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Leather Softening by Shearing

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The research results on leather softening by shearing and the effect of shearing parameters on leather relative elasticity are presented. Leather softening processes have been executed and leather elasticity parameters have been determined by the instruments constructed for the specially defined purposes. It has been stated that employing this particular leather softening technique leather deformation characteristics are of no worse quality when employing soluble technique and for this reason shearing technique of leather softening may be applicable in leather industry. The increase of shearing speed and the number of cycles had no substantial effect on leather elasticity. Having applied the graphical methods with experiment the effect of shearing parameters on one of leather quality indicators – its elasticity - and the calculations of the corresponding dependency equations are presented in the paper.

Keywords: leather, mechanical softening, sharing,deformation, elasticity of leather.

INTRODUCTION

Researche on the development of leather treatment processes is aimed at the development of new leather treatment technologies, the reduction of environment pollution [1 – 3] and stimulation of chrome tanning processes employing pressure [4, 5] as well as focusing on intensified technological processes. In all cases entire pieces of leather are treated.

The authors [6] have experimented with the technology applying which small leather cuttings in a fixed position that were chrome tanned in vacuum. This led to the new processes described in the paper have raised the problem of the development of new leather treatment technologies [6 – 9]. Leather cuttings treated by vacuum and pressure are difficult to be softened by traditional methods. For this purpose leather treatment by shearing was applied. The previous experiments evidenced that the shearing process of leather cuttings results on their softening [9].

The deformation caused by shearing resolves the cohered collagen filaments, thus, alternating the super molecular structure of leather. Consequently, the mechanical characteristics are changed – leather is softened and its elasticity is increased. This is also observed for other forms of mechanical deformation – stretching or bending [10, 11].

The aim of the research is to disclose the possibilities of treatment with chemicals of leather semi-finished of various configurations and alterations of the leather mechanical characteristics during the processes of shearing.

EXPERIMENTAL

The study was focused on the mechanical characteristics of leather samples before and after their softening by shearing. The characteristics of leather softened using vibrodevices were used as a standard. Parameters of leather softened by shearing and of leather with standard mechanical characteristics were set applying the same method.

The methods for testing leather softness were based on the measurements of leather rigidity, which, in its turn, was calculated by its relative stretching under tension. In the study leather relative elasticity within the limits of elastic deformations was assumed as the parameter defining leather softness.

The relative increase of leather elasticity in the process of its softening by shearing was determined by all parameters of mechanical processes and the factors of the initial state of leather. By the effect caused the factors were divided into active (shearing angle, number of shearing cycles and their speed) and passive (leather initial elasticity, sample direction in relation to the leather longitudinal axis). The softening effect is a functional dependence of relative elasticity on the operational factors:

$$E_m = f(y_\alpha, y_v, y_n, y_s, y_k),\ \% \qquad (1)$$

where y_α is the shearing angle; y_v is the shearing speed; y_n is the number of shearing cycles; y_s is the leather initial elasticity; y_k is the sample direction in relation to the leather longitudinal axis.

The effect of each of these factors on the increase of leather elasticity was set by separate trials alternating the values of parameters within the set limits.

The next stage included the study of the softening process of leather pieces. Traditional ways and devices were inappropriate for treatment of small pieces of leather. Thus, for this reason an original device was constructed, which allows to soften pieces of leather by shearing and alternating the angle of shearing, the number of cycles and the speed of the process.

