Analysis on the Causes of Shrinkage of Noise and Thermal Insulation Nonwoven Fabrics and Drafting of Measures to Prevent It

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The use of nonwoven materials in the construction of the General Planetary Vehicle (GPV) is substantiated. Studies of two types of fibers have been carried out, technological features of the production of nonwoven fabrics are described. Since a physico-chemical method of forming polymer glues is used to obtain such materials, the optimal drying temperature of the canvases has been experimentally established to prevent their increased shrinkage.

Keywords: *experiment, fiber, nonwoven materials, sample, secondary raw materials, temperature, textile industry.*

Introduction

The construction of the General Planetary Vehicle (GPV) will require a large number of various materials, which will mainly be delivered from Earth. The use of ecomaterials [1], as well as secondary raw materials (waste) in the erection of the GPV is one of the aspects of reducing the environmental burden on the planet. Waste from the textile industry can also be involved in this process (for example, in the arrangement of the EcoCosmoHouses (ECHs) or for the sound and thermal insulation of transport modules in the GPV).

A promising direction of textile waste application as secondary raw materials is the manufacture of nonwoven composite materials by the method of thermal bonding, which has three modifications: hot pressing, welding and autogesion interaction. The canvases obtained in this way can be used:

- in the construction as noise and thermal insulation, substrates for laminate and linoleum;
- in mechanical engineering as a noise insulation for vehicles [1, 2].

The use of nonwoven composites from textile waste can significantly reduce the complexity of manufacturing materials for the construction of transport and residential buildings; in the future, it will have a positive impact on the cost of GPV construction works.

One of the stages of the technological process in the production of these materials is the drying (stabilization) of the fibrous canvas by exposing it to temperature. Thermal fixation takes place in a furnace due to the melt of evenly distributed binding fibers.

The Vitebsk State Technological University (VSTU) has developed different compositions of fiber mixtures [3], however, all of them contain components that shrink when exposed to temperature, which reduces the size of the finished canvas. For use in mechanical engineering, nonwovens are laminated and shaped according to the size and configuration of the parts for which they are intended. During thermal fixation, the fibrous canvas must be exposed (in order to prevent shrinkage during lamination) to a temperature that will allow the fibers to bond together, i.e., create splices, while performing forced shrinkage in compliance with the required linear dimensions of the canvas width. In this paper, attention is paid to this process.

Research Description

Bicomponent polyester fiber of the 4DE51Slon brand (Figure 1) and polyester fiber of the 6DE64 brand (Figure 2) – a hollow, highly developed, unsiliconized fiber – are used as a heat-binding (bonding) fiber in the splices.


Figure 1 – Fiber
of 4DE51Slon brand
(manufactured in Korea)


Figure 2 – Fiber
of 6DE64 brand
(manufactured in Korea)

The manufacturers have declared the following melting point of the fibers:

- 4DE51Slon brand – 160–180 °C;
- 6DE64 brand – 140–160 °C.

The fiber of 4DE51Slon brand contains two components in its structure – the core and the shell. Due to the low melting point of the shell, bicomponent polyester fiber (BIC), also referred to as "light melt", is used as a binding element. The appearance of such a fiber under a microscope is shown in Figure 3.

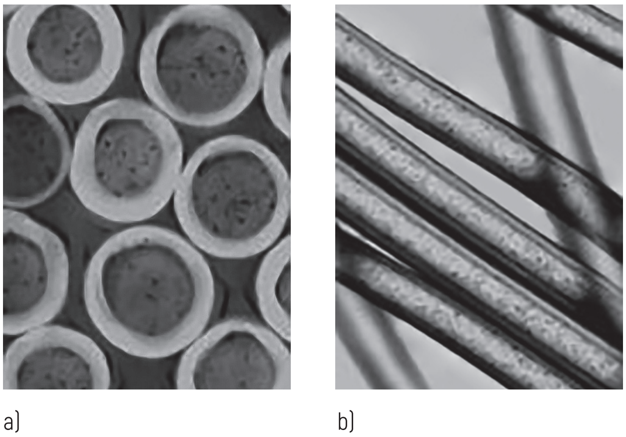
a) b)

Figure 3 – View of the BIC under a microscope:
a – fiber cross section; b – fiber by length

The BIC shell consists of polyethylene, has the property of increased softness, and is also characterized by a low junction temperature; therefore, it can be used as a binding component in a mixture of fibers or with other materials. The core substance (polyester) is necessary to ensure the integrity of the product. The core does not melt during the connection and creates a three-dimensional netting, adding strength to the nonwoven product.

