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Non-Linear MHD Simulations for ITER & Non-Linear MHD Modelling of Edge Localized Modes and their Interaction with Resonant Magnetic Perturbations in Rotating Plasmas

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A

Validation of MHD models and MHD simulations on current experiments is needed to provide a physics basis for the application of these models to ITER. This paper describes the progress made towards validation in the area of the stability of the H-mode edge pedestal and ELM control.

ELM control: pellet pacing

The injection of pellets is one of the methods foreseen to control ELM energy losses and power fluxes in ITER. Previous non-linear MHD simulations using the JOREK code of pacing pellets in DIII-D have shown that the minimum pellet size for an ELM trigger is correlated with the 3D pressure perturbation created by the pellet. This has been extended to the simulation of pacing pellets injected in JET. The simulation domain including the divertor allows simulation of a full pellet triggered ELM cycle. The simulated ELM size is found to depend on the pedestal properties of the target plasma. The divertor heat load shows a n=1 asymmetry for low field side injection (as observed experimentally). The paper will discuss the dependence of the power deposition asymmetry on the injection geometry and the consequences for ITER.

ELM control: QH-mode

Recently, DIII-D has made significant progress in the development of ELM free QH mode plasmas in an ITER relevant regime, using the RMP coils to control the rotation profile. To develop the physics basis for ITER, non-linear MHD simulations of DIII-D QH-mode plasmas have been performed. The JOREK code has been coupled with the STARWALL code for the resistive wall, vacuum and coils contributions. The influence of the rotation and rotation shear on the stability and saturation of the kink mode will be investigated and compared with DIII-D experiments.

SOL MHD stability

Observations of the SOL heat flux width of the inter-ELM scrape-off layer (SOL) for low density H-modes, show an inverse dependence on the poloidal field. Extrapolating to ITER results in a narrow SOL width of ~ 1 mm. The MHD stability limits of the pedestal and SOL pressure profile have been analysed to evaluate whether MHD limits could prevent such narrow profiles. ITER scenarios with narrow SOL widths are found to be stable to infinite-n ballooning modes. The ballooning stability in the pedestal shows a higher (by ~40%) stability limit in the SOL compared to the pedestal. This indicates that the narrow SOL are consistent with MHD stability limits in ITER.

B

The intensive experimental and theoretical study of Edge Localized Modes (ELMs) and methods for their control has a great importance for ITER. The application of small external Resonant Magnetic Perturbations (RMPs) has been demonstrated to be efficient in ELM suppression/mitigation in present day tokamaks. RMPs are foreseen as one of the promising methods of ELM control in ITER. In the present work the dynamics of the full ELM cycle including both the linear and non-linear stages of the crash and the possible explanation of the mechanism of ELM mitigation by RMPs are presented based on the results of the multi-harmonics non-linear resistive MHD modeling using the JOREK code. These simulations are performed in the realistic tokamak geometry with the X-point and the Scrape-Off-Layer (SOL) with relevant plasma flows: toroidal rotation, the bi-fluid diamagnetic effects, and neoclassical poloidal friction. The introduction of flows in the modelling demonstrated a large number of new features in the physics of ELMs and their interaction with RMPs com-

pared to previous results.
The novelty of the present work consists firstly in the demonstration of non-linear MHD simulations with the diamagnetic effects the multi-cycle ELMy regimes. Secondly, the ELMs rotation on the linear stage (precursors) and on the non-linear stage (ELM filaments) were modeled. Finally for the first time ELMs mitigation by RMPs was demonstrated for realistic JET-like parameters. The peak power reaching the divertor is found to be reduced by a factor of ten by RMPs. Mitigated ELMs represent small relaxations due to the non-linearly driven modes coupled to the imposed n=2 RMPs.The divertor footprints of the mitigated ELMs exhibit structures created by n=2 RMPs, however, slightly modulating them due to the presence of other harmonics, feature observed in experiments.

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