Simulation of Cabin Air Filters - Molecular Dynamics vs. Continuum Approach

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ABSTRACT

Cabin air filters are applied to prevent small particles such as pollen, fine dust and soot amongst others from being transferred into the interior (cabin) of a vehicle. Typically such a cabin air filter contains a synthetic non-woven layer, consisting of a network of fibers with different diameters in order to collect aerosol particles via mechanical separation effects (such as inertia, diffusion…). An additional electrostatic filtration effect allows for higher filtration efficiencies compared to common cabin air filters. As a consequence of continuously increasing requirements on the filtration efficiency while at the same time differential pressure shall be decreased (directly linked to energy consumption), the application of electrostatic charge to the polymer fibers became a promising research subject. Despite ongoing research for years (e.g. [1]), these effects still impose a challenge for modeling filtration in 3D fibrous media structures.

This work compares two modeling approaches for the simulation of particle separation with different degrees of complexity. On the one hand a new and basic approach to simulate filtration performance is developed using the molecular dynamic software package ESPResSo [3]. Molecular modeling makes it possible to describe the collection process very precisely on the microscale level. However, the complex calculations entail high computational costs. On the other hand the continuum mechanics software GeoDict is introduced. GeoDict is a well-established tool regarding the simulation of filtration processes. In contrast to ESPResSo GeoDict takes advantage of some strongly simplifying assumptions, such as disregarding the long-range interactions between charged dust particles in the air flow [4]. Following a standard approach in air filtration, a single fiber in a periodic cell is used in the first instance. Based on this model collection efficiency simulations of ESPResSo are cross-checked against the results of GeoDict for given boundary conditions. The methodologies will be evaluated in terms of accuracy and computational effort. Challenges, limitations and benefits of the two different modeling approaches for electret filter media will be discussed.

References

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