine 1022 class. OZLM (Republic of Belarus) and is fully consistent with other organs of the machine. There is no needle, thread take-up, needle thread guides, etc. in the machine. This device can be represented as a unit that includes a polymer dosing unit, a unit for applying it to a part, a plate with holes in the form of a given geometric pattern, and a container with a liquid-phase polymer. Additional nodes are a tank with a tightly closed stopper mounted on the head of a sewing machine and a pipeline through which a liquid-phase polymer composition enters. A device for processing sections of textile materials includes a holder with which the device is attached to the needle bar of a universal sewing machine, a control unit and a gear rack mechanism. Between the gear rack mechanism and the needle bar, there is a dosing tube and a means for supplying a liquid-phase polymer, made in the form of a piston with a conical head and a transverse groove [1].

A device is known for applying a polymeric composition along the sections of garment parts in the sewing industry instead of overcasting to secure the sections from shedding. The device contains a system for supplying a liquid-phase polymer, a unit for applying the polymer to the sections of the garment parts, a support for placing the product with a gear rack for moving it [2]. The liquid-phase polymer is applied to the sections of the parts by contact using counter-rotating rollers, one of which has a special geometry on the rim, and the other, covered with a porous material (spongy polyurethane coating), is signed with a polymer composition.

Both designs of the analogue securely secure the fabric sections from shedding for the entire service life, stabilize the geometry of the sections and ensure the saving of sewing threads.

The disadvantage of the known designs is that these devices apply the polymer composition to only one layer of tissue in order to protect the sections from shedding. This increases the processing time, and requires additional equipment and moving techniques, which increases the duration of the production cycle. The use of this design to secure the threads of the fabric at the seams from being pulled apart is possible (applying a polymer on this installation, and then sewing the cut parts on a universal machine), but this will also require additional equipment, transfer techniques and would increase the technological process of making clothes.

A device containing two rotating rollers covered with a porous material, the rollers are installed on the body of the sewing machine on both sides of the parts to be sewn behind its presser foot and toothed rail and are interconnected by an overlapping belt drive, the liquid polymer composition supply system contains an upper bath connected to the surface of the upper roller through a supply tube with a feed regulator, and a lower bath installed under the working platform of the machine, into which the lower roller is partially immersed [3].

The main disadvantage of the well-known designs is low reliability due to the lack of a drying process for the applied polymer coating on the seams of the materials to be ground.

The objective of the invention is to increase the reliability and strength of thread connections in garments made of fabrics of movable structures, namely, to reduce the spreadability of threads in the seams by fixing the fabric structure in the seam area with a polymer-composite material while reducing labor intensity and multi-stage processing of the product, as well as due to timely drying of the applied polymer composition on the seams of the materials to be sewn, the design of the device has been improved and forced drying of the coating immediately after its application.

➢ **Structural diagram of the recommended device for applying polymer to the lines of materials**

The device includes a sewing machine body 1, an upper rotating roller 2, a lower rotating roller 3, an upper shaft 4, a lower shaft 5, an upper bath 8 with a polymer composition, a lower bath 9 with a polymer composition, a feed tube 10, a polymer supply regulator 11, an upper and lower stitched parts 12, applied polymer composite 13, presser foot 14 of the sewing machine, lower gear rack 15 of the sewing machine, needle 16 and needle plate 17. The surface of the rollers 2 and 3 is covered with a porous material 18. The rollers 2 and 3 are installed on the body 1 of the sewing machine on both sides of the parts to be machined 12 behind the presser foot 14 and the gear rack 15 and are interconnected by an overlapping belt drive (not shown in Figure 1). The upper bath 8, the supply tube 10 connected to it with the feed regulator 11 and the lower bath 9 installed under the working platform of the machine constitute the supply system for the liquid polymer composition 13. The upper bath 8 is connected to the surface of the upper roller 2 through the supply tube 10. The lower bath 9 is partly lower roller 3 is immersed. Casings 6 are installed on both sides of the materials 12, rigidly connected to the body 1 of the sewing machine and together they form guides 19, and 20 of materials 12. Inside the casings 6, electric heaters 7 are installed, which are powered by electric energy and have regulators 21.

