Time evolution of the rotational transform profile in current-carrying LHD plasmas

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Though the net plasma current is not necessary for MHD equilibrium in helical plasmas, finite net toroidal currents have been observed in actual experiments. It is considered that the non-inductive current such as bootstrap current and beam driven current is the main component of the net plasma current. In the neutral beam (NB) heated LHD plasmas, non-inductive current driven by the NB injection to the co(counter)-direction increases (decreases) vacuum rotational transform. Both experimental results and numerical analyses show that the abrupt change of plasma current by the beam driven current is suppressed by the inductive component of the plasma current[1,2]. Because of the finite resistivity, total net current gets close to the non-inductive one with time, but it takes more than 4s to get the stationary state.

If the direction of NB injection is switched from the counter-direction to the co-direction in LHD experiments, the MSE measurement shows that the rotational transform is increased at the peripheral region as usual but it is decreased rapidly at the central region. Time duration for which the decreased central rotational transform is maintained seems to depend on the electron temperature. These experimental results indicate the importance of time evolution of the inductive current profile.

On the other hand, simulation studies for the rotational transform profile or net toroidal current profile in helical plasmas are performed[1,2] in association with the development of the integrated transport code for helical plasmas, TASK/3D code[3]. In these studies, time evolution of the rotational transform by the plasma resistivity in a non-axisymmetric plasma is obtained by solving the following equation;

$$\frac{\partial \iota}{\partial t} = \left(\frac{\phi_a}{s} \frac{\partial \phi_a}{\partial t} \right) \frac{\partial \iota}{\partial s} + \frac{1}{{\phi_a}^2} \left[\frac{\partial}{\partial s} \left\{ \eta_\parallel \mathcal{V}' \frac{\langle B^2 \rangle}{{\mu_0}^2} \frac{\partial}{\partial s} (S_{11}\iota + S_{12}) \right\} + \frac{\partial}{\partial s} \left\{ \eta_\parallel \mathcal{V}' p' (S_{11}\iota + S_{12}) - \eta_\parallel \mathcal{V}' \langle \boldsymbol{J}_s \cdot \boldsymbol{B} \rangle \right\} \right]$$

where S_{11} and S_{12} are susceptance matrix elements[4] calculated by the metric tensors of three dimensional equilibrium, and $\langle \boldsymbol{J}_s \cdot \boldsymbol{B} \rangle$ represents the non-inductive current.

We will apply this simulation code to the LHD experiments in which the direction of NB injection is switched from the counter-direction to the co-direction, and clarify the role of inductive plasma current profile quantitatively.

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