Experiments on Moisture Squeezing from a Leather Semi-Finished Product

Gayrat Bahadirov, Gerasim Tsoy, Ayder Nabiev, Abdurasul Umarov

Abstract: The paper presents the results of experimental studies of manufacturing process of moisture squeezing from a wet leather semi-finished product. The effect of the multiplicity of leather semi-finished product passage between the squeezing rolls is determined. The effect of manufacturing factors, such as passage velocity, clamping force of the rolls and the multiplicity of leather semi-finished product passage between the squeezing rolls, on the wringing process is experimentally determined. The dependence of moisture amount removed from the leather semi-finished product on the velocity of its passage between the squeezing rolls under pressure intensity is established.

Keywords: experiment, stand, leather semi-finished product, rolls, passage velocity, clamping force, residual moisture.

I. INTRODUCTION

All manufacturing processes affect the quality of the finished leather, therefore, after realizing each of them, it is necessary to analyze the conditions of the leather raw materials. Experimental studies in leather industry are aimed at solving complex multifactorial problems, the result of which determines the rational modes of manufacturing processes for leather raw materials processing. The physical mechanical properties of leather semi-finished products vary depending on their moisture content.

II. LITERATURE REVIEW

Research in [1] is devoted to the studies of physical properties of leather materials. The effect of stress on the collagen in sheep and bovine skins was investigated to determine ultimate strength and other characteristics. In [2] the effect of collagen fibers and moisture content on skin stiffness was investigated. [3, 4] is devoted to the study of structure state under skin processing.

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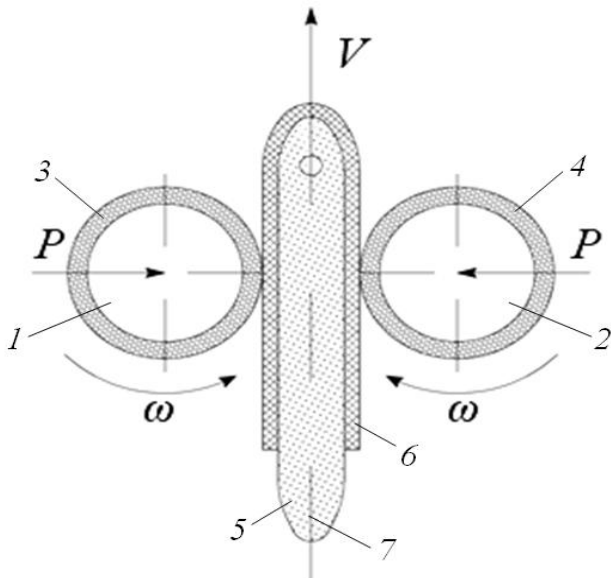
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In [5], the strain properties and characteristics of a chrome leather semi-finished product made of bovine skin were experimentally investigated according to its topographic sections and the coatings of the squeezing rolls. The dependences of the leather semi-finished product strain on the clamping pressure in the topographic sections of the butt, belly, Shoulder and moisture-removing coatings of the squeezing rolls were determined. In [6], the dependence of the amount of removed moisture on the passage velocity of a leather semi-finished product between the squeezing rolls was experimentally determined under the change in pressure intensity and in thickness of the leather semi-finished product. The researchers in [7, 8] have experimentally investigated the process of simultaneous squeezing of several leather semi-finished products in a form of a multilayer package. The effect of the number of skin layers on the amount of moisture squeezed from the wet skin is determined. The dependence of moisture squeezed from leather semi-finished products at various squeezing pressures, passage velocity and the number of leather layers with moisture-removing materials is obtained. In this paper, the authors have experimentally investigated the effect of the multiplicity of leather semi-finished product passage between the squeezing rolls and the amount of moisture squeezed.

III. RESEARCH METHODOLOGY

The experiment was carried out on a special stand, where the squeezing rolls were installed horizontally; the permeable support plate was made of porous material (of PP64S-250-25-76-40 grade) 0.015 m thick, 0.08 m wide and 0.14 m long (Fig. 1). The material of a leather semi-finished product in the experiment was a bovine skin of average weight, after chrome tanning, bifurcated. The moisture content in the topographic areas was: in a butt - 65.5%, in the belly - 73% from initial weight of the wet leather semi-finished product.

