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HAIRINESS AS A SURFACE PROPERTY OF TEXTILE

Purpose. *Determine the essence of the concept of «surface properties of textiles» and justify the degree of influence of the phenomenon of hairiness of textile materials on the surface properties of textile products.*

Methodology. *The analytical method is used in this work. The study contains a systematic analysis of scientific publications, the terminology of international standards and modern developments in the field of determining the surface properties of tissues.*

Findings. *Based on the analysis of scientific research, it was found that various authors refer to the surface properties of textile materials a different set of surface effects, and their analysis through the indicators of tissue hairiness makes this issue relevant. The definition of the general term «surface» has shown that in various branches of science it is interpreted differently depending on the subject and field of study. Textile material science considers the term «supporting surface of the fabric», which needs to be clarified. Analysis of the fibrous structure of the fabric showed a complex structural organization of its surface, which is represented by the relief and various zones of the pile, formed from individual fibers having different locations on the surface of the fabric. As a result, the following terms are formulated: "fabric surface" and "surface properties of fabrics". A list of surface properties of fabrics has been compiled, where hairiness is presented as an equivalent independent characteristic that simultaneously affects the manifestation of other surface effects.*

Originality. *For the first time, the terms «fabric surface» and «surface properties of fabrics» are defined and justified. The nomenclature of the surface properties of fabrics is determined, based on the analysis of which it is proved that hairiness is the main characteristic of the fabric surface.*

Practical value*. The proposed terms for determining the surface of fabrics harmonize the terminology of textile materials science with other branches of science. The study of the effect of hairiness on surface properties opens up new possibilities for expanding the assortment of fabrics and is a promising area in the development of expert methods for assessing the quality of textiles.*

Key words: *surface, surface properties, characteristics, hairiness, indicator, materials science.*

Introduction. Properties of surfaces of textile materials are taken into account when carrying out researches in various spheres of human activity, in particular in the production of clothing and footwear, design, medicine, optics, film industry and many others [1, 5, 15]. This is necessary for a better understanding of the procedure for the interaction of textiles with the environment. The features of this interaction require the attention of researchers, as special types of surface treatment of textiles are widespread, the purpose of which is to obtain various surface effects while preserving the integrity of the textile structure (thermal protection properties, sensory comfort, protection against temperature and radiation, bio-protection and artistic) [2, 4, 7-11]. At the same time in various technologies of surface treatment are processed by substances: from drawing of superfine films to full impregnation of thicker of textile material [3]. From this point of view, it is of scientific interest to define the concept of the surface of textiles and the surface properties of textiles.

Analysis of previous studies. Many scientific works are devoted to the study of the properties of textile materials, ranging from fundamental [4] to well-known modern developments in the field of nanotechnology, neurobiology, etc. [5]. As a result, a list of properties was formed,

which contains the main classes: geometric, mechanical, physical, chemical, biological and organoleptic. These major classes are subdivided into groups, each covering a number of distinctive features of textile materials that manifest themselves with varying effect under appropriate operating conditions. However, the definition of the list of surface properties in this classification is missing, as is the lack of definition of a layer of textile, which means its surface with the definition of its boundaries. Given the fact that a number of textile properties may be due to the same structure characteristics, it is reasonable to assume that surface properties are a collective term by which different researchers understand a different set of properties. For example, the authors of publications [6-7] refer to the surface properties of textiles as wetting, capillarity, breathability, vapor permeability, ability to electrify, and other authors [8-10] name surface properties the following: roughness, friction, softness, shear and profile surface. In the technology of designing fabrics of special purpose surface properties consider touch (haptic) and handle [11], and designers distinguish such features of the surface as shape and color [12]. Social surveys conducted by marketers show that surface characteristics for consumers are color, touch, softness and warmth [13], and the international ISO standard system presents as surface properties a surface profile determined by the method [14]. That is, in this issue there is a lack of consensus of the researchers' opinions. At the same time, there are known scientific works in which the authors analyze surface properties through the indexes of the hairiness of textile materials [10, 15]. It is advisable to assume that the tips of the fibers protruding on the surface of the textile product, forming a pile layer, significantly affect the surface properties. Therefore, the research has actual component and allow determining the place of hairiness in the general system of textile properties.

Setting problem. The main task of this work is to determine the essence of the concept of «surface properties of textiles» and justify the degree of influence of the phenomenon of hairiness of textile materials on the surface properties of textile products.

Results of the study. To begin with defining the surface as a general term of physical science. Solid state physics defines a surface as the area between two phases [16]. In the process of studying the surface, it is considered in combination with both phases. Depending on the subject area of study, the term «surface» is interpreted differently in different fields of science. Present it on a Table 1.

Table 1.

