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Simulation of Heat Transport in LHD Plasmas Using TASK3D code
TASK3Dを用いたLHDにおける熱輸送シミュレーション

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An integrated transport simulation code for helical plasmas, TASK3D, has been developed and applied to the LHD plasmas. In this study, the heating module and TASK3D are newly connected. We applied TASK3D to predictive heat transport simulation for the LHD experiment and compared the simulation results with experimental results.

1. Introduction

Since the various phenomena in fusion plasmas have a very wide range of time scale (1 ns to 1000 s) and spatial scale (1 μm to 10 m), and the dominant phenomena differ in each regime, we cannot describe a plasma discharge using just a single physical model. Thus, it is essential to develop an integrated transport simulation code that connects a variety of physical models describing the different time scale phenomena self-consistently. The goals of the integrated simulation code are to: 1) verify the physical models against experimental data and promote understanding of physical phenomena, 2) predict the performance of burning plasmas, and, 3) contribute to the study of equipment design and operation scenarios. For these purposes, TASK3D [1] is being developed in collaboration with Kyoto University and NIFS. TASK3D is an integrated transport simulation code for the helical plasma based on TASK [2] that is applicable for 2D tokamak configurations.

2. TASK3D

TASK3D has a modular structure and each module describes different physical phenomena. Through the data exchange interface, each module is connected and the plasma is described self-consistently. In non-axisymmetric systems, the helical trapped particles increase the neoclassical transport as the temperature of the plasma is raised (1/ν regime). Moreover, in non-axisymmetric systems, neoclassical transport has a strong dependence on the radial electric field. Therefore, it is important to accurately evaluate the neoclassical transport. To evaluate the neoclassical transport, we have constructed the neoclassical transport database module, DGN/LHD [3]. For calculating the neoclassical diffusion coefficient, we have used the DCOM [4] and GSRAKE [5] codes. We apply the Neural Network method to fitting these results of the diffusion coefficients of LHD. Using the DGN/LHD, we can evaluate the neoclassical transport coefficient accurately even in high-temperature plasmas and finite beta plasmas. We also have developed the radial electric field calculating module, ER, which calculates the radial electric field determined by the neoclassical ambipolar condition using DGN/LHD. And the TR module solves the 1D diffusive transport equation for the density, the temperature, and the toroidal angular momentum of each plasma species and the poloidal magnetic field. So far, heat transfer analyses have been performed in various LHD Plasma Using TASK3D. So far, the heat transport analysis has been performed in various LHD plasmas using TASK3D (mainly using TR, DGN/LHD, and ER modules)[6].

In this study, we newly connect the heating module and TASK3D. The FIT3D code [7] has been generally used for the NBI deposition analyses in LHD plasmas. As a result, it became possible to evaluate the power supply from the NBI whenever there was a change in profile of magnetic field, density, temperature, and so on. This made possible the predictive simulation for the LHD plasma, especially NBI plasma.

3. Simulation Condition and Results

We applied TASK3D to predictive heat transport simulation of the LHD experiment. The characteristic parameters of assumed plasma are R_{axis} is 3.6m and B_0= -2.75T. In this simulation, we assume that the thermal transport coefficients are given as the sum of a turbulent term χ^{TB} and a neoclassical term χ^{NC} and assume that the turbulent diffusivity of the electrons and the ions are equal. We have implemented the turbulent transport model as per the gyro-Bohm model;

$$\chi^{TB}_{\text{gyro-Bohm}} = C_{\text{gyro-Bohm}}\left(T/eB\right)\left(\rho/L\right),$$

where $C_{\text{gyro-Bohm}}$ is a constant factor to match the simulation results with experimental results; in this simulation, we use the value of 16, which had been determined on the previous transport analysis in LHD plasma (#88343, T_e and T_i measured) so as to properly fit the electron and ion temperatures obtained by TASK3D simulation to experimental results. In this simulation, the density profile is fixed as shown in Fig.1. We assumed the NBI heating plasma and each NBI power of port through is: #1=2.15MW, #2=3.19MW, #4=3.6MW, #5=5.6MW, and not incident from #3. We re-calculate the NBI heating power deposition along with the time evolution of electron and ion temperatures. By repeating the procedure, the steady temperature profile is obtained as shown in Fig.1. Experiments were performed to validate the simulation. In the experimental results, the electron and ion temperature at r/a=0 was 2.7keV and 2.1keV respectively. The electron temperature obtained by the predictive simulation is about 10% lower than the experimental result, and the ion temperature obtained by simulation is in good agreement with the experimental result. Thus, the simulation results are found to be reasonable. The obtained electron and ion thermal diffusivities with the gyro-Bohm models are shown in Fig.2. Here, we also show the neoclassical thermal diffusivity. It is found that the turbulent transport dominates in the electron thermal transport.

We will show and compare the simulation results considering other turbulence models.

4. Summary

The development of integrated transport code is an important issue. TASK3D is being developed in collaboration with Kyoto University and NIFS, and the steady-state analysis has been performed using TASK3D so far. By improving the connection of TASK3D and the NBI heating module newly, we can calculate the time evolution of LHD plasma with calculating NBI power deposition. Predictive simulations are performed using TASK3D in LHD plasmas and are compared with experimental results. In this presentation, we will show more detailed comparisons.

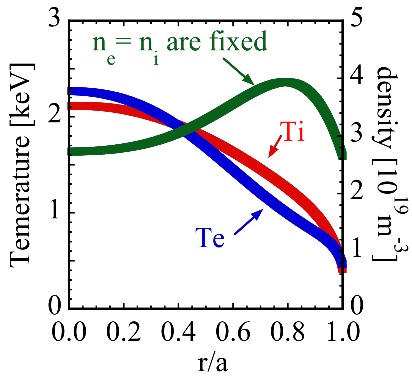

Fig.1. TASK3D simulation results of electron and ion temperature.

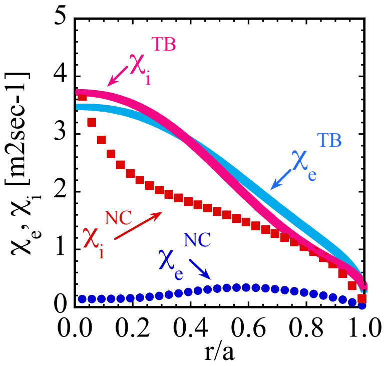

Fig.2. The obtained thermal diffusivities of ions and electrons with the gyro-Bohm model and the neoclassical transport by TASK3D simulation.

Acknowledgments

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