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Vessel Forces from a Vertical Displacement Event in JET and ITER

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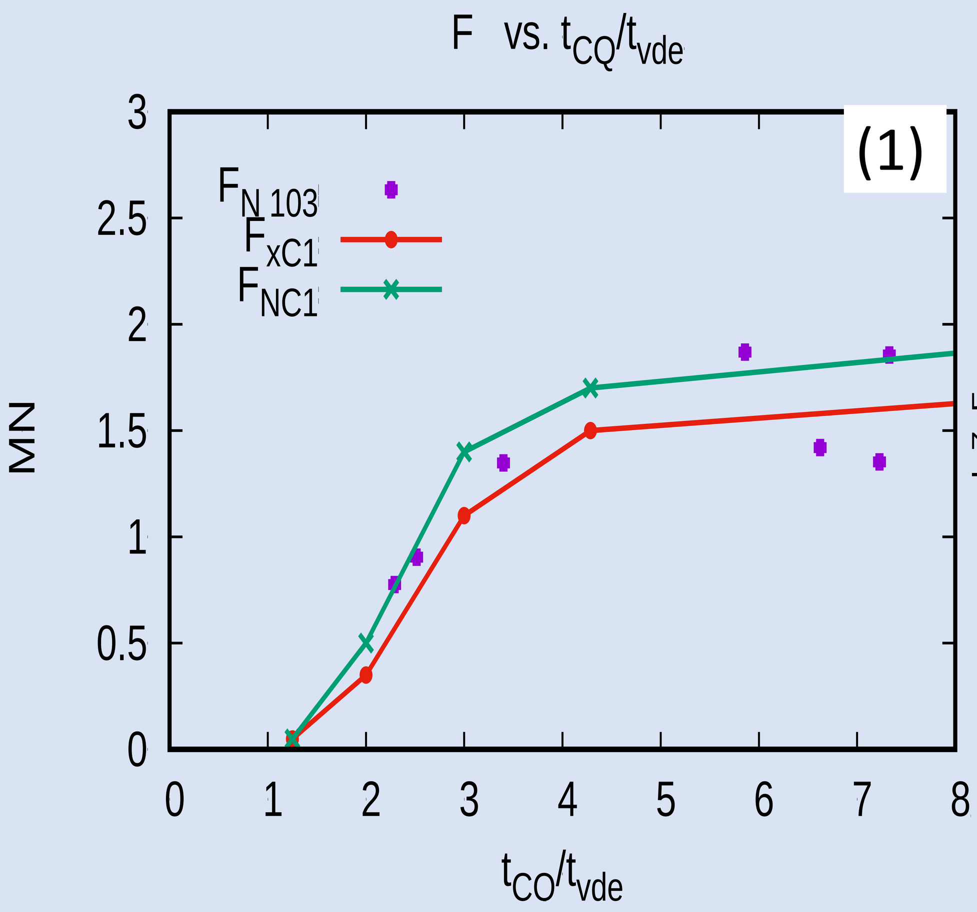
ABSTRACT

- The horizontal force resulting from a vertical displacement event (VDE) in ITER is a big concern.
- Large horizontal forces have been measured on JET, and it is unclear how to scale those results to the size and field strengths of ITER
- We have used the M3D-C1 3D MHD code to simulate a VDE in ITER and so far have not calculated horizontal forces greater than 1 MN
- Application of this code to JET shows that large horizontal forces are produced only when the current quench time is longer than the resistive wall time.

JET RESULTS

M3D-C1 simulations were carried out to calculate the asymmetric wall force in JET asymmetric vertical displacement event (AVDE) disruptions. The main physics result is that the wall force resulting from an AVDE is greatly reduced when the current quench time τ_{CQ} is less than the magnetic wall penetration time τ_{WALL}. The simulations have been done with several values of τ_{WALL}. Simulations with the experimental τ_{WALL} = 5 ms are in progress. The runs were initialized with data from shot 71985 which experienced an AVDE disruption . The current in the simulations was driven with a time dependent electric field to maintain control over the current quench time, while keeping τ_{WALL} fixed. The resistivity varied as $T^{-3/2}$ with an initial central value of $S=10^6$, There was a slow thermal quench during the VDE measured as a drop in β. The asymmetric wall force can be approximated with the Noll force $F_N = \pi B \Delta(IZ)$, where B is the magnetic field strength, I is the toroidal current, Z is the vertical displacement, and Δ is the rms amplitude of the toroidal variation of IZ.



