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Development of Constructive Scheme and Mathematical Model of Plate Oscillations of the Needle Thread Tension Regulator with Three-Stage Shock Absorbers in a Sewing Machine

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Abstract:

The article presents a constructive scheme and principles of operation of the needle thread tension regulator of a sewing machine. The mathematical model of axial oscillations of the plates of the needle thread tension regulator of the stiffness characteristics of three-stage stake shock absorbers and their dissipative properties at changes in the needle thread tension is derived. The results of analytical method of solving the problem of plate oscillations of the thread tension regulator are given.

Keywords: *Sewing machine, needle, thread, tension, regulator, plate, rubber, ring, three-stage, stiffness, dissipation, displacement, speed, amplitude, oscillation, equation, analytical solution.*

Structural scheme and principle of operation of the regulator of shuttle thread tension. Analysis of existing design schemes of regulators of tension of shuttle thread of sewing machine. [1÷7] showed that they do not provide uniformity of change in the tension of the needle thread within the established limits, does not eliminate thread breakage.

The essence of the design is that the needle thread tension regulator sewing machine consists of a rod, put on it two convex plates, on both sides of which are installed on three rubber spherical rings with different stiffnesses. And the ring with the lowest stiffnesses are in contact with the plates are spherical in the shape of the made indentations of the corresponding plates. In addition, the inner holes of the plates mounted on the rod are also spherical in shape. The use of spherical rubber spherical rings with increasing stiffness from the plates and the edges of the plates allow the movement of the plates not only along the axis of the rod, and angular movement relative to their vertical axis. Installing a spherical ring directly next to the plates when changing the tension of the thread, both in value and direction allow the plates to adjust smoothly, making both horizontal and angular movements relative to the vertical axis of the plates.

This leads to an increase in the mobility of convex plates, which adjust to changes in tension, also to the direction of influence, thread tension, eliminate thread breakage.

The design is explained by the drawing, where Fig. 1 shows the construction of the regulator with a section.

Needle thread tension regulator consists of a rod 1, which is rigidly fixed to the head of the machine. Two convex plates 2 and 3 are put on the rod 1, between which the needle thread passes (not shown in Fig.).

On both sides of the plates 2 and 3 are installed spherical rubber rings 4, 5, and 6, which have different stiffnesses C_1, C_2, C_3. In this case, spherical rings 5 with the lowest stiffnesses C3 are in contact with the plates 2 and 3, part of these rings are in the spherical recesses of the plates 2 and 3. There is a ratio: $C_1 > C_2 > C_3$ (where, C_1, C_2, C_3- stiffnesses of spherical rubber rings 4, 5 and 6). In addition, the inner holes of the plates 2 and 3 mounted on the rod 1 also have a spherical shape. The adjusting screw 7 presses the ring 6, 5, 4 to the plates 2 and 3 by means of the washer 8.

The design works as follows. The needle thread is passed between the plates 2 and 3. When it is necessary to regulate the thread tension, the adjusting nut 7 is turned, which presses the plates 2 and 3 against each other due to deformation of spherical rubber rings 4, 5, 6. In doing so, the spherical rubber rings 4, 5, 6 are deformed. Plates 2 and 3 not only press the thread, increasing its tension, but also oscillating in the longitudinal direction on the rod 1, as well as rotating relative to the vertical axis, automatically set the necessary values of the needle thread tension. In this case, the greatest deformation occurs at the spherical rubber rings 6 on both sides of the plates 2, 3. This allows the plates 2 and 3 to be instantly adjusted according to the change in thread tension.

This practically eliminates sudden changes in thread tension, thereby reducing thread breakage.

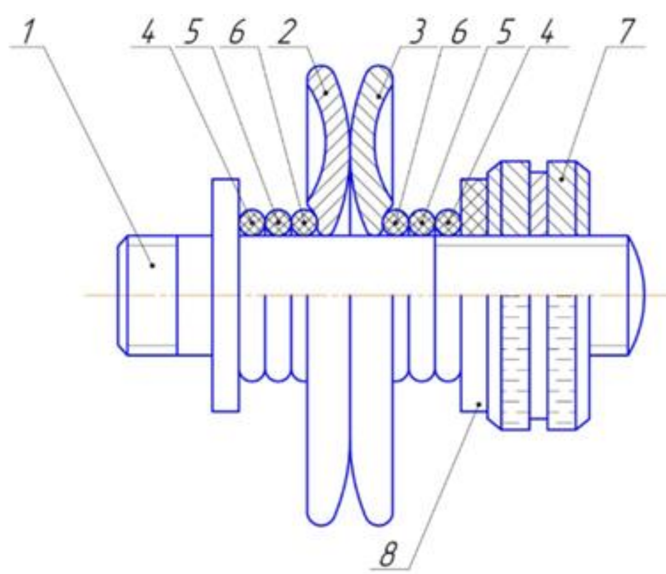
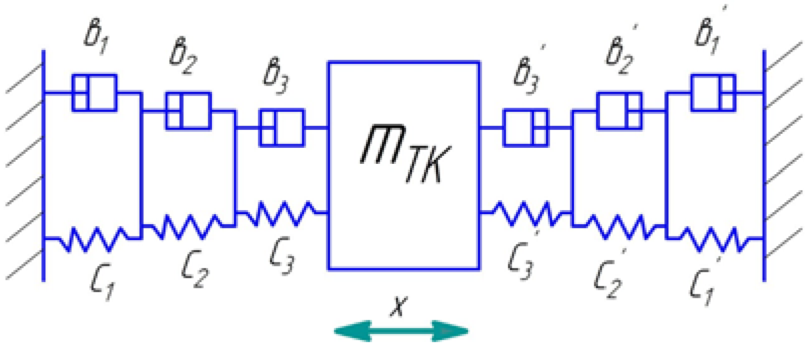


