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Specific pressure under roller squeezing of leather

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Abstract. The influence of factors on the width of the roller contact and the specific pressure under roller pressing of leather is analyzed in the article. As a result of experimental studies, the dependences of the width of the contact area and specific pressure on the intensity of the load, velocity, and diameter of the rollers were determined. It was revealed that the parameter of the technological specific pressure on the hide in the contact zone increases with an increase in the intensity of the load, the speed of rolls, the width of the contact area, and a decrease in the radius of rolls. An analytical dependence of the residual moisture content of leather on the specific pressure was determined. It was established that with an increase in specific pressure, the residual moisture content of leather decreases and asymptotically approaches a certain value of the function. Keywords: leather, roll pressing, specific pressure, contact area width.

1 Introduction

Mechanical processing of genuine leather is characterized by the presence of a large number of operations performed in roller machines. Among them, a special group is the roller pressing of the semi-finished leather product after tanning, which is important for subsequent operations of splitting and planing [1, 2].

The specific pressure parameter is a determinant for achieving the desired technological effect of leather pressing. It is characterized by the value of the linear pressure, referred to the width of the contact area of the rolls. Therefore, the parameters of roll machines affect, first, the width of the contact area of the rolls and the specific pressure, and then, the technological effect.

The width of the contact area depending on the parameters of the roller machines can be determined either theoretically using mathematical modeling of the roller pressing process, or experimentally as a result of studying the influence of the main parameters of the roller pressing of leather.

References [3-17] are devoted to mathematical modeling of the roll pressing process. Analytical expressions for the contact area of the rolls and specific pressure are determined on the basis of modeling the shape of the roll contact curves and the distribution patterns of contact stresses.

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The study in [18] is devoted to experimental research and description of the width of the contact area by the regression model. However, when designing squeezing machines, engineering calculations require simpler dependencies than regression ones. Proceeding from this, the task was set on the basis of the results given in [18] to describe the width of the contact area and the specific pressure as an empirical function of the main parameters of the roll pressing of leather.

2 Materials and methods

In research of the contact zone of modules [2, 10] and considering the experience of the leather roller pressing operation, it was found that the main factors affecting the specific pressure are: load intensity Q; roller radius R; roller speed V.

The working matrix was compiled according to the K. Kano design matrix for a three-factor experiment. After the implementation of the working matrix, the values of the width of the contact area L were obtained (Table 1) [18].

Table 1. the values of the width of the contact area L.

Working matrix			Width of the contact area, mm
Q	R	V	L_0
40	0.114	0.22	0.0502
65	0.170	0.34	0.0676
65	0.058	0.34	0.0326
15	0.058	0.34	0.0179
15	0.170	0.34	0.0431
65	0.170	0.10	0.0665
65	0.058	0.10	0.0321
15	0.058	0.10	0.0234
15	0.170	0.10	0.0574
65	0.114	0.34	0.0539
40	0.058	0.34	0.0295
15	0.114	0.34	0.0355
65	0.058	0.22	0.0307
15	0.058	0.22	0.0222
15	0.170	0.22	0.0549
65	0.170	0.22	0.0637
40	0.170	0.34	0.0600
65	0.114	0.10	0.0530
40	0.058	0.10	0.0314
15	0.114	0.10	0.0467
40	0.170	0.10	0.0639
$\sum$			0.9598

As the basis for the approximation, we will use the technique described in [19], according to which a power dependence is taken in the following form:

$$L_0 = CQ_1^{\alpha} R_1^{\beta} V_1^{\gamma} \tag{1}$$

or

$$\ln L_0 = \ln C + \alpha \ln Q_1 + \beta \ln R_1 + \gamma \ln V_1. \quad (2)$$

where

$$Q_1 = \frac{Q}{Q_{\text{sr}}}, \quad R_1 = \frac{R}{R_{\text{sr}}}, \quad V_1 = \frac{V}{V_{\text{sr}}}, \quad (3)$$

here $Q_{sr} = 40$ *kN/m*, $R_{sr} = 0.114$ *m*, $V_{sr} = 0.22$ *m/s*.

Denoting $\ln L_0 = Y$, $\ln C = \eta$, $\ln Q_1 = X_1$, $\ln R_1 = X_2$ and $\ln V_1 = X_3$, we reduce expression (2) to the linear form

$Y = \alpha X_1 + \beta X_2 + \gamma X_3 + \eta.$

Parameters α, β, γ and η are found by the least squares method, according to which, the sum of the squared deviations ε_i of the experimental points from the straight line should be the least: $\sum_{i=1}^{21} \varepsilon_i^2 = \sum_{i=1}^{21} (Y_i - (\alpha X_{1i} + \beta X_{2i} + \gamma X_{3i} + \eta))^2 -$ the minimum.

Then we have

$$\begin{cases} 9.582\alpha + 0.410\beta + 0.526\gamma - 3.963\eta = 14.549, \\ 0.410\alpha + 4.925\beta + 0.293\gamma - 2.207\eta = 10.489, \\ 0.526\alpha + 0.293\beta + 6.507\gamma - 2.832\eta = 8.446, \\ -3.963\alpha - 2.207\beta - 2.832\gamma + 21\eta = -66.794. \end{cases} \quad (4)$$

System (4) has the following solution: $\alpha = 0.221$, $\beta = 0.740$, $\gamma = -0.09$, $\eta = -3.074$. Hence $C = e^{\eta} = e^{-3,074} = 0.046$.

