§12. Gravitational Effect on Release Conditions of Dust Particle from Plasma-Facing Wall —Critical Radius—

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The total force has a form of a quadratic equation with respect to the dust radius R_d. [1)]

$$F/\pi R_d^2 = a_0(\phi_w)R_d^2 + a_1(\phi_w)R_d + a_2(\phi_w), \quad (1)$$

where the coefficients a_j depend on the macroscopic plasma quantities such as the particle flux, ion flow velocity at the wall and electron temperature as well as the wall potential ϕ_w The balance of the forces, i.e. Eq. (1) = 0, gives the critical radius in the case of the deeper wall potential than the threshold.

$$R_d^{cr}(\xi_d,\phi_w)/\lambda_{Dse} = \frac{1+\delta_g}{\sqrt{2}\,Z_i \ln\Lambda\, \xi_d}\frac{g_w^2}{\sqrt{h_w}},$$

$$\{-1+\sqrt{1-\frac{\ln\Lambda[16+\xi_d(\xi_d-16)h_w/g_w]}{4(1+\delta_g)^2}}\} \quad (2)$$

where

$$g_w(\phi_w) \equiv \sqrt{1-2Z_i e\phi_w/T_e}$$

$$h_w(\phi_w) \equiv \exp(e\phi_w/T_e)-1,$$

$$+\frac{1}{Z_i}(\sqrt{1-2Z_i e\phi_w/T_e}-1)$$

$$\delta_g(\phi_w) \equiv \frac{8\sqrt{\varepsilon_0}\, g\,\rho_d\, g_w(\phi_w)}{3Z_i e\xi_d n_{se}\sqrt{2n_{se}T_e h_w(\phi_w)}}. \quad (3)$$

In Fig. 1, the critical dust radii are shown as a function of the wall potential ϕ_w for the case $Z_i = 1$, $\ln\Lambda = 3.0$, and $\xi_d = 6.58$, where the threshold wall potential $-e\,\phi_w^{th}/T_e$ is 1.40. The parameter δ_{gg} in Fig.1 indicates the effect of the gravitational force

$$\delta_{gg} \equiv \frac{\rho_d(g/cc)}{n_{se,19}\sqrt{n_{se,19}T_e(eV)}},$$

where $n_{se,19}$ is the plasma density at the sheath edge in the unit of 10^{19} m^{-3}. Here $\delta_{gg} = 0$ corresponds to the dust particle on the vertical wall. The smaller dusts than the critical radius can be released. The larger the gravitational effect becomes, the smaller the released region becomes. In the case of the carbon dust in a plasma with high density 10^{18} m^{-3} and T_e = 10 eV, which corresponds to a divertor plasma in fusion devices, the gravitational parameter as low as 20. On the other hand, the low density plasma 10^{16} m^{-3} with T_e = 3 eV increases the gravitational parameter up to 10^4, where the released particle is quite rare.
The gravitational directed force from the wall easily releases the dust particle from the wall. The gravitational force from the wall changes the sign of the gravitational parameter δ_g in

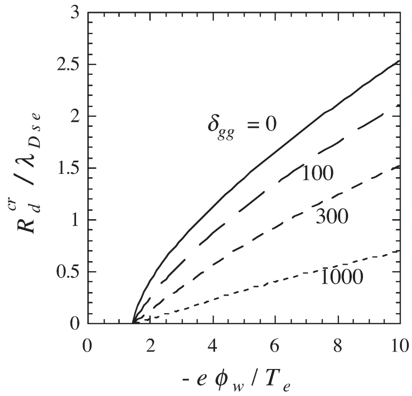

Fig.1 Critical dust radius as a function of the normalized wall potential for the gravitational parameter δ_{gg} = 0, 100, 300, and 1000. The smaller dust than the critical one can release from the wall.

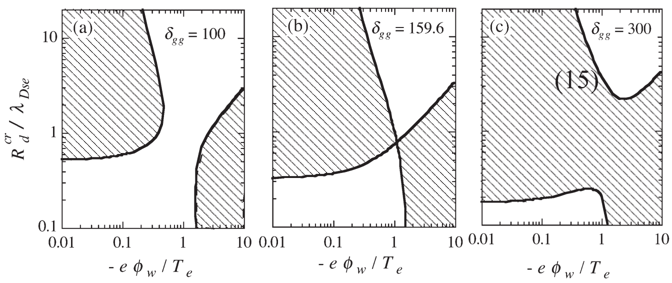

Fig.2 The critical radius as a function of the wall potential for the cases δ_{gg} = 100 (a), 159.6 (b), and 300 (c) with the same parameters as in Fig.2. A dust particle in the shaded regions can be released.

Eq. (2), where the particle is released even if the wall potential is shallower than the threshold (Fig.2.(a) with δ_{gg} = 100 and the same parameters as in Fig.1). In Fig.2 the dust particle in the shaded regions can be released. The released region in the deeper potential and the smaller radius corresponds to that of the gravitational force directed toward the wall. At the released dust region in the shallower wall potential, where the repulsive electrostatic force is very weak, the gravitational force make the dust particle release. The larger gravitational effect expands the released dust region in the shallower potential and merges it into the released dust region in the deeper potential (Fig.2 (b) with δ_{gg} = 159.6). The still more large gravitational effect with δ_{gg} = 300 makes the two released regions overlap.

Reference

1) Tomita, Y., Smirnov, R., T. Takizuka, D. Tskhakaya, Contrib. to Plasma Phys., **46** (2006) 617-622.