Formulation of two-dimensional transport in tokamak plasmas for integrated analysis of core and peripheral plasmas

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In most of core plasma transport simulations in tokamaks, the particle density and the temperature are assumed to be almost constant on a magnetic surface, and flux-averaged quantities are used to describe transport phenomena as a one-dimensional problem, since the transport along the field line is very fast. On the other hand, transport in a peripheral SOL-divertor plasma is usually described as a two-dimensional problem. The analyses, however, often employ simplified models for plasma flow and spatially constant transport coefficients, which are questionable for whole plasma transport modeling. By using a more rigorous model for two-dimensional transport, transport analysis of transient phenomena with poloidal-angle dependence and more consistent analysis including both core and peripheral plasmas will become available.

In the present study, a set of transport equations in the magnetic flux coordinates was derived from Braginskii's equations [1]. We assume four assumptions to derive these equations. The first is that plasmas are axisymmetry, the second is that quantities related to MHD equilibrium depend only on the flux label, the third is that phenomena at the Alfvén velocity are much faster than diffusion of the magnetic field and transport phenomena, and the forth is that time derivatives of the basis vectors are ignored when taking time derivatives of physical vector quantities. The set of equations is composed of continuity equation, energy transport equations and velocity equations including the neoclassical viscosity [2], for each particle species. It is coupled with a set of equations for electromagnetic field; Grad-Shaftranov equation for MHD equilibrium, diffusion equation of magnetic flux [3], and Poisson equation for electrostatic potential. The two sets of equations are reduced to two-dimensional with axisymmetry and the finite element method is used to discretize the differential equations. In order to improve the numerical stability and accuracy, the magnetic surface coordinates are used for spatial mesh and the SUPG method [4] is introduced for stabilizing advection-driven numerical instabilities.

Derived sets of equations and preliminary numerical results of the two-dimensional transport analysis will be presented.

[1] Braginskii S. I., In Reviews of Plasma Physics, Vol. 1 (Leontovich, M. A., Ed), Consultants Bureau, New York (1965) 205
[2] S. P. Hirshman and D. J. Sigmar, Neoclassical Transport of Impulities in Tokamak Plasmas, Nucl. Fusion Vol. 21 (1981) 1079
[3] M. Honda, Simulation tequnique of free-boundary equilibrium evolution in plasma ramp-up phase, Comput. Phys. Comm. 181 (2010) 1490-1500
[4] Brooks, A. N. & Hughes, T. J. R., Streamline upwind / Petrov-Galerkin formulations for convection dominated flows with particular emphasis on imcompressive Navier-Stokes equations, Comput. Methods Appl. Mech. Engrg., 32 (1982)