THE RESEARCH OF THE PROCESS OF FORGING A ROLLING ROLLER THROUGH THE PACK OF THE FINAL FORM OF REWINDING MACHINES

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Abstract: *In the work a comparative analysis of the authors proposed the new design of the rolling roller in the form of segments [1] with the basic design of the rolling roller machine BP-340 [2] (Figure 1). It is established that the application of the segment roller achieves a uniform slip along the entire line of the coil forming cone, with the increase in the number of segments in direct proportion to the decrease in the maximum friction speed. The results of the study allow us to determine the optimal parameters of the segmental stiffening roller, which provide a qualitative process of forming the packing on the conical reel. They also provide a reduction in the heat and energy consumption of the friction roller in the steam, the roller, which leads to an increase in the life of the parts of the winding mechanism. Thread injury in the process of winding the conical reel is reduced.*

Keywords: *packing, bobbin, bobbin holder, rolling roller, slippage, rewinding of threads, winding mechanism.*

1 INTRODUCTION

In preparatory operations, the preparation of textile materials (yarns) plays a significant role in rewinding them into bobbins. In rewinding machines of basic design with direct drive in the winding mechanisms (Figure 1a); a continuous friction rolling roller 1 is used, which is mounted in bearings on a rigidly fixed axis 2, which is fixed to the rocker arm 3. Its main purpose is to secure the threads to the reel 4 in the process of winding it and adjusting its tension which provides the required packing density [3].

The clamping force is regulated by the counter-weight 5. In the process of work over time, wear of the stiffening roller is observed. The magnitude and nature of its wear is uneven in length. More intense wear is observed at its ends. Also, the process of winding the thread on the bobbin, accompanied by the release of heat, when slipping the rolling roller on the packaging at the point of contact. Wear of the rolling roller and its heating occur due to the loss of useful energy on the friction sliding of the kinematic pair of the rolling roller - packaging.

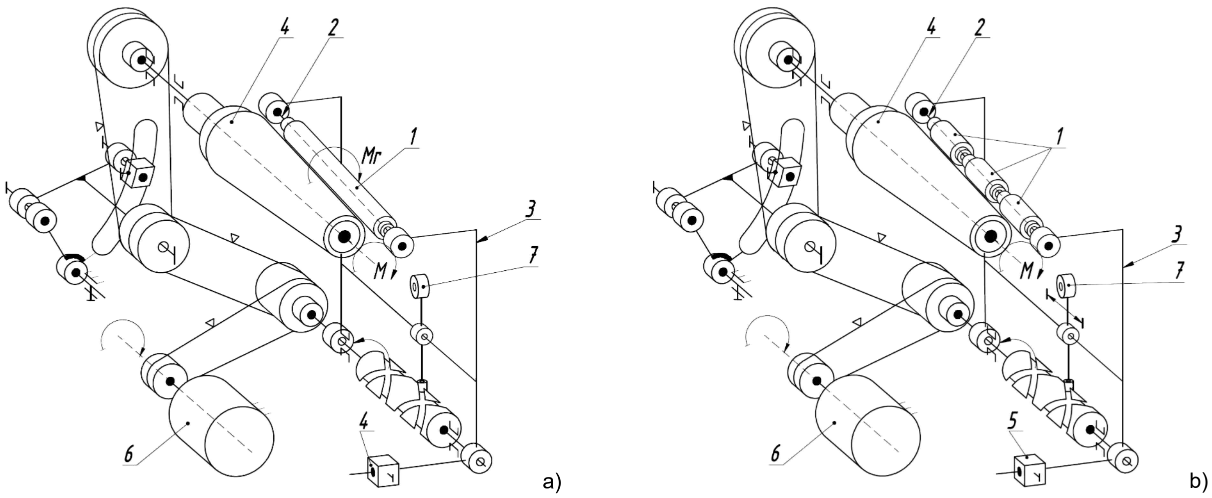

Figure 1 Kinematic-schematic diagrams of the winding mechanism of the rewinding machine: a) basic design of the BP-340 machine, b) new design [1]. 1 - the rolling roller, 2 - the axis, 3 - the rocker arm, 4 - the bobbin with packing, 5 – the counterweight, 6 - the electric motor, 7 - the mechanism of the distributor

References [4, 5] describe the constructions of winding mechanisms and rolling rollers using the rigid fastening of a single rolling roller. But the definition of its effect on packaging slippage has not been considered. At the same time, in [6], in addition to describing the winding mechanisms with a single rolling roller, the technological parameters of winding speed were determined, taking into account the position of the rolling pole. However, the authors do not take into account the effect of the rolling roller force on the displacement of its pole. Also, in the above works, the effect of displacement of the rolling pole on the slippage of the rolling roller relative to the packing has not been investigated.

