

VDE growth rate analysis in EAST including three-dimensional structures

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Abstract

This paper presents the comparison between the experimentally measured growth rates of Vertical Displacement Events (VDEs) in the EAST tokamak with the predictions of a 3D linearized plasma response model (CarMa0). The agreement is good for a large range of growth rates, highlighting the importance of the 3D effects in the analysis of the vertical stability in EAST.

Introduction

The EAST tokamak [1] is a proposed experimental device with ITER-like superconducting poloidal and toroidal field coils, which has the aim to explore the physical and engineering issues of steady state operations for support of future reactors. Concerning the study of the vertical stability, the main conducting structures surrounding the plasma region are the vacuum vessel and the plasma facing components (PFCs), including the low and high field plates, the passive plates and the outer/dome/inner divertor plates.

The aim of this work is to estimate, with suitable numerical models, the growth rate of the axisymmetric vertical instability during the so-called VDEs. The main difficulty in the analysis of the vertical stability relies in the fact that, considering only the vacuum vessel, the growth rate would be in the scale of the Alfvén time, so the plasma mass cannot be neglected [2]. However, considering also the PFCs structures located much closer to the plasma region than the vacuum vessel, the instability is slowed-down to electromagnetic time. Contrary to the vacuum vessel, the PFCs are toroidally segmented and the pattern of the currents induced during a VDE have a 3D profile, flowing partially in the toroidal structures (to guarantee the toroidal continuity) and partially in the PFCs (to guarantee the effective stabilization) which are electrically connected. Consequently, an accurate study of the growth rate requires linearized plasma model coupled with a 3D model of the conducting structures surrounding the plasma region.

Numerical Model

The CarMa0 code [3], which is used in this work, is one of the few codes available that has these features. It couples, self-consistently, a linearized plasma response model with the 3D structures surrounding the plasma region by imposing suitable coupling conditions on a surface located in between. The main conductive structures of EAST and the relative mesh are shown in **Errore. L'origine riferimento non è stata trovata.** The poloidal field coils are driven with fixed currents and the estimated growth rate is the unstable eigenvalue of the dynamical matrix obtained from a state-space model in which the currents flowing in the 3D structures are the space variables. In addition, 2D analysis of the vertical stability is made by means of the CREATE_L code [2], supposing three different simplified scenarios: a) only vacuum vessel, b) vessel + PFCs (toroidally continuous) and c) vessel + passive plate (PP) (toroidally continuous). As before mentioned, the assumption a) yields growth rates on the time scale of the Alfvén time, then it will not be discussed any longer. The analysis made according to the scenario b) provides a lower bound for the effective growth rate whereas the analysis made according to the assumption c) furnishes an upper bound to the actual growth rate (the toroidal continuity of the PP is “optimistic” but it is “pessimistic” to neglect all the other PFCs and this last aspect prevails).

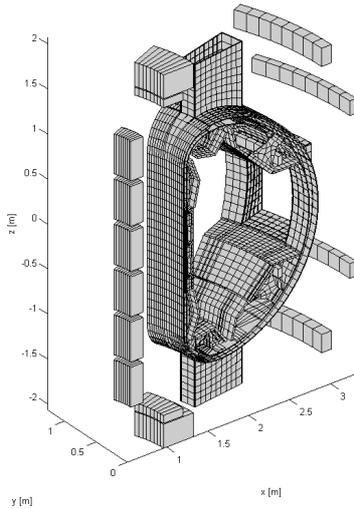


Figure 1: 2D geometry and detailed 3D mesh used.

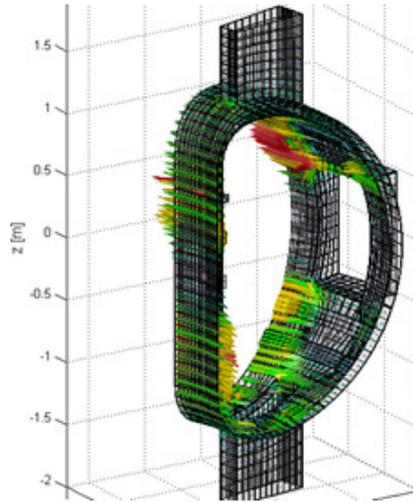


Figure 2: Details of the 3D current patterns in the vacuum vessel

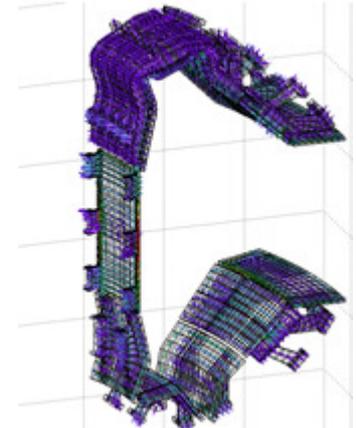


Figure 3: Details of the 3D current patterns in the PFCs structures.

Results

Three shots have been considered with “fast”, “intermediate” and “slow” dynamics. In these experiment, the PF currents are fixed and then the plasma column in left free to evolve. The plasma vertical position evolves according to an exponential trend, from which it is possible to estimate the experimental growth rate. Two different approached have been used to derive it: the exponential fitting of the time trace and linear fitting of its logarithm [4]. The experimental growth rate has been taken as the mean of the two. The numerical estimates of the growth rates are shown in Table 1. Figure 2 and Figure 3 show some details of the current patterns in the 3D structures.

Table 1: Growth rate estimates [s^{-1}]

Shot	Lower Bound (2D)	Upper Bound(2D)	3D Calculation	Experimental
35290	70	144	88	84
43888	142	373	246	220
36539	169	508	320	316

Conclusions

The features of EAST make 3D effects very important in estimating the growth rate. The CarMa0 code has been successfully implemented, providing good estimates of the experimental growth rates. Future activity will be addressed to the comparison on a larger set of experimental data, the analysis of Quasi-Snow-Flake configurations, the assessment of the new in-vessel conducting structure recently implemented and the development of nonlinear 3D models (e.g. for disruption analysis). This work was supported in part by Italian MIUR under PRIN grant 2010SPS9B3 and by the National Magnetic Confinement Fusion Research Program of China under Grant Nos 2012GB105000 and 2014GB103000.

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