§6. 1D Model Study on the Effect of Impurity Radiation Cooling in LHD SOL Plasma

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The increasing heat load onto the plasma-facing wall in reacter-class device such as DEMO and FFHR, could exceed the engineering limit of material if simple scaling is applied in size of device to realize the sufficient energy confinement time. The larger the device becomes, the more severe heat flux the wall has to sustain. One of possible candidates to remove the heat is gas puffing of impurity such as neon and nitrogen.

We developed a one dimensional steady-state two-fluid model based on our previous divertor plasma model[1, 2] to study the cooling effect of gas-puffed neon on the hydrogen SOL plasma. In LHD experiment, sustaining radiation in edge region outside the LCFS (last closed flux surface) is observed for several seconds after an instantaneous neon gas puffing. Since the characteristic time of atomic processes and increase of radiation take place is order of millisecond[3] and the transport time scale is also shorter than one second, we can safely assume that the neon distribution is in steady state. Therefore, we apply a steady state plasma in the model. The radiation cooling is modeled as a loss term in the balance equation of energy flux. The boundary condition of both ends of the 1D model are a stagnation point, i.e. zero parallel velocity, and sheath limited condition. We carried out calculations for two conditions and the parameters used here are summarized in Table I. The case 1 and 2 give low and high density plasma. We note that the input power is a local quantity and different from the heating power of the device. The power transported to the flux tube by cross field diffusion is determined by the transport coefficient, decay length and spatial profiles of density and temperature. The coefficient D and χ are fixed and the decay lengths, $\lambda_{\rm n} = \lambda_{\rm T} \sim 5$cm, are automatically adjusted by the shooting method.

We assumed a uniform density distribution of neon and carried out parameter scans of the neon density. Large impurity density implies large amount of gas puffing. Since we assume constant input power independent of other plasma parameters, the radiation of neon leads to reduction of heat load. Figures 1(a) and (b) show significant reduction of temperature and heat load onto the divertor plate according to the neon density. Figure 1(c) shows the fraction of radiation power to the input power.

Table I: Calculation parameter for two cases: Connection length, i.e. $2L$, transport coefficients and input power into the flux tube.

case	L	D	χ	input power
1	50m	$1\mathrm{m}^2/\mathrm{s}$	$2.63\mathrm{m}^2/\mathrm{s}$	$1.5\mathrm{MW/m}^2$
2	50m	$1\mathrm{m}^2/\mathrm{s}$	$1.9\mathrm{m}^2/\mathrm{s}$	$5\mathrm{MW/m}^2$

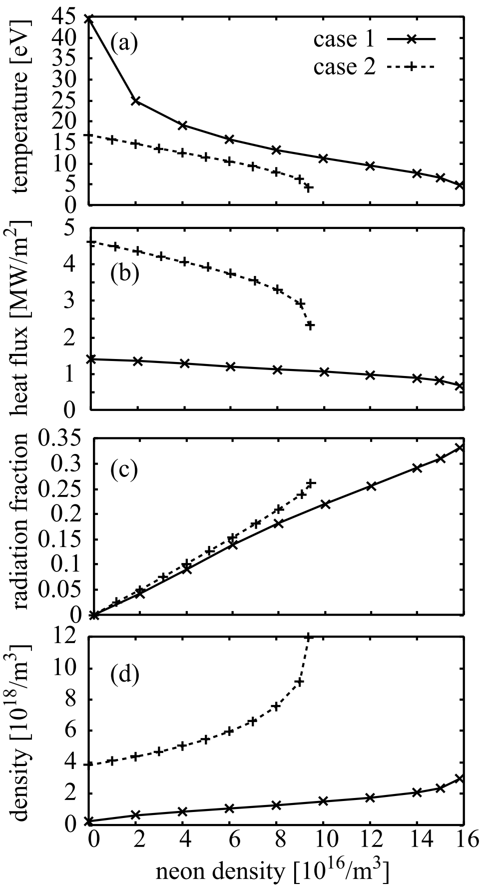

Fig. 1: Plasma response to the neon impurity. Temperature, heat flux, radiation fraction to input power, density and neon fraction at the divertor plate.

They increase linearly to the neon density and reach one third approximately. There is a threshold above which a stable solution satisfying the boundary conditions is not found. The low density condition, i.e. case 1, sustains for large amount of neon. All these tendencies of plasma response are consistent with the experimental observations. Figure 1(d) shows density on the divertor plate. They increase according to the neon density because the pressure is not so sensitive to the impurity and therefore low temperature leads to high density. This responde is the same in the case of low density but opposite in the case of high density. Perpendicular particle transport is one of possible reasons of the discrepancy in the density response. Detailed comparison with experimental results and refinement of the model is a future issue.

1) G. Kawamura, Y. Tomita, M. Kobayasahi and D. Tskhakaya, J. Plasma Fusion Res. Series **8**, 455 (2009).

2) G. Kawamura, Y. Tomita, M. Kobayasahi and D. Tskhakaya, Plasma Fusion Res. **5**, S1020 (2010).

3) I. Murakami, D. Kato, H. A. Sakaue, S Masuzaki, Plasma Fusion Res. **6**, 2403029 (2011).