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THE IMPACT OF LASER FINISHING ON LEATHER PROPERTIES

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According to the results of the study of the influence of laser engraving on the hygienic properties of natural leather for shoe uppers, the nature of the change in the micro- and macrostructure of the dermis under the action of laser engraving and the permissible limit values of the depth of laser ablation, which do not impair their hygienic properties, were determined. With an increase in the ablation depth to 0.7 mm (50% of the total thickness of the sample), the relative vapour permeability increases in all samples of the studied skins. At the same time, the relative vapour permeability for the skin of Crust increased by 5%, Flotar by 13.5%, and Nappa by 9.5%. On the front surface, the structure features are revealed, which are characteristic only for the area of the direct action of the laser beam; namely, the samples of Flotar and Nappa skins have clear signs of welding collagen fibres. In the zone of laser ablation, an increase in interstructural distances between bundles of collagen fibres was also found, resulting from the thermophysical processes of laser radiation’s action.

Keywords: laser finishing, leather products, properties of leather.

INTRODUCTION

The hygienic properties of shoes are mainly determined by the properties of the materials from which they are made and their construction. To ensure comfortable operating conditions, materials for the top of shoes must have vapour permeability and the ability to absorb water vapour to provide the necessary microclimate in the inner space of the shoe. If the removal of steam in shoes is difficult due to low vapour permeability and moisture removal, then in the process of wearing, when the foot rubs, micro-areas of increased temperature are created and, as a result, unpleasant sensations of overheating and burning of the foot. The authors believe that improving the hygienic properties of shoes can be realised by decorating the upper leather parts with laser engraving.

Finishing leather products with laser engraving requires compliance with rational processing parameters, taking into account the individual characteristics of the leather, namely its raw material origin, tanning method, degree of treatment of the front surface, etc. The laser beam can heat the product’s irradiated area to high temperatures in a very short time, during which the heat does not dissipate, and the treated area may be softened, recrystallised, melted, or even partially evaporated. The destructive nature of the process directly affects the facial surface of the skin and its structure, creating a unique three-dimensional pattern, the meaning of which is based on the visual effect and aesthetic features of the product.

The results of previous studies of the impact of laser processing on physical and mechanical properties (Pervaia *et al*., 2022) became the basis for determining the rational technological parameters of laser engraving and its impact on the hygienic properties of natural leather for footwear.

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MATERIALS

The different samples of chrome-tanned leather from raw cattle (Cattle) used for manufacturing shoes and leather goods, namely Krust, Flotar and Nappa, were taken to research the laser effect. Crust leather was produced using a new unified resource-saving technology using polymer compounds at the stage of tanning and liquid finishing (Andreyeva *et al*., 2019).

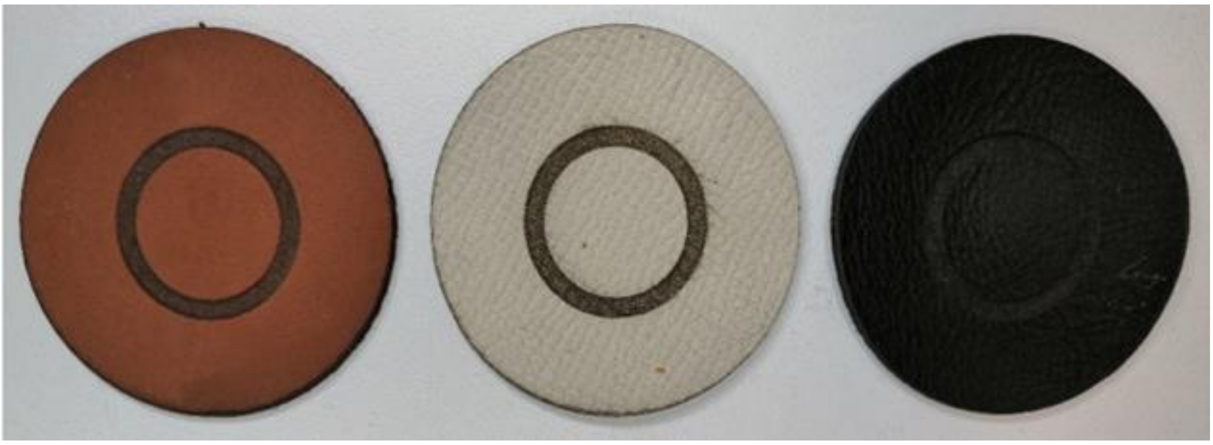
Leather samples with a 1.40-1.45 mm thickness were subjected to laser engraving at a laser ablation depth from 0.1 mm to 0.7 mm in steps of 0.1 mm.

