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First Principle Fluid Modelling of Neoclassical Tearing Modes and of their Control

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The confinement degradation of Tokamak plasma by magnetic islands motivates numerous approaches to better understand their dynamics and possible suppression. We report here on nonlinear simulations using a consistent two-fluid implementation of neoclassical friction forces in the framework of the toroidal Magneto-Hydro-Dynamic model of the XTOR code, recently improved with the implementation of parallel heat fluxes that allows recovering a self-generated bootstrap current that compares well with analytical formulae. The island saturation width increases as expected with the bootstrap current fraction, but with a much weaker dependence than predicted by a Rutherford-type equation. We evidence the strong influence of diamagnetic rotations and to a lesser extent of neoclassical friction on the saturation size and shape of the island, by comparing with a pure resistive MHD simulation. In metastable plasmas, a seed is required for triggering a NTM. We find in a case taken from Asdex-Upgrade that the shape of the seed has an influence on the island dynamics that follows.

The control of these magnetic islands by the coupling of Radio-Frequency waves is modelled by a source term in Ohm's law accounting for the propagation of accelerated electrons along field lines. This implementation is validated against analytical theory regarding the stabilization efficiency, and the 3D spatial localization of the RF source is shown to impact the island dynamics when the plasma is nearly static: the flip instability is recovered and described, and the possibility to create an island from the RF current filament is evidenced.

For metastable modes, a control method allowing the island to go below the critical size is appropriate. A promising stabilization technique based on the radial sweeping of the ECCD source has been successfully demonstrated in TCV and Asdex-Upgrade. Our numerical investigation shows that the effective stabilization efficiency of the sweep is better when remaining close to the resonance or when being decentred on the outside.

These developments on a fluid implementation of neoclassical physics and RF sources in a global MHD code allow further investigations on NTM triggering and saturation, on ECCD stabilization process, as well as on their possible characterizations thanks to density and temperature fluctuation signals.

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