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Interaction of working knives of staking machine with leather fabric of fur semi-finished product

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Abstract: The article is devoted to improving the design of a drum machine for staking and cleaning the leather fabric of fur semi-finished products. Additional rollers are added to the pressing device of the machine, which improve the oriented feed of the semi-finished product to the processing drum. The screw roller ensures staking of the semi-finished product with some stretching and, therefore, an increase in the useful area of the finished product is achieved. The interaction of improved knives with the leather fabric of a semi-finished fur product is theoretically considered. The technological process of staking the leather fabric of a fur semi-finished product is theoretically studied. It is determined that when processing a semi-finished product with small protrusions of the wave-shaped blades of the knives, an increase in the relative energy spent on deformation of the leather fabric is achieved. Consequently, it is possible to reduce the costs spent on the force of the pressing device and the velocity of the staking drum, thus improving the working conditions of the personnel servicing the machine.

Keywords: *Energy during processing, Fur semi-finished product, Pressing device, Knives with wave-shaped blades, Staking machine, Working drum.*

1. Introduction

Currently, the requirements for the quality of finished products and the improvement of processing operations are increasingly expanding. This, in turn, is associated with the solution to several problems in implementing innovative, technical, and technological measures at processing enterprises and clusters. Based on this, it is possible to justify the need to improve the equipment for the mechanical processing of elastic-viscous materials.

Feed-through and non-feed-through types of staking machines are widely used in manufacturing leather and fur products.

The staking machine is designed to impart plasticity, softness, and surface cleaning to fur raw materials after tanning and rolling [1, 2].

The leather fabric of skins is teased and perched under staking, as a result of which it becomes softer and more flexible. Usually, staking is done in two stages: after the first and the second rolling. Skins are fed to the second staking stage with a moisture content of about 14%. Simultaneously with staking, some fleshing of the leather fabric is conducted on the staking machine. During the second stage of staking, the skins are stretched either in width or in length.

Semi-finished products with dense hair sides are usually stretched in width; in this case, the area of the skin is better utilized. Semi-finished fur products with thin hair sides are stretched in length, in which case the hair becomes thicker.

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The staking is performed on a staking machine, the main working element of which is a cast-iron drum with steel knives fixed to its generatrix surface. When the drum rotates, the knives alternately approach the skin, laid with the hair sides down on an elastic support, and, repeatedly striking it, bend the leather fabric.

In fur production machines (staking, softening, ironing ones), pressing devices are used as an elastic stop belt or a pressure conveyor [1, 2].

The advantage of a belt pressing device over a roller device is a larger contact area and uniformity of pressing, which reduces the maximum stress in the material and creates a gentle mode of mechanical processing of leather fabric of fur skins. In addition, the time of action of the working elements on the processed material increases, due to which irreversible plastic deformations are developed, thereby fixing the processing effect [1, 2].

We have considered the known publications devoted to the study of the working bodies of machines and their interaction with the processed material [3-7].

We have also conducted studies on improving the design of technological machines for the mechanical processing of fibrous semi-finished products [8-14].

In addition, theoretical and experimental studies on the interaction of working rollers with elastic-plastic materials at the realization of technological processes under mechanical impact were conducted [15-21].

Based on the new technical solutions developed and the research discussed above, we have improved the designs of the executive devices of the staking machine. New working knives with wave-shaped blades were proposed.

2. Material and Methods

To ensure the required quality of the leather fabric of fur skins and increase their yield in terms of useful area for production, an improved technological machine is required, particularly a drum staking machine. We have developed and improved a non-feed-through staking machine.

The novelty of the technical solution is explained in the drawings: Figure 1 shows a side view of the staking machine [1, 2]. Figure 2 shows a front view; it shows the staking of the leather fabric of fur skin 18 by knives 5 and the installation of rollers on the sides of the table. Figure 3 shows a top view of the table with two side rollers, as well as rollers in front and behind the table. Figure 4 shows a vertical section of rollers 15, 17, 20, 21 mounted on bearings 22, 23, 24, 25 with supports in the form of squares 35, 36, 37, 38 fixed to table 10. Figure 5 shows a tensioning device of elastic belt 12 and the angle of contact with knives 5.

The machine for staking leather fabric of a fur skin (Figure 1) consists of frame 1, on shaft 2 of which a cast-iron drum 4 with flat steel knives 5 in radial grooves of a semicircular contour with a wavy blade is installed by bearing 3.

Electric motor 6 connects pulley 8 with pulley 9 on cast iron drum 4 by belt 7. Table 10 with cutout 11 is fixed on frame 1, on which elastic belt 12 is fixed. Working tools of the machine are flat steel knives 5, rigidly fixed in radial grooves of cylindrical cast iron drum 4, the shaft of which rotates in bearings 3, mounted on frame 1 of the machine. Figure 2 shows rollers 26 and 27 on the ends of table 10. In the front part of drum 4, folding protective shield 13 is located, and in the rear part, branch pipe 14 is installed for dust extraction from the machine's working area.

