Experımental determination of the breakaway force of working rolls when processing semi-finished products

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Abstract. The effect of varying the number of layers of a semi-finished product, that is, its thickness, and the pressing force between the working rolls on the breakaway force of a multi-layer package of semi-finished products is experimentally investigated in the article. The dependence of the required breakaway force of the working rolls on the change in the number of layers of semi-finished products supplied for mechanical processing between the working rolls at different pressure forces was experimentally determined. The values of the required breakaway force for the working rolls at the established values of the pressing force of the working rolls for packages consisting of five, ten, and sixteen layers of semi-finished products were obtained.

1 Introduction

At present, the leather and footwear industry of the Republic of Uzbekistan is dynamically developing and the production volumes of finished leather and leather products are annually increasing. Today, the leather and footwear industry is becoming one of the leading industries not only in Uzbekistan but also in Central Asian countries.

The Resolution of the Cabinet of Ministers of the Republic of Uzbekistan “On the creation of small industrial zones specializing in the production of leather, footwear and fur products” dated September 27, 2022, No. 531 approved the tasks of organizing small industrial zones in the regions of the Republic specializing in leather processing, production of finished leather, footwear, fur and import-substituting products [1]. Based on local leather raw materials, more than 1344.2 million square decimeters of finished leather are produced annually in Uzbekistan [2].

The annual worldwide total production of leather from the hides of cattle and small ruminants is more than 1,700 square kilometers. Of these, North America produces 5% of leather from the hides of cattle and 2% from small ruminants, South America - 29% from cattle and 4% from small ruminants, Europe - 17% from cattle and 14% from small ruminants, Africa - 3% from cattle and 10% from small ruminants, Russia - 9% from cattle

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and 2% from small ruminants, and Asia - 35% from cattle and 67% from small ruminants [3].

The problems of improving the quality of leather industry products are solved on the basis of achievements of scientific and technological progress through further technical re-equipment of leather-processing enterprises, the development of effective technologies, the introduction of innovative technologies, and the automation of raw material processing. At the same time, the experience of leading enterprises in the leather industry shows that the improvement of equipment operating in the industry is a significant reserve for improving the quality of produced leather [4].

Technological processes for the production of leather and fur raw materials are based on the implementation of chemical, physical-chemical, and mechanical processes that occur during the processing of hides of cattle and small ruminants to obtain finished products with high-quality indices at the lowest material and labor costs. Technological processes are improved as theoretical research develops, practical experience is gained, and processing and technological machines are improved. The known technological stages for processing raw hides cannot be considered ideal, since all of them can be improved and replaced by new, more efficient, and technically safe equipment [5].

Modern research on the mechanical processing of leather and fur raw materials quite objectively explains the process of leather and fur production and makes it possible to improve these processes by obtaining high-quality finished leather and fur products with higher value added. The processes of modern leather and fur production are divided into two groups. The first group includes chemical and physicochemical processes, and the second group includes processes of mechanical impacts on semi-finished products.

The quality indices and properties of leather and fur depend on the nature of the raw materials and on the impact of the entire set of chemical, physical-chemical, and mechanical processes on the raw materials and semi-finished products. Chemical and physical-chemical processes affect the condition and structure of raw materials. Therefore, improving the quality of leather and fur requires in-depth research into all processes, including the chemical aspects of leather and fur production. Technological processes for tanning leather and fur are realized in the practical application of the fundamentals of physics, mechanics, and other related sciences.

Today, many research and development projects address issues of increasing the efficiency and quality of a certain technological process but not several technological processes; this does not contribute to improving the quality of the finished product.

When creating technological machines for manufacturing industries, in particular, in tanneries, during the operations of squeezing fluid out of semi-finished leather products on a roller-squeezing machine, it is necessary to determine the required breakaway force for the pairs of working rolls [6–15].

Therefore, it is necessary to determine the energy consumption depending on the change in the number of layers of semi-finished products at the set values of the pressing force of working rolls. Until now, there was no such experimental data on the dependence of energy consumption on the number of layers of semi-finished products. In the first stage of the experiment, we determined the breakaway forces when increasing the number of layers of semi-finished products in a package when feeding it between the working rolls [16–20].

