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Simulation of DTT disruptions with JOREK: benchmarking MaxFEA results and assessing divertor electromagnetic loads

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The Divertor Tokamak Test (DTT) facility is an experimental reactor under construction at ENEA (Frascati, Italy). The goal of the project is to demonstrate the feasibility of various divertor configurations and materials, identifying the most efficient in terms of power exhaust handling during fusion reactions. Some of the most demanding events during the lifespan of a high magnetic field and plasma current tokamak such as DTT are plasma disruptions, which can drive high transient heat loads and electromagnetic forces and lead to damage to in-vessel components (IVC). Generally, the workflow leading to the structural verification of any given IVC design must consider (in addition to all operational loads) the most severe plasma disruption event. Therefore, starting from the disruption simulation results and using them as input for the electromagnetic (EM) analysis, the EM loads acting on the component can be evaluated, and its structural integrity assessed.

DTT IVCs have been verified using, as input data for the EM calculations, the results of MAXFEA simulations [1]—a multi-platform finite element code. MAXFEA can model axisymmetric disruptions by solving the Grad-Shafranov equilibrium equation for the plasma together with Maxwell's equations and Ohm's law in passive and active conductors. However, in MAXFEA, the current density profile and its evolution are predetermined, which prevents the prediction of both the current quench (CQ) duration and the halo width, parameters that are crucial for the accurate calculation of EM loads. The work reported here is focused on benchmarking MAXFEA disruption simulations using JOREK [2] a state-of-the-art non-linear MHD code for plasma simulations, capable of predicting these parameters by solving transport equations for the thermal energy and current density, providing a physics-based benchmark for the simulations performed with MAXFEA.

The results of the MAXFEA unmitigated disruption simulations, used as input for the verification workflow of the DTT Divertor have been compared with the disruptions computed using JOREK. As a first step, all the required DTT data were compiled into the Integrated Modeling and Analysis Suite (IMAS), the software framework to be used for all physics modeling and analysis at ITER (including with the JOREK code) [3] .This also constitutes the beginning of a longer term, wider effort to integrate all future DTT physics analysis and hopefully experimental data eventually obtained from the machine into the IMAS framework. For the purposes of the study described here, DTT data integrated in IMAS include: the machine description (including the central solenoid, poloidal field coils, vacuum vessel, divertor-first wall, and all passive structures considered in a 2D plasma equilibrium/disruption) and the initial equilibrium scenario (5.5 MA plasma current and 6 T toroidal magnetic field) with all the relevant plasma core profiles. JOREK has been initialized using the IMAS data, leading to the simulation of an unmitigated, slow downward Vertical Displacement Event (VDE) with a CQ duration of tCQ = 50 ms and a mitigated VDE with a tCQ = 24 ms. The predictive JOREK results were compared with the initial assumptions taken by MAXFEA, showing very good agreement with the global quantities that drive the evaluation of the EM load.

Key words: IMAS integration, DTT, Disruptions, Divertor,

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