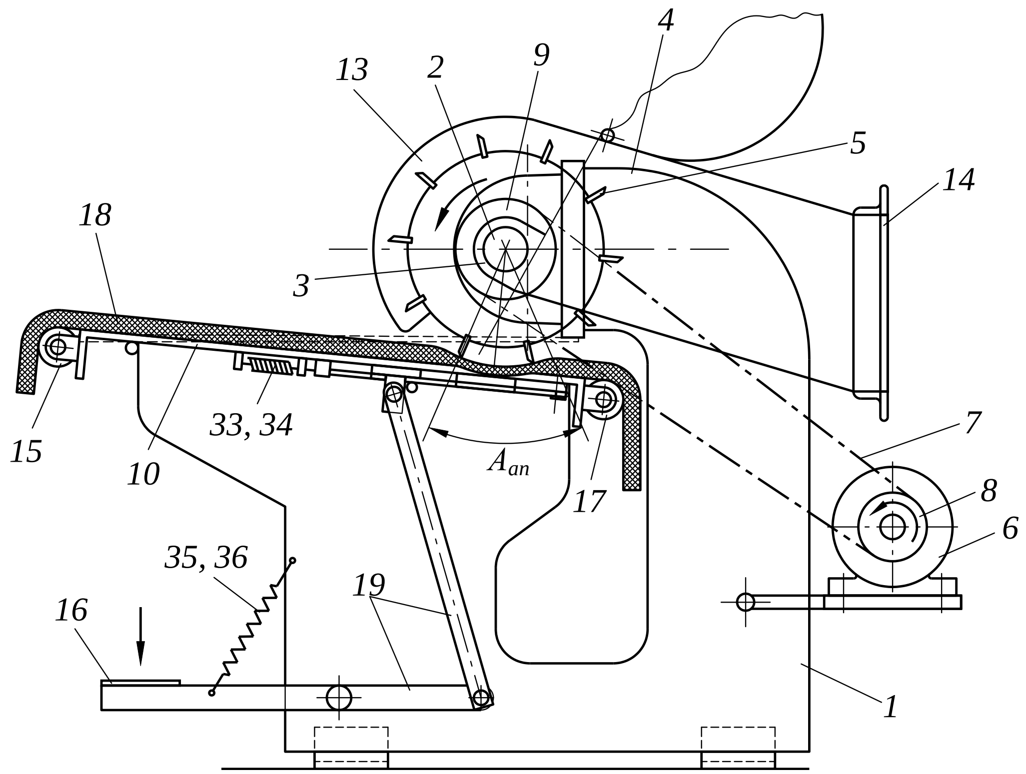

Figure 1.
General view of the improved staking machine.

Knife drum 4 rotates from electric motor 6 via the V-belt transmission 7. Table 10 serves to lay and straighten skins 18. Moreover, in the middle part of table 10, a movable elastic support is placed in the form of belt 12 in a longitudinal cutout. In the front part of the groove of the end of table 10, roller 27 is installed, and in the rear of the end of table 10, roller 26 is installed.

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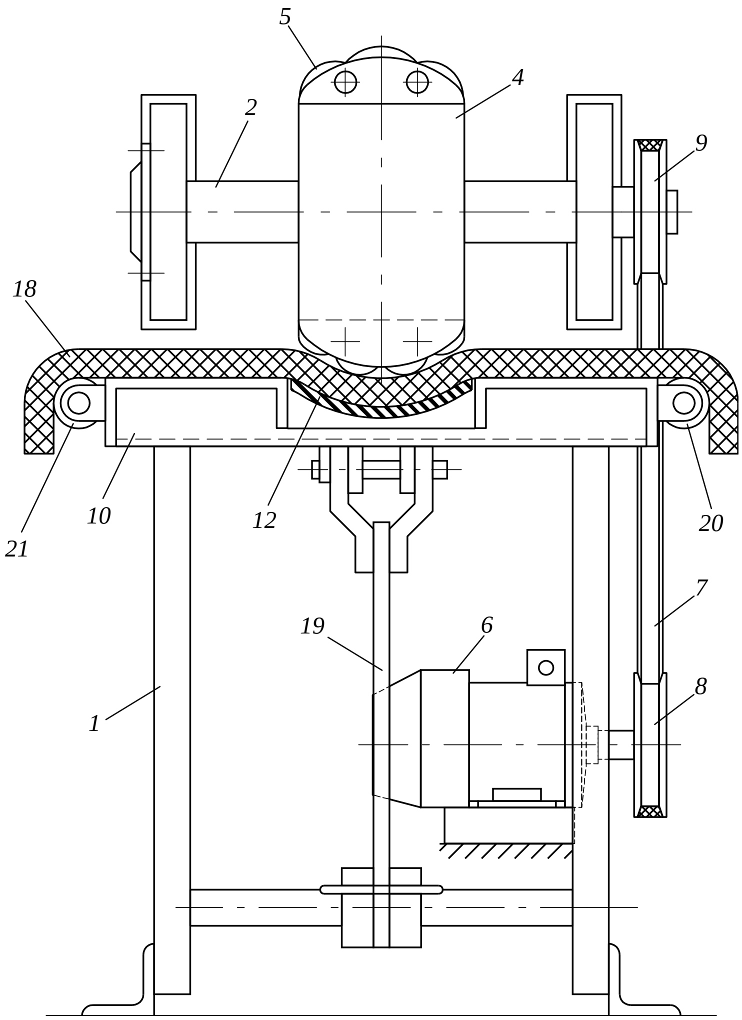

Figure 2.
Staking down the fur skin with a knife drum.

Roller 28 is installed below roller 26. Rollers 26, 27, 28 are encircled by an elastic movable support in the form of belt 12. The front part of belt 12 encircles roller 27 in the front part of the cutout of table 10, and the rear part encircles roller 26 over the top of table 10 and then encircles roller 28 at the bottom. Several ends of the springs are fixed to the pivots of roller 28, and the other ends are fixed to frame 1.

Figure 3 shows skin 18 on the elastic support pressed against knives 5 of rotating drum 4 with lever device 19 with rod 29 that moves elastic support 12 in the form of a belt upward when foot pedal 16 is pressed. The links of lever device 19 and belt 12 reduce the motion force when moving skin 18 forward and backward. At the ends of table 10, there are rollers 15, 17 on bearings 22, 23 with supports 26, 27 in the form of squares fixed to the frame of table 10. On the right and left sides, there are rollers 20, 21 on bearings 24, 25 with supports 28, 29 in the form of squares fixed to the sides of the frame of table 10.

