§9. Effect of Radiation Power Loss due to Impurity Gas Puff on Divertor Plasma

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Reducing high heat load on a divertor plate is an issue to prevent serious damage to it in future fusion devices such as the ITER, a DEMO and a LHD-type reactor (FFHR)[1]. Gas injection into a divertor plasma is one possible idea to reduce the heat load on divertor plates, since impurity gas causes radiative power loss and decreases electron temperature, expected to result in plasma detachment. The effect of impurity radiation loss was examined analytically for the ITER divertor[2] and neon was found to be the optimum candidate. In this work we examine the effect of radiation power loss produced by impurity gas puffs in a divertor plasma and examine whether plasma detachment will be likely or not[3].

Here we consider a one zone model and ignore spatial distribution of electron temperature and density, hydrogen density and impurity density to examine simply the effect of radiation power loss to a plasma. We calculate time-dependent ion and atom densities of the injected impurity gas and bulk hydrogen. The ion and atom densities are changed by electron-impact ionization and recombination processes. The ion number density of i-th charged state $n(i)$ is obtained as

$$\frac{dn(i)}{dt} = S(i-1)n(i-1)n_e - S(i)n(i)n_e - \alpha(i)n(i)n_e + \alpha(i+1)n(i+1)n_e + R_{puff}, \quad (1)$$

where $S(i)$ is ionization rate of i-th ion to be $(i+1)$-th ion, $\alpha(i)$ is recombination rate from i-th ion to $(i-1)$-th ion, and n_e is electron density. The gas puff rate R_{puff} is put constant for the first 0.01s and stoped. Both radiative and dielectronic recombination processes are considered. Three-body recombination is ignored here, since this process is not effective for electron temperatures larger than 1eV. Electron-impact ionization and dielectronic recombination rate coefficients are taken from Voronov[4] and Mazzotta et al.[5], respectively. Radiative recombination rate coefficients are calculated with a Fortran subroutine written by D. Verner[6]. Electron temperature is calculated with the energy conservation equation. The radiation power coefficients due to line transitions, radiative recombination, and Bremsstrhalung by impurity gas are taken from ADAS[7]. We ignore the effect of the time evolution of electron density, the effect of recycling of gas and heat flux from the core plasma in the energy conservation equation for simplicity.

Figure 1 shows time evolution of electron temperature and it decreases less than 1 eV for the case with $R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$, independent of initial electron temperature. We expect plasma detachment in this case. Figure 2 shows time evolution of radiation power of each ion for the case c with $R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=100eV and Ne^{5+}~Ne^{7+} contribute to the maximum radiation power, which leads to a rapid decrease of the electron temperature as seen in Fig. 1.

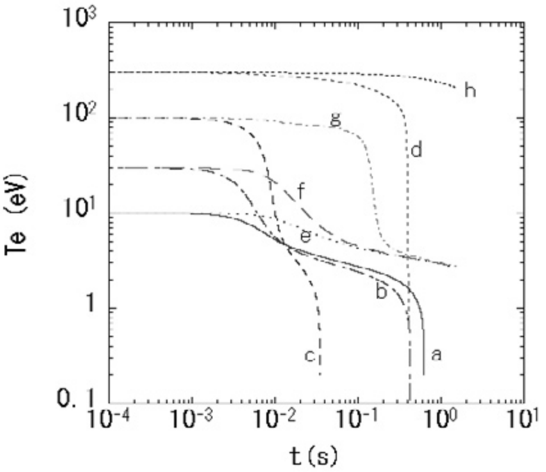

Fig. 1. Time evolution of electron temperature for the cases a ($R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=10eV); b ($R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=30eV); c ($R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=100eV); d ($R_{puff}=10^{13}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=300eV); e ($R_{puff}=10^{12}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=10eV); f ($R_{puff}=10^{12}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=30eV); g ($R_{puff}=10^{12}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=100eV); and h ($R_{puff}=10^{12}\mathrm{cm}^{-3}\mathrm{s}^{-1}$ and $T_e(0)$=300eV).

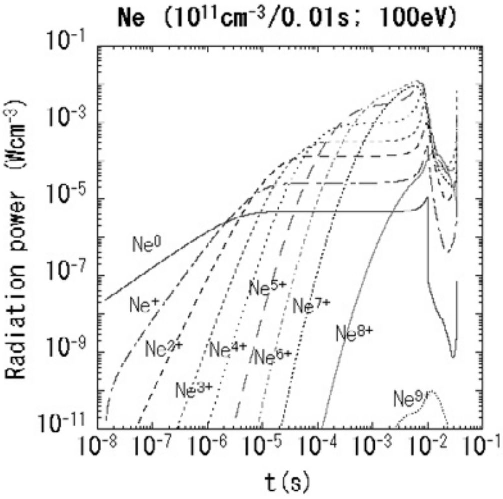

Fig. 2. Time evolution of radiation power due to each ion for the case c with $R_{puff}=10^{13}\mathrm{cm}^{-3}$ and Te(0) = 100eV.

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