

# Dynamics of Dust Particles in Flowing Magnetized plasma

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Plasma flows occur in almost every laboratory device and interactions of flowing plasmas with near-wall impurities and/or dust significantly affects the efficiency and lifetime of such devices [1, 2]. As an example, the fusion devices where the dynamics of dust particles near tokamak walls may significantly modify the plasma transport properties. The charged dust inside the magnetized flowing plasma moves primarily under the influence of the plasma drag and electric forces.

The primary motivation of this work is to examine the motion of the dust particles in non-uniform flowing plasma (which reflects near wall region of plasma devices) by self-consistently calculating the charge and forces on the grain. Such an investigation will complement the ongoing study of the plasma sheath characteristics by using fine dust probes [3].

Two-component plasma consisting of electrons and singly charged ions is considered in the presence of a magnetic field that is parallel to the wall. A stationary magnetized planer plasma sheath boundary is located at  $z = 0$  with the plasma filling the half space  $z < 0$ . The basic set of equations and boundary condition for a magnetized sheath is described in Ref. [4]. The dynamics of the dust grain is determined by numerically solving following set of equations

$$\frac{dz}{dt} = v_d, \quad m_d \frac{dv_d}{dt} = F_{\text{coll.}}(a, v_d) + F_{\text{CD}}(y, a, v_d) + F_E, \quad (1)$$

where collisional and Coulomb drag (CD) forces are both due to electrons and ions. We find that for the micron-sized grains, the collisional drag force dominates the Coulomb drag force. The electrostatic force  $F_E = QE$  becomes important closer to the wall and may modify the dust trajectory considerably. The expressions for the collisional and Coulombic drag forces are

$$F_{\text{drag}}(i, e) = 2\pi a^2 T_{i,e} n_{i,e} G_0(s_{i,e}), F_{\text{CD}}(y, a, v_d) = 2\pi a^2 T_{i,e} n_{i,e} y^2 \log(\Lambda_{i,e}) G_2(s_{i,e}), \quad (2)$$

where  $G_0$  and  $G_2$  are functions of flow parameters [5]. The results are given for  $F/F_0$  where  $F_0 = m_d c_s \omega_{pi}$ . For  $T_e = 1 \text{ eV}$ , for argon ions  $c_s = 2.36 \times 10^5 \text{ cm/s}$  and with reference density  $n_0 = 10^8 \text{ cm}^{-3}$ , the ion plasma frequency is  $\omega_{pi} = 3.1 \times 10^6 \text{ s}^{-1}$ . Thus for a micron-sized grain  $a = 10^{-4} \text{ cm}$ , we get  $F_0 = 3 \times 10^{-5} \text{ N}$ . We shall define  $\beta_j = \frac{eB}{m_j c v_{jn}}$

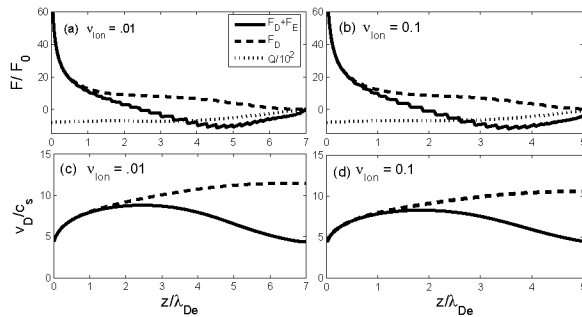


FIGURE 1.

as the ratio of plasma-cyclotron to the plasma-collision frequencies. In Fig. 1(a) – 1(d), the parameters  $\beta_i = 0.01$ ,  $\beta_e = 0.1$ ,  $v_I = 0.001$ ,  $v_{en} = 0.1$  are fixed and  $v_{in}$  is varied. In the absence of sheath field, the drag force which is only due to the collision of ions with the dust grain slowly diminishes towards the wall [Fig. 1(a)]. When the sheath electrostatic field is included, the total force acting on the grain changes sign in the middle of the sheath implying that the total force changes direction causing retardation of the grain. Thus, the dust velocity [Fig. 1(c)] which otherwise shows a saturation towards the wall when only flow drag is considered, decreases near the sheath. Further, we see that inside the sheath, the repulsive electrostatic force on negatively charged grain (dotted line in Fig. 1(a) given in units of  $10^2 e$ ) can exactly cancel the flow drag inside the sheath. The increase in the collision frequency leads to the decrease in the sheath thickness. Therefore, the width over which drag forces and corresponding dust velocities varies, are different for Fig. 1(a) - 1(c) and Fig. 1(b) - 1(d). Therefore, negatively charged grain will feel the field much earlier than when  $v_{in} = 0$ . The total force on grain changes sign much closer to the sheath-presheath boundary when  $v_{in} = 0.1 \omega_{pi}$  than  $v_{in} = 0$ . We also note that the total force on the dust becomes only marginally negative though for a much longer period in comparison with  $v_{in} = 0$  case. This results in the grain velocity becoming much smaller near the wall in the presence of collisions in comparison with the collisionless case. Therefore, the grain charging and grain dynamics are linked to the build up of the sheath potential. To summarize, the drag force acting on the charged dust grain inside the sheath is dependent upon the sheath plasma parameters and the dust dynamics is dictated by the local sheath characteristics.

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