EFFECTS OF PLASMA SHAPE AND PROFILES ON EDGE STABILITY IN DIII–D*

L.L. Lao, J.R. Ferron, R.L. Miller, V.S. Chan, R.J. Groebner, G.L. Jackson, R.J. La Haye, E.A. Lazarus,[1] G.R. McKee,[2] M. Murakami,[1] T.H. Osborne, B.W. Rice,[3] E.J. Strait, T.S. Taylor, A.D.Turnbull

General Atomics, P.O. Box 85608, San Diego, CA 92138-5608

[1]Oak Ridge National Laboratory, Oak Ridge, TN
[2]University of Wisconsin-Madison, Madison, WI
[3]Lawrence Livermore National Laboratory, Livermore, CA

Pressure-driven edge instabilities with low toroidal mode numbers typically terminate the ELM-free phase of DIII–D high performance discharges, often accompanied by a permanent loss of the internal transport barrier. These discharges are characterized by broad pressure profile typical in H–mode plasmas. Recent calculations and experiments show that discharge shaping can be used to reduce or eliminate access to the second stable regime for high-n modes at the edge, thereby limiting the edge pressure gradient and bootstrap current density which would otherwise destabilize the low-n modes.

The edge instabilities terminating the ELM-free phase have moderate toroidal mode number n = 2–5 with a fast growth time $\gamma^{-1} \approx$ 20–150 μs. The attainable β value decreases as the fraction of plasma current contained in the edge region increases, and is consistent with the previously observed operational limit of normalized beta $\beta_N \approx 4\ \ell_i$. The instability can have global effects, ranging from a slight change of T_e near the edge with a saturation of the plasma stored energy, to a drop of T_e across the entire plasma with a decrease in the plasma stored energy. The transport barriers observed in VH–mode and negative central shear discharges are usually destroyed. After this first edge instability occurs, the discharge goes into an ELMing quasi-stationary phase at similar or lower β values. Low n magnetic perturbations are rarely observed during this phase, which suggests that these later ELM events may be driven by edge instabilities with significantly higher n.

The results of ideal stability calculations are consistent with many observed features of the instability. Low n = 1–3 stability analysis using both experimental and simulated equilibria suggests that plasmas with broad pressure profiles, as typically observed in VH– and H–mode discharges, are more unstable to n > 1 modes, and that large edge pressure gradient and current density are the main driving forces. Modes with higher n and a narrow peeling feature become unstable first. The results also suggest that the radial width of the unstable modes increases with the width of the large pressure gradient region at the edge, as qualitatively observed in VH–mode discharges. A conducting wall is not effective for stabilization against these n > 1 modes.

Second ideal ballooning access in the plasma edge region plays an essential role in the occurrence of these instabilities and the resulting ELM character by facilitating the development of a steep edge pressure gradient and the associated edge bootstrap current. Edge instabilities with n = 2–5 have been observed in discharges with a variety of poloidal cross sections with high elongation and moderate squareness including Dee and crescent shapes, and single- and double-null divertors, all of which have second ballooning stability

---

*Work supported by the U.S. Department of Energy under Contract Nos. DE-AC03-89ER51114, DE-AC05-96OR22464, W-7405-ENG-48, and Grant No. DE-FG02-92ER54139.

access in the plasma edge region. The edge pressure gradient in these discharges substantially exceeds the first ideal ballooning stability limit [1]. However, in a recent experiment with high squareness discharges (Fig. 1), these n = 2–5 edge instabilities are not observed or have much lower amplitude. A weak internal transport barrier is maintained in the ELMing phase. These square-shaped discharges have low edge pressure gradients (Fig. 1) which are limited by the first ballooning stability, and the ELMs have very high frequency and low amplitude quite unlike those from the moderate squareness discharges discussed above. These results are consistent with the theoretical simulations of ballooning mode stability using self-consistent pressure and bootstrap current profiles [2] which show that high elongation and moderate squareness facilitate the second ballooning access, whereas for both high and low squareness the edge region is securely in the first regime.

These results suggest that both the high n ballooning modes and the intermediate to moderate n modes play a role in the edge instabilities and that the appearance of ELM amplitude and frequency is determined by the complex interactions between the edge current density and pressure gradient. Second ballooning access is necessary to allow buildup of a large edge pressure pedestal beneficial for plasma core ignition. However, a large edge pressure gradient and its associated large edge bootstrap current destabilize the intermediate to low n kink modes. An optimization between the two is essential for high performance. Since these instabilities are sensitive to details of the edge pressure gradient and the edge current density, to allow a more definite comparison with theory new experiments are planned using the recently upgraded 35-channel MSE system [3] together with a radial sweeping technique to better characterize the plasma edge and the instabilities. A new high n peeling/ballooning mode code in which a crucial role is played by the edge current density using realistic numerically computed equilibria as input is also developed in collaboration with the Culham group for a more detailed comparison with the experimental observations.

[1] OSBORNE, T.H., et al., Proc. of the 24th EPS Conf. on Contr. Fusion and Plasma Physics, Berchtesgaden, Germany (European Physical Society, 1997) Vol. 21A, Part III, p. 1101.

[2] MILLER, R.L., et al., "Ballooning Mode Stability for Self-Consistent Pressure and Current Profiles at the H–Mode Edge," to be published in Plasma Phys. and Contr. Fusion.

[3] RICE, B.W., et al., Phys. Rev. Lett. **79**, 2694 (1997).

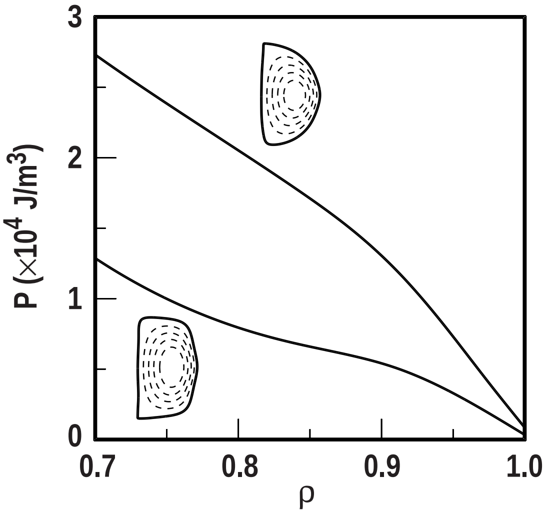

Fig. 1. Comparison of edge pressure of a high squareness discharge to that of a moderate squareness discharge.