The device works as follows. When stitching, the parts 12 are pressed with the foot 14 to the toothed rail 15 and the needle plate 17. The fabric is advanced by the stitch size by the toothed rail 15 located in the slot of the needle plate. Rail 15 feeds materials only under needle 16, and the direction of movement of materials when sewing is set by the worker. When the needle 16 and the shuttle (not

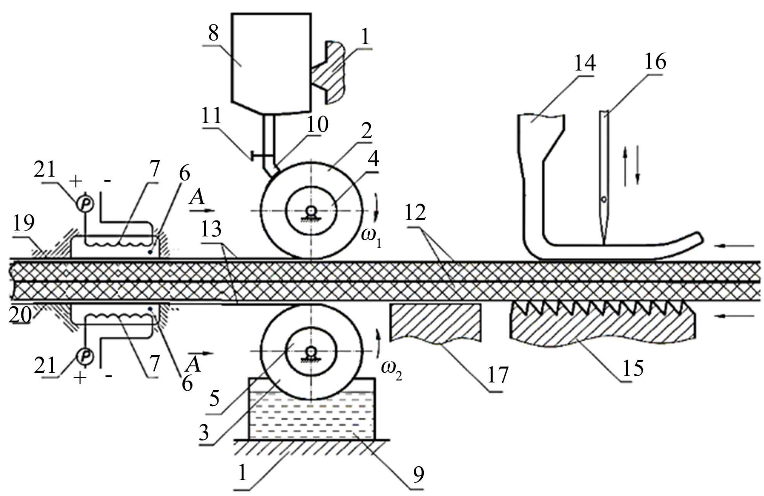


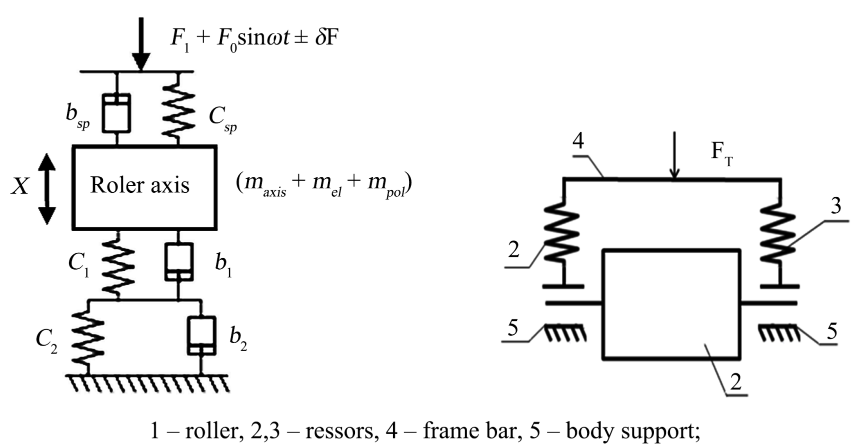
Figure 1. Apparatus for applying a polymer composition to garments.

shown in the drawing) interact, a lockstitch is formed. Next, the materials to be sewn 12 fall under the mutually rotating upper 2 and lower 3 rollers mounted on shafts 4 and 5 connected to the body of the sewing machine 1. In the process of advancing fabrics 12 from the upper bath 8 through the supply tube 10, the polymer composite enters the porous surface 18 of the upper roller 2 and is applied to the upper fabric in the form of a film 13. The supply of the polymer composition is regulated using the regulator 11. The polymer composition 13 is applied to the lower layer of sewn fabrics by means of the lower roller 2, which also has a porous surface 18 and is partially recessed in the solution of the polymer composition in the lower Tray 9. In the process of grinding, the polymer composition is applied in a strip with a width of 15 mm to 20 mm, so that the seam is in the center of the strip. The applied polymer coatings 13 are immediately dried by using electric heaters 7 installed in casings 6. To control the temperature in the cavities of casings 6, regulators 21 for changing the voltage in the power supply system are used, electric heaters 7. Guides 19 and 20 of casing 6 provide reliable advancement of tissues 12. The electric heater 7 can be made one and two in-line (**Figure 2**).