The basis of leather softening by shearing is the parallel shifting of adjacent collagen filaments into the opposite directions in relation to each other, alternating the direction of shifting during separate shearing cycles (Fig. 1). The shearing cycle consists of shifting the leather sample 5 between the fixed grip 4 and flexible grip 5 from the initial position (Fig. 1, b) into the left marginal position

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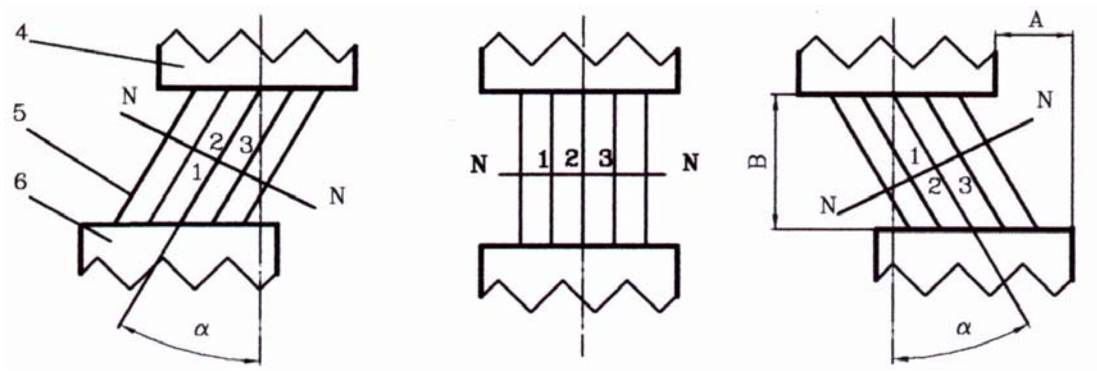

a b c

Fig. 1. Scheme deformation of leather sample: 1, 2, 3 – relative points marking collagen filaments; 4 – fixed grip; 5 – leather sample; 6 – flexible grip; A – shift of the grip 6; B – distance between the grips

(Fig. 1, a) at the angle α and its removal into its initial position, followed by shifting it into the right marginal position (Fig. 1, c) at the same angle and its removal to its initial position.

The leather softening devices are not applicable for the softening small size leather components and for this reason an original device was constructed. It is applicable to soften leather components of the size of 150×85 mm by transverse shearing alternating the shearing angle, the number of deformation cycles and the speed of the process.

The shearing angle α is calculated having measured the values of the parameters *A* and *B* when the flexible grip is in the left position (Fig. 1,a). The average shearing speed ϖ is calculated as a ratio of the set angle of shearing and the time at which it was reached:

$$\omega = \frac{4\alpha}{t}, \qquad (2)$$

where α is the angle of shearing; t is the duration of shearing cycle.

Deformation characteristics of the leather pieces softened by shearing were compared to the standard ones.

For the experiment 10 semimanufactures leather samples for the manufacturing of the footwear upper with thickness of 1.4 ±0.2 mm, made of bovine raw leather were taken from one industrial batch. Five samples were mechanically softened using a vibrating softening device, other five samples (experimental) were set for softening by shearing.

Deformation characteristics of the samples were measured using an electronic dynamometer to measure force and shift. Leather elasticity was measured deforming it by spherical two-spindle stretching [12 – 14]. To measure leather elasticity the device was constructed (Fig. 2).

The effect of shearing parameters on the increase of leather relative elasticity was investigated. The most influential factors were determined and the planned experiment to optimise them was carried out. While rating leather elasticity pressure in the pneumatic unit 2 was raised, the rubber partition of the unit is stretched and stretches the sample leather 5 until the upper camber point contacts the shift fixer 4. The pressure value in the pneumatic unit is fixed at the contact moment. The diameter *D* of the hole, through which pressure in the

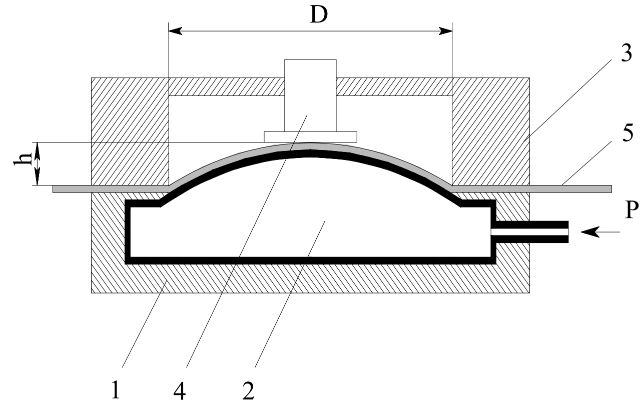

Fig. 2. Pneumatic device occasional to investigate leather mechanical characteristics: 1 – frame; 2 – pneumatic unit; 3 – mandrel; 4 – process sensor; 5 – leather sample

