§44. Statics of a Dust Particle in Sheaths and at Walls

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Production of dust particles due to interaction of plasma with walls and divertor plates in fusion devices is going to be a serious issue for expected long time discharges and high energy output. The main features of dust particles that differ them from other impurities are big size (10^{-2}~10^{2}μm) and large self-consistent electric charge. Presence of such highly charged dust particles in SOL plasmas could cause changing of spatial potential distribution [1] that modifies heat transmission coefficient.

In the present research, we study the conditions for release of dust particles from a wall and their equilibrium positions and charges in a plasma near wall. The spatial distributions of plasma parameters in the system of length $L = 100\lambda_D$ contacting the floating wall were obtained using one-dimensional PIC/MC simulations (Fig.1). Here λ_D is the electron Debye length in bulk plasma, which bounds the system on the left side and has fixed density $n_b = 10^{12} cm^{-3}$ and temperatures $T_{eb} = T_{ib} = 10eV$ that are close to divertor plasmas. One can see the monotonic potential distribution in the system that includes the positively charged sheath and the quasineutral ionizing presheath.

The electron and ion currents on a spherical dust particle in the plasma as well as drag force due to absorption of ions are obtained according to the OML theory [2] using approximations of monoenergetic ions with simulated flow velocity and Maxwellian electrons with simulated effective temperature. The local equilibrium charge of a dust particle of radius R_d will correspond to the zero total current on it. The equilibrium position of the dust particle x_{eq} will be at the point where the ion drag force balances the electrostatic force. The dependences of equilibrium charge and position on dust radius are shown in Fig. 2. As can be seen, a dust particle with radius larger then value R^{cut} has no equilibrium position in plasma and falls on the wall. A dust particle of size $R^* \le R_d < R^{cut}$ has two equilibrium positions; the closer to the wall is unstable one. Therefore, there is no stable equilibrium for dust particles right in front of the wall. A smaller than R^* particle has one stable equilibrium position in plasma, which is the further from the wall the smaller dust particle.

Considering balance of the electrostatic and ion drag forces on a dust particle at the wall position and assuming that its charge there corresponds to the surface charge density of the wall $Q_{dw} = -4\pi\varepsilon_0 E_w R_d^2$, we found the first critical dust radius

$$R_{cl} = \frac{\varepsilon_0 |E_w|}{en_{iw}}\left(2 - \frac{1}{\alpha}\right), \quad \alpha = \frac{2\varepsilon_0 E_w^2}{n_{iw} m_i V_{iw}^2}, \qquad (1)$$

where E_w, n_{iw}, and V_{iw} are the electric field, ion density and flow velocity at the wall, correspondingly. If dust radius is larger than R_{cl} then the ion drag force exceeds electrostatic one and the dust particle cannot leave the wall. Let us note that if the parameter $\alpha < 0.5$ in (1) then all particles will stay at the wall.

The results of this study were published in [3] and will be extended for the case of biased wall potential.

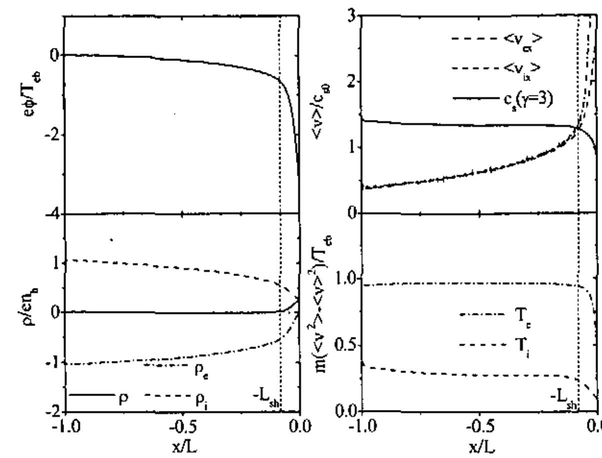

Fig. 1. Simulated spatial distributions of electric potential, charge densities, flow velocities and temperatures of the plasma components in the system.

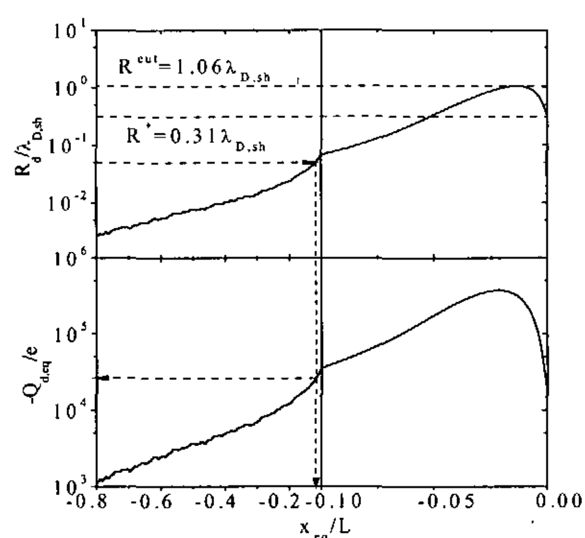

Fig. 2. The equilibrium positions and charges for dust particles of given radius.

Reference

1) Tomita, Y. et al., Contrib. Plasma Phys. **44**, (2004) 162-167
2) Allen, J.E., Physica Scripta **45**, (1992) 497-503
3) Smirnov, R.D. et al., Contrib. Plasma Phys. **44**, (2004) 150-156