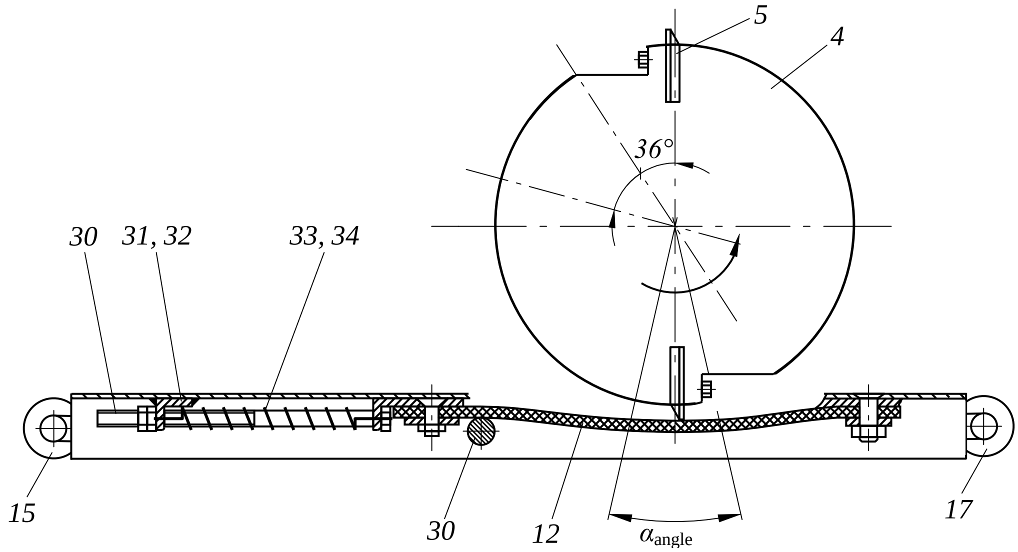

Figure 3.
Scheme of the table with an improved stop belt and its fastenings.

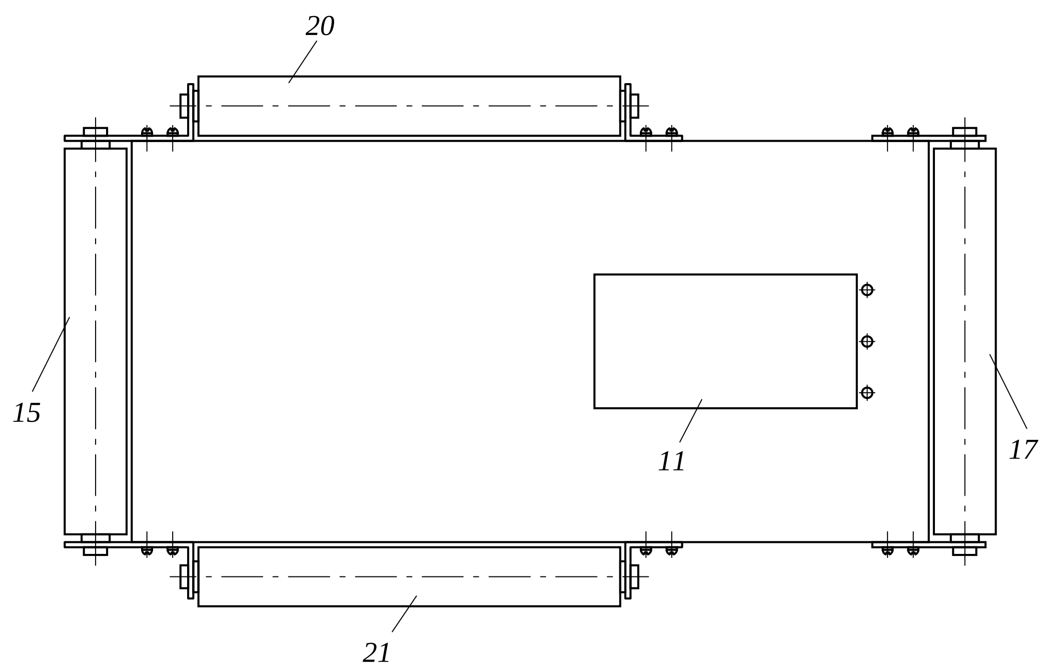

Figure 4.
Scheme of an improved table using rollers.

When pedal 16 is released, belt 12 is lowered down to its initial position due to its weight and is returned by springs 33 and 34. The figure shows a vertical section of the wave-shaped blade of knives 5 in contact with the leather fabric of skin 18 and the belt, where the staking occurs, i.e., the stretching of the leather fabric of the flesh side of skin 18 occurs. The staking of the leather fabric of skin 18 by knives 5, which have a wave-shaped contour, is shown; the sharpening of the knives is one-sided.

Rollers 15, 17, 20, 21 are fastened with identical bearings 22, 23, 24, 25 and supports 26, 27, 28, 29.

Springs 35, 36 raise or release elastic flexible belt 12 by pressing or releasing pedal 16.