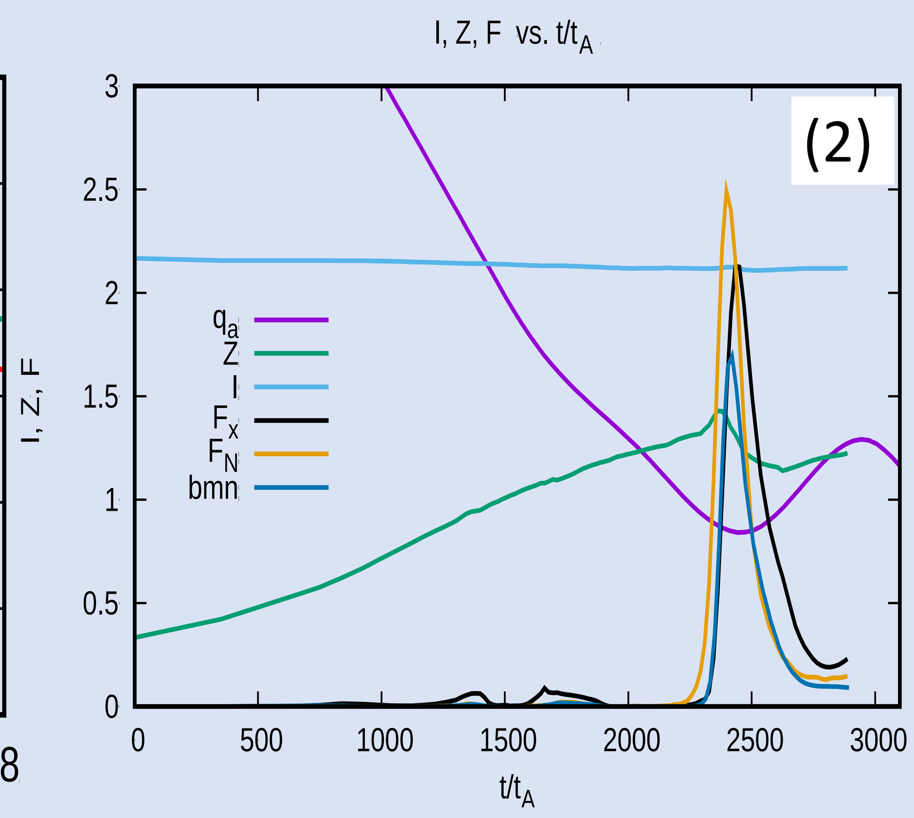
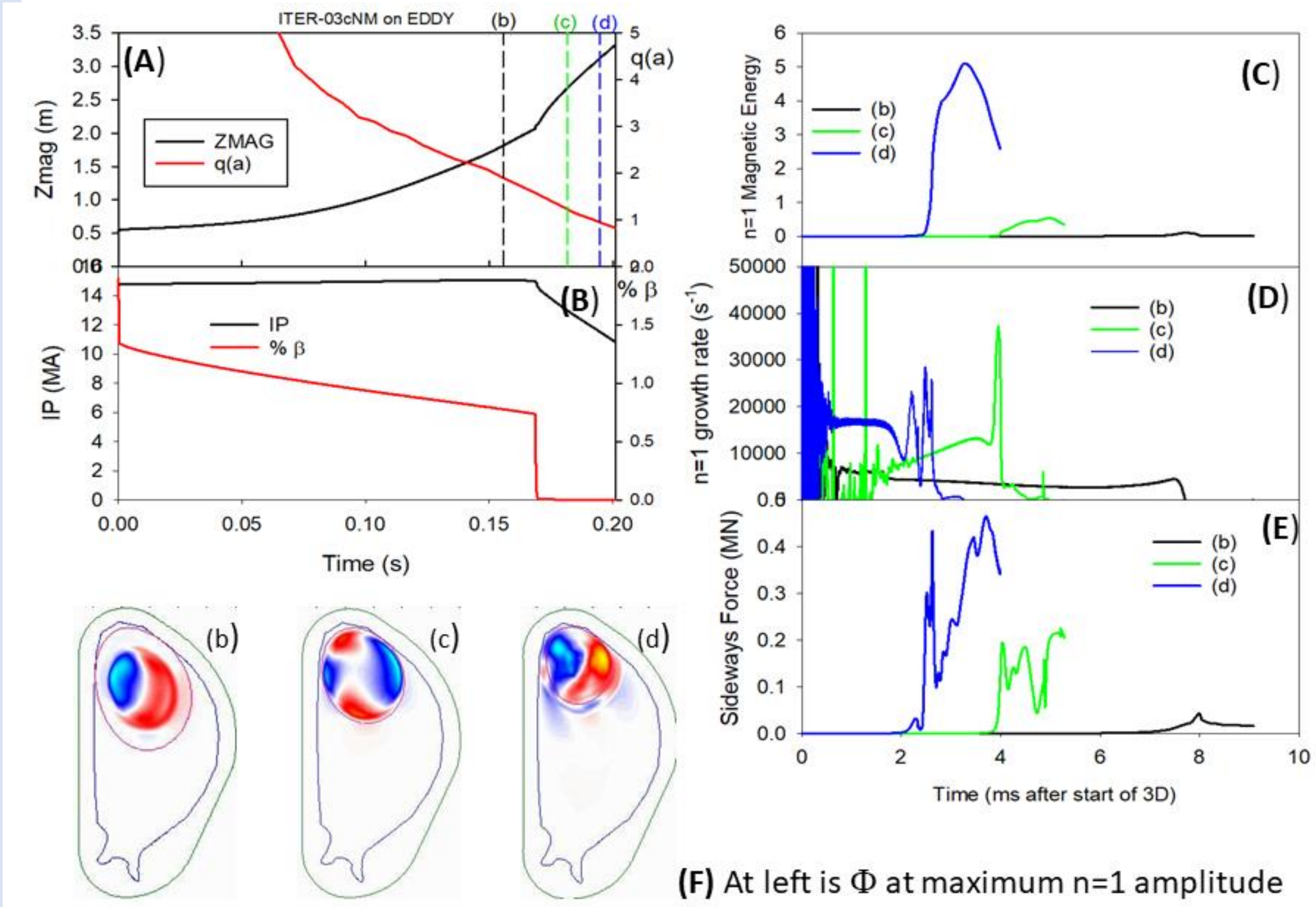


