IAEA FEC 2014

Contribution ID: **174** Type: **Poster**

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

Friday, 17 October 2014 14:00 (4h 45m)

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 compared 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.

Paper Number

TH/6-1Rb

Country or International Organisation

France

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Session Classification: Poster 8