Lattice Boltzmann simulation of coalescence filtration through non-woven fibrous media

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Fibrous porous media are relevant for many industrial products including filters, membranes, and biomedical implants. One particular application is the sequestration of water droplets from diesel within fibrous filters. The efficiency of this process has a significant impact on the performance and lifetime of diesel engines. Despite the importance, there is only scarce research on the fundamental mechanisms of droplet coalescence in fibrous media. This is largely due to the complex kinetics of coalescence behavior and the intricate dependence on geometrical parameters and surface properties. Computer simulations are a cost-effective way of validating semi-empirical relations and predicting the precise relations between macroscopic transport properties and microscopic pore structure. Such predictive computations promise to accelerate the design of improved filters while at the same time reducing the development costs.

In the current work, we use lattice Boltzmann methods to investigate the structure-property relations of non-woven fibrous membranes and perform simulations of droplets interacting with fibers. We study the impact of the wetting behavior on the spreading and retention of liquid on the fiber surface. Results for a droplet interacting with two parallel fibers reveal a morphology transition that depends on the capillary pressure and the inter-fiber distance. The simulation results show agreement with analytical and experimental results, which indicates that the steady-state capillary pressure in fibrous media is correctly recovered. We anticipate that the simulation framework will be used to simulate droplet coalescence in complex geometries and the resulting data will aid in designing advanced filtration devices.

Keywords: LBM, fibrous media, permeability, wetting.