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Improving the method for determining the dust penetration of textile materials for the human protective equipment manufacture

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ABSTRACT

Purpose: Improving the accuracy of determining the coefficient of dust permeability of textile materials and protective products from them.

Design/methodology/approach: The problem solution of human protection from the negative effects of road dust is to improve the quality control procedures of textile materials using modern measurement methods. A methodology has been developed for investigating the dust penetration coefficient of materials based on the use of a television information-measuring system (TIMS).

Findings: The methodology for determining the dust permeability of textile materials through the use of a television information-measuring system has been improved, by increasing the accuracy of measurement and determining the patterns of the influence of structure on the permeability of textile materials.

Research limitations/implications: Improving methods of quality control of textile materials through the use of modern methods of measuring techniques is by solving an important problem of human protection from the negative effects of road dust. Known methods do not take into account the forceful effect of the airflow on the structure of the test sample, which is essential for textile materials that are easily deformed, which affects the objectivity of the results. Significant inconvenience, complexity, and duration of the test process give a large measurement error.

Practical implications: The methodology for determining the dust permeability of textile materials through the use of a television information-measuring system has been improved. This system allows an increase in the accuracy of measurements by 15%, and the availability of software to increase the speed of displaying the results of investigations on the screen.

Originality/value: The main disadvantages of methods and means of determining the dust permeability of textile materials - is the inability to determine the duration and dynamics of the process of dust retention. Known methods do not take into account the force of air flow on the structure of the test sample, which is significant, especially for materials that are easily deformed, which affects the objectivity of the results. Significant inconveniences, complexity and duration of the test process give a large measurement error.

A scientific novelty is the development of a modern and completely new method for determining the permeability of textile materials using a television information - measuring system, by increasing the accuracy of measurement and determining the patterns of influence of the structure of textile materials on dust permeability.

Keywords: Dust penetration, Textile materials, Television information-measuring system

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METHODOLOGY OF RESEARCH

1. Introduction

Air pollution from car exhaust gases and finely dispersed particles from tire wear cause harm to the human respiratory system. Big-city residents, cyclists, traffic police, people whose work is directly related to the constant movement around the city are especially affected [1].

Clean air is the key to good health and good physical condition. It is known that air consists of oxygen (O_2) and nitrogen (N_2) in a ratio of about 1:3. In a calm state, a person inhales about 10 liters of air per minute. During active work or playing sports, the amount of inhaled air increases many times. The air that a person inhales daily can contain many dangerous substances.

Hazardous substances can be in the form of solid or liquid aerosol particles, gases, or vapors. The smaller the size of the dust particles, the longer they are in the air in suspension, and the higher the probability that they will get into the lungs with air.

The effect of dust on the skin and mucous membranes is reflected in the blockage of the excretory ducts of the sebaceous and sweat glands, the occurrence of pyoderma, allergies, and the lipotropic components of the dust can be absorbed, causing toxic effects on the human body. Contaminating the personal human protective equipment, dust reduces its ventilation, steam-flow functions, negatively affecting heat exchange and respiration of the skin [3].

The relevance of the work is the investigation of textile materials used for the manufacture of comfortable in use personal human protective equipment for dust penetration.

2. Materials and methods

As a result of the analysis of the scientific leading expert works, we consider it expedient and relevant to investigate the materials for dust penetration using TIMS to create comfortable conditions for human skin breathing. The main disadvantages of methods and means for determining the penetration of textile materials are analyzed and identified - the impossibility of determining the duration and process dynamics of dust sample retention. Known methods do not take into account the forceful effect of the airflow on the structure of the test sample, which is essential for textile materials that are easily deformed, which affects the objectivity of the results. Significant inconvenience, complexity, and duration of the test process give a large measurement error [4-6].

As a result of theoretical and experimental investigations of various materials that are used to protect people from environmental pollution, it was determined that it is most appropriate to use plain weave fabrics with a surface density of 200 g/m^2, with a maximum percentage of natural fibers to prevent possible allergic reactions [7,8].

Among the textile materials used for the clothing and accessories manufacture, knitwear occupies a special place. Knitted fabrics are increasingly used for sewing products for various purposes. Knitwear is used for sports, tourism, and outdoor activities products. A feature of such products is that they are directly adjacent to the human body [9,10].

