Development of High Accuracy and High Speed Code for Flowing Two-fluid Equilibrium

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Recently, it is recognized that two-fluid effect which consists of ion diamagnetic and inertial effects are significant for smaller scale length, higher beta, and flow velocity approaching the ion diamagnetic drift velocity. The formalism for flowing two-fluid equilibria is developed [1]. The two-fluid equilibrium system is described by a pair of second-order partial differential equations for two surface variables, i.e., the magnetic and ion stream functions, and Bernoulli equations for the density. The system with small but non-zero two-fluid parameter is identified as a singular perturbation problem. This singularity is eliminated by nearby-fluids ordering that the ion and electron flow surfaces are assumed to be close to each other but do not coincide exactly [2]. This elimination of the singularity facilitates to obtain numerical equilibrium solution. However, it leads to a pseudo singularity when the Alfvén Mach number corrected by this ordering approaches unity. For solving this problem, a new equilibrium solver which employs a high-speed iterative method, the multi-grid method [3] to reduce an increase in CPU time is developed to perform a high-speed, high-accuracy computation without using this ordering. The purpose of this study is to apply this solver to a two-fluid equilibrium for geometry and boundary conditions of the NSTX device, and to investigate the convergence properties of the numerical solution. Numerical experiments show that the convergence rate of the residual for the numerical solution is kept at approximately constant with respect to the iteration number of the loop outside the multi-grid iteration (inner loop) and that the average value of the toroidal current density at the symmetry plane converges at the inverse square with respect to the mesh numbers. The multi-grid method is effective for solving the two-fluid flowing equilibrium equations with numerical stability, high accuracy, and high speed.

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