

Dissertation title:

Modeling and Simulation of Cabin Air Filtration with Focus on Electrostatic Effects

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Cabin air filters serve to remove harmful pollutants from the air flow supplied to the car passenger compartment. Electrostatic charges on cabin air filter media significantly improve the degree of particle separation without compromising the air permeability, thus achieving superior filtration performance. In order to optimize the performance metrics, a basic understanding of electrostatic filtration effects is required. However, these effects are largely unexplored due to limited experimental measurement options.

Numerical simulations allow a deeper insight into fundamental physical processes than the measurement of macroscopic quantities. However, the unidirectionally coupled status quo simulation approach leads to results deviating from experimental observations for electrostatically charged systems. Numerous unknown parameters such as the charge distribution on filter fibers and dust particles and the lacking implementation of all simultaneously effective electrostatic separation mechanisms cause these differences.

This dissertation provides an enhanced fully-coupled modeling approach to simulate specific electrostatic filtration effects. The new simulation model includes the interaction of highly bipolar charged dust particles with each other, with filter fibers, and with the background air flow. Extensive studies demonstrate the necessity of this high level of detail in order to dissolve electrostatic agglomeration effects in the inflow area. In addition, combined numerical and experimental test scenarios provide qualitative results allowing to observe the effect of induced dipoles and mirror charges. A combination of the fully-coupled modeling approach with the status quo simulation method in a two-step procedure is highly recommended for further research studies.