COMMUNICATIONS IN
DEVELOPMENT AND ASSEMBLING OF TEXTILE PRODUCTS

IMPROVEMENT OF THE STRENGTH OF ADHESION BONDS OF TEXTILE PRODUCTS FOR THE IMPROVEMENT OF THE EFFICIENCY OF CRIMINALISTIC SUPPORT OF LAW ENFORCEMENT ACTIVITIES

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INFO

CDAPT, peer reviewed article
2020, Vol.1, Nr. 7, Paper 2020-02
DOI:10.25367/cdatp.2020.1.p48-56
Received: 08 May 2020
Accepted: 7 June 2020
Available online: 25 September 2020

ABSTRACT

Analysis of methods of chemical and physical modification and activation in the manufacture of garments made of polymeric materials is carried out. The analysis studied a wide range of possibilities for the use of nanotechnology in the garment industry and can serve as a theoretical basis for the manufacture of garments made of polymeric materials of various purposes, in particular for military and law enforcement agencies. The technology of rendering shape-resistant textiles, including clothing made of genuine leather, by use of the method of chemical modification and activation of its surface, which makes it possible to use more effectively various textile materials, in particular, leather at the cutting stage, is presented.

Keywords
textile materials, garments, genuine leather, bonding, form resistance, adhesion

1 Introduction

The development of the garment industry is nowadays strongly influenced by new technologies. The harsh conditions of the current market economy also place their requirements on textile products. Along with high demand products, the satisfaction of several requirements like strength of the seams is especially important for products used in military and law enforcement activities. Thus, the units of forensic support of pre-trial investigation bodies of the National Police of Ukraine have an urgent need for modern samples of means of maximum preservation and protection of forensically significant information (including physical evidence) and places of finding such information from negative factors, both subjective and objective ones. Such technical means and tools include mobile tents, awnings and protective screens.

The choice of fabric plays an important role and is a decisive factor for the production of both clothing and special textile products, like in their use as power structures. By this means and a proper choice, the final product may deliver all the necessary protective, functional and operational properties.

Therefore, it goes without saying that such products must be made by materials that meet the highest performance, durability, impermeability, and breathability characteristics.

In this case, a particularly important factor for the quality of textiles are the adhesive joints of materials in their formation.

During operation, garments (including clothing) are exposed to moisture, wet-heat treatment, various deformations, which lead to premature deterioration of the appearance of the garment due to the poor quality of the adhesive bonding materials during molding. Increasement of the adhesive strength of the adhesive joints of garments in bonding with adhesive linings is one of the most important problems of the garment industry [1].

Nowadays there are no high-efficiency processes of bonding of garment parts with adhesive pads, which would allow to control the adhesive interaction and to predict its behavior during garment processing. The need for the development of such processes arises because of the tendency of constant updating of the raw material basis for the manufacture of garments (clothing genuine and artificial leather, textile materials with form resistant, abrasion-proof and other types of processing), which adhesion properties have not been studied. Therefore, the search and development of new methods and techniques for the improvement of the quality and reliability of the adhesive joints of polymeric materials in the formation and molding of parts of garments is an urgent problem.

Almost all textile materials are subject to different types of decoration, which can adversely affect the quality of the adhesive. Due to such surface modifications on the garment fibers, a small, but resistant to further technological operations drug layer is fixed. As a result, the active areas of the fibers are blocked, which adversely affects the quality of the adhesive joints during the bonding of garment parts. Due to this, the effect of very expensive finishing of textile materials (for example, hydrophobization, modification of the properties of textile materials – reducing shrinkage, increasing of the invariability of fabrics in both dry and wet conditions, etc.) should sometimes be partially removed during garment production in order to make it possible to perform necessary operations in the later garment manufacturing stage. [1, 2].