2 Material and method of research

A roller test bench was constructed to conduct experiments. The experimental bench of the roller machine (Fig. 1) consists of 4 kW DC electric motor 1, RChU-40 worm gearbox 2, chain 3, a drive for the lower squeezing roll, gears 4, 5 for transmitting rotation from lower roll 13 to upper roll 12. Four cylindrical guide posts 7 are attached to plate 6, on which four supports 9, 11 of the lower and upper rolls are installed. Squeezing rolls 12, 13 are mounted on supports 9, 11 using rolling bearings [12–14].

The working rolls are shown in Fig. 3; the diameter of the working rolls is D_{sh}=0.2 m; the lever arm is L=0.535 m [15].

For the experiment, samples of the semi-finished product were selected in accordance with the International Standard ISO 2588-85 (Leather. Sampling, number of samples for the total sample, 2003. Updated 01/01/2019) according to the following formula [16, 26]:

$$n = 0.2\sqrt{x} \tag{1}$$

where x is the number of semi-finished leather products in a batch, n is the number of semi-finished leather products for the experiment.

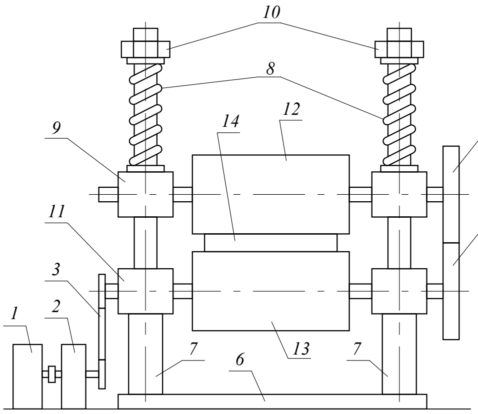

Fig. 1. Scheme of the test bench of the squeezing machine

Then, x=2500 pieces of semi-finished leather product were taken, and 10 pcs. were obtained. From these semi-finished leather products, 0.05×0.25 m strips were cut out with a cutter across the ridge line and numbered using the asymmetric fringe method; then the samples were arranged into groups of 10 pieces according to the scheme [26] (Fig. 2). The average thickness of the semi-finished product was 0.005 m [9–11, 26–29].

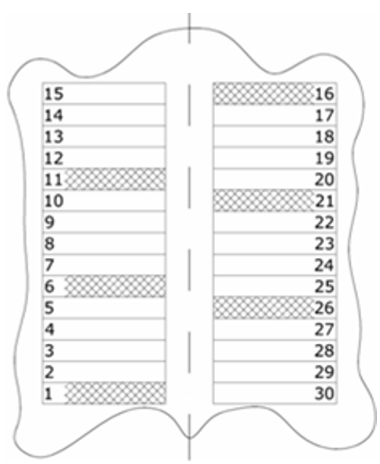

Fig. 2. Scheme of arranging samples of semi-finished leather products into groups [26]

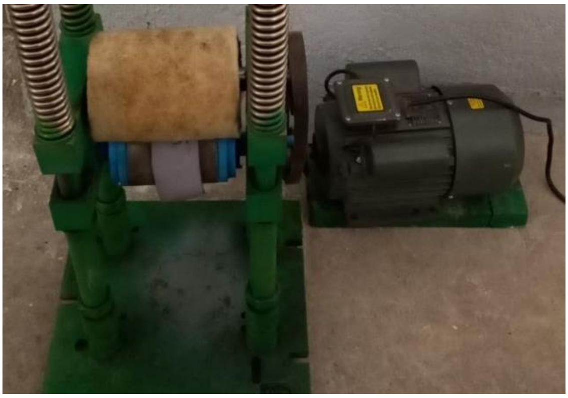

Fig. 3. Test bench of a roller-squeezing machine

From these 10 semi-finished leather products, 0.10 × 0.35 m strips were cut out with a cutter across the ridge line and numbered, and the strips were arranged into groups of 10 pcs. according to the scheme [16–26].