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1, 2 – squeezing rolls, 3, 4 – moisture-removing materials, 5 – base plate, 6 – leather semi-finished products, 7 – chain
Fig. 1. Scheme for feeding a leather semi-finished product into the squeezing zone

According to the technique given in [9], we selected the required amount of leather semi-finished product for the experiment according to formula $n = 0.2\sqrt{x}$, where x is the number of leather semi-finished products in a batch, n is the number of leather semi-finished products taken for the experiment. We took $x = 2500$ pcs of leather semi-finished products, so, $n = 0.2\sqrt{2500} = 10$ pcs. From these ten leather semi-finished products, the strips were cut out by a cutter across the spinal column 0.05×0.25 m in size and they were numbered; then the strips were made up in sets of 10 pieces according to the scheme (Fig. 2) [9].

The experiment was carried out as follows. The stand was turned on, spring compression was set according to the calibration to the desired pressure, velocity was regulated by a laboratory autotransformer of LATR - 1M Type, 220 V., 9 A, No. 5526, and the roll speed was controlled by a clock type tachometer ТЧ 10-Р.
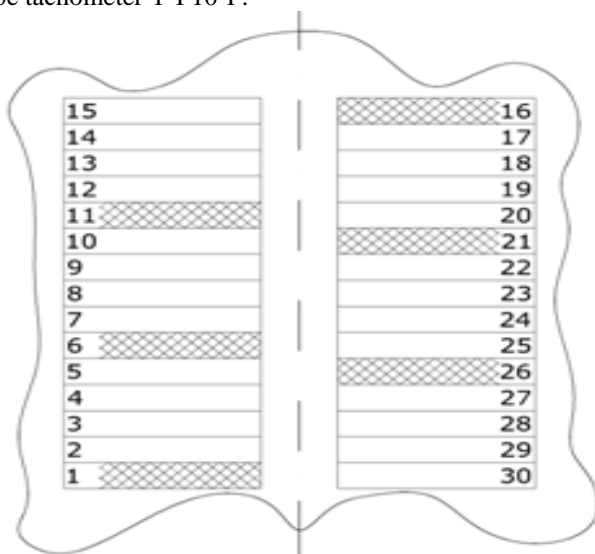
Fig. 2. Scheme of making up the strips of leather semi-finished product in sets

Preliminarily, control samples of leather semi-finished product were fed and spring compression was measured, i.e. the deviation from the established value. If the deviation exceeded 3%, then by tightening the nuts the spring compression was regulated from zero value. Then the main samples were fed. They were weighed before and after the passage on a VLTE-500 laboratory balance with a resolution of 0.01 g (ISO-9001).

In the study, an experimental planning method was used, namely, the second-order D-optimal planning method using the Kano plan matrix, since its application ensured the maximum accuracy in estimating the regression coefficients [10]. It is taken into account that the Kano plan provides for the variation of factors at three levels: lower (-), zero (0) and upper (+) ones, which is appropriate for this study.

Based on a priori information, the process of moisture squeezing was studied taking into account three factors: x_1 – compression intensity P, kN/m; x_2 – passage velocity, V, m/s; x_3 - multiplicity of squeezing, K. The range of compression was from 32 to 96 kN/m. The speed of the squeezing rolls was from 0.17 to 0.34 m/s based on the analysis of various squeezing machines produced in various countries. The multiplicity of squeezing was selected from 1 to 3. The diameter of the squeezing rolls was 0.3 m, and the thickness of coatings was 0.01 m made of BM cloth.

Before the experiment, the required number of measurements (the number of experiment repetitions), which provided the required accuracy, was selected by the methods of mathematical statistics. The working matrix was compiled based on the Kano matrix plans for a three-factor experiment. The factors coding was carried out according to the formula $x_i = \dfrac{c_i - c_{io}}{t}$, where x_i is the coding of the factor value; c_i, c_{io} are the natural values of the factor at the current and zero levels; t is the natural value of factor variation range.

The levels and ranges of variation of experimental factors are given in Table- I.

Table- I: The levels and ranges of variation of experimental factors

Index	Coded value of factors	Natural values of factor		
		x_1, kN/m	x_2, m/s	x_3
Upper level	+	96	0.340	3
Basic level	0	64	0.255	2
Lower level	-	32	0.170	1
Variation range		32	0.085	1

Target functions are approximated by polynomial

$$y = b_0 + \sum_{i=1}^{K} b_i x_i + \sum_{i,j=1}^{K} b_{ij} x_i x_j + \sum_{i=1}^{K} b_{ii} x_i^2 , \qquad (1)$$

where y is the amount of squeezed moisture in coded form; b_0, b_i, b_{ij}, b_{ii} are the regression coefficients.