One of the ways to improve the quality of the adhesive joints of garment parts is to apply methods of physical and chemical influence on the tiled surface of textile materials that have undergone various types of finishing. Such methods can be differentiated not only by the types of finishing, but also by the preparations containing the technological solution. The purpose of such processing is to obtain the maximum positive technological effect for the preservation of the consumer properties of the clothing materials provided during the outfit. The same problem arises in the manufacture of genuine leather products, which are also sensitive to the effects of temperature [1, 3, 4].

Nowadays, modern chemicals are used in the garment industry. This include dispersions based on acrylate (athebin BFF) and polyurethane (aquapol-21) which increase shape resistance and reduce the weight of garments made from costume fabrics. The increase in form resistance is due to the formation of hydrogen and covalent bonds between molecules due to the interaction of the active centers of the fibers with the reactive groups (-NH-CO-C- and -CH_2CH (COOR) -) of the chemicals polymers. Appropriate chemical treatment allows to increase the shape resistance of the form by 15–30% (compared to the sample, duplicated adhesive gasket material without additional processing), regardlessof the materials surface density values and the type of used chemical preparation.

Analysis of the literature showed that the following polymer compositions can be used for direct stabilization: aqueous dispersions of various rubbers (chloropropene, butadiene styrene, etc.), dispersion of polyvinyl acetate, or polyvinyl chloride, polyacrylic or polyurethane adhesives, aqueous solutions, aqueous solutions polyethylene, polypropylene, or polyamides [5].

The use of chemicals for fixing the shape of garments has several advantages over traditional bonding [6–8]. It allows combining the processes of formation and fixation of the form as well as fixing the new arrangement of fibers not only by the surface, but also by thickness. This allows to regulatethe properties of the semi-finished products through changes in number, concentration, and parameters of application of the polymer composition.

For example, as a result from the reinforcement of genuine leather with adhesive gaskets, the modulus of elasticity of the samples increases by 20% and is stabilized by the polymer composition from 12 to 32% (depending on the concentration). Elasticity of the bound increases for 10% and when treated with a polymer composition based on polyvinyl acetate, it is reduced for 24% This is due to the compacting of the structure as a result of the introduction of the polymer composition.

Studies have also shown the effectiveness of using a depolymerizing drug in form of an aqueous solution of ethyl alcohol (concentration of 10 g/l) at the stage of preparation of textile material for bonding (depolarization of antistatic coating). Ethyl alcoholis a solvent for adhesive polyamide components, which promotes more effective penetration of the adhesive into the structure of the material (solvation effect). Due to this treatment, the bundle effort increases by 24–40% and the stiffness increases by 26–64% [7].

The details of garments made of textile materials have to undergo the double bonding effect. It influences the increase of the indices of delamination effort and stiffness for bending. Therefore the significant academic interest consists in the search of chemical means of the influence on adhesive properties of contacting surfaces of the packing materials “skin –adhesive cushioning material". In this regard, it is advisable to search for environments for local processing of individual sections of garment parts. The advice follows up on the basis of which it is possible to equalize the rigidity indices of parts made from different topographic areas (collar, floor, chapra). In addition, it should be considered in mind that the choice of chemicals should prevent the destruction of protein (collagen), which is the basis of natural skin. Such a substance may be an alcohol that does not dissolve the protein but alters the conformational structure of the molecule by displacing water. Water is strongly bound to the active groups of collagen by molecular interaction forces (mainly hydrogen bonds). Water interacts with ionized groups –OH. The amount of H_2O bound depends on the collagen processing technology. Collagen’s behavior through the dehydration with alcohol can cause an increase of the tightness of genuine leather.

2. Method

Sometimes, to obtain adhesive compounds with high strength and shape resistance, the bonding of textile materials is carried out by use of steam chemical active media – a combination of processes of heating, pressure and chemical modification of textile materials and glue by introducing chemical agents into the zone of adhesive contact by means of a steam medium to increase the adhesive activity of components, modifications of their surfaces. Chemical compounds (up to 6 components) may be included into the composition of the vapor chemical active media. The presence of chemical activators in the adhesive contact zone (urea – 5% and sodium bisulfate – 12%) allows reducing the bonding temperature from 180 ºC to 120 ºC, upon receipt of the normalized index of the delamination force. When using a three-component composition (butadiene styrene latex SKS-65GP – 35%, sodium salt – 20%, coagulate – 15%), the stratification force increases by 2.0–3.0 times, the stiffness – 1.5–2.0 times [9].

