

Research into technological parameters in the production of clothing from sustainable nonwoven textiles by wool felting

Nikolay Tranchev and Margaret Sivova

Abstract— The report presents results of a study of the influence of key technological parameters on the properties of clothing made of sustainable nonwovens obtained by the wool felting method. Within the framework of the study, experimental samples were made with variations in key technological factors such as temperature, processing time, amount and distribution of fibers, as well as the use of additional materials. The physico-mechanical and aesthetic characteristics of the resulting textile were analyzed, including thickness, density, flexibility and surface texture. A prototype product was made, illustrating the applicability of felted textiles in modern sustainable clothing. The results of the study contribute to optimizing the technological process and promoting sustainable practices in the textile industry

Keywords—Wool, felt, wet felting, nonwovens, felt products.

I. INTRODUCTION

Textile fibers are complex structures made up of macromolecules, located at a certain distance from each other and connected by internal intermolecular forces. Under the influence of external mechanical forces – tension, pressure, torsion, etc. – which arise both during technological processing and during the operation of the products, the geometry of the fibers changes. These changes lead to deformations – elongation, contraction or bending – which change the intermolecular distances and generate internal stresses. It is these stresses that determine the ability of the fibers to resist external loads, i.e. their durability – a key parameter in assessing the mechanical properties of textile materials [1].

The mechanical properties of fibers vary significantly depending on their origin and structure, which requires detailed knowledge of these properties when selecting materials for specific applications [2, 3]. In this context, nonwoven textile structures, especially those obtained by the wool felting method, are gaining increasing importance both in scientific research and in modern textile practice

Felting is a technique for creating a textile material by mechanically, thermally and/or chemically treating wool fibers, without the need for braiding or weaving [4]. The resulting materials are characterized by low weight, flexibility, good thermal insulation and resistance to mechanical impact. In addition, the technology is environmentally friendly and offers opportunities for innovative design solutions and individualization of products. These advantages make nonwoven wool materials particularly suitable for applications in sustainable fashion [5], technical textiles and interior design.

Despite the increased interest in such materials, there is a limited amount of empirical data regarding their mechanical properties.

in the context of designing shape-retaining outerwear [6, 7].

The aim of this work is to investigate and evaluate the mechanical properties of a nonwoven textile material obtained by the wool felting method, with a view to its applicability in the design of shape-retaining outerwear.

To achieve this goal, the following research tasks have been formulated:

1. Analysis of the structure and behavior of wool fibers under mechanical load;
2. Determination of the influence of felting technology on the formation of the mechanical properties of the final textile material;
3. Conducting experimental testing of the durability and deformation of the studied material;
4. Assessment of its applicability in the design of durable and functional clothing.

II. MATERIALS AND METHODS

2.1. Physico-mechanical testing of wool fibers

Physico-mechanical testing of wool fibers To determine the length and thickness (fineness) of the wool fibers used to produce the experimental samples of nonwoven textiles, a laboratory test was carried out in the textile laboratory of E.MIROLIO EAD [8].

Wool fibers have two types of length - natural and actual (true). The natural length is considered the distance between the two ends of the fibers together with the curls without tension, and the actual length is the stretched fiber. The actual length of the fibers is determined in two ways - organoleptic and laboratory. In this case, the laboratory test was carried out with an apparatus USTER FL 100 (Fig. 1.).



Fig. 1. Apparatus for determining the length of textile fibers

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The measurement method requires that the fibers in the sample are arranged at one end, thus making it easier to

distribute them into groups along their length. About 500 fibers formed into a staple are measured. The samples, which are the subject of the study (Fig. 2.), have the same fiber overlap dimensions.

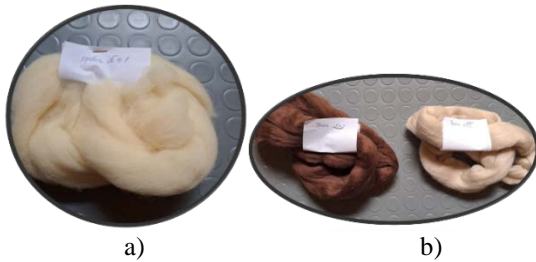


Fig. 2. Wool samples

To measure the fineness of fibers, an “OFDA” apparatus was used (Fig. 3.), and to determine the extensibility and strength of the finished felt samples, a dynamometer was used (Fig. 4.)

