Image Force Effect on Aerosol Penetration through Wire Screen in the Transition Regime

M. Alonso1, F.J. Alguacil1, N. Jidenko2 and J.P. Borra2

1Centro Nacional de Investigaciones Metalúrgicas (CSIC), 28040 Madrid, Spain
2Lab. de Phys. Gaz & Plasmas (UMR 8578 CNRS Univ Paris-Sud Orsay, F-91405) Supélec, F-91192 Gif

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An experimental investigation has been carried out to examine the effect of image force on the penetration of multiply-charged aerosol particles through wire screens.

In the experiments, neutral monodisperse ZnCl2 aerosol particles were charged in a corona ionizer, and classified by means of a DMA into fractions of monodisperse particles having +1, +2 and +3 elementary charges. The neutral and charged aerosols were passed alternatively through two geometrically identical cylinders, one of them equipped with four wire screens. Penetrations were determined from comparison of the concentrations measured at the outlet of both cylinders. Particle number concentrations were kept below 10^4 cm^-3 so as to rule out space-charge effects.

Experiments were carried out for particle diameter between 25 and 65 nm (transition regime) and aerosol flow rates of 1, 1.5 and 2 lpm. The results for 1 and 2 lpm are shown in Figures 1 and 2, respectively. The curves shown in the Figures were calculated by means of the correlation

\[ P = \exp[-nS(\eta_D + \eta_{IM})], \]

(1)

where \( n \) is the number of screens (four), \( S \) is the screen parameter (= 1.437 in our case), and \( \eta_D \) and \( \eta_{IM} \) are the single fiber efficiency for the mechanisms of diffusion and image force, respectively. The diffusional efficiency was calculated with the expression (Cheng and Yeh, 1980)

\[ \eta_D = 2.7\text{Pe}^{-2/3}, \]

Figure 1. Comparison between experimental results (symbols) and Eq.(1). Aerosol flow rate = 1 lpm.

where \( \text{Pe} \) is the Peclet number. The single fiber efficiency for the mechanism of image force has been taken to be of the form (Brown, 1993)

\[ \eta_{IM} = aK_{IM}^{1/2}, \]

where \( a \) is a constant, and

\[ K_{IM} = \left( \frac{\varepsilon_r - 1}{\varepsilon_r + 2} \right) \frac{C^2}{e^2 d^2} \frac{d^2}{12\pi^2 u_{eff} d_f \varepsilon_r}, \]

is the dimensionless number accounting for the image force effect (Shapiro et al., 1988). In the last expression, \( C \) is the slip correction factor, \( pe \) the particle charge, \( \mu \) the air viscosity, \( d_p \) the particle diameter, \( d_f \) the fiber diameter, and \( \varepsilon_r \) the relative permittivity of the grid. From the analysis of experimental data the value \( a = 7.73 \) was obtained for a relatively good agreement between the calculated and experimental data.

Figure 2. Comparison between experimental results (symbols) and Eq.(1). Aerosol flow rate = 2 lpm.