Nonlinear Mode Penetration Caused by Transient Magnetic Perturbations

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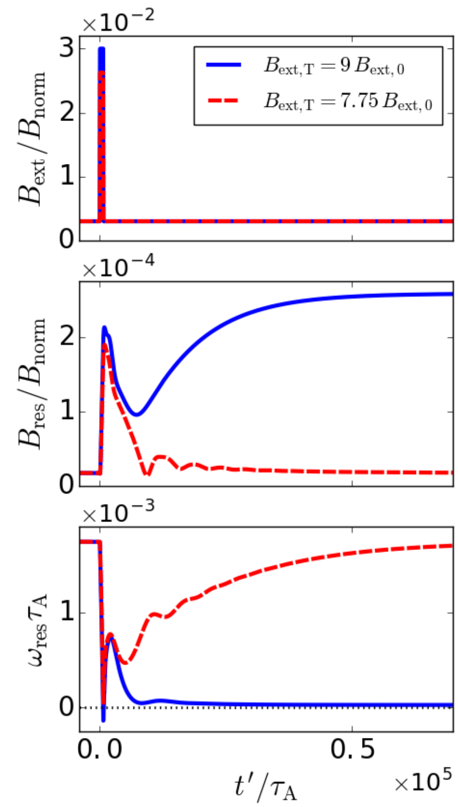
Experimental observations in tokamaks suggest the destabilization of NTMs and the transition to ELM suppression are caused by mode penetration of 3D magnetic fields prompted by transient MHD events. Three dimensional magnetic fields in tokamaks can induce forced magnetic reconnection (FMR) and produce magnetic islands on resonant surfaces. Conventional analytic solutions to FMR focus on describing the time asymptotic state [1]. While this approach successfully describes many aspects of FMR, understanding the nonlinear dynamics of mode penetration, evolution of a metastable equilibrium from a high-slip, flow-screened state into a low-slip, field-penetrated state, is in its early development. Furthermore, understanding how transient MHD events, such as sawteeth and ELMs, trigger mode penetration has been elusive. In this work, we present nonlinear computations employing the extended-MHD code NIMROD, building on previous work [2] by incorporating a temporally varying external magnetic field as a simple model for an MHD event that produces resonant magnetic perturbations. Proof-of-principle computations vary parameterizations of the transient external field and initial metastable state to probe the threshold for mode penetration, a locked mode response and magnetic island evolution. We test these computational results against analytical theory that captures the temporal evolution properties of the electromagnetic and viscous forces during and after a transient. We find qualitative agreement between computational and analytical results, but stress that computational tools are necessary to accurately capture the threshold for mode penetration.



[1] R.Fitzpatrick, Nucl. Fusion 33, 1049 (1993)
[2] M.T.Beidler, J.D.Callen, C.C.Hegna, and C.R.Sovinec, Phys. Plasmas 24, 052508 (2017)

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