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*Lawrence Livermore National Laboratory, Livermore, California.

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Pedestal Performance Dependence Upon Plasma Shape in DIII-D* EX-S

A.W. Leonard,[1] T.A. Casper,[2] R.J. Groebner,[1] T.H. Osborne,[1] P.B. Snyder,[1] and D.M. Thomas[1]

[1]General Atomics, P.O. Box 85608, San Diego, California 92186-5608
email: leonard@fusion.gat.com
[2]Lawrence Livermore National Laboratory, Livermore, California

Higher moments of the plasma shape than triangularity, i.e. squareness, are found to significantly affect the pedestal pressure and edge localized mode (ELM) characteristics in DIII-D. The pedestal pressure was controlled over a range of 40% by minor changes to the plasma shape while maintaining a fixed divertor configuration with constant pumping and fueling. For this report squareness is defined as the degree of modification from a triangler shape to a rectangular one for each quadrant of the plasma. The pedestal pressure change is consistent with that expected from magnetohydrodynamic (MHD) stability analysis of the experimental profiles and magnetic equilibrium. Higher moments of the plasma shape offer the potential to control the pedestal pressure and ELM characteristics without changing the divertor configuration and its associated effect on particle fueling, recycling and pumping.

To test the ITER dependence of pedestal pressure on plasma shape the upper outer squareness was varied about the proposed ITER shape. The range of shapes examined is shown in Fig. 1(a). Over this scan the pedestal pressure, Fig. 1(b), increased by ~20% over the ITER target shape for low squareness while the pressure decreased by ~20% at higher squareness. The ELMs also responded to the change in shape with the energy released at an ELM scling proportonal to the pedestal height. The safety factor, q~3.7, was higher than the ITER target while the average triangularity was held nearly constant at ~0.5 by slightly adjusting the lower triangularity through the scan. The input power of 6.5 MW resulted in regular ELMs with a frequency of ~35 Hz.

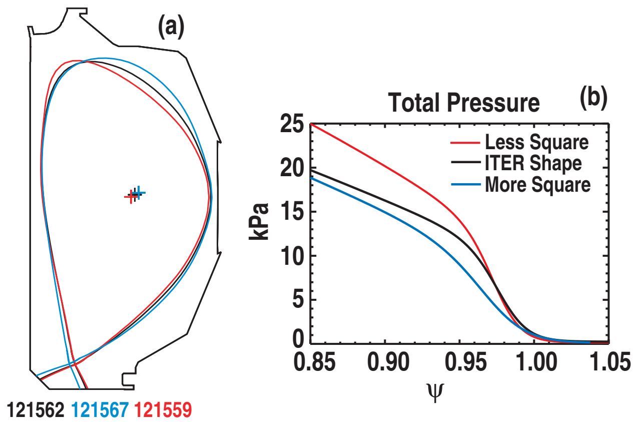

Fig. 1. (a) The upper outer squareness is varied about the proposed ITER shape. The black curve represents the ITER shape with the blue curce more square and the redu curve less square. (b) The pedestal pressure progressively increases withlower squareness.

Variation in pedestal energy with squareness was used to optimize "hybrid" discharges in DIII-D. These discharges are characterized by good confinement and a lack of central sawteeth instabilities when a beneficial internal tearing mode maintains the central safety factor above 1. At low squareness the high stability limit for the pedestal produced a high pedestal pressure with large infrequent ELMs that eventually triggered an internal 2/1 tearing mode that locked, resulting in a disruption. At higher squareness the pedestal pressure was reduced resulting in lower confinement. However, the ELMs were smaller and more rapid and the total stored energy was easily controlled to maintain a steady beneficial internal 3/2 tearing mode. The resulting global beta was higher than could be maintained for the lower squareness shape, while maintaining the optimal divertor configuration for optimal pumping and density control.

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The variation in pedestal pressure with squareness is well described by stability limits imposed by the peeling-ballooning model. The pedestal MHD stability limits were examined by first reconstructing the magnetic equilibrium while constraining the pressure and current profile. The pressure profile was determined by fitting all the relevant profiles, including electron and ion temperature, electron density and carbon impurity fraction to determine the ion density, and calculating the fast ion contribution to total pressure. The edge current was constrained by a collisional neoclassical bootstrap calculation. The growth rate of intermediate toroidal mode number (n~5-30) MHD modes, as calculated by the ELITE code from the reconstructed equilibria, was consistent with the observed change in pedestal pressure.

To gain further insight into pedestal stability variations, additional equilibria were created around the experimentally measured operational point. A stability map for each condition was constructed by stability analysis of multiple equilibria with variations in multipliers of the pedestal pressure and bootstrap current. Such a stability map for the low squareness hybrid discharge is shown in Fig. 2, where the growth rate of the ELM instability, normalized by the Alfvén frequency, is plotted versus both average pedestal current and peak pedestal pressure gradient. A contour of the expected stability limit, $\gamma/\gamma_A \sim 0.1$, as well as the measured operational point is also overlaid. The stability contour of the high squareness case, as well as its operational point, from a similar calculation is also overlaid. As can be seen in the figure, the calculated stability limit increases with lower squareness similar to the measured change in pedestal pressure.

The response of the pedestal pressure to changes in global beta was also found to be dependent upon plasma shape. Global beta was varied by a factor of nearly 2 in a high triangularity configuration by additional heating power to produce an internal transport barrier in an H-mode plasma. The pedestal pressure gradient remained nearly constant with a modest increase in the pedestal pressure width, primarily in the ion temperature component. A beta scan in a lower triangularity configuration produced a nearly constant pedestal pressure. This beta dependence for pedestal pressure in varying shapes has important implications for advanced tokamak modes as well as confinement predictions for ITER. The beta dependence of the pedestal pressure for low and high triangularity will be examined by stability analysis of model equilibria varied around the experimental operational points as described above.

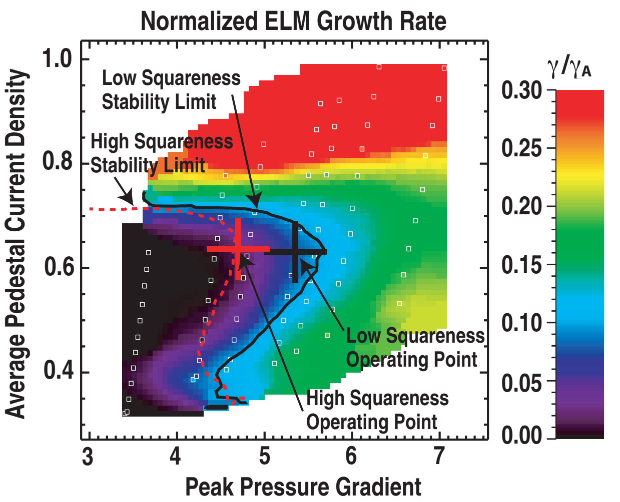

Fig. 2. Color contour of the peeling-ballooning mode growth rate, normalized by the Alfvén time, as a function of pedestal pressure gradient and average pedestal current, for the low squareness hybrid discharge. The contour of the expected stability limit, as well as the observed operational point are overlaid. The high squareness stability limit and operational point are also overlaid.