METHODS

The effect of laser radiation on the microstructure of dermal collagen was examined using scanning electron microscopy (SEM) on a Tescan Mira 3 LMU (Czech Republic). For more complete information, a first layer of conductive material in the form of platinum was sprayed on the front surface of the leather sample after laser finishing, which covered the surface of the sample and the area of the direct action of the laser beam (Krishtal *et al*., 2009).

The leather finishing was performed on a CO_2 Comelz CZ/M (Italy) laser machine.

The study of the hygienic properties of Crust, Flotar, and Nappa leathers was carried out by ISO 14268:2008 by determining the vapour permeability, which characterises the ability of the leather to pass water vapour. Previously, engraved elements were applied to the working areas of the samples, making up 1%, 25%, and 50% of the working area of the tested sample, with different depths of laser ablation from 0.1 mm to 0.7 mm in steps of 0.1 mm (Fig. 1).



a *b* *c*

Figure 1. Leather samples for testing: a – Crust; b – Flotar; c – Nappa

Table 1 shows the technological parameters of laser engraving, in which the engraving of the studied samples of Crust, Flotar and Nappa leathers was performed.

Table 1. Technological parameters of laser engraving of leather for shoe uppers and leather goods

Leather type	Depth of ablation, mm	Beam power, W	Speed of the laser head, mm/s
Crust	0.1	11	
	0.4	17	300-350
	0.7	28	
Flotar	0.1	11	
	0.4	17-19	270-300
	0.7	30	
Nappa	0.1	11	
	0.4	15-17	270-300
	0.7	28	

RESULTS

After laser treatment, all types of leather retained their natural histological structure, collagen bundles were not deformed, and the layers were evenly spaced without increasing the density of the structure. The microphotographs of the sections revealed features that are typical only for the area of direct laser beam exposure, namely, the samples of Flotar and Nappa leathers show clear signs of collagen fibre welding. In contrast, the sample's surface does not have a layer of residual coating film or other chemical components/fillers. The removed layer of leather is converted to amorphous carbon and removed from the surface. Further analysis of microphotographs revealed an increase in the separation of collagen fibre bundles in the laser ablation zone (on the surface).

The results of electron microscopy of leather samples (Fig. 2) indicate that laser treatment has no negative effect on the dermis structure and opens the capillary-porous structure of the leather, thereby increasing its vapour permeability.

