Neoclassical Island Control with Stiff Temperature Model

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A major problem for plasma confinement in Tokamak devices is the appearance of non-ideal Magnetohydrodynamics (MHD) instabilities such as Neoclassical Tearing Modes (NTM). They allow for the formation of metastable magnetic islands driven by the perturbation of the bootstrap current, leading to a degradation of energy confinement. The nonlinear growth of these magnetic islands can be controlled by Electron Cyclotron (EC) wave injection. While the role of the RF current inside the island is known to efficiently reduce the magnetic island size by counterbalancing the island current perturbation, the contribution of the heating associated to these waves is not clear. In fact, such an heating adds a stabilizing mechanism to the current drive and makes it sensitive to the turbulent transport properties, in particular to the dependence of the transport coefficient $\chi\perp$ on the temperature gradient leading to stiff temperature profiles [1]. As a result, the effect of heating is restricted and limits its effect on island stabilization. This mechanism can be modeled through $\chi\perp$ as a temperature gradient power law where the power represents the stiffness (σ). A Rutherford equation is derived that integrates this effect. We implemented our model into the XTOR-2F code [2] and we consider an ITER-like plasma with and without a (3/2) NTM. We test the implication of the σ parameter on temperature gradient using σ=1 and 8 [3]. We verified the limitation of temperature increase with σ. Usually, the RF stabilization efficiency is increased taking into account the heating, but this increase is lower as anticipated with a stiff gradient model. On short time scale, we found that RF heating (PRF) enhances significantly the stabilization by RF current (JRF) (Figure 1, left panel). This seems to be due to the effect of heating on the ohmic contribution of the total plasma current. This fast response enhances the advantage of modulated injection even though the width of the RF current and power profile is smaller than the island size. On longer time scale, the island stabilization is mainly due to the RF current contribution.

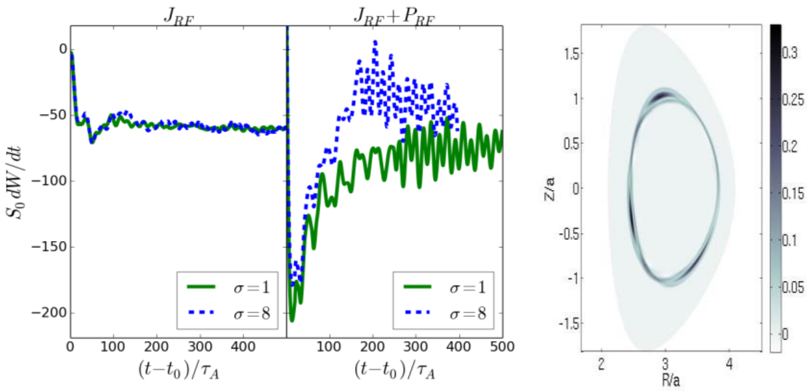

Figure 1: *Left Panel: Magnetic island width time derivative as RF current (left) and combined RF current and heating (right) is applied with and without stiffness. Right Panel: spatial distribution of the RF current density.*

References

[1] F. Imbeaux, F. Ryter, and X. Garbet, Plasma Physics and Controlled Fusion, 43, 1503 (2001)
[2] H. Lütjens, and J.-F. Luciani, Journal of Computational Physics 229, 8130 (2010)
[3] J. E. Kinsey, et al., Nuclear Fusion, 51, 083001 (2011)