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Selecting the operating mode of roller machines

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Abstract. A dependence of the distance between the rolls on the radis of the roll, the thickness of the processed material, and the coefficient (angle) of friction of the processed material on the surface of the roll coating were theoretically studied. An experimental study revealed the dependence of the distance between the rolls on the intensity of the load, the radius of the roll, and the thickness of the material being processed. It was found that with an increase in the roll radius and load intensity, and with a decrease in the thickness of the material being processed, the distance between the rolls decreases.

1 Introduction

Roll machines are widely used in light, chemical, mining and metallurgical and other industries for the implementation of various machining operations. One of these processes is squeezing, which creates the moisture content needed for subsequent operations. In addition, the squeezing process is one of the operations that determine the environmental situation of production.

Currently, there are quite a lot of studies devoted to the process of roller squeezing of fabrics, wool, leather, and paper. These studies were conducted mainly to reveal the phenomena of contact interaction and water filtration during the roll squeezing process. Therefore, part of these studies is devoted to solving contact problems [1-12], and part - to solving hydraulic problems [13-23]. Consequently, the results of these studies were used to determine the parameters of squeezing machines [24-25].

At the operation of the squeezing machine, the selection of its mode of operation, observed at a certain time, for example, when squeezing a certain batch of processed material, is of practical importance. One of the parameters that determine the mode of operation of the squeezing machine is the distance (clearance) between the rolls along the centerline in the steady-state process.

The article considers the issue of determining the distance between the rolls in the steady process of the squeezing machine, the scheme of which is shown in Figure1.

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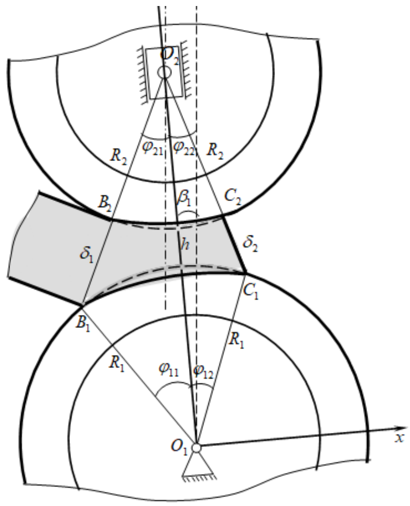

Fig. 1. Scheme of the squeezing machine in a steady state.

2 Materials and methods

In the squeezing machine under consideration, the lower roll is driven, and the upper roll is free.

Gripping conditions in a steady-state process for the considered scheme of the squeezing machine has the following form [26, 27]:

$$\varphi_{11} + \varphi_{21} \le \nu_1 - \nu_2 , \quad (1)$$

where $\varphi_{11}, \varphi_{21} -$ are the nip angles in a steady-state process, $\nu_1, \nu_2 -$ are the angles of friction of the lower and upper rolls, respectively.

According to [28], in triangle $O_1B_1O_2$ we obtain:

$$\cos\frac{\angle B_1}{2} = \sqrt{\frac{p(p-c)}{ab}}, \quad (2)$$

where $p = \frac{1}{2}(a+b+c).$

Here, $\angle B_1 = 180^o - \varphi_{11} - \varphi_{21},$ $a = O_2B_1 = R_2 + \delta_1,$ $b = O_1B_1 = R_1,$ $c = O_1O_2 = R_1 + R_2 + h.$

Substituting the values of the sides of triangle $O_1B_1O_2$ into formula (2), we obtain

$$\sin\frac{\varphi_{11} + \varphi_{21}}{2} = \frac{1}{2}\sqrt{\frac{(2(R_1 + R_2) + \delta_1 + h)(\delta_1 - h)}{R_1(R_2 + \delta_1)}}$$

or

$$\varphi_{11} + \varphi_{21} \approx \sqrt{\frac{(2(R_1 + R_2) + \delta_1 + h_1)(\delta_1 - h)}{R_1(R_2 + \delta_1)}} . \quad (3)$$

For values of $R_1 = 50 \div 150mm,$ $R_2 = 50 \div 150mm,$ $\delta_1 = 5 \div 15mm$ and $h_1 = 0 \div 8mm$, the calculation error according to formula (3) is $0.1 - 2.7\%$.

