Free-boundary simulations of MHD plasma instabilities in tokamaks

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The growing need for a fundamental understanding of complex MHD phenomena in diverted tokamaks requires the development of more sophisticated and highly demanding codes. The numerical MHD code JOREK-STARWALL is adapted and applied to the simulation of free-boundary instabilities. The investigation of this type of instabilities requires a special treatment for the plasma boundary conditions for the magnetic field, where the interaction of the plasma with the vacuum and the surrounding conducting structures needs to be taken into account. In this work, the modelling of the electromagnetic plasma-wall-vacuum interaction is reviewed and generalized for time-varying coil currents and for the so-called halo currents.

The adapted JOREK-STARWALL code is applied to realistic plasma geometries in order to study the physics of two particular free-boundary instabilities: Edge Localized Modes (ELMs) triggered by vertical position oscillations and Vertical Displacement Events (VDEs). Two major results are obtained: 1. The triggering of ELMs during vertical position oscillations is for the first time reproduced with self-consistent simulations. These allow for the investigation of the physical mechanism underlying this phenomenon. The simulations reveal that for the ITER tokamak, these triggered ELMs are mainly due to an increase in the plasma edge current due to the vertical plasma motion [1]. 2. For VDEs, several benchmarks are performed with other existing MHD codes showing a good agreement and therefore allowing the performance of ITER simulations to estimate the expected amount of halo currents in ITER. Additionally, preliminary toroidally asymmetric VDE simulations are presented.

[1] *F.J. Artola et al, Non-linear magnetohydrodynamic simulations of edge localised mode triggering via vertical position oscillations in ITER, Nuclear Fusion 58 (9) (2018) 096018.*