The design makes it possible to increase the reliability and strength of thread connections in garments due to the timely drying of the materials applied to the materials to be sewn.

- **Calculation scheme and mathematical model of vibrations of axis of the compound roller of device**

In order to evenly coat the polymer composite on the seams, it is advisable to keep the roller shaft vibration amplitude as small as possible. However, it should be noted that due to the vertical vibrations of the roller, the polymer composition on its surface is better absorbed by the pressure under sufficient pressure. This means that the vibrations of the equipment roller intensify the polymer coating. Therefore, it is important to study the effect of the roller axis on the laws of vibration of the equipment parameters, to determine the acceptable parameters theoretically.



1 – roller, 2,3 – ressors, 4 – frame bar, 5 – body support;
a – calculation scheme, b – roller placement diagram.

Figure 2. Calculation scheme of polymer coating equipment for tarpaulin seams and layout scheme of roller equipment.

The forces acting on the vibration of the composite roller include: the force acting on the roller axis through the spring through the housing; spring stiffness and dissection forces; roller shaft, rubber bushing and gravity of the outer polymer coating; sewn coal material and roller rubber bushing virginity and dissection forces. **Figure 2** shows the calculation scheme for determining the oscillations of the component roller of the equipment for the application of polymer coating on tarpaulin seams.

Lagrange's second-order equations [4] [5] are used to obtain the differential equation representing the oscillations of the roller according to the calculation scheme:

$$\frac{\mathrm{d}}{\mathrm{d}t}\left[\frac{\partial T}{\partial \dot{x}}\right]-\frac{\partial T}{\partial x}+\frac{\partial P}{\partial x}+\frac{\partial \varnothing}{\partial \dot{x}}=Q(x) \tag{1}$$

here, x—generalized coordinate, vertical displacement of the roller; T, P—kinetic and potential energies; $\varnothing$ —The dyspeptic function of the relay, $Q(x)$—generalized power.

Kinetic energy in the motion of the roller along the vertical X. [6] [7];

$$T=\frac{1}{2}\left(m_{axis}+m_{el}+m_{pol}\right)\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2; \tag{2}$$

here, m_{axis}, m_{el}, m_{el} —the masses of the polymer on the roller axis, the flexible bushing and the surface, respectively.

$$P=\frac{1}{2}C_l x^2 \tag{3}$$

here, C_l —the given virginity coefficient of the elastic elements.

$$C_l=\frac{c_1\cdot c_2\cdot c_{sp}}{c_1\cdot c_2-c_{sp}\left(c_1+c_2\right)}; \tag{4}$$

here, c_1, c_2, c_{sp} –compression springs, roller rubber bushings and tarpaulin material coefficients, respectively.

The dissipative function of the relay [6]:

$$\Phi=\frac{1}{2}\left(b_{sp}-b_1-b_2\right)\left(\frac{\mathrm{d}x}{\mathrm{d}t}\right)^2; \tag{5}$$

here, b_{sp}, b_1, b_2 –compression springs, roller rubber bushing and tarpaulin material dispersion coefficients, respectively.

Taking into account the obtained expressions (2), (3), (4), (5) and the external forces, we determine the additions to Equation (1). As a result, we create a differential equation that represents the motion of the composite roller axis along the vertical axis.

$$\begin{aligned}&\left(m_{axis}+m_{el}+m_{pol}\right)\frac{\mathrm{d}^2x}{\mathrm{d}t^2}\\&=F_1+F_0\sin\omega t\pm\delta F_1-\left(b_{sp}+b_1+b_2\right)\frac{\mathrm{d}x}{\mathrm{d}t}-\frac{c_1\cdot c_2\cdot c_{sp}x}{c_1\cdot c_2-c_{sp}\left(c_1+c_2\right)}\end{aligned} \tag{6}$$

Solution of the problem and analysis of the results of vibrations of the device roller axis.

