Acta of Turin Polytechnic University in Tashkent, 2022, 31, 34-38
Published Online March 2022 in Acta TTPU (http://www.acta.polito.uz/)

EXPERIMENTAL DEHYDRATION OF WET SEMI-FINISHED LEATHER PRODUCTS ON A CERAMIC-METAL BASE PLATE

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Abstract– The article presents the results of an experimental study to determine the influence of such factors as the feed speed, the pressing force of the squeezing rollers on the amount of residual moisture content in the semi-finished leather product after the liquid chrome tanning operation. The experiments were conducted using a cermet base plate, on which one layer of the folded wet leather semi-finished product was previously put and fed vertically between rotating squeezing rollers. The D-optimal method of mathematical planning of the experiment with the K. Kano design matrix was used to conduct experiments. As a result of the study, a mathematical model was obtained for the dependence of the feed speed and the pressing force of the squeezing rollers on the amount of moisture extracted from a wet leather semi-finished product. The analysis of the results of experimental study showed that the use of a base plate made of cermet during squeezing a wet leather semi-finished product increases the efficiency of moisture extraction in comparison with a metal base plate.

Key words– experiment planning; wet leather semi-finished product; ceramic-metal base plate; squeezing rollers; pressure; speed; experiment.

I Introduction

The quality of the finished leather is influenced by all technological stages of processing, therefore, after the realization of each of them, it is necessary to analyze the condition of the leather semi-finished product [1,2,3]. In [4], the influence of the number of layers of leather and moisture-removing materials on the process of extracting moisture during their feed to a metal base plate made of steel 3 was investigated.

Experimental research in the leather industry is aimed at solving complex multifactorial problems, the result of which is determined by rational modes of technological processes for treating leather raw materials. The physical and mechanical properties of semi-finished leather products vary depending on their moisture content. Consequently, the process of extracting excess moisture from a semi-finished leather product after liquid processing substantially affects the quality of subsequent technological processes, for example, planing, splitting, drying [5-8].

This article is devoted to an experimental study of the effect of a cermet base plate on the efficiency of extracting moisture from a wet leather semi-finished product.

II Methods and results of experimental research

The experiment was conducted on a special test bench, where the squeezing rollers were installed horizontally, and the base plate was made of porous cermet material PP64S-250-25-76-40, 0.015 m thick, mounted on a metal guide rod, 0.1 m wide and 0.3 m long (Fig. 1). In the present study, a base plate made of porous cermet material was used. The base plate was turned from an abrasive wheel of the PP64S-250-25-76-40 brand of a universal, straight profile, based on silicon carbide. The percentage of the volume of abrasive grains per unit volume of the wheel is 40. The used material has a 20% porosity, which, at a certain feed rate is sufficient to extract moisture from the inner side of wet leather.

For engineering reasons, the minimum thickness of the base plate was calculated and chosen to be 0.015 m to ensure the required strength under the high pressure of the squeeze rollers. It should be noted that in industrial conditions, after each work shift, the cermet base plate should be rinsed with a pressure of warm water, just as the permeable coatings of the squeezing rollers are washed.

For the experiment, we took a bovine hide of medium weight, splitted, after chrome tanning. According to the International Standard ISO 2588-85, the required size of a leather semi-finished product was selected by the following formula

$$n = 0,2\sqrt{x} \qquad (1)$$

where x is the number of semi-finished leather products for the experiment; 2500 pieces were taken from the batch, so, n=10 pieces. From these 10 samples, 0.05×0.25 m strips were cut out with a cutter across the spine line; the numbered strips were assembled into groups of 5 pieces according to the scheme given in [9].

During the experiment, a wet leather semi-finished product 0.004 m thick was hung folded on a cermet base plate. Before and after squeezing, the samples were weighed on a VLTE-500 laboratory balance with discreteness of 0.01 g (ISO-9001).

The second-order D-optimal planning method with the K. Kano design matrix [10] was used.

