Near-Unity Aspect Ratio H-mode and ELM Studies

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The Pegasus Toroidal Experiment is an ultra-low aspect ratio ($A < 1.2$) spherical tokamak, enabling exploration of the unique plasma characteristics of the tokamak at near-unity A. 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 compared to 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} to be 10–20× higher than projected by the conventional ITPA08 scaling. This continues and emphasizes 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 results, these findings hint at missing underlying physics in our understanding of the L-H power threshold that manifests at low-A. The power threshold on Pegasus is observed to increase with density in both topologies. However, unlike at higher-A, no minimum P_{LH} with density is observed. Also in contrast to higher-A tokamaks, where P_{LH} is ~2× higher in limited plasmas than diverted plasmas, the threshold in approximately the same in both limited and favorable SN diverted Pegasus plasmas.

Some of these results are consistent with the FM^3 model for the L-H transition.[1] This model predicts the density at which the minimum power threshold exists for Pegasus to occur at $\sim 1 \times 10^{18}$ m^{-3} ($n_e/n_G << 0.1$), which is too low to be routinely accessed. The P_{LH} insensitivity to magnetic configuration on Pegasus is related to the model's prediction that $P_{LH} \sim q_{edge}^{-7/9}$. At low-$A$, q_{edge} is approximately the same in both limited and favorable SN plasmas. Hence, the P_{LH} for limited and diverted plasmas would be similar, 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. The mode numbers for Type III ELMs at low-A are opposite those seen at large-A, which likely reflects an increased J/B peeling drive at $A \sim 1$. The unique edge plasma parameters afforded by near-unity A operations allow long-sought measurements of the edge current profile dynamics during an ELM. Such measurements on Pegasus with a multi-channel magnetic probe array show a complex, multimodal pedestal collapse and the subsequent ejection of a current-carrying filament.

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