24P029-P

Improvement of edge-plasma modeling and its impact on the SONIC simulation for JT-60SA divertor

周辺プラズマモデリングの改良と JT-60SA ダイバータの SONIC シミュレーションにおけるその効果

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For SONIC simulation on JT-60SA divertor, the heat flux limiter is introduced in the ion parallel heat transport besides electron one. Changing the limit factor from α_i = 0.5 to 10, density decrement and temperature increment in the edge-plasma are remarkable at α_i = 0.5 in comparison with a case without limiter. Sensitivity on the radial particle or thermal diffusivity is surveyed with range of D = 0.1~1 m^2/s and χ = 0.1~2 m^2/s. Divertor heat flux increases from 7.5 to 10.5 MW/m^2 with decrease of D. This sensitivity is stronger than that for χ.

1. Introduction

We have studied the JT-60SA [1] divertor design with an integrated divertor simulation code SONIC [2,3]. To identify compatibility the low heat load (≤15 MW/m^2) with a maximum input power P_{in} = 41 MW controlling the particle flux, the vertical divertor targets with *V-shaped* corner was adopted [4], and the gas-puff and divertor pump were optimized [5]. Parametric survey of such as divertor geometry, gas-puff flux, and pumping speed was carried out for the optimization using the SONIC code. While, the flux limit with regard to parallel heat transport was not included in the code. For particle and thermal diffusivity to the radial direction, fixed values were used. And the non-coronal model [6] was used restrictively for the impurity treatment.

In order to improve the modeling, the heat flux limiter is introduced in the code and its effect is evaluated varying the factor of heat flux limiter. Parametric studies varying the radial diffusivity are carried out to clarify the effect to the edge plasma.

2. Parallel heat flux limit

The use of parallel heat flux limiter affects the modeling [7,8]. This is used in the codes to transition smoothly from collisional regime to a kinetically limited term as the collisionality drops. Simulations are carried out a condition for the JT-60SA operation scenario of full non-inductive current drive (R_p=2.9 m, a_p = 1.1 m, I_p = 2.3 MA, B_t = 1.8 T) with P_{in} = 41 MW. Figure 1 shows the effects of changing the factor of ion heat flux limit from α_i = 0.5 to 10.0 (including a case without flux

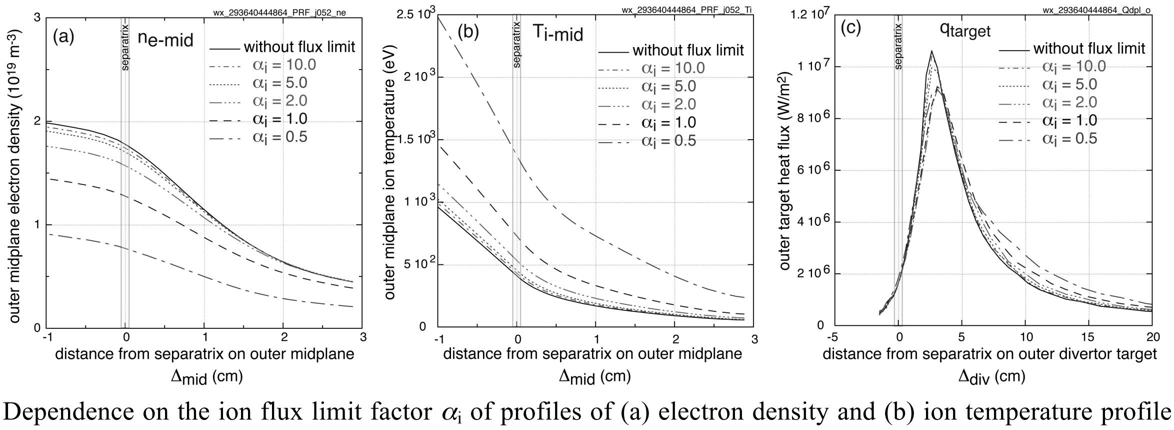

Fig.1. Dependence on the ion flux limit factor α_i of profiles of (a) electron density and (b) ion temperature profile on the outer midplane ($n_{e\text{-mid}}$, $T_{i\text{-mid}}$), and (c) heat flux profile on the outer divertor target q_{target}. Following parameters on SONIC simulations are fixed. Total exhaust power and ion flux across r/a=0.95; Q_{total} = 37 MW and Γ_{ion} = 2.8×10^{21} s^{-1}. Gas-puff flux; Γ_{puff} = 6×10^{21} s^{-1}. Pumping speed; S_{pump} = 50 m^3/s. Carbon and argon fraction; n_c/n_i = 2% and n_{Ar}/n_i = 1%. Particle and thermal diffusivity to the radial direction; D = 0.3 m^2/s and χ = 1.0 m^2/s.

