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STUDY ON THE STRENGTH OF NEEDLE-PUNCHED NONWOVEN MATERIAL MADE ON THE BASIS OF SOLE TRADER "MIRAS"

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Coarse sheep wool and wastes from the production of woolen yarns are currently considered to be a special waste that requires large disposal costs due to low market demand. For this reason, wool has serious consequences for the environment. However, this type of raw material is considered a promising insulating natural fiber due to its thermal and acoustic properties. Moreover, wool meets the requirements of environmentally friendly materials that are used for yurts, insulation of buildings, and acoustic insulation for the automotive industry. Nevertheless, the sustainability and energy efficiency of insulation materials are currently evaluated comprehensively. In this context, the correctness of the composition of nonwoven fabric, its thickness and strength characteristics, as well as the number of layers play an important role. The purpose of this work is to study the relationship between strength characteristics

and thickness, as well as the number of layers in nonwovens made of 100% wool mixed with coarse and fine fibers, and to determine the most optimal variant of insulating nonwovens. 4 samples of one, two, three and four-layered materials were used in the study. The tested samples of insulating materials were evaluated according to the parameters of breaking load, strength and elongation. The results of the research showed that with an increase in the number of layers of material, there is an increase in the tested two indicators: breaking load and strength. The elongation rates were uneven. Consequently, by examining all three parameters, it was found that the best option is a three-layered nonwoven material.

Keywords: sheep wool, waste reuse, strength, breaking load, nonwoven fabric, natural fiber, insulation material.

ИССЛЕДОВАНИЕ НА ПРОЧНОСТЬ ИГЛОПРОБИВНОГО НЕТКАНОГО МАТЕРИАЛА, ИЗГОТОВЛЕННОГО НА БАЗЕ ИП «МИРАС»

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Грубая овечья шерсть и отходы шерстопрядильного производства в настоящее время из-за нереализованности считаются особым отходом, требующим больших затрат на утилизацию. По этой причине шерсть оказывает серьезные последствия и для окружающей среды. Однако, этот вид сырья считается перспективным изоляционным натуральным волокном благодаря своим тепловым и акустическим свойствам. Более того, шерсть отвечает требованиям экологически чистых материалов, которые используются для юрт, утепления зданий, шумопоглощения в автомобильной промышленности. Тем не менее, устойчивость и энергоэффективность изоляционных материалов в настоящее время оцениваются комплексно. В этом контексте, правильность состава нетканого материала, его толщины и прочностных характеристик, а также количества слоев играют важную роль. Целью данной работы является исследование взаимосвязи между прочностными характеристиками и толщиной, а также количеством слоев в нетканых материалах, изготовленных из 100% шерсти в смеси с грубой и тонкой, и определение наиболее оптимального варианта изоляционного нетканого материала. Испытуемые образцы изоляционных материалов были оценены по параметрам разрывной нагрузки, прочности и удлинения. В исследовании было использовано 4 образца одного, двух, трех и четырех слоев. Результаты исследования показали, что с увеличением количества слоев материала наблюдается рост исследуемых двух показателей: разрывной нагрузки и прочности. Показатели удлинения были неравномерны. Следовательно, исследуя все три параметра, было установлено, что наилучшим вариантом является нетканый материал, состоящий из трех слоев.

Ключевые слова: овечья шерсть, повторное использование отходов, прочность, разрывная нагрузка, нетканый материал, натуральное волокно, изоляционный материал.

"МИРАС" ЖК БАЗАСЫ НЕГІЗІНДЕ ЖАСАЛҒАН ИНЕТЕСІМДІ БЕЙМАТА МАТЕРИАЛДЫҢ БЕРІКТІК СИПАТТАМАЛАРЫН ЗЕРТТЕУ

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Қатты қой жүні мен жүн иіру өндірісінің қалдықтары қазіргі уақытта іске асырылмауына байланысты кәдеге жаратудың үлкен шығындарын талап ететін ерекше қалдық болып саналады. Осы себепті жүн қалдықтары қоршаған ортаға да ауыр зардаптарын тигізуде. Алайда, шикізаттың бұл түрі жылу және акустикалық қасиеттеріне байланысты перспективалы оқшаулағыш табиғи талшық болып саналады. Сонымен қатар, жүн киіз үйлер, ғимараттарды оқшаулау, автомобиль өнеркәсібінде акустикалық дыбыс оқшаулағыш үшін қолданылатын экологиялық таза материалдардың талаптарына