The analytical solution of the second-order differential Equation (6), which represents the oscillation of the axis of the roller of the polymer composite coating on the tarpaulin seam on the sewing machine, was determined using the existing method [8] [9] without taking into account the random component of external force.

In this case, the following initial conditions are $t = 0$; $x = x_0$; The solution was obtained at $x_0 = 0$;

$$X = \frac{F_0^{/} \sin\left(\omega t - \beta\right)}{\sqrt{\left[\frac{c_1 \cdot c_2 \cdot c_{sp}}{\left(m_{axis} + m_{el} + m_{pol}\right)\left[c_1 \cdot c_2 - c_{sp}\left(c_1 + c_2\right)\right]} - \omega^2\right] + \frac{\omega\left(\mathrm{B}_{sp} - \mathrm{B}_1 - \mathrm{B}_2\right)}{m_{axis} + m_{el} + m_{pol}}}}; \quad (7)$$

$$F_0^{/} = \frac{F_0}{m_{axis} + m_{el} + m_{pol}};$$

Correspondingly, the specific oscillation frequency of the equipment component roller force:

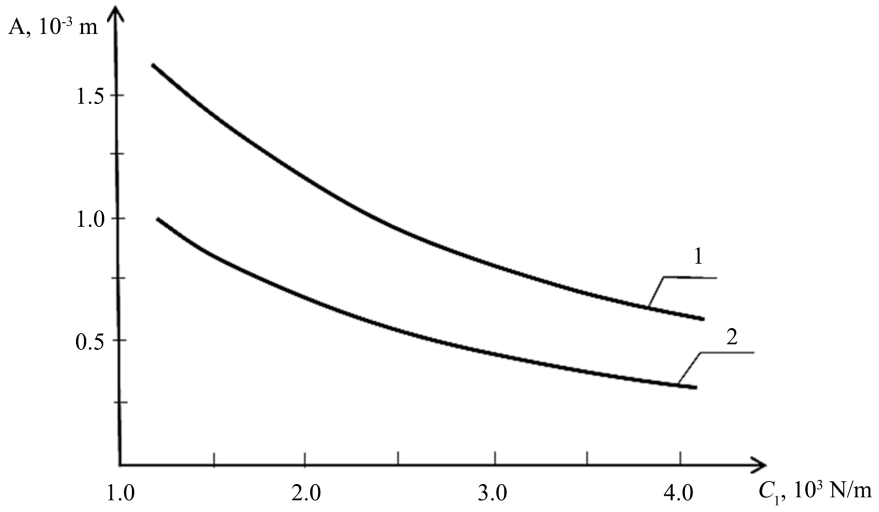
$$f_x = \sqrt{\frac{c_1 \cdot c_2 \cdot c_{sp}}{\left(m_{axis} + m_{el} + m_{pol}\right)\left[c_1 \cdot c_2 - c_{sp}\left(c_1 + c_2\right)\right]}}; \quad (8)$$

The numerical solution of the obtained (8) was performed at the following initial values of the parameters: $C_{sp} = (3.8 \div 4.5) \times 10^3$ N/m; $C_1 = (1.5 \div 2.4) \times 10^3$ N/m; $C_2 = (1.8 \div 2.5) \times 10^3$ N/m; $m_{axis} = (3.5 \div 4.5) \times 10^{-2}$ kg; $m_{el} = (2.0 \div 2.4) \times 10^{-2}$ kg; $m_{pol} = (0.6 \div 0.14) \times 10^{-2}$ kg; $b_{sp} = (3.0 \div 4.0)$ Ns/m; $b_1 = (0.8 \div 1.1)$ Ns/m; $b_2 = (0.7 \div 0.9)$ Ns/m.

