

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

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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 2013 are summarized.

The investigation of the power handling in tokamak DEMO divertor was progressed by using a suite of integrated divertor codes SONIC¹⁾. In development of the power handling scenario for a compact DEMO reactor, SlimCS, further reduction of the target heat load was required even in the case where more than 90% of the exhausted power from the core plasma was radiated by the Ar impurity gas seeding. The impact of the impurity seeding and the machine specifications on the power handling in the fusion reactor divertor has been investigated. With decreasing the fusion power, the divertor plasma detachment is extended and the target heat load decreases. The SONIC simulation showed the operational regime, i.e., the target heat load less than 6 MW/m² for a tungsten mono-block divertor with a ferritic steel water-cooling pipe, at the fusion power less than 2 GW. It is also showed that the impurity radiation fraction on the exhausted power can be reduced to 80% at the fusion power of 2 GW in the case of a copper-alloy water-cooling tube.

Effectiveness of suitable conditions of pellet injection for ELM pacing has been confirmed by JT-60U and then ITER simulation with an integrated core-SOL-divertor transport code TOPICS-IB²⁾. Pellet particle content required for ELM pacing is larger for the pedestal plasma with higher density and farther from stability boundary of ideal ballooning mode. For ITER standard scenario, the required

pellet particle content is about a few % of pedestal particle content, which gives physics background to present design value. It is also confirmed that fueling pellet can be injected just after ELM pacing pellet without disturbing the ELM pacing.

In order to understand the formation mechanism of the detached divertor plasma, development of a one-dimensional plasma simulation code was progressed. In 2013, the anisotropic ion temperature with virtual divertor model has been introduced³⁾. By introducing the anisotropic ion temperature directly, the second-derivative parallel ion viscosity term in the momentum transport equation can be excluded and the boundary condition at the divertor plate becomes unnecessary. Dependence of the ion temperature anisotropy on the normalized mean free path of ion has been investigated. The ion temperature shifts quickly from isotropic to anisotropic in the collisional regime. In addition, the parallel ion viscosity for the Braginskii expression has been validated. The parallel ion viscosity has a good proportional relation to the definition of the parallel ion viscosity in the source-less region, but the correlation becomes worse in the source region.

In development of the integrated code, maintainability of the integrated code is important because each code is maintained/improved independently. One of solutions for such a problem is Multi-Program Multi-Data (MPMD) parallel computing system. In the MPMD system, an integrated simulation can be carried out by multiple modules with data exchange via Message Passing Interface (MPI). Independence of each module is almost kept and therefore model improvement or implementation of new model become possible with small effort. The MPMD system has been improved mainly in the viewpoint of the data exchange method in order to restructure of the SONIC suite. The MPMD integrated simulation for the controllability of temperature at the divertor plate are carried out as a demonstration¹⁾. On the MPMD system, individual models, such as the core transport, divertor recycling, heating, impurity radiation, etc., can collaboratively simulate discharge scenario containing various physical interactions.

- 1) K. Hoshino, et al.: 23rd International Toki Conference, Toki, Nov. 2013
- 2) N. Hayashi, et al.: 30th JSPF Annual Meeting, Tokyo, Dec. 2013
- 3) S. Togo, et al.: 21th International conference on Plasma Surface Interactions, Kanazawa, Japan, May 2014.