Therefore, the urgent task is to determine the parameters that affect the slippage of the rolling roller in order to take them into account when developing a rational design of the rolling roller.

2 THEORETICAL SUBSTANTIATION

The reliable operation of the friction roller is due to several factors that influence the nature and magnitude of the rolling roller's slip on the package, which include:

1. A condition that ensures a secure friction connection of the rolling roller with the packing, which is determined by the balance of the friction force [4]. In this case, it is pure rolling friction, in the rolling pole, and rolling friction with slip (with sliding friction) at other points of contact of the rolling roller and packaging:

$$F_{tp} = F_n \cdot f = F_t \cdot \beta \qquad (1)$$

where F_{tp} – friction force [N]; F_n – the force of clamping the rolling roller to the pack [N]; f – coefficient of the materials friction of the rolling roller and packing; F_t – rotating effort [N]; β – clutch of the stock coefficient (chosen with such a calculation that the rolling roller will not slip on the pack in all possible operating modes).

2. Condition of stability work at change of speed modes. To reduce the energy consumption of friction under different modes of operation of the mechanism and reduce the tension of the contacting pair, the roller - packing, it is necessary that the ratio of the magnitude of the pressing force F_n and F_t are constant [10]:

$$F_n/F_t = const \qquad (2)$$

3. Factors affecting the slippage should also include the geometric and mass-inertia parameters of the bobbin and the roller.
4. Factor of technological necessity of application of greasing solution. The process of rewinding textiles can be carried out, both with the application of a greasing solution and without it. In the first case, the coefficient of friction is less than in the second ($f_1<f_2$), therefore, to maintain the friction contact of the rolling roller with the packaging, it is necessary to increase the clamping force $F_{n1} = F_{n2}\frac{f_2}{f_1}$. At the same time, the use of a grease solution improves the heat removal and the packing of the textile material.
5. The factor of geometric slippage, which arises due to unequal change of the linear speed along the contact length of the rolling roller and packing, and depends on the geometrical and structural parameters of the reel and rolling roller.

Specified working conditions of a pair of the roller - packing should be taken into account both when selecting the material of the rolling roller and when calculating and designing the winding mechanism. Particular attention should be paid to the maximum reduction in the amount of slip can be achieved by determining the rational parameters of the mechanism.

3 THE SOLVING OF THE PROBLEM

One of the main factors influencing the work of the friction pair is the rolling roller - the packaging is a geometric slip. Geometric sliding results in uneven slippage of the rolling roller on the conical bobbin, which results in uneven wear over the entire length. Consider ways to reduce the value of geometric slip. The work of a kinematic pair of a rolling roller - packing with straight lines and linear contact can generally be considered as rolling of a cone and a cylinder with inordinate vertices: O - the top of a cone, O' - the top of a cylinder which is at infinite distance from the rolling pole P (Figure 2). The work of a kinematic pair is a rolling roller - the packing can be represented by the plots of the velocity distribution of the sliding velocities v_k and the friction forces F_f along the length of the contact line (Figure 2).

When rolling the rolling roller, the packing velocity along the contact line AB changes not uniformly $v_{A1} < v_{B1}$ respectively at points A and B. On the driven rolling roller, the speed at the same points has the same value and is equal to the velocity in the rolling pole P– $v_{A2} = v_{B2} = v$. In the rolling pole P of the contact line AB, there is a pure rolling, at all other points - rolling occurs with sliding at velocities respectively v_{SA} and v_{SB}, while at the section PA the sliding occurs with a negative sign and at the section PB with the positive one.

In the complete absence of loads, the rolling pole P lies in the middle of the line of contact AB, and the moments of friction forces M_{f1} and M_{f2} between the surfaces of the rolling roller and the packing that occur respectively on the sections PA and PB are balanced. When the mechanism is loaded, the rolling pole P shifts. In this case, the friction force F_{f1} arising on the PA section plays a negative role - it slows down the driven roller, and the friction force F_{f2} arising on the section PB, on the contrary, accelerates it. Having started the coordinates in the middle of the contact line AB at point C ($AC = CB$). We consider the coordinate x to the vertex of packing p. O to be positive.