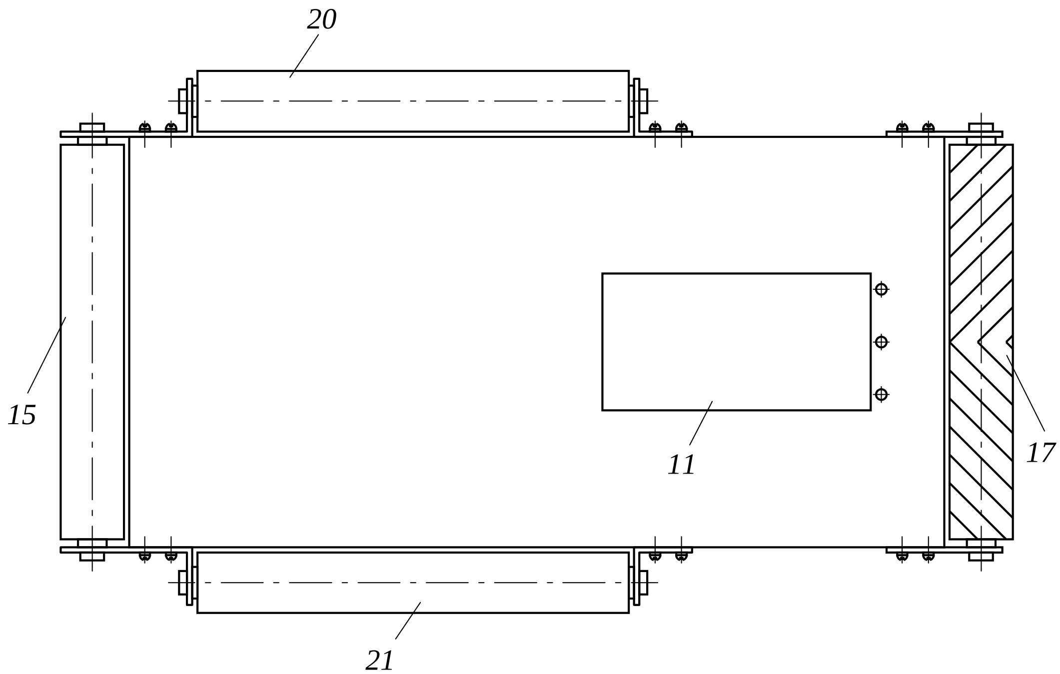

Figure 5.
Scheme of an improved table using a staking roller.

The staking machine operates as follows.

Preliminarily, belt 12 is fixed against longitudinal movement with bolts 30 on square 31. Square 31 is fixed to table 10 from below with screws in the zone of roller 27.

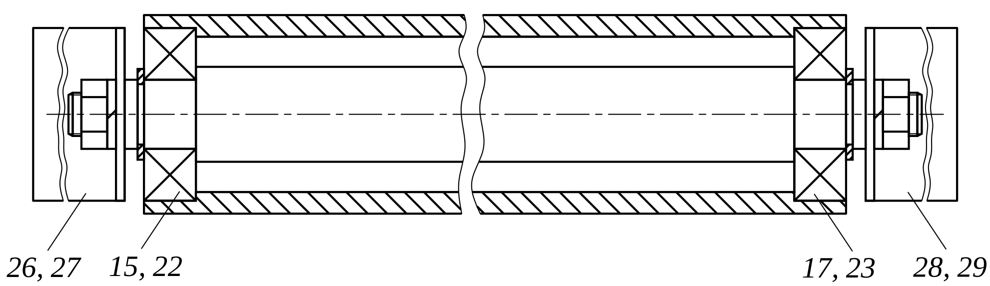

Figure 6.
Longitudinal section of the roller.

When electric motor 6 is turned on, rotation is transmitted via belt drive 7 to drum 4, on which ten knives 5 are installed in the grooves; each knife is fixed with two bolts.

Figure 5 shows an improved table using screw staking shaft 17. Screw shaft 17, due to the screws with an inclination relative to the shaft axis, during the staking process straightens the leather tissue from the middle in different directions, thereby increasing its area.

Skin 18 is installed with the flesh side upward and is put behind knife 5. Then pedal 16 is pressed and lever device 19 lifts skin 18 on belt 12 of table 10. Skin contacts the blades of knives 5 alternately and the operator pulls the skin towards himself and stakes it. This operation is repeated and the entire

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section of fur skin 18 is staked.

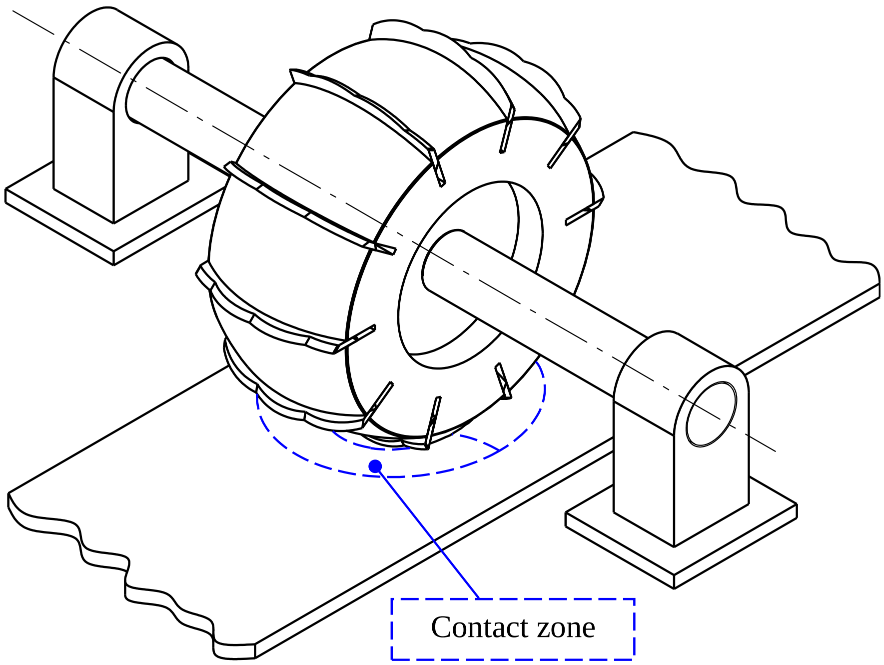

Figure 7.
Scheme of the contact zone of the processed material with the drum (in a free state).

