Study the environmental impact on mobile electronics in a heat-protective sewing shell

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Abstract. The environment (Winter cold) affects both the individual and the equipment and communications needed to support workflow or general communication. Therefore, the issue of providing thermal conditions in which the communication device is located while a person stays in the cold is relevant. To protect such devices from premature cooling, they are placed in special parts of clothing. Model-ling and research of thermal insulation properties of garment parts for protection from cold of mobile communication devices will allow to establish effective parameters of thermal insulation structure. Such parameters will allow to develop and manufacture warm clothes with special details, which will maintain the performance and increase the time of stable operation of mobile communication devices necessary for a person in cold conditions. The geometrical model and the model mesh were developed. According to the results of numerical model-ling, the dependence of temperature in the thermal pocket on the ambient temperature was obtained, taking into account the presence or absence of the heating plate. The results of numerical modelling of model calculations al-lowed to theoretically justify by zoning and heating power the system of artificial thermoregulation in thermal protective clothing with integrated electronic devices. Keywords: Modeling of heat transfer, heat-protective clothing, mobile elec-tronics, thermal insulation, textile materials, fibrous materials, artificial heating, clothing design

1 Introduction

Humans are often forced to face cooling effects of the climate. This is related to both professional activities and tourism and recreation. All variants of human activi-ty in cold natural and industrial conditions require the use of warm clothing [1]. It is important to note that modern style and technologies of human life are continuously connected with the use of mobile communication devices [2]. Mobile communication devices include mobile phones and radio communication equipment. Winter cold affects both the individual and the equipment and communications needed to support workflow or general communication [3]. In the harsh conditions of northern countries, mobile communication devices are an important

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way to support human safety and even rescue [4]. The performance of communications in cold conditions is often directly related to the timely provision of emergency assistance to people. Research and development that focuses on the stable operation of batteries for mobile phones and radio communication devices has significantly increased their stability in cold conditions. However, cooling of mobile communication devices, as a rule, leads to a rapid loss of energy reserve in the battery and complete stop of mobile phone operation [5]. Such situations are systematic. They are not only an inconvenience to the individual, but can also lead to accidents if contact with other people who are away is lost. Therefore, the issue of providing thermal conditions in which the communication device is located while a person stays in the cold is relevant [6]. To protect such devices from premature cooling, they are placed in special parts of clothing (protective pockets for phones or radios). Such pockets have special sizes, which should correspond to the size of mobile devices [7]. At the same time, the temperature inside such heat-protective pockets is the main condition for stable operation of communication devices, as each device has limitations for conditions of use at low temperatures [8]. Modelling and research of thermal insulation properties of garment parts for protection from cold of mobile communication devices will allow to establish effective parameters of thermal insulation structure. Such parameters will allow to develop and manufacture warm clothes with special details, which will maintain the performance and increase the time of stable operation of mobile communication devices necessary for a person in cold conditions. State of the art

A large number of scientific papers and engineering projects are devoted to the study of thermal insulation of garments [9-10]. The main task of such research is to identify the effective thermal insulation of the object that is in the shell of textile materials from which the garment is made [11]. However, there is almost no research and development of garments to protect mobile communication devices from cold [12].

Modern technologies for finding effective solutions in thermal insulation of clothing parts rely on methods of mathematical modelling of physical processes [13]. A system that consists of a heat source (electronic device), a set of thermal insulation materials (garment parts) and an external space with low temperature (environment) is considered to protect mobile devices from cold. Such a system has a great similarity with the complex system of modelling the heat exchange of a per-son in clothing (person-clothing-environment) [14]. The analysis of existing meth-ods of modelling thermal processes in clothing has shown that both analytical and numerical methods of modelling are widespread [15]. Modern tasks of modelling thermal processes in textile layers of garments are aimed, as a rule, at describing and estimating the temperature under the garment, which will contact human skin. This is important for assessing the thermal comfort and efficiency of the thermal insula-tion properties of the textile shell [16]. Another part of the models describes thermal processes not only in the layers of clothing, but also in the biological layers of the human body. Similar conditions in modelling the thermal insulation of a person and an electronic device from cold is the general principle.