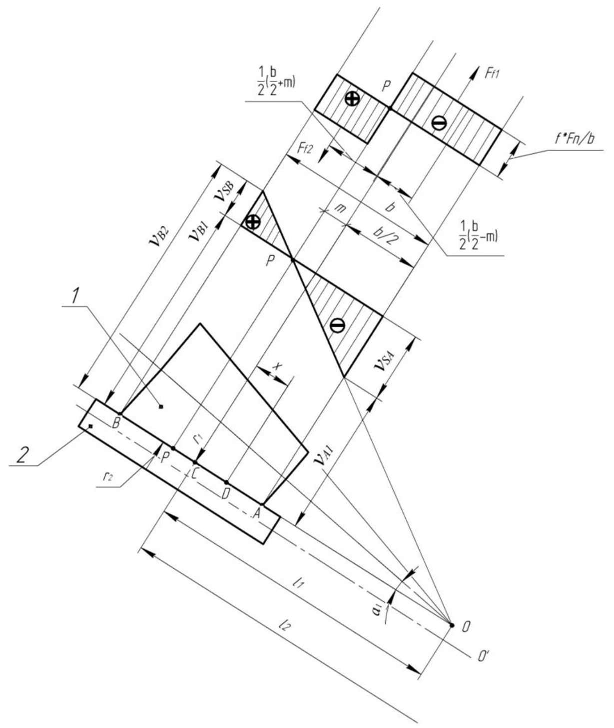

Figure 2 Scheme of distribution of velocity, slip and friction forces along the length of the contact line when using a continuous rolling roller: 1 - packaging; 2 - the rolling roller

We introduce the coordinate m which determines the position of therolling pole of p. P into all dependencies also with its sign: "minus" when moving from the middle to the base of the packing and "plus" when shifting the pole of rolling P to the vertex p. O. The difference between the moments of friction forces M_{f1} and M_{f2} arising from the friction forces F_{f1} and F_{f2} is balanced by the moment of resistance M_r on the rolling roller [8]. M_r is understood as the full moment of resistance to the rolling roller, including useful resistance, as well as the friction in the roller bearings and the rolling friction of the rolling roller.

$$M_r = F_{f1} \cdot \left(r_2 - \frac{1}{2} \cdot \left(\frac{b}{2} + m\right) \cdot \sin(\alpha_2)\right) - F_{f2} \cdot \cdot (r_2 + + \frac{1}{2} \cdot \left(\frac{b}{2} - m\right) \cdot \sin(\alpha_2)) \quad (3)$$

$$F_{f1} = q_n \cdot f \cdot \left(\frac{b}{2} - m\right); \; F_{f2} = q_n \cdot f \cdot \left(\frac{b}{2} + m\right);$$

$$r_2 = l_2 \cdot \sin(\alpha_2) = const; \; l_2 = \infty; \; q_n = \frac{F_n}{b}$$

where q_n – normally distributed load [N/m]; α_2 – the angle of inclination of the rolling roller ($\alpha_2=0$) [radian]; l_2 – the distance from the roller pole P to the top of the rolling roller p.O' ($l_2=\infty$); b – the length of the contact line of the AB rolling roller with the packing [m].

After substitution and transformations in general form:

$$M_r = -q_n \cdot f \cdot sin(\alpha_2) \cdot \left(m^2 - 2 \cdot m \cdot l_2 - \frac{b^2}{4}\right) \quad (4)$$

Since the rolling roller has a cylindrical shape in the bearings, the moment of resistance M_r including the resistance in the bearings of the rolling roller can be taken to be zero $M_r=0$.

Similarly to the previous difference of moments of friction forces M_{f1} and M_{f2} relative to the driving shaft of the packing gives the moment on the packing:

$$M = -q_n \cdot f \cdot sin(\alpha_1) \cdot \left(m^2 - 2 \cdot m \cdot l_1 - \frac{b^2}{4}\right) \quad (5)$$

where l_1 – the distance from the pole of the rolling p. P to the top of the pack p. O [m]; α_1 – the angle of inclination of the rolling roller [radian].

The coordinates of the rolling pole, taking into account the moment on the packing and the friction power when geometric sliding is determined from the expression (5):

$$m = l_1 - \sqrt{l_1^2 + \frac{b^2}{4} - \frac{\mathrm{M}^2}{q_n \cdot f \cdot \sin(\alpha_1)}} \quad (6)$$

Assume that the rotational force F_t is applied in the rolling pole, then the moment of resistance:

$$M = -F_t \cdot (r_1 - m \cdot sin(\alpha_1)) = -F_t \cdot (l_1 - m) \cdot sin(\alpha_1) \quad (7)$$

Equating this to expression (4) and considering that:

$$F_t = \frac{F_n \cdot f}{\beta} = \frac{q_n \cdot b \cdot f}{\beta} \quad (8)$$