Graphs of the dependence of the amplitude of vertical oscillations of the polymer coating roller on the tarpaulin seams on the coefficient of elasticity of the elastic elements and the tarpaulin material are obtained. According to the laws of this connection, the amplitude of the vertical vibration of the roller increases when the coefficient of elasticity of the flexible elements and the tarpaulin material increases from 0.6×10^3 N/m to 2.1×10^{-3} N/m. A decrease of 1.58×10^{-3} m to 0.63×10^{-3} m can be seen in the nonlinear connection. (**Figure 3**)

However, when the total mass value is doubled, the oscillation amplitude decreases linearly from 1.0×10^{-3} m to 0.31×10^{-3} m. That is, the smaller the mass and virginity, the lower the vibration amplitude. A large vibration amplitude causes the polymer layer to be of uneven thickness. Therefore, the following parameters are recommended: $C_l = (3.0 \div 3.5) \times 10^3$ N/m and $(m_{axis} + m_{el} + m_{pol}) = (8.0 \div 10) \times 10^{-2}$ kg. The laws of vertical vibrations of the roller with a polymer coating equipment on the tarpaulin seams on the sewing machine are shown in **Figure 4**.

In this case, the rotational frequency of the main shaft is taken as 2500 rpm. According to the analysis of oscillograms, the amplitude of the vibration of the composite roller increases accordingly with the increase in the impact force,



1 - $(m_{axis} + m_{el} + m_{pol}) = 5.6 \times 10^{-2}$ kg;

2 - $(m_{axis} + m_{el} + m_{pol}) = 11.2 \times 10^{-2}$ kg.

Figure 3. Graphs of the dependence of the amplitude of vertical vibrations of the polymer coating roller on the tarpaulin seams on the coefficient of elasticity of the elastic elements and the tarpaulin material.