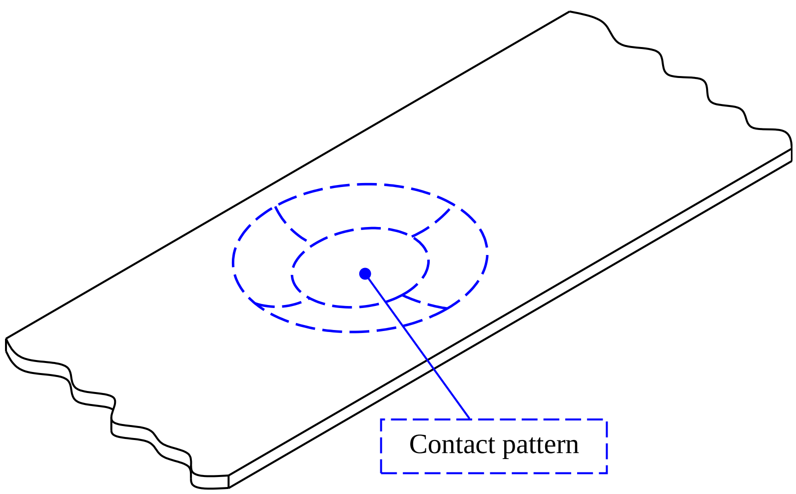

Figure 8.
The contact pattern formed between the processed material and the drum (in a free state). (Contact pattern).

When the pedal is lowered, belt 12 is lowered to its original position. The elastic belt is lowered due to gravity and compression force of springs 33, 34. Elastic belt 12 is periodically moved and fixed with a stopper made of two bolts to prevent its wear.

When one blade of knife 5 wears out, the rotation of drum 4 is stopped and two bolts of knife clamp 5 are unscrewed. Then, the blade is turned over and the worn end is inserted into drum 4 and tightened with two bolts to fix knife 5. This improves the quality of processing fur skins 18.

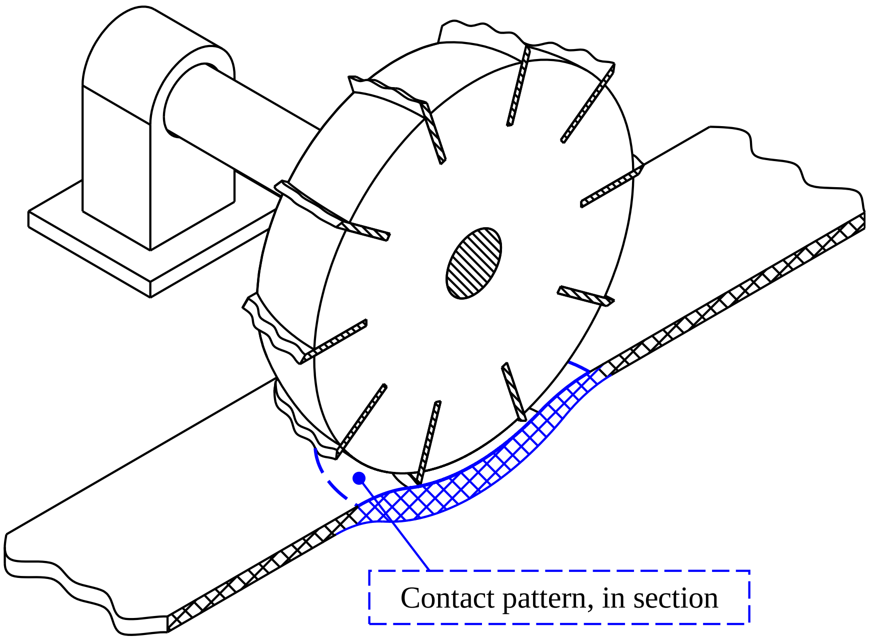

Figure 9.
Longitudinal section of the contact formed between the processed material and the drum (in a free state).

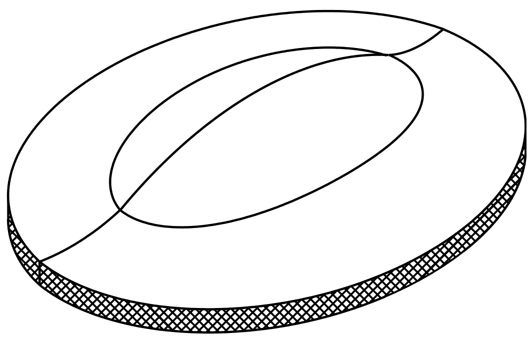

Figure 10.
A piece of material illustrating its contact with the drum (in an inverted state).

Due to the arched design of knives 5, the leather fabric 18 is stretched lengthwise forward and backward and across to the left and right sides of the table; this increases the yield area of fur.

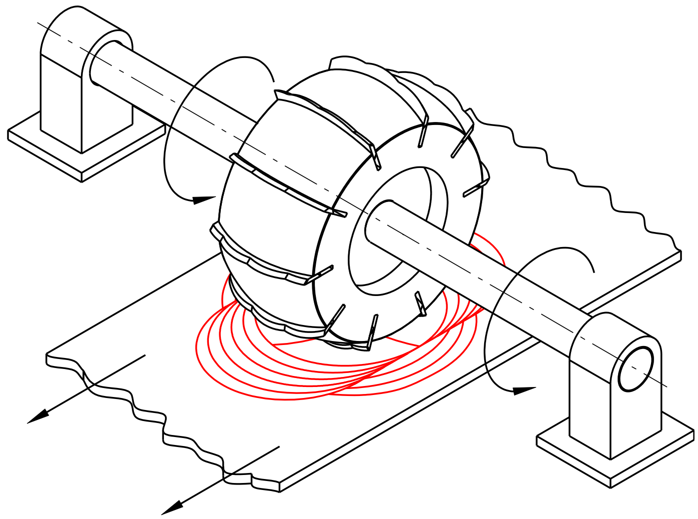

Figure 11.
Scheme of the contact zone of the processed material with the drum (in motion).

