§4. Comprehensive Investigation on the Role of Numerical Simulations for Heat and Particle Control in Fusion Reactor

Takizuka, T. (Osaka Univ.), Sagara, A., Fukada, S. (Kyushu Univ.), Furukawa, H. (Inst. Laser Tech.), Hatayama, A. (Keio Univ.), Hoshino, K. (JAEA), Ibano, K. (Osaka Univ.), Kaburaki, H. (JAEA), Kawamura, G., Konno, C. (JAEA), Masuzaki, S., Kunigi, T. (Kyoto Univ.), Morishita, K. (Kyoto Univ.), Murata, I. (Osaka Univ.), Norimatsu, T. (Osaka Univ.), Satake, S. (Tokyo Univ. Sci.), Tanaka, T.

Heat and particle control is the most critical issue to realize the fusion reactor without serious erosion of the plasma facing components. Besides experimental studies, numerical simulations play an important role for the development of the control methods.

In the DEMO divertor, the neutral density becomes high to produce the full detachment and therefore the photon trapping can become important. "Photon trapping effects in DEMO divertor plasma" were studied. The photon trapping effects in the fixed background plasma profile were evaluated using a self-consistent collisional radiative model. The recombining plasma near the inner target and the private region changed to the ionizing plasma by the photon-excitation. Iterative calculation of the SONIC including the photon trapping effects was carried out. While the electron density increased and the neutral density decreased in the wide region, the electron density decreases close to the inner strike point. This may be due to decrease in the ionization rate by decrease in the neutral density.[1)]

"Effects of classical and neo-classical cross-field transport of tungsten impurity in realistic tokamak geometry" were studied with the IMPGYRO code. In the IMPGYRO code, the Larmor orbit of a test impurity particle under Coulomb collisions with background ions, is traced. Classical and neo-classical transport processes in the SOL/ divertor plasma as well as in the core can be naturally simulated. We performed simulations for the self-diffusion of tungsten impurity in a JT-60U plasma. Background plasma profiles were calculated with SOLPS5.0. The IMPGYRO full orbit model was compared with a guiding center model. Preliminary results showed a difference in the radial average velocity at the top region of the SOL. The mechanism causing this difference was discussed.[2)]

The three-dimensional transport code, EMC3-Eirene, has been extended to simulate peripheral plasma of LHD including ergodic and divertor leg regions. "Three-dimensional transport analysis of plasma, neutrals and impurities in LHD peripheral regions with impurity gas-puff" was progressed. Qualitatively good agreement of radiation distribution was obtained between the code and the bolometer measurement. Strong radiation was observed at divertor legs in closed divertor sections and upstream plasma connected to them by the magnetic field. Radiation region moves toward the last closed flux surface when neon amount is increased beyond a certain level. The shift is caused by the reduction of T_e with increasing impurity radiation. The low T_e under intensive radiation leads to longer penetration length of neon atoms into the plasma.[3)]

Detachment of divertor plasma is considered essential to reduce particle and heat fluxes to the divertor plates drastically. "Simulation study of detached plasmas by using one-dimensional SOL-divertor fluid code with virtual divertor model" was carried out. Introducing the anisotropic ion temperature, the parallel momentum transport equation becomes the first-order differential and the Mach number at the sheath entrance is determined self-consistently by the upstream condition. The particle flux to the divertor plate and the flux amplification factor from the attached- to detached- states were shown as functions of the plasma density at the stagnation point. The dependence of these parameters on the heat flux from the core plasma, radial width of the flux tube in the divetor region and the strength of the impurity radiation was investigated.[4)]

"Bohm criterion and virtual divertor model for SOL-divertor simulation" were studied. Bohm criterion, $V_f \geq C_s$ (V_f: flow speed at the sheath entrance, C_s: sound speed), has been derived from the sheath formation condition. For two-ion-species plasma, two branches of the criterion are derived. PARASOL simulations, however, give always the upper branch but never the lower. Introducing a linear stability analysis, it was found that the upper branch is stable but the lower unstable. Also found that the Bohm criterion is not directly related with the sheath formation. Generalized fluid model with anisotropic ion temperature does not require a down-stream boundary condition on V_f. For this sake, a virtual divertor model has been developed. Simulations with a new code demonstrate that V_f exceeds C_s automatically without using the boundary condition of Bohm criterion.[5)]

Tungsten, a promising candidate as divertor plasma facing material in magnetic fusion devices, is anticipated to promptly redeposit when sputtered or evaporated from surface due to its small ionization energy and large gyro radius. "Simulations of tungsten re-deposition using a particle-in-cell code with non-uniform super particle sizes" were carried out. Treating weight, electric charge, and mass of super particles (background ion, electron and tungsten) as particle variables, a special scheme for ionization and recombination was developed. Simulations neglecting the electric force revealed the effects of ejection angles. Secondary electrons from surface weakened the sheath potential, and reduced the re-deposition rate. It was found that the multi-ionization as well as the ionization mean-free-path influences the re-deposition rate.[6)]

1) Hoshino, K. et al.: 15th Int. WS on Plasma Edge Theory in Fusion Devices (PET-15) (Nara, Japan, 2015), to be published in Contrib. Plasma Phys. **56** (2016) (CPP).
2) Yamoto, S. et al. : PET-15, t.b.p. in CPP.
3) Kawamura, G. et al. : PET-15.
4) Togo, S., Takizuka, T. et al. : PET-15, t.b.p. in CPP.
5) Takizuka, T. et al. : PET-15.
6) Ibano, K. et al. : PET-15, t.b.p. in CPP.