The structural unit of collagen is tropocollagen (monomer, 1.5 × 280 nm triple helix segment). The monomers, when cross-linked, form collagen. Hydrophobic radicals are inside the protein molecule of collagen, and the hydrophilic are oriented toward the solvent. Denaturation breaks these bonds and spins. This leads to the displacement of water, changes in the conformational structure of the molecule. Intramolecular cross-links can be between spiral chains of three-helical particles, inter-molecular cross-links can be between three-helical particles. Mucopolysaccharides in the structure of collagen stabilize the fibrils, regulate the fibril formation, limiting the thickening of the fibrils, and prevent their sticking. Polar polysaccharide sites bind to ethanol. Ethyl alcohol may bind to phosphate groups of phospholipids and carboxyl groups of oil chains. Ethanol molecules displace "bound" water molecules from phospholipids, thereby disrupting their structure [3, 4].

An important factor of the implementation of skin transformation processes at the stage of manufacture of garments, including the processes of bonding, is the temperature of welding of collagen, which is 60–65ºC for cattle skins. Welding temperature limits vary depending on the type of tanning (the fat tanning skin has a welding temperature of 65°C, vegetable – 70–85°C, chromium – up to 130°C, formaldehyde – 90°C).

In this regard, the abovementioned factor should be considered when choosing a genuine leather garment manufacturing technology. This may be managed by the appropriate selection of adhesive liners, improvement of the processes of bonding, including the skin removal itself, beyond the direct influence of temperature, determining the rational parameters of bonding and as stated above, the use of chemicals.

3 Research results

The object of the study was the process of bonding and evaluation of viscoelastic properties of genuine leather and packages based on chemical modification and activation methods. Subjects of the study: two types of natural garments (upholstery (C1, C2) and velor (V1, V2)) of the chrome tanning method and two adhesive pads of Hänsel firm (art.1101 / 2ZM4 – with low melting point of adhesive point and art. 2102 / 105MS6 used for costume bonding).

Low temperature gasket adhesive materials of various origin were used to form duplicate packages based on genuine leather velour. Initially, a number of preliminary studies were carried out, which consisted of bonding of prototypes on a stationary press and subsequent determination of the quality of the formed package on the basis of indicators of rigidity and delamination effort, as well as visual assessment of the skin surface. After testing three low-temperature adhesive pads designed to duplicate leather and fur, none of them met the quality requirements. For this type of skin adhesive pad material – art. 2102 / 105MS6 "Hänsel" was selected (most often used in bonding of so-called "complex" costume fabrics – fabrics that have undergone final stages of the treatment to give the effects of increasing invariability, reducing shrinkage, etc.). Hänsel materials are of very high quality, reliability and great technological variety. This is due to the use of the latest technology and extensive experience in production of non-wovens and other nonwovens.

The use of an aqueous solution of ethyl alcohol is the first option to evaluate the ability to create form-resistant garments, including clothing made of genuine leather. The basis of the fixing effect of alcohol is the effect on the degree of protein hydration. As a result of water loss, protein molecules decrease in size and coagulation of the plasma component occurs. In the process of fixing alcohol shows the following features:

– reduction of dielectric constant of proteins with corresponding strengthening of mutual attraction between molecules;

– the emergence of new stereochemical bonds as a result of the convergence of previously distant groups of protein molecules;

– no effect on active protein groups.

