Modelling of TAE mode excitation with an antenna in X-point geometry

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In magnetic fusion devices, excitation of Toroidal Alfven Eigenmodes (TAEs) can be caused through wave-particle resonance by fusion-born alpha-particles or fast ions generated by ion cyclotron resonance and neutral beam heating. TAEs may affect fast particle confinement, reduce heating and current drive efficiency, cause damage to the first wall, and decrease overall plasma performance. In the absence of fast ions, TAEs can be investigated by launching electromagnetic waves by an external antenna and sweeping the antenna frequency across the TAE frequency range in order to detect a high-quality peak in the plasma response marking the weakly-damped TAE resonance. Excitation of TAE modes with an external antenna has been very successful [1]. It was found, however, that TAEs, probed with an external antenna in the limiter phase of the discharges, disappear when the X-point forms in the magnetic configuration. This effect was thought to be likely due to an increase in the TAE damping rates. More detailed studies [2] show that the damping rates increase significantly with elongation and ellipticity.

The aim of the present work is to investigate in detail the effect of the X-point geometry on the efficiency of the TAE excitation with an external antenna and on the TAE damping rate. An equilibrium from a JET discharge with a clear effect of the X-point on the TAE (pulse #42870) just before and after the X-point phase was analysed with the CASTOR linear resistive MHD code including the external TAE antenna [3]. As the plasma boundary of the simulation domain approaches the separatrix from the core, the amplitude of the excited TAE mode is strongly reduced, in agreement with observations. Damping rates of 0.5 to 10% are found, consistent with the previous results [1]. However, in the castor code the X-point geometry can be only closely approximated. The JOREK-STARWALL nonlinear MHD code has been extended to include the active TAE coils [4]. This does allow the simulation of the excitation of TAE modes with an external antennas in full X-point geometry, including the scrape-off layer. The simulations of antenna excitation of TAE modes is challenging due to the low dissipation (i.e. resistivity, viscosity) that is required to avoid a strong damping. Results in a limiter plasma with the time evolution code JOREK-STARWALL are in good agreement with the steady state solution from CASTOR. Simulations of the JET case in x-point geometry are compared to the linear MHD results to identify the cause for the absence of antenna excited TAE mode in this configuration, as observed in the experiments.

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