Conditions for vertical pulling of semi-finished leather products under driving rollers

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Abstract. The conditions for the vertical pulling of a semi-finished leather product laid bent on a transporting base plate between rotating squeezing rollers are theoretically investigated in the article for the first time. At that, an important role is played by the value of the radii of the squeezing rollers, installed in one row in the horizontal plane, and the value of the corner radius of the front part of the transporting base plate. If the value of the corner radius and the thickness of the base plate are large, then when it contacts the squeezing rollers, a significant frontal resistance arises. Thus, to derive the conditions for gripping the semi-finished leather product between the rotating squeezing rollers, the pulling-in force of the traction chains, the normal pressure force of the squeezing rollers, the coefficient of friction between the rotating squeezing rollers and the leather semi-finished product are taken into account. The condition for the vertical pulling of the semi-finished leather product laid on the base plate is determined, taking into account the coefficient of friction between the semi-finished leather product and the squeezing rollers when they come into contact.

1 Introduction

The variety of technological processes performed by roller technological machines has not allowed until now to create a unified system for their calculation and design, due to the difference in technological requirements and physical and mechanical phenomena occurring in the contact zone of the rollers with the material being processed.

To remove excess moisture after tanning, the squeezing of hides takes place: hard hides are squeezed out on hydraulic presses, chrome-plated hides - on roller machines. Operators do this operation. When working on hydraulic presses, several dozen layers of leather are stacked piece by piece on a hydraulic press plate. Dissembling the hides after pressing requires great physical effort from the operators, as they are pressed into a strong briquette. This operation can be greatly facilitated if each layer of hides is laid on metal gratings that prevent them from sticking together. Pressing the hide on roller machines of a non-throughput type for press operators is also associated with significant physical efforts. Taking wet hides from the "trestles", the operator (like the machinists of the ash shops)

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twice throws them onto the rollers of machine. However, such machines have a small height of the working plane from the level of the platform on which the operator stands, so he does his work in an inclined (up to 25–30°) position. It takes from 30 to 40 seconds to squeeze out one medium-sized hide. With a good organization of work, operational time, i.e. the time of machine-manual processing of a hide is from 94 to 96%. In quantitative terms, this means the processing of 1500 to 4500 hides, or from 7 to 15 tons of semi-finished leather products [1].

Consider the issues devoted to the improvement of technology and equipment for leather and fur processing.

In [2], the current trend in the development of the production of leather goods in developed countries was considered and various factors that affect the operation of enterprises were analyzed. One of the factors is the timely technological modernization of leather equipment in tanneries, the absence of which will negatively affect sustainable development.

The authors of [3] studied various types of shoe leather made from the hides of cattle and small ruminants. Various leather samples were used in the study and their tensile strength, elongation, tear strength, vapor permeability, bending wear resistance, abrasion resistance, perspiration resistance, color abrasion resistance, adhesion strength, and other physical, mechanical, and chemical properties were studied. The conclusions made, showed that in order to improve the quality of finished leather, it is necessary to improve the accuracy of leather testing.

In [4], a 21-year (2000–2021) review and analysis of studies on the treatment of wastewater from the leather industry were presented. Complex and combined methods of wastewater treatment were analyzed, which, to the authors' opinion are more promising. Besides, integrated treatment methods were recommended in that article to achieve the required efficiency of decontamination of chromium deposits. Therefore, the process of extracting excess moisture from a semi-finished leather product after liquid processing significantly affects the quality of subsequent technological operations, for example, planing, splitting, and drying [5–10].

The study in [11] is devoted to the influence of technological and other factors on the physical-mechanical, filtration, and quality properties of a leather semi-finished product. The development of methods and the improvement of means for studying the physical and mechanical properties of fibrous-porous materials were considered in the dissertation [12]. In [13], the dynamic loading of a roll pair was studied to intensify the pressing processes. The article [14] analyzes the influence of factors on the specific pressure in the roller nip of the module. As a result of experimental studies, the graphs of these dependencies were determined and a mathematical model was built. The study in [15] defines the conditions for the strip pulling-in in the output devices, where the fibrous material is pulled between the roll and the surface. The author of that article determined that in order to reliably pull the strip under the working roller, the value of the friction coefficient of the strip against the base should be as small as possible.

Publications of foreign scientists are devoted to modern methods of research and analysis of the properties of leathers and hides [16–18]. The issues of improving the design of roller equipment, including the study of the interaction of the roll module with the processed material, are described in [19–22].