We get it:

$$m = [1 +\cdot \frac{1}{\beta} \cdot \frac{b}{2 \cdot l_1} - \sqrt{1 + \left(\frac{b}{2 \cdot l_1}\right)^2 \cdot \left(1 + \frac{1}{\beta^2}\right)}] \cdot l_1 \quad (9)$$

In order to reduce the slip ratio b/l_1 is taken as small as possible [9], so the terms with the factor $(b/2l_1)^2$ in formula (9) can be neglected. Then with sufficient accuracy it is possible to record:

$$m \approx \frac{F_t}{F_n \cdot f} \qquad m \approx \frac{1}{\beta} \cdot \frac{b}{2} \quad (10)$$

The instantaneous value of the gear ratio of a pair of roller - packing is determined by the expression [10]:

$$i(m) = \frac{r_1 - m \cdot \sin(\alpha 1)}{r_2} = \frac{\sin(\alpha 1) \cdot (l_1 - m)}{r_2} \quad (11)$$

In the winding mechanism at constant rotational force $F_t=const$, the rolling pole of the P is shifted depending on the force of the rolling roller along the contact line AB. For the boundary case, where $F_t = F_n \cdot f$ and $\beta = 1$, the coordinate $m \approx 0.5b$, i.e. the pole of p. P rolling coincides with p. B. Further reduction of the clamping force $F_t > F_n \cdot f$ and the clutch coefficient $\beta<1$ will result in complete slipping of the stiffening roller - slip.

The oscillation of the clamping force, which is differentially related to the time of packing, is accompanied by a change in the position of the rolling pole, p. P, and with it the estimated radius of packing r_1 (r_2 = const) and, accordingly, a change in gear ratio (11). With a constant pressing force F_n the pole p. P occupies a constant position, i.e. m = const.

One of the most important characteristics is the relative sliding speed ε_x of the rolling roller and packing.

The velocity of relative slipping v_s at an arbitrary point D with the coordinate x (Figure 2) is determined by the difference in the speed of the rolling roller and the packing v_1 and v_2:

$$v_s = v_1 - v_2 = -\frac{(l_2 - l_1)\cdot(x - m)}{(l_2 - m)\cdot(l_1 - m)} v \tag{12}$$

The relative velocity of the geometric slip of the rolling roller in the packing in the General case:

$$\varepsilon_x = \frac{v_s}{v} = -\frac{(l_2 - l_1)\cdot(x - m)}{(l_2 - m)\cdot(l_1 - m)} \tag{13}$$

Considering in expression (13) that $l_2=\infty$, it is possible to take $l_2-m \approx l_2-l_1$ then the expression of geometric slippage takes the form:

$$\varepsilon_x = -\frac{x - m}{l_1 - m} \tag{14}$$

Complete elimination of geometric slippage can be achieved provided $\alpha_1=0$. In this case, we get cylindrical packaging.

Partial reduction of slippage can be achieved by distributing the load on several rolling rollers – a segment roller. To analyze this, consider the design of the rolling roller with three segments proposed by the authors [1] (Figure 3).

The geometric slippage of a segmental stiffening roller will be equal to the sum of the geometric slippages of each segment according to (14) will have the following form:

$$\varepsilon_x = -\sum_{i=1}^{n} \frac{x_i - m_i}{l_i - m_i} \tag{15}$$

where l_i – i - those distances from the rolling poles p. P_i to the top of the pack p. O [m]; x_i – i - those coordinates of arbitrary points for calculating the slip relative to the geometric mean of each segment [m]; m_i – i - those coordinates of the i-th poles of rolling of p. P_i of each i-th segment, relative to their geometric mean [m]; n – the number of segments of the rolling roller.

Consider the marginal case for $F_t = F_n \cdot f$ for a rolling roller made of three identical segments, when the linear speeds of the roller and the reels are equal at the right end of the roller.