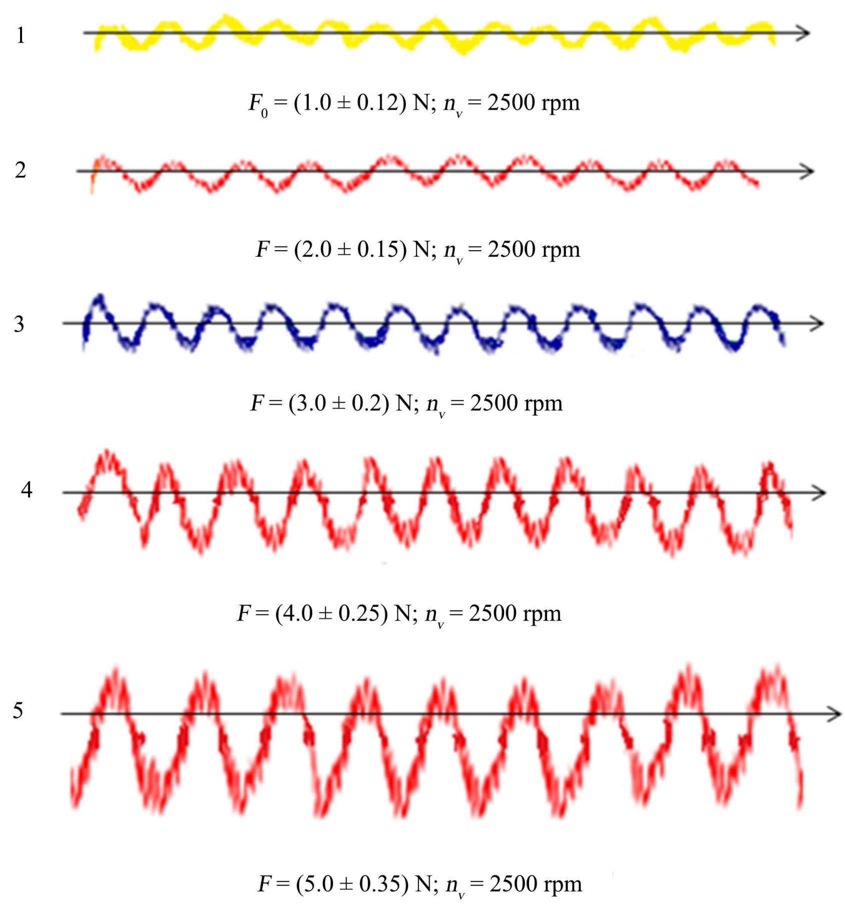


Figure 4. Laws of vertical vibrations of the roller with polymer coating equipment on the tarpaulin seams on the sewing machine.

which is an external random component. In this case, depending on the value of the impact force, the axis of vibration of the roller moves down relative to the axis of symmetry. The main reason for this is due to the deformation of the roller flexible bushing. As the deformation increases, the axial displacement also increases. The rotational frequency of the main shaft has almost no effect on the vibration amplitude. But the oscillation frequency increases accordingly (Figure 5, Figures 1-5). Figure 5 shows a graph of the dependence of the roller displacement and velocity vibration coverage on the coefficient of uniformity of the roller rubber bushing. When the polymer coating roller rubber bushing height increases from 1.2×10^{-3} N/m to 2.6×10^{3} N/m, it can be seen that the roller displacement and velocity vibration coverage decrease in a nonlinear pattern. In this case, the values of ΔX decrease from 2.05×10^{-3} m to 0.74×10^{-3} m at $F_0 = 2.5$ N, and at ΔX by 2.8×10^{-3} m at $F_0 = 5.0$ N, respectively. Decreases to 41×10^{-3} m. It can also be noted that the velocity oscillation coverage decreases from 5.2 m/s to 3.2 m/s at $\Delta \dot{X}$ $F_0 = 5.0$ N, respectively. As mentioned above, an increase in the vertical vibration coverage of the roller leads to an uneven distribution of the polymer. However, an increase in $\Delta \dot{X}$ ensures that the polymer is absorbed between the welds. Therefore, to ensure that $\Delta X \le (2.0 \div 2.5) \times 10^{-3}$ and $\Delta \dot{X} > (3.0 \div 3.5)$ m/s, the roller flexible bushing coefficient of virginity $(1.5 \div 2.0) \times$ A selection in the range of 10^{3} N/m is recommended (Figure 6).

