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A RESEARCH ON THE AIR PERMEABILITY OF NEEDLE-PUNCHED NONWOVENS MADE FROM SHEEP WOOL FIBERS

Abstract. Air permeability is one of the important properties affecting the quality of insulation materials. This property is related to the passage of air through the fabric. This article presents the method of measuring airflow resistance according to Frazier. And also the dependence of air permeability index on such parameters as: density and thickness is given. Insulating mats made by needle-punching method from coarse and semi-coarse wool of Kazakhstani sheep breeds were used in the work. The main parameters of mats were determined: thickness, density, air permeability. It is established that 4-layer mats with згтсрштп density of 600 rpm have the lowest value of air permeability.

Keywords: nonwoven material, air permeability, wool, needle-punched material, density, waste, bio-insulation material, animal by-products.

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Introduction. Wool is an environmentally friendly, renewable material suitable for many applications. Today, wool is also used in the construction industry, as it has properties that provide good thermal and acoustic insulation. Wool insulation materials with the addition of various blends can be produced as mats, batts, or panels and used to insulate roofs, walls, and ceilings [1-4]. Such materials can be produced by different technologies, with different compositions and characteristics.

The fundamental parameters of thermal insulation materials are the characteristics determined by their physical, mechanical and chemical properties. And the key characteristic in choosing the type of thermal insulation is thermal conductivity, the value of which for thermal insulation materials should be less than 0.065 W/mK [5]. In turn, when assessing the quality of insulation materials, measurements of properties such as: density, thermal conductivity, air permeability, water absorption, moisture, sorption moisture, compressibility, strength are carried out.

Air permeability is the property of a material to allow air to pass through. This parameter is measured using the Frazier test method in accordance with standard test methods such as ASTM D737 and DIN 53887 [6], GOST ISO 9237-2013 [7]. It is determined by the airflow passed through the unit air area of the sample per unit time at a specified differential pressure, usually about 200 Pa, and is characterised by the air permeability coefficient. The air permeability parameter for insulation materials should correspond to low values. Tang et al [8] presented different airflow measurement methods: direct airflow method, alternating airflow method and acoustical method. It was established that these methods are based on parameters such as density, fibre diameter, porosity and thickness. Thus, the air permeability of nonwovens depends mainly on the density of the nonwoven material.

Mendrek et al [9] studied basic parameters of materials from Polish sheep wool. Two felts with different thicknesses – 9.9 and 19.5 mm – were obtained for the experiment. The surface density of the 19.5 mm felt was higher and the air permeability was twice lower. Thus, the following relationship was established: the increase in fabric thickness and surface density led to a decrease in air permeability, this in turn affects the increase in the path length of the sound wave passing through the material.

Kicińska-Jakubowska A. et al. [10] determined the main parameters of mats: thickness, surface density and air permeability. Insulating materials with different content of wool and linen made by needle-punching method were used. The air permeability of the mats was tested at a pressure of 200 kPa. The air permeability values of the tested samples increased as the wool content increased, and reached 2539 mm/s. Thus it was found that mats with higher bast fibre content have a greater ability to absorb sound, while mats with higher wool content have better thermal insulation properties.

Thus, the literature review shows that air permeability is one of the indices necessary in the study of insulating properties of nonwovens.

This paper presents a comparative characterisation of 6 samples of nonwoven materials and the dependence of air permeability on density. The studied samples were made of 100% coarse and semi-coarse wool of Kazakhstan sheep breeds by needle-punching method.

Materials and methods. Six samples of sheep wool nonwoven fabric obtained by needle-punching were analysed (Fig. 1.). The samples differed in the number of layers, thickness and density. The materials were obtained from 100% coarse and semi-coarse wool of fat-tailed and “Bayys” (Kazakh fat-tailed semi-woolly breed) sheep breeds, provided by IP “Miras”.

Fig. 1. Samples of nonwoven materials

Sample 1. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light. Number of layers 1. Frequency of punching 600 rpm . Needle punching depth 12-13 mm.

Sample 2. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light and coarse wool of fat-tailed sheep breed, dark. Number of layers 3. Frequency of punching 600 rpm . Needle punching depth 12-13 mm.

Sample 3. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light and coarse wool of fat-tailed sheep breed, dark. Number of layers 4. Frequency of punching 600 rpm . Needle punching depth 12-13 mm.

