No Sweat: Modeling Clothing and Fabrics with FLUENT

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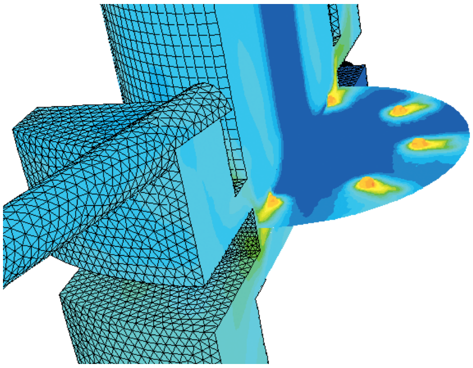
Advances in textile technology are expanding the performance boundaries for clothing and technical fabrics. Outdoor and athletic clothing provide weather and thermal protection and manage moisture. Protective clothing controls the exposure of laboratory and hazardous materials workers, heathcare providers, fire fighters, and military personnel to chemicals, biological materials, and heat sources. Depending on the specific application, characteristics such as impermeability to hazardous materials, breathability, rapid moisture transport, insulation value, weight, cost, and ruggedness must be balanced to deliver comfort and performance. Recent innovations now enable CFD to play a significant role in the development of technical fabrics and clothing systems.

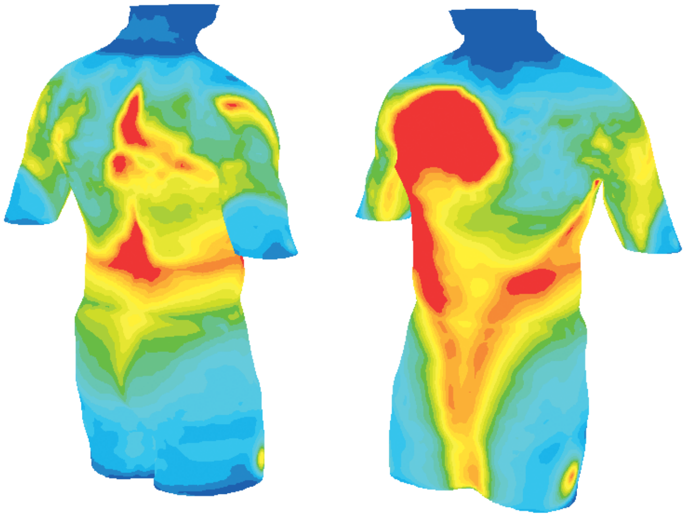
In clothing development, a macroscopic CFD approach has been used that looks at the interactions of the fabric with the body and its surrounding environment. From this macroscopic perspective, each fabric layer is treated as a porous medium with spatial- and time-varying properties. Multiple fabric layers and air gaps between layers can be addressed. Microscopic analyses of fabrics – where individual fibers are modeled – form a separate area for CFD applications. FLUENT's porous media model provides a starting point for the fabric model, and substantial new capabilities for transport processes in the fabrics can be incorporated via user-defined functions (UDFs).

Important transport processes in textile fabrics include the convection and diffusion of vapor and liquid, as well as the adsorption and desorption of fluids from solid fibers. Using UDFs, engineers at Creare have implemented models for variable permeability (dependent on local moisture content in the fibers and liquid blockage), condensation/evaporation in the fabric, vapor/liquid sorption to fibers, and capillary transport of free liquid. A special sorption model has also been developed for fabrics incorporating activated carbon. Using the extensibility built into FLUENT's graphical user interface, the setup of the properties and modeling options for the fabric zones has been automated. In addition, visualization capabilities have been customized using FLUENT's standard tools.

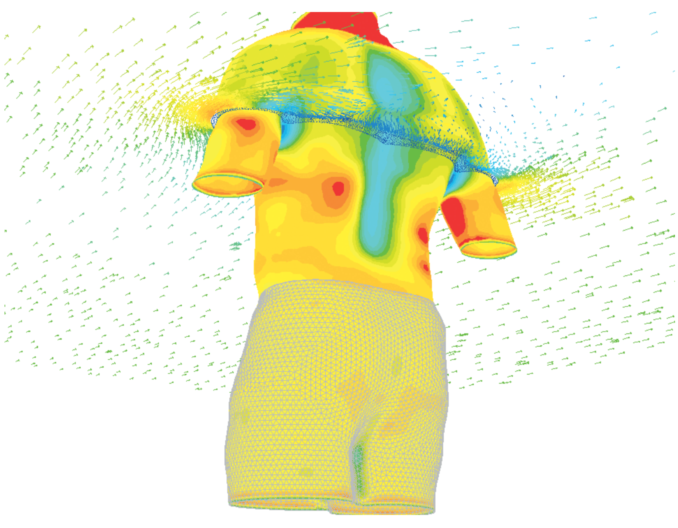
Applications of the textile fabric models include predicting the penetration of chemical agents through protective materials. Protective fabrics often are tested as swatches in small, enclosed cells. The CFD models of the swatch tests not only provide detailed insights into the transport processes within the fabric, but enable a better understanding of the effects of convective flow above the swatch on test results. To predict the performance of protective fabrics on humans, simplified 2D models of clothed body sections and more complex 3D models have been developed. Starting from laser body scan data, a combination of computer-aided design software and GAMBIT has been used to create a meshed model of a human with one or more layers of clothing. For both protective and outdoor clothing, thermal comfort is a critical factor. A sweating "skin" model has also been implemented in FLUENT using UDFs. Using 3D models of clothed humans, the effects of varying fabric properties, weather conditions (including temperature, wind, and humidity), metabolic output, and clothing ventilation features have been assessed. ■



Circular pattern of chemical agent droplets on a fabric swatch in a test cell



Humidity levels under ventilated single-layer clothing; the clothing fit is not symmetrical on the body



Clothed human model shows contours of sweat evaporation, assisted by a slight headwind