Fig. 1. Design diagram of the recommended needle thread tension regulator

Mathematical model of oscillations of the plates of the needle thread tension regulator. For the basis of the mathematical model of horizontal oscillations of the plates of the needle thread tension regulator in the sewing machine was made a calculation scheme, which is presented in Fig. 2.

$$F_1 \pm F_0 St - wt$$



m_{TK}- mass of the plates of the yarn tension regulator;

$c_1, c_1', c_2, c_2', c_3, c_3'$ −stiffness coefficients of three-stage shock absorbers of the thread tension regulator;

$b_1, b_1', b_2, b_2', b_3, b_3'$ − dissipation coefficients of the regulator shock absorbers, x-axis displacements of the plates, F_1, F_0 −components of the disturbing force from the needle thread tension.

In the design, the needle thread passes between the convex plates. In this case, the total reduced mass of the plates:

$m_{TK} = m_{T_1} + m_{T_2}$ (1)

where, m_{T_1}, m_{T_2}-masses of corresponding plates.

In this case are based on the equality of energy according to the equality of dissipative Rayleigh function [9]. Then given the case under consideration at three-stage setting of shock absorbers of the thread regulator we obtain:

$b_{\text{пр}} = [(b_1 + b_2 + b_3) - (b_1' + b_2' + b_3')]$ (2)

Accordingly, the reduced stiffness coefficient of three-stage shock absorbers is obtained according to [10, 11]:

$C_{\text{пр}_1} = \frac{c_1 \cdot c_2 \cdot c_3}{c_1 c_2 + c_1 c_3 + c_2 c_3}$; $C_{\text{пр}_2} = \frac{c_1' \cdot c_2' \cdot c_3'}{c_1' c_2' + c_1' c_3' + c_2' c_3'}$; (3)

or $\frac{1}{C_{\text{пр}}}$=$C_{\text{пр}_1} - C_{\text{пр}_2}$; (4)

$$C_{\text{пр}} = \frac{C_{\text{пр}_1} - C_{\text{пр}_2}}{C_{\text{пр}_2} - C_{\text{пр}_1}}$$

Then, considering (3) and (4) substituting into (5) we have:

$$C_{\text{пр}} = \frac{c_1 \cdot c_2 \cdot c_3 \cdot c_1' \cdot c_2' \cdot c_3' \left[(c_1 c_2 + c_1 c_3 + c_2 c_3) - (c_1' c_2' + c_1' c_3' + c_2' c_3')\right]}{c_1 \cdot c_2 \cdot c_3 (c_1 c_2 + c_1 c_3 + c_2 c_3) - c_1' \cdot c_2' \cdot c_3' (c_1 c_2 + c_1 c_3 + c_2 c_3)} \quad (5)$$

Using the Langrage equation of II kind [12, 13] we have the differential equation of axial vibrations of plates with three-stage shock absorbers of needle thread tension regulator of sewing machine [14]:

$(m_{T_1} + m_{T_2}) \frac{d^2 x}{dt^2} + [(b_1 + b_2 + b_3) - (b_1' + b_2' + b_3')] \frac{dx}{dt^2} + \frac{C_{\text{пр}_1} - C_{\text{пр}_2}}{C_{\text{пр}_2} - C_{\text{пр}_1}} x = F_1 \pm F_0 St - wt$ (6)

Taking into account the initial conditions at $t = 0, x = x_0$; $\dot{x} = \dot{x}_0$the solution (6) according to the existing method according to [15], setting the plate oscillations of the recommended sewing machine needle thread regulator has the form:

$$x = \frac{F_0}{(m_{T_1}+m_{T_2})[\left(\frac{C_{\text{пр}_1}-C_{\text{пр}_2}}{n}-w^2\right)^2+[\frac{(b_1+b_2+b_3)-(b_1'+b_2'+b_3')}{m_{T_1}+m_{T_2}}]^2-w^2} \cdot [w \cdot \frac{[(b_1+b_2+b_3)-(b_1'+b_2'+b_3')]}{(m_{T_1}+m_{T_2})} \cdot sinwt + \left(\frac{C_{\text{пр}_1}-C_{\text{пр}_2}}{(m_{T_1}+m_{T_2})}\right) - w^2 \cdot cos\, wt] \quad (7)$$

The analysis of the obtained (7) shows that the main parameters affecting the displacement, velocities and accelerations of the controller plate oscillations are $m_{T_1}, m_{T_2}, w, C_{\text{пр}_1}, C_{\text{пр}_2}, b_{\text{пр}_1}, b_{\text{пр}_2}$. By varying these parameters it is possible to obtain values of $x, \dot{x},$ and $\ddot{x}$ acceptable for minimum values of ΔF_0.

Conclusions. A new needle thread tension controller with a three-stage shock absorber has been developed. The problem of oscillations of the regulator plates is solved by analytical method.

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