# Annual report of the ITPA Topical Group on MHD Stability

## For the period July 2009 to June 2010

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The Topical Group (TG) on MHD Stability held two meetings during the reporting period – (i) at Culham Laboratories, UK during October 6-9, 2009 and (ii) at NIFS, Toki, Japan during March 8-12, 2010. The Culham meeting was held in conjunction with an IEA Workshop (W70) on “Key ITER Disruption Issues” while the Toki meeting was held in jointly with a US-Japan Workshop on "Physics of MHD Control of Toroidal Plasmas". The two TG meetings derived a great deal of scientific benefit from the presence of these specialized workshops. At the Culham meeting the IEA workshop provided an excellent opportunity to devote major time and in-depth attention to several important disruption issues such as disruption mitigation, halo currents, disruption statistics and database, runaways and heat loads, and disruption modeling. At the Toki meeting the focus was on the importance of 3-d effects in ITER and in drawing upon the common physics base of helical systems, tokamaks and reversed field pinches and tools developed in helical system research for addressing these 3-d issues in ITER. Detailed reports on the two meetings as well as the viewgraphs presented at the two meetings are available at the ITER website for ITPA. In this report we provide the main scientific highlights and progress made by the TG in its R&D efforts towards addressing the high Priority Research issues related to MHD stability for ITER. The report also summarises the progress achieved in the joint experiments during the year and the work carried out by six internal working groups that were formed during the Culham meeting with the goal of providing timely recommendations on urgent, short-term research questions.

## Disruptions

The subject of disruptions continued to receive major attention during the year through joint experiments, development and updating of the experimental database and modeling efforts. The principal issues addressed were in the areas of disruption mitigation, halo currents, runaways and heat loads, and development of better disruption modeling. Valuable new experimental data was reported during the year from AUG and C-MOD on MGI radiation asymmetries following MGI for disruption mitigation. DIII-D reported promising first results from the shotgun pellet injector. The successful avoidance of disruptions by ECRH application was reported from FTU and AUG. Halo current measurements from NSTX, JET and DIII-D have provided valuable inputs for better modeling of halo widths. Disruption modeling efforts have shown a significant rise during the year with major initiatives using the TSC, DINA, M3D and NIMROD codes. A Task Agreement has been signed between the US, Japan and India to carry out improved halo modeling and provide useful projections for ITER. A parallel effort has also begun in EU to carry out similar work. Tore Supra and DIII-D have reported promising results on runaway control using resonant magnetic perturbations. The results of the joint experiment activities devoted to this topic (namely MDC-1, 16 and 17) are detailed in a later section of the report.

successfully restores the linear correlation of locking threshold with density in H-modes.

2.3. Characterize RWM stability thresholds and destabilization mechanisms across

DIII-D: On DIII-D, preemptive use of ECCD at q=2 was used to maintain stability of ITER demonstration discharges at the ITER collisionality and at lower rotation. Suppression of a locked mode was demons

14.3. Other physics impacting thresholds

Resistive MHD modelling of JET discharges shows that the 2/1 NTM becomes more unstable as evolution of the q profile leads to an increase of magnetic shear (and hence less curvature stabilization).

| MDC-15 | Disruption database development |
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The International Disruption Database has been expanded to include scalar quantities associated with halo currents and electromagnetic impulse on the vessel. Initial data from AUG, DIII-D and NSTX have been submitted. Variables related to MGI experiments are currently being defined toward the next phase of expansion. An ITPA-sponsored presentation has been accepted for the 2010 Fusion Energy Conference.

| MDC-16 | Runaway electron generation, confinement, and loss |
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Measurements: New diagnostics are beginning to provide information on runaway electron dynamics, including gamma ray imaging and visible synchrotron imaging on DIII-D and C-Mod.

Modeling: NIMROD modeling of runaway electron orbits now includes relevant relativistic effects (drifts, acceleration, synchrotron and bremsstrahlung radiation, slowing down. Modelling of C-Mod cases matches the timescales & dynamics of the electron acceleration & loss.

