§84. Higher-precision Reconstruction and the Real-time Display of Divertor Plasma Shape in QUEST

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In the present RF-driven (ECCD) steady-state plasma on QUEST ($B_\mathrm{t} = 0.25\mathrm{T}, R = 0.68\mathrm{m}, a = 0.40\mathrm{m}$), plasma current seems to flow in the open magnetic surface outside of the closed magnetic surface in the low-field region according to plasma current fitting (PCF) method. We consider that the current in the open magnetic surface is due to orbit-driven current by high-energy particles in RF-driven plasma. We calculated high energy particles guiding center orbits as a contour plot of conserved variable in Hamiltonian formulation[1)] and considered particles initial position with different levels of energy and pitch angles that satisfy resonance condition. Then the profile of orbit-driven current is estimated by multiplying the particle density on the resonance surface and the velocity on the orbits. This analysis shows negative current near the magnetic axis and hollow current profile is expected even if pressure driven current is considered.

Concerning orbit-driven current density profile, we assume the following assumptions, similarly as in the reference[2)]. (1) $N_{//}$ spectrum of ECCD: uniform for $-1 < N_{//} < +1$. (2) Particles, which satisfy non-relativistic resonance condition, can exist in steady state. (3) Initial particle density: uniform in velocity space. (4) Initial particle density: uniform in real space. (5) Collision-less. (6) Particle density: uniform along the orbit.

Current density profile on equatorial plane represented hollow current profile and shifted outward. The positive current density profile is contributed by the particles of positively polarized initial parallel velocity, which initiated by coupling with positive $N_{//}$ from the outside of the resonance surface. The negative current density profile contributed by the particles of negatively polarized initial parallel velocity, which initiated by coupling with negative $N_{//}$ from the outside of the resonance surface.

Here, we discuss the equilibrium with the hollow current profile within nested magnetic surfaces. Figures 1 and 2 show the equilibrium reconstruction by J-EFIT coded by MATLAB. In Fig. 1, hollow current profile is assumed and in Fig. 2, peaked one is assumed.

$$(1-\psi_p^2)\{1-\alpha_d(\frac{1-\alpha_c-\psi_p}{1-\alpha_c})^2\} \qquad (1)$$

The reconstruction result in Fig. 1 was expected to be near the one of normal D-shape. But the one in Fig. 2 is rather similar to the one of normal D-shape. Both fitting results are good enough, since the RMS error of the difference between the fitted magnetic sensor signals and the measured ones is less than 3 %. Even if the assumed current profile is changed, the plasma shape is changed and the fitting result remains good. Namely, the plasma boundary shape reflects the plasma current density profile.

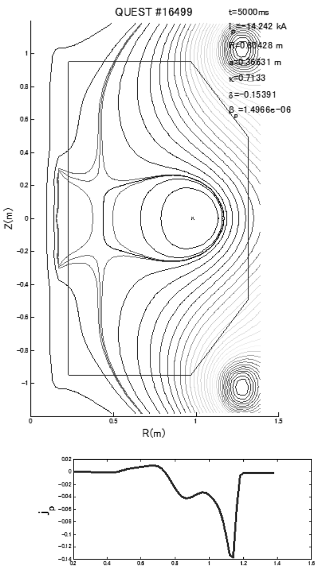

Fig. 1: Plasma equilibrium reconstruction and current profile by J-EFIT code. Hollow current profile is assumed: $\alpha_c = 1/3, \alpha_d = 3/4$.

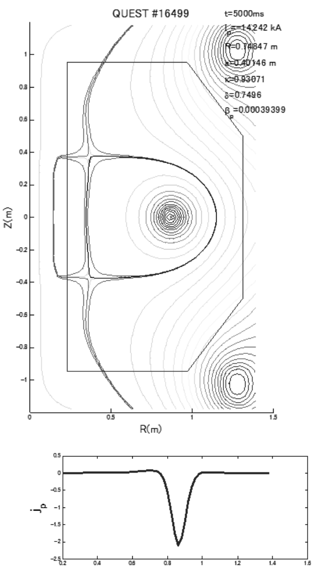

Fig. 2: Plasma equilibrium reconstruction and current profile by J-EFIT code. Peaked current profile is assumed: $R*(1-\psi_p)^4$.

1) Roscoe B. White, " The Theory of Toroidally Confined Plasmas, " (Princeton University).
2) M. Uchida, T. Yoshinaga, H. Tanaka, T. Maekawa, " Rapid Current Ramp-Up by Cyclotron-Driving Electrons beyond Runaway Velocity, " Phys. Rev. Lett. Vol. 104, 065001 (4pp), 2010.