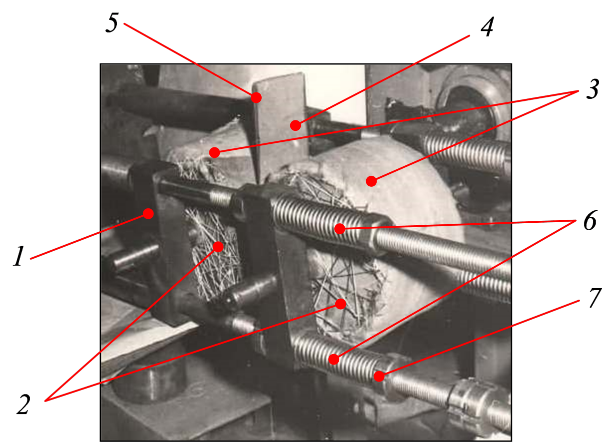

Fig. 1: Fragment of pressing machine for a semi-finished leather product on an experimental test bench: 1 – bed frame, 2 - squeezing rollers, 3 - roller coatings (monchon BM), 4 - semi-finished leather, 5 - cermet base plate, 6 - springs, 7 - tension nuts

On the basis of prior information, the process of moisture extraction was studied considering the following factors:x_1 - pressure intensity P, kN/m; x_2 - feeding speed V, m/s. Based on the analysis of various squeezing machines, the pressure range was selected from 32 to 96 kN/m; the rotation speed of the squeezing rollers was taken from 0.17 to 0.34 m/s; the number of semi-finished leather products was one.

The diameter of the squeezing rollers was 0.2 m and they were coated with 0.01 m thick moisture-removing material made of BM brand felt. Before conducting the experiment, the required number of measurements (the number of replicates) was selected by the methods of mathematical statistics, which ensured the required accuracy.

The working matrix was drawn up according to the K. Kano plan matrix for a two-factor experiment. Factors were encoded according to the formula

$$x_i = \frac{c_i - c_{i0}}{t_0} \tag{2}$$

where x_i is the coding of the factor values; c_i, c_{i0} are the natural values of the factor at the current and zero levels; t_0 is the natural value of the factor variation interval. The levels and intervals of variation of experiment factors are shown in **Table 1**.

Index	Coded value of factors	Natural values of factors	
		x_1, kN/m	x_2, m/s
Upper level	+	96	0.340
Zero level	0	64	0.255
Lower level	-	32	0.170
Variation interval		32	0.085

TABLE 1: LEVELS AND INTERVALS OF VARIATION OF EXPERIMENT FACTORS

Target functions are approximated by a polynomial

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i,j=1}^{k} b_{ij} x_i x_j + \sum_{i=1}^{k} b_{ii} x_i^2 \tag{3}$$

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

The homogeneity of the variance was realized using the Cochran test [10-12] at a confidence level of $\alpha = 0.95$. Knowing the total number of variances estimates N and the number of degrees of freedom f=k–1 from Table 3 [10], we determine $G_T = 0.358$, for N=9; f=k–1=5–1=4; k is the number of parallel experiments.

$$S_{er}^2 = \frac{\sum_1^n (y - \bar{y})^2}{n-1} \tag{4}$$

$$\sum_1^N S_i^2 = \frac{\sum_1^N \sum_1^n (y - \bar{y})^2}{N(n-1)} \tag{5}$$

$$G_{cal} = \frac{S_{max}^2}{\sum_1^N S_i^2} = \frac{0.4153}{1.7555} = 0.2365 < G_T = 0.358 \tag{6}$$

Consequently, the study results are reproducible.

We determine the regression coefficients b_0, b_i, b_{ij}, b_{ii} from Table 4 [10].