Generation: On JET, analysis suggests runaway generation to be more complex than simple production via the classical Dreicer and secondary processes.

Confinement: On Tore Supra, DIII-D, and JET, active position control can hold the runaway electron beam in the chamber after the thermal quench. In JET, toroidal field ripple and applied n=1 and n=2 magnetic perturbations were ineffective at removing runaway electrons. However, argon changes runaway electron behaviour, suggesting the possibility of collisional removal.

Loss: NIMROD simulations of runaway electron confinement and loss are in progress for MGI disruptions in C-Mod and DIII-D. Previously TEXTOR and JT-60U have shown evidence for enhanced runaway loss with applied magnetic perturbations; a recent DIII-D experiment with the RMP coils is promising but needs better statistics.
Future experiments are planned to test removal or mitigation of a confined runaway beam using RMP, collisions (argon injection), and inductive electric fields.

| MDC-17 | Active disruption avoidance |
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At AUG and FTU, disruption delay or avoidance has been established with feedback controlled local ECRH at the resonant surface of the dominant MHD mode. HL-2A reported NTM stabilization using off-axis ECH near the q=2 surface. ECH near q=2 for improved stability is also used in DIII-D experiments for advanced scenario development. New DIII-D results show that locked mode islands can be stabilized by combined use of ECCD and magnetic perturbations. NSTX has made progress with real time beta and n=1 feedback control, which assist with disruption avoidance. A joint multi-machine scaling is in progress to provide data for predictions for the required

ECRH power at ITER.

The topical group will keep the scope of this joint experiment narrowly focused on the use of ECH and ECCD. Identification of further research needs could lead to additional joint research in related topics such as reliable early detection of disruptions and improved shutdown scenarios.

Progress on Working Groups:

Several new working groups were formed at the October 2009 TG meeting, with the goal of providing timely recommendations on urgent, short-term research questions. Since then, the groups have conferred by e-mail and videoconference. A significant amount of time at the March 2010 TG meeting was devoted to discussing the work of these groups. Progress to date is summarized below.

| WG-1 | Waveforms of current in error field correction coils |
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Hypothetical waveforms were developed that represent the extreme limit of what the error field correction coils might be asked to do with feedback-driven "dynamic error field correction." If evaluation by the ITER Magnet group of these preliminary results shows that the resulting AC losses would be unacceptable, more realistic waveforms will be developed for further evaluation.

| WG-2 | Guideline for optimization of distribution of ferritic inserts |
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The possible effects of resonant and non-resonant field errors that could arise from irregular ferritic inserts in some sectors were evaluated in the light of the recent test blanket module mockup experiment in DIII-D. A preliminary recommendation will be written.

| WG-3 | Power requirements for ECRH and ICRF control of sawteeth |
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Nine subtasks were identified and begun. A multi-machine database has been established for the dependence of NTM beta limit vs sawtooth period. Modeling of the fast ion distribution in ITER and its effect on the sawtooth period is in progress. Modeling of ECCD effects on the sawtooth period has begun, and current experimental results on modification of fast ion-stabilized sawteeth by ECCD and ICRF are being assessed. These activities are expected to be completed by Spring, 2011.

| WG-4 | Diagnostic requirements for MHD stability control |
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It was agreed that the scope of this working group will be requirements for the physical quantities that should be measured, and not specific recommendations on the type, quantity, or location of the sensors. Leads and potential contributors have been identified for subgroups on diagnostic requirements for various instabilities. Tables of requirements are now being circulated in draft form among the WG. This activity is expected to be completed by November 2010.

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| WG-5 | Halo currents caused by disruptions |

Recent experimental data from halo current measurements in several tokamaks have been evaluated, including frequency of occurrence, upper bounds, and discussion of one exceptional case. The ITPA disruption database (MDC-15) is expected to provide further data in the near future. A preliminary report is expected in June 2010. Comparison of experimentally measured halo current width and modeling predictions has begun. The issue of rotation of asymmetric halo currents was transferred to WG-6.

WG-6