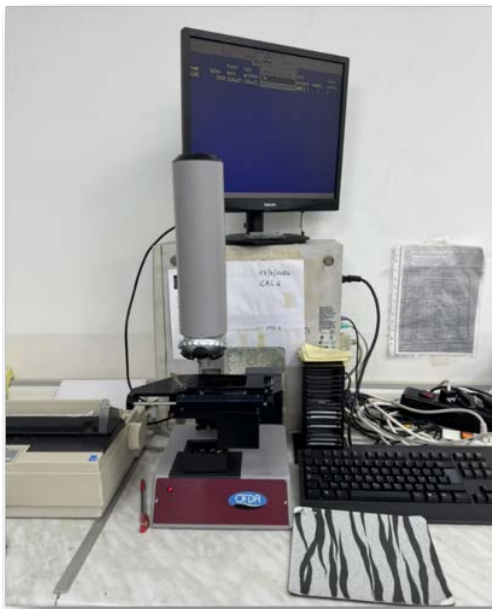


Fig. 3. Apparatus “OFDA” to measure the fineness of fibers

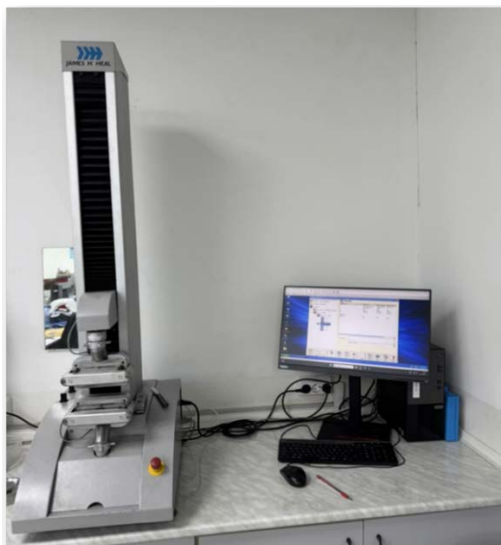


Fig. 4. Dynamometer

Rectangular samples for Sample 1, Sample 2 and Sample 3 with dimensions of 50 cm x 20 cm were prepared using the wet felting method.

Fig. 5. shows the method of laying the wool fibers for Sample 1 and Sample 2, respectively, and Fig. 6. – for Sample 3.

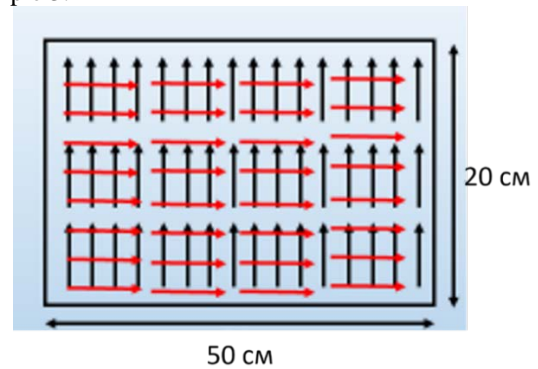


Fig. 5. Fiber laying method in sample 1 and sample 2

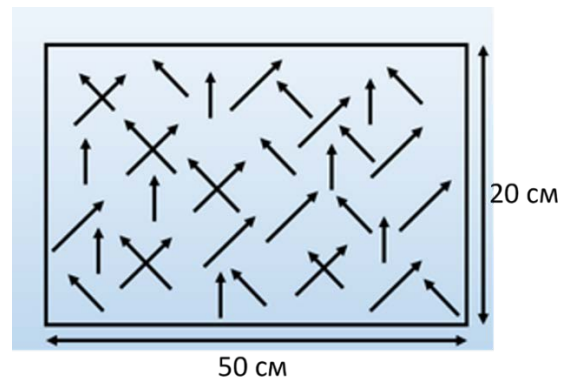


Fig. 6. Fiber laying method in sample 3

Fig. 7., Fig. 8. и Fig. 9. Show the method of laying and the finished felt for the respective test specimen..



