Suppression of Edge Localized Modes in the DIII-D Tokamak with Small 3D Magnetic Perturbations

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Edge Localized Modes (ELMs), associated with large edge pressure and current profile gradients in high confinement (H-mode) plasmas, are a significant concern for the next generation of large tokamaks such as ITER where the stored plasma energy is expected to exceed several hundred megajoules. The largest transient energy bursts driven by ELMs in ITER are predicted to release as much as 6%-7% of the plasma energy in less than a millisecond. This is expected to cause a substantial increase in the divertor target plate erosion rate resulting in a reduction of the operational lifetime of these essential components. In addition, the eroded divertor target plate material may cause an increase in the influx of impurities into the core plasma that could limit the fusion power output of the device and trigger instabilities that are known to lead to a rapid termination of the discharge. Over the last few years, a series of experiments done in the DIII-D tokamak have demonstrated that large ELMs can be reproducibly suppressed over a wide range of H-mode conditions and plasma shapes including ITER similar shapes with ITER pedestal collisionalites. In these experiments, it is found that small 3D magnetic perturbations ($b_{3D}/b_{tor} \sim 2\times10^{-3}$), primarily localized to the edge of the plasma, can be used to suppress the first ELM following the L-H transition and to maintain an ELM suppressed discharge for up to 24 energy confinement times, limited only by the heating duration of DIII-D neutral beams. During this time the line average density, pedestal density, Z_{eff} and core radiation rate all remain constant, in contrast to a conventional ELM-free H-mode, suggesting that robust steady-state H-mode conditions, with an H-mode factor H89Y2 of approximately unity, have been achieved. ELM suppression has been obtained using both n=3 and n=2 resonant magnetic perturbation fields from the DIII-D internal non-axisymmetric coils. The current requirements for ELM suppression and plasma response to the applied perturbation fields are most sensitive to the safety factor at the 95% flux surface and the shape of the outer flux surfaces. In this talk, examples of the plasma characteristics observed in DIII-D ELM suppressed H-mode plasmas will be discussed along with a summary of the operational space required for suppression and an overview of the physics mechanisms that are believed to be important for obtaining ELM suppression in DIII-D. Implications for scaling these results to ITER will also be discussed.

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