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A Cross-Benchmarking and Validation Initiative for Tokamak 3D Equilibrium Calculations

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We are pursuing a cross-benchmarking and validation initiative for tokamak 3D equilibrium calculations, with 11 codes participating: the linearized tokamak equilibrium codes IPEC and MARS-F, the time-dependent extended MHD codes M3D-C1, M3D, and NIMROD, the gyrokinetic code XGC, as well as the stellarator codes VMEC, NSTAB, PIES, HINT and SPEC. A full day of dedicated experiments on the DIII-D tokamak for the purpose of generating data for validation has been scheduled for May. The data will allow us to do validation simultaneously with cross-benchmarking. Initial cross-benchmarking calculations are finding a disagreement between the VMEC stellarator equilibrium code and the tokamak linearized 3D equilibrium codes IPEC and MARS-F. Investigation of the source of the disagreement has led to new insights into the domain of validity of linearized 3D equilibrium codes and of the VMEC code. The initial case being studied is DIII-D shot number 142603, which was part of a campaign to study ELM suppression using externally imposed nonaxisymmetric fields. We are working with stellarator-symmetric equilibria to allow us to do cross-benchmarking between stellarator and tokamak codes. One approach to understanding the differences between the VMEC and linearized solutions has been to compare the solutions of the two codes for simple model equilibria. For a large aspect ratio plasma with a circular boundary perturbed by a single m=2, n=1 harmonic, there is a large localized current near the rational surface. The IPEC solution readily captures this feature, but the VMEC code requires an impractically large number of radial grid surfaces to arrive at a reasonable approximation to it, leading to a substantially altered global solution when VMEC is run with even the highest radial resolutions that are normally used in VMEC calculations. On the other hand, it has been found that the approximation used in the linearized equilibrium codes can break down at surprisingly small perturbation amplitudes due to the overlap of the calculated perturbed flux surfaces. The MARS-F and IPEC linearized equilibrium codes assume nested flux surfaces. For the linearized equilibrium solutions for shot 142603, roughly everything outside of the q = 3.5 surface satisfies the overlap condition, despite the fact that the perturbation amplitude, delta-B/B, is of order .001 at the plasma boundary.

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