Fig. 7. Sample 1 – laying and finished look



Fig. 8. Sampl 2 – laying and finished look



Fig. 9. Fiber laying method and finished look of Sample 3

The test results of Sample 1(Fig. 10) show:

- Fineness of the fibers in the sample - 26.84 μ (Fig 10, a)
 - Length of the fibers in the sample:
- | | |
|--------------------------|--------------------------|
| H: 54.2 mm (Fig. 10, b) | B: 66.3 mm (Fig. 10, c) |
| CvH : 47.4% (Fig. 10, b) | CvB: 40.6% (Fig. 10, c), |
- where:

- H /average length/ - the average value of all measured fibers in the sample;
- B /modal length/ - the most common length of the fibers in the sample with the largest mass;
- CvH (Coefficient of Variation of the Hauteur) - characterizes the variations (deviations) of the fibers along the average length in the given sample, i.e. shows how homogeneous the sample is along the average length. The lower the CvH value, the better the quality;
- CvB (Coefficient of Variation of the Barbe) - shows the variations (deviation) along the modal length of the fibers.

effects of the edge of the fabric and represents its actual characteristics.

The procedure includes:

- sample preparation;
- specimen clamping;
- tensile testing;
- data recording.



Fig. 13. Test to determine the strength and elongation

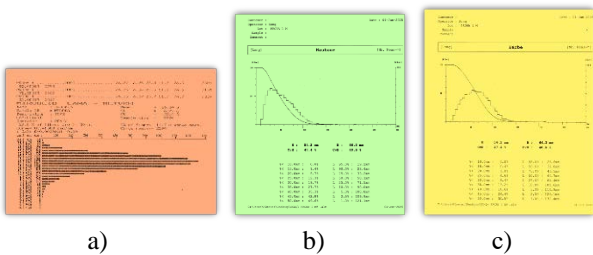


Fig. 10. Results of fiber fineness testing from Sample 1

Test results of Sample 2 show.

- Fiber fineness in the sample - 19.69 μ (Fig. 11, a)
- Fiber length in the sample:
- H: 61.7 mm (Fig. 11, b) B: 75.4 mm (Fig. 11, c)
- CvH :47.2% (Fig. 11, c) CvB: 39.7% (Fig. 11, c)

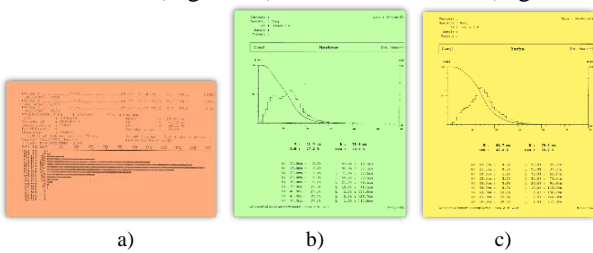


Fig. 11. Results of fiber fineness testing from Sample 2

Test results of Sample 3 show.

- Fiber fineness in the sample - 19.46 μ (Fig. 12, a)
- Fiber length in the sample:
- H: 58.8mm (Fig. 12, b) B: 72.5mm (Fig. 12, c)
- CvH :48.4% (Fig. 12, b) CvB: 41.2% (Fig. 12, c)

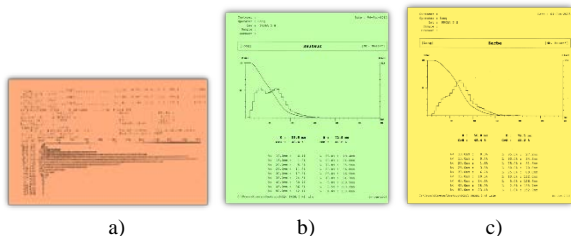


Fig. 12. Results of fiber fineness testing from Sample 3

2.2. Testing the extensibility and strength of the experimental samples

The extensibility and strength of the samples were tested on a fabric dynamometer using the Grab method [11, 12].

The Grab method is a tensile test that determines the breaking strength and elongation of woven and nonwoven fabrics. The method determines the “effective” strength of the sample by gripping it in the center, which reduces the

The samples, which are the subject of the test, are of the same size and different fineness of the fiber overlay.

In Fig. 14. The results obtained from the test of the three samples are presented in graphical form.