The dependences of the sliding friction coefficient of the rollers on the frequency of their rotation and friction were experimentally established in [23]. The authors of that paper determined that the coefficients of friction of metal roller with coatings made of rubber, polyurethane, and wool increase to a maximum value with an increase in the speed of rotation of the drive roller, and then stabilize at a constant level.

For squeezing wet leathers, roller machines of non-throughput and throughput types are used. The most promising machines are the throughput ones with a vertical feed of the semi-finished leather product bent on the base plate since they combine all the advantages of other types of technological machines. As the leather semi-finished product is bent, the passage time is halved, and the feed from the bottom upwards increases the efficiency of removing moisture from the leather semi-finished product and improves the working conditions of operators. The quality of processing is especially improved when squeezing from the middle of the semi-finished leather product, as it is done in non-throughput roller squeezing machines. The setting of semi-finished leather from the bottom upwards also improves the process of removing and straightening wrinkles, creases, and folds.

When studying the parameters of a roller machine for squeezing moisture out of a semi-finished leather product with its vertical feed on a base plate, the following problems arise:

– to investigate the condition of gripping the semi-finished leather product by roll pairs at vertical feed on the base plate;

– to study the process of squeezing moisture out of a semi-finished leather product for different types of squeezing rollers and base plates;

– to consider the process of straightening the semi-finished leather product by setting rollers;

– to develop and investigate the squeezing unit;

– to develop and investigate the feeder for vertical feed;

– to study the process of feeding and removing semi-finished leather products;

– to investigate and substantiate the parameters of the base plate;

– to investigate the drive of the machine for squeezing moisture out of a wet semi-finished leather product at its vertical feed on the base plate.

Consider the dynamics of a squeezing machine with a vertical feed of a semi-finished leather product.

2 Material and method of research

Consider the process of gripping the material by squeezing rollers. Let us study the gripping of a semi-finished leather product at its vertical feed on the base plate between squeezing rollers. Let us assume that pressing force P is constant. The leather semi-finished product is brought to the rotating rollers on the base plate and touches the rollers with leading edges. The gripping conditions determine whether a grip will occur or not. If pulling force Q is small, then the grip will be free. At the points of contact from the side of the rollers, normal pressure force N and friction force T act on the semi-finished leather product (Fig. 1).

Let us assume that force Q pulling the leather semi-finished product in, is directed along the movement of the base plate. Friction forces T and normal pressure forces N act on the semi-finished leather product at the points of contact with the squeezing rollers. In addition, here it is necessary to take into account the gravity of the base plate G_{pl} and of the semi-finished leather product itself G_l [14, 23].

The friction force tends to pull the semi-finished leather product into the bite of the squeezing rollers, and the forces of normal pressure prevent this if the squeezing rollers are driven.

In the scheme under consideration, when the hide is vertically fed into the squeezing zone, the gravity forces of the plate G_{pl} and the hide's own weight G_l prevent gripping. To realize a normal grip, it is necessary that the vertical components of the friction forces be greater than the vertical components of the forces of normal pressure, the gravity forces of the plate G_{pl} and the own weight of the semi-finished leather product G_l, i.e. when the force equilibrium equation has the following form

$$2T_y = 2N_y + G_{pl} + G_l \tag{1}$$

Now let us consider a special case when the semi-finished leather product is fed vertically into the pressing zone on a base plate with driving working rollers.

1. Consider the initial zone of gripping the leather semi-finished product by the base plate (Fig. 1).

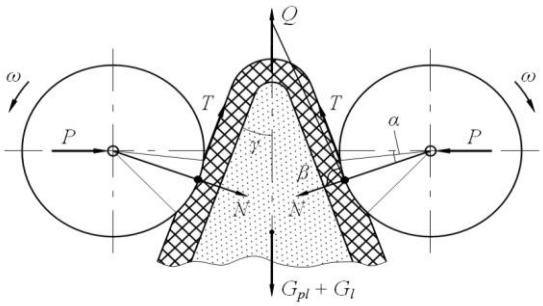

Fig. 1. Scheme of the initial zone of gripping the semi-finished leather product on a base plate between rotating squeezing rollers.

$$2N_y + G_{pl} + G_l = 2T_y + Q \tag{2}$$

It is known that $N_y - N\sin\alpha, T_y = f_{gr}N,$ then (2) takes the following form

where f_{gr} is the coefficient of friction, which ensures the fulfillment of the condition for gripping the semi-finished leather product with the base plate between the rotating squeezing rollers.