3 Results

The mechanism of the process of fluid squeezing from the full-scale system has not been sufficiently studied; the equation describing this phenomenon is unknown, complete modeling is not possible, especially since the fluid flow through the porous roll has not been studied. Complete modeling of the process of removing water from a semi-finished product using roller-squeezing machines is impossible; so a partial modeling analysis was performed. Consider, for example, the length of the squeezing rolls

Table 1. Dependence of the breakaway force of the working rolls P_{br} at a 5-layer leather package on the pressure of the working rolls P_{pr} between the rolls

Pressure of working rolls P_{pr}, kN/m	32	48	56	64
Breakaway force of working rolls, P_{br}, kN	3.5	4.3	6.1	1.8

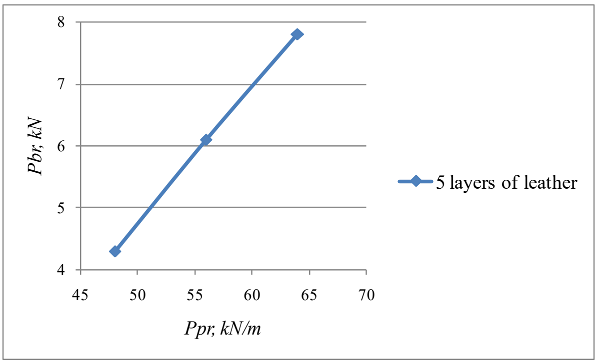

Fig. 4. Graph of changes in the resistance force of leather when squeezing fluid from 5 layers of semi-finished leather product after chrome tanning

When simulating the length of the roll on a bench, its dimensions can be significantly reduced. We study the influence of the roll length on the squeezing process by varying the width of the semi-finished product fed for squeezing during the experiment. It is impractical to model the feed rate (or to reduce/increase it) on a bench compared to the full-scale machine as this effect is not studied. It also makes no sense to model the pressure of rolls because this phenomenon has not been sufficiently studied. In this regard, on the experimental bench, the diameters of the rolls and all simulated parameters are taken as in a full-scale machine, except for the length of the rolls (the influence of the roll length on the process of fluid squeezing is studied below when choosing the width of the sample of semi-finished product). Considering the above, the following parameters of the test bench were selected: the diameter of the pressing rolls is 0.2 m, and their length is 0.1 or 0.15 m.

Table 2. Dependence of the breakaway force of the working rolls P_{br} at a 10-layer leather package under the pressing force between the rolls P_{pr}

Pressure of working rolls P_{pr}, kN/m	32	48	56	64	80
Breakaway force of working rolls, P_{br}, kN	4.5	5.1	6.4	8.8	9.5

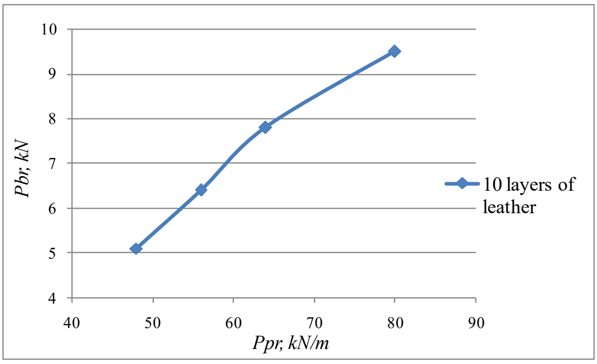

Fig. 5. Graph of changes in the breakaway force of resistance when squeezing water out of 10 layers of semi-finished leather product after chrome tanning.

The lever was installed horizontally, and then the free end of the lever was hooked with a dynamometer and pulled up; the breakaway forces were determined on an electronic dynamometer with an accuracy of 0.05 N (Fig. 2).