жауап береді. Дегенмен, оқшаулағыш материалдардың тұрақтылығы мен энергия тиімділігі қазіргі уақытта жан-жақты бағаланады. Бұл тұрғыда бейматаның дұрыс құрамы, оның қалыңдығы мен беріктік сипаттамалары және қабаттар саны маңызды рөл атқарады. Бұл жұмыстың мақсаты-беріктік сипаттамалары мен қалыңдығы, сондай-ақ қатты және меринос жүн қоспасында 100% жүннен жасалған бейматаның қабаттар саны арасындағы байланысты зерттеу және оқшаулағыш бейматаның ең оңтайлы нұсқасын анықтау. Оқшаулағыш материалдардың сынақ үлгілері үзу жүктемесі, беріктігі және салыстырмалы ұзару параметрлері бойынша бағаланды. Зерттеуде бір, екі, үш және төрт қабаттың 4 үлгісі қолданылды. Зерттеу нәтижелері материал қабаттарының санының артуымен зерттелетін екі көрсеткіштің өсуі байқалатынын көрсетті: үзу жүктемесі және беріктік. Салыстырмалы ұзару көрсеткіштері біркелкі болмады. Сондықтан барлық үш параметрді зерттей отырып, ең оңтайлы нұсқа ретінде үш қабаттан тұратын беймата материалы екендігі анықталды.

Негізгі сөздер: қой жүні, қалдықтарды қайта пайдалану, беріктік, үзу жүктемесі, беймата, табиғи талшық, оқшаулағыш материал.

Introduction

Over the past few years, the major problem in Kazakhstan has been the problem of the implementation of coarse wool and wastes from the production of woollen yarns. Today, according to the Ministry of Agriculture, about 70% of wool, which is about 26 thousand tons of raw materials, go to wastes. Natural unprocessed sheep wool, as a rule, is completely biodegradable [1]. However, when this wool is not used by the textile industry, it passes into the category of agricultural special wastes with high disposal costs. That is the main reason for improper disposal of wool, which in turn causes a number of environmental pollutants: groundwater pollution, the formation of greenhouse gases during combustion, contributing to global warming [2]. In this context, the best solution to the above-mentioned problem is the application of the concept of circular economy: reuse and recycling of products and materials [3]. According to research of “Woolmark”, among all textile materials, wool is the most reused and easily recyclable fiber [4].

Basically, natural fibers obtained from textile waste are used in the manufacture of thermal and acoustic insulation products [5]. According to the researches, nonwoven wool materials represent a perspective alternative for use in the construction and automotive industries as eco-friendly insulation materials. Sheep wool mats have many distinctive characteristics that fully comply with current standards and exceed the characteristics of inorganic insulators. In addition, the use of wool waste as a new raw material in industry is an excellent opportunity to support the circular economy model, as it reduces the need for non-renewable resources, lower the carbon footprint, and is a resource-efficient method of manufacturing industrial components. In general, thermal and acoustic insulation from wool waste can play an essential role in saving energy and reducing environmental pollution [6].

Currently, there are many different studies that have shown the benefits of sheep wool insulation boards, but tested materials contain mixtures of various components and vary in different parameters. Since the insulation properties are influenced by many factors, the use of such materials requires thorough research. Therefore, the choice of suitable materials is determined by a holistic approach, which takes into account the structure of insulating materials, their composition, surface area, optimal cross-sectional characteristics, diameter and length of fibers, strength characteristics, LCA analysis (life cycle assessment), the impact of various conditions and factors such as fire resistance, water resistance, vapor permeability, pest, dust, fungi and bacteria resistance, impact on the environment and human health, etc.

The purpose of this work is to study the relationship between strength characteristics and thickness, as well as the number of layers in nonwovens made of 100% coarse and fine wool, and to determine the most optimal variant of layers in insulating nonwovens. In the course of this work, the parameters of breaking load, strength and elongation were evaluated.

Materials and research methods

Studies of the strength characteristics of sheep wool nonwovens were conducted in the M.H. Dulaty Taraz regional university in the laboratory of the Department of "Textiles, materials science and standardization". Nonwoven woolen materials of four different layers provided by sole trader "Miras" (Kazakhstan, Taraz) were used as objects of research. The composition of the material is 100% fine and coarse wool.

Nonwoven boards were obtained by needle-punching method on a semi-automatic machine 220 (Fig. 1).

