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EVALUATION OF HEAT CONDUCTIVITY OF SPECIAL CLOTHING

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Abstract:

Objective. The importance of special clothing for workers who are working in closed buildings in the exchange of air (heat) between the human body and the environment has been studied. In this case, as samples of special clothes, the actual special clothes which are made of cotton + polyester fiber fabric of automobile factory workers, the special clothes which are made of 100% cotton fiber fabric taken for comparison, and the special clothes made of cotton + modal fiber fabric is recommended as fabric with high hygienic properties were researched.

Methods. In the research used equipment comprehensively determines the temperature, relative humidity, and carbon dioxide content of the environment under clothing and allows the data to be transferred directly to an application on a mobile phone via bluetooth. Based on the obtained results, the magnitude of the heat flow density between a person - special clothing - external environment was determined using Fourier's law.

Results. As a result of the research, it was determined that the value of the heat flow released from the human body is high based on the research of the indicators of the microclimate of the special clothing made from the new (cotton + modal) fiber-containing fabric.

Conclusion. From the results of the research, it was found that a large amount of heat exchange occurs between the external environment and special clothing made of cotton + modal fiber fabric. The results of the research revealed that special clothing made of cotton + modal fiber fabric has high hygienic properties.

Keywords: special clothing, hygienic properties, modal fiber, thermal conductivity, heat flow, indicators of microclimate under clothing.

Introduction. Currently, the use of fabrics produced abroad, the lack of sufficient information about their quality and properties, significantly complicates the design and production of clothing. At the stage of technological processes of clothing preparation, the sudden manifestation of fabric properties affects the quality and consumption indicators of clothes [1]. As special clothing performs the task of improving the working conditions of workers, increasing work productivity and creating comfort for workers during the shift, the task of producing special clothing from fabrics with high hygienic properties is urgent [2-3]. Hygienic properties of special clothing fabrics should be suitable for climatic conditions or labor intensity. Therefore, special clothing should serve to optimize the parameters of the microclimate under the clothing resulting from the physical activities of workers [4-5].

In studies [6-7], clothes made of modal fiber fabrics belonging to the group of natural fibers or artificial fibers were found to be the most suitable for hot, dry climate conditions. Studies have shown [8-9-10] that clothes made of cotton and modal fibers have lower temperatures under clothes than clothes made of other fabrics. The passage of moisture (sweat) through the fabric is a complex process, water vapor diffusion through the pores, sorption-desorption of steam (or droplet liquid sweat) and capillary condensation by fibers and threads occur, especially for fabrics with a dense structure, this process is difficult [11].

Unlike most man-made fibers, modal fiber is considered an environmentally friendly fiber and is made from wood cellulose. The composition of modal fiber is completely free from toxic substances and other harmful impurities, therefore, this fiber is considered an environmentally friendly and harmless raw material for human health. In addition, fabrics made of modal fiber have a number of advantages over natural fabrics, namely, high hygroscopicity, air permeability, lightness, durability, comfort, softness, etc. Also, despite the chemical composition of modal and cotton fibers being the same, modal has 1.8 times more moisture absorption than cotton. Modal fiber has 50% more moisture absorption than cotton, which makes modal fabrics dry and highly breathable. Therefore, it is considered the best fabric useful for improving the physiological cycle and health of the body [11].

The moisture absorption properties of fabric fibers depend on their chemical composition and molecular structure. Cellulose and protein fibers have high hygroscopic properties. Most synthetic fibers, including polyester (polyether) fibers, have a low rate of moisture absorption, because they almost do not contain hydrophilic groups [12-13]. The above-mentioned properties of modal fiber indicate that the special clothes which are made of fabrics and fibers are optimal for the heat exchange of the human body with the external environment, performing intensive physical activity [14-15-16].

Methods. The microclimate under clothing is evaluated by a number of indicators such as air temperature and relative humidity, the amount of carbon dioxide gas in the air measured in fabrics or clothing items using standard methods in laboratories. In the study, the method and equipment for determining the microclimate parameters were used to determine the comfort of the undergarment environment. The equipment allows to comprehensively determine the temperature, relative humidity and carbon dioxide content of the environment under the clothes and transfer the data directly to the application on the mobile phone via bluetooth [17].

Depending on the type of physical activity of workers during the day, the indicators of microclimate parameters under special clothing are different. The amount of heat flow released from the body as a result of physical activities of workers affects the temperature of the microclimate under clothing [16]. In the course of the study, the temperature (heat) under the clothes of the workers of the automobile factories during the shift of the special clothes made of cotton + polyester (CPE), 100% cotton fiber (C) and cotton + modal fiber (CM) fabrics taken for control were studied (Figure 1).

