H-mode and ELM Studies at Near-Unity Aspect Ratio[1]

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The H-mode confinement regime is achieved at near-unity aspect ratio (A < 1.2) on the Pegasus Toroidal Experiment. Ohmic H-mode is attained in both limited and diverted magnetic geometries via high-field-side fueling and low edge recycling. The features of this regime are: reduced D_α emissions; formation of a quiescent edge and an edge current pedestal; increased rotational edge shear; increased central heating; energy confinement consistent with the ITER98pb(y,2) scaling; and the presence of ELMs.

The H-mode power threshold, P_{LH}, behaves quite differently at low-A when compared with high-A operations. This threshold power has been studied in both limited and favorable SN diverted plasmas in Pegasus. It is found that Pegasus requires P_{LH} = 10–20x more power than that predicted by the ITPA08 scaling. This continues the trend indicated from NSTX and MAST that increasingly more power than predicted by the scaling is required as A decreases. Since the ITPA08 P_{LH} scaling is derived from high-A tokamak H-mode studies, these results hint at missing underlying physics in the P_{LH} scaling and understanding. The power threshold on Pegasus is observed to increase with density in both topologies. However, unlike at higher-A, no minimum power threshold is observed. Also in contrast to higher-A tokamaks, where P_{LH} is ~2x higher in limited plasmas than diverted plasmas, the power threshold in limited plasmas on Pegasus is approximately the same as the power threshold in favorable SN diverted plasmas. Some of these results are consistent with the FM^3 model for the L-H transition[2]. This model predicts the density at which the minimum power threshold exists for Pegasus to occur at ~$1\text{x}10^{18}$ m^{-3} (n_G << 0.1). This is too low of a density to be routinely accessed on Pegasus. The model also suggests that $P_{LH} \sim q_{edge}^{-7/9}$. As A approaches unity, the safety factor profile $q(\psi)$ for limited and diverted discharges becomes increasingly similar. On Pegasus at A ~ 1.2, q_{edge} is approximately the same in both limited and favorable SN plasmas. Under this condition, the FM^3 model predicts that P_{LH} for limited and diverted plasmas would be the same, as observed.

Two classes of ELMs have been observed on Pegasus. Small, Type III-like ELMs are present at input power $P_{OH} \sim P_{LH}$ and have toroidal mode number $n \leq 4$. At $P_{OH} >> P_{LH}$, large, Type-I-like ELMs with intermediate $5 < n < 15$ appear. These general mode numbers are opposite those seen for Type I and III ELMs at large A. This likely reflects the increased peeling drive present at low A. The unique operating characteristics available at A ~ 1 in Pegasus allow long-sought measurements of the time evolution of the $J_{edge}(R,t)$ pedestal collapse during an ELM event. Such measurements with a multi-channel magnetic probe array show a complex, multimodal pedestal collapse and the subsequent ejection of a current-carrying filament.

The present experimental emphasis is to measure the edge pressure profile to complement the edge current measurements.

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[2] Fundamenski *et al.*, Nucl. Fusion **52**, 062003 (2012).