Taking into account expressions (3), from inequality (1), we obtain:

$$\sqrt{\frac{(2(R_1+R_2)+\delta_1+h_1)(\delta_1-h)}{R_1(R_2+\delta_1)}}\le \nu_1-\nu_2\,. \tag{4}$$

Transforming inequalities (4) and assuming that $h_1^2 \approx 0$, we have

$$h \ge \frac{(2(R_1+R_2)+\delta_1)\delta_1 - R_1(R_2+\delta_1)(\nu_1-\nu_2)^2}{2(R_1+R_2)}. \tag{5}$$

According to condition (5), it is possible to determine what minimum distance between the rolls must be set in order for the processed material of a given thickness to be gripped:

$$h_0 = h_{\min} = \frac{(2(R_1+R_2)+\delta_1)\delta_1 - R_1(R_2+\delta_1)(\nu_1-\nu_2)^2}{2(R_1+R_2)}. \tag{6}$$

Thus, the distance between the rolls depends on the radii of the rolls, the initial thickness of the processed material and the coefficient (angle) of friction of the processed material on the surface of the roll coating. Therefore, the minimum distance between the rolls can be determined when the coefficients of friction of the material being processed against the surface of the roll coating are known. However, the coefficients of friction during the pressing process from the beginning of the contact zone to the line of centers vary, and primarily depend on the load applied to the rolls. These dependencies can be obtained only in the course of complex experimental studies.

In addition to dependence (6), the dependence of the distance between the rolls on the radius of the roll, the initial thickness of the processed material and the load applied to the roll were experimentally determined.

An experimental study was conducted on an installation shown in Figure 2; it corresponds to the scheme of the squeezing machine given in Figure 1. It consists of main components: a frame, working rolls, and a spring-screw system.

The diameters of the working rolls are equal and rotate toward each other at the same velocity. The lower roll is mounted on supports in the frame and has an angular motion about its axis of rotation. The upper roll is mounted on supports and has translational and rotational motion. The upper roll is displaced to distance L relative to the lower roll toward the movement of the semi-finished leather product.

On the basis of a priori information, the range of factors change was taken as follows: load intensity - $15-65kH/m$; roll radius $-0.058-0.170m$; and thickness of the material being processed $-0.003-0.007m$.

Using the technique described in [22], we will take the dependence of the form:

$$h_o = AQ_1^{k_1}R_1^{k_2}\delta_1^{k_3}\,, \tag{7}$$

where $Q_1=\frac{Q}{Q_{\text{cp}}}$, $R_1=\frac{R}{R_{\text{cp}}}$, $\delta_1=\frac{\delta}{\delta_{\text{cp}}}$, $Q_{cp}=40kN/m$, $R_{cp}=0.114m$, $\delta_{cp}=0.005m$.

Coefficients in formula (8) were determined by the least squares method:

$$h_0 = 2{,}6476Q_1^{-0{,}2277}R_1^{-0{,}3406}\delta_1^{1{,}0124} \tag{8}$$

or

$$h_0 = 0{,}5737Q^{-0{,}2277}R^{-0{,}3406}\delta^{1{,}0124}. \tag{9}$$

The degrees of reliability and accuracy of approximation of experimental data were estimated by the coefficients of correlation and variation [29, 30].

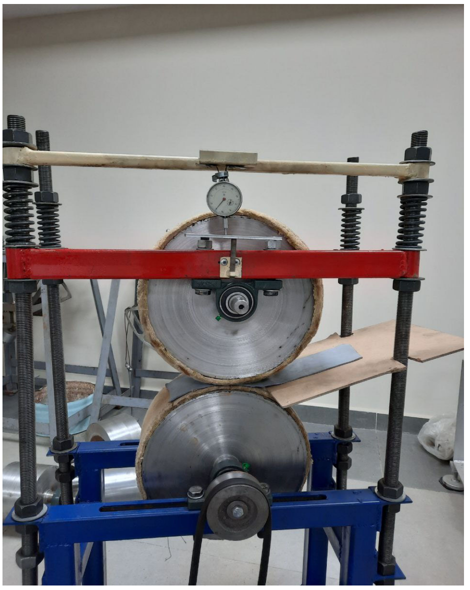

Fig. 2. Installation for determining the distance between the rolls.

