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Investigation of the detached divertor model in the SONIC simulation
SONICシミュレーションにおける非接触ダイバータモデルの検討

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In order to improve the detachment modeling, effects of various processes are investigated by using a suite of integrated divertor codes SONIC. The increase in the radial diffusion loss at the private edge decreases the ion density and the ion flux by 15%. The supersonic flow effect on flux reduction is small because the supersonic flow occurs just in front of the target under the present simulation condition. Due to effects of the wall pumping, the poloidal profile of the ion flux is significantly changed. However the change in the ion flux at the target is small. The weak rollover of the ion flux appears due to the combination of effects of the radial diffusion loss and the wall pumping.

1. Introduction

The large heat load to the divertor plate is one of the crucial issues for magnetic fusion devices. The detached divertor operation is the most promising candidate to reduce the heat load and it has been achieved in many devices [1].

A number of divertor codes have been developed to interpret and predict the SOL/divertor plasma characteristics. To investigate the detached divertor plasma, the various physics processes, such as the atomic and molecular processes, drift, current and so on, have been implemented into the divertor codes. However, it seems to be still challenging to reproduce the detached divertor plasma observed in the experiments, especially significant reduction of the particle flux onto the divertor target [2].

In this study, several models and processes are evaluated for improvement of the detachment characteristics simulated by a suite of integrated divertor codes SONIC [3, 4].

2. SONIC result with Standard Setup

The SONIC code is applied to the study of JT-60U divertor plasmas [5]. The ion and electron input power across the core interface boundary (r/a~0.9) is set to Q_i=Q_e=1.6MW, respectively. The ion flux across the core boundary, Γ_{in}, and D_2 gas puff rate, Γ_{puff}, are adjusted for a parameter survey. The anomalous transport coefficients for the particle ($D_\perp = 0.3\ \mathrm{m}^2/s$) and heat ($\chi_\perp^i = \chi_\perp^e = 1.0\ \mathrm{m}^2/s$) are assumed to be spatially constant. The recycling coefficient R at the divertor and the wall is set to 1, i.e. saturated wall is assumed. An effective pumping speed is set to $S_{pump} = 30\ \mathrm{m}^3/s$. The chemical sputtering yield is assumed to be Y_{ch}=3 % on all plasma facing walls.

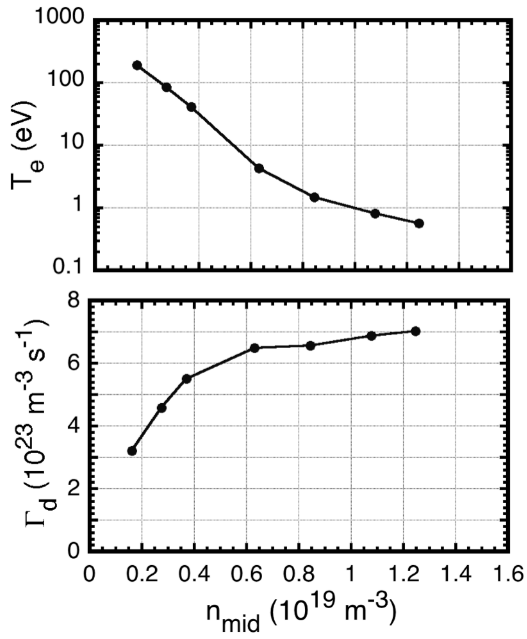

Fig. 1 Detachment characteristics in the SONIC simulation.

The electron temperature T_e and the ion flux Γ_d at the outer strike point are plotted as a function of the mid-plane density n_{mid} in Fig. 1. With increasing n_{mid}, T_e significantly decreases and Γ_d initially increases. Although T_e becomes less than a few eV, Γ_d does not decrease. The rollover of the ion flux, which is a feature of the detachment, cannot be reproduced in the standard setup for the SONIC simulation.

3. The radial diffusion loss from the private edge

In the SONIC code, the radial decay length λ of density is given as the boundary condition at the private side edge. The decrease in λ corresponds to increase in the radial diffusion at the private edge. To investigate effects of the radial diffusion loss from the private edge, a radial decay length of density λ is changed. Figure 2 shows the radial profile of the ion density along the inner divertor target. With decreasing λ, particle loss by the radial diffusion increases. As a result, the ion density n_i in the private region decreases. Although decrease in n_i leads to decrease in the ion flux Γ_d near the strike point, the change in Γ_d is 15% at most.

4. The supersonic flow in the divertor region

At the sheath entrance, M=1 (M: Mach number) is generally fixed in the plasma fluid model. However, The solution of the supersonic flow (M>1) at the sheath entrance was expected analytically or numerically as was discussed in Ref. [6-9]. To investigate effects of the supersonic flow on the detachment, the boundary condition of the momentum at the target is improved to allow the supersonic flow. The SONIC simulation shows the solution of the supersonic flow in the detachment state. Although n_i at the target significantly decreases, change in Γ_d is small. If the supersonic flow and the resultant decrease in the ion density occur along the field line from the X-point to the target, significant effect on the divertor plasma due to the change in the plasma-neutral interaction, such as ionization, charge-exchange etc, is expected. However, in the present simulation condition, the supersonic flow occurs just in front of the divertor target. As a result, the change in Γ_d is small because the ion flux is conserved from the upstream.

5. The wall pumping

The effect of the wall pumping is investigated by changing the wall recycling coefficient R. As the recycling coefficient in the exhaust chamber decreases, the electron temperature at the strike point increases. Because the ionization front moves to the target from the X-point, the poloidal profile of Γ_d is significantly changed. However, the change in the ion flux at the outer target is relatively small.

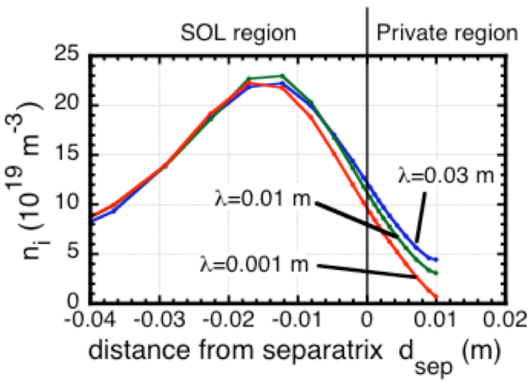

Fig. 2 Radial profile of the ion density n_i along the inner divertor target. Radial decay lengths at the private region boundary (d_{sep}~0.01 m) are set to be λ=0.03 m, λ=0.01 m and λ =0.001 m.

6. Synergetic effects and future work

By taking into account both effects of the large radial diffusion by the small radial decay length and the wall pumping effect, the weak rollover of the ion flux appears. However, reduction in Γ_d after the rollover is still small compared with experimental data.

For further understanding of the formation of the detached divertor plasma, evaluation of a dependence of the detachment characteristics on the anomalous transport coefficients, the hot-electron effects, is in progress and will be discussed in the presentation.

Acknowledgments

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