

Numerical Simulation of the Motion of Aerosol Particles in Open Cell Foam Materials¹

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Abstract—The motion of aerosol particles in open cell foam material is studied. The porous medium is investigated for a three-dimensional case with detailed simulation of cellular structures within an ordered geometry. Numerical calculations of the motion of particles and their deposition due to inertial and gravitational mechanisms are performed. Deposition efficiency curves for a broad range of particle sizes are constructed. The effect deposition mechanisms have on the efficiency of the porous material as a filter is analyzed.

Keywords: open cell foam material, numerical simulation, aerosol, particles deposition, efficiency

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INTRODUCTION

Open cell foam materials are media that combine high porosities of up to 97%, high permeabilities, and developed adjustable surfaces. Low differential pressures and high mechanical strengths due to the fractions of open pores and skeleton structures are the main characteristic of porous media. Open cell foams therefore find a large number of technical applications: they can serve as heat- and mass-transfer accelerators, separators of gas–vapor media, catalyst carriers, and so on. In Russia, Antsiferov's studies of open cell foams from the viewpoint of the catalysis problems are noteworthy [1].

The use of porous materials in air filtration and personal protective equipment are specific cases of their practical applications [2, 3]. The deposition of submicrometer-size aerosol particles in ceramic, synthetic, and metallic open cell foam materials is a separate field of the filtration of aerosols in a porous medium because of their more complex porous structure when compared to fibrous filters [4, 5].

The penetration of aerosol particles through a porous medium in the form of a polyurethane cellular material was studied experimentally in [6]. The study was performed with the aim of correctly choosing the sizes of a porous cellular material for different types of existing samplers. However, it showed that a thin cellular material in samplers does not adequately detain particles. The work's authors concluded that the use of

porous cellular materials for capturing particles had not yet been fully investigated and is still possible at certain parameters of a porous medium (e.g., thickness, and the size and location of cells). By increasing the particles' area of adhesion, considerable advantages can be achieved in using porous cellular materials, rather than fibrous materials.

In [6], a series of experiments was performed on the penetration of particles through a porous cellular medium with variation of its pore size and the lengths of the porous area. An existing semiempirical model with a particular fiber thickness and diameter was corrected using the obtained data. The model considered inertial, gravitational, and diffusion deposition.

Experimental studies on the filtration efficiency of porous cellular media used for protection from monodisperse aerosols were described in [7]. It was shown that the deposition efficiency curves obtained experimentally were in good agreement with the theory of gravitational settling for low velocities of an incident flow and close to the theory of inertial precipitation for high flow velocities. The problems of aerosol formation create an upper limit for the size of particles that can be used in an experiment. The behavior of much larger particles was studied using polydisperse dust particles. The capture efficiency curve for monodisperse particles lies much higher than for monodisperse aerosols but is generally in good agreement with a simple model of capturing particles at high levels of inertia.

Increased computational capacity allows us to numerically simulate in detail the motion of a gas and

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