EFECT OF MESOSCALE INHOMOGENEITY ON FIBROUS FILTER PERFORMANCE – CFD INVESTIGATION
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Aerosol particles are present in many industrial processes. Aerosol filtration in fibrous filters is one of the principal methods of accurate removal of particulate matter from stream of gas. During the past fifty years, many researchers have investigated the filtration process using “classical theory” of filtration: (Davies, 1973), (Brown, 1993) The “classical theory” of depth filtration of aerosol particles in fibrous structures based on the assumption of existing single fiber efficiency, \( E \), which may be used to recalculation of overall efficiency of entire filter, according to well-known formula:

\[
P = \exp\left(-\lambda L \right)
\]

where: \( P \) is penetration of aerosol particles through a filter, \( L \) is filter thickness and \( \lambda \) is filter coefficient, related to the single fiber efficiency, \( E \), as:

\[
\lambda = \frac{4E}{\pi d_f} \left(\frac{1-\varepsilon}{\varepsilon}\right)
\]

where: \( d_f \) is the fiber diameter and \( \varepsilon \) denotes the fiber porosity. The single fiber efficiency \( E \) is defined as a ratio of the flux of particles depositing onto one fiber to the flux of particles passing a surface being the projection of the fiber on to a plane perpendicular to the direction of the mean gas motion. Deposition of the aerosol particles on fibrous surface may occur due to different mechanisms, which may be divided into two groups: deterministic mechanisms (inertial impaction, sedimentation, electrostatic forces, interception), \( E_{\text{det}} \), an stochastic one (Brownian diffusion), \( E_{\text{diff}} \). Taking into account assumption of independent action of deterministic and stochastic deposition mechanisms, the overall deposition efficiency of the filter may be calculated as follows:

\[
E = 1 - \left(1 - E_{\text{det}}\right)\left(1 - E_{\text{diff}}\right)
\]

Using “classical theory” of filtration one may introduce some errors. There are several reasons for inappropriate estimation of the single fiber efficiency: i) neglecting of short-range interactions, ii) separation of the inertial and Brownian effects, ii) perfect adhesion of the particles to the fiber, iv) assumption of perfect mixing of aerosol particles in the gas stream, v) assumption of negligible effect of the presence of neighboring fibers and vi) assumption of perpendicular orientation of the homogenous fibers in the filtration structure. The aim of this work is to investigate influence of mesoscale inhomogeneity on fibrous filters performance using CFD calculations in models of filters differ by internal structure (Figure 1).

Obtained results show that for structures with small porosity there are optimal value of “randomness” of internal structure, which guarantee high value of aerosol deposition. (Figure 2)

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Figure 1. Different filtration structures a) regular, b) random;

Figure 2. Deposition as a function of particle diameter for two different porosities of the filter structure;