American Filtration & Separations Society - 2010 Annual Conference

METHODS FOR SIMULATION OF FLUID FLOW AND PARTICLE DEPOSITION IN VIRTUALLY GENERATED NONWOVEN STRUCTURES

T. Warth and M. Piesche

University of Stuttgart, Institute of Mechanical Process Engineering

Böblinger Straße 72, D-70199 Stuttgart, Germany

Phone: (0049) 711 685-85209, Fax: (0049) 711 685-85390, Email: warth@imvt.uni-stuttgart.de

Due to the highly stochastic character of nonwoven filter media and the resulting complex flow field, the examination of a representative cutout of an assembly of randomly arranged fibers is necessary for the prediction of the properties of nonwoven filter media – in particular filter efficiency and pressure drop. Especially when the relevant particle sizes are comparable to the pore sizes of the nonwovens and hence the filtration is dominated by inertia effects, the knowledge of the flow field and a reproduction of the pore size distribution within the nonwoven are required. But the flow field has an influence on particle capture for smaller particles as well, even when Brownian motion is the dominant filtration mechanism.

There are various options to generate the geometric structure of a nonwoven. Time-consuming methods like CT-scanning or Digital Volumetric Imaging (DVI) are capable to convert the real stochastic structure into a simulation domain. Alternatively, the model geometry can be generated through random algorithms [2, 3], which allow fast replication of nonwovens based on geometric properties like porosity, fiber diameter and the thickness of the media. Using a structure generator, the influences of single geometric parameters of the nonwoven structure on the flow field, the pressure drop and the filter rating can be detected.

Model validation was previously done on the basis of a woven square mesh filter medium (Figure 1) comparing the Lattice-Boltzmann Method (LBM) with the Finite Volume Method (FVM) as well as measurements for pressure drop. The LBM simulation was tested then regarding the grid dependency of flow simulation results and influences of the stochastic parameters for the generation of nonwoven structures.

We replicated different nonwoven filter media based on the geometric properties of real metal fiber nonwovens using the structure generator implemented in GeoDict™ to get the simulation domain for the numerical investigations. The generated nonwoven structures were then used to compare the simulation of air flow at Reynolds Numbers between 0.5 and 10 using the LBM with pressure drop measurements (Figure 2).

For the simulation of the particle deposition a Lagrangian formulation implemented in the GeoDict™ code [1] is used. The results of these calculations were again compared to the corresponding measurements of the separation efficiency of the metal fiber nonwovens at our developed test rig for filter testing.

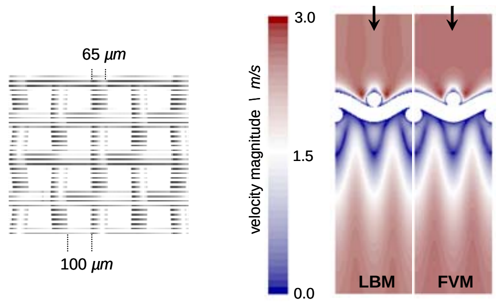

Fig. 1: Left: square mesh dimensions; right: comparison of simulated flow fields using LBM respective FVM

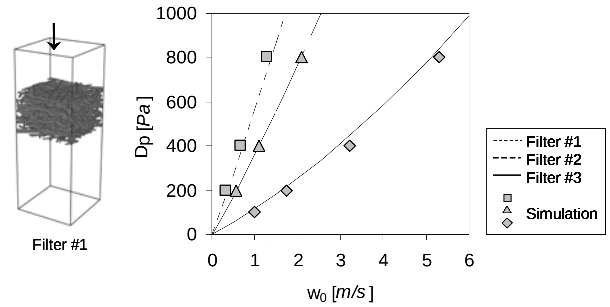

Fig. 2: Comparison of simulation results (LBM) of generated nonwovens and pressure drop measurements

References

[1] A. Latz and A. Wiegmann, "Simulation of fluid particle separation in realistic three dimensional fiber structures", Filtech Europa, Düsseldorf, Germany (2003)
[2] A. Wiegmann, S. Rief and A. Latz, "Computer Models of Nonwoven Geometry and Filtration Simulation", International Nonwoven Technical Conference, Houston, Texas (2006)
[3] Q. Wang, B. Maze, H. Vahedi Tafreshi, B. Pourdeyhimi, "Simulating through-plane permeability of fibrous materials with different fiber lengths", Modeling and Simulation in Materials Science and Engineering, 15 (2007), pp. 855-868

BIOGRAPHY, SHORT SKETCH

Tobias Warth
Institute of Mechanical Process Engineering, University of Stuttgart, Germany
Böblinger Str. 72
70199 Stuttgart
Germany
+49(0)711 68585 398
warth@imvt.uni-stuttgart.de

Bio

Tobias Warth, born in 1981 started his studies of environmental engineering at the University of Stuttgart in 2001 and graduated after a stay abroad in India with a diploma degree. Since 2007 he is working as a research assistant at the Institute of Mechanical Process Engineering at the University of Stuttgart on the field of filtration