Mathematical study of penetration efficiency of aerosol particles for human breathing with protective facemask

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The results of numerical investigations of penetration efficiencies of aerosol particles through a protection field and through faceseal leakage for human breathing with protective facemasks are presented.

Filtering facepiece particulate facemasks are widely used to reduce inhalation exposure to airborne particles that may be associated with negative health effects. The protection level of facemasks is defined by the percentage of ambient particles penetrating inside the protection device. In a real situation, there are two ways of particle penetration: the expected way through a facemask porous medium and through the faceseal leakage. It is impossible to provide zero size of faceseal leakage for real facemasks. Due to large aerodynamic drag of porous medium the air and particles will move to the faceseal leakage. The experimental studies of two particle pathways showed that the penetration efficiency of the faceseal leakage can be considerable (Grinshpun, 2009). It means that the use of these protection devices will not provide the needed level of protection from airborne particles of infectious nature.

As a human head model an idealized spherical body with suction through a circular orifice is taken. It was shown in previous investigations than the human inhalation fraction can be described by the aspiration efficiency of an idealized spherical sampler. A thin porous layer is located before the suction orifice to simulate the facemask. The mathematical model includes the fluid flow and particle motion equations. To describe the air flow through the facemask the porous medium model is applied within the porous layer. The equations are numerically solved by a CFD code, FLUENT. The trajectories of aerosol particles are calculated in the found velocity field.

The example of particle trajectories with a diameter of 20 μm near the facemask before the suction orifice of a spherical body is shown in fig.1. Some particles penetrate through the faceseal leakage. The dependence of the ratio *P* of particle flux through leakage to particle flux to protective mask on diameter of particle at various permeabilities *k* is shown in fig.2. Depending on the permeability of the porous layer and the leakage size the part of particles that penetrates through leakage can be considerable.

The parametrical studies of the dependencies of the penetration efficiencies as a function of permeability of the protection device, particle size, faceseal leakage size and wind velocity are made. The mathematical model and the obtained results can be used in optimization of the geometrical and physical properties of facemasks to eliminate or minimize the particle penetration outside the protection field.

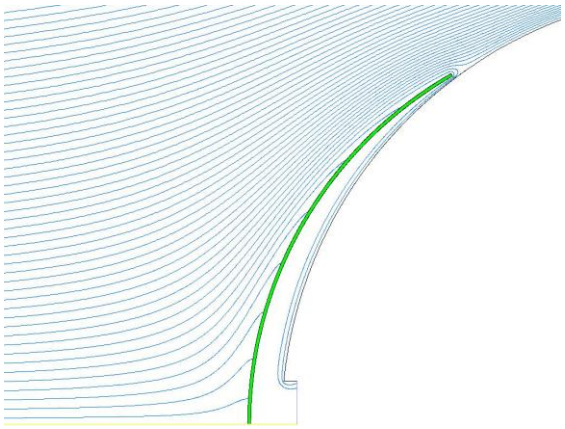

Fig.1. The trajectories of aerosol particles

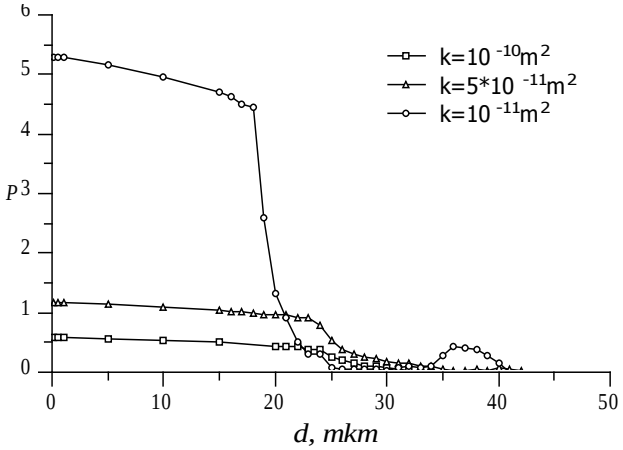

Fig.2. *P* is a particle diameter function

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REFERENCES

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