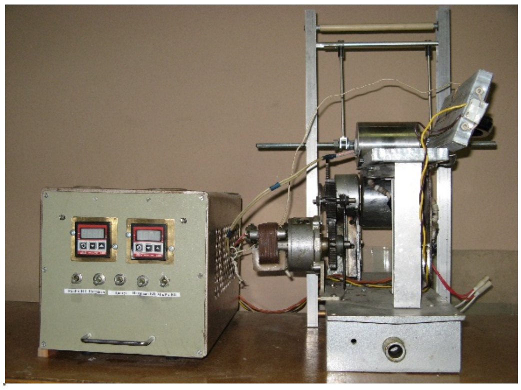
Application of the ethanol to the top layer of the wrong side of the skin was performed by a spray (2 ml per 10 cm^2) in a special chamber, without passing to the front.

Batch bonding was performed on a semi-automatic laboratory facility developed by us for bonding of parts from thermosensitive materials within the framework of the experimental design matrix (Box B2 design). The advantages of the developed installation include the reduction of the effect of temperature on genuine leather, which reduces the likelihood of its structural changes. Under these conditions it is possible to expand the range of adhesive liners with a higher melting point of the adhesive point.

The creation of an original laboratory installation designed for the bonding of heat-sensitive materials (natural and artificial leather) with adhesive gaskets by non-contact method of heating the adhesive coating directly, followed by the connection with heat-sensitive material with the help of the pressure shafts. The general view and schematic diagram of the installation is shown on Fig.1.

Samples for research are made in the longitudinal direction of genuine leather and adhesive materials in the form of strips: length l = 160 ± 1 mm, width b = 30 ± 1 mm. Before the test, the samples are kept in normal atmospheric conditions in accordance with ISO 2419 (T = 20 ± 1 ºC, φ = 65 ± 5%).

a



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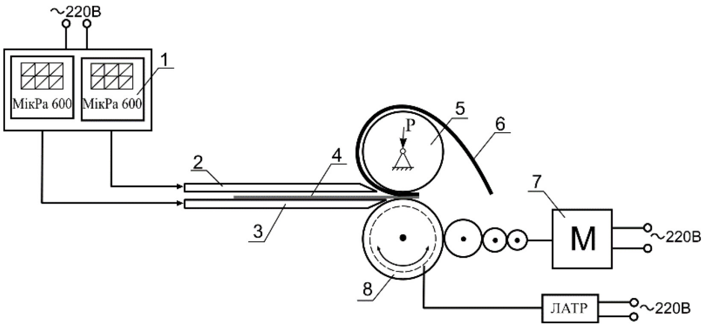

Fig.1. General view (a) and schematic diagram (b) of the laboratory installation for bonding of parts made of thermosensitive materials: 1 - temperature controller MikRa 600 upper (2) and lower (3) flat heater; 4 - sample of adhesive gasket material; 5 - upper calender; 6 – leather sample; 7 - engine; 8 - lower calender with heating.

The principle of operation of the installation. Connect the device to a power source. Switch on the MicRa 600 temperature controller 1. Set the temperature of the upper and lower flat heaters 2, 3 (the rate of temperature rise of the heaters is 6 ºC/min). Switch on the heating of the lower Heated roller 8 (Heated roller temperature rise rate 20 ºC/min). Allow time to heat the lower Heated roller and heaters to the needed temperature. Place a sample of adhesive gasket material on the lower flat heater 3, and the leather sample is positioned on the surface of the upper Heated roller 5. Close the upper flat heater. Withstand time according to the value of the melting point of the adhesive coating of the gasket material. Start the engine that will actuate the lower 8 and upper 5 rollers (rollers speed 0.02 m/s). After the bonding process, turn off the engine. The pressure in the working area is set by the load of the upper calender. At the end it is necessary to disconnect the installation from the power supply.

Taking into account previous search studies, as well as the recommendations of manufacturers, the value of input factors for bonding is presented in Table 1.

