§26. Integrated Simulation Study of Heat and Particle Control for DEMO

Hoshino, K. (JAEA),
Kawamura, G.,
Shimizu, K., Kawashima, H., Yagi, M., Aiba, N.,
Hayashi, N., Nakamura, M. (JAEA),
Nakajima, N., Tomita, Y., Kobayashi, M.,
Takayama, A.,
Hiwatari, R. (CRIEPI), Fukuyama, A. (Kyoto Univ.),
Hatayama, A., Toma, M., Homma, Y. (Keio Univ.),
Takizuka, T. (Osaka Univ.), Ogawa, Y., Togo, S.
(Univ. Tokyo), Ohno, N. (Nagoya Univ.)

The particle and heat control toward the plasma-surface materials are the most important issue for the magnetic confinement device, such as ITER and DEMO. The purpose of this collaborative work is to understand the key physics for the particle and heat transport in the peripheral plasma and to establish its control method. For that purpose, we progressed modeling of the critical physical issues in the core plasma, the SOL/divertor plasma and the plasma-wall interaction and investigated the particle and heat control by integrated simulation. In this report, some of the collaborative works in 2012 are summarized.

(I) ELM control method

The reduction of ELM energy loss by the pellet injection for ELM pacing has been studied by an integrated core-SOL-divertor transport code TOPICS-IB with an MHD stability code and a pellet model taking account of the ExB drift of pellet plasma cloud [1]. It is found that the energy loss can be reduced by a small pellet injected from the low-field-side, which penetrates deeply into the pedestal and triggers high-n ballooning modes with localized eigenfunctions near the pedestal top. In addition, the integrated simulation successfully demonstrated the ELM pacing with the reduced energy loss with small impact on plasma performance and less particle fueling.

As for the other control method for ELM, new concept of the resonant magnetic perturbation (RMP) for tokamak DEMO reactor by inserting ferritic steel of the helical configuration was proposed [2]. Helically perturbed magnetic field is naturally formed in the axisymmetric toroidal magnetic field. Perturbation amplitude was estimated in the DEMO reactor condition and it can be enough for the RMP to mitigate/suppress ELMs.

(II) Modelling of the detached divertor plasma

In order to understand basic characteristics of the detached divertor plasma, one-dimensional SOL-divertor transport code is being developed. In 2012, the neutral model has been improved from the simple analytic model [3]. The improved code has been applied to the investigation of heat and particle balance in attached and detached regime. It was indicated that the difference in the particle balance between attached and detached regime might stabilize the partially detached divertor plasma.

Two-dimensional modeling of the detachment is important for understanding of the detachment phenomena in experiments and development of its control method in future devices. In order to improve the two-dimensional detachment modeling, the divertor code benchmark between SONIC and SOLPS was started [4]. In the preliminary analysis, similar tendency of the ion flux toward the strike point with JT-60U experiment was obtained by SONIC, while the electron temperature calculated by SONIC was lower than the experimental data. Therefore, more basic analysis by 1D modeling is necessary. SOLPS showed that effects of the neutral-neutral collision and drifts were not so large under the present calculation condition. Detailed comparison between SONIC and SOLPS will be carried out in 2013.

(III) Power handling in DEMO divertor

The investigation of the power handling in tokamak DEMO divertor was progressed by using a suite of integrated divertor codes SONIC. By the large impurity seeding, the partially detached divertor plasma is formed under the compact DEMO condition (P_{out}=500MW, R=5.5m). The divertor heat load by the plasma convection/conduction is reduced by the partially detachment. However, the heat load due to the impurity radiation and the surface recombination of the ion particle flux increase because of the large radiation power close to the target and the high recycling. As a result, the peak of the total divertor heat load becomes 16 MW/m^2. In order to reduce the total divertor heat load, effects of the divertor geometry, such as extension of divertor leg, were investigated [5]. The peak divertor heat load decreases by 30% due to decrease in the ion and electron temperature along the long filed line and enhancement of the recycling in the longer divertor leg case.

1) Hayashi N., et al.: 24rd IAEA Fusion Energy Conf., TH/5-3, San Diego, California, USA, 2012.
2) Takizuka T., et al.: 29th JSPF Annual Meeting, Fukuoka, Nov. 2012.
3) Togo S., et al.: 22th International Toki Conference, Toki, Nov. 2012.
4) Hoshino K., et al.: 29th JSPF Annual Meeting, Fukuoka, Nov. 2012.
5) Hoshino K., et al.: Contributions to Plasma Physics, 52(2012)550-554.