Two-fluid Flowing Equilibria of Helicity-driven Spherical Torus Plasmas

T. Kanki[1], M. Nagata[2], and T. Uyama[2]

[1]*Japan Coast Guard Academy, Kure, Hiroshima 737-8512, Japan*

[2]*Department of Electrical Engineering, University of Hyogo, Himeji, Hyogo 671-2201, Japan*

Many spherical torus (ST) experiments such as CTX, SHPEX, FACT/HIST, HIT-II, SSPX, and NSTX have been performed to make progress in elucidation of a mechanism for magnetohydrodynamic (MHD) relaxation phenomena and current drive by coaxial helicity injection (CHI). In these experiment, ion toroidal flow related to the toroidal mode number n=1 is observed during CHI. This fact has offered a crucial issue of the equilibrium and stability properties of flowing plasmas. Especially, importance of a flowing two-fluid effect has recently attracted considerable interest in the high-β operation regimes of ST. The flowing equilibria based on the two-fluid model are expected to explain the MHD stability of high-β ST configuration. However, details of concerning how such the flowing two-fluid model affects the MHD equilibrium configurations of helicity-driven ST (HD-ST) are not investigated numerically. The purpose of present study is to numerically determine the flowing two-fluid equilibrium configurations of HD-ST and to explore their properties. The axisymmetric equilibrium of the flowing two-fluid was described by a pair of second-order partial differential equations for the magnetic and ion flow stream functions, and Bernoulli equation for the density [1]. By applying the two-fluid formulation to the HD-ST equilibrium with purely toroidal ion flow, we modify the non-flowing single-fluid equilibrium code [2] which computes the HD-ST equilibrium in the more realistic region including the spherical flux conserver (FC) and the magnetized coaxial plasma gun of HIST [3]. In this code, the computation of HD-ST equilibrium reflects the realistic condition that the bias coil flux penetrates the FC wall and the electrode. We employ the finite difference and the boundary element methods as the numerical approach incorporating this situation to solve the equations governing the flowing two-fluid equilibria. The numerical results show that the electron fluid near the central conductor is tied to the external toroidal field and the ion fluid is not. The magnetic field profiles change from the HD-ST with high-q (q>1) and low-β ($\langle\beta\rangle \approx 2$ %) through the spheromak and the RFP to the HD-ST with low-q ($0<q<1$) and high-β ($\langle\beta\rangle \approx 20$ %) as the external toroidal field at the inner edge regions decreases and reverses the sign. The two-fluid effects are significant in this equilibrium transition when the ion diamagnetic drift is dominant in the ion fluid flows.

[1] H. Yamada, T. Katano, K. Kanai, A. Ishida, and L. C. Steinhauer, Phys. Plasmas **9**, 4605 (2002).

[2] T. Kanki, M. Nagata, T. Uyama, S. Ikuno, and A. Kamitani, J. Phys. Soc. Jpn. **67**, 140 (1998).

[3] M. Nagata, T. Kanki, N. Fukumoto, and T. Uyama, Phys. Plasmas **10**, 2932 (2003).