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TYPES OF NON-WOVEN FABRICS FROM WOOL FIBERS, THEIR AREAS OF USE, AND COMBINATION WITH DIFFERENT FIBERS

Abstract: This study explores the advancements and applications of non-woven fabrics in the textile industry, which are valued for their heat resistance, abrasion resistance, and noise insulation properties. Predominantly crafted from wool, cotton, and synthetic fibers, these materials highlight a global raw wool distribution, primarily from the Netherlands and Italy, with 25-30% waste incorporated into the production process. Challenges in producing high-quality yarn from wool arise due to impurities like vegetable and organic residues.

Recent innovations in processing techniques, such as needle perforation and water processing, have enhanced the technical properties of non-woven fabrics, making them effective for sound absorption and thermal insulation. Additionally, the integration of fire-resistant materials has improved their safety features, making them suitable for various applications in construction and the automotive industry.

Furthermore, computer-aided design processes facilitate the simulation of fabric properties, enabling the optimization of sound absorption characteristics influenced by fiber arrangement and density. This research underscores the versatile and evolving nature of non-woven fabrics, highlighting their significance in energy-efficient and protective textile solutions.

Key words: Non-woven fabrics, textile industry, wool fibers, sound insulation, thermal insulation, acoustic properties, yarn production, waste composition, processing techniques, needle perforation, fire resistance, composite materials, computer-aided design, material properties, technical textiles

In the textile industry, non-woven fabrics possess characteristics of heat resistance, abrasion resistance, and noise insulation. Additionally, technical textiles, upholstery, filtering, and technical materials are primarily produced using cotton, wool, and synthetic fibers.

In the wool industry, the total raw material distribution is as follows: 28% in the Netherlands, 18% in Italy, 7% in Japan, 5% in the USA, and 3% in France. The composition of the raw material includes 25-30% waste [1; pp. 384-391].

When producing yarn from wool fibers, the presence of waste and defects in the fiber composition poses significant challenges. Within the wool composition [2], there are vegetable residues, organic waste, as well as fat and sweat substances found in the fiber, mineral residues, and defects from the shearing process (short fibers, various mixtures). Their quantity depends on the breed of sheep, type of wool, feeding regimen, nutritional content, climatic conditions, and other factors.

The amount of waste for general wool fibers has been reported by V.E. Gusev, a professor at the Moscow Textile Institute, along with researchers N.V. Rogachev and E.A. Kusakov, as well as

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foreign researchers like V. Kling, H. Doener, and others, indicating that the oil content ranges from 0.5% to 25.4%, sweat (lard) from 2% to 24.2%, and mineral residues from 4% to 43.8% [2].

In the textile industry, the production of non-woven fabrics has rapidly developed in the last decade. This fabric provides a sufficiently large surface area and volume compared to biological textiles. The finishing of non-woven fabrics is performed to improve their technical properties and external appearance [3; pp. 2504-2514].

The average length of camel wool fibers is 8-8.5 mm, while sheep wool fibers measure 4-4.5 mm [4, 5]. The thickness of the fabric in the longitudinal direction is laid in a flat layer with a thickness of 1.8±2 mm and fixed using an IM-2500 machine with a needle perforation. The technical indicators of the needle perforation process include a needle length of 2.2 m, a perforation frequency of 280-300 min^{-1}, a distance between needles of 8 mm and 5 mm, a perforation density of 6000 m^{-2}, and productivity of 80-84 m/hour.

Non-woven fabrics are directly prepared from fibers using certain methods. Various processing methods give different characteristics to the final product through additional finishing. One such method involves continuously processing the fibers in water to form a mesh or melting polymers to create a uniform mesh.

From a technical aspect, the interconnection of fibers is a key factor in determining their quality. Although the strength and rigidity of non-woven fabrics are lower compared to woven fabrics, they are notable for their low cost, high deformability, and ability to absorb thermal energy [6; pp. 1-13].

Currently, two types of felts of different thicknesses are produced from wool fibers for sound-absorbing materials [7, 8; pp. 3139]. The sound absorption coefficient is measured using an impedance tube, and the noise reduction coefficient is calculated. When the height of both types of fibers is increased from 12 to 16 mm, the NRC value increases from 0.4 to 0.42. Locally produced wool fabrics exhibit good absorbency [9; pp. 1224-1241].

The tensile deformation of non-woven fabrics has been studied, revealing that in the first sample, the elastic deformation component in non-woven fabrics decreases while the plastic (residual) deformation component increases. The significance of the research results has been assessed based on comparison criteria. It has been determined that the characteristics of the non-woven fabric obtained based on the second sample's elastic deformation are better than those of non-woven fabrics made from other composite raw materials [10; pp. 575-581].

