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Modelling Toroidal Rotation Damping in ITER Due to External 3D Fields

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Three-dimensional external magnetic field perturbations, can either be intentionally applied such as in the experiments of mitigating edge localised modes (ELM) using resonant magnetic perturbations (RMP), or be un-intentionally generated such as the intrinsic error fields (EF). One crucial consequence of applying these (nearly) static 3D fields is the plasma flow damping.
In this work, we model the toroidal rotation damping in ITER plasmas using the recently developed MARS-Q code. This code solves the n = 0 toroidal momentum balance equation together with the single fluid MHD equations describing the plasma response to external 3D fields. The code includes the momentum diffusion and pinch terms, as well as various momentum sink/source terms (torques) that contribute to the momentum balance and consequently determine the time evolution of the flow profile and its amplitude. We include the resonant electromagnetic JxB torque, the neoclassical toroidal viscous (NTV) torque, the (v,grad)v type of Reynolds stress torque associated with the plasma inertia, the torque source due to neutral beam injection (NBI), the torque due to energetic particle losses in the 3D fields, as well as the torque source associated with the intrinsic rotation. Both the RMP field and the intrinsic error field are considered, with somewhat different toroidal spectra: n = 3 and 4 for the former and n = 1 and 2 for the latter.
For an ITER 15MA plasma with the pedestal temperature of 4.5kA, that we have modeled, preliminary results from the MARS-Q runs show a minor damping of the plasma flow with 30kAt RMP coil current in the n=4 configuration. On the other hand, the plasma rotation at the edge is fully damped with 45kAt current after about 40ms of applying the n=4 RMP field. A further increase of the coil current to 60kAt leads to a quicker damping of the edge flow (~20ms). Similar simulations with the n = 3 coil configuration at 45kAt current also show edge rotation braking. The modelling suggests that the primary damping comes from the NTV torque.

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