Sample 4. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light. Number of layers 2. Frequency of punching 500 rpm . Needle punching depth 12-13 mm.

Sample 5. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light and coarse wool of fat-tailed sheep breed, dark. Number of layers 3. Frequency of punching 500 rpm . Needle punching depth 12-13 mm.

Sample 6. Fibre composition: semi-coarse wool of "Bayys" sheep breed, light and coarse wool of fat-tailed sheep breed, dark. Number of layers 4. Frequency of punching 500 rpm . Needle punching depth 12-13 mm.

The following parameters were determined to calculate the density: length, width and thickness of samples.

The formula is used to determine the density (g/cm^3) of wool nonwovens:

$$J = \frac{m_П}{V} \quad (1)$$

where: $m_П$ – sample mass, g; V – sample volume, cm^3.

The volume of the sample (cm^3) is calculated according to the formula:

$$V = l \cdot b \cdot a \quad (2)$$

where: l – length, cm; b – width, cm; a – thickness, cm.

Air permeability was carried out in accordance with GOST ISO 9237-2013 "Textile materials. Method for determination of air permeability". The tests were carried out using the Air Permeability Tester MT 160 by "Metrotex" (Fig. 2).

Fig. 2. Air permeability tester MT 160

Research results and discussion. The air permeability values of the samples were analysed as a function of density and number of layers (Table 1).

Table 1

Air permeability index of the samples

Number of the sample	Density, g/cm^3	Number of layers	Air permeability, dm^3/(m^{2}s)
1	0.11	1	2854.61
2	0.14	3	1241.98
3	0.15	4	554.66
4	0.11	2	2130.96
5	0.12	3	1114.39
6	0.13	4	963.66

The thickness of the tested samples was in the range of 3-10 mm. Sample 1 consisting of 1 layer was the thinnest. The density of the mats was in the range of 0.11-0.15 g/cm^3. The lowest density was characterised by samples 1, 4. The air permeability values of the evaporated mats were in the range of 554.66-2854.61 dm^3/m^{2}s. The lowest air permeability was shown by sample 3. As the number of layers and punching density increased, the air permeability decreased.

The relationship between air permeability and material density for the analysed samples is shown in Figure 3. This relationship shows that the denser the nonwoven material, the lower the air permeability value (Fig. 3.). This is due to the fact that a dense structure prevents the passage of air.

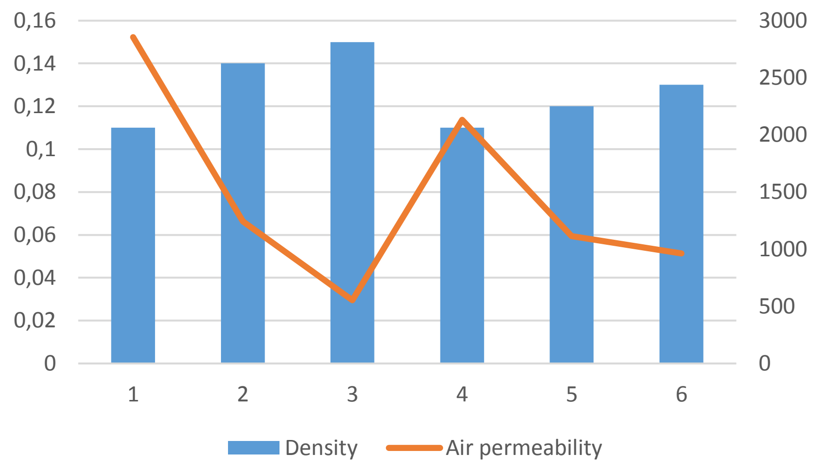

Fig. 3. Analysis of air permeability characteristics of sheep wool insulation materials depending on density

Figure 4 shows the relationship between the air permeability index and the number of layers of the tested specimens. The air permeability index for the samples with more layers and higher punching density is low. This is due to the fact that these materials were denser than samples with a punching density of 500 rpm.

