§5. Integrated Modeling Study of Heat and Particle Control

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The magnetic confinement device of fusion plasmas 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 understanding of the interaction have not yet accomplished so far. The integrated models help to understand the interaction and establish efficient methods of heat and particle control in magnetic fusion devices. From the above points of view, we have done some works to develop the integrated modeling and to study their interaction. We here pick up the following two works.

(1) Mechanisms of ELM energy loss

An integrated code TOPICS-IB has been developed on the basis of the 1.5-dimensional core transport code TOPICS, with which a dynamic five-point model of the peripheral plasma (scrape-off-layer (SOL) and divertor plasmas) is coupled. Up to now, we applied the TOPICS-IB to the study of the energy loss caused by edge localized modes (ELMs) in tokamaks. The TOPICS-IB successfully simulated a series of transient behaviors of an ELMy H-mode plasma. The experimentally observed collisionality dependence was found to be caused by the bootstrap current, the SOL conductive heat transport and the equipartition effect. The reduction rate of total energy loss is comparable with that in experiments. The magnitude of energy loss is comparable with that in JT-60U, however smaller than JET and DIII-D with the same collisionality. Other effects may cause the difference in the magnitude.

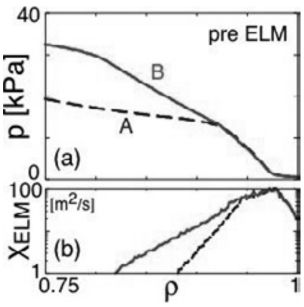

Fig.1 Profiles of (a) pressure at ELM onset and (b) ELM enhanced diffusivity for two cases A and B with different core pressure gradients inside pedestal.

We study the effect of core pressure gradient just inside the pedestal top on the ELM energy loss. Figure 1 shows profiles of pressure at the ELM onset and ELM enhanced diffusivity for two cases with different core pressure gradients just inside the pedestal and almost the same pedestal pressure gradients where the core pressure gradient is increased by reducing the anomalous transport inside the pedestal. The steep core pressure gradient just inside the pedestal top broadens eigenfunction profiles of unstable modes and thus the region of ELM enhanced transport as shown in Fig. 1. Figure 2 shows the ELM energy loss as a function of core pressure gradient just inside the pedestal for the two cases. The steep pressure gradient inside the pedestal top enhances the ELM energy loss. This prediction is being validated by the experimental analysis and preliminary results show good agreement of dependence between simulations and experiments [1].

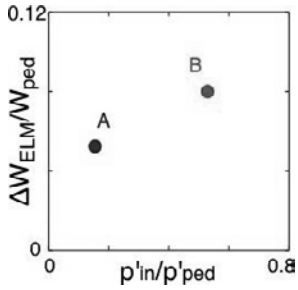

Fig.2 ELM energy loss as a function of core pressure gradient inside pedestal for two cases in Fig. 1.

(2) SOL flow driven by core particle orbits

The SOL flow plays an important role in the particle control, for example, it can control the impurity retention in the divertor region if the flow is directed towards the divertor plate. The 2D PARASOL shows complex SOL flow patterns very similar to the experimental results in upper and lower null divertor configurations with downward ion ∇B drift. By changing the aspect ratio and cutting artificially the electric field in the simulation, it is found that the finite orbit size of ions, especially trapped ions, is essential for the flow pattern formation. The outer orbit of trapped ion enhances the SOL flow in the upper null case, while it reduces the SOL flow in the lower null case. Based on the simulation results, the ion orbit induced flow is modeled by separating untrapped part and trapped part of ions, and by taking account of the collision effect and poloidal distribution. A new model of ion momentum equation with the ion orbit induced flow is derived as,

$$m\frac{D}{Dt}\left(nV_{//}\right)_g = -\nabla_{//}P + F + m\frac{\left(nV_{//}\right)_{orb,u}}{\tau_c} + m\frac{\left(nV_{//}\right)_{orb,t}}{\varepsilon\tau_c} \qquad (1)$$

where ε and τ_c denotes the inverse aspect ratio and the collision deflection time, respectively. Subscripts g, orb, u and t means guiding-center part, orbit-induced part, untrapped-ions part and trapped-ions part, respectively. Third and forth terms in RHS of Eq. (1) are collisional relaxation terms caused by untrapped and trapped ions. The relaxation terms are consistent with the neoclassical viscosity [2].

1) Hayashi, N. et al. : "Integrated Simulation of ELM Energy Loss and Cycle in Improved H-mode Plasmas", Nucl. Fusion **49** (2009) 095015.
2) T. Takizuka, et al. : "Modelling of Ion Kinetic Effects for SOL Flow Formation", Contrib. Plasma Phys. **50** (2010) 267-272.