Table 1. Input Factors for Bonding

Natural garments		**velor (V1, V2)**			**upholstery (C1, C2)**		
Adhesive gasket material		**art. 2102/105MC6**			**art.1101/2ZM4**		
The levels of variation		+1	0	-1	+1	0	-1
Temperature of the lower Heated roller of T_{LC}, ºC	X1	160	150	140	120	100	80
Bonding time t, c	X2	20	15	10	20	15	10
The temperature of the flat heaters, T_{FH}= const, ºC		130			90		
Pressure P = const, MPa		0,02			0,02		

Example of mathematical processing of the planning matrix of the experiment (Boxing plan B2) PP = f (T, t) for bonding of the package V1 + art. 2102 / 105MS is given in table. 2.

Table 2. The results of mathematical processing for the package V1 + art. 2102 / 105MS

Variance of reproducibility:	*0,022*
The dispersion of the mean according to parallel observations:	*0,007*
Estimated Kohren criterion:	*0,362*
Tabular value of Kohren's criterion:	*0,516*

Regression equation coefficients:

coefficient	coded value	accuracy	natural significance	significance
X0	*2,10850*	*0,20182*	*-40,60708*	**Significant**
X1	*0,43333*	*0,07369*	*0,51883*	**Significant**
X2	*0,45000*	*0,07369*	*-0,00094*	**Significant**
$X1^2$	*-0,15850*	*0,15633*	*-0,00159*	**Significant**
X1X2	*0,00850*	*0,09026*	*0,00000*	**Irrelevant**
$X2^2$	*0,09150*	*0,15633*	*0,00143*	**Significant**

Planning matrix and experiment results:

NN	*X1*	*X2*	*Y1*	*Y2*	*Y3*	*YMIN*	*YMAX*	*YSR*	*YRAS*	*DISP*
1	*1*	*1*	*2,900*	*3,200*	*3,000*	*2,656*	*3,410*	*3,033*	*2,925*	*0,023*
2	*-1*	*1*	*1,900*	*2,100*	*2,100*	*1,750*	*2,316*	*2,033*	*2,058*	*0,013*
3	*1*	*-1*	*2,200*	*1,900*	*2,000*	*1,656*	*2,410*	*2,033*	*2,025*	*0,023*
4	*-1*	*-1*	*0,900*	*1,200*	*1,100*	*0,690*	*1,444*	*1,067*	*1,158*	*0,023*
5	*1*	*0*	*2,300*	*2,300*	*2,200*	*2,131*	*2,403*	*2,267*	*2,383*	*0,003*
6	*-1*	*0*	*1,700*	*1,600*	*1,600*	*1,497*	*1,769*	*1,633*	*1,517*	*0,003*
7	*0*	*1*	*2,800*	*2,300*	*2,600*	*1,944*	*3,190*	*2,567*	*2,650*	*0,063*
8	*0*	*-1*	*1,700*	*2,000*	*1,800*	*1,456*	*2,210*	*1,833*	*1,750*	*0,023*

Table value of the Fischer criterion (F_{tab}):	*3,2389*
Estimated value of the Fischer criterion (F_{est}):	*2,81949*
The model is adequate.	

Mathematical processing of the obtained data allowed us to obtain two-factor second-order mathematical models that adequately characterize the process under study according to Fisher's criterion (according to which, the calculated values (F_{est}) of this criterion should be less than the tabular (F_{tab}) F_{est} = 0.71–2.77 < F_{tab} = 3.63):

- *V1* + art. *2102/105MC:*
  Y=2,11+0,43X1+0,45X2-0,16$X1^2$+0,09$X2^2$;
- *V1 + C_2H_5OH* + art. *2102/105MC6:*
  Y=2,59+0,43X1+0,54X2-0,12$X1^2$-0,07$X2^2$;
- *V2+* art.*2102/105MC6:*
  Y=1,21+0,37X1+0,13X2+0,21$X1^2$+0,04$X2^2$;
- *V2+ C_2H_5OH* + art.*2102/105MC6:*
  Y=2,99+0,91X1+0,16X2-0,06$X1^2$+0,04$X2^2$;
- *C1* + art.*1101/2ZM4:*
  Y=1,51+0,45X1+0,34X2+0,06$X1^2$+0,04$X2^2$;
- *C1 + C_2H_5OH* + art.*1101/2ZM4:*
  Y=1,48+0,46X1+0,35X2+0,08$X1^2$+0,07$X2^2$;
- *C2* + art.*1101/2ZM4:*
  Y=1,46+0,53X1+0,38X2+0,46$X1^2$+0,24X1X2-0,31$X2^2$;
- *C2 + C_2H_5OH* + art.*1101/2ZM4:*
  Y=2,18+0,53X1+0,16X2+0,19$X1^2$+0,10X1X2-0,01$X2^2$.

