Effect of resonant and non-resonant magnetic braking on error field tolerance in high beta plasmas

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Abstract. Tokamak plasmas become less tolerant to externally applied non-axisymmetric magnetic "error" fields as beta increases, due to a resonant interaction of the non-axisymmetric field with a stable $n=1$ kink mode. Similar to observations in low beta plasmas, the limit to tolerable $n=1$ magnetic field errors in neutral beam injection heated H-mode plasmas is seen as a bifurcation in the torque balance, which is followed by error field driven locked modes and severe confinement degradation or a disruption. The error field tolerance is, therefore, largely determined by the braking torque resulting from the non-axisymmetric magnetic field. DIII-D experiments distinguish between a resonant-like torque, which decreases with increasing rotation, and a non-resonant-like torque, which increases with increasing rotation. While only resonant braking leads to a rotation collapse, modeling shows that non-resonant components can lower the tolerance to resonant components. The strong reduction of the error field tolerance with increasing beta, which has already been observed in early high beta experiments in DIII-D [R.J. La Haye, *et al.*, Nucl. Fusion **32**, 2119 (1992)], is linked to an increasing resonant field amplification resulting from a stable kink mode [A.H. Boozer, Phys. Rev. Lett. **86**, 5059 (2001)]. The amplification of externally applied $n=1$ fields is measured with magnetic pick-up coils at normalized beta values as low as 1 and seen to increase with beta. The rate at which the amplification increases with beta becomes larger above the no wall ideal MHD stability limit, where kinetic effects stabilize the resistive wall mode. The beta dependence was not previously appreciated, and was not included in the empirical scaling of the error field tolerance reported in the IPB [ITER Physics Basis, Nucl. Fusion **39**, 2137 (1999)] leading to overly optimistic predictions for low torque, high beta scenarios. However, the measurable increase of the plasma response with beta can be exploited for "dynamic" correction (i.e. with slow magnetic feedback) of the amplified error field.