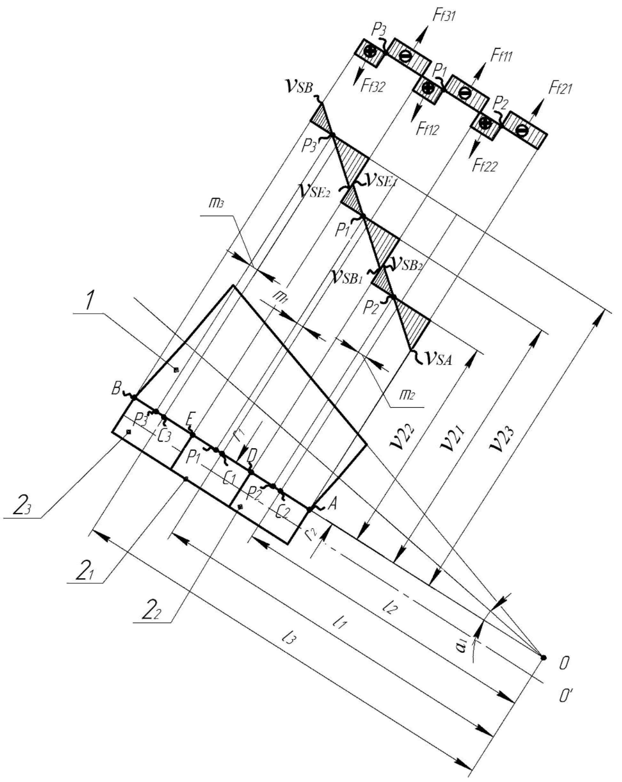

Figure 3 Scheme of distribution of velocity, slip and friction forces along the length of the contact line when using a segmental roller

The amount of slippage for a rolling roller of three segments with the same length is determined by the expression:

$$\varepsilon_x = -\frac{x_1 - m_1}{l_1 - m_1} - \frac{x_2 - m_2}{l_2 - m_2} - \frac{x_3 - m_3}{l_3 - m_3} \tag{16}$$

where $l_2 = l_1 - \frac{b}{3},\quad l_3 = l_1 + \frac{b}{3},\quad x_1 = x,\quad x_2 = x_1,\quad x_3 = x_1,$ $m_1 = m_2 = m_3 = \frac{m}{3}$

Then (15) taking into account the given coordinates in the limit case $m=b/2$ and $x=-b/6$ looks like:

$$\varepsilon_{x''} = \frac{\frac{b}{3}}{l_1 - \frac{b}{2}} + \frac{\frac{b}{3}}{l_1 - \frac{b}{6}} + \frac{\frac{b}{3}}{l_1 + \frac{b}{6}} \tag{17}$$

Similarly, for the boundary case when, $m=b/2$ and $x=-b/2$ (14) for a one-component stiffening roller will look like:

$$\varepsilon_{x'} = \frac{b}{l_1 - \frac{b}{2}} \tag{18}$$

Thus, by adopting the parameters of the rolling roller used on the BP-340 machine [2] at the beginning of the winding $b=0.25$ and $l_1=0.56$, we obtain the maximum slip value, respectively, for the basic design and the new rolling roller design with three segments ε_{x1}=0.797 and $\varepsilon_{x2}=0.649$.

Figure 4 presents a graph of the maximum total value of geometric slip ε_x as a function of the number of rollers *n*.

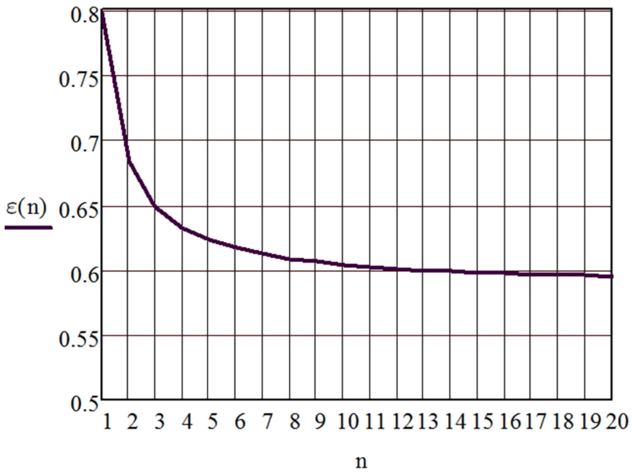

Figure 4 The dependence of geometric slip on the number of segments of the rolling roller

4 CONCLUSIONS

As a result of a comparative analysis of the new design of the rolling roller with the base structure, it is established that the value of geometric slip in the application of the segmental roller allows to reduce the value of maximum slip at the beginning of the winding process by more than 18.5%. It has also been found that an increase in the number of roller segments results in a decrease in the amount of slippage, which varies in law with a degree function. This reduces the injury of the thread during the winding process. The results of the calculations show a decrease in slippage when using a three-segment roller. The results obtained allow us to determine the optimal parameters of the winding mechanisms. The results can be used to design new winding mechanisms and upgrade existing equipment.

According to the results of the study, it is advisable to use a rolling roller with a number of segments from 3 to 5. With more segments, the effect of reducing the relative sliding is counterbalanced by friction in the bearing supports on which the segments are installed.

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