The authors [16, 17] performed modelling of heat transfer in layers of clothing taking into account a number of factors: radiant heat, convective heat transfer and others. Fibre textile materials were used as materials: fibrous non-woven materials, films with special coatings, barrier fabrics against the wind, fabrics for obtaining a shape. As a result, the main points (temperature distribution in the layers of clothing during external cooling, taking into account the biological heat inside the system) are established.

In paper [16,18], a heat transfer model considering the main points (evaporation, condensation, and wet conduction) is developed and presented.

The analysis of modern models that describe the thermal system "object-clothing-cooling environment" has shown the following:

- numerical methods using geometric models in the form of meshes are effective for rapid analysis and prediction of the object thermal insulation;
- the layers of the system are often considered as a multilayer flat figure, each layer of which has its own geometric and thermophysical characteristics;
- a general assessment of object cooling inside a polymer shell can be made on the basis of the description of linear heat transfer of a flow directed along the normal to a flat layer.

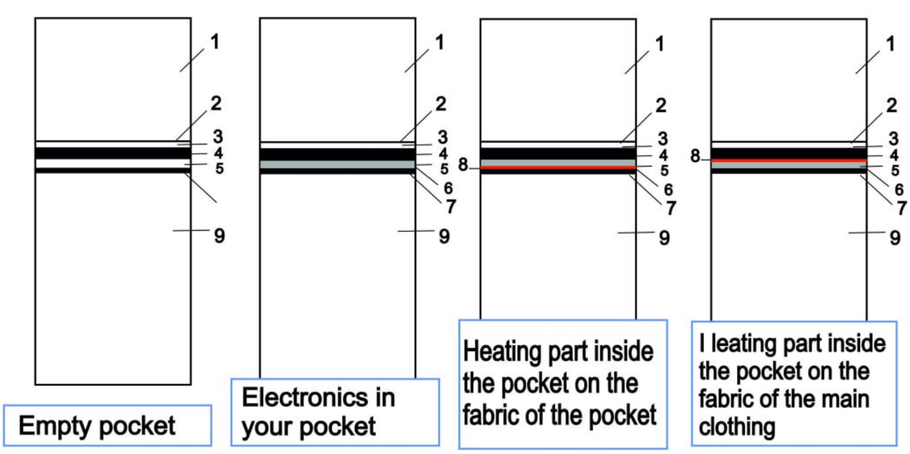
At the same time, no ready models have been found to describe the thermal insulation of mobile devices in a polymer shell, which requires new research.

2 Method, means and object of the study

For effective thermal insulation of mobile communication devices, the principle of additional active heating is the most ergonomic. The reason is that the thickness of the thermal insulation layer made of textile materials cannot be made for a relatively small object (phone or portable radio transmitter). Artificial heating can be provided by relatively thin polymer materials with integrated heating elements. The heating elements can have different variants and designs [19].

In garments for heating objects located inside, special fabrics with embedded conductive threads and fibres that are conductive materials over the entire surface can be used. The functioning of such materials is based on the operation of an embedded carbon or copper thread, which is connected to a power source. All the considered variants of the source of additional heat in the garment part (in particular - in the pocket of warm clothes) can be represented in the form of a flat layer with its own power and other thermophysical properties [20, 21].

Operation of technical equipment in the cold requires its own local thermal protection and saving of direct technical energy resources (batteries). At the same time, communication equipment is itself a source of heat and requires a number of serious requirements to maintain its functionality. The structure of the pocket layers in Fig. 1.



1 - the human body, 2 – underwear, 3 – interior space, 4 – a set of heat-protective clothing materials, 5 – air, 6 – a mobile electronics device, 7 – a set of textile pocket materials, 8 – a heating layer, 9 – a cooling medium

Fig. 1. Layers distribution schemes of the system " Person - heated pocket - cold environment.

At any variant of such materials the sewing part is a heating plate.