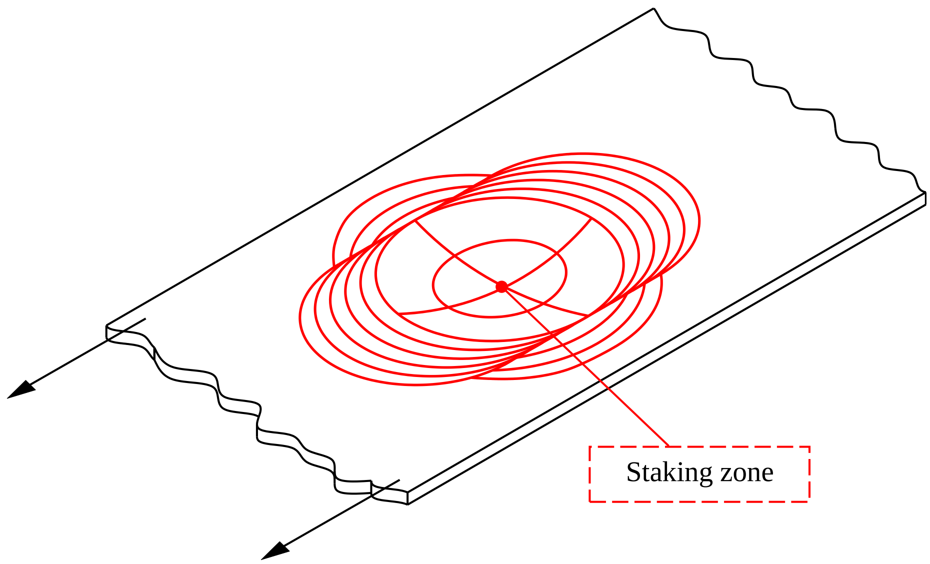

Figure 12.
Scheme illustrating the material staking zone.

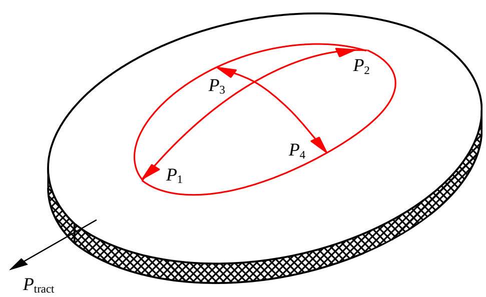

Figure 13.
Directions of forces stretching the leather fabric of the fur skin with knives with wave-shaped blades (in an inverted form).

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Due to the design of movable elastic support as belt 12, its service life can be increased many times and the time for its replacement can be reduced. By installing rollers 20, 21 on the sides and rollers 15, 17 in front and behind the table, the process of moving the skin forward and backward and to the right or left on table 10 during the staking of fur skin 18 is simplified.

All this improves the quality of staking skin 18, the yield area, and the processing productivity.

Now we consider theoretically the interaction of wave-shaped knives with the leather fabric of the fur semi-finished product.

It is known that staking machines are used for the mechanical processing of the leather fabric of fur semi-finished products by repeated bending and stretching with simultaneous cleaning of the knives' surfaces. As a result of the staking process, the necessary elastic-plastic properties of the leather fabric are finally formed, and the flesh side of the skin becomes smooth and clean.

3. Results and Discussion

The main working element of the staking machine is a narrow drum rotating at high speed with sharp blade-knives fixed on its surface.

Next, we will consider the mechanical impact of a knife with wave-shaped blades on the leather fabric of a fur semi-finished product during its staking.

For this, we will obtain a calculation scheme (Figure 14).

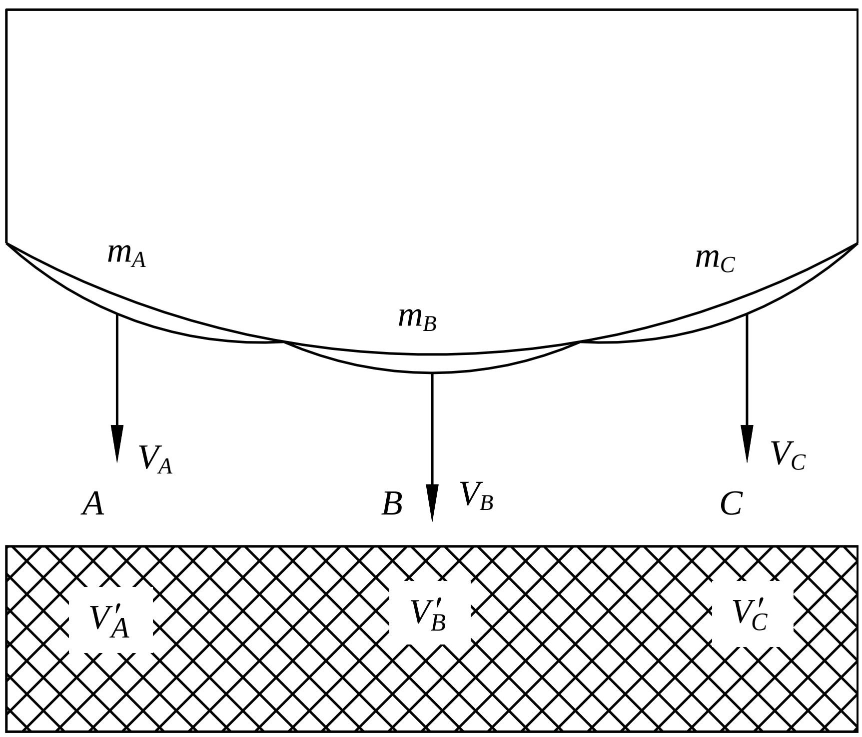

Figure 14.
Scheme of interaction of three wave-shaped knife blades with the processed material.