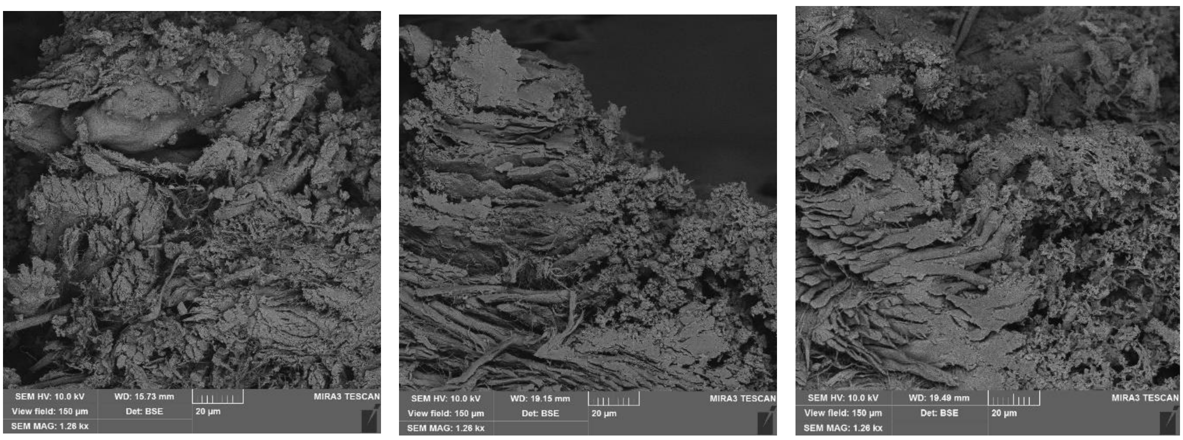


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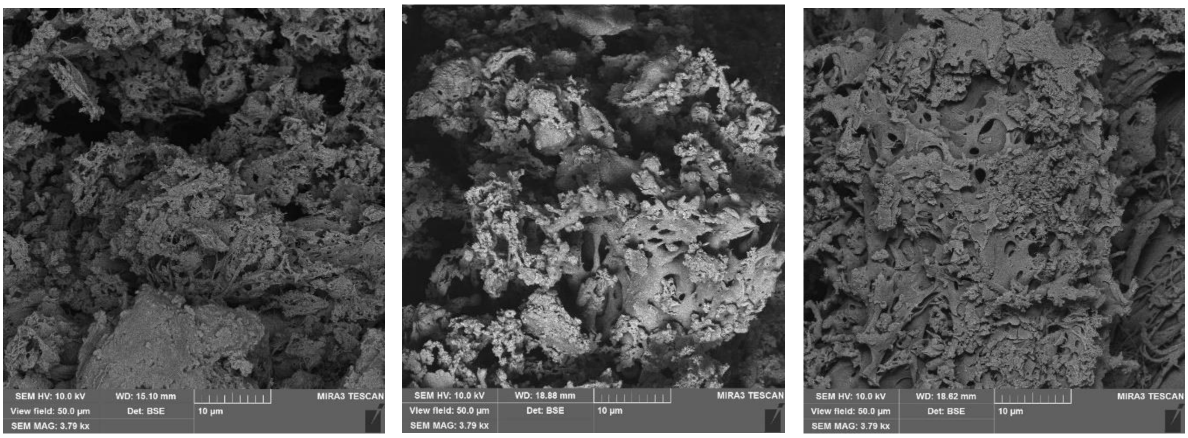
Figure 2. Electron microscopic images of cross-sections of leather samples in the ablation zone: a – Crust leather; b – Flotar leather; c – Nappa leather

The results of electron microscopy show that the structure of the dermis under laser radiation has not undergone morphological changes, which confirms the correct choice of technological parameters for the laser engraving operation. All types of leather have retained their natural histological structure, collagen bundles are not deformed, and the layers are evenly spaced without increasing the density of the structure. Microphotographs (top view) of the sections revealed features that are characteristic only of the area of direct laser beam exposure, namely, samples of Flotar and Nappa leathers have obvious signs of welding of collagen fibres, while the surface of the sample does not have a layer of residues of the covering film or other chemical components/fillers of the leather (Fig. 3 b, c).

The leather layer removed by the laser beam is converted into amorphous carbon and removed from the surface. Further analysis of microphotographs revealed an increase in the separation of collagen fibre bundles in the laser ablation zone (on the surface).

The results of electron microscopy of skin samples indicate that laser treatment has no negative effect on the dermis structure and opens the capillary-porous structure of the skin, thereby increasing its vapour permeability (Fig. 4).

