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 2014, are reported in this section.

Linear stability analyses of LHD plasmas including resonant magnetic perturbation (RMP) are done numerically by utilizing the HINT2 and MIPS codes for equilibrium and stability calculations. Dependences of the interchange mode growth rate on the viscosity and the RMP amplitude are investigated. It is found that the reduction of the growth rate due to the viscosity is more evident in the case with the RMP than without it.

In LHD, energetic ions produced by NBI are lost due to the charge exchange reaction with cold ions, which leads to the degradation of the heating efficiency of NBI. In order to examine the mechanism of the charge exchange loss due to cold ions, numerical simulations are done using the MORH code, which is a Monte Carlo code to calculate the steady state distribution function by tracing the orbits of energetic particles scattered by Coulomb collisions and charge exchange processes. Density profiles of energetic ions produced by co-NB and ctr-NB are calculated and the charge exchange loss in the core plasma region is shown to be more influential on energetic ions in the co-NB case than in the ctr-NB case. Heating efficiencies for the two cases are also evaluated.

Steady state plasmas can be produced by the ICRF minority ion heating in LHD and long-time discharges are successfully maintained for about one hour. In order to optimize the ICRF heating, simulation codes are developed for calculation of the wave propagation, absorption, and power transfer from fast ions produced by ICRF to a bulk plasma. The transferred power efficiency defined by the ration of the transferred power to the absorption power from the ICRF waves is evaluated by the developed code for typical ICRF discharges in LHD. The comparison of the transferred power efficiency between the developed code and another full Monte Carlo code shows a good agreement. The profile of the transferred power is also calculated and its dependence on the plasma density is clarified.

The three-dimensional edge fluid transport code, EMC3-EIRENE, has been implemented in order to analyze transport processes in stochastic magnetic field regions in LHD plasmas. The code solves the Braginskii equations for particle, momentum, and energy conservations, in which the parallel transport along field lines is prescribed by classical formulae. The cross-field transport coefficients are selected as free input parameters such that the simulation results best fit the profiles of the electron temperature and density obtained in LHD experiments.

Turbulent transport in a high ion temperature discharge of the Large Helical Device (LHD) is investigated by means of electromagnetic gyrokinetic simulations, which include kinetic electrons, magnetic perturbations, and full geometrical effects. Including kinetic electrons enables us to firstly evaluate the particle and the electron heat fluxes caused by turbulence in LHD plasmas. The simulation reproduces the electron energy transport observed in the experiment, and gives the inward turbulent particle flux. The contribution of magnetic perturbation to the transport is small because of very low beta.

The integrated transport analysis suite, TASK3D-a, has been developed and applied mainly to NBI-heated LHD plasmas. Further extension is conducted such as including ECH ray-tracing codes (TRAVIS and LHDGauss) and the module for creating ascii files to be registered onto the International Stellarator-Heliotron Confinement Database. Inclusion of the ECH ray-tracing code can significantly enhance systematic energy transport analysis of ECH- (and NBI-) heated LHD plasmas, for which previously stand-alone ECH absorption calculations were performed. Physics analyses on plasma flows, Alfven eigenmodes, and energetic particles are in progress. Accumulation of TASK3D-a analysis results has led to the attempt at deducing functional fittings for radial profiles of the electron and ion heat diffusivities with local parameters. Such deduced fitting expressions can be directly implemented into the predictive modeling.

(Sugama, H.)