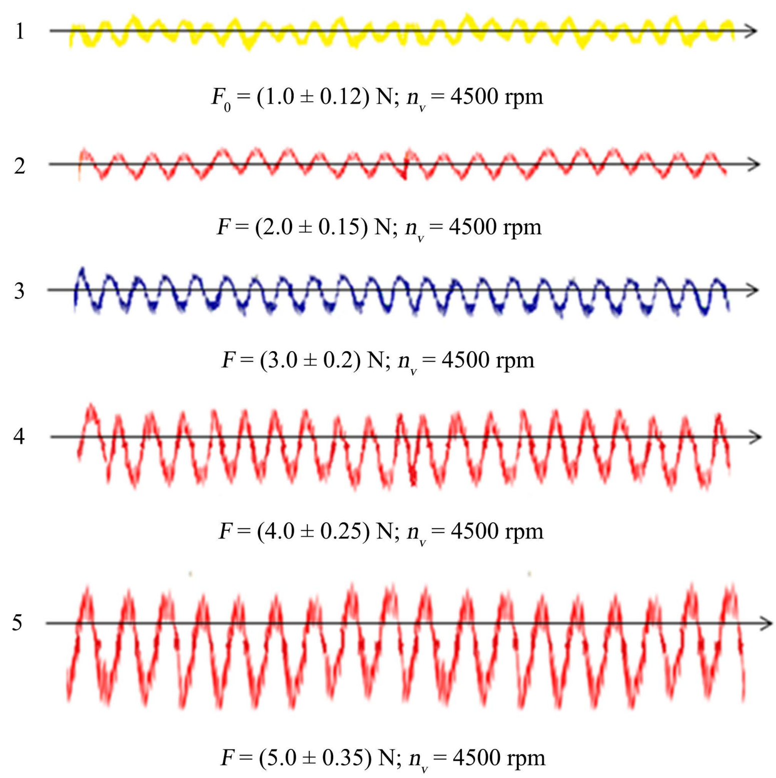
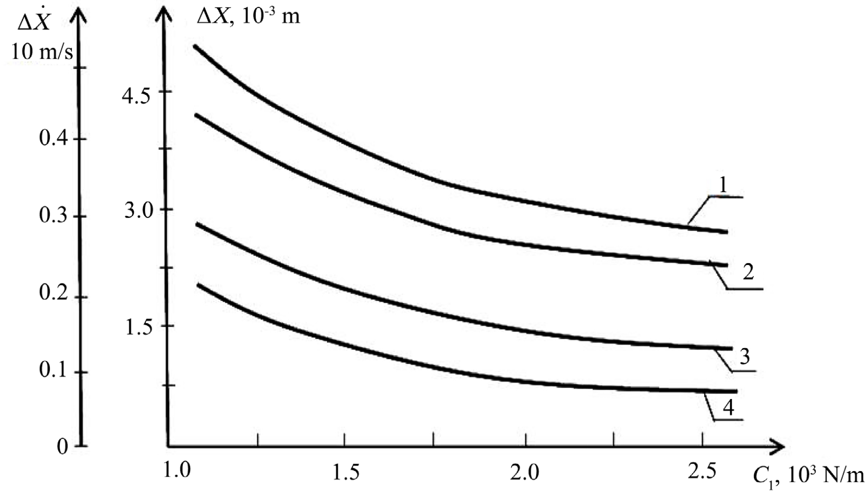


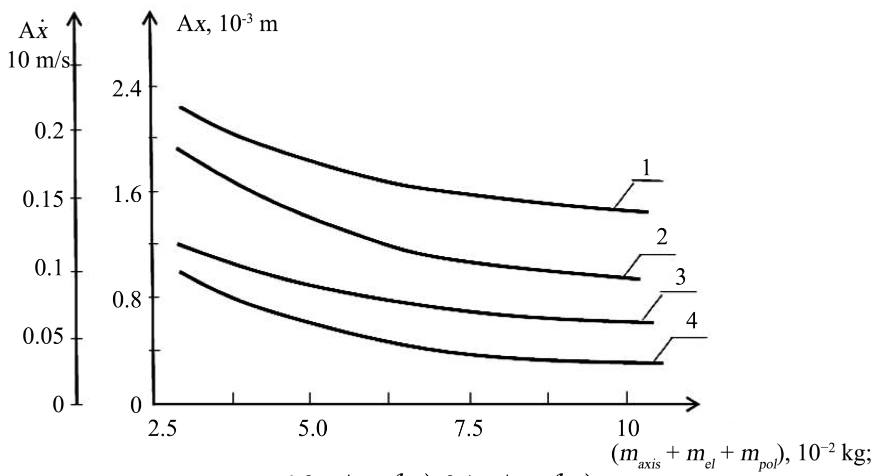
Figure 5. Laws of vertical vibrations of the roller with polymer coating equipment on the tarpaulin seams on the sewing machine.

It is known that an increase in the total mass of the roller reduces the amplitudes of oscillation and velocity of the roller. **Figure 7** shows graphs of the dependence of the roller displacement and velocity amplitudes change on the roller mass values. It should be noted that it can be seen that the deviation of the coupling graphs from the random component of the impact force does not exceed (5.0 ÷ 7.0)% (**Figure 7** and **Figure 8**). Therefore, in order to obtain the recommended values of Ax and $A\dot{x}$, it is necessary to take the total mass of the roller in the range $(8.0 \div 10) \times 10^{-2}$ kg.