According to mathematical models, geometric surfaces of the dependence of the response function on factors X1 and X2 in three-dimensional space were constructed. The graphical dependencies of the stratification force on the temperature and the time of bonding (Fig. 2), allow determining the range of rational parameters at which the achievement of the recommended level of bonding quality (P_p ≥2 N/cm) is guaranteed.

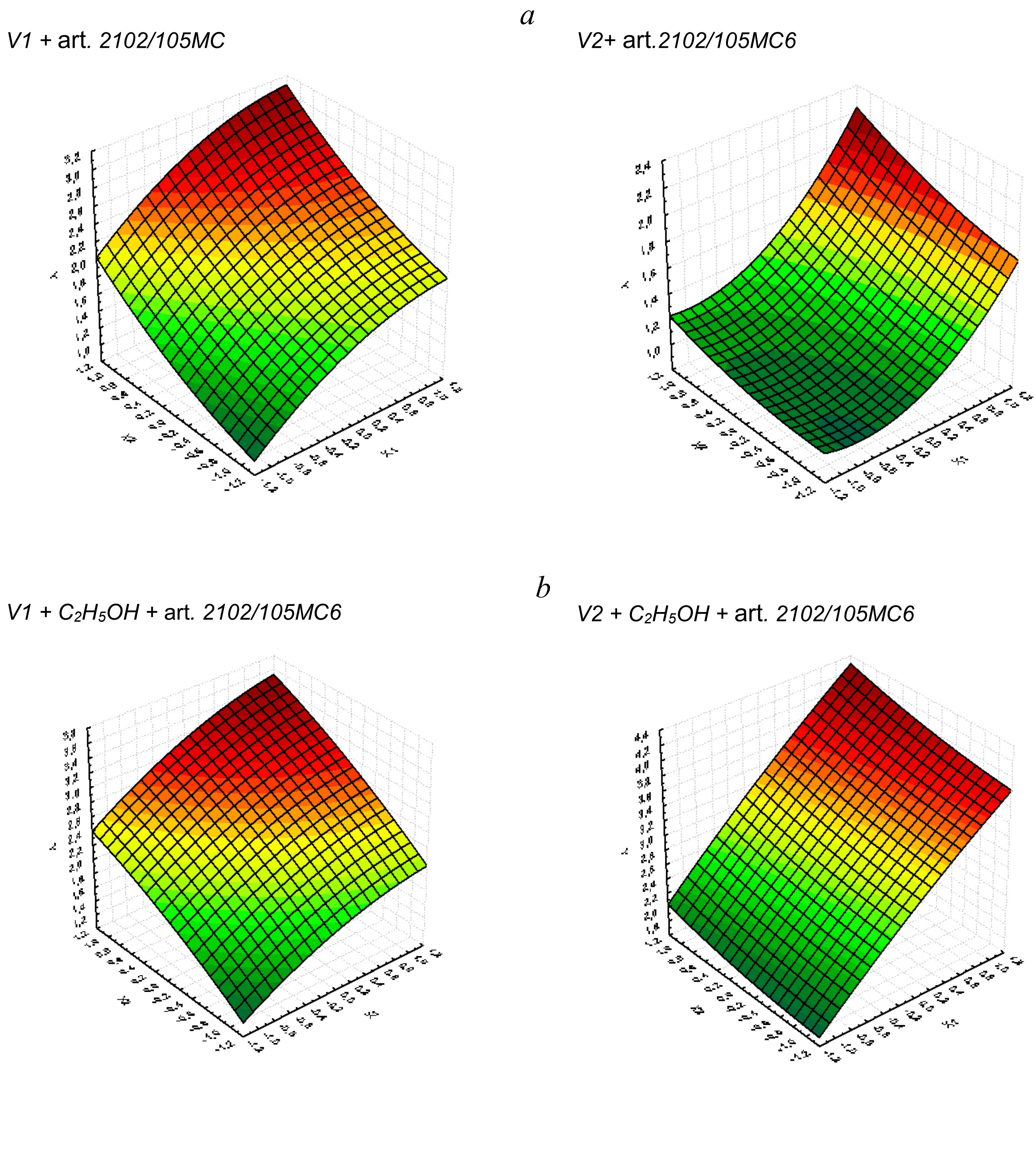

Fig. 2 Dependence of Response Function on Factors X1 and X2 for Packages Based on Genuine Leather velor (V1, V2) Before (a) and After Surface Treatment C_2H_5OH (b).

Previous studies have investigated differences in the properties of individual areas of genuine leather, which creates some complexity in the technology of manufacturing garments both at the stages of cutting individual parts, and when applying thread connections. It is established that when duplicating some types of leather with adhesive gaskets, there are certain difficulties in ensuring the normative indexes of the delamination effort. In this regard, the technology of increasing the adhesive properties of individual parts of garment parts by treating the surface of the skin with substances with amphiphilic properties (ethyl alcohol), which allow due to partial leaching of the fat component and changes occurring on the skin surface (impact on collagen fiber) to obtain more rational (in terms of energy consumption) bonding parameters and to provide the prerequisites for creating packages with different zonal stiffness indicators (Table 3).

Table 3. Rational Options for Packet Bonding Based on Genuine Leather

Components of packages	**Bonding options**			
	without pre-treatment of the genuine leather surface		**the surface of genuine leather is pre-treated with ethanol**	
	T_{LC}, ºC	*t*, c	T_{LC}, ºC	*t*, c
C1 + art.1101/2ZM4	110	15	100	10
C2 + art.1101/2ZM4	110	15	100	10
V1 + art.2102/105MC6	150	15	130	15
V2 + art. 2102/105MC6	150	15	130	15

