Modeling edge MHD instabilities and their interaction with magnetic perturbations in ASDEX Upgrade

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Reaching high confinement regimes while limiting the heat flux on divertor targets is a necessary condition in current and future tokamaks. The understanding of the dynamics and control of edge MHD instabilities is therefore crucial. To this end, non-linear resistive two-fluid MHD modeling is performed with JOREK using parameters from ASDEX Upgrade discharges.

In a first step, the natural dynamics of edge instabilities is studied in H-mode. The following regimes are observed in modeling while increasing the edge pressure gradient: from the saturation of edge medium-n modes reminiscent of QH-mode observations or inter-ELM modes to the non-linear growth of Edge Localized Modes (ELMs) with and without precursor activity. The dynamics of the ELMs and their possible precursors shows features qualitatively comparable to experimental observations: mode numbers and rotation frequencies of the modes, appearance of filamentary structures and energy losses.

After describing the dynamics of uncontrolled ELMs, their control by Resonant Magnetic Perturbations (RMPs) will be addressed. Maximum ELM mitigation is found in experiments when the applied RMP spectrum maximizes both edge kink and resonant responses of the plasma. The poloidal coupling between these two components results in a larger penetration of RMPs characterized by a larger ergodic layer and an increased transport across the separatrix.

Depending on this response, different regimes of interaction between ELMs and RMPs are observed. When the RMP penetration is maximized, the strong toroidal coupling between the $n = 2$ RMPs and the even medium-n modes enforces the structure and dynamics externally driven by RMPs while odd modes are damped. In contrast, for a weaker RMP penetration, the medium-n modes do not couple to RMPs and thus grow and lead to a crash similar to uncontrolled ELMs, with only slightly reduced growth rates and amplitudes due to the degradation of the pressure gradient by RMPs. The impact of plasma parameters and RMP amplitude on the access to these regimes will be described.