§30. Modeling of Integrated Core and Peripheral Plasma for DEMO

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The aim of this collaborative work is that the development of the integrated simulation method on the control of the core and peripheral plasma for DEMO. For this aim, we carry out modeling on the critical physical issues on the control of the core and peripheral plasma for DEMO. In 2011, we focused on the following topics: (1) proposal and its critical issue on the control method for the core and peripheral plasma for the commissioning period for DEMO, (2) 1-D plasma modeling on the SOL-Divertor plasma to understand the stability and control of detachment in the divertor plasma, (3) improvement of modeling and code of the integrated core-peripheral plasma. Several results were presented in the domestic and international conferences shown in references.

As for the first topic, we firstly surveyed what kind of control method is required in a power plant based on the thermal and nuclear power plant. The inevitable control methods are controls of the rating operation, start-up operation, stop-down operation, and commissioning operation. Accordingly, we investigated the control method of plasma start-up operation including the commissioning operation for a tokamak fusion power plant. To propose the integrated control method for the core and peripheral plasma of the tokamak power plant, the analysis on MHD stability, current drive operation and divertor transport was carried out. Here, we proposed two methods to control the fusion power to keep the high density preferable for the divertor detachment[1]: one is control of the ratio of tritium in the fuel density and the other is that of helium in the ion density. In case of plasma parameters of Demo-CREST, those control methods require the confinement performance of HH>1.2 and the current drive power more than 150MW.

The other plasma control issue on the ELM was also discussed. The integrated transport code with the pellet injection was also developed, and parametric survey on the ELM triggered by the pellet injection was carried out[2]. This survey made clear the dependence of ELM energy loss on the injection speed and size of the fuel pellet. This integrated transport code will be applied to the development of the control method of ELM consistent with the fueling control for the plasma operation of ITER and DEMO.

As for the second topic, we have developed a one dimensional SOL-divertor code to investigate the physics of detachment phenomena and to control it in the divertor for the plasma operation in ITER and DEMO. This code can handle the radial transport effect in the SOL and divertor region. When the detachment is appeared in the divertor region, the energy flux comes into the detachment flux tube from the outer attachment flux tube. Our divertor code can analyze the stability on the detachment front including the effect of such radial transport. In this year, neutral particle model is improved and we analyzed the effect of both radial particle and energy transport on the stability of the detachment front. The result of this code qualitatively showed that the radial particle and energy transport in the divertor region is effective to stable the detachment front.

As for the third topic, we investigated the precise modeling on the peripheral plasma in order to integrate the core plasma modeling. First of all, an integrated code of 1.5D tokamak transport code (TOPICS) and 2D divertor transport code (SONIC) has been developed, and it was applied to the analysis on LH transition phenomena in the tokamak plasma[3].The effect of LH transition on the divertor plasma was investigated, and temporal fluctuation and burst phenomena are obtained in the simulation. To understand this result physically, we also carried out transport simulation by two point model for the SOL-divertor plasma. It was found that the burst phenomena obtained in the integrated simulation could be reproduced when the high recycling characteristics is assumed in the divertor region. We also discussed a basic equation set of a 2D core-edge transport code for the tokamak plasma configuration.

Finally, several critical issues on the future reactor plasma were investigated. In the present DEMO design, the divertor heat load is considered as a critical issue. To investigate how to reduce the divertor heat load, simulation study on the long leg geometry was done by 2D divertor transport code SONIC, and result shows that 1.5 times longer of the divertor leg make the heat load less than 10 MW/m^2, which is the design parameter in the ITER design. The main reason is the increase of radiation loss in the divertor region, which does not come to the divertor target. However, the longer divertor leg has a bad effect on the pumping efficiency, because the recycle neutral particles are trapped in the V-shape region of the divertor. The applicability of this longer leg divertor configuration to DEMO will be investigated precisely in the future.

1) R. Hiwatari,et al., "A control method of divertor plasma start-up assisted by tritium-ratio control for Demo-CREST", Fusion Engineering and Design 86, 2011, p1099–1102
2) N. Hayashi,et al., Integrated simulation of ELM triggered by pellet through energy absorption and transport enhancement, Nucl. Fusion 51 (2011) 103030
3) K. Shimizu, et al., "L/H transition simulation with integrated modeling of core and SOL/divertor transport", Plasma Conference 2011, 24P034-P (2011)