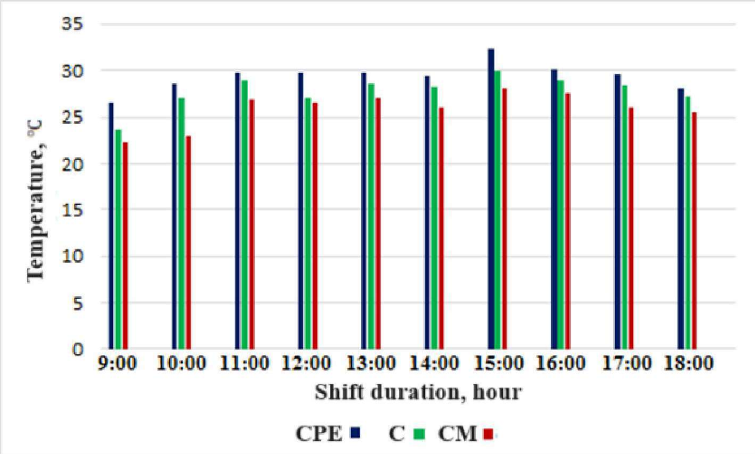

Figure 1. Temperature indicators of the underwear microclimate during the shift

At 35°C, air movement in industrial buildings creates conditions for increased heat transfer by the body. As the air temperature rises, the moving hot air gives off its heat to a person and begins to warm him. Sudden changes in temperature in the building, for example, cold air blowing (draught), significantly disrupts thermoregulation in the body in winter and causes colds [18]. Therefore, it is very important to study the transmission of air through multi-layer clothing sets. Many researchers have studied different methods of air transfer through fibrous materials [19-20-21]. A number of other researchers have examined the effect of various fabric parameters on their thermal properties and developed models to control air permeability and moisture transfer [22-23-24].

The connection between the heat flux density and the temperature gradient vector is represented by Fourier's law [25-26]. On the basis of this law, it is possible to determine the thermal conductivity of single and multi-layer bodies (including special clothing). The Fourier equation for the elementary layer is as follows:

$$q = \frac{t_1 - t_2}{\delta/\lambda} \quad \textbf{(1)}$$

λ – coefficient of thermal conductivity is the most important thermophysical property of materials and characterizes the density of heat flow when the temperature gradient is 1 K/m. λ determined from special tables or by experience; δ – thickness of layer (material) (m); t – temperature at layer boundaries (℃)

In the research work, the transfer of heat flow in the environment under clothing to the external environment was studied based on Fourier's law. For this, based on formula (1), the following actions were performed:

$$q = (\lambda_1/\delta_1)(t_1 - t_2) \quad \textbf{(2)}$$

$$q = (\lambda_2/\delta_2)(t_2 - t_3) \quad \textbf{(3)}$$

In the stationary (stable) mode, the specific heat flow (q) passing through each layer of the material changes depending on the thermal conductivity coefficient and thickness of the material [18]. Figure 2 shows the air (heat) conductivity of two-layer material of different thicknesses.

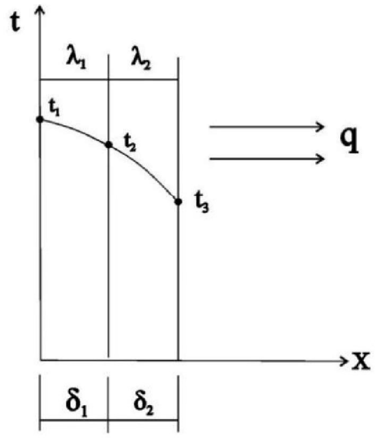

Figure 2. Air (heat) conductivity of two-layer material

Discussion. The following results were obtained when the heat flow density between the human body and the T-shirt was calculated based on the formula (2) and the heat flow density between the t-shirt and the special clothing made of cotton + PE fiber fabric was calculated based on the formula (3) in the Excel program (Fig. 3). Here: λ1 and λ2 are thermal conductivity coefficients of the fabric from which T-shirts and special clothes are made, respectively; q1 and q2 are the heat flux density between the human body and the T-shirt and between the T-shirt and special clothing, respectively; δ1 and δ2 - the thickness of the fabric from which the T-shirt and special clothing are made, respectively; t1, t2, and t3 are temperatures at the boundaries of the human body, T-shirt, and special clothing, respectively.

