§15. Modeling and Implementation of Gyrokinetic Simulation

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Understandings on physics mechanisms of the turbulent transport in magnetized plasmas and quantitative prediction of the transport level are still regarded as a central subject in magnetic confinement fusion research. Being based on the NIFS collaboration research, we are developing the gyrokinetic simulation code, GKV, and are promoting simulation studies on the anomalous transport caused by local plasma turbulence. Utilizing the developed simulation code, we have conducted the collaboration researches on several topics. Some of the recent topics are listed as follows: (1) Implementation and evaluation of the linear collision operator that can be applied to multi-species ion plasma with different temperatures[1]. (2) Verification of the flux tube train model for the local gyrokinetic simulation of the ion temperature gradient turbulence[2]. (3) Theoretical analysis of simulation results obtained from research collaborations.

Implementation and evaluation of the new collision operator are mainly carried out by research group members at NIFS and JAEA, where ion-ion, ion-electron, electron-ion, and electron-electron collisions are accurately solved while preserving the self-adjointness. The new collision operator has now been installed to the GKV code to check the conservation properties of particle, momentum and energy. The benchmark tests are also carried out for the thermal relaxation process through collisions of multi-ion species and for the collisional damping of zonal flows. The successful benchmark results confirm capability of the GKV code for simulations of anomalous transport processes with realistic collisional effects in multi-ion species (including impurity carbon) plasma turbulence as well as in tapped electron mode turbulence (including gyrokinetic electrons). It is also expected that the newly developed method should be useful for simulations of LHD plasma experiments of the deuterium discharge.

The flux tube train model, which is made of multiple flux tube simulation boxes connected in serial as schematically plotted in Fig. 1, has been implemented into the GKV code. The new method is useful for simulations of turbulence of which fluctuations elongate along field lines over one poloidal turn. A detailed benchmark test is carried out for the ion temperature gradient turbulence for a low magnetic shear case. Fig. 2 shows comparison of the ion heat transport coefficient obtained from the conventional single flux tube model and the flux tube train model. It is clearly found that the new method successfully reproduces the conventional flux tube results while improving the numerical properties, such as a limit on time-step size and a symmetry preserving property for image modes. Furthermore, the new method can confirm the convergence against the flux tube length (or number of cars in a train), which was not completed by the conventional model.

The research collaborations under the present subject have been promoted as the basic framework for the gyrokinetic research program using GKV, and will be continued for future works.

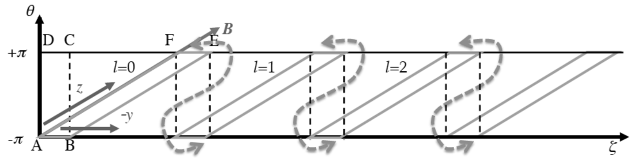

Fig. 1. Schematic view of the flux tube train model. Several flux tubes are connected in serial with the boundary condition twisted by the magnetic shear.

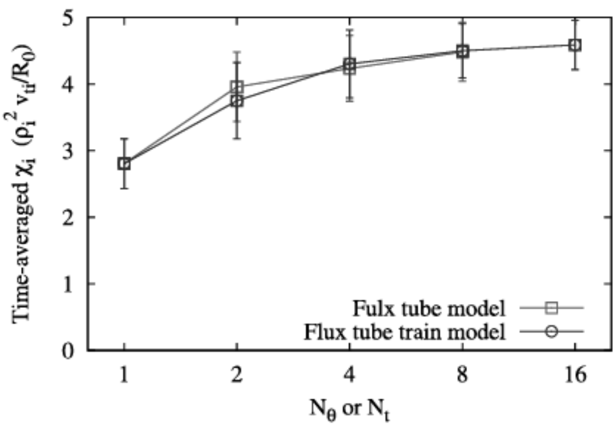

Fig. 2. Comparison of the ion heat transport coefficient obtained by GKV simulations of ion temperature gradient turbulence for cases using a single flux tube and a flux tube train model [T.-H. Watanabe, H. Sugama, A. Ishizawa, and M. Nunami, Phys. Plasmas **22**, 022507 (2015)].

1) M. Nakata et al., Plasma Fusion Res. **9**, 1403029 (2014).
2) T.-H. Watanabe, H. Sugama, A. Ishizawa, and M. Nunami, Phys. Plasmas **22**, 022507 (2015).