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Noll forces, stiffness model of vacuum vessel, and radial displacement data on JET

The large disruption in the JET shot 38070 in 1995 demonstrated the possibility of large sideways forces due to asymmetric vertical disruption. The effect was missed in the theory, and JET engineers in 1996 gave their own explanation of forces $F_{sideways}$

$_{sideways,MN} =_{\overline{2}} {}_{tor,T} \cdot \; {}_{Z,MA\cdot m}$ (1)

based on consideration of force balance in a simplistic kink mode model. In this Noll's formula B_{tor} is the toroidal magnetic field, M_Z is asymmetry in the first vertical momentum. In 2007 this formula created an alarming situation in ITER design by predicting unexpectedly large sideways forces in this machine.

Because of importance of the issue, a brainstorming validation of the above engineering scaling was conducted in 2007. It resulted in correction of the original simplistic kink model by the plasma physics-based model. Remarkably, the Noll's formula, contained its own inconsistency with the simplistic kink model in substituting the plasma kink deformation multiplied by the plasma current by its magnetically reconstructed M_Z. In fact, this cancelled inconsistency of the simplistic model with classical kink mode, resulting in a correct scaling (1), confirmed by the plasma physics-based model in 2007.

However, since 2007 some of 3-dimensional numerical simulations, questionable from the physics point of view, as well as theory of the resistive wall modes, challenged the Noll's scaling projections to ITER and predicted much smaller sideways forces.

The direct measurement of JET vacuum vessel (VV) radial displacements was available from 1993 for each of 8 octants of VV. At the same time an engineering model of stiffness of VV became available recently in the form of two differential equations: one second order and another the first order.

Here, we report the results of comparison of JET measured displacement waveforms with calculated numerically ones using the stiffness model and Noll's assessment for sideways forces from magnetics measurements. 1735 shots (from 2011-16 JET-ILW database) were processed with 23 disruptions having displacements greater than 1 mm in direction octant 5 to 1 (along x- axis) or octant 7 to 3 (along y-axis). Although, there are some expected discrepancies of the order of 50 %, it is evident that the Noll's formula is applicable. Moreover, in most cases the Noll's formula as a source of a sideways force for the stiffness model underestimates the measured displacements. This result devalues the alternative reduced estimates of forces and emphasises potentially dangerous asymmetrical disruption for ITER.

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