Contribution ID: **36** Type: **Poster**

Physics of Unlocked Tearing Modes and Disruption Avoidance by Feedback-Based Electromagnetic Torque Injection

Wednesday, 19 October 2016 08:30 (4 hours)

Resistive and quasilinear 3D modeling is improving the understanding of recent experiments [1] carried out in DIII-D and RFX-Mod, in which disruptions were prevented by means of electromagnetic torque applied by non-axisymmetric (3D) coils. We will report the 3D aspects of experimental observations in comparison with finite resistivity (tearing) response by MARS-F and a time dependent torque balance simulation by MARS-Q [2]. Even though these codes are based on linear perturbation theory, many experimental observations are consistent with these 3D model predictions. One is the discovery of stable formation of a multi-layered tearing structure just after avoiding the tearing mode locking. According to magnetic sensors and the internal profile perturbed signals such as toroidal rotation and ion temperature, the mode's maximum perturbation is poloidally and radially concentrated toward the poloidal angle of the control coil location. This is completely different from the ideal-MHD based RWM response, which is nearly independent of the poloidal structure of the applied 3D fields. But, the resistive (tearing) plasma response by MARS-F in the presence of finite plasma resistivity predicts precisely this type of unique poloidal features. The large flow shear observed in experiments is considered as a possible mechanism to stably sustain the multi-layer structure for long duration. This flow shear buildup seems to be qualitatively consistent with the initial results of time dependent torque balance simulation with MARS-Q.
The experimental results and their consistency with 3D MHD models suggest that the use of electromagnetic torque, applied by error field coils or ELM control coils, could help to avoid locked-mode disruptions in ITER.

This work was supported in part by the US Department of Energy under DE-AC02-09CH114661, DE-FC02-04ER546984, DE-FG02-04ER547615, DE-AC05-06OR231006, and DE-AC05-00OR227257.

[1] M. Okabayashi, IAEA Fusion Energy Conference 2014. (2014 IAEA conference, EX/P2-42, Publication in progress)
[2] Y.Q. Liu et al, Phys. Plasmas 20, 042503 (2013)

Paper Number

EX/P3-16

Country or International Organization

USA

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Session Classification: Poster 3

Track Classification: EXS - Magnetic Confinement Experiments: Stability