Method for Evaluation of Fibrous Structure Materials’ Drapability

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Method for Evaluation of Fibrous Structure Materials' Drapability

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Abstract. The object of the article's research is fibrous structure materials, and the subject is the method of evaluation of their drapeability. The aim of the work is to develop a new method for evaluating textile and leather materials drapability. This method is categorized as an express method, involving the use of digital technologies in research, processing of results and the possibility of forming an electronic database of the characteristic properties of the materials. The existing methodological and technical-technological approaches to determining the characteristics of mechanical properties during bending deformation were analyzed. The possibility of using wave processes in determining drapability were theoretically justified and a new method for the assessment of drapability was developed. The developed method is intended for the study of textile and leather materials. As an informative parameter in evaluating the drapability, it is proposed to use the parameters of quasi-resistant transverse vibrations generated in a certain direction on a standard size material sample. Taking into account the time spent on the experiment, the developed method can be categorized as an express method with the ability to generate an electronic database on-line. The results of the practical approbation of the proposed method for evaluating drapability, obtained by comparing the estimates formed on its basis with the data obtained based on the widely practiced method, suggest sufficient accuracy and the possibility of applying the developed research method.

1. Introduction

As is known [1], the material's drapability is understood to mean its ability to form soft movable folds in a suspended state. Drapability is one of the half-cycle characteristics of materials' mechanical properties during bending deformation. The amount of drapeability is functionally related to the stiffness and weight of the material. Moreover, the dependence of drapability on stiffness is reverse, and on mass — direct. Drapability is one of the most important factors affecting the formative properties of a material when creating garments, especially clothing and interior textiles, the so-called "soft" form. The ability to select and implement such design solutions as draping, assembling, backstage, frill, shuttlecocks, etc. depends on the value of drapability. In addition, drapability should be taken into account when selecting materials in the product package [1 - 4]. This determines the significance of the named characteristic as an indicator of textiles, leather and other materials' quality.

1.1. Relevance and Scientific Significance of the Issue

Due to the high significance of drapability in making various design decisions, fashion industry experts should have accurate and reliable data on the named characteristic of the mechanical properties of fibrous structure materials, since they are most often used in the manufacture of garments. Accordingly, there is a need for simple and accurate methods for evaluating drapability. Analysis of the methods and instrumental base for the study of textile, leather and fur materials drapability and the flexural rigidity related to it showed that experimental methods for their determination and technical base used in Russia, countries of the Eurasian Union and other foreign countries [5 - 16] do not provide the required accuracy, are often structurally-technologically complex, and not reliable enough. In addition, technologically they take up a sufficient duration of the experiment and do not allow an automatic database generation of the properties of fibrous structure materials. Based on the above, research on the development of new rapid methods for determining a fibrous material's drapability, taking into account the elimination of the above-mentioned deficiencies, is relevant and has scientific value.

1.2. Formulation of the Problem

The aim of the work is to develop a new method for evaluating textile and leather materials' drapability, which can be categorized as an express method, involving the use of digital technologies in research, processing of results and the possibility of forming an electronic database of the characteristic properties of materials. The object of the article's research is fibrous structure materials, primarily textile and leather materials, and the subject is the method of evaluation of the material's drapeability. The proposed research method is based on the basic principles of the theory of wave processes in solid media. In the development of technical support, general engineering approaches and methods for measuring systems design were used. Testing of the proposed design solutions was carried out using existing and developed experimental methods for studying the geometric and mechanical properties of fibrous materials and statistical methods for processing measurement results.

2. Theoretical Part

Taking into account the experience of using wave processes in assessing the mechanical properties of fibrous composites, including bending deformation [17-21], it can be assumed that the mechanical vibrations parameters can be considered as informative parameters in determining drapeability.

In [22, 23], a theoretical justification of this fact was performed. The justification was based on a number of well-known provisions [24] relating to the physics of wave processes occurring in a uniform flat sample when creating a transverse displacement, changing with time according to the sine law, provided that the sample is fastened at the end sections and is under constant tension. Graphically, this process is shown in Figure.