Definition of the term «surface» depending on the subject area of study

Physics of Materials Science	The boundary of the separation between the two contacting phases; an outer zone of a solid or fluid array that is different from the structure and has properties specific to that area only.
Standardization	The boundary between the two contacting environments.
Commodity Science	The contact area of the object with the environment.
Design	An element of a structure that transmits information about the texture of an object.
Textile science	The area of actual contact of the material with the plane of objects under a certain pressure

Different interpretation of the term «surface» is due to the complexity of determining the surface of the body in general. Moreover, it is difficult for textile material, which is an

inhomogeneous amorphous body [4], which has a non-uniform surface that can only be expressed graphically [8]. To determine the surface of the textile material, which is given in Table. 1, the notion of a reference surface was used [17]. The support surface consists of projecting ridges of waves of filaments for smooth fabrics and fibers, which project separately above the surface, for pile fabrics during contact with objects under certain pressure. Since the support surface depends on the pressure, and the textiles can interact with the environment without pressure (for example, the effect of radiation or light), so the term "surface" for the fabric needs clarification. Physically, any surface, as a rule, consists of shape, waviness, and roughness in the wavelength or frequency of the surface particles [18], so it is appropriate for fabrics as fibrous materials to state that fibers are constituents of the entire surface. Let's examine and analyze the fabric on the bend.

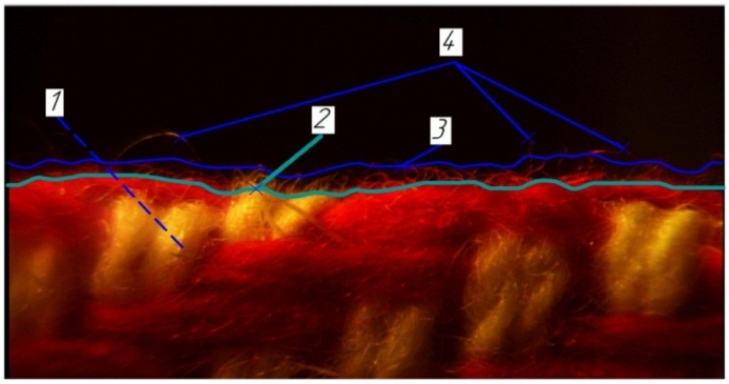

Fig. **Bending of fabric: 1 - body of fabric; 2 - a relief of a fabric; 3 – the outer boundary of the pile zone; 4 - random pile**

Consider the region of tight fit of the filaments between the body of fabric 1, then the outline of the body of the fabric on the bend forms a relief 2, and the ridges of the bending waves of the filaments form waves of relief [14]. The fabric body also includes a zone of dense pile [19]. Between the contacting space (in this case, air) and the relief of the fabric 2 there is a zone of free pile, the outer boundaries of which can change under the influence of the contacting phase, while the relief of the body of the fabric will remain unchanged. Next, in this area are the separate pile 4 (random pile), the impact of which on the surface property can be neglected. According to the terminology of physical materials science [16] zone 2-3, which is located between the relief of the fabric and the space in contact with the fabric, corresponds to the term «surface». Therefore, the term «tissue surface» can be formulated as follows.

The surface of the fabric is a layer formed by the relief of the fabric and fibers protruding from the body of the fabric in the form of villi. From this term, the surface of the fabric follows the term «surface properties».

Surface properties of a fabric are properties whose effect is manifested only in the area of the surface of the fabric (does not penetrate beyond the relief) and does not change its structure. Moreover, the basic structure of the fabric is in equilibrium (state of rest) during the manifestation of the effects of surface properties.

From all the nomenclature of the properties of fabrics used in textile science and the surface properties in physical material science, we present those effects with manifestation only on the surface of the fabric (Table 2).

Table 2.

