§25. 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 2010, 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. Those 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 the ratio of tritium in the fuel density to control the fusion power to keep the high density preferable for the divertor detachment[1]. Another candidate for the plasma start-up scenario is also collaboratively discussed, and the ratio of helium ash in the plasma ion density is concluded to be also pursued.

The other plasma control method on the ELM was also discussed. The integrated transport code with the pellet injection was also developed, and the modeling on the ELM triggered by the pellet injection was carried out[2]. That integrated transport code could reproduce the phenomena of ELM generation by the rapid growth of plasma pressure by the pellet fueling. 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[3]. 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. We analyzed the effect of such radial 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. To analyze it more precisely, the neutral transport modeling is a critical issue to discuss the stability limit quantitatively.

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, the simulation study on the particle wall interaction was carried out, and the effect of impurity species on the erosion was estimated in the LHD configuration. This result made the modeling basis for the effect of the impurity generated in the divertor region on the core plasma performance.

The detachment physics is also investigated. When the detachment is occurred in the tokamak configuration, the reduction of the ion particle onto the divertor plate is observed. However, this phenomenon has not been reproduced in the framework of the fluid transport modeling in the SOL-divertor region. We investigated whether the particle diffusion to the dome region and the super-sonic flow have an important effect on the ion flux or not. The result did not show the clear relationship between those phenomena and the reduction of the ion flux. We will also investigate the effect of the drift and orbit induced flow in the next year.

Finally, we also discussed the standardization of the integrated transport code, and the way to apply it to the DEMO design activity. The following considerations were pointed out. The system code for the design activity is based on the 0 dimensional modeling. However, recent improvement of PC performance probably enables the system analysis based on the multi-dimensional modeling such as the equilibrium and MHD stability code. Furthermore, how collaborative alliance among the experimental study, the integrated modeling study, and the DEMO design study should be made was also discussed. Those important issues will be discussed in the following year.

1) R.Hiwatari, et al.,Plasma commissioning scenario and initial tritium inventory for Demo-CREST FTP/P6-17, 23rd IAEA Fusion Energy Conference, Korea, Oct. 2010.
2) N. Hayashi,et al., Integrated simulation of ELM triggered by pellet through energy absorption and transport enhancement, THS/P3-02, 23rd IAEA Fusion Energy Conference, Korea, Oct. 2010
3) M. Nakamura et al., "Multi-layer" one-dimensional model for stability analysis on partially detached divertor plasmas, to be published in J. Nucl. Mater. (2011)