The drying (stabilization) process is carried out as follows: the cloth is automatically placed on the conveyor in front of the furnace and moves along the line between two perforated conveyor belts. The furnace consists of hot chambers and a cooling section. In the hot chamber, the air is forced into the fan through the diffuser. On the burner, the air is heated to the preset fiber processing temperature. In the cooling section, the fan operates in a suction mode, using external air to cool and stabilize the product. Then the air is blown out through the exhaust pipe.

When exposed to temperature, all fibers undergo changes. Let us consider the behavior of a canvas consisting of an experimental mixture (Table 1) in the stabilization process.

The height of the canvas at the exit from the canvas-forming machine was 0.2 m, after passing the furnace under the modes and parameters specified in Table 2 – 0.16 m; the width of the canvas before drying – 1 m, after drying – 0.98 m.

Thus, the shrinkage of the material was 20 % in height and 2 % in width, which indicates its anisotropy. Such indicators are unacceptable, since the maximum possible shrinkage in width, which is subsequently compensated by the pressure shafts in the cooling section, is equal to 1 %.

Let us analyze the percentage of fiber components at the outlet of the furnace for the sample shown in Table 1. The research was carried out at the VSTU Testing and Certification Center.

Table 1 – Fibrous composition of the experimental mixture

Component	Proportion of component specified by recipe in finished mixture, %	Actual proportion of component in the test sample, %	Absolute difference, %	Uneven distribution of component fibers in the mixture, %
Polypropylene	15.6	15	0.6	3.8
Polyester	40	43	3	7.5
Grating mixture	2.8	0	2.8	100
Polyamide	13.6	13	0.6	4.4
Wool	12	13	1	8.3
Viscose	8	8	0	0
Cotton	8	8	0	0

Table 2 – Technical characteristics of the thermal fastening furnace

Indicator	Value
Furnace length, m	9
Exposure temperature, °C	180
Speed of canvas passage, m/min	15

The results according to the test report are given in Table 3: the proportion of components in the test sample of nonwoven material decreased in comparison with the indicators of the sample of the generated canvas. Such changes are associated with the behavior of fibers included in the mixture. Some of their properties are presented in Table 4 [4].

Table 4 shows that polypropylene and polyethylene included in the BIC have melted – they are not identified in the finished material, and wool, viscose and cotton are close to destruction at the temperature of the furnace operation, which explains the decrease in their proportion.

The considered method of obtaining nonwovens is physico-chemical, based on the creation of splices of polymers included in the mixture and being under the impact of temperature. The activation of the adhesive ability of the fibers is carried out when they transition to a viscous-flow state. Polymers (polypropylene, polyester, polyamide) in this form, like liquids, are able to spread over the surface of the fibers and wet it, which is necessary to make up an adhesive contact and obtain a strong adhesive bond.

Splices are created by a layer of a binding component between the fibers at their intersections and therefore are considered contacting ones. They have minimal dimensions and strength, as well as optimal hinge mobility (Figure 4).

The width of the finished canvas should be at least 1 m. Shrinkage of 1 cm across the width of the nonwoven fabric, as noted earlier, is compensated when passing between the sealing shafts after the cooling system. In this case, the irregularities are cut off with a longitudinal cutter.

Table 3 – Percentage of components in the experimental mixture

Proportion of component in the test sample of the generated canvas		Proportion of component in the test sample of nonwoven material*	
Component	Content, %	Component	Content, %
Polyester	43	Polyester	40
Polypropylene	15	Wool	10
Polyamide	13	Other types of fibers (polyamide, viscose, cotton)	50
Wool	13		
Viscose	8		
Cotton	8		

* The proportion of a component in the nonwoven material sample under study was determined by two types of fibers, since the test protocol did not detect a component content below 10 %.

