§52. Higher-precision Reconstruction and the Feedback Control of Divertor Plasma Shape in QUEST

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In the spherical tokamak QUEST ($B_{\mathrm{t}} = 0.25\mathrm{T}, R = 0.68\mathrm{m}, a = 0.40\mathrm{m}$), as the methods to obtain a steady-state divertor plasma, we have two methods: First, a high-density divertor plasma is made by OH (ohmic heating) and the plasma current is planned to be sustained by EBW (Electron Bernstein Wave) current drive. Second, a low-density plasma is made by ECRH (Electron Cyclotron Resonance Heating), the plasma current is ramped up by ECCD (Electron Cyclotron Current Drive) and sustained by ECCD.

In RF-startup, ramp-up and sustained divertor plasma on QUEST (Fig. 1), plasma current is driven even in the outside of the LCFS (Large Closed Flux Surface) on the low-field side. The current is interpreted to be carried by trapped particles in the open magnetic surfaces. The magnetic surfaces are reconstructed by assuming multi-filament current in the vacuum chamber[1)] or assuming truncated current profile, which is a function of poloidal magnetic flux even in the outside of the closed magnetic surfaces[2)]. In both cases, the current density profile is shifted to the low-field side from the LCFS. The trapped particles carry current also in the inside of the closed magnetic surfaces, and the equilibrium can be reconstructed by taking into account the anisotropic pressure profile all over the plasma[3)]. In this reconstruction, the perpendicular pressure profile is shifted outward reflecting the perpendicular velocity component of the trapped particles.

Plasma equilibrium solution is fitted assuming all plasma current is flowing in the inside of the LCFS. It is solved within the isotropic pressure profile by EFIT code (Fig. 2a). The overall current density profile is shifted to the low-field side from the LCFS and apparent poloidal beta becomes larger than unity. Opposite-polarity current density region appeared in the high-field region (negative n-index), where $R < 0.56$m. The fraction of the opposite-polarity current is small to be about 2 %. The elongation ratio of the LCFS (separatrix) is about unity and the aspect ratio is lower than two. The elongation ratio of the same-polarity region is about 1.4 though the aspect ratio becomes larger than two.

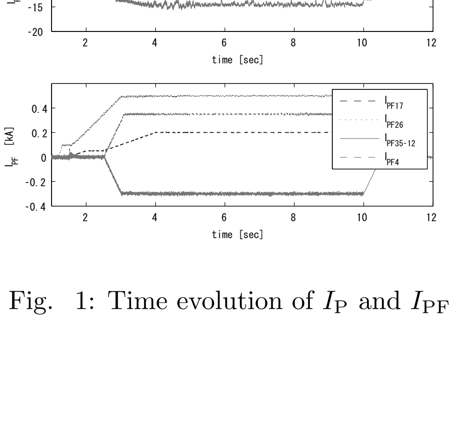

Fig. 1: Time evolution of I_{P} and I_{PF}.

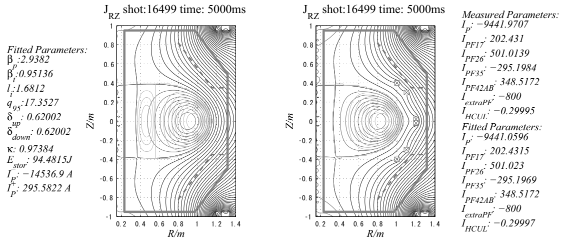

Fig. 2: Magnetic surfaces (red) and current profile (green). In-vessel poloidal field coils are indicated by red squared x markers.

Plasma equilibrium solution is fitted assuming open-field plasma current flows discretely in in-vessel poloidal field coils in the outside of the LCFS. Anisotropic pressure component is expressed by the in-vessel poloidal field coils and isotropic pressure component is fitted by EFIT code (Fig. 2b). From the result, where the opposite polarity current disappears, the amount of the open field current fraction is estimated to be about 30 % of the total current.

Plasma shape was reproduced by CCS (Cauchy Condition Surface) method assuming all plasma current is flowing in the inside of the LCFS. The ill posedness could not be prevented by reducing the number of fitting parameters. It is reproduced preventing ill-posedness by Tikhonov regularization. When Tikhonov regularization is applied to LSM (Lease Square Method), it is a problem, how to select the Tikhonov matrix and how to determine the regularization parameter. When the Tikhonov regularization is applied to SVD (Singular Value Decomposition) method, the regularization parameter may be determined according to the optimal criterion function for GCV (Generalized Cross Validation).

In preparation for high-temperature wall (red dashed line in Fig. 2) in QUEST in near future, we'd like to shift inward the current density by shifting inward the region with positive n-index. We'd like to increase the elongation ratio. Such a divertor plasma configuration may be produced by using only inner divertor coil (PF35-1).

1) M. Ishiguro, et al.: Physics of Plasmas **19** (2012) 062508.
2) A. Ejiri, et al.: Nucl. Fusion **49** (2009) 065010.
3) T. Maekawa, et al.: Nuclear Fusion **52** (2012) 083008.