2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Two-dimensional modeling of plasma production and heating by electromagnetic waves including collision-less damping

Atsushi Fukuyama
Department of Nuclear Engineering, Kyoto University
e-mail: fukuyama@nucleng.kyoot-u.ac.jp

Electromagnetic waves have been widely utilized for plasma production and heating in various plasma applications, e.g. plasma processing and nuclear fusion. In order to quantitatively describe the time evolution of density and temperature in a confined plasma, self-consistent analysis of wave excitation, propagation and absorption and transport of plasma and neutral particles is required. For this purpose, a two-dimensional full wave analysis component TASK/WF2D and a transport analysis component TASK/TF2D have been developed [1] as a part of the code package TASK. Both components are implemented by the finite element method (FEM) with triangular elements for various configuration, e.g. rectangular, axisymmetric cylindrical, and axisymmetric MHD equilibrium coordinates, and are parallelized using the parallel matrix solver libraries, such as PETSc and MUMPS.

The full wave component TASK/WF2D solves Maxwell's equation for wave electric field or vector and scalar potentials with fixed frequency as a boundary-value problem. Waves can be excited by wire antenna currents, wave guides on wall, or electrodes. In most of previous full wave analyses, plasma response has been represented by dielectric tensor with cold plasma approximation including collisional dissipation. Kinetic response of plasma, e.g. Landau damping, cyclotron damping and finite gyro-radius effects is usually expressed in terms of wave number which is well-defined in a homogeneous plasma. Since the wave number cannot be obtained a priori when FEM is employed in an inhomogeneous plasma, innovative wave analysis scheme free from wave number is required. Recently the integral form of dielectric tensor has been introduced to describe kinetic response of plasma. With this component, the influence of Landau damping in Helicon wave heating was evaluated.

The plasma transport component TASK/TF2D solves the advection-diffusion equation for density and temperature of electrons, ions and neutral particles as well as Gauss's law of the electric field, Poisson equation. The following atomic processes are included; thermal ionization, wave-induced ionization, elastic collision, charge exchange, line radiation, and bremsstrahlung. Bohm condition is used for the boundary condition along the field line and the recycling condition for perpendicular direction. In order to mitigate numerical instability driven by strong advection due to parallel electric field, the upwind FEM is employed.

By combining these two components of TASK, plasma production using the electron cyclotron waves, helicon waves, lower hybrid waves and ion cyclotron waves are simulated. First, the density dependence of the plasma production rate and absorbed power are examined. The spatial profiles of plasma production and heating and their input power dependence are discussed. Next, the time evolution of plasma density and temperature as well as its input power dependence are studied. Finally schemes of optimization and the dependence on antenna excitation mode are discussed

References

[1] A. Fukuyama et al.: Proc. of International Symposium on Plasma and Flow Simulation for Materials Processing (ISPFS, July 1997, Sendai, Japan)