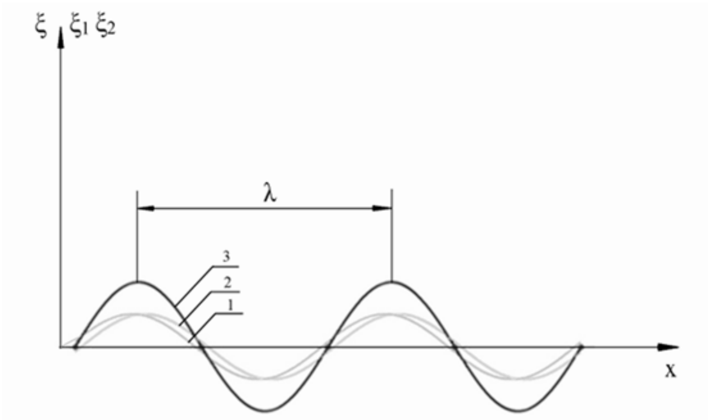

Figure 1. The superposition of two traveling shear waves and a steady standing shear wave: 1, 2 are traveling waves, 3 is a standing wave.

In the course of the mathematical description of the considered wave process, it was shown that vibrations occur at each point of the sample in the state described above, leading to the formation of a standing wave, which has a frequency equal to the frequency of the traveling wave's vibrations, and an amplitude different from the amplitude of its vibrations. The amplitude of the standing wave *B* is defined as a modulus of time-independent factors, namely:

$$B=\left|2A\sin\frac{2\pi}{\lambda}x\right|, \qquad (1)$$

where *A* - the wave amplitude of the generated vibrations, $K=2\pi/\lambda$ - wave number, λ - the wavelength parameter.

The closest distance between two points of the medium, denoted by λ (Fig. 1), is a parameter characterizing the length of the standing wave. Thus, taking into account that when a sample is bent, the projection distance between its points changes. The magnitude of the characteristics of the mechanical properties during bending deformation can be judged by the value of the parameters of the standing wave.

If with the help of a mechanical vibrations generator, one of the sections of the sample with a certain reference length $(l_э)$, upon the stationary fixation of the other section, provides stable transverse vibrations in a certain frequency spectrum, then visually visible standing waves, which can be considered as a special case of interference waves, arise on the sample. The number of maxima or minima of standing (interference) waves *(m)* on a sample of length *(l)* according to [24] is defined as:

$$m=\frac{2l}{\lambda}+\frac{1}{2}, \qquad (2)$$

where $\lambda = 2\lambda_{cm}$ - a parameter characterizing the ratio of the generated wave length λ and the standing wave length λ_{cm}.

Taking into account the propagation velocity of generated transverse waves in a sample determined as $V=\sqrt{\frac{F}{\rho S}}$, where F, ρ, S - tension, surface density and cross-sectional area of the sample, respectively, after simple transformations without taking into account the structure parameters of the sample elements, it is possible to obtain the calculated number of standing waves $(m_э)$ on the reference length $(l_э)$ in the following form:

$$m_э = 2l_э f\sqrt{\frac{\rho S}{F}}+\frac{1}{2}. \qquad (3)$$

In accordance with Formula 3, the number of interference waves $(m_э)$ generated on the material reference length is a function $m_э=\varphi(f, l_э, F, \rho, S)$, and for fixed values of the segment length $(l_э)$, initial loading (F_n) and cross-sectional area *(S)* are the functions of only two parameters, namely $m_э=\varphi_1(f, \rho)$, where *f* - the second frequency of forced vibrations, Hz. If we take into account that the drapability of a material is a function of stiffness, which, all other things being equal, given the conditions of research, is a function of density, then with good reason we can assume that the number of generated standing waves is a function of stiffness and, therefore, drapability.

3. Results of the Study and Their Discussion

Considering the results of theoretical studies, a method for estimating the fibrous materials drapeability was developed. In the proposed method, the ratio of the number of standing waves $(m_э)$ to the number of waves (m_i) on the studied *i*-th sample is used as an informative parameter. This method involves determining the correction coefficient for the number of generated waves of quasi-resistant vibrations on the reference sample, as an informative parameter in determining the drapeability of the material of the fibrous structure.

Developed for the implementation of the method, the device and methodology of the experiment are described in detail in [25, 26]. The essence of the method is as follows. To prepare the device for the start of work, several preparatory procedures are carried out. These procedures are aimed at obtaining and recording the required initial information in the processor's memory, which will be used to determine the drapability of any material studied. These procedures include:

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- A reference material is selected and its drapeability ratio ($K^{э}_{др}$) is determined by one of the known methods for determining drape, for example, by the “needle” method. The resulting value is stored in the computer's memory automatically. In the future, when assessing the drapability of any material, it will participate in the calculation of the drapability ratio of this material($K^{i}_{др}$).

Note: The selection of reference material may be random. As a reference sample, any fibrous structure material can be used.

