MHD simulations of magnetic island stabilization

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The confinement degradation of Tokamak plasma by magnetic islands motivates to better understand their possible suppression using Electron Cyclotron Current Drive (ECCD). Experimental observations show that parameters such as the injected power, the narrowness of the current deposition and its alignment with the resonant surface are critical, and should guide the design of the control system [Maraschek12].

In this work, we present nonlinear simulations of this process with the toroidal MHD code XTOR [Lütjens10], which has been extended to incorporate in Ohm's law a source term modelling the RF driven current resulting from the interaction of the RF waves with the plasma. The implementation has been validated, in a single fluid MHD model, against analytical theory [Hegna97] regarding the stabilization efficiency, while the effect of the 3D spatial localization of the RF source appears to impact the island dynamics when the plasma is nearly static [Fevrier14]. The coupling of the code with a raytracing code, REMA [Krivenski85], allows computing consistent current deposition profiles depending on ECCD launcher characteristics.

Nonlinear simulations including neoclassical and bi-fluid effects permit to study the dynamics of a NTM in presence of an external current source. Two neoclassical models are compared: a first one, the so-called Sauter's model, where the neoclassical effects are modeled by a supplemental term for the bootstrap current, proportional to the pressure gradient in the Ohm's law. The second one uses a consistent two-fluid implementation of neoclassical friction forces, leading to a deformed island shape and a more complicated structure of the bootstrap current perturbation [Maget16], whose effects on the efficiency of the island control is assessed.

One of the issues associated with NTM control is the need for precise rational surface location, as control efficiency depends strongly on the ability to target precisely the mode. To mitigate this constraint, a new method, relying on sweeping ECCD deposition around the estimated position of the mode has been successfully tested on TCV and applied to ASDEX-Upgrade during the 2014 MST-1 campaign [Maraschek15]. It relies on the fact that the mean effect of the sweeping will still be favourable for the mode reduction, which removes the need for modulation or precise mode localization. Our analysis shows that in such conditions linear stability evolution presents a hysteresis due to the finite current diffusion time τ_R. The amplitude of the linear stability modification can be reduced by decreasing the sweeping period [Fevrier15]. The efficiency of this new method is compared with other strategies such as modulation and continuous ECCD deposition.

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