Kinetic integrated modelling of the start up phase for steady-state operation in ITER

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Optimization of start-up scenario of burning plasmas in tokamaks is one of the key issues in preparing research plans and designing fusion reactors. In order to accurately predict the behavior in the start-up phase of burning plasmas and to develop reliable schemes controlling them, development of integrated modeling codes for burning plasmas is needed. Fusion reactions and external plasma heating and control modify the momentum distribution functions of electrons and ions and affect transport phenomena and various instabilities as well as the heating and current-drive efficiencies. In order to self-consistently describe these phenomena, we have updated the integrated modeling code, TASK, to describe the time evolution of momentum distribution functions. Previous analyses of momentum distribution functions usually assume background species with Maxwellian distribution and the temperatures of the bulk components are fixed during the analyses. These assumptions are not satisfied in the burning start-up phase where energetic ions and electrons can be easily generated and the bulk temperature changes rapidly. In TASK, the Fokker-Planck component TASK/FP describes the behavior of the tail and bulk components including radial transport, and self-consistently simulates the start-up phase for steady-state operation of ITER plasmas. The relativistic bounce-averaged Fokker-Planck component TASK/FP describes the time evolution of the multi-species momentum distribution functions. In this modeling, axisymmetry, time scale longer than the particle bounce time, and small bounce orbit width are assumed. The Fokker-Planck equation includes nonlinear Coulomb collision, quasi-linear wave-particle interaction, parallel electric field acceleration, radial diffusion, and particle sources. In the present analysis, we employ the CDBM transport model for radial diffusion and introduced an inward pinch term to keep the initial density profile. First the dependences of external heating power (NB and EC) and heating sequence during the current ramp-up phase are studied with conventional diffusive transport simulations using TASK/TR. Then kinetic transport simulations using TASk/FP are carried out using the optimized heating parameters. The results of diffusive and kinetic transport simulations are compared with each other. In both simulations internal transport barriers are generated by the use of the CDBM transport model. Finally the dependence of the transition to a burning state on heating parameters, such as absorbed power, deposition location, and start timing of NB and EC heating has been studied, and the optimum condition for reducing total heating power is discussed.