Table 4 – Properties of components in the experimental mixture

Component	Temperature, °C		Shrinkage at melting point, %
	Melting	Destruction	
Polypropylene	130–170	325	12–15
Polyester	255–260	341	40–50
BIC:			
• core (polyester)	255–260	341	40–50
• shell (polyethylene)	130–145	349	1–2
Polyamide	254–260	355	1–2
Wool	–	170	2–3
Viscose	–	150–160	5–8
Cotton	–	180–220	2–6

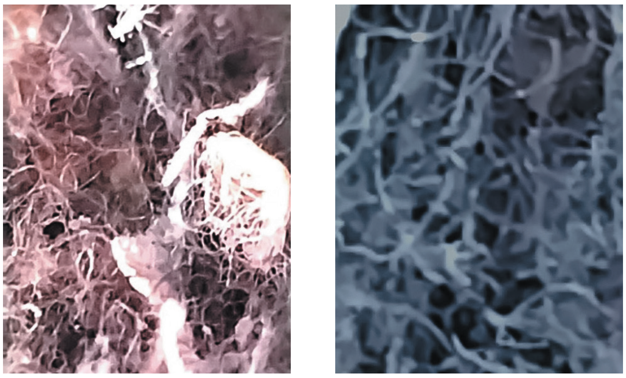

Figure 4 – View of the formed canvas under a microscope

Thus, when creating nonwovens, shrinkage is an essential characteristic (respectively, also the temperature range in which it is detected). However, it is important to know not only the possible change in the size of the canvas as a result of this process, but also the shrinkage rate at different temperatures.

As for any thermally activated relaxation process, the rate and time of shrinkage are determined by the activating energy. Therefore, it is of interest to determine the relaxation parameters of the canvas shrinkage process according to linear dilatometry data in order to establish the mechanism, kinetics of the process and assess the stability of nonwovens with polymer content at different temperatures.

To optimize the technological process of thermal fixation, it is necessary to choose such a temperature of exposure to the material that would allow creating splices sufficient for adhesion, while not changing the width of the canvas in the finished form. To do this, an experiment was conducted in which mixtures with different percentages of binding fiber were used (in some, the binding element was BIC 4DE51Slon, in others – polyester fiber 6DE64) (Table 5).

The work was guided by the following parameters: the planned thickness of the canvas – 27 mm, the speed of the tape – 15 m/min, the duration of temperature exposure to the samples – 36 s. The shrinkage of the canvas with an initial thickness of 0.2 m was neglected, since the material is compacted to a thickness of 27 mm in a follow-up.

The test results are shown in Figure 5.

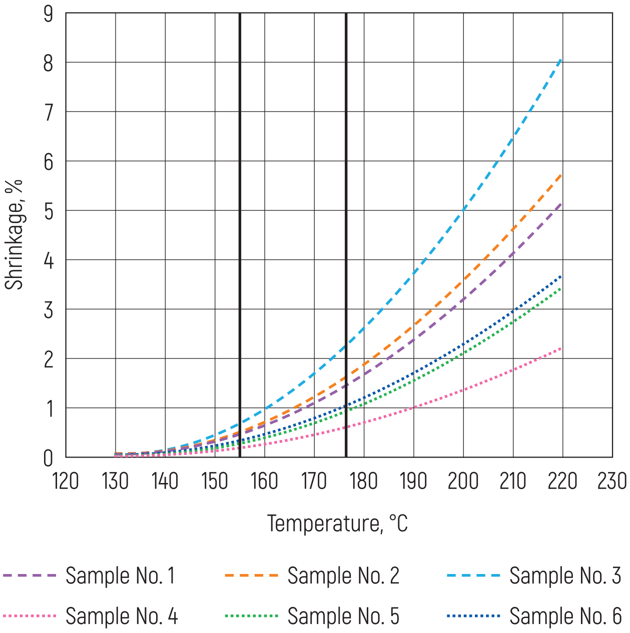

Figure 5 – Graph on the dependence of the shrinkage of samples on the exposure to temperature

The lowest limit of the experiment temperature is selected by the melting point of polyethylene, the upper limit is selected by the maximum possible temperature of the furnace.

Table 5 – Composition of experimental mixtures

Sample	Components	Proportion in the mixture, %	Sample	Components	Proportion in the mixture, %
No. 1	6DE64	15	No. 4	4DE51Slon	15
	Regenerated fiber	85		Regenerated fiber	85
No. 2	6DE64	25	No. 5	4DE51Slon	25
	Regenerated fiber	75		Regenerated fiber	75
No. 3	6DE64	35	No. 6	4DE51Slon	35
	Regenerated fiber	65		Regenerated fiber	65

Conclusions

The graph (Figure 5) shows that mixtures with BIC 4DE51SIon content should be dried at a temperature of 130–178 °C, and with the content of fiber 6DE64 brand – 130–160 °C (with a maximum allowable shrinkage of the material of no more than 1 %). Non-compliance with these temperature conditions contributes to increased shrinkage of canvases in width and, as a result, manufacturing of defective products. In order to prevent defects in finished products, these parameters should be taken into account during the further lamination of a material for its use in the GPV.

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