In the production of non-woven fabrics from wool, it is significant to utilize coarse wool. Precise variations in thickness often prove viable for the production of non-woven fabrics. During the felt production process, when fibers are mechanically interconnected, they interlace, resulting in materials with an average density of up to 0.7 g/cm^2 [11; pp. 1-32].

From another perspective, non-woven fabrics can be viewed as layers or mesh structures formed by bonding fibers or filaments through various mechanical, thermal, or chemical processes. These can be directly prepared from individual fibers or melted plastics or plastic films. The inclusion of bonding yarns in knit structures, sewn-together layers, or wet-processed felts, as well as additional needle processes, is an essential component [12; pp. 55-78].

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Researchers have developed improved non-woven fabrics with various advantages for sound insulation, recommending their use for insulation [13]. These insulating fabrics can be utilized primarily in the automotive industry, construction, agriculture, and as protective clothing for textile firefighters. Recently, thermal insulation has become very important for energy savings. Non-woven fabrics are recommended for covering entire buildings, including walls, ceilings, and floors [14; pp. 330-336].

One of the new properties of non-woven fabrics is fire resistance; films consisting of polylactic acid (PLA) mixed with lignin or starch, or ammonium polyphosphate, are coated on bast or wool non-woven fabrics. The aim of this research was to study the fire-resistant and mechanical properties of FR PLA films protected for regular use in construction. Tests conducted to reduce fire hazards in horizontal and vertical positions indicate a significant reduction in the flammability characteristics of non-woven fabrics [15; pp. 33-39].

Methods based on topology create a 3D sketch of fabrics using data from contact points between yarns. The cross-section of the yarn remains constant in textile constructions, and its definition is provided for rigid and multi-filament yarns. Finally, several methods for transitioning the 3D sketch to more accurate geometries are presented [16; pp. 1-15, 17; pp. 79-103].

The efficiency of sound wave protection offered by non-woven fabrics excels in a wide frequency range until the depth of surface irregularities and the onset of perforation interference become significant. The stochastic nature of these materials, their complexity, and local variability have been modeled and align well with experimental results. Anisotropic layer permeability has been modeled based on yarn-to-yarn contact resistance, evaluated at up to 1% in the higher shielding direction and 2% in the orthogonal direction [17; pp. 1-6].

The properties of non-woven fabrics can be simulated and very accurately predicted using computer-aided design processes. Optimizing technology for operation in other contexts, safety engineering, testing, and education is involved. Computer simulation (or “sim”) attempts to model real-life or hypothetical situations on a computer [19; pp. 11-17].

Non-woven fabric was assessed by performing treatments on composites reinforced with bast fibers [20; pp. 713-716]. During the processing of the composites, a significant increase in the viscosity of the mixture was noted, with a mixture containing 10% alkyd resin being twice as viscous compared to its resin alone. Furthermore, improvements in water absorption, thermo-mechanical properties, and a better bond between the fiber and matrix of the composite were observed. The enhancement of properties indicates expanded opportunities for fiber-reinforced composites in various fields such as construction textiles, furniture, aerospace, and nanoapplications [21; pp. 2540-2548].

The mechanical properties of composites strengthened with woven wool fabrics and poly(lactic acid) have been studied. In solution and woven directional NWF (non-woven fabric) composites, superior mechanical properties are presented compared to non-woven wool fabric composites. The chemical treatment of wool fabrics through benzoic acid positively impacted the properties of the composites [22; pp. 69-74].

Detailed information is provided regarding the improvement of the sound absorption characteristics of non-woven fabrics and fiber-reinforced composites, which is primarily associated with optimizing production conditions, material components, mass density, morphology, and structural parameters developed [23; pp. 1297-1309].

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The sound absorption characteristics of needle-punched non-woven fabrics containing polyester fibers of various sizes (from 7 to 15 denier) and configurations (hollow, 4-holes, trilobal) have been studied [24; pp. 1-7].

The most significant independent variables affecting sound absorption were regional density and the method of network bonding. The sample manufactured according to optimal levels of production achieved a value of 0.57 SAC at a frequency of 2000 Hz, which could be an appropriate choice for acoustic applications in the automotive industry [25; pp. 575-585].

The cross-sectional shape of composites made from flax, jute, okra, sisal, and wool fibers, as well as their density and absorbency, was studied for its effect on the sound absorption coefficient [26; pp. 1-14].

This research has developed a composition of hempcrete consisting of gypsum and hemp fibers for sound absorption, with the addition of graphite to enhance its anti-static properties. Three controllable factors—hemp length, hemp composition, and four levels for each factor—were determined [27; pp. 1-11].

To provide comparable samples, a needle-punched and melt-blown non-woven fabric made from 100% polypropylene fibers was produced. According to sound absorption tests, the non-woven fabric sample with needle perforation located in the lower part exhibited a similar composition to the hybrid structure sample, whereas the melt-blown non-woven fabric, placed as a surface layer, performed better acoustically than the other samples [28; pp. 1092-1108].

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