Application of Brownian dynamics approach to evaluate a fibrous filter efficiency

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Brownian dynamics (BD) is a method where the collection efficiency is calculated considering simultaneously different forces acting on the particle during its motion in a fiber vicinity. At the same time the following forces can be taken into consideration: drag and resistance force, stochastic Brownian force, and external forces (gravitational force, van der Waals force, electrostatic force, etc.). This approach can be used instead of the classical single fiber (SF) theory, which is commonly utilized, but it does not take into consideration the interactions between various mechanisms. The aim of this work is to present the usefulness of the BD method for theoretical estimation of aerosol filtration efficiencies in fibrous filters. We performed the calculations for spherical particles and fractal-like aggregates. The values of the filter efficiency determined utilizing the BD approach have been compared with the experimental data or the values obtained using the SF theory.

In Fig. 1 the experimental data for a HEPA filter, Gougeon et al (1996), are compared with the filter efficiencies determined using the BD approach and the SF theory. It can be observed that the values obtained using the former method are much closer to the experimental data in a wide range of particle sizes. The SF theory is in a good agreement with the experimental values for diffusional and deterministic ranges, but in the transition regime it significantly underestimates the measured efficiency.

Moreover, for the first ever time the BD approach was used to determine the particles’ deposition efficiencies on bipolarly charged fibers. Fig. 3 shows a comparison of the experimental data obtained for an electret filter and the results of calculations carried out using the BD approach. As can be seen, a quite good agreement was obtained for the fiber charge density between 1.2 and 1.3 nC/m.

The results presented here indicate that the Brownian dynamics is a powerful tool, enabling one a more accurate evaluation of a filter efficiency than the commonly used classical single fiber theory.