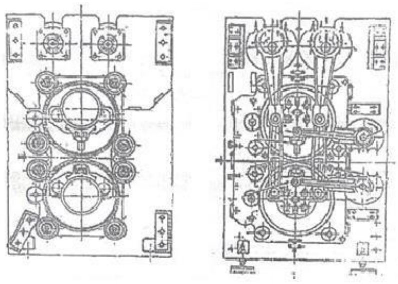

Figure 1 – Technological scheme of the semi-automatic needle punching machine 220

Technical parameters of the machine:

1) Pretreatment shaft:

a) Working capacity of the shaft: ≤ 550 rev/ min (idling)

b) Move: 60 mm

c) Width of the material: 2200 mm

d) Needle density: 4500 pieces/m

e) Material feed rate adjustment system: 0~6 m/min

f) Main engine: 11 kV (changing the frequency of speed adjustment)

g) Electric motor of material supply: 1,5 kV (changing the frequency of speed adjustment)

h) Electric motor for material output: 0, 75 kV (changing the frequency of speed adjustment)

i) Electric motor of the rack lift: 1,1 kV (spot move)

1) The main shaft:

j) Working capacity of the shaft: <600 rev/ min (idling)

a) Move: 40 mm

b) Width of the material: 2200 mm

c) Needle density: 5000 pieces/m

k) Material feed rate adjustment system: 0~6 m/min

d) Main engine: 11 kV (changing the frequency of speed adjustment)

e) Electric motor of material supply and output: 1,5 kV (changing the frequency of speed adjustment)

f) Electric motor of the rack lift: 1,1 kV (spot move)

The strength characteristics of nonwovens was determined according to SUST R 53226-2008 (State Union Standard). To determine the breaking characteristics, 5 samples of the one, two, three, and four-layered mats were taken, measuring 200x50 mm in length, and separately 50x200 mm in width, respectively. The research was carried out on a universal burst testing machine with dual column H10-50KT/S by Tinius Olsen (Fig. 2). This machine has a T/S configuration, i.e. it is equipped with control from a personal computer with special software, and a console control unit. Frame capacity 50 kN, the maximum crosshead travel is 1075 mm, the speed range is within 0.001-500 mm/min. The machine's force measuring system and integrated deformation measurement system fully comply with national and international standards: SUST, ISO, ASTM, DIN, BS, EN, etc. The feature of the machine is the automatic calculation and display of the maximum and breaking load and voltage, absolute and relative elongation, average, median and standard deviation. It is also possible to graphically display the measurement results [7].

In the first study, the breaking load, elongation and strength properties of a 1-layer nonwoven fabric were analyzed. Samples of 1-layer needle-punched material and the test workflow are shown in Figure 3.

Figure 2 – The universal testing machine with dual column H10-50KT/S by Tinius Olsen

Figure 3 – 1-layer material samples and testing process

2-, 3- and 4-layered nonwovens were tested in a similar way.

The results of the study were calculated using machine software. Statistical methods were used to analyze the results of the research.

Literature review

Nowadays, widely used building insulation materials are made of synthetic materials. About 60% of thermal insulation materials are mineral or inorganic materials (glass wool, stone wool), 30% are foam materials (expanded polystyrene, extruded polystyrene, polyurethane), and the remaining 10% are other non-traditional or composite materials (insulating materials made of wood sawdust and wool, foam gypsum, etc.) [8]. Inorganic insulation materials can have a detrimental effect on both the environment and human health. Fiberglass-based materials are obtained from silica sources, mineral wool, glass wool, polyurethane and polyester are produced on the basis of petrochemicals, which has a carcinogenic effect on the human body [9]. It is for this reason that the demand for environmentally friendly insulation materials has been growing recently. These materials include panels made of wool waste. Some of them are already on the market, but are still at the stage of research and development of new solutions.

In the work of Pennacchio et al., the "FITNES" panel made of wool and hemp fibers was presented. In that work hemp fibers were added in order to improve the density of material, compared to panels made of 100% wool. In this material, wool acts as a binder. The production process consists of 3 main stages:

1. Mixing wool and hemp fibers;
2. Treatment with soda solution. The purpose of this process is the release of keratin protein for gluing wool and hemp fibers, i.e. the use of wool keratin as a natural glue.
3. Removal of soda solution residues and drying the panel in a special oven.

The most optimal chosen panel was a material with a square size 0.468 cm^2 (90.00 cm x 52.00 cm), a thickness of 4.50 cm and a weight of 3 kg, made of wool and hemp in equal weight. These panels were compared with other insulating materials, such as Cartonlana panel made of sheep wool and other insulation products available on the market (soft panel made of 100% sheep wool, semi-rigid panel made of sheep wool and polyester (80/20%), semi-rigid panel made of 100% wool, glass wool, stone wool, kenaf fiber material with polyester). Thus, it was found that heat-insulating panels with high density provide high thermal characteristics, panels made of natural fibers demonstrate less need for non-renewable energy, and has less harm to the environment and human health, and are also recyclable [10].

