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Validating Extended MHD Models of Plasma Response Against Measurements of Islands in DIII-D

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Measurements of islands induced by resonant magnetic perturbations (RMP) in the core of a L-mode DIII-D plasma are used to challenge predicted screening trends from linearized extended MHD and to examine modeling of the nonlinearly saturated island state. In these plasmas, fine torque scans reveal that large n=1 RMP-induced islands are present at multiple mode-rational surfaces at low rotation, but are completely screened at higher rotation. Understanding trends of rotational screening is crucial for predictive capability of RMP ELM control solutions. At sufficiently low torque (<0.2 N-m), the fields form n=1 island chains at m=2,3,4. There is an observed nonlinear threshold for this torque, where small torque increments lead to a completely screened plasma response. Island formation correlates best with near-zero perpendicular electron flow, Omega_{e,perp}, at the q=2 surface. These measurements are compared to linearized single-fluid and two-fluid extended MHD modeling to examine rotational screening. Simulations using the linearized extended MHD code, M3D-C1 do not find clear agreement between calculated resonant fields and observations of island dependent on Omega_{e,perp} in contrast to previous expectations –these L-mode plasmas are predicted to have strong screening even at these values of low rotation. However, single-fluid simulations show better agreement with strong resonant field penetration at low rotation. New nonlinear resistive 3D modeling of the saturated island state is validated against these experimental island measurements. These MHD simulations in the absence of rotation are performed with the SIESTA code. A series of meta-stable equilibria are modeled with an increasing helical 2/1 perturbation until the modeled island width matches experiment. These meta-stable equilibria demonstrate the transition from even-parity screening currents at the rational surface at low perturbation levels to odd-parity Pfirsch-Schlüter currents when a large island is present. Basic plasma response experiments challenge current modeling capability used in understanding 3D fields and also more specifically for predicting ELM control capabilities.

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