Thus, formula (1) has the following form

$$L_0 = 0.046 Q_1^{0.221} R_1^{0.74} V_1^{-0.09}. \quad (5)$$

Let us now estimate the accuracy of the experimental data approximation obtained by the formula [20]: $\sigma = \sqrt{\frac{\sum_{i=1}^{n} \varepsilon_i^2}{n-2}} = 0.044$, $v = \frac{\sigma}{\sqrt{n}} = 0.01$.

As can be seen, the accuracy of the experimental data approximation by formula (5) is more than satisfactory.

The sum of the width of the contact area during the experimental study was 0.9598. Hence, we have $L_{osr} = 0.0457$. Taking into account this and expression (2), from expression (5) we obtain

$$L = 0.089 Q^{0.221} R^{0.74} V^{-0.09}. \quad (6)$$

It is known [19] that

$$P = \frac{Q}{L}, \tag{7}$$

where $P-$ is the specific pressure.

Substitute in the formula (7) the value L from equality (6), we find

$$Q = 0.0245 P^{1.28} R^{0.96} V^{-0.116}. \tag{8}$$

Where

$$P = 11.23 Q^{0.779} R^{-0.74} V^{0.09} \tag{9}$$

Then, with expression (6), we obtain

$$P = 56603.32 L^{3.52} R^{-3.35} V^{0.41}. \tag{10}$$

Figures 1-4 give graphical interpretations of formulas (11) and (12).

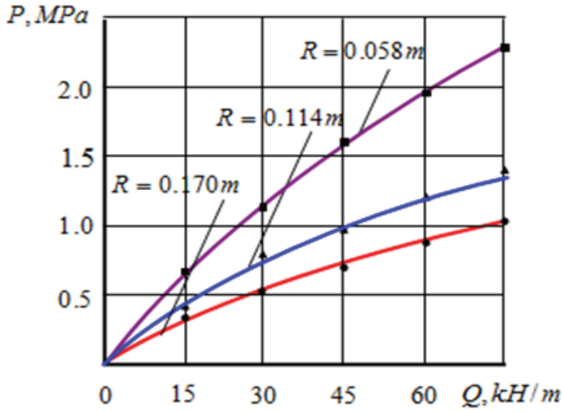

Fig. 1. Dependence of specific pressure from linear pressure.

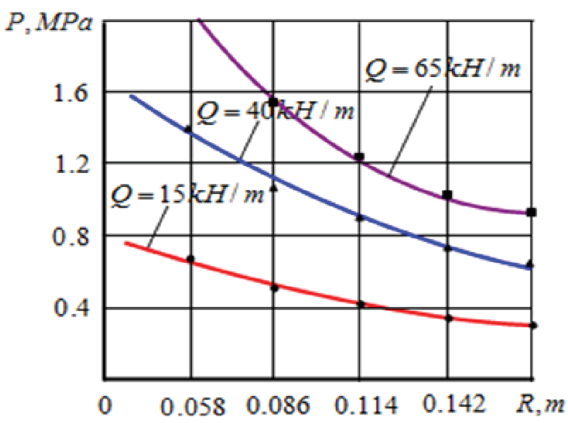

Fig. 2. Dependence of specific pressure from roll radius.

In [2], analytical dependencies were determined that describe the residual moisture of leather on the factors of the two-roll module:

$$W = 92.58Q^{-0.077}D^{0.046}V^{0.074}. \tag{11}$$

Let us transform formula (11) taking into account equality (8)

$$W = 130.97P^{-0.1}D^{-0.028}V^{0.083}. \tag{12}$$

From Fig. 5, it follows that with an increase in specific pressure, the residual moisture content of leather decreases and asymptotically approaches a certain value (for example, at $D = 0{,}22$ m and $v = 0{,}19$ m/s approaches the value of $W = 57\%$).

3 Results

An empirical dependence was obtained that describes the specific pressure as a power function of the load intensity, diameter, and speed of the roll. An analytical dependence of the residual moisture content of leather on the specific pressure was also found.

4 Conclusions

In the experimental study, the following was determined

- with an increase in the load intensity, the width of the contact area increases and approaches a certain value;
- at high values of the load intensity and the diameter of the rolls, the dependence of the width of the contact area on the speed of the rolls is characterized by a linear function;
- at lower intensities of the load, with an increase in the speed of the rolls, the width of the contact area decreases, and at high intensities, on the contrary, it increases;
- with an increase in the load intensity, the speed of the rolls and the width of the contact area, the specific pressure increases;
- an increase in the roll radius leads to a decrease in the specific pressure;

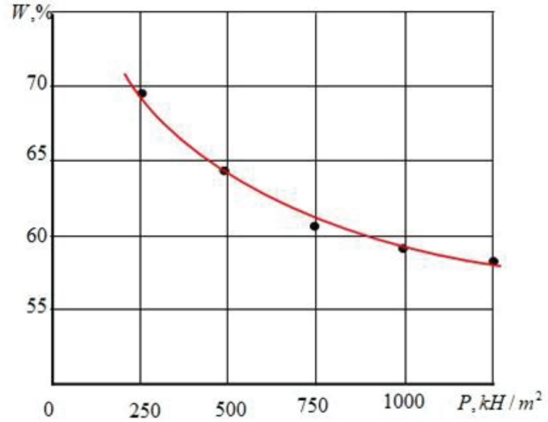

Fig.5. Dependence of residual moisture of leather from specific pressure at $D = 0{,}22m$ $v = 0{,}19m/c$.

• the residual moisture of leather decreases and asymptotically approaches a certain value.

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