§17. Comparison of Transfer Efficiency of High Energy Ion at Inward-Shifted and Standard Magnetic Axis

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In the minority ICRF heating the most of the RF power is absorbed by minority ions[1]. The bulk plasma is heated by high energy ions via a slowing down process due to electrons in the following power balance equation about the tail and bulk plasmas;

$$\frac{dW_{tail}}{dt} = \eta_h P_A - \frac{W_{tail}}{\tau_E^{tail}},$$

$$\frac{dW_{bulk}}{dt} = \frac{W_{tail}}{\tau_s/2} - \frac{W_{bulk}}{\tau_E}.$$

The heating power source for the bulk plasma is a term of $W_{tail}/\tau_s/2$. A transfer efficiency η_{trns} is defined as what fraction of absorbed power is transferred to the bulk plasma using a following equation;

$$P_{abs} = \frac{W_{tail}}{\tau_E^{tail}}, \quad P_{trns} = \frac{W_{tail}}{\tau_s/2},$$

$$\eta_{trns} = \frac{P_{trns}}{P_{abs}} = \frac{\tau_E^{tail}}{\tau_s/2}, \quad \frac{1}{\tau_E^{tail}} = \frac{1}{\tau_s/2} + \frac{1}{\tau_E^{loss}}.$$

η_{trns} is expressed using a ratio of $\tau_E^{tail}/\tau_s/2$. When the energy loss time τ_E^{loss} is much longer than the electron slowing down time, the transfer efficiency becomes 100%. It is also expressed as the ratio of T_{tail} to T_{eff}:

$$T_{tail} = \frac{\tau_E^{tail}}{\tau_s/2} T_{eff},$$

$$\eta_{trns} = \frac{T_{tail}}{T_{eff}}.$$

In the Monte Carlo simulation η_{trns} is scaled as shown in the following equation[2]:

$$\eta_{trns} = \frac{P_{trns}}{P_{abs}} = \frac{\tau_E^{tail}}{\tau_s/2} = \frac{T_{tail}}{T_{eff}} = \frac{1}{1 + CP_{abs}T_e^2(n_H/n_e)^{-1}n_e^{-2}}.$$

Here C is a numerical factor to evaluate η_{trns}; C depends on the magnetic configuration and the magnetic strength. It is determined using the ratio of T_{tail} to T_{eff} for 2 cases as described in the previous section and plotted in Fig.1, where the abscissa is $P_{abs}T_e^2(n_H/n_e)^{-1}n_e^{-2}$. C is determined to be C_{exp}=0.032 at R_{ax}=3.75m and 0.005 at R_{ax}=3.6m, respectively. C is also evaluated in the Monte Carlo simulation to be C_{MC}=0.043 at R_{ax}=3.75m and 0.004 at R_{ax}=3.60m as shown in Fig.1. These experimental values fairly agree with the Monte Carlo simulation results.

The reduction of the transfer efficiency is caused by a decrease in the energy loss time of high energy ions τ_E^{loss}. It is expressed using the transfer efficiency η_{trns} in the following equation;

$$\tau_E^{loss} = \frac{\tau_E^{tail}\tau_s/2}{\tau_s/2 - \tau_E^{tail}} = \frac{\eta_{trns}}{1-\eta_{trns}}\tau_s/2.$$

It is plotted in Fig.2, whose abscissa is $n_eP_{abs}^{-1}T_e^{-0.5}(n_H/n_e)^{-1}$. The energy loss time ranges in 0.1~0.2s in the plasma discharge at R_{ax}=3.75m; however it is expected 10 times longer at R_{ax}=3.6m than that because C was 1/10.

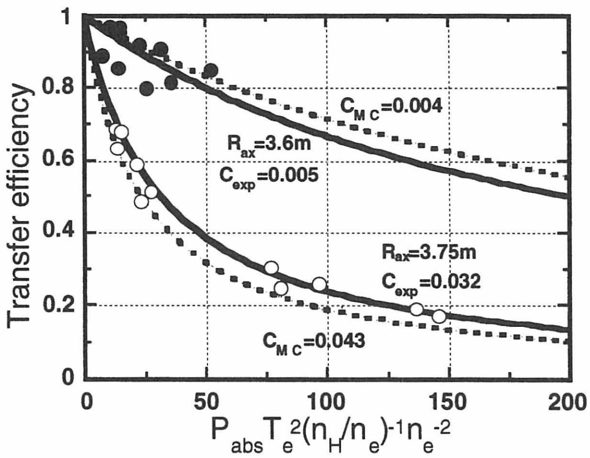

Fig.1 Dependence of transfer efficiency in the cases of R_{ax}=3.6m and =3.75m with the calculation results from the Monte Carlo simulation.

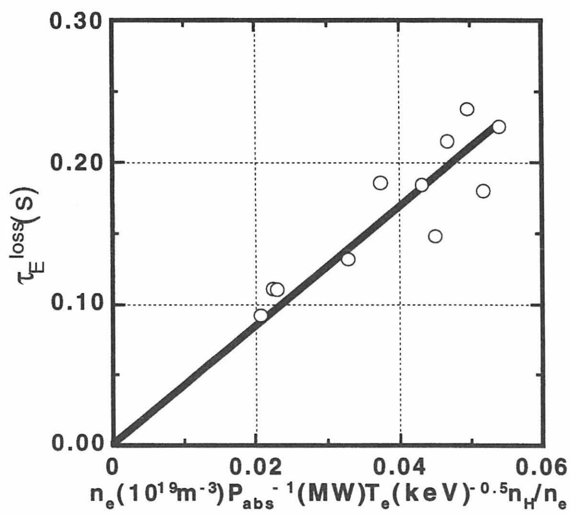

Fig.2 Dependence of energy loss time of high energy ions on $n_eP_{abs}^{-1}T_e^{-0.5}(n_H/n_e)^{-1}$.

References

1) K.Saito et. al., Nucl. Fusion **41** (2001) 1021.
2) S.Murakami et. al., Nucl. Fusion **39** (1999) 1165.