pneumatic unit cambers the leather sample, and the camber height *h* were selected in the way that leather relative stretching was 2.6 %, i.e., leather was stretched within the limits of elastic (proportional) deformation. By the fixed pressure value in the pneumatic unit and the parameters of the device the average stress in the leather sample was calculated:

$$\sigma = \frac{FP}{L\delta}, \qquad (3)$$

where *F* is the inner surface area of the cambered dome; *P* is the fixed pressure in the pneumatic unit; *L* is the perimeter length of the cambered dome base; δ is the thickness of the sample.

Relying on the mechanical characteristics of leather in the tension interval of 0 – 1.5 MPa the ratio with relative elasticity is close to the linear (Fig. 3). The recalculation of the obtained relative elasticity of the leather sample at the standard stress σ_1 = 1 MPa is possible.

Relative elasticity was calculated at the standard stress σ_1 = 1 MPa according to[6]:

$$\Delta s = \frac{2.6\sigma_1}{\sigma}, \qquad (4)$$

where σ is stress of the sample leather; σ_1 is the standard stress; 2.6 is the relative elasticity (%), at which stress are calculated.

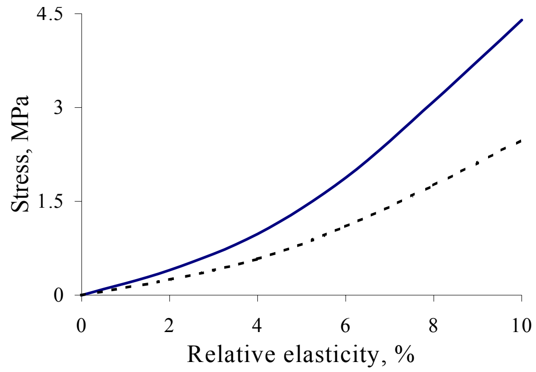

Fig. 3. Stress dependence on stretching of leather sample: — softened by standard methods; --- softened by shearing

To avoid the effect of calculations error in the interim results on the value of elasticity, stress values of σ and σ_1 in the (4) may be substituted by the values of pressure, which was caused by them:

$$\Delta S_s = \frac{2.6 P_1}{P}, \qquad (5)$$

where P is pressure in the device; P_1 is the calculated pressure constant, which causes standard stretches; 2.6 is the constant of relative elasticity, at which pressure P was fixed.

For the first trial leather samples saturated up to the humidity of 20 – 25 % [11], size of 50 × 150 mm, cut from softened and non-softened leather were taken. The samples from non-softened leather were softened by shearing, fixing such force (stress) values, which are required for sample shearing at each stage. Shearing parameters were: $\alpha = 28°$, $v = 0.01$ m/s, $n = 50$ cycles.

In order to obtain reliable results the elasticity parameters were measured on the entire area of leather samples.The leather samples were divided into 40 zones with size of 210 × 170 mm. It was defined that elasticity values were inconsistently distributed on the entire area of leather. For the trials samples of 85 × 100 mm in size were cut from freely selected zones in the way that their longitudinal axis was parallel to leather longitudinal axis. Their elasticity was determined. Sample groups (5 pieces in each) soaked up to humidity of 24 % were softened by increasing shearing angles from 7 to 37° until crease signs were detected. The shearing speed and the number of cycles were constant: $v = 0.025$ m/s; $n = 4$.

RESULTS AND DISCUSSION

The highest decrease of stretching was reached during the first 10 softening trials by shearing (Fig. 4). The stress values insignificantly decreased further increasing softening cycles.