Surface properties of fabric

The name of the effect	Manifestation	Class of properties of fabrics	Determination method
1	2	3	4
Hairiness	*The presence of tips of fibers, loops and loose fibers protruding from the body on the surface of the fabric, which are chaotically arranged and which can be removed without disturbing the basic fabric structure*	*Geometric (structural); physical (optical)*	*ISO 10290:2018(en) Textiles – Cotton yarns – Basis for specification; ASTM D5647 Standard guide for measuring hairiness of yarns by the photo-electric apparatus*
Luster	The ability of the surface to reflect rays of light	Physical (optical); aesthetic	ISO 2813:2014(en) Paints and varnishes — Determination of gloss value at 20 degrees, 60 degrees and 85 degrees
The ability to electrify	The ability to generate and accumulate static electricity under certain conditions	Physical	ISO/TR 11610:2004(en) Protective clothing
Dichroism	Changing the color in light that passes in anisotropic bodies, depending on the direction of the light rays (associated with double refraction of rays)	Physical (optical); aesthetic	ISO 15076-1:2010(en) Image technology color management – Architecture, profile format and data structure – Part 1: Based on ICC.1:2010
Contamination of the surface	Diffusion of dust particles upon contact with the surface of the fabric and their deposition or trapping of them from the flow of moving air due to electrical attraction, as well as by transfer from one surface to another	Physical (optical); aesthetic	ISO 11057:2011(en) Air quality – Test method for filtration characterization of cleanable filter media
Adhesion	The ability of the surface to interact with the liquid; the interaction takes place in three phases: surface, liquid and gas	Mechanical	ISO 4920:2012 Textile fabrics – Determination of resistance to surface wetting (spray test); method of lying drop; the Washburn method
Shear	Deformation (change of the outline of the outer boundary) of the surface upon contact with other surfaces	Mechanical	KES-FB Kawabata Evaluation System for Fabrics; EN ISO 14125:1998 Fibre-reinforced plastic composites. Determination of flexural properties.
Cognitive Impact	The perception of the surface of the fabric in its study with the involvement of cognitive mechanisms: attention, memory and thinking	Aesthetic	ISO 13299:2003, Sensory analysis – Methodology – General guidance for establishing a sensory profile, IDT; psychological testing
Color	Subjective characteristic of light wave perception; the ability of human vision to distinguish electromagnetic radiation from wavelengths within the visible range	Optical; aesthetic	ISO 10617:2010 Textiles – Standard data format for colorimetric communication – Textiles and related measurements
Peeling	The ability of tissues to form small balls (saws) from wrapped tips and separate sections of fibers during operation or processing	Mechanical; operational	ISO/DIS 12945 (en) Textiles — Determination of fabric propensity to surface pilling, fuzzing or matting
Figure (image clarity)	Image quality property; reproducibility of small parts, is defined by the minimum distance between them when these details in the image are perceived as separate	Optical; aesthetic	ISO 20471:2013(en) High visibility clothing — Test methods and requirements. organoleptic analysis
Abrasion	A kind of wear that separates particles from the surface during friction	Mechanical; operational	ISO 12947-2:2016 Textiles – Determination of the abrasion resistance of fabrics by the Martindale method – Part 2: Determination of specimen breakdown

Continue Table 2

Thermal conductivity (surface heat)	Surface property to perceive heat and interact (dissipate or accumulate)	Physical	International Standard: ASTM D7984. Test method for measurement of thermal effusivity of fabrics using modified transient plance source (mtps) instrument
Friction	Resistance to moving a surface over another surface when sliding	Mechanical; operational	ASTM D1894; ISO 8295; TAPPI T549
Heptic (touch)	The nature of the fabric surface, which is determined to the touch	Mechanical; operational	ISO 13299:2003, Sensory analysis – Methodology – General guidance for establishing a sensory profile, IDT; KES-F4 Kawabata evaluation system
Texture	Visual characteristic of the surface of the textile product	Optical; aesthetic	ISO 1302:2002(en) Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentationc
Roughness	Characteristics of surface irregularities, expressed in numerical values, which determine the degree of their deviation at the base length from theoretically smooth surfaces of a given geometric shape	Mechanical; operating	ISO 4287:1997. Geometrical product specification (GPS). The structure of the surface. The profile method. Terms, definition and parameters of the structure; KES-F. Kawabata evaluation system - Fabrics

Shown in Table. 2, the list of surface properties is consistent with the nomenclature of international ISO standards [14]. The attribution of one or another surface effect to a particular class of fabric properties corresponds to the basic provisions of textile materials science [20] and confirms the assumption that surface properties are a generic term, and the effect of these properties is manifested as a qualitative characteristic within this class. The presented methods for determining the surface properties of textiles prove the independence of their manifestation. It should be noted that the principle of operation of some surface effect detection methods needs to be adapted to analyze textile materials for better evaluation of the quality of textile products.

In this list of surface effects hairiness is presented as an equivalent independent characteristic. But, as can be seen from the definition of the surface of the fabric, the hairiness is main property, which affects the nature of the manifestation of other surface effects, namely: increased porosity decreases shine, increases dichroism, reduces image clarity, evens out color tone [13], reduces pollution, increases the ability to electrify, adhesion [6]; determines the degree of shear, peeling, abrasion, friction, roughness, texture [4, 8, 10]; the intensity of hairiness influences thermal conductivity, carcasses and cognitive perception [9, 11]. Thus, hairiness can be represented as the main surface characteristic of tissues.

Conclusions. The analysis of scientific literature has shown that researchers working in the field of textile materials science, attribute to various surface effects of the surface properties of textiles. That is, in this issue there is a lack of consensus of the researchers' opinions.

Based on the study of the fibrous structure of the fabric, the terms «fabric surface» and «surface properties of the fabric» are substantiated and proposed.

