Research Article

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Structure and Properties of Layered Material Based On Non-Woven Sheep's Wool

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Abstract
A three-layer non-woven composite material for clothing and footwear has been obtained by an adhesive bonding method. The thickest middle layer of the material consists of evenly laid coarse fibers of sheep wool, the top and bottom layers are made of cotton jersey, polymer glue is located between the layers. The layers are bonded by thermal duplication at a temperature of 150 ± 5 ° C for 2.0 ± 0.2 minutes. The structure of the layered material was investigated by FT-IR spectroscopy and scanning electron microscopy. Established chemical and adhesive interaction between fibers of sheep wool, cotton and polymer glue. In the process of thermal exposure, the molten polymer is sorbet, both into the structure of wool and knitted fabric, which leads to a decrease in the density and an increase in the thickness of the adhesive layer. Sorption and excellent adhesion of the molten polymer to the fibers ensures the solidity and strength of the composite material. The strength and thermos physical properties of the layered material have been determined.

Key words: Sheep Wool, Laminated Nonwoven Fabric, Structure, Sorption, Adhesion

Introduction

In recent years, nonwovens have become an extremely important segment of the textile industry. Technical developments in the fields of polymers, nonwovens processing and fabric finishing have led to significant improvements in the physical and mechanical properties of materials [1]. Nonwovens are a part of technical textiles used for the manufacture of clothing and footwear, mainly for functional purposes, for insulation, support and reinforcement of products [2]. They are made using various bonding technologies, such as needle-punched bonding, chemical bonding, thermal bonding, thermochemical hybrid bonding [3-8]. Nonwoven materials are used to reinforce polymer composites, in membrane materials for clothing and footwear, etc [9-13]. A large group is represented by insulated nonwoven materials with heat-retaining and thermoregulatory properties [14, 17]. Fibrous raw materials are the basic component for nonwovens, which determines the main properties of the final products, not only in terms of chemical properties, but also in terms of physical or other functional properties. Nonwovens used for clothing and footwear must have both high sorption and permeability [18]. Waste wool fibers are a potential source of thermal and acoustic applications due to their natural properties [19, 20]. Among natural fibers, sheep wool is one of the oldest textile fibers used by mankind [21]. Wool is much coarser than other fibrous materials, and wool factories accumulate a sufficient amount of coarse wool fibers that are not spun and knitted. Meanwhile, there is a shortage of warm, comfortable, lightweight, soft lining materials for clothes and shoes based on natural raw materials. The aim of this study is to assess the potential use of course, uneven size sheep wool fibers as a non-woven thermal insulation layer of a lining material for clothes and shoes.

Experimental

Materials

Washed, free from impurities, ready for use, but not suitable for spinning, sheep wool fibers were provided by the private enterprise “M. Sayfullaeva” in Tashkent. Cotton knitted fabrics of two types were provided by JV LLC "UZTEX" in Chirchik, Tashkent region. Dry polymer film glue was purchased in the market of the city of Tashkent.

The layered material is formed by alternately stacking the layers and simultaneously duplicating under pressure while heating. The complete material is passed through heated pressure rolls. The shaft temperature is 150 ± 5°C, the contact time of the material with the shaft is 2.0 ± 0.2 min. In fig. 1 shows a schematic diagram of the construction of the resulting layered material.

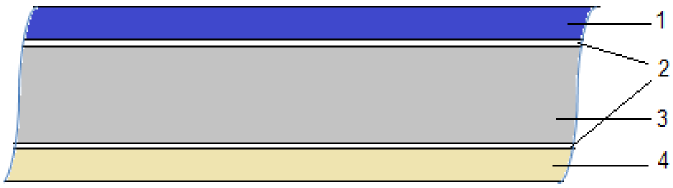

Figure 1: Construction of a layered nonwoven material: 1 - knitted fabric, 2 - adhesive layer, 3 - sheep wool, 4 - knitted fabric.