$$2N\sin\alpha + G_{pl} + G_l = 2N \cdot f_{gr} \cdot \cos\alpha + Q \tag{3}$$

from (3)

$$f_{gr} = \frac{G_{pl} + G_l - Q}{2N\cos\alpha} + tg\alpha \tag{4}$$

The gripping condition is expressed by the following relationship

$$f_{gr} \geq \frac{G_{pl} + G_l - Q}{2N\cos\alpha} + tg\alpha \tag{5}$$

if $Q = G_{pl} + G_l,$ then $f_{gr} \geq tg\alpha$

$$f_{gr1} \geq \frac{G_{pl} + G_l - Q}{2N\cos(\beta + \gamma)} + tg(\beta + \gamma) \tag{6}$$

2. Next, consider the process of gripping the semi-finished leather product in the transition zone with the base plate (Fig. 2) [7].

The equilibrium equation of vertical forces has the following form:

$$Q + 2T_y = 2N_y + G_{pl} + G_l \tag{7}$$

$$Q + 2N f_{gr} \cos\alpha = 2N \sin\alpha + G_{pl} + G_l \tag{8}$$

Substituting (β+γ) instead of α, we obtain

$$f_{gr} = \frac{G_{pl} + G_l - Q}{2N \cos\alpha(\beta_1 + \gamma)} + tg(\beta_1 + \gamma) \tag{9}$$

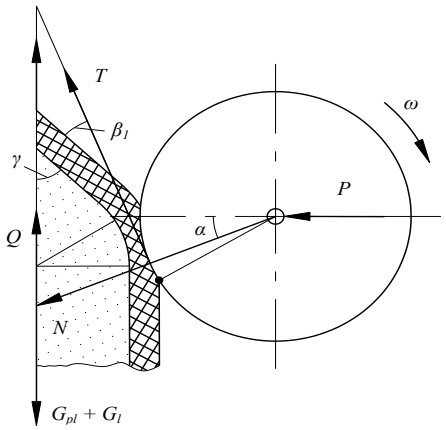

Fig. 2. Scheme of gripping the semi-finished leather product on the base plate between the rotating squeezing rollers in the transition zone.

The gripping condition in the considered transition zone has the following form

$$f_{gr2} \geq \frac{G_{pl} + G_l - Q}{2N \cos(\beta_1 + \gamma)} + tg(\beta_1 + \gamma) \tag{10}$$

3. Let us consider the condition for gripping the semi-finished leather product during the steady-state squeezing process (Fig. 3), [20].

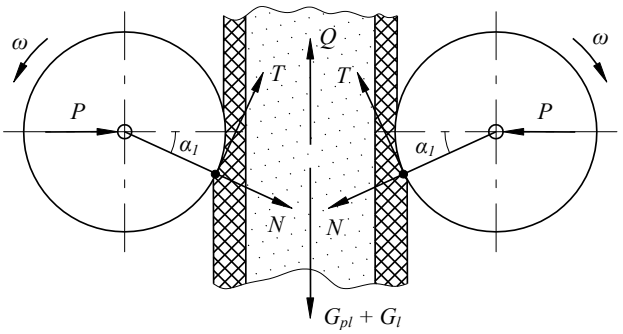

Fig. 3. Scheme of the semi-finished leather product exit from the gripping zone with the base plate between rotating squeezing rollers.

The equilibrium equation of acting forces is:

$$2T_y + Q = 2N - G_{pl} + G_l \tag{11}$$

taking into account the value of T_y and N_y, (11) has the following form:

$$f_{gr} = \frac{G_{pl} + G_l - Q}{2N\cos\alpha_1} + tg\alpha_1 \tag{12}$$

Hence, the condition for a steady-state process of motion at the stage of a steady squeezing is

$$f_{gr3} \geq \frac{G_{pl} + G_l - Q}{2N\cos\alpha} + tg\alpha_1 \tag{13}$$

if, $G_{pl} + G_l = Q$, then $f_{gr} \geq tg\alpha$.

4. Finally, we consider the last zone of squeezing - when the semi-finished leather product exits the gripping zone (Fig. 4), [14, 23].