	B	C	D	E	F	G	H	I	J	K	L
1	λ1	λ2	δ1(m)	δ2(m)	t3(C)	t1(C)	t2(C)	Δt2	Δt1	q1 (J/m2)	q2(J/m2)
2	0,22	0,03	0,0015	0,004	26,5	35,8	27,8	1,3	8	1173,333	9,75
3	0,22	0,03	0,0015	0,004	28,6	36	29	0,4	7	1026,667	3
4	0,22	0,03	0,0015	0,004	29,7	36,2	31	1,3	5,2	762,6667	9,75
5	0,22	0,03	0,0015	0,004	29,7	36,4	31,2	1,5	5,2	762,6667	11,25
6	0,22	0,03	0,0015	0,004	29,7	36,6	31,5	1,8	5,1	748	13,5
7	0,22	0,03	0,0015	0,004	29,4	36,6	29,9	0,5	6,7	982,6667	3,75
8	0,22	0,03	0,0015	0,004	32,3	36,8	33,2	0,9	3,6	528	6,75
9	0,22	0,03	0,0015	0,004	30,1	36,7	30,8	0,7	5,9	865,3333	5,25
10	0,22	0,03	0,0015	0,004	29,6	36,6	30,4	0,8	6,2	909,3333	6
11	0,22	0,03	0,0015	0,004	28,1	36,6	30	1,9	6,6	968	14,25

Figure 3. Heat flux density under special clothing made of cotton +PE fiber fabric

The following results were obtained when the heat flux density was calculated for special clothing made of cotton fiber fabric (Fig. 4):

	A	B	C	D	E	F	G	H	I	J	K	L
17	t	λ1	λ2	δ1(m)	δ2(m)	t3(C)	t1(C)	t2(C)	Δt2	Δt1	q1 (J/m2)	q2(J/m2)
18	9	0,22	0,21	0,0015	0,004	23,6	35,8	24,1	0,5	11,7	1716	26,25
19	10	0,22	0,21	0,0015	0,004	27	36	27,9	0,9	8,1	1188	47,25
20	11	0,22	0,21	0,0015	0,004	28,9	36,2	29,3	0,4	6,9	1012	21
21	12	0,22	0,21	0,0015	0,004	27,1	36,4	28	0,9	8,4	1232	47,25
22	13	0,22	0,21	0,0015	0,004	28,5	36,6	29,1	0,6	7,5	1100	31,5
23	14	0,22	0,21	0,0015	0,004	29,3	36,6	30	0,7	6,6	968	36,75
24	15	0,22	0,21	0,0015	0,004	29,9	36,8	30,6	0,7	6,2	909,333	36,75
25	16	0,22	0,21	0,0015	0,004	28,9	36,7	29,8	0,9	6,9	1012	47,25
26	17	0,22	0,21	0,0015	0,004	28,4	36,6	29,4	1	7,2	1056	52,5
27	18	0,22	0,21	0,0015	0,004	27,2	36,6	28,2	1	8,4	1232	52,5

Figure 4. Heat flux density under special clothing made of cotton fiber fabric

When the heat flux density was calculated for the recommended special clothing made of cotton + modal fiber fabric (Fig. 5), the following results were obtained:

	A	B	C	D	E	F	G	H	I	J	K	L
32	t	λ1	λ2	δ1(m)	δ2(m)	t3(C)	t1(C)	t2(C)	Δt2	Δt1	q1 (J/m2)	q2(J/m2)
33	9	0,22	4,42	0,0015	0,004	22,3	35,8	22,9	0,6	12,9	1892	663
34	10	0,22	4,42	0,0015	0,004	23	36	23,6	0,6	12,4	1818,67	663
35	11	0,22	4,42	0,0015	0,004	26,9	36,2	27,1	0,2	9,1	1334,67	221
36	12	0,22	4,42	0,0015	0,004	26,9	36,4	27,1	0,2	9,3	1364	221
37	13	0,22	4,42	0,0015	0,004	27	36,6	27,8	0,8	8,8	1290,67	884
38	14	0,22	4,42	0,0015	0,004	26,1	36,6	27,6	1,5	9	1320	1657,5
39	15	0,22	4,42	0,0015	0,004	28,1	36,8	29	0,9	7,8	1144	994,5
40	16	0,22	4,42	0,0015	0,004	27,6	36,7	28,3	0,7	8,4	1232	773,5
41	17	0,22	4,42	0,0015	0,004	26	36,6	27,2	1,2	9,4	1378,67	1326
42	18	0,22	4,42	0,0015	0,004	25,5	36,6	26,3	0,8	10,3	1510,67	884

Figure 5. Heat flux density under special clothing made of cotton+modal fiber fabric

Results. A comparative analysis of these obtained indicators is presented in the following diagrams (Figures 6-7).

