§8. Development of Neoclassical Transport Code and its Applications

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Neolclassical(NC) transport analysis and determination of ambipolar radial electric field are one of the key issues to study the plasma confinement property of LHD plasmas. For detailed studies of NC transport in helical plasmas without using those approximations which have usually been adopted in analytic formulae or numerical solvers of NC transport, we have developed FORTEC-3D code[1], which solves the DKE and the time evolution of radial electric field by the f Monte-Carlo method. Making use of the wide applicability of the code, we have started several research activities as followings:

Benchmark of neoclassical transport calculation with a gyrokinetic simulation

In recent gyrokinetic simulation studies on micro-instability and anomalous transport, the neoclassical effects have been attracting attention. Gyrokinetic and drift-kinetic equations are constructed from a same kinetic equation but assumes different scales in length. When one include macro-scale neoclassical effects into a gyrokinetic simulation, it should reproduce neoclassical transport in the limit of drift-kinetic orderings. GT5D gyrokinetic code was benchmarked with FORTEC-3D by comparing neoclassical transport coefficient in a simple tokamak geometry[2]. It was shown that GT5D calculation agrees with FORTEC-3D very well. This result also ensures that FORTEC-3D correctly solve NC transport with the finite-orbit-width effects, which is a higher-order term to be neglected in conventional NC theory but is included in GT5D.

New technique of GAM simulation in helical plasmas

We had used FORTEC-3D to investigate the configuration dependence of GAM oscillation in LHD plasmas[3]. In that research, however, we chose a low-ι profile to make GAM damping weaker. To adopt the code to more general situation of LHD experiments, we need to wake up GAM oscillation constantly, otherwise initial oscillation will damp quickly in helical plasma and analyzing GAM frequency from simulation result becomes very difficult. We developed a new simulation technique last year. By adding a band-limited white noise term in the equation of radial electric field evolution, GAM oscillation was constantly excited as shown in the following figure. Using this method, we will study GAM oscillation in LHD and compare the simulation with experiments.

Neoclassical toroidal viscosity calculation in perturbed tokamaks

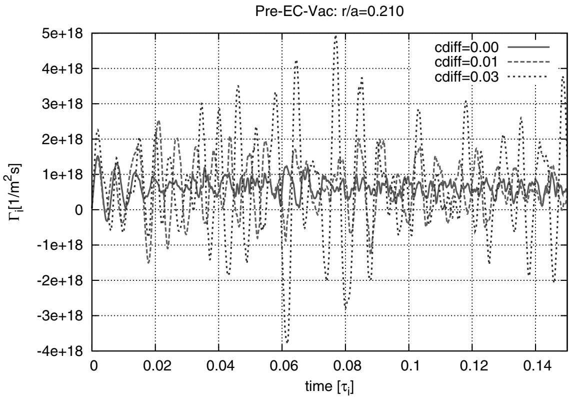

Fig. 1: GAM oscillation in FORTEC-3D simulation. GAM damps fast in LHD configuration (red line), but by adding a white-noise term (green and blue lines) it is continuously exited.

We adopted FORTEC-3D to calculate neoclassical toroidal viscosity in tokamaks with external perturbation magnetic field. Such perturbation coils are installed in some tokamaks to control ELMs. However, broken symmetry generates NC toroidal viscosity and its effect on plasma rotation damping is an important issue. NC viscosity is directly evaluated in the code from the information of f distribution function. It is expected to give more accurate solution of NC viscosity than analytic formulae. Last year, it had been verified the viscosity calculation was quantitatively accurate in LHD plasmas. Benchmark test of NC viscosity calculation and investigation of basic dependence of the toroidal viscosity on collisionality, strength of perturbation magnetic field, radial electric field and so on, are continuing this year.

Transport analysis in high-T_e LHD plasmas

LHD experiment has achieved very high-T_e plasmas in recent years which is called CERC (core electron root confinement) [4], and it is considered that positive ambipolar electric field at core region has a role to achieve a good confinement property of CERC plasmas. Because of its very high temperature and very low collisionality, however, it is anticipated that conventional tools to solve ambipolar conditions has some errors. We have started to adopt FORTEC-3D. which had originally been developed for ions, to electron NC transport calculation in super high-T_e plasmas. Code development was almost finished last year, and we will benchmark the code and then analyze CERC plasmas using experimental observation data this year.

1) Satake, S. *et al.*, Plasma and Fusion Research 3 (2008) S1062.

2) Satake, S. *et al.*, Comp. Phys. Comm. 181 (2010) 1069.

3) Satake, S. *et al.*, Nuclear Fusion 47 (2007) 1258.

4) Yokoyama, M., *et al.*, Nuclear Fusion 47 (2007) 1213.