§55. Feedback Control of the Plasma Position and Shape in QUEST

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For feedback control of ST plasma position and shape, reproduction of the plasma shape is indispensible under existence of eddy current in vacuum vessel. CCS (Cauchy Condition Surface) method is a numerical approach to reproduce plasma shape, which has good precision in conventional tokamak[1)]. In order to apply it in plasma shape reproduction of ST (Spherical Tokamak), the calculation precision of the CCS method in CPD (Bt = 0.25 T, R = 0.3 m, a = 0.2 m) has been analyzed[2)]. The precision was confirmed also in ST and decided to be applied to QUEST (Bt = 0.25 T, R = 0.68 m, a = 0.40 m).

In present stage from the magnetic measurement, it is known that the eddy current effect is large in QUEST experiment, and there are no special magnetic measurements for eddy current now, so some proper model should be selected to evaluate the eddy current effect. As the eddy current model, we divided the vacuum vessel into 8 parts, in each part lots of filament with different current (distributed current density) represent the eddy current[3)]. The eddy current density by not only CS (Center Solenoid) coil but also plasma current is calculated using EDDYCAL (JAEA). The eddy currents are taken as unknown variables and solved together with plasma shape reconstruction. In Cauchy-condition surface method, if $N_E + M_{CCS} < N_{FL}$, the eddy current can be evaluated, and plasma shape is also reproduced.

Figure 1 shows waveforms of CS, plasma and vertical field currents in ohmic discharge assisted by ECRH. PF4-2 consists of A and B coils. After CS (PF4-1+PF4-2A+PF4-3) was excited negative with CT power supply, plasma current was increased up to 25 kA by decaying the CS current. The plasma current was maintained by exciting PF4-2B with another SP power supply. PF26 was excited to make vertical field necessary for the horizontal equilibrium.

Eddy current effect must be regarded even in moderate phase, where the currents do not change. In the ohmic plasma with a lot of high-energy electrons, there may be an isotropic plasma pressure, which makes difficult a usual equilibrium analysis, but the CCS method can reconstruct the plasma shape precisely regardless of the anisotropy.

Figure 2 shows CCS points and eddy current sections utilized for CCS method. Uniform eddy current was assumed in 3 sections on the inboard and 3 sections on the outboard of the vacuum vessel. Figure 3 shows the reproduced plasma shape (t = 0.5 sec) using minimum 13 flux loops among 67 flux loops euipped every 0.1 m on the inner surface of the vacuum vessel.

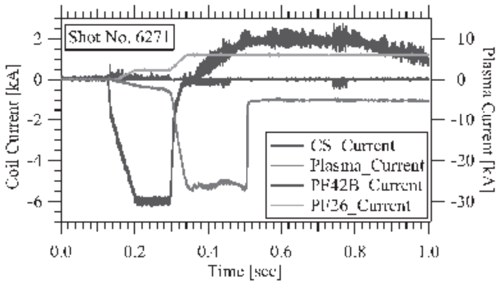

Fig. 1: Coil and plasma current waveform in QUEST ohmic discharge.

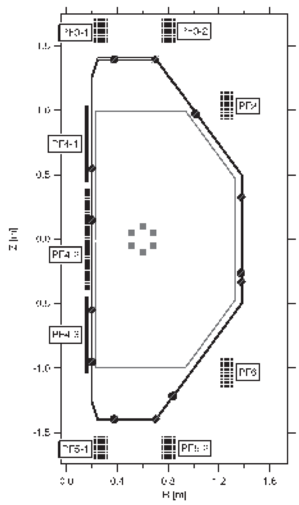

Fig. 2: Utilized CCS points and eddy current sections.

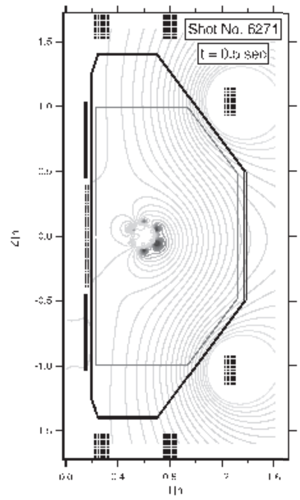

Fig. 3: Reproduced magnetic surface.

Since eddy current profile depends on the model of the vacuum vessel, expansion into eddy current modes with each time constant may be a candidate.

Eddy current model is considered to be essentially a projection (the necessary condition is satisfied but the sufficient is not). Since the tangential magnetic field on the flux loop measurement surface must satisfy a boundary integral equation, we can determine more physically consistent eddy current density and shape reproduction by installing tangential magnetic probes inside the vacuum chamber.

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3) K. Nakamura, S. Matsufuji, Y. Jiang, X.L. Liu, O. Mitarai, K. Kurihara, et al., APFA, Aomori (2009) P27p1.