The equilibrium equation of all forces acting on the system is

$$Q + 2N_y = 2T_y + G_{pl} + G_l \tag{14}$$

$$Q + 2N\sin\alpha_2 + 2N f_{gr} \cdot \cos\alpha_2 = G_{pl} + G_l \tag{15}$$

Here, $\alpha_2 = \gamma_1$, in this case, the gripping condition in the zone of exit from the contact of the base plate with the rollers is:

$$f_{gr4} \geq \frac{G_{pl} + G_l - Q}{2N\cos\gamma_1} - tg\,\gamma_1 \tag{16}$$

if, $G_{pl} + G_l = Q$, then $f_{gr} \geq -tg\,\gamma_1$

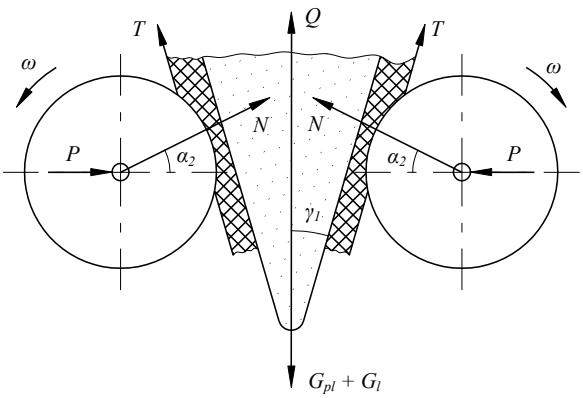

Fig. 4. Scheme of the semi-finished leather product exit from the gripping zone with the base plate between rotating squeezing rollers.

Thus, to ensure reliable vertical pulling of the semi-finished leather product under the driving squeezing rollers, it is necessary to meet the conditions described by expressions (6), (10), (13), (16).

3 Results

Equations should be centred and should be numbered with the number on the right-hand side.

Based on the results of theoretical studies, we have derived the conditions for gripping a semi-finished leather product with a base plate by squeezing rollers in the initial zone (6), in the transition zone (10), in a steady-state process (13) and in the zone of a semi-finished leather product exit from a base plate between rotating squeezing rollers (16).

1. The derived formula (6) can be called the condition of forced initial gripping. As seen from formula (6), during the process of forced gripping in the initial zone, the limiting value of friction coefficient fgr1 depends not only on the gripping angle α, but also on the value of the pulling force of the transporting chain Q and on contact pressure N.

2. The derived formula (10) can be called the condition of forced gripping in the transition zone. As seen from formula (10), during the process of forced gripping in the transition zone, the limiting value of friction coefficient f_{gr2} depends not only on the gripping angle α, but also on the magnitude of the pulling-in force of the transporting chain Q and on contact pressure N in the transition zone.

3. The derived formula (13) can be called the condition of forced gripping for a steady process. As seen from formula (13), in the steady-state process of forced gripping, the limiting value of friction coefficient f_{gr3} depends on the gripping angle α 1and on contact pressure N, the pulling-in force of the transporting chain Q, the weight of the base plate G_{pl} and the weight of the semi-finished leather product G_l.

4. The derived formula (16) can be called the condition of forced gripping in the exit zone of the semi-finished leather product with the base plate between the rotating squeezing rollers.

As seen from formula (16), at the exit from the zone of forced gripping, the limiting value of friction coefficient f_{gr4} depends on the gripping angle α_2, the value of contact pressure N, and the pulling-in force of the transporting chain Q.

It should be noted that at a small value of friction coefficient f_{gr}, forced gripping would be realized at high pulling forces of transporting chain Q.

Fig. 5 shows the dependence of the change in the griping angle – α_{gr} on the number of layers of semi-finished leather products – n, laid bent on the base plate, which is non-linear; the dependence is obtained for the following initial data: the radius of the squeezing rollers R=160 mm, the thickness of the base plate t_{pl}=5 mm, the thickness of the semi-finished leather product t_l=4 mm, the pressure of the squeezing rollers P=0.96 kN/mm.