The effect evaluation is based on the bending stiffness and delamination efforts, such as the processing of genuine leather. It is established that due to such processing, the indices of delamination force increase by 20–35% and the indices of bending stiffness in the longitudinal direction, when placing the skin face up and face down, increase respectively by 1.5–2.2 times and by 1.4–1.6 times.

Appropriate local surface treatment of the leather gives the opportunity to simultaneously obtain the following effects: changing of the elastic properties (in particular, stiffness) and increasement of the adhesive properties of the surface of the genuine leather, while maintenance and improvement of the performance properties provided by the manufacturer.

4 Conclusions

It is established that in the manufacture of garments made of polymeric materials, which have undergone many stages of processing at the stages of production and furnishing of textile and leather materials, it is necessary to take into account the change of primary properties, including especially the adhesion of the surface.

A wide range of methods and means for activating the surface of materials have been identified that significantly affect the quality of garment performance, including changes in viscoelastic and performance properties. In this regard, it is advisable to carry out further research in the area of forming the sewing products due to the biased activation of the surface and bonding of their details. This should consider the topographical features of garments, including genuine leather, and the possibility of provision of a high-quality adhesive connection, taking into account the temperature indices of collagen welding.

Further improvement of the adhesive technology in the production of garments can be achieved due to the use of polymeric adhesives with high cohesive strength and adhesion to polymeric materials of various purposes, as well as to the development of more rational technological solutions in the production of garments that meet the economical and ecological modern challenges. Addressing this issue will not only improve the quality and competitiveness of domestic garments, but also reduce the cost of imported materials and garments, including these for the needs of power structures.

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