FIGURE 1 shows the maximum wall force from many M3D-C1 simulations of JET shots that experienced AVDE disruptions. Also shown are the results of the "Noll Force" from the experiment and as calculated from the M3D-C1 simulation.

FIGURE 2 shows the time history of the edge safety factor, q(a), the vertical displacement A, the plasma current I, the asymmetric wall force F_x, the Noll force F_N, and magnetic energy b_{mn}. When Z reaches its peak, q(a) drops below 1, and the forces and magnetic energy grow and then saturate.

APPLICATION TO ITER

We have performed several 3D VDE simulations in ITER geometry with the M3D-C1 code. We used a newly developed vessel model with 2 regions. A 60 cm thick region, closest to the plasma has different resistivities in the poloidal and toroidal directions the poloidal resistivity is very low, η_P = 1.0 E-6 Ω-m, allowing halo currents to easily flow to the outer conducting structure. However, the toroidal resistivity is very high, η_T = 1.0 E-2 Ω-m, preventing substantial stabilizing toroidal currents from appearing in this region. This region is surrounded by a 6 cm thick conducting structure with poloidal and toroidal resistivity of 0.8E-6 Ω-m. This vessel has a L/R time of over130 ms, more than 10^5 Alfven times. The results of the 3D simulations are summarized in Figures (A)-(F) below



(F) At left is Φ at maximum n=1 amplitude

FIGURE (A) and (B) show Z_{MA}, q(a), I_P, β from a 2D simulation. The three 3D simulations began at times marked (b) q(a) = 1.7, (c) q(a) = 1.2, and (d) q(a) = 0.9. The 3D results are shown in **FIGURES (C) – (F)**. From (E) is is seen that the maximum horizontal force to date is less than 1 MN. This relatively small force is consistent with what is seen in Figure 1. **FIGURE (F)** shows the scalar potential for the three runs at time of maximum amplitude. It is seen that run (b) has an internal (1,1) mode, run (c) has an external (2,1) mode, and run (d) has an external (1,1) mode.

ACKNOWLEDGEMENTS

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For list of JET contributors, See the author list of 'Overview of JET results for optimising ITER operation' by J. Mailloux et al to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)