The factors, affecting during the process of leather softening by shearing, were divided into passive (initial leather elasticity, direction in relation to leather longitudinal axis) and active (angle of shearing, number of shearing cycles and shearing speed).

Obtained results, presented in Fig. 5, revealed that deformation characteristics of leather softened by shearing were no worse than that determined by standardised ways.

Alterations in shearing angle in the interval of changes increased leather relative elasticity by 96 %, while the effect of its initial elasticity on the increase of relative elasticity was 15 %. In order to reduce data dispersion samples for further trials were selected from closer leather zones and the shearing angle was limited from 8 to 36°.

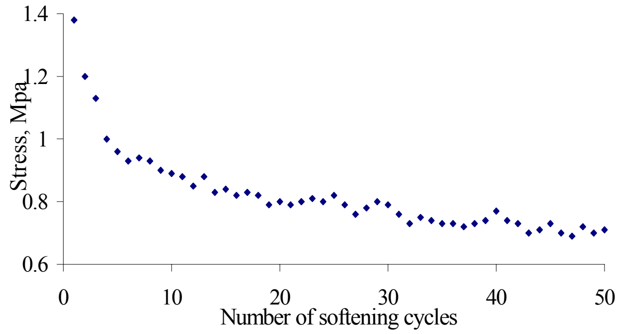

Fig. 4. Stress dependence on the number of softening cycles

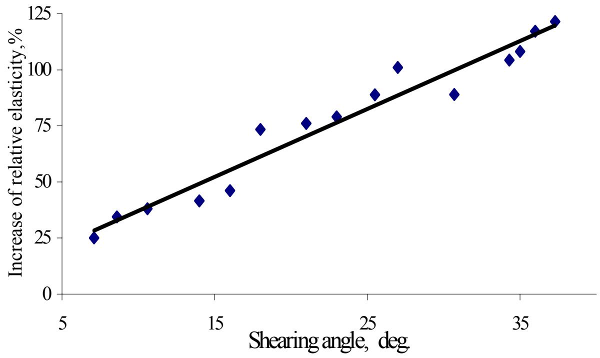

Fig. 5. Dependence of the increase of relative elasticity on the shearing angle

The investigation of the dependence of the relative elasticity increase on the number of shearing cycles was carried out. Five samples from the shearing cycles 2, 3, 4 and 5 were selected for softening, fixing the constant speed of shearing $v = 0.004$ m/s at the fixed shearing angles 8, 11, 14, 16, 18, 21, 25, 27, 35 and 36°.

Elasticity was measured and relative elasticity increase was calculated in percentage, also average values were calculated.

Relying on it theoretical regressive equations of relative elasticity increase in relation to the shearing angle and relative elasticity increase from initial elasticity were calculated according to (6) and (7):

$$y = 3.025x + 6.874 \qquad (6)$$

$$y = -7.341x + 61.459 \qquad (7)$$

Dependences are presented in Fig.5 and 6.

From the experimental data obtained during leather deformation by varying the number of shearing cycles theoretical regression (8 – 11) were obtained:

$$y = 3.242x + 3.492, \quad n = 2 \qquad (8)$$

$$y = 3.038x + 11.236, \quad n = 3 \qquad (9)$$

$$y = 3.039x + 13.673, \quad n = 4 \qquad (10)$$

$$y = 3.300x + 11.055, \quad n = 5 \qquad (11)$$

The value of elasticity increase due to the increase of the number of shearing cycles is 5 %.

