Numerical Modelling of Temperature Gradient in Layered Structure of Textiles for Firemen Clothing

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Abstract. This paper presents numerical investigations of textile structures for the production of firemen protective clothing. These structures must ensure both user safety and comfort. The influence of various structure elements, such as the thickness of the air cushion or the Airlock layer construction) on the temperature distribution occurring during the heating of the surface layer up to 300°C was investigated.

INTRODUCTION – FIREMEN CLOTHING STRUCTURE AND RESEARCH AIM

Protective clothing should comprehensively protect against threats, which means protection from the outside as well as from the inside. In a simplified way, protection from the outside is understood as a barrier against the effects of heat in various forms with water, chemical substances, while inside protection is understood as a breathability. During rescue operations firemen are accompanied by stress, rush and increased physical effort. In order not to overheat, body produces heat and sweat. An overly tight material layer can cause dangerous effects. One of them are burns, which are formed due to lack of protection against heat, as a result of soaking up the material directly in contact with the skin. Another dangerous consequence is the stress caused by body overheating. It is caused by a disturbed mechanism of cooling. When it is not possible to discharge the heat released by the body, its quantity increases, raises the temperature, to the extent that in the worst case leads to death due to heat stroke [1].

Since a material having all of the protective properties previously described has not yet been constructed, clothing that has a layered structure has been designed (Fig. 1). It consists of an outer layer, membrane, thermal insulation layer and lining. Each layer is made of a different material and has characteristic features, which in combination are an effective innovative solution with a wide range of protection.

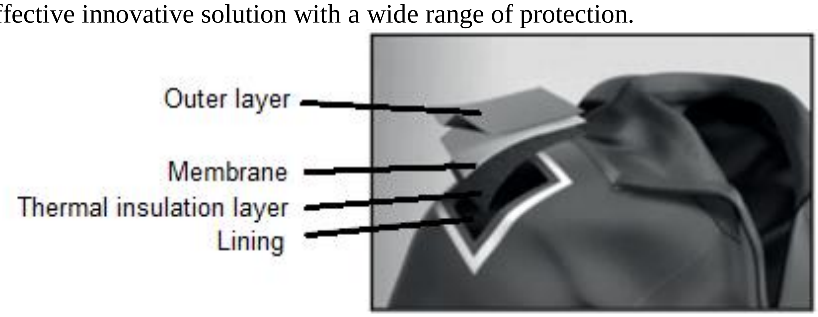

FIGURE 1. Layered structure of firemen clothing [1]

The aim of the work presented in this paper was to analyze the temperature changes (insulation) in the layered structure of textiles used for firemen's clothing.

NUMERICAL MODELLING

Three types of models have been proposed for the implementation of the task (Fig. 2):

- without Airlock layer (domes filled with air in the Gore-Tex laye)r in variants with 1, 2 and 3 mm airbags and with different mesh sizes,
- with prismatic Airlock layer in full and air filled variants,
- with Airlock in the shape of hemispheres in full and air filled variants.

Thermal Isotropic material model from the MSC.Patran-Nastran package was. Heat conduction coefficients for layers were selected according to [2]: Kevlar coated with silicone - 0.080 W/(mK), aramid felt - 500 g/m^3 0.130 W/(mK), Nomex 195 g m^3 - 0.050 W/(mK), - Gore-Tex - 0.071 W/(mK), aramid-viscose 130 g/m^3 - 0.052 W/(mK), air - 0.025 W/(mK).

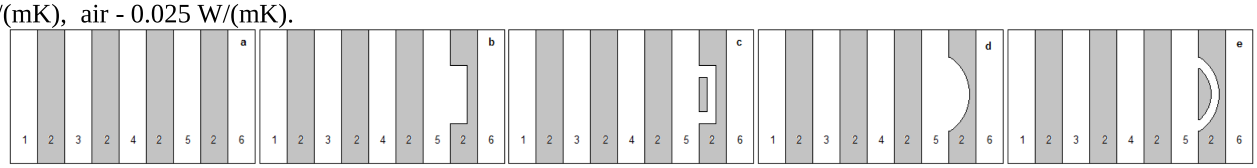

FIGURE 2. Analyzed models: a - without Airlock insert including different air layer thicknesses, b, c, d - models including different types of Airlock inserts; 1 - Kevlar, 2 - Air, 3 - aramid felt, 4 - Nomex, 5 - Gore-Tex, 6 - aramid-viscose

RESULTS AND DISCUSSION

The example of results is shown in Fig. 3 as a comparison of the temperature gradient distribution along the sample for models with different thicknesses of air layers.

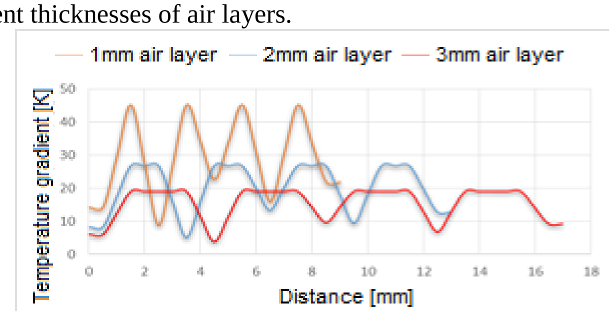

FIGURE 3. Comparison of temperature gradient distribution along the sample for models with different thicknesses of the air layer

On the base of achieved results it can be concluded that the influence of the thickness of the air layer is visible, especially in the case of the temperature gradient test - there is a significant reduction of these gradients and the temperature increases more gradually. The effect of using a shape change in the Gore-Tex element is also visible. It is most advantageous if this element is hemispherical (it does not matter whether it is filled with air or not), then the lowest temperature gradient is obtained near the firefighter's body. One should also note the additional advantage of such a system - it maintains a constant increased layer of air (by supporting it with domes), which gives the possibility of using the positive effect of the layer's width on the temperature gradient, which can and usually is eliminated during firefighter's movements (layers move relative to yourself and may start to touch).

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