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JT-60Uにおける電流ホール平衡の過渡応答の解析
Analysis of transient response of current hole equilibria in JT-60U

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A nearly zero current density region in the central part of a tokamak plasma, "current hole", is observed [1]. Increase in the off-axis noninductive current j_{NI} causes reduction in the central toroidal electric field $E_\phi(0)$ and the central current density j(0) through the Faraday's law, resulting in the current hole. The fact that no significant reversed current has been observed so far suggests that j(0) does not become negative even when $E_\phi(0)$ is negative, which is called "current clamp". When j_{NI} is present in the central region, this condition could be generalized such that j(0) is not negative for negative $\sigma E_\phi(0)+j_{NI}$, though evaluation of j_{NI} and the electrical conductivity σ is not confirmed yet in the current hole. In JT-60U, co and counter ECCD were applied in the current hole, but neither positive nor negative current was observed during the ECCD period (0.8 s). This is the first experimental observation of current clamp. Furthermore, it showed that the j(0) does not become *positive* in some cases even in presence of *positive* $\sigma E_\phi(0)+j_{NI}$, which was not predicted by any theory.

In the analysis of the above experiment, $E_\phi(\rho)$ was evaluated as the time derivative of the poloidal flux Ψ, $E_\phi = -\partial\Psi/\partial t$, by analysis of equilibrium evolution using MSE. As a different approach, in this study, evolution of j(ρ) and the $E_\phi(\rho)$ is analyzed by a 1.5D transport code TOPICS. Diffusion of j(ρ) is calculated in a usually way even in the current hole region, but the safety factor to be used for the equilibrium and the transport coefficients was restricted to be less than some threshold value (typically 30) [3]. Initial results are shown in Fig. 1. Note that though $T_e(0)$ and the current hole radius are similar to those in the experiment, adjustment of the n_e, T_e, T_i and q profiles, which are so far calculated using a transport model (CDBM), is not completed yet. In Fig. 1 (a), j_{EC} is assumed to be the same as the EC-driven current evaluated by a Fokker-Planck code (EC-Hamamatsu) for an equilibrium with nested flux surfaces. An off-axis peak in j(r) is predicted to be formed within 0.8 s, though its height is significantly smaller than j_{EC} because of remaining negative loop voltage. This does not agree with the experiment. In Fig. 1 (b), a flat j_{EC} within the current hole was assumed, corresponding to no confinement in the current hole. In this case, a change of j(ρ) is predicted only around the edge of the current hole. This change also seems to disagree with the experimental observation, but more precise adjustment of n_e, T_e, T_i and q profiles is needed before reaching a conclusion on validation of this model. Results of improved simulation will be reported in the conference.

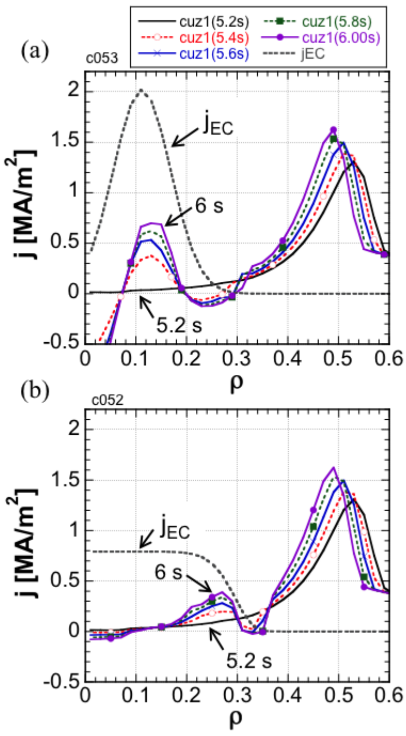

Fig. 1. Evolution of calculated current density profile after EC injection at t = 5.2 s. (a) With a j_{EC} profile predicted by a Fokker-Planck code. (b) With a j_{EC} profile flat in the current hole region. The EC-driven current is 0.22 MA and the plasma current is 1 MA.

References

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