After working matrix implementation, the arithmetic mean values were obtained (Table- II).

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The dispersion uniformity was carried out using the Cochren criterion with a confidence probability of $\alpha = 0.95$.

$$G_{cal} = \frac{S_{\max}^2}{\sum_1^N S_i^2} < G_T ; \qquad (2)$$

$$S_{er}^2 = \frac{\sum_1^n \left(y_n - \overline{y_n}\right)^2}{n-1} ; \qquad (3)$$

$$G_{cal} = \frac{40.6}{404.5} = 0.1 \le G_T = 0.11. \qquad (4)$$

Determine regression coefficients b_0, b_i, b_{ij}, b_{ii} from the table given in [10]: $b_0=25.1293$; $b_1=5.0509$; $b_2=-2.8428$; $b_3=3.6988$; $b_{11}=0.0815$; $b_{22}=-1.1563$; $b_{33}=0.9613$; $b_{12}=1.0690$; $b_{13}=0.6509$; $b_{23}=-0.0365$.

Regression equation in a coded form is:

$$y = 25.1293 - 0.0815x_1^2 + 1.1563x_2^2 - 0.9613x_3^2 +$$
$$+ 5.0509x_1 - 2.8428x_2 + 3.6988x_3 + 1.069x_1x_2 - \qquad (5)$$
$$- 0.6509x_1x_3 - 0.0365x_2x_3.$$

The hypothesis of the adequacy of obtained equations was checked using the Fisher test with a confidence probability of $\alpha = 0.95$,

$$F_{cal} = \frac{S_{ad}^2}{S^2\{y\}} < F_T , \qquad (6)$$

S_{ad}^2 – is the residual variance or adequacy variance; $S^2\{y\}$ is the reproducibility variance. The value of S_{ad}^2 is obtained from Table- I and Table- II.

$$S_{ad}^2 = \frac{\sum_1^N b(\overline{y}_u - y_u)^2}{N - \frac{(k+2)(k+1)}{2}} = 15.87 \qquad (7)$$

$$S_{\{y\}}^2 = \frac{\sum_1^N \sum_1^n (y_u - \overline{y}_u)^2}{N(n-1)} = 19.59 ; \qquad (8)$$

$$F_{cal} = \frac{15.87}{19.59} = 0.81 , \qquad (9)$$

Table- II: Planning matrix

| № | x_1 | x_2 | x_3 | Measurements results | | | | | | | | | | $\overline{y}_u$ | $\sum_1^n (y_u - \overline{y}_u) \hat{y}_{cal}$ | $\hat{y}_{cal}$ | S_{er}^2 | $(\overline{y}_u - \hat{y}_{cal})^2$ |
				y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0	0	22.8	26.9	24.1	26.3	24.7	26.4	21.5	22.4	29.5	26.9	25.1	55.7	6.2	24.89	0.0625
2	+	+	+	39.4	31.7	25.6	37.4	25.6	28.5	27.2	28.1	28.8	69.4	30.1	206.45	22.94	31.23	1.1449
3	+	-	+	34.3	36.4	42.4	31.8	38.5	35.1	30.4	35.2	34.7	42.9	37.9	79.65	19.96	37.28	1.2321
4	-	-	+	27.5	35.5	23.9	29.4	36.4	29.3	28.8	29.6	28.5	28.6	29.2	176.1	19.6	28	1.2321
5	-	+	+	21.6	26.2	19.6	23.3	21.5	22	26.3	21.3	22.5	30.4	23.5	185	20.6	21.6	3.61
6	+	+	-	34	26.1	17.4	31.7	19.9	22.3	21.9	19.7	22.6	23	23.9	252.9	28.1	22.45	1.9881
7	+	-	-	26	30.5	37	27.9	31.2	30.5	26	26.7	29.4	38.4	30.4	176.3	19.6	30.65	0.0841
8	-	-	-	17	27.1	16.4	23.2	28.7	20.8	21.4	17.3	16.7	21.1	21	164	18.2	19.71	1.5376
9	-	+	-	15	16.9	12.6	13.2	14.8	14.7	16.4	13.9	12.7	12.6	11.7	87.1	9.7	12.25	0.2809
10	+	0	+	46.2	35.6	29	29.9	31.9	32.1	30.5	44.8	26.4	38.7	34.5	398.76	40.3	35.1	0.36
11	0	-	+	41.3	311.1	31.5	42	29	31.2	28.6	30.2	29.8	29.3	32.5	212.7	23.6	31.48	1.0404
12	-	0	+	19.9	18.4	19.8	22.2	21.6	22.7	20.8	21.3	26.6	19.5	21.5	47.7	5.3	20.49	0.6561
13	+	-	0	30.6	34.1	40.5	30.5	34.9	33.1	28.2	32.9	32.1	40.7	33.8	150.4	16.7	34.6	0.7056
14	-	-	0	24.2	33.9	21.5	27	34.2	26.3	28.5	25.7	20.2	26.2	28.5	170.3	18.9	25.31	1.3225
15	-	+	0	19.3	23.5	16.7	19.1	19	19.1	21.9	18.4	18.5	26.9	20.2	82.5	9.2	17.32	0.2025
16	+	+	0	37.1	29.8	22.5	35.3	24.4	26.2	25.6	25.2	25.7	26.9	27.8	213.6	23.7	27.4	0.1369
17	0	+	+	36.6	25	27.3	29.2	26.6	25.9	26.4	28.8	30.4	24.3	25.9	276.3	30.17	24.9	0.8464
18	+	0	-	39.1	28.4	23.8	24.7	23	21.7	25.4	38.9	21.9	33.7	28	401.4	40.6	28.24	0.0784
19	0	-	-	33.8	24.3	22.3	32.2	28.3	24.8	26.6	22.6	24	23	25.4	180.2	20	26.11	0.5776

