7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Validation of the plasma equilibrium configuration designed by FEEQS in the HL-2M experiment

Y.Y. Zhong [1], L. Xue [1], W.L. Zhong[1], J.X. Li[1], X. Song[1], Z. Yan[1], H. Heumann[2]
[1] *Southwestern Institute of Physics, China,*
[2] *Université Côte d'Azur, Inria, CNRS , France*
e-mail (speaker): Zhongyuanyun@swip.ac.cn

Plasma equilibrium is essential for tokamak engineering design and physical research. It has been frequently applied for scenario development, MHD instability analysis, plasma control, etc. HL-2M[1] is a new copper-conductor tokamak device built at the Southwestern Institute of Physics (SWIP), and recently achieved plasma current of 1 MA. Owing to the poloidal field (PF) coils inside the toroidal field coils, it is easy to flexibly control the plasma equilibrium configuration. One of its important missions is to develop the configuration research for various divertor configurations. This paper presents that simulation results of the free-boundary equilibrium code FEEQS[2,3] , has been successfully used to design the HL-2M limiter and divertor configurations. The design has been validated in the recent experiments. The study provides a significant equilibrium analysis and benchmark method, accumulating relevant technology experiences toward IMAS[4].

FEEQS solves the free-boundary equilibrium equation, based on the Finite Element Method with triangular mesh and applies piecewise linear shape functions to approximate the magnetic flux. The direct static mode in FEEQS solves the equilibrium problem by given PF coil currents. For the evolution problem, it couples the plasma equilibrium and circuit equations in a time-dependent way and results in plasma boundaries, plasma profiles of toroidal current density, and safety factor in an offline way.

We designed a few configurations by direct static mode and made benchmark with EFIT code. In addition several shots by direct evolution have been validated with the HL-2M experiments in the flat-top phase with limiter and conventional divertor configurations. The fundamental parameters of these limiter shots are R=1.78m, a = 0.65m, I_P = 0.6MA and k = 1.2-1.4. It has been demonstrating that

(i)with static mode, the EFIT plasma boundary is well matched during the benchmark, as shown in Figure 1(a), FFEQS is capable of designing various shape configurations.

(ii)With evolution mode, Figure 1(b) shows that the current evolution of central solenoid (CS) coils and poloidal coil (PF) simulated by FEEQS fit the experimental data well. The plasma boundary evolution of FEEQS can match the image of the fast camera and EFIT's reconstruction. The trend consistency of a and R is fairly well. According to all the simulated shots, the relative error on a is less than 3%, and the case for R is no more than 1.7%. Nevertheless, it could be concluded that the FEEQS simulation on shape configuration and coil currents are reliable.

These works and validations would be helpful in providing reference to the next engineering testing and physical study. More details will be presented in this conference.

Reference

[1]. X.R. Duan et al 2022 Nucl. Fusion 62 042020
[2]. Heumann H. et al 2015 Quasistatic free-boundary equilibrium of toroidal plasma with CEDRES++: computational methods and applications J. Plasma Phys. 81 905810301
[3]. Xiao Song. Model-based control-oriented scenario construction in tokamaks. Automatic Control Engineering. COMUE Université Côte d'Azur (2015 - 2019), 2019. English. ⟨NNT : 2019AZUR4089⟩.
[4]. F. Imbeaux *et al* 2015 *Nucl. Fusion* 55 123006

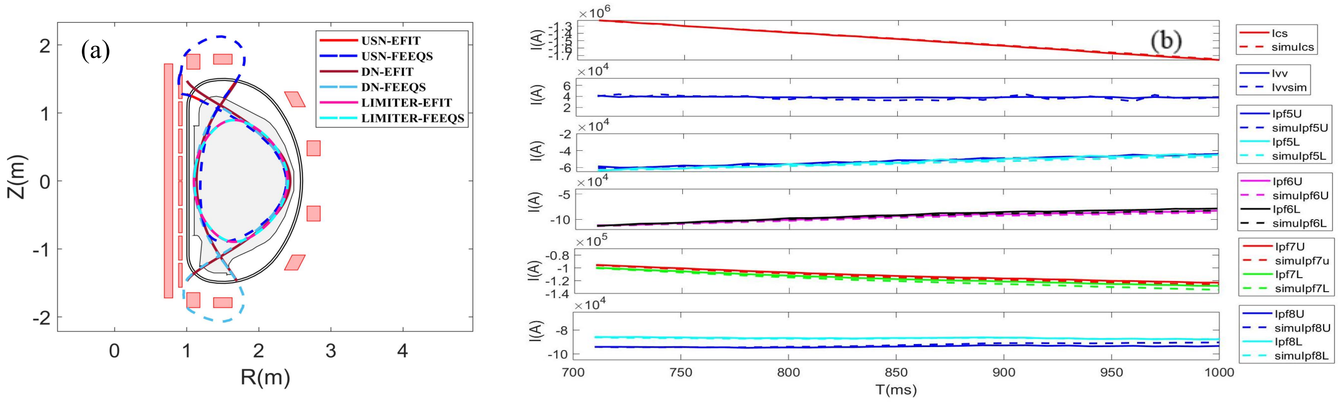

Figure 1. Boundary comparison of Upper Single Null (USN), Double Single Null (DN), and Limiter configurations(a), designed by FEEQS(dotted) and EFIT(solid) . Comparison for experimental data (dashed) and simulated (plain) trajectories of coils currents (b), I_{vv} represents the current in the vacuum vessel, I_{cs} and PF4-8 is put in use for shot 1555.