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Focus on IFA's work

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Modelling and simulation of the filtration of ultrafine particles

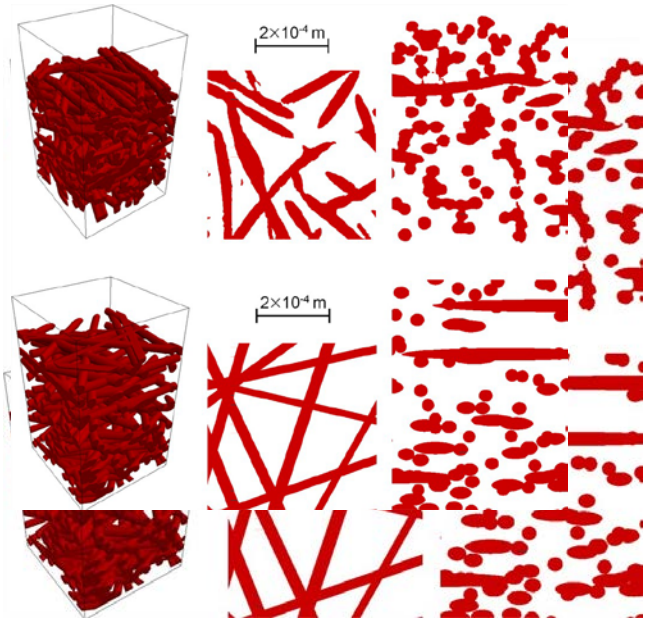
Problem

As in many other areas of process engineering, a desire exists for the deep-bed filtration of particles to be analysed in accordance with scientific and engineering principles sufficiently well for it to be modelled mathematically. In the case of air filtration, modelling may pursue the following objectives:

- Rapid and cost-efficient development of optimized filter media
- Design of filters and their adaptation to the separation problem in question
- Optimization of filtration, for example in conjunction with life-cycle modelling

Numerous deep-bed filtration models formulated mathematically and with physically based reasoning are described in the literature. However, they are all based upon simplified assumptions, and permit adequate estimation of the real-case processes only within certain constraints.

In a large proportion of the models, the filtration mechanisms are based upon a single fibre of the filter medium and its extrapolation to a filter surface with reference to averaged parameters of the filter medium structure; the actual structure of the filter medium and the complex flow occurring within it are not considered.



3D models of the tomography (top left) and the generated filter medium (bottom left), plan view (centre), side view (right)

For many applications, optimized deep-bed filters are available that have been adapted empirically to the relevant application over a number of years.

Activities

For preliminary evaluation of the filtration efficacy of filter media, reference can be made to the parameters declared by the manufacturer. These include the material, porosity, mass per unit area, layer thickness, fibre fineness, fibre diameter distribution, and air permeability at a defined test pressure. Determination of the fractional efficiency levels requires resource-intensive experimental studies.

Estimation is however also possible by means of a phenomenological analysis approach based upon empirical equations in consideration of the stated filter medium parameters or by numerical simulation. The filtration of low concentrations of ultrafine particles on microstructured media was studied and a range of different filter media were evaluated in the first instance with regard to their overall separation and fractional efficiency levels. A number of methods for determining the fractional efficiency levels were presented in detail and compared for a typical filter medium: measurement by scanning mobility particle sizer (SMPS), empirical methods, and 3D simulations.

Results and Application

Direct comparison of the results of measurements and simulations revealed close correlation for the filter medium studied. Should these results be confirmed for further filter media, the use of 3D simulations will substantially improve and facilitate the manufacture and selection of suitable filter media.

Area of Application

Companies and individuals manufacturing or using filter media; Statutory Accident Insurance Institutions

Additional Information

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Expert Assistance

IFA, Division 3: Hazardous Substances: handling – protective measures

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