An analysis of the curves in Figures 3-5, constructed according to formula (9) shows that they are in good agreement with the experimental curves. The approximation accuracy indices for these formulas are quite satisfactory, and the reliability indices are high. So, for example, the coefficients of variation and correlation of formula (9) for $Q_{cp} = 40kN/m$, $R_{cp} = 0.114m$ are 0.01 and 0.99.

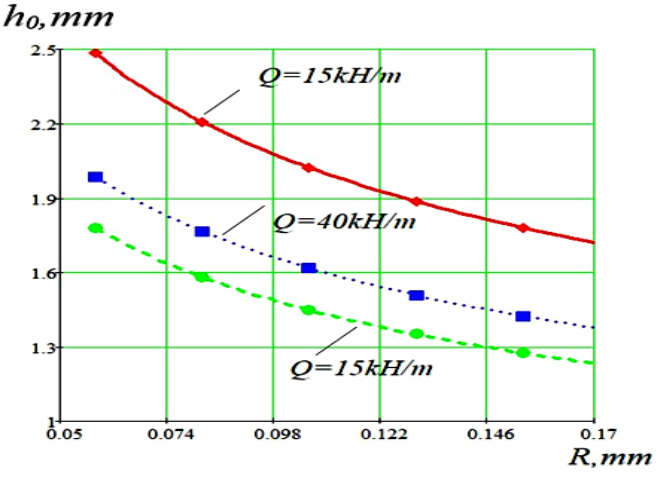

Fig. 3. Dependence of the distance between the rolls on the roll radius for $\delta = 0.005mm$.

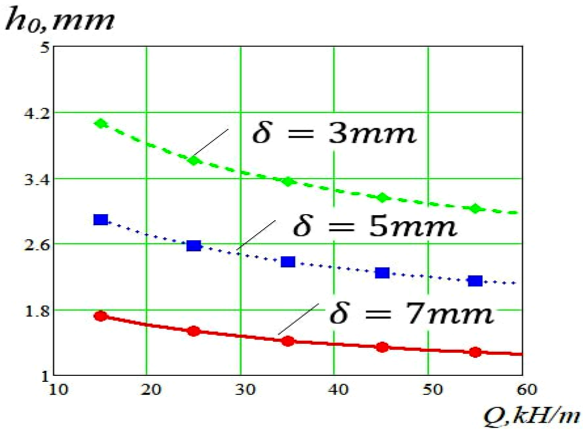

Fig. 4. Dependence of the distance between the rolls on the intensity of the load for $R = 0{,}058m$.

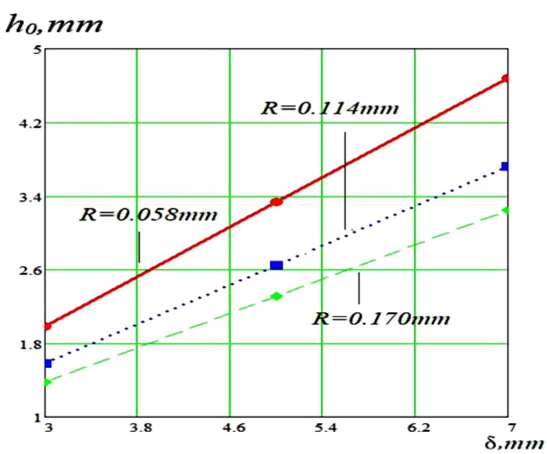

Fig. 5. Dependence of the distance between the rolls on the thickness of the material for $Q = 0{,}15kN / m$.

3 Results

The dependence of the distance between the rolls on the radii of the rolls, the initial thickness of the material being processed, and the coefficient (angle) of friction of the material being processed on the surface of the roll coating was obtained by a theoretical study.

An experimental study revealed the dependence of the distance between the rolls on the intensity of the load, the radius of the roll, and the initial thickness of the material being processed.

4 Conclusions

An analysis of the graphs (Figures 3 -5) and the dependencies obtained by the experimental curves showed that with an increase in the radius of the roll and the intensity of the load, and with a decrease in the thickness of the material being processed, the distance between the rolls decreases.

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