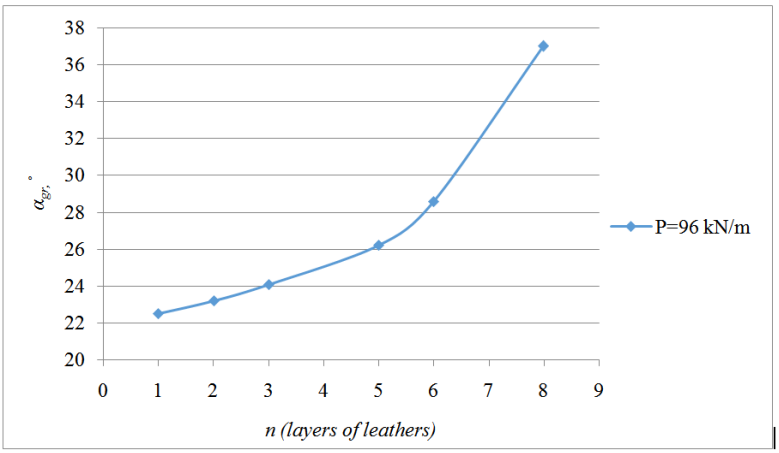

Fig. 5. Graph of the dependence of the gripping angle on the number of semi-finished leather products laid in layers on the base plate.

From the graph in Fig. 5, it can be seen that with the number of layers of semi-finished leather products from 1 to 3, the value of the gripping angle increases slightly, and when the number of semi-finished leather products increases from 3 to 8, the gripping angle gradually increases.

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Fig. 6 shows the dependence of the change in the contact width – b, formed between the squeezing rollers and the pulled-in semi-finished leather product (with a base plate) on the number of layers of semi-finished leather products – n, laid bent on the base plate, which has a non-linear character; the dependence is obtained for the following initial data: the radius of the squeezing rollers R=160 mm, base plate thickness t_{pl}=5 mm, the thickness of the semi-finished leather product t_l=4 mm, squeezing roller pressure P=0.96 kN/mm.

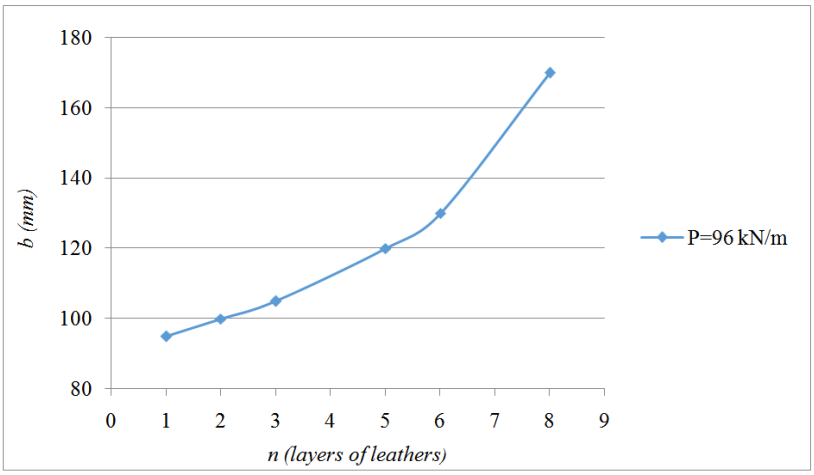

Fig. 6. Graph of the dependence of the contact width on the number of semi-finished leather products laid in layers on the base plate.

From the graph in Fig. 6, it can be seen that with the number of layers of semi-finished leather products from 1 to 3, the value of the contact width b increases slightly, and with a further increase in the number of semi-finished leather products from 3 to 8, the contact width increases sharply.

4 Conclusion

Thus, we have investigated the conditions for gripping the semi-finished leather product by driving squeezing rollers in four zones, without taking into account inertial forces, because the number of revolutions of squeezing rollers is not high. The conditions for gripping a semi-finished leather product with a base plate at a vertical feed between rotating squeezing rollers were derived.

When deriving the gripping conditions, the inertial forces arising from slowing down or accelerating the motion of the gripped leather semi-finished product were eliminated from considerations.

The results of the study and analysis of the gripping of a semi-finished leather product with a base plate by rotating squeezing rollers will be used to improve the design of a vertical feed roller squeezing machine. Therefore, the calculation of the energy-power parameters of the roller squeezing machine will also be made.

Thus, for smooth gripping of the semi-finished leather product by rotating squeezing rollers, the gripping angle between them must be less or equal to the friction angle. It is necessary to take into account the pressure of the squeezing rollers acting on the semi-finished leather product. Since the transportation of the base plate with the semi-finished leather product is conducted with traction chains, the frontal resistance will adversely affect their smooth gripping by the squeezing rollers. The study took into account the gravity of the base plate and the semi-finished leather, which significantly prevent their gripping between the rotating squeezing rollers.

Conflicts of interest

The authors declared no conflict of interest.

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