Performance of the basic functions of respiratory protection can be reached by keeping with a certain thickness of cloth, a combination of materials, and a multi-layered structure. Recently, there has been a question in the development of multifunctional textile materials, the layers of which would have diametrically opposite properties. There are several ways to get the desired result, namely: 1) combining raw materials with different properties in the process of weaving or knitting; 2) creation of multifunctional multilayer composite textile materials, the layers of which are made of raw materials with different properties.

To identify the functionality of bicomponent knitwear formed from raw materials with opposite hygroscopic properties, we chose two-layer knitwear shown in Figure 1

[7]. During breathing, condensation occurs between the human body and the respiratory mask, and moisture forms, which must be removed for a comfortable stay. Therefore, the inner layer of the samples is responsible for the removal of moisture, and the outer – for filtration and sorbing.

Fig. 1. Samples of textile respiratory masks based on two-layer knitwear

For the manufacture of samples, yarn was used as a hydrophilic type of raw material, the composition of which is cotton 34%, linen 33%, viscose 33%, and polypropylene multifilament string as hydrophobic. Used raw materials for the samples of two-layer knitwear manufacture are shown in Figure 2 [7]. The combination of natural and synthetic materials, as a result, gives different types of masks for various operating conditions [11].

Fig. 2. Used raw materials for the samples of two-layer knitwear manufacture

The dust penetration of such fabrics, namely, the ability of a material to pass dust particles into the undercoat layer, has sizes from 10^{-4} to 10^{2} cm. Dense fabrics with a smooth surface are less contaminated than loose, rough fabrics. Cotton fabrics are most prone to pollution; silk and linen are less polluted.

Density and filling of materials affect their thickness, weight, thermal properties, breathability, air penetration, strength, shape stability, and other features. The shape of the material cells is one of the main parameters that determine the similarity or difference in material properties in the lobar and transverse directions.

With the same actual fabric density, the degree of their filling with threads can be different depending on the thickness of the threads. To compare the fabrics by the density characteristics, relative density indicators are used: linear filling and filling of the fabric with threads, as well as surface filling, which take into account the thickness of the threads of used fabric [12].

Linear filling (E_m, E_w, %) indicates how much of the length of the fabric along the warp or weft is filled with the parallel threads cross without taking into account their interweaving with the threads of the perpendicular system. A linear filling is defined as the ratio of the actual density (P_m, P_w) to the maximum possible, which theoretically can be located without jamming the threads, landslides, and gaps on the same length. When determining the density over a length L = 100 mm, the maximum density P_{max} is determined as the ratio of the length to the diameter of the thread d [12]:

$$P\frac{100}{d}{}_{max} \qquad (1)$$

Linear filling is calculated by the formula:

$$d = \frac{T}{31.6 \cdot C} \qquad (2)$$

where d is the diameter of the thread and C – is a coefficient that is equal to: for cotton yarn – 83-100; for wool – 74-80; for viscose staple – 80; for viscose threads – 83;for raw silk threads – 100 and so on [12].

Linear fabric filling can range from 25% to 150%. If the linear filling exceeds 100%, the threads are flattened or are offset.

Linear filling shows how much of the fabric length along the warp or weft is occupied by the diameters of both filament systems, taking into account their mutual interweaving. Linear filling characterizes the degree of compaction of the weave.

Coats and some costume fabrics are produced with maximum density. Most fabrics are made with a density of 35-70%. The density of tissues is determined by their purpose.

Surface filling (E_s, %) is characterized by the ratio of the area of the fabric, which is filled with projections of the main and weft threads, to the entire area of the fabric and is determined by the formula [12]:

$$E_s = E_m + E_w - 0.01 \cdot E_m \cdot E_w \quad (3)$$

The surface filling is determined for fabric with linear fillings that do not exceed 100%. Most fabrics are produced with a higher density at the base.

The absolute densities ratio determines the shape of the fabric cell. With increasing density along the warp, the threads are shifted in the vertical direction, with increasing density in the weft - in the horizontal direction. As a result, the cells become asymmetric and stretch in one direction or another. The shape of the tissue cell is one of the main parameters that determine the similarity or difference in tissue properties in the lobar and transverse directions [3].

3. Results and interpretation

Investigations of the cells shape of various textile materials were carried out on the basis of the educational and scientific laboratory of the Department of Scientific, Analytical and Ecological Instruments and Systems.

