A NONLINEAR SIMULATION STUDY OF THE EFFECT OF TOROIDAL ROTATION ON RMP CONTROL OF ELMS

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Abstract: We present numerical simulation studies on the combined influence of a resonant magnetic perturbation (RMP) and a sheared toroidal flow on the characteristics of edge localized modes (ELMs). We find that the presence of a sheared flow enhances the stabilising effect of the RMP in a synergistic manner. For a fixed RMP power a comparative study is made of the nature of ELM dynamics for different flow configurations. A counter-current-off-axis flow is found to be the most effective in mitigating ELMs by changing their nature from spiky Type-I ELMS to a grassy variety. There is also a concomitant improvement in the overall plasma beta and energy confinement time.

Introduction

• Edge Localized Modes (ELMs), a common feature of tokamak plasmas, can cause severe damage to PFCs.

• A resonant magnetic perturbation (RMP) introduced from the edge of the tokamak plasma can be employed to terminate the growth and eventual onset of ELMS.

The dynamic of ELMs is still complex, introduction of an RMP complicates it further. So numerical simulations are a convenient way to study them.

• In an actual controlled scenario additional physical factors such as plasma rotation can introduce significant modifications in the characteristics of ELMs.

Past studies do not provide definitive conclusions or a complete understanding of the influence of equilibrium flows on the stability of ELMs.

• It is important to investigate what happens to the efficacy of RMP to control ELMs in the presence of plasma rotation.

Control of ELM dynamics with RMP without flow

• Considerable reduction of ELMS amplitude with application of RMP

• As a consequence, plasma beta and energy confinement of the system improve considerably

Power spectrum of fluctuations with RMP without flow

• Significant change in fluctuation spectra with application of RMP

• Application of RMP causes shift in the spectrum towards higher frequencies

Influence of Off-axis negative flows without RMP

• The stabilising effect of RMP to be most effective for off-axis negative (counter) flows

• Higher the amount of flow – Smaller the amplitude of ELMS

• The off-axis negative flows modify the power distribution and shift power to lower frequency – Consequently negative flows have significant influence on ELMS dynamics.

Influence of Off-axis negative flows with RMP

• The combined presence of RMP and flow further reduce the ELMS amplitude

• Higher the amount of flow – Smaller the amplitude of ELMS (for RMP amplitude remains constant)

• The combined presence of RMP and flow further spread the power distribution towards higher frequencies - Consequently further reduction in the amplitude of ELMS

Synergy of RMP and Flow on ELMS

• The addition of RMP and flow enhancement in presence of both RMP and flows in comparison to only RMP or only flow case

• So the result along with the relative improvement of confinement support clear synergistic influence of RMP and flows on ELMS.

• The synergistic effect continues even for higher flows through the relative difference between RMP and off-axis RMP case. This can be attributed to the flow screening of RMP.

Summary

• The ELMS simulations have been carried out using 2D finite element code that models ELMs by utilizing particle source in the confinement region and particle sink in the scrape-off-layer.

• RMP PARAMETER Profile-dependent torus shape and self-consistent evolution of plasma gradients

• We have studied the multi-timescale ELMs cycle in presence of toroidal rotation

• The objective is to understand the combined influences of the sheared equilibrium flows and RMPS on the characteristics of ELMS.

• We have done comparative studies with different combinations of flows for a fixed RMP amplitudes

• Even from the combinations, the relative order of the counter-current sheared flows shows the most synergistic impact on the RMP controlled ELMS mitigation

• For strong flows the stabilisation mostly due to flows as the RMP-effect diminished by flow screening.