§17. Integrated Modeling of Peripheral and Core Plasmas

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The magnetic confinement device of fusion plasmas, such as tokamaks and helical devices, generally consists of a closed and an open system. In the closed system, the magnetic field forms nested flux surfaces and confines the core plasma. The open system with the peripheral plasma surrounds the closed one and both ends of the magnetic field line contact with divertor plates. Although core and peripheral plasmas naturally interact with each other, the integrated modeling of both plasmas and the understanding of the interaction have not yet accomplished so far. The integrated modeling is required especially for dynamic phenomena, such as edge localized modes (ELMs) in tokamaks.

From the above points of view, we have done some works to develop the integrated modeling of peripheral and core plasmas. We here pick up the following two works.

(1) TOPICS-IB

An integrated code TOPICS-IB has been developed on the basis of the 1.5-dimensional core transport code TOPICS extended to the integrated simulation for burning plasmas. In the TOPICS-IB, a dynamic five-point model of the peripheral plasma (scrape-off-layer (SOL) and divertor plasmas) is coupled with TOPICS. Up to now, we applied the TOPICS-IB to the study of the energy loss caused by ELMs. The TOPICS-IB successfully simulated a series of transient behaviors of an H-mode plasma; the pedestal growth and an ELM crash. We found that the rapid increase of the SOL temperature during the ELM crash reduces the ELM energy loss by flatting the radial edge gradient. The experimentally observed collisionality dependence was found to be caused by both the bootstrap current and the SOL conductive heat transport. In this study, however, the density profile was fixed simplicity. The density collapse enhances the ELM energy loss through the convective heat transport. The dynamics of the pedestal density strongly connects with the neutral recycling. Thus, the integration of the neutral model is necessary for the density dynamics. For this purpose, we newly integrate a 2D Monte Carlo code for core neutrals and a simple integral model for neutrals in SOL-divertor regions with TOPICS-IB.

We study the density dynamics effect on the ELM behavior and the resultant particle and energy losses. The TOPICS-IB successfully simulates the behavior of the whole plasma with the density dynamics. The collisionality dependence is investigated by varying the density and the temperature instead of artificially enhancing the collisionality in the previous study. Figure 2 shows the ELM energy loss, ΔW_{ELM}, normalized by the pedestal energy, W_{ped}, as a function of the normalized collisionality, ν^*_{ped}. In the electron energy loss, the conductive loss is larger than the convective one and decreases with increasing the collisionality while the convective loss is almost constant. The constant electron convective heat loss is caused by the independence of the ELM particle loss of the collisionality, which was also observed in experiments. The collisionality dependence of the electron energy loss is caused by the bootstrap current and the SOL conductive transport, as found in the previous study. On the other hand, for lower collisionality, the ion temperature becomes higher than the electron one due to the ineffectiveness of the equipartition proportional to the collisionality. As a result, ion convective and charge-exchange losses bring the collisionality dependence of the ion energy loss, which could not be found without the density dynamics. The collisionality dependence becomes strong comparable with that in experiments [1].

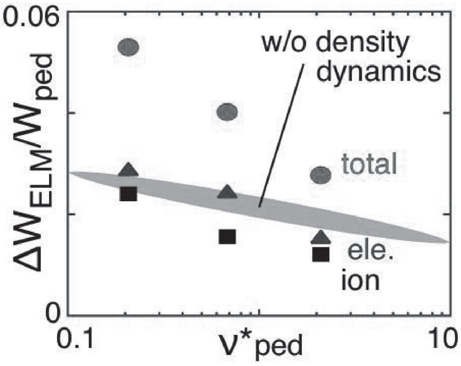

Fig.2 Collisionality (ν^*_{ped}) dependence of ELM energy loss ΔW_{ELM} normalized by pedestal energy W_{ped} and its electron and ion components. Shaded region denotes ΔW_{ELM} without density dynamics.

(2) CSD model

A simple Core-SOL-Divertor model has been developed in order to understand qualitatively the overall features of plasma operational space including the requirements for the SOL-divertor plasmas, especially for the future power plant design. The CSD model integrates the 0D plasma model based on ITER physics guidelines for the core plasma transport with the static two-point model for SOL-divertor plasmas. Up to now, the applicability of the CSD model to low and high recycling states was confirmed. In the present study, taken impurity radiation and momentum loss in the divertor region into consideration, the the applicability of CSD model to the divertor detachment is investigated.

Three solutions for the low recycling state, the high recycling state and the detached state can be obtained from the CSD model. The dependence of the ratio of the decay length for the density (Δ_n) and temperature (Δ_T) in the SOL region is also examined. It is found that $\Delta_n/\Delta_T \sim T_s^{0.5}$ scaled by the SOL temperature (T_s), which is based on the experimental data, has a good potential to reproduce B2-EIRENE results [2].

1) Hayashi, N. et al. : "Simulation study of density dynamics effect on the ELM behavior with TOPICS-IB", to be published in J. Phys. Conf. Series

2) Hiwatari, R. et al. : Contrib. Plasma Phys. **48** (2008) 174.