Study the influence of the environment on heat transfer processes in sewing sheaths with heat-accumulating properties

Irina Cherunova [1*], *Salikh* Tashpulatov [2,3], *Svetlana* Knyazeva [1], *Pavel* Cherunov [1], and *Anna* Subbotina[1]

[1] Don State Technical University, Shakhty, Russia
[2] Namangan institute of textile industry, Namangan, Uzbekistan
[3] Jizzakh Polytechnic Institute, Jizzakh, Uzbekistan

Abstract. In the article research results are presented, which aim to modeling of heat transfer processes in a system for evaluating the heat storage effect of combined cooling shells. Clothing and equipment corresponding to the type and activity of movements and work performed by a person are considered as a shell. To a certain extent, the task of compensating for excessive heat load is solved by special materials that are used in the manufacture of such shells. Such shells are multicomponent structures of materials from various fiber systems with the inclusion of ice modules. The main means of processes for evaluating and improving such technologies are mathematical modeling tools, in particular, heat transfer modeling in multilayer shells. The structure of a heat transfer model with the inclusion of a heat storage module in a fibrous sheath. To describe the heat transfer the mean radii of curvature of the geometric system "man-heat-shielding shell" were calculated. The problem is considered when layers of various materials separate the external environment from ice. For the "man-clothing" section, the temperature field is calculated. The data obtained make it possible to evaluate the heat storage effect in combined cooling shells.

1 Introduction

Currently, one of the priorities of the development is the development of technologies related to the formation of high efficiency of human life [1]. To a large extent, the effectiveness of the human body depends on its external non-biological shell. Clothing and equipment corresponding to the type and activity of movements and work performed by a person are considered as a shell [2]. In conditions of high activity under external heat load in professional types of work, a person is at risk of thermal overheating. To a certain extent, the task of compensating for excessive heat load is solved by special materials that are used in the manufacture of such shells. The solution to the problems of compensating for excess heat is associated with the use of special components in materials and their combinations

* Corresponding author: i_sch@mail.ru

with heat-accumulating properties [3,4]. One of the main natural heat accumulators is water ice [11]. Ice is a combination of modern heat-shielding shells for clothes and equipment. There are a large number of professional works, where the main condition for the use of heat accumulators in the individual protection system of a person is environmental friendliness at any risk of structural damage. An indispensable solution is the use of heat-accumulating properties of water ice [5,6].
Ice is a combination of modern heat-shielding shells for clothes and equipment.
Such shells are multicomponent structures of materials from various fiber systems with the inclusion of ice modules [7,8].
Assessing and improving the effectiveness of such structures is of great interest both from a scientific point of view, and for the development of labor safety technologies, ensuring human health and comfort.
The main means of processes for evaluating and improving such technologies are mathematical modeling tools, in particular, heat transfer modeling in multilayer shells [5, 9, 10].

2 Topicality, Scientific Relevancy

Fig.1 shows a diagram of a combined cooling shell based on textile materials and heat storage modules made of ice.

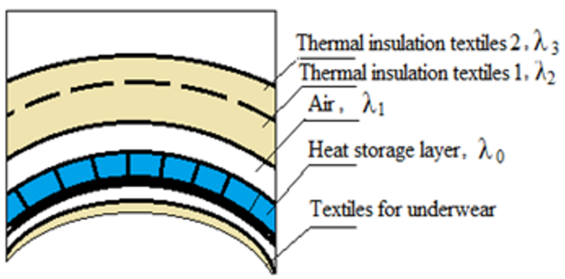

Fig. 1. Diagram of a combined cooling shell based on textile materials and heat storage modules made of ice.

In the field of research and the creation of modern polymers and materials from them, a real revolution is currently underway. Materials on structure and properties have a huge variety and unlimited scope [11,12]. One of the key areas of research in domestic and foreign science is related to obtaining and applying new functions embedded in a polymer composition or a structure from it [13] and others.
There are basic provisions for assessing the heat-shielding effect of multilayer shells. Despite the presence of works by domestic and foreign scientists on modeling the heat transfer of a human system in the environment [5,10,14], insufficient attention has been paid to studies of the effect of heat-accumulating components of complex fibrous membranes on human heat transfer [15]. A common drawback of the existing mathematical models "Man-external protective shells-Environment" is their weak link with the specific design solutions in the design. This is due to a very conditionally constructive representation of the model of the body, which in fact, in its sectional shape, approaches closer to more complex geometric shapes [5,9]. Mathematical descriptions of the system, as a rule, consider a person as a source that evenly spreads its heat radiation [14,16]. Moreover, under the conditions of intersection of the heat flux emanating from a person and received by him in confined spaces, occurs concentration of heat. The regime of an uneven

intrinsic level of human heat production leads to new conditions for formalizing problems and mathematical methods for solving them.

Modeling the response of the human body to external thermal influences is a popular tool for understanding its behavior under various environmental conditions and the level of human activity. The task of describing or predicting a person's thermal state is a non-trivial and purely thermophysical task. Modeling directly breaks down into two main sub-tasks: a) external thermodynamic interaction in the "human-environment" system; b) internal heat transfer in the body.

The solution to the first subtask is determined by convective heat transfer from the surface of the human body or its shell to the environment [17,18]. However, when integrating heat storage modules into complex fibrous shells, heat transfer models require development, including detailing of the geometry and heat transfer processes in the areas of intersection of heat fluxes.

3 Theoretical part

In Fig. 2 shows the structure of a heat transfer model with the inclusion of a heat storage module in a fibrous sheath.