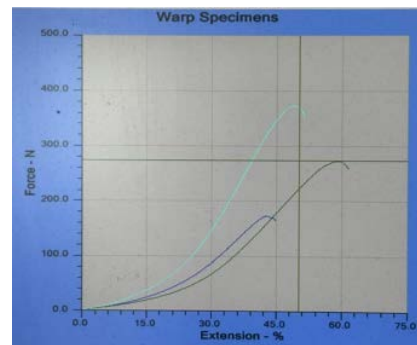


Fig. 14. Graph of the results obtained from the study of the three samples

TABLE I presents the analytical data obtained regarding the elongation and strength for the three samples.

TABLE I

Characteristics	Sample 1	Sample 2	Sample 3
Extensibility - %	64	39	45
Strength - κΓ	18	46	49

The shrinkage of the experimental samples after compaction is calculated by the following formula:

$$Shrinkage [\%] = \left| \frac{L - L_1}{L} \right| 100$$

- L – sample size at laying;
- L_1 - sample size at felting.

Fig. 15., Fig. 16. And Fig. 17. show in graphic the sizes of the experimental samples obtained after compaction.

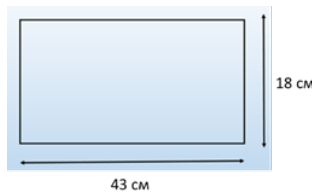


Fig. 15. Experimental sample 1 – size after compaction

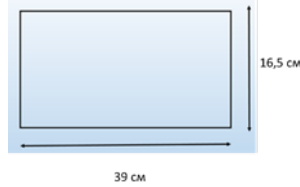


Fig. 16. Experimental sample 2 – size after compaction

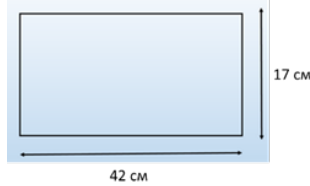


Fig. 17. Experimental sample 3 – size after compaction

TABLE II presents the analytical data obtained regarding the shrinkage in width and length for the three samples.

TABLE II

Sample	Shrinkage in width, %	Shrinkage in length, %
Sample 1	14	10
Sample 2	22	17,5
Sample 3	16	15

III. RESULTS AND DISCUSSION

The study of wool fiber samples with different fineness and laying configuration showed a significant influence of these parameters on the mechanical and physical properties of the products obtained by wet felting.

- *Fiber fineness and length:*

The results of the sample analysis indicate that the fineness of the fibers varies from 19.46 μ (Sample 3) to 26.84 μ (Sample 1). The fiber lengths also show deviations, with Sample 2 demonstrating the highest values (H: 61.7 mm; B: 75.4 mm). The lower coefficients of variation in the modal length (CvB) indicate better fiber homogeneity in Samples 2 and 3 compared to Sample 1.

- *Extensibility and strength:*

The mechanical tests performed using the Grab method revealed distinct differences between the samples. Sample 1 demonstrated the highest extensibility (64%) and the lowest strength (18 kg), while Sample 3 showed the best ratio between strength (49 kg) and extensibility (45%). Sample 2 has the highest strength (46 kg) and lowest extensibility (39%), making it suitable for applications requiring stability and load resistance.

- *Shrinkage:*

After wet felting, significant shrinkage of the materials is observed. Sample 2 shows the highest shrinkage in both width (22%), and length (17.5%), which is associated with the finer structure and better fiber compaction. Sample 1 has the lowest shrinkage – 14% in width and 10% in length.

In summary, we can state the following: The fineness of the fibers is confirmed as a determining factor for the properties of felted materials. Finer fibers provide better compaction, which leads to higher strength and lower elongation. From the point of view of applicability for shape-retaining outerwear, Sample 3 shows the most balanced characteristics between strength, extensibility and shrinkage.

IV. CONCLUSION

The results obtained from this study confirm the significant influence of the fineness and structure of wool fibers on the mechanical and physical properties of nonwoven textiles produced by wet felting. The study showed that products made of finer fibers have higher strength and lower deformability, which makes them particularly suitable for the production of durable, shape-retaining clothing.

The applicability of felted nonwovens in modern textile design and industry can be significantly expanded by purposeful design of the fiber structure and control of the technological parameters of production. The felting technique, combined with an innovative approach to the selection of raw materials, provides opportunities for the creation of aesthetic, durable and functional textile products.

In the future, research can be directed towards the development of methodologies for industrial application of the obtained results, as well as expanding the spectrum of natural fibers and additives used in felting.

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