§31. Simulation Methods in State-of-the-art Computer Systems

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It is expected that applications of massively parallel supercomputer system and peripheral equipments are effective in improving the performance of large-scale simulations in plasma and fusion. The purposes of this collaborative research are 1) to investigate the effective application of such computer systems and peripheral equipments and to verify the productiveness, 2) to investigate the models of combination of micro and macro phenomena, and the algorithms for the massively parallel computer systems, 3) to develop state-of-the-art computational techniques.

In this paper, we report the developments of PIC simulation code with particle collision model and Coulomb collision term for plasma transport simulation with many kinds of ions, the researches of Large Eddy simulation and multi-hierarchy model.

Development of PIC simulation code with particle collision model

In order to investigate the process of detached divertor plasma formation, we added the binary Coulomb collision process between charge particles by Nanbu's model [1] to electrostatic particle simulation code in addition to the collision process between charge particle and neutral particle [2]. It was found that there is a strong decrease in the electron temperature inside the neutral gas box when the neutral gas pressure is increased, and that the electron temperature in front of the divertor target decreased, which was one of the conditions for detached plasma.

Development of Coulomb collision term for plasma transport simulation with many kinds of ions

In order to deal with the transport phenomenon of impurity ions which penetrate into the core plasma, we need the numerical calculation model which handles the Coulomb collision between particle species. For helping the neoclassical transport code FORTEC-3D to handle the plasma with many kinds of ions, we developed the calculation method which expanded the linearized collision operator by δf Monte Carlo method to the plasma with many kinds of ions [3]. We performed the benchmark calculation on collision relaxation process. It was confirmed that the conservation laws which the linearized collision term should satisfy, Boltszman's H theorem, the adjointness of the operator and so on were reproduced well.

Research on Large Eddy simulation

We investigated Large Eddy simulation (LES) in order to perform an extended MHD simulation at low calculation cost. We performed both large-scale numerical simulation based on the Hall MHD model, which is one of the extended MHD simulations, and LES on uniform turbulence, and compared their results. It was shown from the comparison that Smagorinsky model, which was rooted in neutral fluid turbulence, can be applied to LES of Hall MHD [4].

Research on multi-hierarchy model

We have worked on the conjugation between PIC code and the extended MHD code, which included Hall effect, finite Larmor radius effect, and so on, in order to perform multi-hierarchy simulation on the downstream of magnetic reconnection by using the model which linked together the hierarchies appropriately. We performed simulation on Whistler wave propagation for checking validation of the model in which Hall MHD and PIC were combined, and improved the model [5,6].

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