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TREATMENT OF POLYESTER FIBRE NEEDLE-PUNCH MATERIAL

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Processing of needle-punch material with the examined method increases the deformation resistance and does not affect the strength characteristics. The increase in the deformation resistance is a function of the bulk density of the initial needle-punch material. The change in the porosity during processing of the material is a function of the mobility and orientation of the fibres.

For use of man-made leather as a filter, fibre sorbent, or base, needle-punch material made of synthetic fibres must have a set of properties which is not totally achieved during needle-punching. The structure of the highly porous fibre material formed during needle-punching ensures phase permeability of gases and liquids. At the same time, needle-punching does not provide the deformation and strength characteristics required in many cases, and these characteristics can only be increased by additional processing of the material.

Calendering of needle-punch material made from a blend of high-melting polyester and low-melting polypropylene fibres is the most effective processing method. The specific features of processing the material on roller equipment and the shrinkage properties of the polypropylene fibre cause the formation of closed pores and transformation of the surface layer into a monolithic state. Such a change in the pore structure reduces the permeability of the material.

To eliminate the noted drawbacks, we proposed using a bicomponent fibre in the material [1] and processing the material on special equipment [2]. The proposed method of modifying the mechanical properties of the material decreases the change in the pore structure but increases the cost and makes the manufacturing technology more complicated due to the necessity of uniform mixing of the fibres. We investigated the possibility of using the method for processing needle-punch material made of polyester fibre.

We investigated needle-punch material made of polyester fibre with a linear density of 0.33 tex (TU 6-13-0904077-95-91). The fibre web was prepared by a mechanical method of spinning. The material was processed on a special setup that exercised a deformation-heat effect on the material in the gap between the heated spindle and the conveyor belt. At a constant spindle temperature of 210°C, the processing rate varied from 1.2 to 10 m/min. The structural characteristics of the material were determined according to GOST 15902.2-79 and the strength characteristics were determined according to GOST 15902.3-79. To evaluate the deformation resistance of the material, we used the load required for attaining 10% elongation of a sample of standardized size. The structural and mechanical characteristics of the needle-punch materials are reported in Table 1.

It is important to determine the dependence of the processing efficacy on the bulk density of the material at constant surface density and on the surface density at constant bulk density. This combination of structural parameters was selected because of their effect on deformation of the material in the gap between spindle and conveyor belt and the effect on heating the material during processing. The bulk density of the material was varied by changing the needle-punching density; increasing the density, in addition to increasing the bulk density of the material, caused the fibres to be reoriented over the thickness. The data in Table 1 indicate some anisotropy of the deformation and strength properties of the needle-punch

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TABLE 1. Physicomechanical Characteristics of the Needle-Punch Material Used for Processing

Sample No.	F, kg/m^2	$d \cdot 10^3$, m	ρ, kg/m^3	Load, N				Elongation at break, %	
				at 10% elongation		at break		along	across
				along	across	along	across		
1	0.225	1.9	112	3	5	350	460	120	100
2	0.250	1.8	142	8	26	440	740	105	80
3	0.615	4.3	144	16	40	970	1780	140	105

Notation: F — surface density; d — thickness; ρ — bulk density.

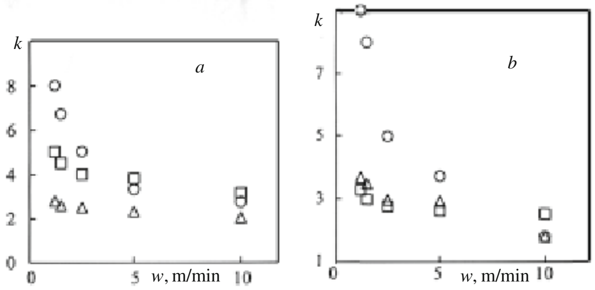

Fig. 1. Strengthening as a function of material processing rate in longitudinal (a) and transverse (b) directions. Samples (according to Table 1): ○ — 1; □ — 2; △ — 3.

materials, the consequence of the mechanical method of spinning the fibre web; this method ensures the predominant orientation of the fibres in the longitudinal direction.

We found that at a spindle temperature of 210°C, the change in the thickness of the material or packing density of the fibres was almost independent of the processing speed. At the maximum speed of 10 m/min, a 30-40% decrease in the initial thickness was attained and at the minimum speed of 1.2 m/min, the thickness decreased by 40-45% of the thickness of the initial needle-punch material. The decrease in the thickness is common to materials of different bulk and surface density. The change in the structure of the material does not affect the strength characteristics of the treated material.

