1-3. Theoretical Study

Theoretical and simulation studies, which have been done on the Large Helical Device (LHD) plasmas through the NIFS collaborative research programs in the Japanese fiscal year 2015, are reported in this section.

Effects of shear flows on the magnetohydrodynamics (MHD) property of LHD plasmas are studied by numerical simulations using the three-dimensional (3D) numerical codes, HINT and MIPS. In the simulations, a finite poloidal flow is included in the initial conditions and the profile of the flow is chosen to be close to an experimental data. The simulation results show that the interchange mode grows linearly and saturated nonlinearly and that the mode generates local vortices around the resonant surface so as to generate high and low pressure regions. The rotation of the global mode due to the poloidal plasma flow is also reproduced.

Effects of the thermal conductivity on the resistive ballooning mode in high beta LHD plasmas are investigated to clarify how high beta plasmas are obtained in LHD experiments. The HINT2 code is used to construct the MHD equilibrium. The thermal conductivity is generally anisotropic and the thermal conductivity parallel to the magnetic field line is extremely larger than one perpendicular to the magnetic field line. A stabilizing effect of the large parallel thermal conductivity on the linear growth rate of the resistive ballooning mode is confirmed by the simulation.

A new MHD code is developed to investigate effects of the broken solenoidal condition and/or the plasma deformation on LHD plasmas. The 4th order finite difference method and the Rational Constrained Interpolation Profile (R-CIP) method are adopted as the computational techniques, based on which the linear and non-linear MHD codes are constructed. The developed codes are applied to the simple cylinder plasma equilibrium and the validities of our codes are checked. The code is to be modified in order to appropriately treat the indifferentiable quantities between the plasma and pseudo-vacuum regions in the LHD.

A comparison is made between three-dimensional transport simulation and impurity radiation measurement in the RMP (resonant magnetic perturbation) assisted detachment discharge in the LHD in order to clarify to what extent the current transport model can reproduce and interpret the phenomena. In both experiments and simulations, the radiation is peaked at the upper part of the figure (i.e. inboard side of torus) in the attached phase. The numerical simulations reproduce the experiments qualitatively, but the radiation is more concentrated around the X-point trajectories than the experiments. The current transport model predicts more peaked distribution than the experiments. As a possible reason for the difference, a drift motion of impurity due to ExB or gradient of magnetic field is considered. A further analysis and improvement of the transport model are underway.

In order to optimize the ICRF heating condition for LHD experiments, the transferred power evaluation code is developed using the simple model where the fast ions is produced on the resonance layer by the ICRF wave. In this code, the re-entering fast ions are included, which is important for analyses of fast ions in LHD plasmas. In the LHD typical ICRF discharge, the transferred power efficiency is evaluated by using the developed code.

The integrated transport analysis suite, TASK3D-a (Analysis), has been developed to be capable for routine whole-discharge analyses of plasmas confined in 3D magnetic configuration such as the LHD. The suite is further extended through implementing additional modules for neoclassical transport and ECH deposition (LHDGauss) for 3D configurations. The module is also added for creating the systematic data for the International Stellarator-Heliotron Confinement and Profile Database (ISH-DB). In addition, data uncertainty quantification (UQ) tool and improvement of NBI modules for multiple-ion species plasmas are highlights of recent development. Further extensions are to be pursued towards full-integration by incorporating modules for other physics process such as re-distribution of energetic particles and particle transport issues.

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