In order to simulate the heat transfer processes in the presented system, at the first stage a geometrical model of the heat-protective sewing part was developed, which is based on the parameters of electronic devices. The shape is represented as three rectangular parallelepipeds connected to each other and placed in the centre of a cube. The cube has dimensions that, relative to the dimensions of the communication device, allows the space to be considered as a section of the environment. The geometrical model includes four layers: 1 - air, 2 - polymer heating plate, 3 - layer for isolation of the working surface of the electronic device (screen), made in the form of a silicone transparent plate, 4 - polycarbonate material from which the body of the mobile electronic device is made (placed between the two layers of polymer heating plates).

A silicone plate with heating carbon filaments embedded along the contour is effective as a polymer heating plate in terms of strength and thermophysical properties [22].

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Based on the application of numerical methods of modelling of thermal processes in the combined system, initial data and boundary conditions were developed.

The minimum distance from the heat cover to the boundaries of the system bounded by the calculation grid for the ambient space is 5 metres. The permissible measurement error of the distance from the heat cover to the system boundaries is 0.1 mm. The parameters of the heating system of the cover are based on the technical requirements for the operation and storage of communication equipment.

It is established that the thermal protection pocket in the garment should provide the temperature regime of the internal space from +16ºC to +35ºC (minimum and maximum temperature, respectively). Ambient temperature conditions that are relevant for modelling and evaluation of the presented system: from +5ºC to -45ºC with an interval of 5ºC.

3 Theoretical study

In our problem we applied the model of heat conduction in solids. The simulations were performed in the COMSOL Multiphysics software environment.

In the next step, the geometrical model and the model mesh were developed. Further, for each layer the type of material, its physical parameters were established; the boundary conditions (Dirichlet) were set.

Further, a flat heating source was introduced into the mathematical model. Its power of 5 W was preliminarily calculated. According to the results of numerical modelling, the dependence of temperature in the thermal pocket on the ambient temperature was obtained, taking into account the presence or absence of the heating plate (Fig. 2).

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.

To analyse the results, the temperature interval of the heat shield cover surface, which limits the conditions for stable performance of the electronic means of communication, is marked.

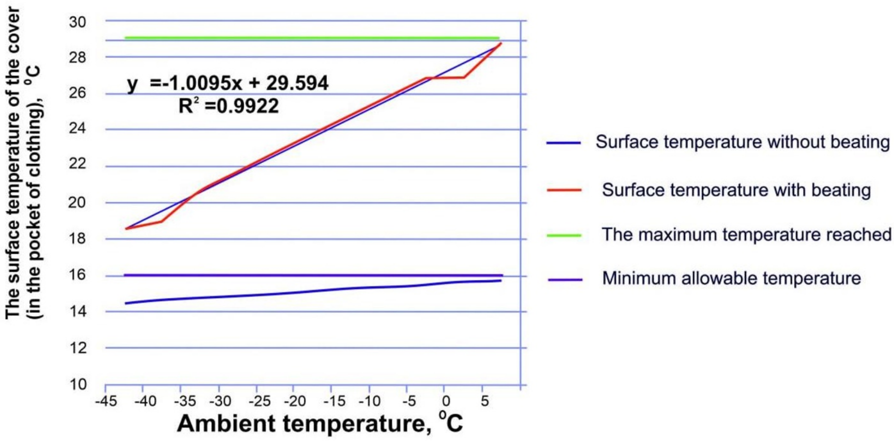

Fig. 2. The dependence of temperature in the thermal pocket on the ambient temperature taking into account the presence or absence of the heating plate.

4 Conclusions

The temperatures under the heated garment, obtained as a result of modelling the thermal system, do not exceed the threshold level of the surface temperature of the heat protective pocket (lower and upper temperature limits). At the same time, the surface temperature of the heat-protective garment pocket without heating was be-low the permissible minimum temperature threshold. This result confirmed that an integrated heating system for the local area of the special pocket detail is essential for maintaining the performance of mobile communication devices.

The structure and thermal parameters of the heat protective garment part that provide the necessary temperature level for the performance of electronic communication devices placed in it have been revealed.

The results of numerical modelling of model calculations allowed to theoretically justify by zoning and heating power the system of artificial thermoregulation in thermal protective clothing with integrated electronic devices

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