The deformation resistance, whose value is determined by the processing speed and structure of the material, increases to a significant degree during processing. The complexity of evaluating the mechanical characteristics of fibre materials is due to its dependence on the fibre packing density, manifested by a combination of surface and bulk density indexes. To exclude this dependence, an arbitrary strengthening coefficient (k), calculated from the following equation, is used

$$k = P_i / P_0$$

where P_i and P_0 are the load for attaining 10% elongation at a certain processing speed and the corresponding load of the initial needle-punch material. The dependence of the strengthening coefficient on the processing speed is shown in Fig. 1.

At a processing speed of 4 to 10 m/min, its effect on the strengthening coefficient in the longitudinal and transverse direction of materials of different surface and bulk density is described by a common curve which is close to linear. At a processing speed of less than 4 m/min, coefficient k is a function of the bulk density of the material. Processing material with the minimum bulk density at this speed causes the strengthening coefficient to deviate from linear, while its shape shows a significant increase in the deformation resistance in the longitudinal and transverse direction of the material. For materials with the maximum bulk density, the linear shape of the curve of its effect on the strengthening coefficient persists (see Fig. 1).

The different effect of processing on the deformation resistance and strength of the material is the consequence of a specific feature of its structure formed in the needle-punching stage and the change in it during processing. When the fibres are caught in the needle notches, fibre bundles oriented over the thickness with high packing density are formed.

Fibres contained in several bundles and fibres free of links with bundles are located between bundles. The packing density of the fibres in the space between bundles is much lower than the packing density in bundles. Deformation of the material develops due to movement of the fibres in the force field in the interbundle space and redistribution of the load on the fibres in the bundles. Failure of the material is determined by the behavior of the fibres in the bundle. The deformation resistance and strength of the material are a function of the friction of the fibres against each other in the interbundle space and directly in the bundles.

The increase in the deformation resistance of the processed material at constant strength indicates an increase in the friction between fibres in the interbundle space and preservation of the strength in the bundles. The change in the friction in the interbundle space is due to an increase in the fibre packing density in compression of the material in the gap between spindle and conveyor belt, which is reflected in an increase in the contact area between fibres. However, the compression of the material is insufficient for changing the packing density of the fibres in the bundle, and deformation of the bundles during processing alters their shape while preserving the volume or distance between fibres formed in the needle-punching state.

The dependence of the deformation resistance on the bulk density of the material is due to its effect on the reorientation of the fibres attained during processing. The increase in the bulk density of the material limits movement of the fibres and attaining their optimum packing density which increases the contact area. The decrease in the mobility of the fibres is also due to an increase in the number of bundles, which in addition to their resistance to movement of the fibres, decreases the length of segments between neighboring bundles. In processing material of low bulk density, the high mobility of the fibres resutls in the optimum packing density and increases the contact area between them. The most marked effect of the structural factors on the mobility of the fibre is manifested in the longitudinal direction of the material or in the direction of processing of the material. In the given direction of the material, the strengthening coefficient is not only a function of the bulk, but also the surface density of the initial needle-punch material (see Fig. 1).

The dependence of the deformation resistance on not only the density of the material but also the processing speed shows that the change in the deformation resistance is determined by fixation of the fibres when their packing changes. Fixation of the fibres is the consequence of melting of their surface layer and formation of a cohesive bond in pressure on the fibres in the gap between spindle and conveyor belt, which is a function of the adjustable processing speed of the material. The low strength of the bond between fibres determines the resistance to the development of deformation and after its failure, does not affect breaking of the material.

For material with a relatively high bulk density, fixation of the fibres occurs at their contact sites in the needle-punching stage. The number of contacts between the fibres in such material is not a function of the processing speed, but the increase in the deformation resistance with a decrease in the processing speed is the consequence of an increase in the depth of heating. At a high processing speed, the effectiveness of reorientation of the fibres is insignificant, and the deformation resistance is primarily determined by formation of a cohesive bond between fibres. Decreasing the processing speed below 4 m/min results in the predominant dependence of the deformation resistance on reorientation of the fibres, most marked for material of low bulk density (see Fig. 1).

We can conclude that when the proposed method of processing needle-punch material is used, its deformation resistance increases. The processing efficacy is a function of reorientation and melting of the fibres, and the relation between them is determined by the processing speed and the bulk density of the material. At the same time, in the processing conditions used, the strength of the material does not increase. Material with increased strength can be manufactured by conducting the process at a higher temperature, which is accompanied by melting of the polyester fibre.

REFERENCES

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