Full MHD modeling of flux pumping in ASDEX Upgrade using JOREK code

Haowei Zhang[1], Matthias Hoelzl[1], Isabel Krebs[2,3], Andreas Burckhart[1], Alexander Bock[1], Valentin Igochine[1], Hartmut Zohm[1], Sibylle Günter[1], and the JOREK team[4]

[1] Max Planck Institute for Plasma Physics
[2] Eindhoven University of Technology
[3] Dutch Institute for Fundamental Energy Research
[4] see author list of [10]
e-mail (speaker): haowei.zhang@ipp.mpg.de

In high-performance Tokamak operations, sawteeth [1] are frequently observed, which can trigger neoclassical tearing modes (NTMs),[2] degrade energy confinement, and even result in disruptions, thus posing significant challenges to plasma confinement. Nevertheless, stationary hybrid discharges without sawteeth due to anomalously self-regulating redistribution of current, i.e., flux pumping, were reported in different Tokamaks.[3-7] In the presence of flux pumping, the current density and pressure profiles are continuously redistributed to prevent them from peaking. As a result, q_0 (the safety factor on the magnetic axis) is maintained slightly above unity to achieve sawtooth-free discharges.[8,9]

Recently, discharges demonstrating the existence of flux pumping have been conducted successfully in ASDEX Upgrade (AUG).[3] By adjusting the NBI (Neutral Beam Injection) power and co-ECCD (Electron Cyclotron Current Drive) intensity, different phases with or without flux pumping were reproduced in the same discharge. To understand the nonlinear dynamics in flux pumping discharges, and to describe flux pumping more precisely, simulations of AUG flux pumping discharge[3] have been carried out with the JOREK code[10] using the two-temperature full MHD model,[11] realistic resistivity and current & heat sources, which are able to show flux pumping due to the negative dynamo loop voltage induced by quasi-interchange mode.[8, 9] As shown by Figure 1, in 3D simulations with flux pumping, the safety factor is maintained above unity while the toroidal current density becomes flat in the plasma core. Parameter scans on critical parameters, including viscosity, resistivity, plasma beta and current, have been carried out and are currently moving forward. The nonlinear simulation results and explored parameter regimes help to understand the transition and bifurcation behavior of core plasmas in phases with or without flux pumping and help to build a useful database for further extrapolation towards JET,[7] ITER and DEMO.[12]

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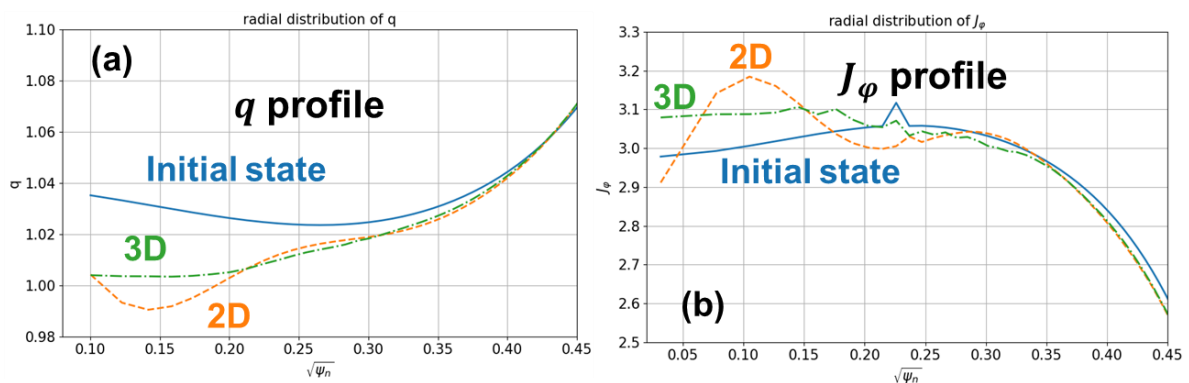[12] M. Siccinio et al, Fusion Eng. Des. **156**, 111603 (2020)

Figure 1. Radial distributions of (a) safety factors and (b) toroidal current densities of initial equilibrium (blue solid lines), 2D simulations (orange dashed lines) and 3D simulations (green dash-dotted lines).