From the scheme in Figure 14, we determine the energy generated at point A before the occurrence of tensile stress between the blades of a three-wave knife with masses m_A, m'_A, and velocities V_A and V'_A and the leather fabric of the fur semi-finished product [22-24].

$$E'_A = \frac{m_A v_A^2}{2} + \frac{m'_A v'^2_A}{2}. \tag{1}$$

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When the knife interacts with the leather fabric, part of the kinetic energy is spent on moving m_A and m'_A with velocity u_A. Then, from the equation of change in momentum, we can find velocity u:

$$m_A v_A + m'_A v'_A = (m_A + m'_A) u_A, \tag{2}$$

hence,

$$\frac{m_A v_A + m'_A v'_A}{m_A + m'_A} = u_A. \tag{3}$$

The kinetic energy after complete mechanical interaction is expressed as:

$$E''_A = \frac{(m_A + m'_A) u_A^2}{2}. \tag{4}$$

Considering that $V'_A = 0$, we can find E'_A through E_A as follows.

$$E''_A = E_A \frac{m_A}{m_A + m'_A}. \tag{5}$$

The amount of energy E_A spent on deformation of the material can be estimated as follows:

$$E_A = E'_A - E''_A \quad , \tag{6}$$

$$E_A = E'_A - E''_A = E'_A - E'_A \frac{m_A}{m_A + m'_A} = E'_A \left(1 - \frac{m_A}{m_A + m'_A}\right) = E'_A \left(1 - \frac{1}{1 + \frac{m'_A}{m_A}}\right). \tag{7}$$

The specific amount of energy spent on deformation can be calculated using coefficient γ_A,

$$\gamma_A = \frac{E_A}{E'_A} = \left(1 - \frac{1}{1 + \frac{m'_A}{m_A}}\right). \tag{8}$$

Since the masses and velocities of the wave protrusions of the knives are equal, the energy spent at points A and C on deformation of the material interacting with them will be:

$$E_A = E_C.$$

Let us perform the above calculations for point B by the scheme given in Figure 14.

We determine the energy at point B between the knife blades with masses m_B, m'_B and velocities V_B, V'_B and the leather fabric before they come into contact [22-24].

$$E'_B = \frac{m_B v_B^2}{2} + \frac{m'_B v'^2_B}{2}. \tag{9}$$

During interaction, part of the kinetic energy is spent on the movement of m_B and m'_B with velocity u_B. Then, from the equation for the change in momentum, we can find velocity u_B:

$$m_B v_B + m'_B v'_B = (m_B + m'_B) u_B, \tag{10}$$

hence

$$\frac{m_B v_B + m'_B v'_B}{m_B + m'_B} = u_B. \tag{11}$$

The kinetic energy after contact is expressed as:

$$E''_B = \frac{(m_B + m'_B) u_B^2}{2}. \tag{12}$$

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Considering that V'_B=0, we can find E''_B through E'_B as follows.

$$E''_B = E'_B \frac{m_B}{m_B + m'_B}. \tag{13}$$

The amount of energy spent on deformation of the material E can be estimated as follows:

$$E_B = E'_B - E''_B \quad , \tag{14}$$

$$E_B = E'_B - E''_B = E'_B - E'_B \frac{m_B}{m_B + m'_B} = E'_B\left(1 - \frac{m_B}{m_B + m'_B}\right) = E'_B\left(1 - \frac{1}{1 + \frac{m'_B}{m_B}}\right). \tag{15}$$

The specific amount of energy spent on deformation can be calculated using coefficient γ_B.

$$\gamma_B = \frac{E_B}{E'_B} = \left(1 - \frac{1}{1 + \frac{m'_B}{m_B}}\right). \tag{16}$$

Let us consider the process of staking when two blades of a two-wave knife contact leather fabric [22-24].

Consider the following scheme (Figure 15).

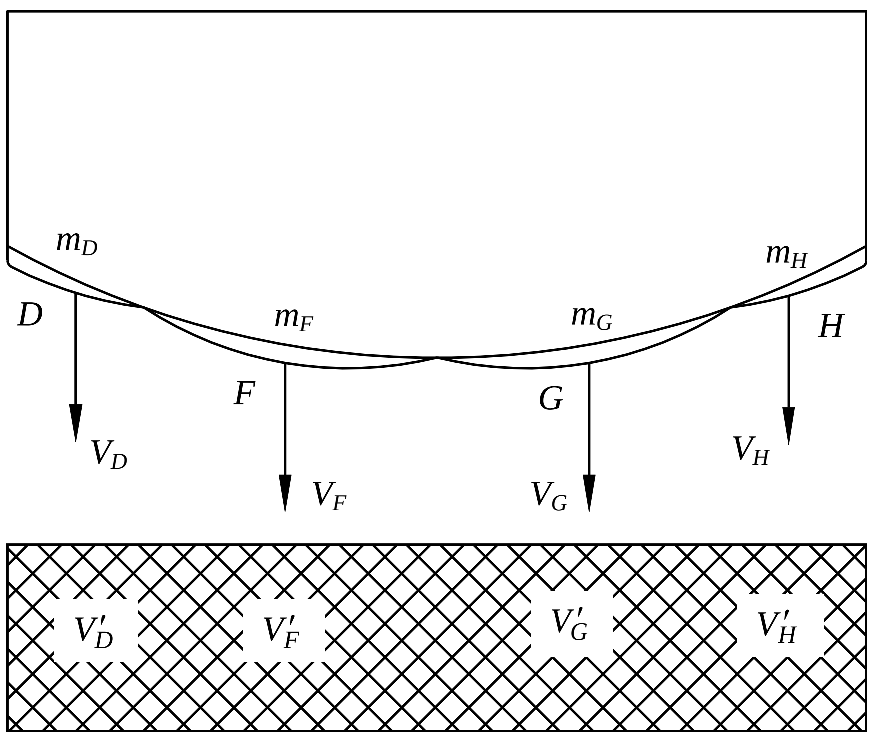

Figure 15.
Scheme of interaction of two wave-shaped knife blades with processed material.

Let us determine the energy of the knife blades with masses m_D and m'_D and velocities V_D and V'_D before contacting leather at point D.