20	-	0	-	11.6	11.1	13.7	14.2	12.8	13.9	13.5	14.8	18.3	13.6	13.7	34.2	3.8	14.05	0.0961
21	0	+	-	24.2	25	21.8	19.4	21.1	19.3	18.6	21.2	24.6	16.4	18.6	61.1	6.79	19.16	0.2601
															3703.5	404.5		17.4549

Where N is the total number of experiments; K is the number of factors; n is the number of repetitions in the experiment; y_u is the result of an isolated observation; $\bar{y}_u$ are the arithmetic mean values of the result of experiment; $\hat{y}_u$ are the calculated criterion values from the regression equation for $S_{ad}^2 = 15.87$; $S_{\{y\}}^2 = 19.59$; $F_T = 2.40$; $f_1 = 11$; $f_2 = 189$; $F_{cal} = 0.81 < F_T = 2.40$.
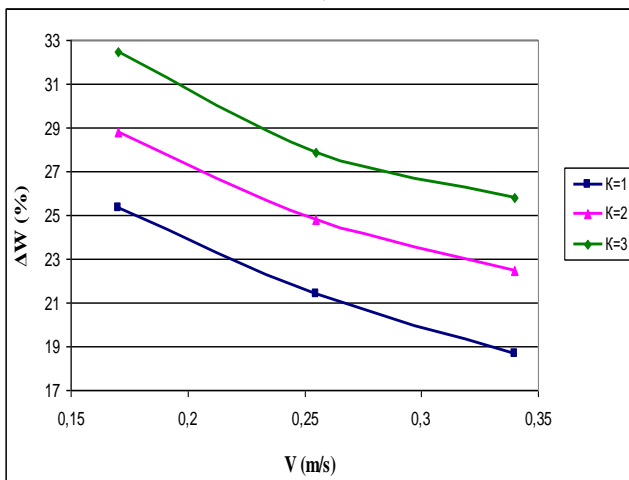
IV. DISCUSSION

Thus, the regression equation (10) can be considered suitable with a 95% confidence probability, since the regression equation in the denominated form after decoding has the form:
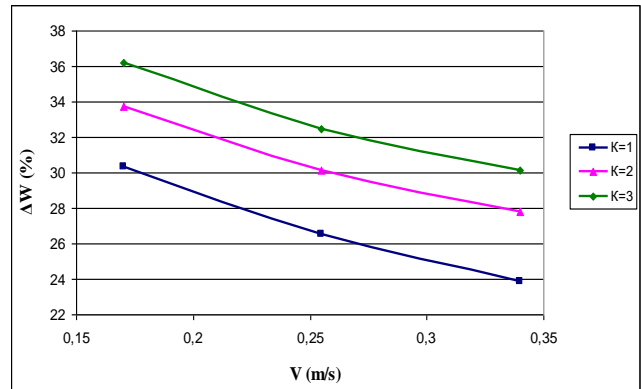
$$\Delta W = 101.2 + 0.0004P^2 + 0.3270V^2 - 0.861K^2 - \\ - 0.023P - 11.312V + 6.64K + 0.0094PK - \qquad (10) \\ - 0.02PV - 0.091VK.$$
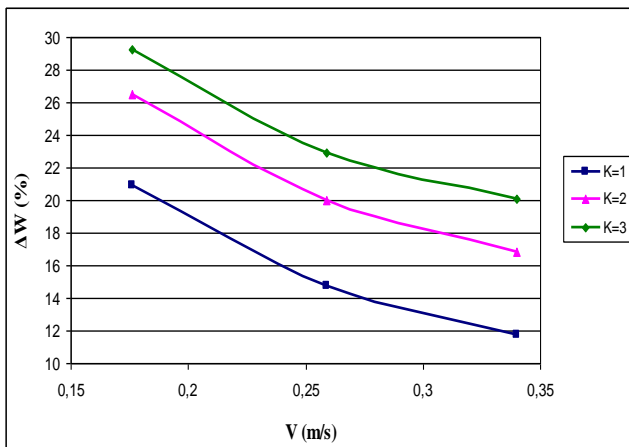
a)