For a semi-finished leather product in coded form they are $b_0 = 18.3372$; $b_{11} = 1.0867$; $b_{22} =$ ˘0.8083; $b_1 = 3.7063$; $b_2 =$ ˘2.7359; $b_{12} =$ ˘0.3. We get the following coded regression equations: for semi-finished leather

$$y = 18.34 + 1.0867x_1^2 - 0.8083x_2^2 + \\ +3.7063x_1 - 2.7359x_2 - 0.3x_1x_2 \tag{7}$$

TABLE 2: EXPERIMENT PLANNING MATRIX

№	P, x_1	V, x_2	Measurement results, in %						$\sum_1^n(y-\bar{y})^2$	S_{er}^2	y_{cal}	$\bar{y}$-y_{cal}	$(\bar{y}$-$y_{cal})^2$
			y_1	y_2	y_3	y_4	y_5	$\bar{y}$					
1	0	0	18.53	18.61	18.36	18.20	18.55	18.50	0.1311	0.0327	18.34	0.16	0.0256
2	+	+	19.39	18.77	18.78	20.11	19.47	19.30	1.2444	0.3111	19.29	0.01	0.0001
3	-	+	11.65	13.13	13.02	12.26	12.45	12.50	0.4499	0.1124	12.48	0.02	0.0004
4	-	-	17.15	17.5	17.53	16.95	17.86	17.40	0.6035	0.1508	17.30	0.1	0.001
5	+	-	26.33	25.55	25.26	24.98	24.89	25.40	1.3435	0.3358	25.36	0.04	0.0016
6	+	0	22.62	23.23	23.36	23.10	22.98	23.06	0.3205	0.0801	23.13	0.07	0.0049
7	0	+	14.16	15.60	14.46	14.86	14.68	14.75	1.1563	0.2891	14.80	0.05	0.0025
8	-	0	15.60	15.63	15.80	15.43	15.44	15.60	0.1114	0.0278	15.72	0.12	0.0144
9	0	-	20.74	20.18	20.57	19.09	20.02	20.12	1.6614	0.4153	20.27	0.15	0.0225
									$\sum 7.022$	$\sum 1.755$			$\sum 0.082$

Substituting $x_1 = \frac{P-64}{32}$, where$P$ is the pressing force of the squeezing rollers and $x_2 = \frac{V-0.255}{0.085}$, where V is the feed speed of wet leather semi-finished products between the rotating squeezing rollers, we obtain the equations for the amount of moisture removed from wet leather semi-finished products between the rotating squeezing rollers in a natural form.

After the implementation of the working matrix, the arithmetic mean values were obtained (Table 2).

III ANALYSIS OF THE RESULTS

The hypothesis of the adequacy of the equations obtained was tested using Fisher's variance ratio at a confidence level of $\alpha = 0.95$ [10-14].

$$F_{cal} = \frac{S_{ad}^2}{S^2\{y\}} < F_T \quad (8)$$

where S_{ad}^2 is the residual variance or the variance of adequacy; $S^2\{y\}$ - is the variance of reproducibility.

S_{ad}^2 and $S^2\{y\}$ are defined from **Tables 1, 2,** and **3**.

$$S_{ad}^2 = \frac{\sum_1^N n(\bar{y}-y)^2}{\frac{N-(x+2)(x+1)}{2}} = \frac{5 \cdot 0.082}{3} = 0.1366 \quad (9)$$

$$S_{\{y\}}^2 = \frac{\sum_1^N \sum_1^n (y-\bar{y})^2}{N(n-1)} = \frac{7.022}{36} = 0.1950 \quad (10)$$

Fisher's variance ratio of the model adequacy is:

$$F_{cal} = \frac{S_{ad}^2}{S^2\{y\}} = \frac{0.1366}{0.1950} = 0.70 < F_T = 2.880 \quad (11)$$

where N – is the total number of experiments; k is the number of factors; n is the number of experiment repetitions; y_i is the result of a separate observation; $\bar{y}$ is the arithmetic mean of the results of the experiment; y_p is the calculated values of the criterion according to the regression equation.

So, the regression equation can be considered suitable with a 95% confidence level, which in the named form after decoding has the following form: for semi-finished leather:

$$\triangle W = 10.006 + 0.001P^2 - 111.875V^2 - 0.0403P + \\ +17.8165V - 0.1102PV \quad (12)$$

A dependence graph of the amount of extracted moisture $\triangle W$ (12) from a wet leather semi-finished product in percentage at different feed speeds V and pressing forces P (Fig. 2) is built.

