Control of Edge-Localized Mode in Magnetically Confined Fusion Plasmas

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A great challenge for fusion energy research and technology is to confine burning plasma while maintaining tolerable steady state and transient heat and particle fluxes on plasma-facing components. When tokamak plasmas operate in a high-confinement (H-mode) regime, a significant increase in the plasma energy confinement time is observed. However, as a consequence, a steep plasma pressure gradient and an associated increased current density at the plasma edge could exceed a threshold value to drive magnetohydrodynamic (MHD) instabilities referred to as edge-localized modes (ELMs).

The research of ELMs is of high interest generally, as it involves both linear and non-linear relaxations, requires knowledge of microscopic and macroscopic processes in a volatile plasma with a large magnetic field, and includes higher dimensional effects such as turbulence and 3-dimensional distortions. This understanding enhances similar research into the mechanisms occurring at the edge of stars, for example solar flares.

Similar to the solar flares, ELMs lead to quasi-periodic expulsions of large amounts of energy and particles from the confined region, which in turn could result in serious damage to plasma-facing components (PFCs). The next generation fusion machines, like ITER and DEMO, will need a reliable method for controlling or suppressing large ELMs.

To date, investigation of ELM control is mainly directed into three different strategies:

i) Radiating dispersion: Dispersing the ELM energy loss by radiation before it is deposited at the PFCs,
ii) ELM suppression: stabilizing the ELM instability by means of controlling either the pedestal pressure gradient or the edge current density below the peeling-ballooning ELM stability limit,
iii) ELM mitigation: destabilizing the ELM instability, thus increasing ELM frequency and reducing the ELM energy losses, by applying either steady-state or transient perturbations at the plasma edge.

Over the last decade, several active methods, including (i) radiating divertors (impurity gas puffing), (ii) magnetic triggering (vertical kicks), (iii) pellet pace-making of ELMs, and (iv) resonant magnetic perturbation (RMP) fields, have been developed for large ELM suppression/mitigation on many different devices (DIII-D, JET, MAST, NSTX, AUG, TCV, KSTAR and EAST). Those promising results could help us to understand ELM suppression/mitigation physics and provide more solid support for success of ELM control on ITER.

On the basis of the physics achievements in the past few years and the exceptional capabilities being implemented in 2013, EAST has demonstrated in the first time ELM suppression/mitigation with lower hybrid wave (LHW) and Li-pellet injections, and is capable of investigating ELM control in long-pulse high performance steady-state scenario with all existing ITER-relevant methods, including RMP, pellet-pacing and SMBI.

In this paper, a brief introduction on the present common understanding of ELM physics will be presented. An overview of recent developments of ELM control methods for next-generation tokamaks, e.g., ITER will be given. Based on the recent experimental results from EAST, some key physics issues related to the mechanism of ELM control are described. In addition, the role of magnetic topology in accessing ELM suppression will be discussed.

References

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