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APPLICATION OF COMPUTATIONAL FLUID MECHANICS FOR PROTECTION CLOTH DESIGN

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The aim of this paper is to make the community acquainted with a relative new application area for CFD: design of clothes necessary to protect people from the action of extremly low or high temperatures with and without wind. The task can be classified as a typical problem with thermomechanical coupling of fluids (air or water) and structures (human body and clothes). The body generates the heat within certain organs which is then transferred by the thermal diffusion through the body substance possessing very non uniform properties. A large fraction of the heat generated by internal organs is transported to the body periphery by a complicated net of blood vessels. Penetrating the cloth the heat is transported away from the human by heat conduction in surrounding medium, natural and forced convection, breathing, radiation and transpiration. While a full detailed model of the human thermodynamics is still remaining the problem of the future, the practical design of protection clothes demands the reliable models already now. Such models are necessary to reduce the time and costs consuming measurements and to avoid dangerous experiments with people under emergency conditions.

The paper presents a few CFD models which reflect the evolution of CFD modelling for cloth design done in our research group. Each model is built on previous ones with increase of complexity and accuracy of modelling. The coupled problem of thermomechanical interaction can be subdivided into inner (heat transfer through the body and cloth) and outer (dissipation of heat into surrounding medium) submodels. For some specific purposes they can be decoupled. The interaction is considered by formulation of proper boundary conditions. In the most of modern inner submodels the human body is represented as a set of geometric elements according to the original idea proposed by Stolwijk. The human body is considered as a slender body with heat transfer dominating in horizontal planes neglecting the heat fluxes in the vertical direction. This model was utilized in [1] to design special jackets made of the textile with embedded ice layer

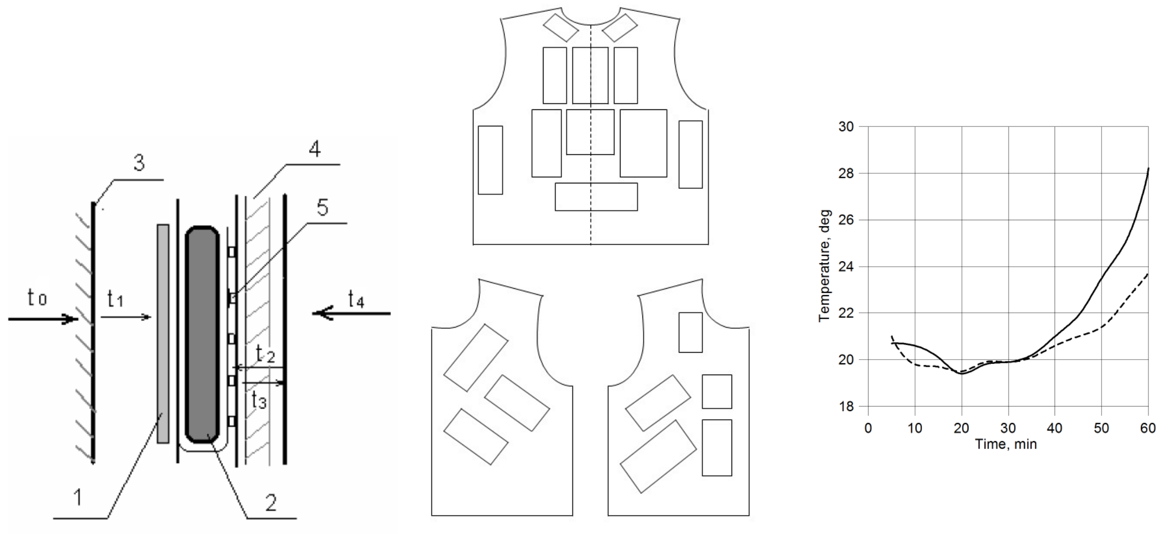

Figure 1: **Left:** Ice protection construction. 1- polyurethane foam, 2- ice briquette, 3- human body, 4- special overheating protection clothes, 5- polyurethane net (air layer). **Centre:** Overheating protection jacket designed on the base of simulations. **Right:** Development of the averaged temperature in the air gap between the underwear and the ice protection on the human chest. Comparison between the measurement (solid line) and the numerical simulations (dotted line).

(Fig. 1, left) to protect the human from the overheating. The heat transfer within each horizontal plane is modelled using a simple sector model. The problem is reduced to the solution of the one dimensional heat conduction equation with certain initial and boundary conditions. The temperature at the outer boundary of cloth was specified. Numerical calculations are performed with the aim to determine the ice layer thickness necessary to keep the temperature of the human body core at the temperature of $36.7^0 \pm 1^0$ within one hour. Results of simulations were utilized to design a special protection clothes for rescue team working in the mining industry (Fig. 1, centre). The experiments with clothes supported the simulation prediction (see Fig.1, right). Further works to be presented during the congress will cover the following topics: 3D OPEN FOAM solution of the outer problem with given distribution of the temperature on the human body aiming at the study of influence of cloth contamination on heat release, implementation in OPEN FOAM of three dimensional model (3D) of heat transfer within the human body, development of conjugate heat transfer model using OPEN FOAM (3D) and Fiala's (1D) model, estimation of the effect of cloth deformation caused by wind on heat conduction inside of cloth and comparison of 3D CFD calculations with wind tunnel measurements performed for human bodies.

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