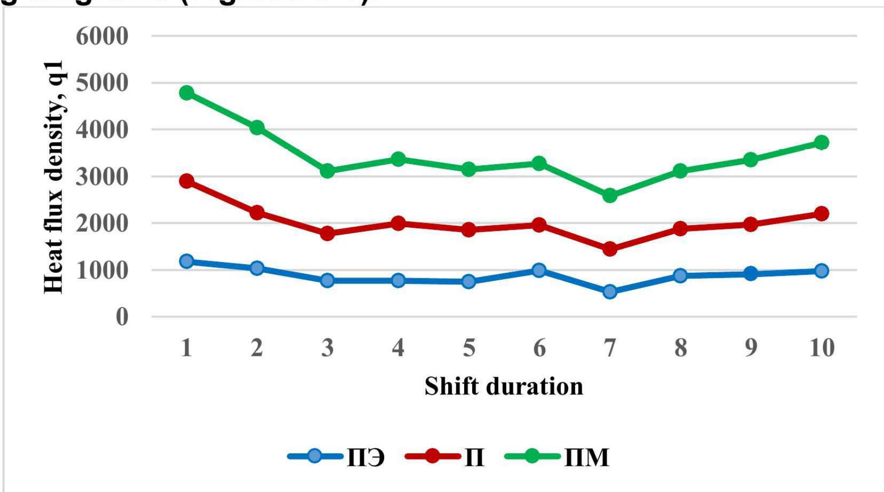

Figure 6. Heat flow in layer 1 (between the human body and the T-shirt)

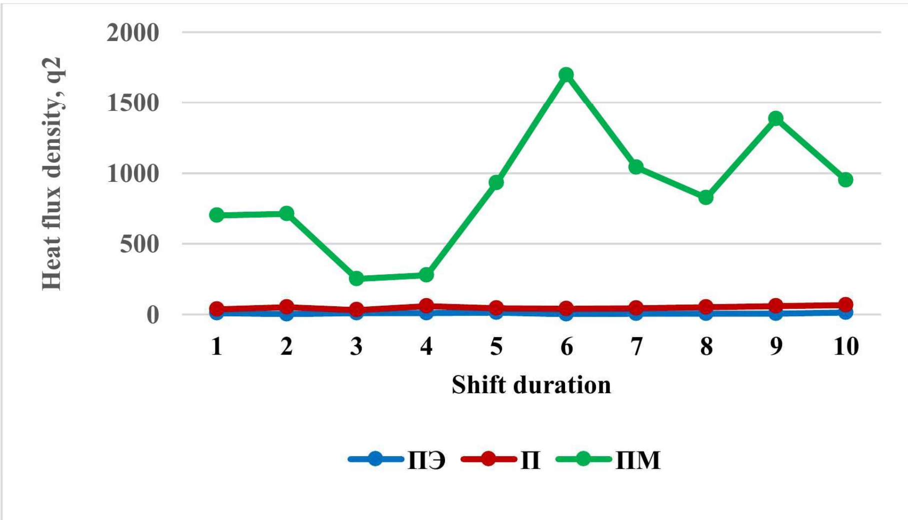

Figure 7. Heat flow in layer 2 (between T-shirt and special clothing)

As can be seen from diagram 6, the heat flux density values in layer 1 (between the human body and the T-shirt) are proportional to each other for all three cases. The reason is that a T-shirt made of cotton fiber forms the layer under the three different types of special clothing.

From diagram 7, it is possible to observe a sharp change in the heat flux density values for three different cases. Because as the 2nd layer, special clothes made of fabrics with different fiber content were taken.

Conclusion. Based on the obtained results, it can be concluded that the special clothing made of cotton + modal fiber fabric has the ability to transfer a large amount of heat flow to the external environment. That is why, as a result of the application of special clothing with high hygienic properties for workers engaged in intensive physical activities in closed buildings (especially car factory workers), their work ability increases, that is, moisture (sweat) released from the worker's body and high temperature modal fiber moisture does not allow the worker to overheat due to the ability to transmit a large amount of heat flow to the outside environment. As a result of the non-occurrence of unpleasant situations caused by the sweating of the worker, there is an opportunity to increase labor productivity.

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MATHEMATICAL MODEL OF THE INFLUENCE OF A GYMNAST'S STRENGTH ON CLOTHING FABRIC

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Abstract:

Objective. This article discusses the impact of various forces that can arise during the movement of athletic girls in gymnastics clothes, the study of the stress-strain state, the types of fabric used for clothing, and the mathematical model of the force acting on it. Information about the values of the coefficients determined as a result of the actions is also discussed and highlighted.

Keywords: mathematical modeling, physical phenomena, learning, complex dynamic systems, multiplicity, parameters, gymnastics-clothing-environment, human body.

The developed mathematical model of the gymnasts' sportswear system makes it possible to develop a reasonable design and choose the materials of a set of clothes intended for use in conditions of human body movement. The developed mathematical system model "gymnast-clothing-environment" allows us to develop a rational design and selection of the material of a special fabric package designed for use in special conditions of the parameters of the area of movement of the gymnast's body. In world and domestic practice, computer mathematical modeling is widely and successfully used to solve such problems [3].

Mathematical modeling is a method of studying physical phenomena by constructing their mathematical models. So, when studying very complex dynamic systems and objects with a large number of parameters; they are non-linearly interconnected, it is difficult to get the dependence of output indicators on the

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