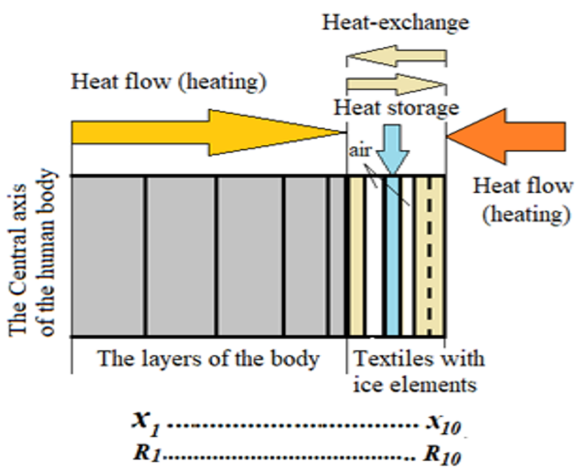

Fig. 2. The structure of a heat transfer model with the inclusion of a heat storage module in a fibrous sheath (A - The layers of the body, B - The textile sheath).

One of the layers of the combined shell has a heat-accumulating effect and is made of water ice. The freezing temperature is justified by biological and technical operating conditions and is -18 °C.

Some layers of the system are simultaneously affected by different heat flows.

Modelling of the heat exchange process in the system was performed for three variants of the geometrical model structure: 1 - without heating layer; 2) heating layer inside the pocket on the garment material; 3) heating layer inside the pocket on the pocket material.

In each layer of the sector of the horizontal section of the system, the heat transfer process is described by an equation of the form (1):

$$\frac{\partial T}{\partial t} = \lambda(x,t)\frac{\partial^2 T}{\partial x^2} + c(x,t)\frac{\partial T}{\partial x} + f(x,t), \tag{1}$$

where x - the distance from the central axis of the human body (Fig. 2), m; t - time, s; T(x,t) - temperature, ºC, in relation to x and t ; f(x,t) - function of the heat source from the central axis of the system.; λ(x,t) и c(x,t) - coefficients for the heat transfer process..
Initial condition:

$$T(x,0)=\varphi(x) \tag{2}$$

For time t=0 the temperature corresponds to the function φ(x). Boundary condition:

$$T(0,t)=\varphi(t) \tag{3}$$

The temperature of the suit can be equal φ(t).
At the next stage, the boundary-value problem is solved by the finite difference method, for which a grid of the following form is introduced [19]:
The scope of the argument x: 0≤x≤l. This segment is broken by dots xi=ih(i=0,1,2,…,N;h>0) on the N equal parts of length h=l/N each. Many points xi called a difference grid on a given segment, the number h - the distance between adjacent points (nodes) is called the grid step.
The scope of the function arguments T(x,t), there are rectangle D={0≤x≤l, 0≤t≤T0}.
In addition to the grid for the variable x a grid is built for the variable t, tj=jt, where j=0,1,2,…,N0 in increments τ=T0 /N0. Many nodes (xi, ti) are a grid in a rectangle D. This grid is uniform in each of the variables x and t.
The result is a six-point pattern.
This system of equations has the following form:

$$A_i y_{i-1} - C_i y_{i+1} + B_i y_{i+1} = -F_i, \qquad 0\langle i\langle N, \tag{4}$$

Fi - given function.
This system of equations was solved by the sweep method [5, 19, 20] .
At the next stage, the problem of heat transfer between the environments through a protective shell with elements of ice is solved.
The ambient temperature is T2 ice temperature is T1.
The problem is considered when three layers of various materials separate the external environment from ice, conventionally presented in Fig.3.

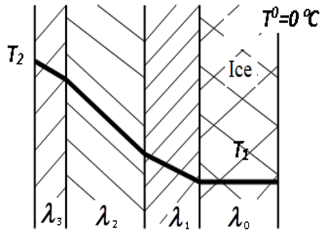

Fig. 3. Heat transfer scheme for the insulating layers of the suit.

For this case, insulating materials with thermal conductivity coefficients were taken λ0, λ1, λ2, λ3, where λ0 - thermal conductivity coefficient of ice. The initial temperatures of ice and three materials are equal T00, T01, T02, T03. The thickness of the ice plate and textile cloths are equal respectively l0, l1, l2, l3. A task of this type can be considered similarly to the previous case.

Here we consider a single site and determine the heat flux through one layer of material per unit time, which is equal to:

$$\Delta Q = \lambda_n \frac{\Delta T^{(n)}}{l_1}, \quad (5)$$

where $\Delta T^{(n)}$- temperature difference at the ends of the material, °C; n - material serial number (n=1...4).

If the process is stationary, then all these values Q will be equal.

For the "man-clothing" section, the temperature field is calculated (the average radii R1...R10 correspond to Fig. 4).

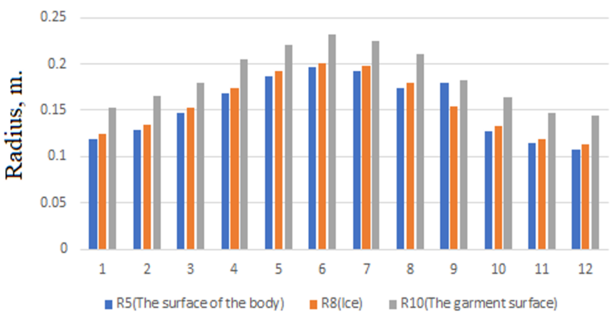

Fig. 4. Radii of the section of the system "man-clothing made of textiles with elements of ice"..

4 Conclusions

The data obtained make it possible to evaluate the heat storage effect in combined cooling shells. The proposed technology for the application of mathematical modeling in the presented problem allows us to create new automation tools for the design and forecasting of biotechnological systems in the development of anti-thermal personal protective equipment from new materials and their combinations.

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