Characterizations

The structure of the samples was determined using infrared spectroscopy with Fourier transform (FT-IR) Nicolet IN10 Company Thermo Fisher Scientific (USA) in the scanning range of 500-4000 cm-1. Samples were prepared using KBr tablets sample identification was performed using OMNIC Spectra software and from literature. The morphology of the surface and cross section of the starting fibers, as well as fibers sized with starch and collagen solutions were studied using a SEM – EVO MA 10 scanning electron microscope (Carl Zeiss, Germany). Physical and mechanical properties of materials were tested at the certification center "CENTEXUZ" TITLI, room temperature 20 ± 3°C, relative air humidity 65 ± 5%. The breaking load of materials was determined on a dynamometer "AO-1" (tensile machine), the maximum breaking force of the device is 1000 N. The air conductivity of materials was determined using an AP-36 OSM air conductivity meter; sample dimensions 160 x 160 mm. The abrasion resistance of the materials was determined on a device for determining the strength of fabrics to abrasion M 235/3, the rotation speed of the abrasives was 47.5 ± 2.5 rpm, the sample size was a circle with a diameter of 50 mm.

Results and Discussion

To determine the nature of the interaction between sheep wool fibers and a macromolecule of polymer glue, FT-IR spectra of sheep wool fibers (Fig. 2), polymer glue (Fig. 3) and the product of their thermal interaction (Fig. 4) were studied. In the FT-IR spectrum of sheep wool, absorption bands related to the bonds of the protein macromolecule were found.

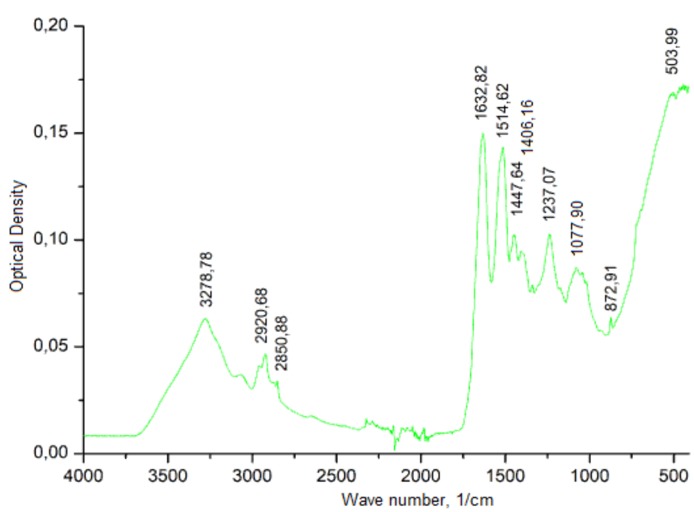

Figure 2: FT-IR spectrum of sheep wool fibers: 3278.78 – $\nu_{N\text{-}H}$, 2920.68, 2850.88 – $\nu_{C\text{-}H}$, 1632.82 – $\nu_{C=O}$ (lane amide I), 1514.62 – $\delta_{N\text{-}H}$ (lane amide II), 1447.64 – $\delta_{O\text{-}H}$, 1406.16 – $\delta_{C\text{-}H}$, 1237.07 – δ_{NH}+ ν_{CN}, 1077.90 – $\nu_{C\text{-}O}$, 872.91 – $\delta_{N\text{-}H}$, 503.99 – $\delta_{O=C\text{-}N}$.

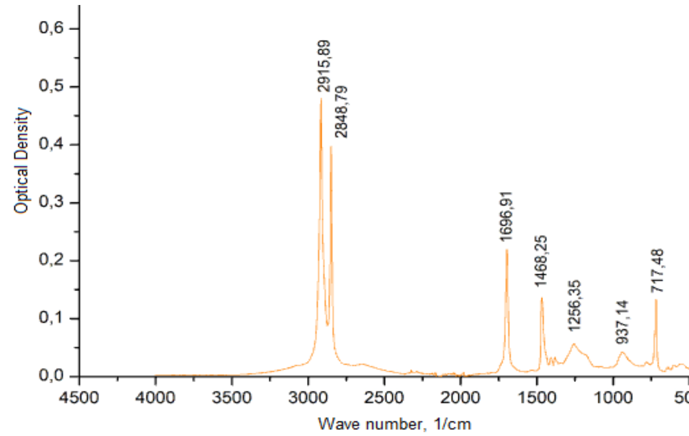

Figure 3: FT-IR spectrum of polymer adhesive: 2915.89, 2848.79 – $\nu_{C\text{-}H}$, 1696.91 – $\nu_{C=O}$, 1468.25 – $\delta_{C\text{-}H}$, 1256.35, 937.14 – $\nu_{C\text{-}O}$, 717.48 – $\delta_{C\text{-}H}$.