Cell sizes were determined using a television information measuring system (TIMS). TIMS is a combination of optical and electronic means by which information about the structure, condition and properties of an object contained in its radiation is converted into an electrical signal.

The TIMS block diagram is shown in Figure 3 [13].

The main characteristics of TIMS are: light signal characteristic, spectral characteristic, and resolution [14].

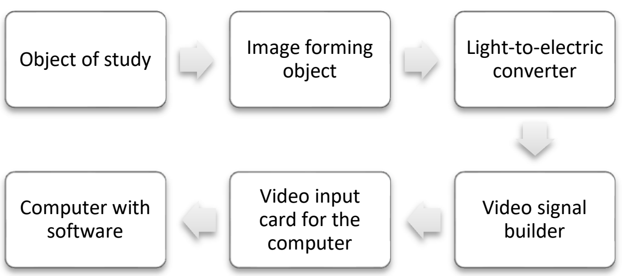

Fig. 3. The TIMS block diagram

The light-signal characteristic is the signal ratio to the pixel illumination. The energy characteristic that each pixel perceives.

Spectral characteristic is the dependence of the television signal on the wavelength of the photosensitive surface of the radiation. The spectral characteristics of the converter are determined by its specific purpose.

Resolution is the minimum distance between two turned light sources at which these sources are perceived separately.

The threshold contrast is the signal-to-noise ratio at a given probability of the input contrast divided by the product and the signal-to-noise ratio under illumination [14].

$$K_p = \frac{q_p(P)}{K_{in} \cdot q(E)} \quad (4)$$

where K_{in} – input contrast; q(E) – signal-to-noise ratio in illumination E; q_p (P) – signal-to-noise ratio at a given probability P.

The illuminance of the surface E is called the surface density of the radiation light flux that equal to the ratio of the light flux incident on the surface to the area of the illuminated surface S [14].

$$E = F \cdot S \quad (5)$$

where F – light flux; S – illuminated surface area.

The maximum illuminance is the minimum illumination that the device still perceives.

The main components of TIMS are a television microscope [15].

A television microscope (TM) is not just a mechanical combination of a light microscope, a television camera and computer equipment, but the only device in which each parameters of the components are mutually agreed and optimized as a whole with respect to a specific task. Figure 4 shows the structure of the simplest TM [15].

The lighting system provides uniform and sufficient illumination of the test sample. The sample is placed on a stage, which provides the ability to move the investigated material in two mutually perpendicular directions normal to the optical axis of the microlens. The lens forms an enlarged image on the CCD - the matrix of the camera. The tube fixes the image plane at a certain distance from the microlens. The camcorder produces a complete video signal, which in turn is transmitted to the monitor [15-19].

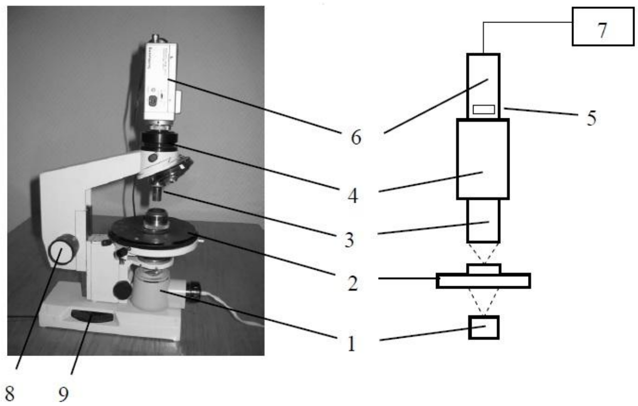

Fig. 4. TM structure: 1 – lighting system; 2 – table with the test sample; 3 – lens; 4 – tube; 5 – video camera; 6 – CCD matrix; 7 – monitor; 8 – the handle for rough sharpness setting; 9 – the handle for exact sharpness setting

4. Conclusions

So in this article, we solve the scientific and practical problem of increasing the accuracy of dust penetration measuring of textile materials for human protection manufacture from the negative effects of roads. The methodology for determining the dust permeability of textile materials through the use of a television information-measuring system has been improved, by increasing the accuracy of measurement and determining the patterns of the influence of structure on the permeability of textile materials. This system allows an increase in the accuracy of measurements by 15%, and the availability of software to increase the speed of displaying the results of investigations on the screen.

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