Dependence of the filter efficiency on nanoparticle velocity and shape

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The filtration efficiency of fibrous filters may decrease because of particle bounce from the fibers (Ellenbecker et al, 1980). Boskovic et al. (2008) showed the influence of the face velocity on the filtration efficiency for three types of particles of different shape (PSL, NaCl and MgO), at the velocity of 5cm/s, the shape of the particles plays a significant role, but for the velocity of 10 and 20 cm/s, the effect of particle shape is less obvious because inertial removal mechanism is becoming dominant.

Based on the experimental data, Boskovic et al (2008) further calculated the probability of NaCl particles to roll or to tumble. They considered that inertial impaction is the key factor and got the rolling probability of particle due to inertia.

But diffuison is another important filtration mechanism, the thermal velocities of the particles of different shape are calculated according to Hinds. 1999 and listed in Table1.

Table 1. Thermal velocities of the particles of 50nm and 300nm.

Particle type	Size (nm)	Thermal velocity (cm/s)
PSL	50	15.8
	300	1.08
NaCl	50	11.0
	300	0.748
MgO	50	8.54
	300	0.501

As shown in Table 1, the thermal velocity is larger than the face velocity of 5cm/s for all types of particles of 50nm, so only considering the inertia mechanism is not sufficient, and at least the diffusion mechanism should be added to investigate the probability of NaCl to roll or to tumble.

In this paper, the equations provided by Boskovic et al. (2008) would be modified as the equation (1), α and β are two parameters determined by the number, position and kinetic energy, etc. of particles come into contact with the filter fiber. So, it is very complicated to get α and β , here, for simplicity, α and β are assumed as 0.5.

$$\frac{\left[q_{sngl}^{\exp} / \left(\alpha\varepsilon_{sngl-impa}^{thr} + \beta\varepsilon_{sngl-diff}^{thr}\right)\right]_{MgO}}{\left[q_{sngl}^{\exp} / \left(\alpha\varepsilon_{sngl-impa}^{thr} + \beta\varepsilon_{sngl-diff}^{thr}\right)\right]_{NaCl}} = \frac{\left[\ln\left(1-E_f\right) / \left(\alpha\varepsilon_{sngl-impa}^{thr} + \beta\varepsilon_{sngl-diff}^{thr}\right)\right]_{MgO}}{\left[\ln\left(1-E_f\right) / \left(\alpha\varepsilon_{sngl-impa}^{thr} + \beta\varepsilon_{sngl-diff}^{thr}\right)\right]_{NaCl}} \quad (1)$$

According to the equation (1), the calculated results are listed in Table 2 and different from those got by Boskovic et al. (2008).

Table 2. Rolling probability of NaCl versus MgO calculated by equation (1) and Boskovic et al. (2008)

Calculated equation	5cm/s face velocity	
	50nm	300nm
Equation (1)	1.06	0.65
Boskovic et al. (2008)	0.64	0.42

In conclusion, inertial impaction, diffusion and interception are all capture mechanisms of fibrous filter. The possiblities of particle rolling or tumbling should consider all of them. In fact, it is very complicated to descibe the rolling probability of particles in detail and need further research.

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