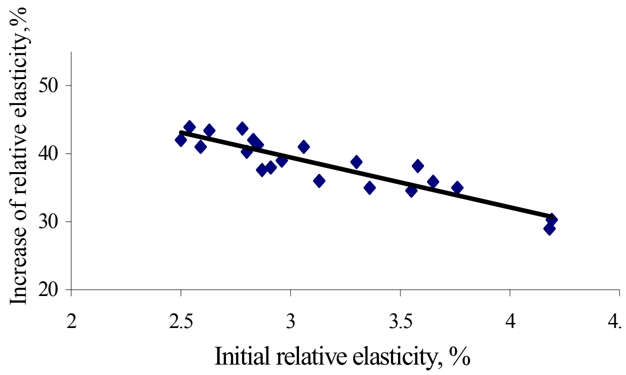

Fig. 6. Dependence of the increase of relative elasticity on leather initial elasticity

The influence of shearing speed on the increase of relative elasticity was investigated by softening 6 groups of samples by speed variations (0.009; 0.010; 0.014; 0.018; 0.024 and 0.036 m/s), fixing the constant number of shearing cycles $n = 4$ at the fixed angle of $\alpha = 12°$. The increase in 6.7 % was determined relying on the calculated theoretical regression eg. (12) of the dependence of relative elasticity on the alterations in shearing speed and the graph is obtained (Fig. 7):

$$y = 272.45x + 34.772 \qquad (12)$$

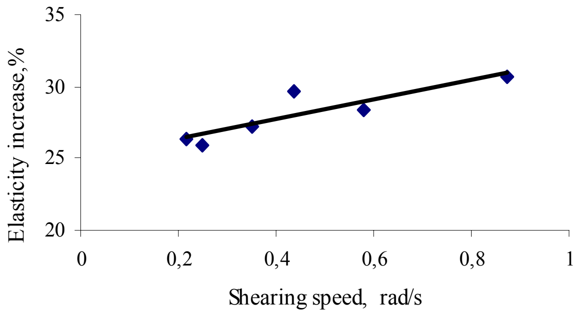

Fig. 7. Dependence of the increase of relative elasticity on the shearing speed

Determining the effect of shearing direction on leather relative elasticity in relation to the leather longitudinal axis the experiment with samples of size 30 × 85 mm and marked leather axis directions was carried out.

The samples were categorised into 3 groups so that the initial average elasticity indices were comparatively equal. The selected leather softening regime (speed 0.004 m/s, number of cycles – 4, shearing angle – 23°) was constant alternating the shearing direction. One group of samples was softened crosswise another – lengthwise the marked direction, the third one – 2 cycles of crosswise and 2 cycles of lengthwise.

The experimental results proved (Fig. 8) that during the lengthwise softening procedure leather was more elastic in 40 % compared to the that of the crosswise softening procedure. Third softening procedure evidenced the relative increase of leather elasticity in 4.3 % compared to at of the lengthwise softening procedure.

By summarizing up the results of the experiment it has been determined that the highest effect on the increase of the relative elasticity was obtained by the increase of the shearing angle. Shearing direction is also significant, however, the possibility of applying this factor in the practice is low because of the limited chances to cut pieces of leather in the desirable direction.

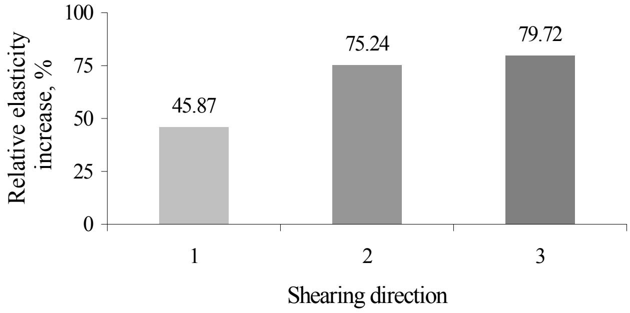

Fig. 8. Dependence of the increase of relative elasticity on the shearing direction: 1 – crosswise; 2 – lengthwise; 3 – crosswise and lengthwise

The effect of the number of shearing cycles and speed is low, however, these parameters directly alternate the efficiency of the process.

