Kinetic modeling of bifurcation conditions of resonant magnetic perturbations in ASDEX Upgrade experiments

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One experimentally verified way to mitigate or suppress edge localized modes (ELMs) in tokamaks is the application of resonant magnetic perturbations (RMPs). Although the plasma response usually shields small perturbations, RMPs with high enough amplitudes can bifurcate into unshielded states. As shown with a fluid model and experimental measurements in DIII-D in Ref. [1], the bifurcation of RMPs at the pedestal top correlates with the suppression of ELMs.

In this work, necessary conditions for the bifurcation of RMPs and their correlation with ELM suppression in ASDEX-Upgrade (AUG) are studied within the quasilinear kinetic cylinder model established in Ref. [2] coupled with the linear ideal MHD solver GPEC [3] to account for realistic device geometry (in part, similar to [1]). Bifurcations are studied by following the quasilinear evolution of plasma parameters (density, temperature, toroidal rotation velocity) during the ramp-up of the RMP coil current and comparing the results with an approximate, but numerically efficient criterion, which poses a sufficient condition for a bifurcation. Additionally, the effect of the electron fluid resonance on the threshold is inspected, where the resonance includes a kinetic shift with respect to MHD predictions. A positive scaling of the bifurcation threshold with the plasma density sets the upper density limit for the bifurcations which correlates with the upper density limits also seen in ELM suppression experiments. Based on the above modeling, analysis of experimental time evolution of plasma parameter profiles in AUG shows that the ELM suppression phase correlates with the approximate bifurcation condition for the poloidal RMP mode resonant at the pedestal top. Simultaneously, it correlates with the capture of the electron fluid resonance by this mode, where the resonance is computed assuming a plateau on the electron temperature profile in the resonant layer of that mode.

References

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[3] J.K. Park and N.C. Logan 2017 Physics of Plasmas **24** 032505