Predicting Ideal MHD Stability From Perturbed Equilibria: Successful Wall Perturbations and Limitations from Compressional Alfvén Energy[1]

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The effects of equilibrium parameters on long wavelength ideal MHD instabilities in toroidal plasmas are traditionally studied using numerical parameter scans. Previously, we introduced a new perturbative technique to explore these dependencies: changes in the potential energy δW due to small equilibrium variations are calculated using a perturbation of the energy principle, rather than with an eigenvalue-solver instability code.

With this perturbed equilibrium approach, stability dependencies can, in principle, be quickly determined without numerically generating complete MHD stability results for every set of parameters (which can be time-intensive for accurate representations of several configurations). Compared to a routine parameter scan, this approach may also provide the researcher a more intuitive feel for the effects of various parameters.

Previous applications of this approach to toroidal geometry used GATO (an ideal MHD stability code) and both experimental and simplified equilibria. Experimental analysis focused on DIII-D shot 87009, which exhibits global internal n=1, m=2 and m=3 kink modes. This technique was expected to work well with global modes; however, changes more than only $\sim 0.1\%$ to q_o or β predicted δW several orders of magnitude too large. Perturbing the simple equilibria (circular cross-section, $\beta = 0$ and $1 < q < 2$) gave similar results: allowable perturbations in aspect ratio A were also limited to only $\sim 1\%$.

We first briefly review the perturbed stability analysis for a cylindrical circular equilibrium, which works well with this approach. We also review results from DIII-D shot 87009 and the simple equilibria, which are valid only over a small range of most perturbations. Wall parameters are an exception, and we show instances where wall distance and shape *do* tolerate significant variation. The unexpected sensitivity to equilibrium (rather than wall) perturbations is due to the compressional Alfvén contribution to δW. Beyond a very small range of perturbations, second order terms in the expansion of compressional Alfvén energy become large. We explore methods of ameliorating these second order terms.

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