The research of Ye, Z. et al. was aimed at studying the thermal characteristics of insulation panels made of wool. The results of their work showed that with a wool density of more than 11 kg /m^3, thermal qualities increase. The authors in this paper concluded that thermal resistance is directly related to the thickness of nonwovens [11].

Cheung, H.Y. et al. in their work, studied the mechanical properties of natural fibers that represent the potential for use as reinforcing materials for composite materials. In the course of research, it was revealed that sheep wool, in comparison with other natural fibers, has the highest elongation at break, which ranges from 25-35%, and a tensile strength of 120-174 MPa [12].

Petit-Breuilh et al. investigated natural fibers with insulating potential, among which natural sheep wool was also studied. Five samples were made of various insulating materials for testing. When studying the thermal conductivity coefficient of materials, the main parameters affecting this indicator were also considered: the thickness and density of materials. According to the data obtained, the authors concluded that sheep wool with an electrical conductivity coefficient of 0.45 W /mK has the best insulation performance. Since, along with other distinctive characteristics, it is the lightest natural insulation material. The density of wool was 38.8 kg/m^3, the thickness was 13.8 cm [13].

In the work of Schiavoni et al. a review and comparative analysis of the main commercial insulation materials was carried out, among them sheep wool was also analyzed. It was found that mainly the density of sheep wool materials ranges from 10 to 25 kg/m^3, thermal conductivity from 0.038 to 0.054 W/mK and specific heat capacity from 1.3 to 1.7 kJoules/Kkg. The tested samples were characterized by high acoustic parameters and high hygroscopicity values, which makes this material an optimal humidity regulator [14].

Results and their discussion

Samples of one-, two-, three-, and four-layered nonwovens were studied. During the study of the breaking load in length and width, it was found that the breaking load of nonwoven material increases linearly with increasing number of layers. Moreover, the characteristics of the breaking load in the width of all samples slightly exceed the data in length. A comparative characteristic of the breaking load in width and length is shown in Figure 4. As can be seen from this figure, the breaking load indicators of a four–layered nonwoven fabric sample are the highest: in width – 435 N, in length - 397 N. A single-layered sample has the lowest breaking load: 14.2 N and 6.45 N, in width and length, respectively. The breaking load of 3-layered samples is slightly inferior to 4-layered ones, i.e. it is 338 N in width and 332 N in length. For all samples, the length indicators exceed the width indicators.

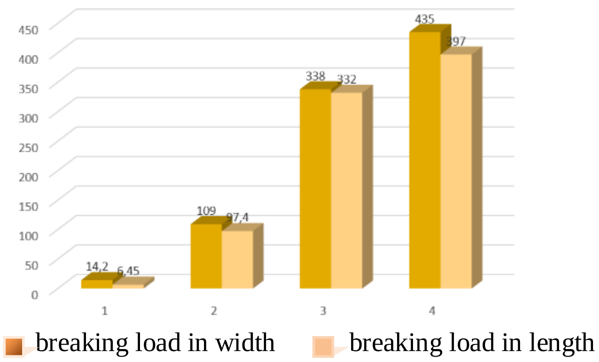

Figure – 4. Breaking load in width and length

Figure 5 shows the comparative strength characteristics of four tested materials in length and width. The 4-layered samples have shown the greatest strength (in width – 10.9 MPa, in length – 9.92 MPa). The lowest strength indicators were also shown by single–layer samples (in width - 8.45MPa, in length – 8.31 MPa). The strength of the three-layered samples was 8.45 MPa in width and 8.31 MPa in length. The width indicators are also slightly higher than the length indicators.

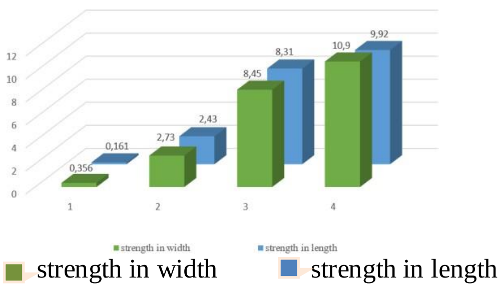

Figure – 5. Strength in width and length

Thus, the analysis of the breaking load and strength of the tested samples shows that these indicators are directly proportional to the number of layers.

