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Dynamic reconstruction of tokamak magnetic configuration by using the measurement coupled MHD simulation

Tara Ahmadi[1],Yasushi Ono[1], Hiroshi Tanabe[1], Yunhan Cai[2]
[1] Graduate school of frontier sciences, [2] Graduate school of engineering,University of Tokyo
e-mail (speaker): tara@ts.t.u-tokyo.ac.jp

We developed a novel tool which is able to reconstruct the internal plasma parameters by solving the 2D MHD system of equations utilizing the magnetic field measurements by the external plasma diagnostics[1].

Due to the high plasma temperature inside Tokamak, it is not possible to measure the core plasma parameters such as magnetic field, temperature and current directly, while these parameters are vital to maintain and control the hot dense core plasma inside the experimental devices[2].

Currently, the EFIT model is widely used to reconstruct the magnetic configuration and current of the core plasma by solving the Grad-Shafranov equation at the equilibrium state. However, tokamaks with the presence of plasma flow such as zonal flows and merging tokamaks do not satisfy the plasma equilibrium condition which leads us to the new reconstruction method.

To investigate the validity of the current model, data received from the magnetic diagnostic systems and plasma current measurements are coupled with the 2D MHD model to reconstruct the magnetic configuration of a pair of Spherical Tokamak (ST) plasmas. Spherical Tokamak is a compact device utilizing multiple heating methods besides a small central solenoid. Initial test case is the University of Tokyo TS-6 device utilizing the reconnection of flux ropes (merging) as a current start-up as well as a plasma heating method. As the plasma temperature is low in low magnetic field operations, it is possible to measure both internal and external magnetic field components during the plasma formation, merging and equilibrium stages. Initial results show that the developed tool is able to reconstruct the global plasma parameters with low reconstruction error. Unlike the EFIT, the current model is able to give useful information regarding the plasma shape, position and pressures during the active phase of plasma-magnetic field interactions.

Calculation of the reconstruction error of poloidal flux contours shows that the maximum error during the flux tubes reconnection is observed at the x-point region (6%) where the electron dynamic is dominant, while at the plasma equilibrium state, maximum error is observed at the position of magnetic axis (3.5%) where the 3D effects of flux tubes merging are ignored in the current 2D model.

After confirming the ability of measurements coupled MHD model to reconstruct the magnetic configuration with low error in the case of TS-6 device, a more complicated case has been studied. ST-40 spherical Tokamak built by Tokamak Energy Inc. is another compact device utilizing the merging-compression start-up method in its operations. Unlike the previous device, ST-40 is operating in the high temperature, high magnetic field regime making it impossible to measure the internal plasma parameters. Thus, there are only a limited number of external magnetic field data measured on the vacuum vessel available. In this case, it is not possible to determine the quality of the reconstructed profiles. In this case, the separatrix reconstructed by the EFIT model and CCD image is used to validate the accuracy of reconstructed configuration at the plasma equilibrium .

References

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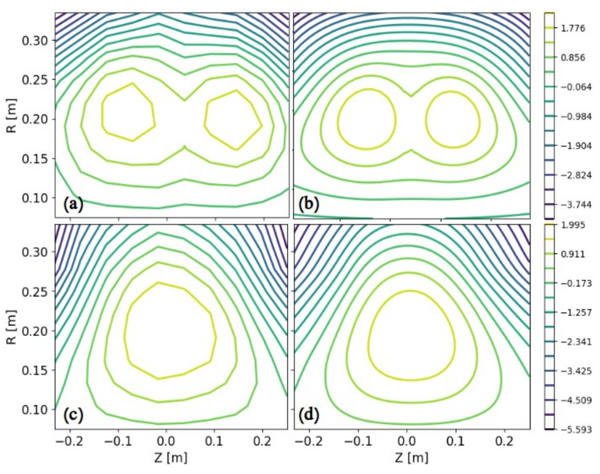

Figure 1: TS-6 poloidal flux contours during merging a(high resolution magnetic probe array), b(MHD reconstruction model) and at the equilibrium c (high resolution magnetic probe array), d (MHD reconstruction model)

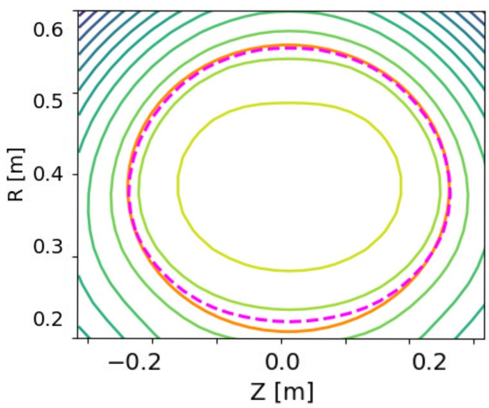

Figure 2: Reconstruction of the core plasma boundary of ST-40 operation, shot No 9850, by EFIT(solid) and MHD - reconstruction(dotted)