§ 7. Macroscopic Oscillation of a Detached Plasma in the TPD-II Device with a Simulated Closed-divertor

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Impurity screening of a closed divertor is closely related to the position of ionization front, z_f. If z_f can be laid in the divertor (D) region between the baffle and the divertor plate, the impurity flow toward the main plasma can collide with the SOL plasma flow at the slot or the opening in the baffle, leading to the local enhancement of the friction. This improves the impurity screening, called "plasma plugging".

Last year, the macroscopic z_f oscillation around the baffle was discovered in the linear machine, TPD-II [see Figs. 1 and 2(a)] [1, 2]. It has been observed that the z_f oscillation accompanies the oscillation of neutral pressures: both P_D in the D region and P_E in the edge plasma region (E region). Here, we show a simple numerical model that reproduces such oscillations.

The model is described with 1/2-dimension fluid equations in consideration of the z_f dependence of P_D and P_E, as schematically shown in Fig.3. The rate of changes in P_D and P_E are respectively expressed as

$$V_E \frac{dP_E(t)}{dt} = C(t)\{P_D(t)-P_E(t)\} - SP_E(t) + Q_f, \qquad (1)$$

$$V_D \frac{dP_D(t)}{dt} = -C(t)\{P_D(t)-P_E(t)\} + Q_i + Q_D, \qquad (2)$$

where, V_D/V_E is volume for D/E region, S is the pumping speed, and Q_i, Q_f, and Q_D are the effective gas feed due to ions carried by the plasma flow coming into the D region, the gas feed for discharge, and the second gas feed into the D region, respectively. The symbol C means the flow conductance reflecting the plasma plugging. It seems that C is described as

$$C(t)=\frac{C_0}{1+C_0/C_p(t)}, \text{ where, } C_p(t)=\{\zeta\, n_i^{o}(t)\}^{-1}, \qquad (3)$$

and C_0 is the conductance for vacuum, n_i^o is ion density at the orifice, ζ is a constant which may be attributed to the friction (under consideration). The equation concerning z_f can be written as

$$\frac{d\, n_{i0} S_p z_f}{dt} = n_{i0} u_i S_p - v_R(t) n_{i0} S_p z_f, \qquad (4)$$

meaning an ion conservation for the plasma column with cross-section S_p and with the length of z_f. The first and second terms in the right hand side represent the inflow (from the source) and the recombination loss, respectively. We suppose that n_{i0} and S_p are independent of t; eq. (4) prescribes the movement of z_f. The ion density profile along the axis as shown in Fig. 3 can be written as

$$n_i(z,t) = -\frac{n_{i0}}{2}\left\{\tanh\left(\frac{z-z_f(t)}{\lambda}\right)-1\right\}, \qquad (5)$$

where, λ is the scale length of the density gradient around the z_f. By substituting the position of the orifice, L, into z in eq. (5), n_i^o is determined, and z_f dependence of C is prescribed [see eqs. (1)-(3)].

The numerical solutions of $P_D(t)$, $P_E(t)$, and $z_f(t)$ show a self-excited oscillation [see Fig. 2(b)] for the experimental condition corresponding to Fig. 2(a), and well reproduce the experimental observations. This suggests that the plasma plugging and loss (recombination) terms play a very important role in the oscillation of detached plasma in this experiment.

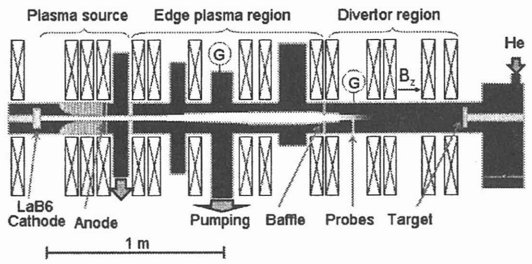

Fig.1. Schematic of TPD-II with the baffle.

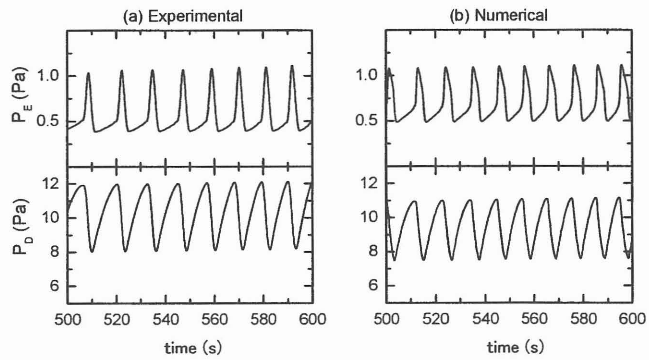

Fig.2. Oscillations of P_D and P_E for the periodical movement of the ionization front.

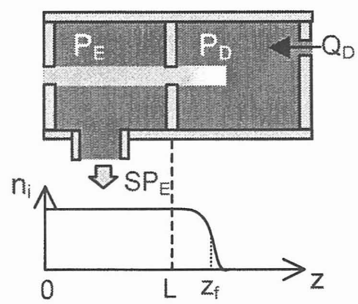

Fig.3. Schematic for the model.

References
[1] Matsubara, A., et al., J. Plasma Fusion Res. 78, 196 (2002).
[2] Matsubara, A., et al., ICPP, Sydney, 2002 (in press).