The study of the hygienic properties of Crust, Flotar, and Nappa leathers was carried out by ISO 14268:2008 by determining the vapour permeability, which characterises the ability of the leather to pass water vapour.



a *b* *c*

Figure 3. Electron microscopic image of the top view of the surface layer of leather samples in the laser ablation zone: a – Crust; b – Flotar; c – Nappa

The constructed diagrams demonstrate (Fig. 3) that with an increase in the ablation depth up to 0.7 mm (50% of the total thickness of the sample), the relative vapour permeability increases in all samples of the studied leathers. Compared to the control samples, where there is no ablation, the relative vapour permeability for the skin of Crast increased by 5%, Flotar by 13.5%, and by 9.5% for Nappa. When the ablation area is increased to 50% of the working area of the samples, there is a sharp increase in the relative vapour permeability of Flotar leather by 25% compared to the control sample. Correspondingly, the indicator's increase is within 8.5% for Crust’s leather and for Nappa – 11.6%. Thus, the dependence of vapour permeability on the depth and area of laser ablation has been proven, and the influence on the hygienic properties of the leather decorated with laser engraving has been established.

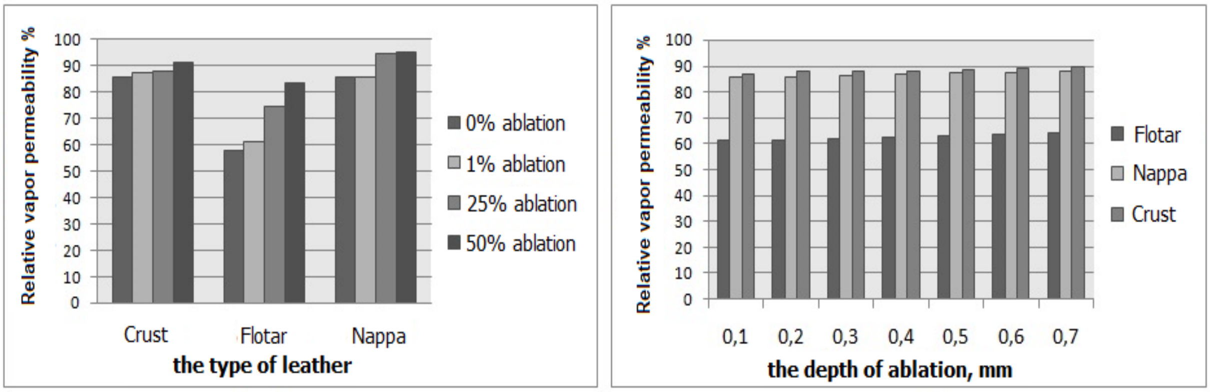


Figure 4. Dependence of vapour permeability on the area and depth of ablation

Thus, it is proved that the increase in vapour permeability is directly proportional to the increase in the depth and area of laser ablation, which significantly affects the hygienic properties of leather products, especially footwear.

CONCLUSION

It has been proven that the increase in vapour permeability is directly proportional to the increase in the depth and area of laser ablation. This significantly affects the hygienic properties of leather products, especially footwear.

It was established that the state of the structure of the skin dermis under the influence of laser radiation does not undergo fundamental morphological changes in structure, and the laser engraving process itself does not hurt its macrostructure. The changes observed in the ablation zone, namely in the Flotar and Nappa skin samples, indicate clear signs of welding of collagen fibres.

It has been proven that increasing the ablation depth to 50–52% of the sample thickness and the ablation area to 50% of the total area significantly increases its vapour permeability in all leather samples, which occurs due to the opening of the capillary-porous structure of the leather. Compared to the control samples, where there is no ablation, the relative vapour permeability for Crust increased by 8.5%, Flotar by 25%, and Nappa by 11.6%.

The depth of laser ablation, equal to 25-30% of the leather thickness, and the area of engraved elements less than 50% of the total area of the part are rational technological parameters for laser treatment of leather, which will ensure good hygienic properties and will not impair the operational characteristics of the products.

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