limit) on profiles of electron density and ion temperature in the outer midplane, and heat flux profile on the outer divertor target. We are focusing to the ion heat flux limit in this time. As shown in Figs. 1(a) and (b), lower density (separatrix density $n_{\text{e-mid}}^{\text{sep}}$ = 0.8×10^{19} m^{-3}) and higher temperature (separatrix temperature $T_{\text{i-mid}}^{\text{sep}}$ = 1.4 keV) in comparison with a case without limiter ($n_{\text{e-mid}}^{\text{sep}}$ = 1.8×10^{19} m^{-3}, $T_{\text{i-mid}}^{\text{sep}}$ = 0.4 keV) are exhibited at α_{i} = 0.5 in the core edge regions. Its effect becomes small rapidly with increase of α_{i}. Then α_{i} = 10.0 case is almost same as a case without flux limit. On the other hand, the target heat flux, which peak value is changed in range of $q_{\text{target}}^{\text{peak}}$ = 9~10.5 MW/m^2 with change of α_{i}, is not so affected by the flux limiter (Fig. 3(c)). It cannot make clear only by simulation which factor is suitable, but it shows that the parallel heat transport can be changed with those effects.

3. Sensitivity of particle or thermal diffusivity

The sensitivity of particle or thermal diffusivity to the radial direction in the edge-plasma is evaluated with the range of D = 0.1~1.0 m^2/s and χ = 0.1~2.0 m^2/s based on the empirical values for various tokamaks [9]. Figure 2 shows the dependence on D of the midplane density profile and the target heat flux profile. The density profile can be steepened with increment of separatrix density from $n_{\text{e-mid}}^{\text{sep}}$ =1.4 to 1.8×10^{19} m^{-3} with decrease of D. Heat flux profile on the target tends to peak and peaked value becomes from 7.5 to 10.5 MW/m^2 with decrease of D.

Dependence on χ of the electron temperature profile on outer midplane $T_{\text{e-mid}}$ and the target heat flux profile are shown in Fig. 3. Decreasing χ, the electron temperature profile can also be steepened and separatrix temperature is increased from $T_{\text{e-mid}}^{\text{sep}}$ = 200 to 450 eV. Besides, $n_{\text{e-mid}}^{\text{sep}}$ also increased from 1.4 to 1.8 ×10^{19} m^{-3} with decrease of

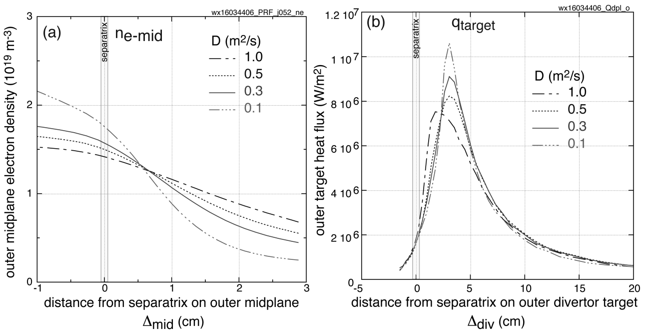

Fig.2. Dependence on the particle diffusivity D of (a) $n_{\text{e-mid}}$ and (b) q_{target}.

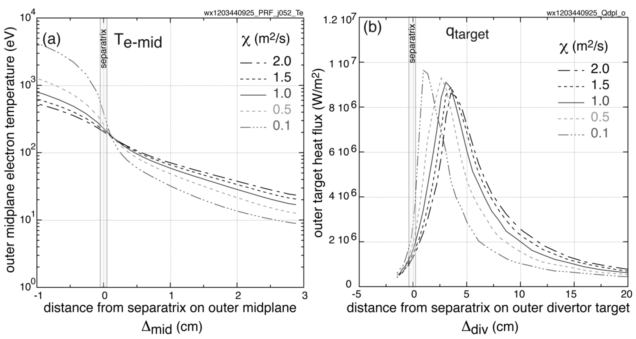

Fig.3. Dependence on the thermal diffusivity χ of (a) electron temperature profile on the outer midplane $T_{\text{e-mid}}$ and (b) q_{target}.

χ. The target heat flux profile shifts outward with decrease of χ (Fig.3 (b)), keeping $q_{\text{target}}^{\text{peak}}$ in ranges of 8.5~9.6 MW/m^2. Resulting for the heat flux, sensitivity of D is stronger than that of χ, and the range of D =0.1~1.0 m^2/s gives a difference to the heat flux of Δq = 3 MW/m^2

Those results indicate that a new modeling or sensitivity of fixed parameters gives effects as mentioned above to the previous simulations and has a possibility to improve the physics understanding of the edge-plasma at the operation. A similar thing is suggested for comparison of different model such as impurity treatment. Study of impurity treatment using the Monte Carlo model IMPMC [10] is in progress for comparison with that on the conventional non-coronal model.

Acknowledgement

This work is partly supported by a Grant-in-Aid for Scientific Research of Japan Society for the Promotion of Science.

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