Negative drag force on finite-size dust grain in strongly collisional plasma

A.I. Momot

Faculty of Physics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

A finite-size charged conductive spherical dust grain in strongly collisional weakly ionized plasma is considered. It is assumed that the grain is charged due to collection of encountered electrons and ions. The stationary plasma flow or the movement of the grain with a constant velocity v breaks the spherical symmetry of the electric field and the plasma particle distribution around the grain, and the force on the charged grain appears. The nonlinear problem for the drag force is solved numerically within the drift-diffusion approximation.

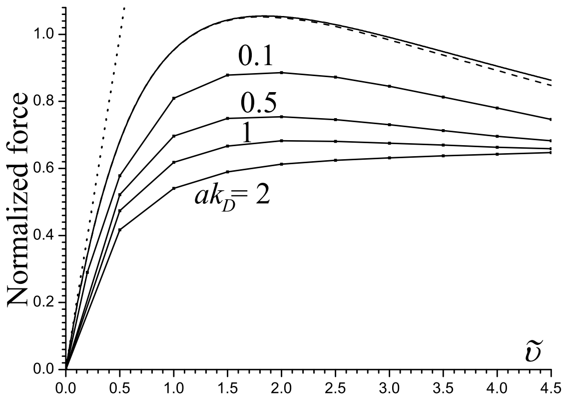

Figure 1: *Absolute value of normalized negative drag force $Fe^2/(T_e a k_D)^2$ vs $\tilde{v}$ in isothermal plasma. Solid lines with dots are results of numerical calculations. Solid line corresponds to (1), dashed line is given by formula (98) from [1] and dotted line is $q^2 k_D^2 \tilde{v}/24$.*

The analytical expression for the drag force in strongly collisional plasma is presented in [1] by Eq. (98). It was obtained in the linear approximation for point-like grain. Considering the ratio of diffusion coefficients D_i/D_e as a small parameter this expression can be expanded to

$$F = -\frac{2q^2k_D^2}{\pi\tilde{v}}\int_0^\infty dx\,\frac{x^2}{A^2}\left(\frac{x(A+\tau)}{A\tilde{v}}\arctan\frac{A\tilde{v}}{x(A+\tau)} - 1\right), \quad A = x^2\tau + x^2 + 1, \tag{1}$$

where $\tau = T_e/T_i$, $\tilde{v} = v\lambda_D/D_i$, $k_D = 1/\lambda_D$, q – grain charge, a – radius. Sign "$-$" in (1) means that the drag is negative. For small velocity $\tilde{v} \ll 1$ Eq. (1) gives $F = -q^2k_D^2\tilde{v}/24$, which coincide up to the designations with Eq. (11) from [2].

The force acting on a charged grain is directed along its velocity, i.e. the negative drag is take place. This force depends nonmonotonically on grain velocity (see Fig. 1) and is approximately proportional to the square of grain radius. Formula (1) is applicable for quantitative estimates of the drag force on small particles $a \ll \lambda_D$ in both non- and isothermal plasmas. It gives the upper boundary of the negative drag force on finite-size grains [3].

References

[1] A.V. Filippov, A.G. Zagorodny, A.I. Momot et al., J. Exp. Theor. Phys. **108**, 497 (2009)

[2] S.A. Khrapak, S.K. Zhdanov, A.V. Ivlev, and G.E. Morfill, J. Appl. Phys. **101**, 033307 (2007)

[3] A.I. Momot, Phys. Plasmas **24**, 103704 (2017)