§20. Theoretical Study and its Experimental Verification for Effects of Toroidal Currents on MHD Equilibrium

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The MHD equilibrium is the basis of both most theoretical considerations and physics interpretation of the experimental results. In recent experiments, net toroidal currents, which are the bootstrap and Ohkawa and so on, were observed. Net toroidal current affects the topology of the magnetic field. In particular, in low magnetic shear configuration like Heliotron J, appearing of magnetic islands and ergodization of the magnetic field are expected. In order to consider the sensitivity of the configuration, the topological study is necessary using the code without the assumption of nested flux surfaces such as HINT/HINT2 [1, 2] and PIES [3] codes. In this study, MHD equilibrium including net toroidal currents of Heliotron J device is studied using HINT2 code.

In previous studies [4, 5], the effect of the net-toroidal current on the magnetic configuration was studied. Since the magnetic shear in Heliotron J configurations is very weak, the magnetic field is sensitive to the change of the rotational transform. If the net-toroidal current follows the direction to increase the rotational transform on the magnetic axis, large magnetic islands appear and magnetic field lines become stochastic in the peripheral region. Then, the plasma volume decreases. On the other hand, if the net-toroidal current follows to the oppsite direction, magnetic islands disappears and clear flux surfaces are kept. Thus, to keep clear flux surfaces, the control of the net-toroidal current is necessary.

Figures 1 (a) and (b) show Poincaré plots of magnetic field lines for finite-β equilibria with/without the net-toroidal current, respectively. The profile of the plasma pressure is specified to $p = p_0(1-s)^2$, where s is the normalized toroidal flux at the plasma edge. For the net-current free, clear flux surfaces are kept. However, in above mentioned, the net-toroidal current breaks clear flux surfaces. To suppress the net-toroidal current, the feedback control by the electron cyclotron current drive (ECCD) is simulated. In fig. 1 (b), a result of the feedback control is shown. In this case, two net-toroidal currents flow with two profiles; (i) $\mathbf{j}_{\rm net} = \mathbf{j}_0(1-s^2)s^2$ and (ii) $\mathbf{j}_{\rm net} = \mathbf{j}_0(1-s)^8$. The profile (i) simulates the bootstrap current and another simulates the ECCD. In fig. 1 (b), in spite of suppressing the net-toroidal current, magnetic islands appear and field lines become stochastic. This means the magnetic configuration is not affected by the net-toroidal current but by the local current on the flux surface. Thus, to control the local current, studies how to drive the current and to control the profile are necessary as an urgent issue.

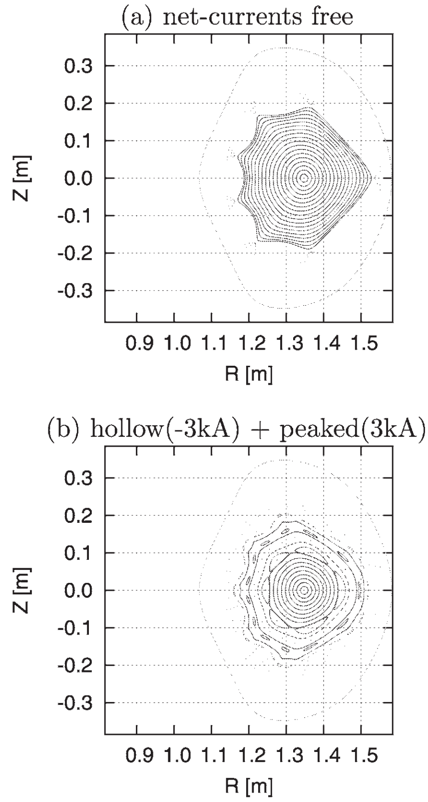

Fig. 1: Poincaré plots of magnetic field lines for finite-β equilibria with/without the net-toroidal current are shown, respectively.

1) Harafuji, K., *et al.* : J. Comput. Phys. **81** (1989) 169.

2) Suzuki, Y., *et al.* : Nucl. Fusion **46** (2006) L19.

3) Reiman, A., *et al.* : Compt. Phys. Commnun. **43** (1986) 157.

4) Mizuuchi, T., *et al.* : Nucl. Fusion **47** (2007) 395.

5) Motojima, G., *et al.* : Nucl Fusion **47** (2007) 1045.