- The number of generated waves of quasi-resistant vibrations on the reference sample ($m_э$) is determined. For this purpose, a developed device on which transverse waves are generated in the range of the spectrum of its own frequencies.(1–4 Hz), using a generator of mechanical vibrations on a reference sample, is used. This is recorded by a digital video camera. Information on the number of generated waves of quasi-resistant vibrations on the reference sample ($m_э$) at a given frequency of forced vibrations is also stored in the processor’s memory automatically. In the future, this parameter will be used when calculating the correction coefficient of the drapability ratio ($K^{i}_{кор}$).

With direct research on the drapability of the desired material, the following procedures are performed:

- In the same way as the parameter ($m_э$), the number of the generated waves of quasi-resistant vibrations on a sample of the *i*-th material (m_i) is determined. The parameter values (m_i) in the frequency range of forced vibrations of 1–4 Hz are automatically stored in the processor’s memory.
- The processor determines the correction coefficient of the drapability ratio for all given frequencies of forced vibrations as:

$$K^{i}_{кор} = \frac{m_э}{m_i}, \quad (4)$$

The obtained value of the correction coefficient of the drapeability ratio is stored in the processor’s memory and is used in determining the drapability of the *i*-th material as needed.

- Given the correction coefficient of the drapeability ratio ($K^{i}_{кор}$), the value of the drapability ratio of the sample material *i*-th is calculated according to the formula:

$$K^{i}_{др} = (K^{э}_{др})\,(K^{i}_{кор}), \quad (5)$$

To test the proposed method, an experimental test bench was made and a research program to determine the drapeability ratio of two fibrous materials of different origins, namely wool fabric (with a surface density of 150 g/m^2) and thin clothing leather (with a surface density of 480 g/m^2), was conducted. Measurements as applied to a material of the same type were carried out at different frequencies of forced vibrations corresponding to the spectrum of natural vibration frequencies of fibrous materials, namely, in the range of 1–4 Hz with a step of variation of 1 Hz. The change in the forced vibrations frequency of the material sample was carried out in order to eliminate the effect of this parameter on the value of the correction coefficient of the drapeability ratio ($K^{i}_{кор}$).

Lining fabric with a surface density of 100 g/m^2 and a drapeability ratio of 91% was chosen as the reference material. The results of the research and comparative evaluation with the results of the determination of the drapability ratio, using the widely practiced method - the “needle” method, are shown in the table. The choice of the “needle” method as the base one is due to the fact that it allows to estimate the drapability of the material separately by the length and width of the material, as provided for by the proposed research method, and, therefore, the values of the drapability parameter obtained by the “needle” method can be used as basis for comparison in assessing the accuracy of development.

The results of approbation show that the divergence magnitude of the drapability ratio, determined by the proposed method, and the drapeability ratio obtained by the “needle” method, does not exceed 7 percent. Considering that objective data on the measurement error using the “needle” method is not available, and the measurement accuracy with an error of 10% provides an opportunity to adequately evaluate a material's drapability to make sound design decisions, it is safe to say that the method can be used in the study of the indicators of the physio-mechanical properties of materials upon bending deformation.

Table 1. The results of the experimental testing of the developed method.

The material type	$K^{э}_{др}$, %	Forced mechanical vibrations frequency, Hz	Experimental and calculated results obtained by the developed method $m_э$	m_i	$K^{i}_{кор}$, %	$K^{i}_{др}$, %	Experimental data obtained by the "needle" method $K^{эксп}_{др}$, %	Magnitude of discrepancies $K^{i}_{др}$ and $K^{эксп}_{др}$, %
Knitted warp fabric	91.0	1	2.5	2.9	0.86	78.0	75.0	6.7
		2	5.0	5.5	0.91	82.0		
		3	8.1	9.2	0.88	80.0		
		4	10.6	12.2	0.87	79.0		
		average $K^{i}_{др}$				80.0		
Natural leather for clothes	91.0	1	2.5	6.0	0.42	38.0	36.5	6.8
		2	5.0	11.1	0.45	40.0		
		3	8.1	18.5	0.44	40.0		
		4	10.6	25.2	0.42	38.0		
		average $K^{i}_{др}$				39.0		

4. Conclusion

The developed method for the time spent on testing can be categorized as an express method. The method ensures the fulfillment of the requirements specified by the research purpose and can be used to study the drapability of fibrous materials of various structures and production methods. The results of the data analysis obtained during the testing show that the magnitude of the measurement error carried out using the proposed method ensures the required accuracy of the evaluation of the drapability of fibrous structure materials for the design of finished products.

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