EFTC 2017

17th European Fusion Theory Conference

9 - 12 October 2017, Athens - Greece

Ideal saturated 3D external kink structures in quiescent H mode plasmas

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Future tokamak devices like ITER are designed to operate in high confinement mode (H mode), but the associated deleterious effects of ELMs are well known. The quiescent H mode (QH mode) [1] was first discovered in DIII-D and was subsequently observed in other machines, e.g. ASDEX-U and JET. Instead of edge-localised modes (ELMs), the QH mode shows benign edge harmonic oscillations (EHOs), which can enhance both energy and impurity exhaust. In the peeling-ballooning stability diagram, the QH mode is thought to be located around the kink/peeling edge. EHOs are argued to correspond to saturated 3D external kink states [2] and saturated edge corrugations have been previously observed in VMEC equilibrium simulations [3]. Since experimental measurements show that EHOs could be saturated modes, a comparison to theoretical predictions can be made in terms of the saturated amplitude of the edge perturbation. Neglecting the phase of the mode, the problem can be described by a time-invariant force balance equation. Such saturated peeling structures, which have features similar to infernal modes, are modeled in the current work by three different approaches. First, by using free-boundary simulations with the ideal MHD equilibrium code VMEC. The non-linear saturated external kink mode amplitude is evaluated from the edge perturbation in the converged equilibrium state. Second, neighbouring equilibria are identified and non-linear external kink stability is determined from free-boundary simulations with the full-MHD initial value code XTOR-2F [4]. Third, the non-linear amplitude of saturated external kink modes is also calculated according to an analytical model valid for poloidal mode numbers $m > 2$ and arbitrary current density profiles [5]. A study is presented that compares the saturated non-linear external kink amplitude obtained numerically by equilibrium computations, MHD stability simulations and from an analytical theory.

References

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