Table 3. Dependence of the breakaway force of the working rolls P_{br} at a 16-layer leather package under the pressing force between the rolls P_{pr}

Pressure of working rolls P_{pr}, kN/m	32	48	56	64	80
Breakaway force of working rolls, P_{br}, kN	6	7.8	8.5	10	11.2

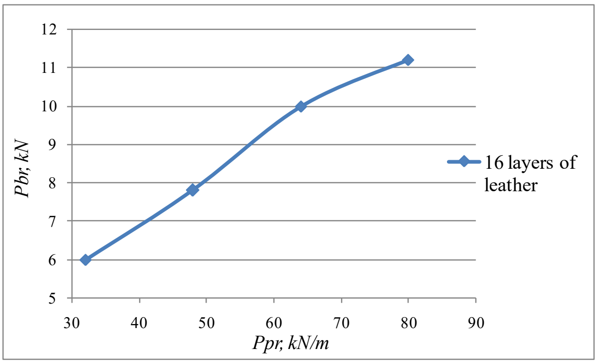

Fig. 6. Graph of changes in the breakaway force of resistance of a semi-finished leather product when squeezing out water from 16 layers of leather after chrome tanning.

Table 4. Dependence of the breakaway force of the working rolls P_{br} on the change in the number of leather layers in the package under the pressing force between the rolls P_{pr} =32 kN/m

Pressure of working rolls P_{pr}, kN/m	1	2	3	5	10	16
Breakaway force of working rolls, P_{br}, kN	2.0	2.5	3.0	3.5	4.5	6.0

To justify the width of the samples of semi-finished products according to the method developed, samples were fed in groups of 10 pcs. at a pressing force of the working rolls 32; 48; 64; 80 kN/m, (combining a pair of working rolls; two working rolls with cloth coating (monchons); upper roll with monchon); and the length of the lever was 0.535 m.

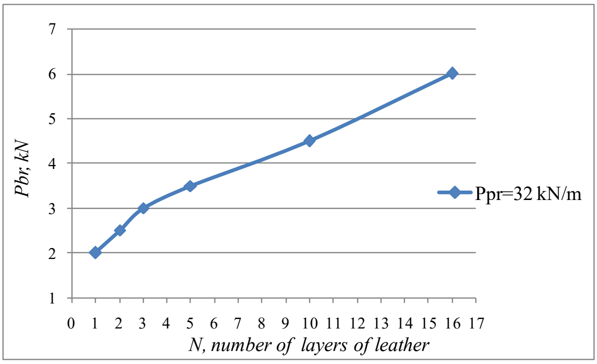

Fig. 7. Graph of changes in the resistance force of a semi-finished leather product when squeezing out water depending on the number of layers of leather at a pressing force of the working rolls – 32 kN/m.

The experiment was conducted as follows. A test bench was constructed. A semi-finished leather product was fed between the working rolls.

Then, tightening the nuts, the springs were compressed to the required pressure. Previously all springs were calibrated with weights and the relationship between the mass of the weights and the value of deformation was determined (Tables 1–2).

Thus, the breakaway force was determined and recorded at different pressing forces of the working rolls and different numbers of layers of the semi-finished leather product; see graphs in Figs. 4–6.

4 Conclusion

The following values of the required breakaway force of the working rolls at the set values of the pressing force of the working rolls for the packages consisting of five, ten, and sixteen layers of semi-finished products were obtained by authors in laboratory conditions on a test bench:

1. By varying the pressing force of the working rolls of a 5-layer leather package from 48 to 80 kN/m, the breakaway force of the working rolls increased from 4.2 to 7.8 kN/m, and the torque on the working rolls increased from 44.94 to 83.46 kN/m.
2. By varying the pressing force of the working rolls of a 10-layer leather package from 48 to 80 kN/m, the breakaway force of the working rolls increased from 5 to 9.5 kN/m, and the torque on the working rolls increased from 53.5 to 101.66 kN/m.
3. By varying the pressing force of the working rolls of a 16-layer leather package from 32 to 80 kN/m, the breakaway force of the working rolls increased from 6.0 to 11.2 kN/m, and the torque on the working rolls increased from 64. 2 to 119.84 kN/m.
4. The breakaway force of a 16-layer leather package is 3 times greater than that of a 2-layer leather package at the pressing force of the working rolls 32 kN/m.

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