The study of sample elongation, the results of which were also grouped into two groups by width and length, shows that the indicators are uneven (Figure 6). The largest percentage of elongation in length was shown by a two-layered sample – 104%, and in width – by a four-layered sample - 87.2%.

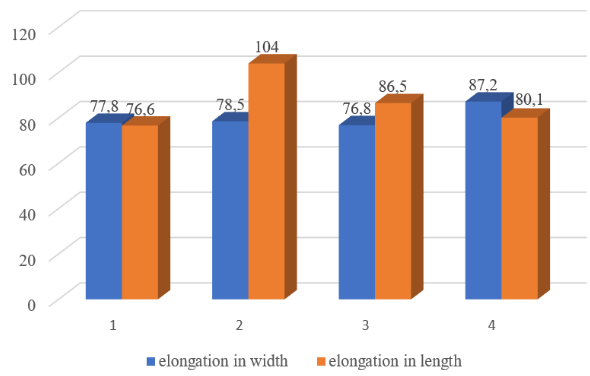

Figure – 6 Elongation in width and length

Comparing the results obtained, it can be stated that the most optimal option to use for industrial purposes is a three-layered material, since it has good indicators of strength and breaking load. The breaking load and strength of nonwoven woolen materials is higher in the direction of width. Consequently, in this direction, insulating nonwovens have better strength properties.

The breaking load may depend on various factors: the properties of the fibers, structure, fabric density, thickness, formation methods, types of textile finishing, etc. [15].

Conclusions

In this research work, the dependence of strength characteristics on thickness and the number of layers in nonwovens made of 100% coarse and fine wool were studied. Based on the study of the parameters of the breaking load, strength and elongation of 4 samples of one-, two-, three-, and four-layered materials, it was found that nonwoven materials consisting of a single layer are characterized by poor strength indicators. Moreover, the results of the research showed that with an increase in the number of layers of material, there is an increase in the tested two indicators: breaking load and strength. The elongation rates were uneven. Consequently, by examining all three parameters, it was found that the best option is a three-layered nonwoven material. The breaking load coefficients of such a material were 338 N in width, and 332 N in length. The strength in width is 8.45 MPa, in length – 8.31 MPa. The elongation data showed 76.8% and 86.5% in width and length, respectively.

Non-woven materials made of coarse and fine wool can be used as an alternative raw material for the production of heat and noise insulation panels. The breaking characteristics of such a material are high due to the use of natural fiber – wool, which surpasses all other natural fibers in these parameters.

Moreover, aspects concerning other properties of natural wool insulation mats, such as sound insulation, thermal characteristics, breathability, should be further investigated.

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СОВЕРШЕНСТВОВАНИЕ ПРОЦЕССА КРАШЕНИЯ ШЕРСТИ НАТУРАЛЬНЫМИ КРАСИТЕЛЯМИ

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В данной статье описывается процесс крашения обесцвеченных-отбеленных шерстяных волокон натуральными красителями с использованием в качестве протравы солей алюминия, железа и меди (изучены колористические особенности процесса крашения киноварью). Процесс окрашивания осуществлялся в трех различных последовательностях: предварительная обработка протравами, затем окрашивание в растворе натурального красителя (I); одsecurityованное крашение в растворе красителя и протравы (II); крашение в растворе натурального красителя с последующей обработкой протравами (III). Влияние последовательности окрашивания на показатели качества окраски оценивали по данным, определенным при стандартной освещенности D_{65} на лабораторном колориметре. В статье показана зависимость процессов крашения шерсти натуральными красителями Мареной (Rubia tinctorum L.), Куркумой (Cúrcuma lónga) и Кармином (Minium - киноварь) от присутствия и места солей-протрав в технологической проводке. Сам краситель Марена дает золотистый цвет, а в присутствии сульфата меди и железа дает бледно-коричневый цвет, а бихромат калия дает яркий насыщенный красный цвет. При крашении шерсти красителем Кармином в присутствии в качестве протрав солей железа и меди карминовая шерсть дает в 1,5-2,5 раза более интенсивные темно-красные цвета в зависимости от способа окраски, чем при окраске без солей. Изучена зависимость интенсивности окраски от pH среды с учетом того, что pH процесса крашения влияет на прочностные и колористические параметры окрасок, получаемых на шерстяном волокне натуральными красителями. Был проведен ИК-спектральный анализ образцов, окрашенных исследуемыми красителями в сравнении с неокрашенным волокном шерсти для выявления характера возникновения связей шерстяного волокна с натуральными красителями.

Ключевые слова: **шерсть, кератин, колорирование, природный краситель, колористические характеристики.**