Comparative analysis of the efficiency of pressing a wet leather semi-finished product on a porous cermet base plate versus a metal base plate showed the difference in the amount of removed moisture $\triangle W$ by an average of 7%.

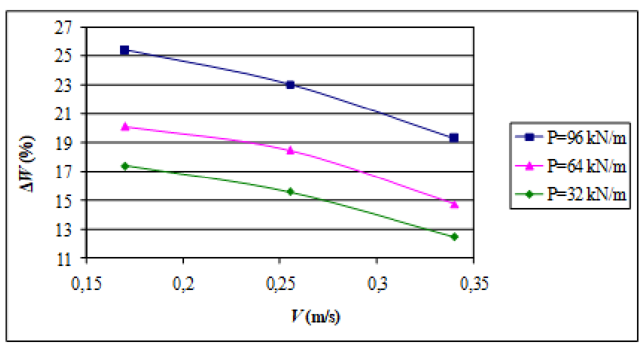

Fig. 2: Dependence of the amount of extracted moisture $\triangle W$ on the feed speed V of the semi-finished leather product with the following values of the pressing force of the squeezing rollers: P=32 kN/m, P=64 kN/m, P=96 kN/m

Consequently, in this case, it is possible to reduce the values of the pressing force between the squeezing rollers and it is recommended in vertical squeezing roller machines to use base plates made of hard porous materials in order to increase the productivity of the technological process.

TABLE 3: DETERMINATION OF REGRESSION COEFFICIENTS

№	P, x_1	V, x_2	Coefficient multipliers						
			b_0	b_{11}	b_{22}	b_1	b_2	b_{12}	$\bar{y}$
1	0	0	0.5772	-0.3234	-0.3234	0	0	0	18.50
2	+	+	-0.1057	0.1691	0.1691	0.1961	0.1961	0.25	19.30
3	-	+	-0.1057	0.1691	0.1691	-0.1961	0.1961	-0.25	12.50
4	-	-	-0.1057	0.1691	0.1691	-0.1961	-0.1961	0.25	17.40
5	+	-	-0.1057	0.1691	0.1691	0.1961	-0.1961	-0.25	25.40
6	+	0	0.2114	0.1617	-0.3383	0.1078	0	0	23.062
7	0	+	0.2114	-0.3383	0.1617	0	0.1078	0	14.750
8	-	0	0.2114	0.1617	-0.3383	-0.1078	0	0	15.60
9	0	-	0.2114	-0.3383	0.1617	0	-0.1078	0	20.12

IV CONCLUSIONS

Analysis of the experimental results (Fig. 2) shows that it is possible to increase the productivity of moisture extraction from semi-finished leather products by increasing the extraction speed on a base plate made of porous cermet material PP64S-250-25-76-40. The results of the experiments show that the removal of moisture at the pressing force P=32 kN/m of the squeezing rollers, the maximum feed speed is slightly less than V=0.34 m/s. At the pressure of the squeezing rollers P=64 kN/m, the maximum feed speed is more than V=0.34 m/s. At the pressure of the squeezing rollers of a roller machine P=96 kN/m, the feed speed is substantially higher than 0.34 m/s. The experiment showed that the moisture removed in excess of the required 13% is from 6 to 1.75% of the initial weight of the leather semi-finished product. Consequently, it will be possible to squeeze out moisture from wet leather semi-finished products at the feed speed of more than 0.34 m/s with the pressing force of the squeezing rollers from 64 to 96 kN/m.

In the future, the maximum speed of moisture extraction from semi-finished leather products of more than 0.34 m/s will be experimentally determined with the proposed design of the base plate in the form of a cermet material PP64-250-25-76-40 with a thickness of 0.015 m and at pressing forces from 64 to 96 kN/m.

The use of the proposed structure as a base plate made of porous cermet material provides moisture removal without fibrous porous materials that wear out quickly. This will increase the efficiency of the technological operation of extracting excess moisture from the wet leather semi-finished product.

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