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# Non-linear modeling of the threshold between ELM mitigation and ELM suppression by resonant magnetic perturbations in ASDEX Upgrade

François Orain[1,2], M.Hoelzl[1], F.Mink[1], M.Willensdorfer[1], M.Dunne[1], E.Viezzer[1], M.Bécoulet[3], G.T.A.Huijsmans[3,4], W.Suttrop[1], S.Pamela[5], S.Günter[1], K.Lackner[1], the ASDEX Upgrade Team[1] and the EUROfusion MST1 Team[6]

[1]Max-Planck-Institut für Plasmaphysik, Garching
[2]CPHT, Ecole Polytechnique, CNRS, Université Paris-Saclay
[3]CEA, IRFM, Saint-Paul-Lez-Durance
[4]Eindhoven University of Technology
[5]CCFE, Culham Science Centre
[6]see author list in H. Meyer et al., Nucl. Fusion 57, 102014 (2017)

e-mail: francois.orain@polytechnique.edu

Instabilities occurring at the edge of tokamak plasmas, called Edge Localized Modes (ELMs), are a key concern for ITER, as they may induce too large heat loads on divertor targets. It is therefore crucial to control them in a reliable way. A promising method is the application of Resonant Magnetic Perturbations (RMPs), found to be capable of mitigating or suppressing ELMs in existing tokamaks [1-4]. However, the necessary conditions to achieve ELM suppression are so far not clearly understood. In order to improve the understanding of the mechanism behind ELM mitigation and suppression, non-linear modeling of the interaction between ELMs and RMPs has been performed with the extended MHD code JOREK [5-6], based on ASDEX Upgrade experimental discharges.

Depending on the applied RMP amplitude, on the applied spectrum (more or less kink- and tearing-resonant depending on the phasing between RMP coil currents) and on the plasma rotation, different regimes are found in modeling: unaffected, mitigated or suppressed ELMs. ELM mitigation or suppression is not only due to the degradation of the pedestal pressure gradient by RMPs, but can be explained by the non-linear toroidal coupling of medium $n$ modes with the applied RMPs [7] (here characterized by $n=2$).

When the "penetrated" RMP amplitude (corresponding to the amplitude on edge resonant surfaces once taken into account the plasma response to RMPs) is small, the mode coupling with RMPs is not strong enough to affect the growth of peeling-ballooning modes; thus, an ELM crash dominated by medium toroidal modes $n=4$-$8$ is observed, similar to uncontrolled ELMs. At larger "penetrated" amplitude, the coupling with RMPs forces the medium $n$ modes to reach a saturation level lower than the ELM crash level, resulting in rotating saturated modes [8]. Beyond a specific amplitude threshold, the modes are entirely driven by the external perturbation and locked to it: hence, they remain at low amplitude and ELMs are fully suppressed.

The detailed suppression mechanism as well as the impact of different parameters (in particular the plasma background rotation, the resonant/non-resonant spectrum and the amplitude of applied RMPs) on the ELM-suppression threshold will be presented [9].

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