§15. 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 developed [1] a dynamic five-point model of the peripheral plasma (scrape-off-layer(SOL)-divertor plasmas) [1)] and [2] an integrated code TOPICS-IB based on the 1.5-dimensional core transport code TOPICS extended to the integrated simulation for burning plasmas [2)]. The five-point model can reproduce both static and dynamic features obtained by particle and fluid codes with very short calculation-time. This five-point model is suitable for coupling with core transport codes. We couple the five-point model to the TOPICS and investigate the self-consistent transport covering core-SOL-divertor plasmas.

We apply the TOPICS-IB to the study of the energy loss caused by ELMs. In the TOPICS-IB, the ELM model has been developed by coupling the TOPICS with a linear MHD stability code MARG2D. In order to produce a H-mode pedestal structure, the transport is reduced to the neoclassical level in the pedestal region. When modes become unstable, an ELM is assumed to occur. The diffusivity is assumed to be enhanced according to radial profiles of eigenfunctions of unstable modes. Figure 1 shows the time evolution of electron temperature profiles during an ELM crash for typical JT-60U parameters. When the collapse of the temperature profile occurs in the pedestal region, the energy flows into the SOL and the SOL temperature rapidly increases. The increase of the SOL temperature lowers the ELM energy loss due to the flattening of the radial edge gradient. The total ELM energy loss is about three times lower than that in the case without the SOL-divertor model (i.e., fixed boundary conditions). The electron energy loss is higher than the ion one due to larger parallel heat conduction of electrons. These findings indicate the importance of the peripheral plasma. The resultant ELM energy loss is less than 10 % of the pedestal energy and is comparable to that obtained in JT-60U. [2)]

The analysis of the ELMs from multi-machine experiments has shown that the ELM energy loss decreases with increasing the collisionality. The relevant physical mechanisms, however, are not yet fully understood. We investigate the collisionality dependence of the ELM energy loss by artificially enhancing the collisionality in both models of the bootstrap current and the SOL-divertor plasmas. Figure 2 shows the ELM energy loss, $\Delta W_{ELM}/W_{ped}$, as a function of the normalized collisionality, ν^*_{ped}. The collisionality dependence is found to be caused by both the bootstrap current and the SOL transport. The bootstrap current decreases with increasing the collisionality and intensifies the magnetic shear in the pedestal region. The increase of the magnetic shear reduces the width of eigenfunctions of unstable modes, which results in the reduction of both the area of the ELM enhanced transport and the ELM enhanced transport near the separatrix. On the other hand, the parallel electron heat conduction determines how the SOL electron temperature increases. For higher collisionality, the conduction becomes lower and the SOL electron temperature increases more. By the above two mechanisms, the ELM energy loss decreases with increasing the collisionality in Fig.2. [2)]

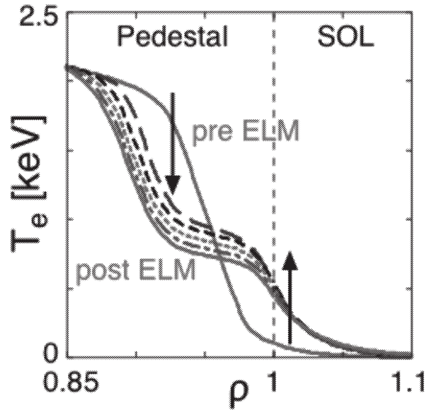

Fig.1 Time evolution of electron temperature profile of pedestal (ρ<1) and SOL plasmas (ρ>1) during an ELM crash (40 s intervals).

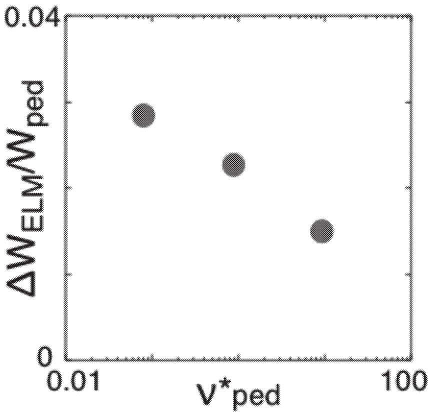

Fig.2 Dependence of ELM energy loss ΔW_{ELM} on collisionality ν^*_{ped} where ΔW_{ELM} is normalized pedestal energy W_{ped}.

Reference
1) Hayashi, N. et al. : J. Nucl. Mater. **363-365**, (2007) 1044.
2) Hayashi, N. et al. : "Integrated Simulation of ELM Energy Loss Determined by Pedestal MHD and SOL Transport", to be published in Nucl. Fusion.