§26. Influence of the Wall Material on the H-Mode Performance

Itoh, K.

Itoh, S.-I. (Kyushu Univ.)

It is well known, from various experiments, that the property of the H-mode plasma depends on the wall materials [1]. The improvement of the energy confinement τ_E over that of the L-mode is higher when the wall material is composed of the low-Z material (Z being the ionic number). The threshold power for the H-mode transition is lower for the case of low-Z wall. In spite of these importance, there was no model to explain these dependencies. We theoretically study the influence of the wall material based on our model of the H-mode, the radial electric field bifurcation model [2].

The neutral particles in the plasma causes the drag force on ions. As the neutral density exceeds a threshold value $n_{0,c}$, $n_0 > n_{0,c}$ the hard transition is prohibited and a soft transition takes place [2]. If n_0 is increased more, even the slow and soft transition becomes impossible. An estimate for $n_{0,c}$ was given

$$n_{0,c} \approx \frac{v_i}{\langle \sigma_{cx} v \rangle} \frac{\rho_p}{\Delta_n} \text{ where } v_i \text{ is the ion collision}$$

frequency, ρ_p is the ion poloidal gyro radius, σ_{cx} is the charge-exchange cross section and Δ_n is the penetration length of the neutral particles in the core. This result explains the experimental knowledge that the energy confinement of the H-mode is degraded by the neutrals in the plasma.

Now we discuss the influence of the wall material on the neutral density. The wall reflection is known as an important source of neutrals in the core, and we here consider the neutrals of such origin. The penetration probability of neutrals from the wall into the plasma, p , is evaluated as

$$p = \exp\left(-\int ds \frac{n_e \langle \sigma_{ion} v \rangle}{v_0}\right) \text{ where the integral}$$

is taken along the path of neutrals across the SoL, v_0 denotes the neutral velocity, and σ_{ion} indicates the ionization cross section. Since the probability p has a strong dependence on the initial velocity, one must consider the multiple energy component from the wall. We take two components, which are characterized by the average velocity V_s and V_f as is shown in Fig.1. The experimental study on the influence of the

wall materials on the neutral energy distribution was done in TEXTOR device.

For the simplicity we assume $p(V_f)R_f \gg p(V_s)R_s$, where R_s is the recycling coefficient and R_f is the reflection coefficient. Introducing the thickness of the layer of recombination, Δ_{recom} , we have

$$n_0 = \frac{p(V_f)R_f \langle \sigma_{recom} v \rangle n_e n_i}{\langle \sigma_{ion} v \rangle n_e + \langle \sigma_{cx} v \rangle n_i (1 - p(V_f)R_f)} \frac{\Delta_{recom}}{\Delta_n}$$

These results clarify that, as the reflection coefficient or the initial velocity V_f increases, the neutral density in the plasma increases, and thus deteriorates the H-mode performance.

The reflection coefficient was given for incident ions as a function of the reduced energy (normalized energy), W , in the study on the plasma wall interactions:

$$W = 32.5 \frac{M_2}{M_1 + M_2} \frac{1}{Z_1 Z_2 (Z_1^{2/3} + Z_2^{2/3})^{1/2}} E(\text{keV})$$

where M and Z are mass and atomic numbers, and the suffix 1 denotes the incident ion and 2 denotes the target atom, and E is the energy of incident particle measured in keV. If W is above unity, the reflection coefficient decreases rapidly. If W is below 0.1, it approaches to unity. For example, let us compare the cases of iron ($Z_2=26$, $M_2=56$) and Boron ($Z_2=5$, $M_2=11$). Injection particle is deuteron. We see that $W < 0.1$ for $E < 260\text{eV}$ (iron) and for $E < 36\text{eV}$ (Boron). The reflection of fast particle is allowed for the case of iron.

Fig.1 Schematic velocity distribution of the neutral particles leaving from the wall.

References

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- 2) Itoh S-I and Itoh K 1988 *Phys. Rev. Lett.* **60** 1269.
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