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Study of isotope effects on transport phenomena in LHD by TASK3D
TASK3Dを用いたLHDにおける輸送現象に対する同位体効果の研究

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An integrated simulation code for helical plasmas, TASK3D, is applied to transport simulation for hydrogen/deuterium/helium plasmas in order to clarify isotope effects on transport phenomena. In this analysis, 3D MHD equilibrium module VMEC, 1D diffusive transport module TR, ambipolar radial electric field module ER and NBI heating module FIT3D are used. Dependence of the stationary state on main ion’s mass number is reported.

1. Introduction

For systematic analysis of confinement physics in helical plasmas, an integrated transport code for three-dimensional configurations (TASK3D[1]) is being developed on the basis of an integrated modeling code for tokamak plasmas, TASK [2]. In order to extend the TASK code to be applicable to three-dimensional configurations, the transport equations for the rotational transform and the radial electric field have been reformulated by taking the three-dimensional nature of configurations into account. With the new formulation, new modules for the rotational transform (EI module)[3] and radial electric field (ER module) [1] have been developed and implemented. For the neutral beam injection (NBI) heating, FIT3D module[4] has added to the TASK3D and the demonstration of simulation was shown by combining FIT3D, VMEC and TR modules, in order to check the consistency of the interface among modules[5]. In the previous studies, the transport phenomena for a hydrogen plasma have been analyzed by TASK3D. In this study, TASK3D is applied to a deuterium plasma and a helium plasma as well as a hydrogen plasma, in order to clarify isotope effects on transport phenomena.

2. Numerical Model

TASK3D has a modular structure, allowing us to conduct simulations using an individual module or combination of some modules according to the user’s objective. In this study, 3D MHD equilibrium module VMEC, 1D diffusive transport module TR, radial electric field module ER and NBI heating module FIT3D are used. Numerical scheme used in this study is shown in Fig.1. In the TR module, the following particle and heat transport equations are solved;

$$\frac{\partial}{\partial t}(n_s V') = -\frac{\partial}{\partial r}\left(V'\langle|\nabla r|\rangle n_s V_s - V'\langle|\nabla r|^2\rangle D_s \frac{\partial n_s}{\partial r}\right) + S_s, \qquad (1)$$

$$\frac{1}{V'^{5/3}}\frac{\partial}{\partial t}\left(\frac{3}{2}n_s T_s V'^{5/3}\right) = -\frac{1}{V'}\frac{\partial}{\partial r}\left(V'\langle|\nabla r|\rangle \frac{3}{2} n_s T_s V_{Es} - V'\langle|\nabla r|^2\rangle n_s \chi_s \frac{\partial T_s}{\partial r}\right) + P_s, \qquad (2)$$

where, n_s is the density, T_s is the temperature and s expresses the particle species. $V_{Es}=V_{Ks}+(3/2)V_s$, where V_{Ks} is the heat pinch velocity and D_S, χ_s, and V_s are the particle diffusion coneffcient, thermal diffusion coefficient, and particle pinch velocity, respectively, which consists of a neoclassical part and an anomalous part. S_s is the particle source and

Ps is the energy source (or sink). *t*, *r*, *V* are the time, minor radius variable of magnetic surface, and volume enclosed by the magnetic surface, respectively. The prime denotes the derivative with respect to *r*, and $\langle\rangle$ represents the magnetic surface average. The geometry factors V', $\langle|\nabla\rho|\rangle$, $\langle|\nabla\rho|^2\rangle$ in eq.(1) are calculated by the VMEC module. Since the ambipolar condition is not satisfied intrinsically due to the non-axisymmetry of helical plasmas, radial electric field E_r is determined by neoclassical transport. The time scale of the time evolution of E_r is much shorted than that for the density and temperature. Therefore, the time step in the calculation of E_r has to be smaller than that for the density and temperature. In this study, E_r is determined from the ambipolar condition by assuming the stationary state of the equation of the temporal evolution of E_r. Estimation of neoclassical particle fluxes is required for obtaining the ambipolar E_r in the ER module. For the neoclassical transport model, two models are implemented in TASK3D. One is analytic single helicity model[6] and the other is the database of neoclassical diffusion coeffcients, DGN/LHD[7], being constructed using DCOM and GSRAKE.

3. Test Simulation

Figure 2 shows one of test simulation results for H-He plasmas. Here, for simplicity, the plasma density is fixed in the transport module TR. It is also assumed that the plasma is heated by ECH and anomalous transport coefficient is set to be 1 m^2/s. For neoclassical transport model, the analytic single helicity model is used. The stationary state depends on the density ratio of ions. As the density ratio of H to He increases, positive radial electric field becomes negative at some critical density ratio. The transition of the structure of the radial electric field is sensitive to the ratio of ions.

4. Concluding Remarks

TASK3D has been applied to analysis of isotope effects on transport phenomena. Test simulation results show that there is a clear difference in the stationary state. The detail analysis using DGN/LHD and FIT3D will be reported in this conference.

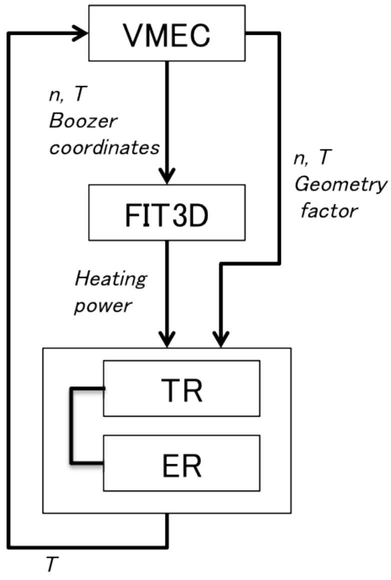

Fig.1. Numerical scheme for transport simulation by TASK3D.

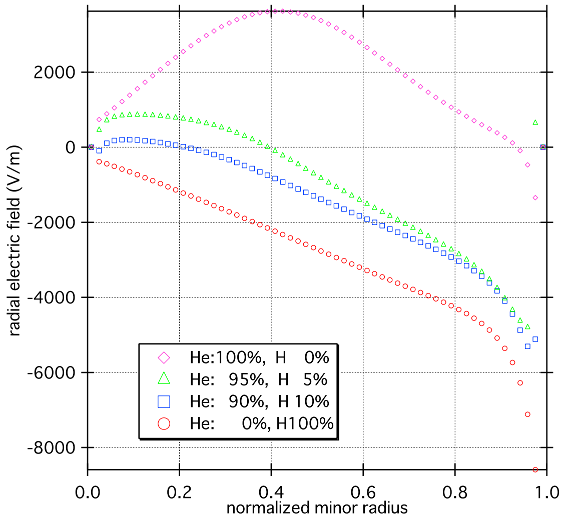

Fig.2. Structure of radial electric field at the stationary state calculated by TASK3D.

References

[1] M.Sato et al., Plasma Fusion Res., **3** (2008) S1063.

[2] A.Fukuyama et al., Proc. Of 20th IAEA Fusion Energy Conf. (Villamoura, Portugal, 2004) IAEA-CSP-25/CD/TH/P2-3.

[3] Y.Nakamura et al., FusionSci.Technol. **50** (2006) 457.

[4] S.Murakami et al., Trans. Fusion Technol. **27** (1995) 256.

[5] M.Sato et al., Proc. of 18th Int. Toki Conf. (2008) P1-05.

[6] K.C.Shaing, Phys. Fluids **27** (1984) 1567.

[7] A.Wakasa et al., Contributions to Plasma Phys. **50** (2010) 582.