

Overview of Flow through Textile and Fabrics

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An overview of single and multiphase flows through woven and nonwoven fibrous materials is presented. A computational model for analyzing fluid flow through such media is described and sample computational results are presented. It is shown that by generating virtual geometries that resemble the microstructure of a fibrous material one can study the fluid and particle transport through such porous media and compute their permeability and particle capture efficiency. As an example, the modeling strategy developed for evaluating the pressure drop and nano-particle collection efficiency of light-weight nonwoven air filter medium is described in details. Comparison of the results of the micro-scale modeling with the existing analytical models as well as the experimental data in the literature is also presented. Earlier studies on modeling permeability of multi- and mono-filament woven fabrics are also reviewed.

Particular attention is given to application of the computational modelling approach to development of protective clothing for different applications. Motion of a drop through a fabric due to a wettability gradient is described. The wettability gradient is typically introduced by varying the contact angle along the staggered fibers of a fabric. The computational model for solving unsteady gas-liquid laminar flow a fixed Eulerian unstructured grid is described. The Volume of Fluid Model (VOF) is used to account for tracking the gas-liquid interface. The motion of a water drop with a given initial velocity through the fabric is studied. Several sample computer simulations results under different conditions for different fiber concentrations, contact angle distribution, and drop initial velocity are presented. In order to verify the accuracy of the computational model, the motion of a drop on a surface due to a wettability gradient is simulated as a benchmark and compared with experimental data.

Flow modelling/transport in random, woven or stitched fibre mats used as reinforcement in the manufacture of polymer composites

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Liquid Composite Molding (LCM) processes that include processes such as Resin Transfer Molding (RTM), Reaction Injection Molding and Vacuum-Assisted RTM, have been steadily gaining popularity as convenient, low-pressure and cost effective methods for manufacturing net-shaped polymer composites parts by combining a thermosetting polymer with fibrous reinforcements. In LCM, a porous preform made from the fiber mats is packed into a mold and a liquid resin of Newtonian nature is injected or sucked from one or several ports. Several software such as Moldflow that simulate the LCM mold-filling process to optimize mold design depend on accurate flow physics to generate a reliable simulation. This talk will describe several aspects of flow science devoted to process modeling of LCM processes. Basic concept of treating the mold-filling as a quasi-steady, moving boundary problem, where the porous fiber-mat behind the resin front is assumed to be completely saturated, will be presented. A detailed description will be devoted to the experimental and theoretical estimation of permeability tensor for the anisotropic fibrous porous media. Science for modeling the wetting of fibrous porous media through capillary suction will also be described.

In the last few years, it has been acknowledged that certain fiber mats that are woven or stitched like a cloth from fiber bundles display the unsaturated flow that is characterized by partial saturation of fiber mat behind the moving resin front in an LCM mold. This presentation will also describe how the conventional theories of two-phase flow have been unsuccessful in modeling the unsaturated flow which is characterized not only by partial saturation and air bubbles behind the front, but also by a drooping inlet-pressure history. A synopsis of recent theoretical, numerical and experimental work done to model the unsaturated flow will be presented. The talk will conclude with outlining the great scientific challenge of modeling both the flow variables as well as void migration during mold-filling in LCM.

Flow and transport in porous media: modelling and simulation- Water management in polymer electrolyte membranes fuel cells

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The development of alternative power sources/supplies is an important task nowadays. Polymer electrolyte membrane (PEM) fuel-cells currently are intensively investigated and improved for applications. This requires a profound understanding of the physical and electrochemical processes occurring in fuel cells. It has been found that the kinetics of the oxygen reduction at the cathode is a limiting factor for the performance of fuel-cells. The transport of oxygen to the cathode through its porous diffusion layer takes place in a predominantly diffusive manner. The generation of liquid water at the cathode-site limits this oxygen transport to the reaction layer. A crucial issue here is the wettability of the porous media. The material might consist, for example, of a carbon fibre structure hydrophobized with Teflon. Hydrophobic properties enhance the removal of the generated liquid water. However, it has been observed that, under operating conditions, at least parts of the diffusion layer become hydrophilic and retain liquid water in high residual saturations. Thus, an efficient water management in the cathode diffusion layer is necessary to improve the performance of the fuel-cell.

Multiphase multicomponent models originally developed at our working group for the simulation of non-isothermal multiphase processes in the subsurface are applied for modelling the diffusion layer of PEM fuel-cells. However, this is in an early stage. So far we have simulated processes occurring in the diffusive layer. Further research is necessary e.g. to understand the complex wettability behaviour.

The aim of this presentation is to discuss the physical and numerical model concept, the assumptions that are necessary and with numerical results the possibilities and restrictions.