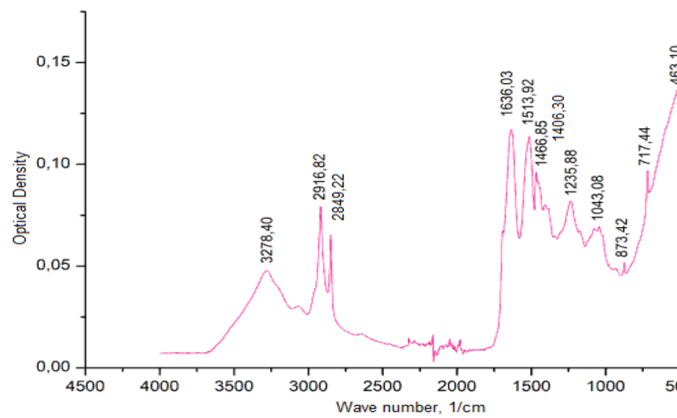

Figure 4: FT-IR spectrum of the product of interaction between sheep wool and polymer glue: 3278.40 – $\nu_{N\text{-}H}$, 2916.62, 2849.22 – $\nu_{C\text{-}H}$, 1636.03 – $\nu_{C=O}$ (lane amide I), 1513.92 – $\delta_{N\text{-}H}$ (lane amide II), 1466.85 – $\delta_{C\text{-}H}$, 1406.30 – $\delta_{C\text{-}H}$, 1235.88 – δ_{NH}+ν_{CN}, 1043.08 – $\nu_{C\text{-}O}$, 873.42 – $\delta_{N\text{-}H}$, 717.44 – $\delta_{C\text{-}H}$, 463.10 – $\delta_{O=C\text{-}N}$.

Table 1: Absorption bands in FT-IR spectra

Substance	Vibration mode, bonds, absorption band, cm^{-1}								
	ν_{N-H}	ν_{C-H}	$\nu_{C=O}$	δ_{N-H}	δ_{O-H}	δ_{C-H}	$\delta_{NH}+\nu_{CN}$	ν_{C-O}	$\delta_{O=C-N}$
Sheep wool	3279	2921 2851	1633	1515 873	1448	1406	1237	1078	504
Adhesive		2916 2849	1697			1468 717		937	
Wool + adhesive	3278	2917 2849	1636	1514 873		1406 1467 717	1236	1043	463

As can be seen from the data in Table 1, in the FT-IR spectrum of the product of thermal interaction of sheep wool with polymer glue, the absorption bands of stretching and deformation vibrations of C-N bonds of the peptide group of wool, stretching and deformation vibrations of C-H bonds of wool and glue remain almost unchanged. The absorption band of deformation vibrations of O-H groups of wool in the product was not found. A shift of absorption bands of stretching vibrations of C = O and C-O bonds of wool and glue, deformation vibrations of the skeleton of O = C-N wool is observed. These changes indicate the occurrence of a chemical interaction between the wool molecule and the polymer adhesive. Possibly, trans esterification occurs due to the hydroxyl group of the protein macromolecule and the ester group of the glue macromolecule with the formation of new ester bonds between the wool and the polymer. This assumption is to some extent confirmed by the study of the microstructure of wool and the product of its interaction with glue.

Sheep wool contains fibers of varying thickness and length (Fig. 5).