b)

c)

Fig. 3. Dependences of the amount of squeezed moisture ΔW on passage velocity V of a semi-finished leather product between squeezing rolls at the pressure intensity: at $P = 32$ kN (a), $P = 64$ kN (b), $P = 96$ kN (c); $K = 1$, $K = 2$, $K = 3$ - the multiplicity of squeezing

The dependence graphs of the amount of squeezed moisture ΔW vs compression pressure P, passage velocity V, and squeezing speed K were obtained using the regression equation (Fig. 3).

V. RESULT

The experimental results show that (Table- III):

A. The minimum amount of moisture removed from the leather semi-finished product under single squeezing is 11.7%, and the maximum amount is 30.4% from the initial weight of the wet leather semi-finished product after liquid-based operation of chrome tanning.

B. Under double passage of the leather semi-finished product between squeezing rolls, the minimum amount of moisture removed is 20.2%, and the maximum amount is 33.8%.

C. Under triple passage of the leather semi-finished product between squeezing rolls, the minimum amount of moisture removed is 23.5%, and the maximum amount is 37.9%.

Table- III: The amount of moisture removed from the leather semi-finished product

Repeat moisture squeezing from a leather semi-finished product	Minimum amount of moisture removed, %	Maximum amount of moisture removed, %
Under single	11.7	30.4
Under double	20.2	33.8
Under triple	23.5	37.9
Mean	18.4	34

This means that the most rational option is to accept the results of the manufacturing process of moisture squeezing from a wet leather semi-finished product after a liquid chrome tanning process during its single squeezing (point A), since according to the requirements of the squeezing technology, the residual moisture in the leather semi-finished product should be within 55–60% of all its topographic sites.

VI. CONCLUSION

Thus, we have obtained the regression equation for the dependence of the amount of moisture removed on the parameters of claming force, passage velocity, and the multiplicity of squeezing of the leather semi-finished product by bending on a permeable base plate under vertical feeding.

The minimum amount of moisture removed under the second passage is 8.5%, and the maximum is 3.4% from the initial weight of the wet leather semi-finished product.

So, under single squeezing: at a minimum roll pressure - P_{min} and a maximum passage velocity V_{max} of the leather semi-finished product, its residual moisture content is ΔW_{min} =11.7%, and at P_{max} and V_{min} the maximum moisture removal is $\Delta W_{max} = 30.4\%$.

Under double squeezing: at a minimum roll pressure - P_{min} and a maximum passage velocity V_{max} of a leather semi-finished product, its residual moisture content is $\Delta W_{min} = 20.2\%$, and at P_{max} и V_{min} the maximum moisture removal is $\Delta W_{max} = 33.8\%$.

Under double squeezing, ΔW_{min} is 8.5%, and ΔW_{max}=4.4%.

Under triple squeezing: at a minimum roll pressure P_{min} and a maximum passage velocity V_{max} of a leather semi-finished product, its residual moisture content is $\Delta W_{min} = 23.5\%$, and at P_{max} и V_{min} the maximum moisture removal is $\Delta W_{max} = 37.9\%$.

Under triple squeezing, ΔW_{min} is 3.3%, and ΔW_{max}= 4.1%.

So, we have obtained technological parameters of squeezing of a wet leather semi-finished product to determine the minimum and maximum amounts of removed moisture ΔW_{min} and ΔW_{max} using a permeable cermet base plate under single, double and triple passage between the squeezing rolls.

The results of the experiments could be used in the tanning industry, namely in improving the manufacturing processes of moisture squeezing from wet leather semi-finished products on wringing roller machines after liquid-based processes.

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