A list of surface properties of fabrics has been compiled, which is in line with the nomenclature of international ISO standards. It is proved that surface properties are a general term, and their action is manifested as a qualitative characteristic within the main known classes of fabric properties.

It has been determined that hairiness is the main surface property that influences the character of the manifestation of other surface effects of textiles.

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ВОРСИСТІСТЬ ЯК ПОВЕРХНЕВА ВЛАСТИВІСТЬ ТЕКСТИЛЮ

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Мета. *Визначити сутність поняття «поверхневі властивості текстилю» та обґрунтувати ступінь впливу явища ворсистості текстильних матеріалів на поверхневі властивості текстильних виробів.*

Методика. *У роботі використаний аналітичний метод. Дослідження містить системний аналіз наукових публікацій, термінології міжнародних стандартів та сучасних розробок у сфері визначення властивостей поверхні тканин.*

Результати*. На основі аналізу наукових досліджень з'ясовано, що різні автори до поверхневих властивостей текстильних матеріалів відносять різний набір поверхневих ефектів, а їх аналіз через показники ворсистості тканин робить дане питання актуальним. Визначення загального терміну «поверхня» показало, що в різних галузях наук воно по-різному інтерпретується в залежності від того, що виступає в якості предметної області дослідження. Текстильне матеріалознавство розглядає термін «опорна поверхня тканини», який потребує уточнення. Аналіз волокнистої будови тканини показав складну структурну організацію її поверхні, яка представлена рельєфом і різними зонами ворсу, утвореними із окремих волокон (ворсинок), що мають різний характер розташування на поверхні тканини. У результаті сформульовані наступні терміни: «поверхня тканини» і «поверхневі властивості тканини». Складений перелік поверхневих властивостей тканин, де ворсистість представлена як рівноцінна незалежна характеристика, що одночасно впливає на характер прояву інших поверхневих ефектів.*

Наукова новизна*. Вперше визначені та обґрунтовані терміни «поверхня тканини» та «поверхневі властивості тканини». Визначена номенклатура поверхневих властивостей тканин, на основі аналізу якої доведено, що ворсистість є основною характеристикою поверхні тканин.*

Практична значимість*. Запропоновані терміни для визначення поверхні тканин гармонізують термінологію текстильного матеріалознавства з іншими галузями наук. Дослідження впливу ворсистості на поверхневі властивості відкриває нові можливості для розширення асортименту тканин та є перспективним напрямком у сфері розробки експертних методів оцінювання якості текстилю.*

Ключові слова: *поверхня, поверхневі властивості, характеристика, ворсистість, показник, матеріалознавство.*

ВОРСИСТОСТЬ КАК ПОВЕРХНОСТНОЕ СВОЙСТВО ТЕКСТИЛЯ

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Цель. *Определить сущность понятия «поверхностные свойства текстиля» и обосновать степень влияния явления ворсистости текстильных материалов на поверхностные свойства текстильных изделий.*

Методика. *В работе использован аналитический метод. Исследование содержит системный анализ научных публикаций, терминологии международных стандартов и современных разработок в сфере определения свойств поверхности тканей.*

Результаты. *На основе анализа научных исследований установлено, что различные авторы к поверхностным свойствам текстильных материалов относят разный набор поверхностных эффектов, а их анализ через показатели ворсистости тканей делает данный вопрос актуальным. Определение общего термина «поверхность» показало, что в различных отраслях науки он по-разному интерпретируется в зависимости от того, что выступает в качестве предметной области исследования. Текстильное материаловедение рассматривает термин «опорная поверхность ткани», который нуждается в уточнении. Анализ волокнистого строения ткани показал сложную структурную организацию ее поверхности, которая представлена рельефом и различными зонами ворса, образованными из отдельных волокон (ворсинок), имеющих различный характер расположения на поверхности ткани. В результате сформулированы следующие термины: «поверхность ткани» и «поверхностные свойства ткани». Составлен перечень поверхностных свойств тканей, где ворсистость представлена как равноценная независимая характеристика, которая одновременно влияет на характер проявления других поверхностных эффектов.*

Научная новизна. *Впервые определены и обоснованы термины «поверхность ткани» и «поверхностные свойства ткани». Определена номенклатура поверхностных свойств тканей, на основе анализа которой доказано, что ворсистость является основной характеристикой поверхности тканей.*

Практическая значимость*. Предложенные термины для определения поверхности тканей гармонизируют терминологию текстильного материаловедения с другими отраслями наук. Исследование влияния ворсистости на поверхностные свойства открывает новые возможности для расширения ассортимента тканей и является перспективным направлением в области разработки экспертных методов оценки качества текстиля.*

Ключевые слова: *поверхность, поверхностные свойства, характеристика, ворсистость, показатель, материаловедение.*