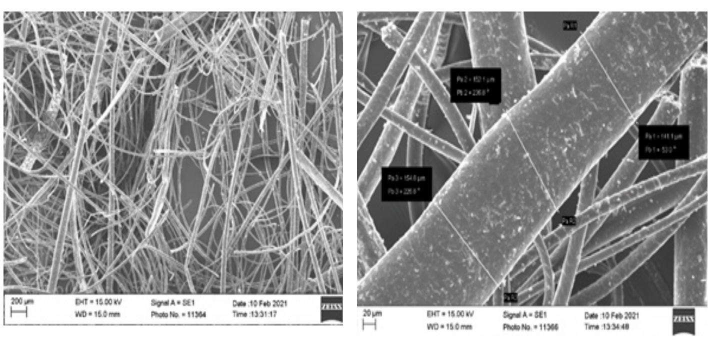

Figure 5: SEM images of sheep wool fibers

The diameter of sheep wool fibers ranges from 25 to 170 microns, so it is very difficult to obtain uniform and high-quality yarn. Such fibers are most suitable for forming a nonwoven web. Good compatibility of wool and polymer glue is shown by SEM images of their mixture, as well as the microstructure of the cross-section of the laminated composite material (Fig. 6).

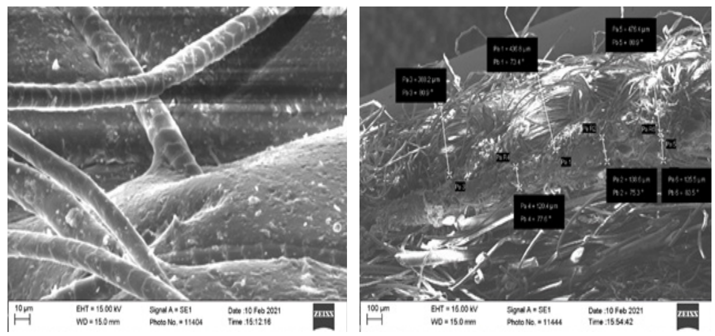

Figure 6: The structure of the mixture "wool fibers + glue" and the cross-section of the composite material

As can be seen from Fig. 6, wool fibers are well wetted by the melt adhesive, strong adhesive interaction can be seen. The polymer adhesive also binds well to the fibers of the knitted fabric. In the volume of the adhesive layer, you can see both fibers of sheep wool and fibers of cotton knitwear. The initial thickness of the adhesive film was about 100 µm, and the knitted layer was about 500 µm. In the resulting fibrous material, the thickness of the knitted layer decreases to 390-480 microns, and the thickness of the fiber-adhesive layer increases to 120-140 microns. This indicates the interpenetration of the layers in the composite material. The adhesive layer very strongly bonds the nonwoven wool layer to the surface knitted layer, ensuring overall structural strength. The thickness of the material is 2.4-2.5 mm. Determined the physical-mechanical properties of the original knitted fabrics and the resulting layered material (table 2).

Table 2: Physical-mechanical properties of textile materials

Properties	Bottom knitted fabric	Upper knitted fabric	Layered material
Breaking strength, N by length in width	 269 203	 401 296	 348 354
Elongation at break,% by length in width	 39 71	 18 68	 35 82
Adhesive strength between layers, N			79.0
Surface density, g / m^2	160.3	157.5	682.5
Air conductivity, dm^3 / m^2 · s	72.6	148.7	40.9
Heat retention,%			46
Abrasion resistance, cycles	9500	14500	

An increase in areal density, tensile strength and elongation at tensile of the laminated material is found in comparison with knitted fabrics. The revealed air permeability index makes it possible to use the layered material as parts of clothing and footwear, although this index decreases in comparison with the original components. In general, the composite laminate has satisfactory physical-mechanical properties, including adhesion strength between layers and heat retention.

Conclusions

Coarse, variably sized sheep wool fibers are suitable fibrous components for heat retaining nonwovens for clothing and footwear. A three-layer material is obtained, the outer layers of which are made of cotton knitted fabric, and the inner non-woven layer is made of sheep wool. The layers are held together by means of polyacrylic glue. In the process of thermal exposure at a temperature of 150 ± 5°C for 2.0 ± 0.2 minutes, a chemical interaction occurs between the molten polyacrylic polymer and protein macromolecules of wool. Chemical interaction and mutual sorption of the fibres with the molten adhesive provides the adhesive strength between the layers and the solidity of the material. The composite layered material based on non-woven sheep wool has satisfactory physical-mechanical properties and retains heat.

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