

# Filtration simulation on the nano scale – the influence of slip flow

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## Abstract

Nano fibers in filter media have become increasingly interesting for filtration applications. The benefit of using nano fibers is the improvement with respect to filter efficiency and the relatively low pressure drop due to the nano slip. The cost of nano fibers and slow down in production process when using them leads to the desire to use as few nano fibers as possible. We treat such optimization issues by simulating filter media and filtration processes resolving the smallest scale. When considering the nano regime, two problems arise: The scales of the nano fibers and filter media thickness are very far apart, and the models for fluid flow and particle movement have to be extended by new physical effects like slip flow. The presentation gives an overview on the latest developments concerning nano filtration in Fraunhofer ITWMs software suite GeoDict / FilterDict.

**Keywords.** Slip Flow – nano fibers – nano particles.

## INTRODUCTION

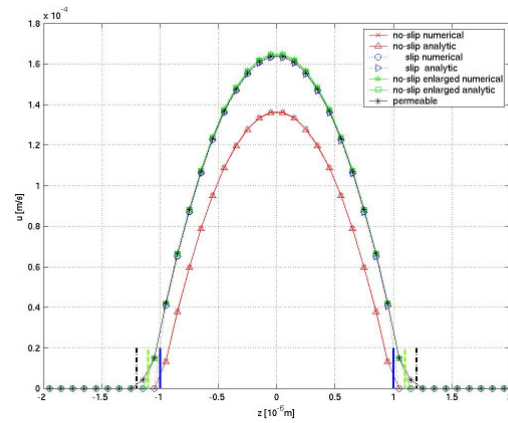
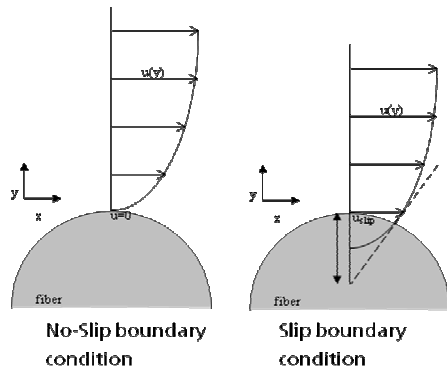
It is observed by many authors and in many applications that the use of small amounts of nano fibers improves the filter efficiency with low penalty in pressure drop. It is the goal of our work to better understand, simulate and quantify these effects by using three-dimensional computer models of fibrous filter media and computing the fluid flow and particle deposition in them.

## METHODS

Previous work on creating realistic models of fibrous filter media [1, 2], the simulation of the fluid flow therein [1, 4] and the deposition of particles based on the computation of the fluid flow [1, 3], friction of particles with the ambient fluid and collisions of the particles with the fibers [1, 3] is currently extended from the regime of micrometers to that of nanometers [3, 5]. The fiber generation is random and matches the porosity, fiber shape, fiber orientation and ultimately, pressure drop characteristics of the media. The latter happens by solving the Stokes or Stokes-Brinkman equations in the fully resolved filter media. Due to the choice of computational grid as voxelized image, the slip-flow boundary condition could not previously be implemented in a satisfactory fashion. The new Ansatz is to use equivalent shrunk fibers and equivalent permeable fibers to overcome these limitations of limited tangential direction resolution on voxelized grids.

## RESULTS

The left illustration shows, why the pressure drop is lower for slip flow than for no-slip boundary conditions for the same mean velocity. The tangential component of the velocity on the fiber surface is simply higher. For the case of two infinite parallel plates, all three methods under consideration, a) the direct implementation of slip flow, b) the use of equivalent shrunk fibers and c) the use of equivalent permeable fibers create velocity profiles that agree with the analytic solution (the so-called Poiseuille profile for no-slip flow and a similar solution for slip flow, seen in the figure below on the right). Due to a different location of the stream lines, slip flow also explains why particles will deposit more than for no-slip conditions both for smallest particles that deposit due to Brownian diffusion but and also larger particles that are intercepted. The talk will present the simulation results for realistic three-dimensional fiber webs and include comparisons with measurements both for the pressure drop and filter efficiency of filter media with nano fibers along the lines as presented recently in Chemnitz [6].



## CONCLUSION

Slip flow around nano fibers leads to a lower pressure drop and higher filter efficiency than would be achieved by no-slip conditions on the fiber surfaces. Computer simulations confirm, explain and quantify these effects and permit the virtual design of filter materials for specific applications.

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