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$$E'_D = \frac{m_D v_D^2}{2} + \frac{m'_D v'^2_D}{2}. \tag{17}$$

During the interaction, part of the kinetic energy is spent on the movement of m_D and m'_D with velocity u_D. Then, from the equation of the change in momentum, we can find velocity u_D:

$$m_D v_D + m'_D v'_D = (m_D + m'_D) u_D, \tag{18}$$

hence

$$\frac{m_D v_D + m'_D v'_D}{m_D + m'_D} = u_D. \tag{19}$$

The kinetic energy after contact is expressed as:

$$E''_D = \frac{(m_D + m'_D) u_D^2}{2}. \tag{20}$$

Considering that V'_D=0, we can find E''_D through E'_D as follows.

$$E''_D = E'_D \frac{m_D}{m_D + m'_D}. \tag{21}$$

The amount of energy spent on deformation of the material E can be estimated as follows [28–30]:

$$E_D = E'_D - E''_D, \tag{22}$$

$$E_D = E'_D - E'' = E'_D - E'_D \frac{m_D}{m_D + m'_D} = E'_D \left(1 - \frac{m_D}{m_D + m'_D}\right) = E'_D \left(1 - \frac{1}{1 + \frac{m'_D}{m_D}}\right). \tag{23}$$

The specific amount of energy spent on deformation can be calculated using coefficient γ.

$$\gamma_D = \frac{E_D}{E'_D} = \left(1 - \frac{1}{1 + \frac{m'_D}{m_D}}\right). \tag{24}$$

Since the masses and velocities of the knife blades are equal, the energy spent on deformation of the material at points D and H is $E_D = E_H$.

Using the scheme in Figure 15, we perform the above calculations for point F.

We determine the energy of the knife blades with masses m_F and m'_F and velocities V_F and V'_F before impact with leather at point F [22-24].

$$E'_F = \frac{m_F v_F^2}{2} + \frac{m'_F v'^2_F}{2} \tag{25}$$

During interaction, part of the kinetic energy is spent on moving m_F and m'_F with velocity u_F. Then, from the momentum equation, we can find velocity u_F:

$$m_F v_F + m'_F v'_F = (m_F + m'_F) u_F, \tag{26}$$

hence

$$\frac{m_F v_F + m'_F v'_F}{m_F + m'_F} = u_F. \tag{27}$$

The kinetic energy after contact is expressed as:

$$E''_F = \frac{(m_F + m'_F)u_F^2}{2}. \tag{28}$$

Considering that $V'_F = 0$, we can find E''_F through E'_F as follows.

$$E''_F = E'_F \frac{m_F}{m_F + m'_F}. \tag{29}$$

The amount of energy spent on deformation of the material E can be estimated as follows:

$$E_F = E'_F - E''_F, \tag{30}$$

$$E_F = E'_F - E''_F = E'_F - E'_F \frac{m_F}{m_F + m'_F} = E'_F\left(1 - \frac{m_F}{m_F + m'_F}\right) = E'_F\left(1 - \frac{1}{1 + \frac{m'_F}{m_F}}\right). \tag{31}$$

The specific amount of energy spent on deformation can be calculated using coefficient γ_F [28–30].

$$\gamma_F = \frac{E_F}{E'_F} = \left(1 - \frac{1}{1 + \frac{m'_F}{m_F}}\right). \tag{32}$$

Since at points F and G the masses and velocities are equal, the energy spent on deformation of the material is $E_F = E_G$.

From expressions (8), (16), (24), (32), it is clear that with a decrease in the mass of the wave-shaped knife blades m_A, m_B, m_C, m_D, m_F, m_G, m_H (in our case, particles in the processing flow), the relative energy spent on deformation of the material increases.

4. Conclusion

It has been established that the speed between the working elements and the processed fibrous material will change depending on the angular velocities of the gears, the diameters of the working elements.

It was determined that the velocities of the working units and the processed fibrous material change depending on the angular velocities of gears and the diameters of working units.

It was stated that the velocity between the working shafts and the semi-finished product changes depending on the angular velocities of the gear wheels, the diameters of the working shafts, and the cosine of the angle between the projections of their velocities V_1 and V_2 onto the axis. Since the angular velocities of the gear wheels are equal, $\omega_1 = \omega_2$, the linear velocities of the contact points of the working shafts with the semi-finished product will also be equal, $V_1^/ = V_2^/$.

The feed rate of the conveying device is important here. In this case, the quality of the processed raw material is improved, i.e., no excessive braking or other undesirable effects occur when raw material is conveyed between the rotating working shafts during its processing.

According to formulas (20) and (21), obtained from the above-mentioned theoretical studies, the velocities of the transmission mechanism's characteristic points were determined by numerical solutions, and a graph was plotted (Figure 8).

1. Due to the wave-like design of knives 5, during processing, leather fabric 18 of the fur skin is stretched lengthwise forward and backward and across to the left and right sides, relative to the table, which increases the area yield of the fur skin and improves the quality of processing.

2. Due to the implementation of an elastic movable support in the form of belt 12, it is possible to significantly extend its service life and reduce the time required for replacement. The installation of

rollers 20 and 21 on the sides, along with rollers 15 and 17 in front of and behind table 10, facilitates the movement of fur skin 18 forward and backward, as well as to the right or left, on table 10 during staking.

3. The placement of rollers 15, 17, 20, and 21 on the sides of table 10 improves and streamlines the oriented feed of fur skin 18 under the staking knives 5 across the entire surface of table 10.

4. All these enhancements contribute to improved quality in the staking of fur skin 18, as well as increased processing productivity and yield in the useful area of fur semi-finished products.

5. Thus, processing to stake the leather fabric of a fur semi-finished product with small protrusions of wave-shaped knife blades leads to an increase in the relative energy spent on deformation of the material.

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Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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