H–mode Edge-Driven Instabilities as Low-n Kink/Ballooning Modes*

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Variation of the discharge shape offers a powerful tool for investigating the MHD stability of the plasma edge. Recent DIII–D experiments using this technique support the hypothesis that edge-localized modes (ELMs) normally result from low-n instabilities driven by the pressure gradient and current density in the H–mode edge. Ideal MHD theory predicts a variation with discharge shape of the pressure gradient threshold for current and pressure driven modes and the toroidal mode number (n) of the most unstable mode. These predictions are in agreement with observed changes in edge pressure gradient and ELM amplitude and frequency in discharge shapes with either high squareness or low triangularity. In these discharge shapes the stability threshold in the edge pressure gradient is predicted to be reduced and the most unstable mode is expected to have higher values of n.

Both low and high n stability thresholds are found to be relevant. The combination of proper discharge shape and sufficient edge-region current density (bootstrap current, for example) results in access in the pedestal region to the second regime of stability for high n modes, in particular the ideal MHD ballooning mode. This allows the edge pressure gradient to increase, to values up to several times the ballooning mode first regime stability limit, until a low toroidal mode number ($n < 10$) coupled kink/ballooning mode is destabilized. The theory predicts that there is a minimum value of n for second regime access and that the most unstable mode is expected to have n near this threshold.

The measured edge pressure gradient during type I ELMs is within 40% of the calculated stability threshold for $n = 5$ kink/ballooning modes, and the experimental and calculated values scale similarly with discharge squareness and triangularity. In contrast, the measured pressure gradient is significantly above the level that would be expected if ELMs are destabilized at the ballooning mode first stability regime threshold. In addition, both the measured edge pressure gradient and the calculated stability threshold for $n = 5$ decrease as the width of the H–mode pedestal region increases. This is consistent with a relatively low n, long wavelength, instability that is sensitive to the profiles of the pressure gradient and current density rather than a high n instability, such as the ballooning mode, which is sensitive only to the local pressure gradient and magnetic shear. The dependence of the stability threshold on the pedestal width is evident in discharges in which ELMs are triggered by injection of a deuterium pellet. After the pellet injection the pedestal width decreases with time and the ELM P'_{edge} threshold increases. Observation of changes in H–mode pedestal parameters resulting from variation of discharge shape and injection of deuterium pellets, then, leads to a model of Type I ELMs in DIII–D as low-n current/pressure driven instabilities.

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