Experimental Tests of Linear and Nonlinear 3D Equilibrium Models in DIII-D*

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A major upgrade to the DIII-D magnetic diagnostics has been used to show that linear ideal MHD captures the key features of plasma response to 3D fields over a wide range of conditions, while a nonlinear model disagrees with observations. New measurements on the low and high field sides of the torus allow detailed comparisons with "synthetic diagnostic" predictions of several MHD models, in plasmas with edge safety factor (q_{95}) and plasma pressure (beta) spanning the range expected for ITER's baseline scenario. Model comparisons with DIII-D data confirm that the linear ideal MHD code MARS-F provides a quantitative description of the plasma response to applied fields with toroidal mode numbers n=1 and n=3. Similarly, good experimental agreement is seen for the linearized two-fluid M3DC-1 code and ideal MHD IPEC code. In contrast, the n=1 plasma response predicted by the nonlinear 3D equilibrium code VMEC is found to disagree with measurement in both amplitude (by a factor of 3 or more) and qualitative structure – perhaps related to VMEC's strong sensitivity to the current density near the plasma edge. The measured plasma response to n=3 perturbations is characterized by strong variations in amplitude at the high field side as the edge safety factor is varied, in good qualitative agreement with ideal MHD predictions of resonant behavior as rational surfaces reach the edge (q_{95}=m/3). However, the resonance at q_{95}=11/3 appears significantly weaker than the others, which suggests the presence of non-ideal effects – possibly loss of screening currents and formation of islands. This observation may shed new light on the physics of the suppression of edge localized modes (ELMs) by n=3 magnetic perturbations, which in DIII-D occurs most easily with q_{95} near 11/3. The success of linear, ideal MHD models, as well as the understanding of the limits of their validity (e.g. edge resonances, and the well-known role of kinetic effects in high beta plasmas), will be important in predicting the response of future burning plasmas to small 3D perturbations.

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