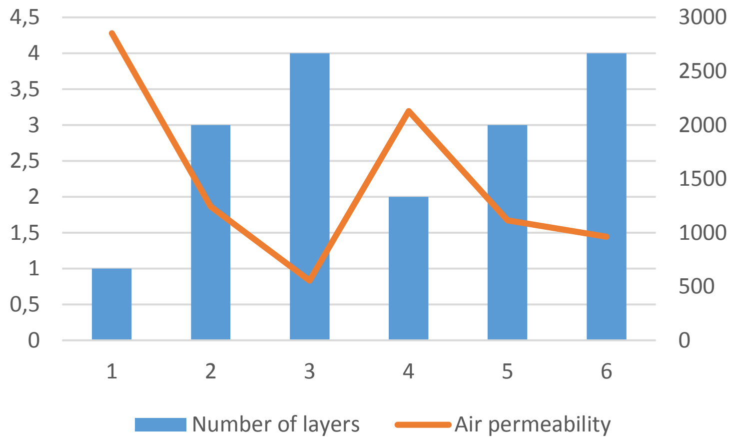

Fig. 4. Analysis of air permeability characteristics of sheep wool insulation materials depending on the number of layers

The air permeability of samples 2, 3 and 6 is the lowest, which is optimal for thermal insulation. According to literature [11], material thickness and air permeability also affect the sound absorption coefficient.

Comparing the obtained test results, it can be concluded that the air permeability of the materials will depend on the material density, the value of which is influenced by such parameters as: number of layers (indirectly), punching density.

Conclusion. In this study, nonwoven mats made of sheep wool from Kazakhstani coarse wool and semi-coarse wool breeds of sheep obtained by needle-punching method without the use of binders. Coarse wool is often considered as a by-product of animal husbandry. However, based on other studies and on the results of this work, it can be concluded that coarse wool can act as a valuable raw material in the production of insulation materials.

By analysing the properties of all six samples, it was shown that the mats with the highest density and number of layers, as well as with a higher punching density, have better insulation properties, i.e. they have low air permeability.

The average density of a material mainly depends on its porosity, at the same time porosity is the main factor on which the thermal conductivity of the material depends, so indirectly, by the value of the average density, it is possible to judge the effectiveness of the thermal insulation properties of the material. The lower the average density of the material, the more pores there are in it and the lower its thermal conductivity.

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ҚОЙ ЖҮНІНЕН ЖАСАЛҒАН ИНЕТЕСІМДІ БЕЙМАТА МАТЕРИАЛДАРДЫҢ АУА ӨТКІЗГІШТІК ҚАБІЛЕТІН ЗЕРТТЕУ

Аңдатпа. Ауа өткізгіштік – оқшаулағыш материалдардың сапасына әсер ететін маңызды қасиеттердің бірі. Бұл қасиет ауаның мата арқылы өтуіне байланысты. Мақалада Фразер бойынша ауа ағынының кедергісін өлшеу әдісі келтірілген. Сондай-ақ, ауа өткізгіштік көрсеткішінің тығыздық пен қалыңдық сияқты параметрлерге тәуелділігі келтірілген. Жұмыста қазақстандық қой тұқымдарының өрескел және жартылай өрескел жүнінен инемен тесу әдісімен жасалған жылу оқшаулағыш материалдар пайдаланылды. Кілемшелердің негізгі параметрлері анықталды: қалыңдығы, тығыздығы, ауа өткізгіштік қабілеті. Иненің тығыздығы 600 айн/мин болатын 4 қабатты материалдар ауа өткізгіштіктің ең төменгі мәніне ие екендігі анықталды.

Тірек сөздер: беймата, ауа өткізгіштік, жүн, инетесімді материал, тығыздық, қалдықтар, биоқшаулағыш материал.

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ИССЛЕДОВАНИЕ ВОЗДУХОПРОНИЦАЕМОСТИ ИГЛОПРОБИВНЫХ НЕТКАНЫХ МАТЕРИАЛОВ ИЗ ВОЛОКОН ОВЕЧЬЕЙ ШЕРСТИ

Аннотация. Воздухопроницаемость - одно из важных свойств, влияющих на качество изоляционных материалов. Это свойство связано с прохождением воздуха через ткань. В данной статье представлен метод измерения сопротивления воздушному потоку по Фразеру. А также приведена зависимость показателя воздухопроницаемости от таких параметров, как плотность и толщина. В работе использовались теплоизоляционные маты, изготовленные иглопробивным способом из грубой и полугрубой шерсти казахстанских пород овец. Определены основные параметры матов: толщина, плотность, воздухопроницаемость. Установлено, что наименьшим значением воздухопроницаемости обладают 4-слойные маты с плотностью иглопрокалывания 600 об/мин.

Ключевые слова: нетканый материал, воздухопроницаемость, шерсть, иглопробивной материал, плотность, отходы, биоизоляционный материал.