

#### §4. Development and Application of Integrated Transport Code for Helical Plasmas, TASK3D

Yokoyama, M., Wakasa, A. (Kyoto Univ), Seki, R., Sato, M., Murakami, S. (Kyoto Univ.), Suzuki, C., Nakamura, Y. (Kyoto Univ.), Fukuyama, A. (Kyoto Univ.), LHD Experiment Group

The Large Helical Device (LHD) experiments have steadily expanded the parameter regime of helical plasmas<sup>1)</sup>. In order to deepen and further increase the physics understandings, the integral simulation code applicable to LHD experiments is indispensable. We, therefore, are developing an integrated transport code, TASK3D, by modifying modules in TASK<sup>2)</sup>. For the development, the wide-range applicability is required, and, in the mean time, verification of each module and its integration should be performed. The simulation code is designed to predict the overall time evolution of observable physics quantities in the plasma core, based on the diffusive transport equation with fluxes and source/sink terms for the particle and heat incorporating the three-dimensional (3D) nature of magnetic configurations. The applications of TASK3D to LHD experiments are of great importance. It should increase physics understandings, accurate discussion and scientific systemization for phenomena observed in LHD experiment. On the other way, it will provide significant opportunities to improve the models/extend the modules through the validation process. Based on such progresses, predictive capability of TASK3D can be increased.

Recently, one of emphases for the application of TASK3D to LHD experiment has been put on the heat transport analyses. It consists of two aspects: one is the predictive, and the other is interpretive analysis. This has been performed by packaging modules, TR, DGN/LHD, and FIT3D, along with 3D equilibrium modules, VMEC and BOOZER.

For the predictive analysis, the sum of the neoclassical (NC) heat diffusivity estimated by DGN/LHD and assumed anomalous transport contribution to the heat diffusivity,  $\chi(r_{\text{eff}})$ , is given to TR module so that the profile evolution is solved in a time-dependent manner along with the NBI deposition profiles,  $P_{\text{NBI}}(r_{\text{eff}})$ , calculated by FIT3D with assumed beam information. One-dimensional transport is analyzed in the direction of effective minor radius  $r_{\text{eff}}$ . A wide range of anomalous transport models has been implemented in TR module, so that the variety of validation studies and predictive analyses are available<sup>3)</sup>. This has been made possible through the fast and accurate evaluation of NC contribution by equipment of DGN/LHD. Estimated NC ambipolar  $E_r$  (by module ER) is also taken into account for the estimate of the NC heat diffusivity in DGN/LHD. So far, the equilibrium is fixed throughout the evolution of the temperature profiles. NBI power deposition is repeatedly evaluated by FIT3D during the evolution of temperatures. Then the temperatures reach steady-state profiles. The

steady-state profiles calculated here are considered to be a “prediction” of the achievable temperature profiles under an assumed NBI heating condition and an anomalous transport model. An experimental discharge corresponding to the employed conditions, such as the density range and NBI input power, was conducted for the validation. The differences of temperature profiles between the prediction and measurement provide several clues for the modification of assumption of the anomalous transport contribution. Such systematic study will be performed with the predictive analyses by TASK3D and comparisons with measurement in corresponding discharges. In this way, anomalous transport modelling appropriate for LHD plasmas is anticipated to be elucidated, to provide the reliable basis for the predictive capability towards further extension of plasma parameters.

On the other hand, the “interpretive” analyses are based on the measurement (so called, power balance analyses). For this purpose, a module package, TR-snap<sup>4)</sup>, has been established. It has included modules, TR and FIT3D, along with the implementation of equilibrium geometry information from VMEC equilibria. Recent progress of its application to LHD experiments is to establish the interface to the real-time magnetic coordinate mapping system<sup>5)</sup>. This system (so called TSMAP) has provided a mapping from the real coordinates to the effective minor radius ( $r_{\text{eff}}$ ) using based on wide-range of pre-calculated VMEC equilibrium database. Thus, establishing the interface between TSMAP and TR-snap has significantly enhanced the capability of quick interpretive analyses. The interface includes the functions as follows: to prepare a VMEC input by utilizing “best-fitted” equilibrium parameters (for VMEC equilibrium reconstruction, and then transformed into the Boozer coordinates for providing equilibrium information to other modules), to describe measured temperature and density profiles as a function of  $r_{\text{eff}}$ , and to acquire NBI energy/port through power. TR-snap is currently extending for implementing modules to be applicable to ECH (LHDGauss) and ICH (WM) heating in LHD. Thus, comprehensive analyses for a wide range of heating scenario in LHD experiments should become possible as its extension proceeds.

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