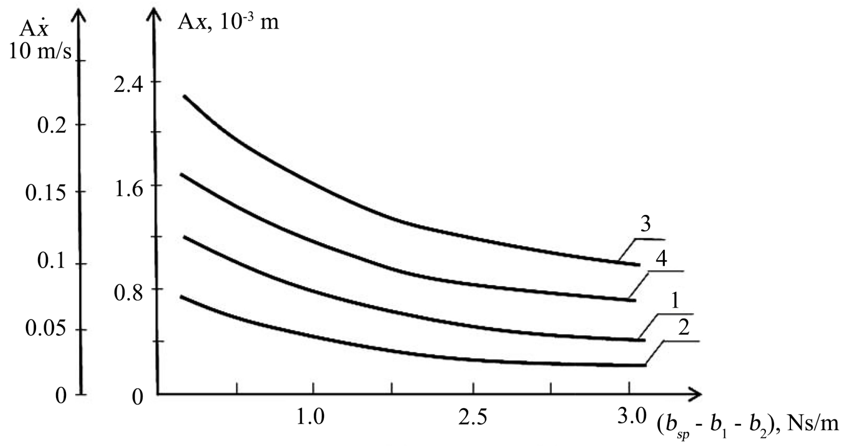
1,2 - $\Delta X = f(F_0)$; 3,4 - $\Delta\dot{X} = f(F_0)$;
1,3 - $(m_{axis} + m_{el} + m_{pol}) = 5.6 \times 10^{-2}$ kg;
2,4 - $(m_{axis} + m_{el} + m_{pol}) = 11.2 \times 10^{-2}$ kg.

Figure 6. Graphs of the dependence of compression and velocity coverage on roller oscillations on the external force amplitude.



1,2 - $A\dot{x} = f(m)$; 3,4 - $Ax = f(m)$;
1,3 - $F = (4 \pm 0.35)$ N; 2,4 - $F = (2 \pm 0.15)$ N
Deviation from graphs (5 ÷ 7)%.

Figure 7. Graphs of the dependence of the roller displacement and velocity amplitudes on the values of the roller mass given.



1,2 - $Ax = f$(в); 3,4 - $A\dot{x} = f$(в);
1,3 - F = (4 ± 0.35) N; 2,4 - F = (2 ± 0.15) N.
Deviation from graphs (5 ÷ 7)%.

Figure 8. Graphs of dependence of the displacement coefficients of the sliding elements and the velocity amplitudes of the polymer coating coating equipment on the seams of the tarpaulin materials.

Figure 8 shows graphs of the displacement coefficients of the displacement coils of the polymer coating on the seams of the tarpaulin materials and the velocity amplitudes of the elastic elements, given the elastic elements. It is known from the properties of elastic elements that an increase in the dispersion coefficient leads to a partial absorption of energy, a decrease in the amplitude of vibration [10] [11]. According to the analysis of the obtained graphs, when the impact force values increase to (4 ± 0.35) N, the dissociation coefficients of the elastic elements increase from 0.35 Ns/m to 3.0 Ns/m, the Ax values from 1.2 × 10^{-3} m to 0.45 × to 10^{-3} m, and we can see that the values of $A\dot{x}$ decrease in a linearly divided law from 2.3 m/s to 1.3 m/s (**Figure 8**). To ensure the amplitude of the vibration of the roller $Ax \leq (1.0 \div 1.3) \times 10^{-3}$ m and the oscillation amplitude of the velocity above (1.5 ÷ 2.0) m/s, 9) It is recommended to take in the range of Ns/m.

2. Conclusion

An effective device for a sewing machine for applying a polymer composition to the lines of tarpaulin materials is recommended. The problem of vibrations of the roller axis is solved by the analytical method, and the main parameters of the system are substantiated.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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