The methods attaching to optimise leather softening parameters by the process of shearing were developed in the course of the research. The number of shearing cycles and the shearing angle, at which relative elasticity (i. e. relative elasticity of softened leather would be increased up to the standard) for the whole sample was reached, were fixed in result. To solve the task, experimentally set dependence of the increase of leather elasticity on its initial elasticity was used. This dependence proves that greater increase of leather elasticity occurs in the zones of minor initial elasticity. Therefore, to reach the planned increase of elasticity the combination of alternations of the number of shearing cycles and the shearing angle should be applied and, thus, the set elasticity increase in various zones could be reached at the same time (Fig. 9).

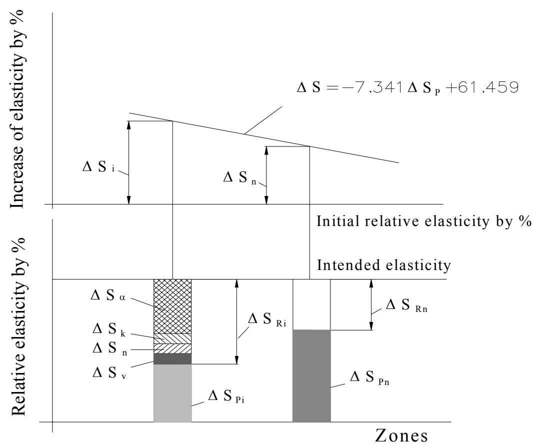

Fig. 9. Scheme to optimise the initial data selected

The combination of the selected parameters must comply the condition:

$$\frac{\Delta S_i}{\Delta S_{Ri}} = \frac{\Delta S_n}{\Delta S_{Rn}}, \qquad (13)$$

where ΔS_i and ΔS_n are the presumable increase of relative elasticity in i and n topographical zones respectively of softened leather samples; ΔS_{Ri} and ΔS_{Rn} are the required relative elasticity increase in leather topographical zones.

The required elasticity increase in leather topographical zones is calculated according to:

$$\Delta S_R = \Delta S_N - \Delta S_P , \tag{14}$$

where ΔS_N is the projected relative elasticity; ΔS_P is the initial relative elasticity.

Elasticity increase in separate topographical zones ΔS_R of softened leather is reached under the effect of the following factors: shearing angle Y_α, direction – Y_k, number of shearing cycles – Y_n and speed – Y_v.

The factor of shearing speed has been eliminated, as its effect has not been sufficiently researched.

The effect of the direction factor is a constant value, thus, it is as a coefficient. During leather softening across its longitudinal axis the coefficient was equall to 1.

To set the remaining values of the shearing angle and the number of shearing cycles from the experimentally obtained results the monogram has been designed (Fig.10).

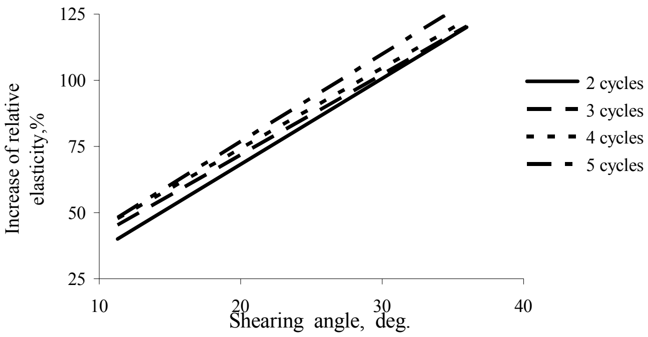

Fig. 10. Monogram: number of shearing cycles – shearing angle – relative elasticity

Applying monograms of this type it is possible to select the most optimal parameters in leather softening by shearing.

CONCLUSIONS

Deformation characteristics of leather pieces softened by shearing was found to be no worse than applying standard softening method.

Leather softening by shearing is more advantageous than using vibrodevices.

It has been determined that the increase of leather relative elasticity was mainly affected by the value of the shearing angle, its initial elasticity and shearing direction. The increase of shearing speed and the number of cycles had no substantial effect on leather elasticity.

Rating the possibilities of the technological processes under investigation it is possible to maintain that the new direction in leather and leather ware technology and material investigation is viable.

Acknowledgments

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