Extending the boundary heat flux width database to 1.3 Tesla poloidal magnetic field in the Alcator C-Mod tokamak

D. Brunner, B. LaBombard, A.Q. Kuang, J.L. Terry, J.W. Hughes, A. Hubbard, M.L. Reinke[a], S.M. Wolfe, and the Alcator C-Mod Team

Massachusetts Institute of Technology Plasma Science and Fusion Center, 175 Albany Street, Cambridge, Massachusetts 02139 United States of America
[a]Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States of America

brunner@mit.edu

The boundary heat flux width (λ_q), along with the power flowing into the boundary, sets the peak heat flux that must be exhausted in the boundary of magnetic confinement fusion reactors. Understanding what sets λ_q has largely been an empirical science [1], however physics understanding is progressing [2-4]. Results from a 6-machine international database of measurements of λ_q at the outer divertor in H-mode indicated that the poloidal magnetic field at the outer midplane (B_p) was the only significant parameter associated with the heat flux width: λ_q [mm] = $(0.63\pm0.08)\times(B_p\ [\mathrm{T}])^{-1.19\pm0.08}$ [1]. The maximum B_p in the database was ~0.8 T, whereas the 15 MA scenario in ITER will be 50% higher at ~1.2 T. Alcator C-Mod has been the only diverted tokamak in the world capable of operating at and above ITER-level B_p. Therefore, a major focus of the final experimental campaign on C-Mod was to extend λ_q measurements to reactor-relevant B_p, up to 1.3 T. Measurements clearly indicate a continuation of the inverse scaling of λ_q with B_p in H-mode up to and exceeding ITER-level B_p. While these results are broadly consistent with the HD model [2] they will, perhaps more importantly, provide a benchmark for first principles models [3,4], one of which presently projects [3] to ~10 times larger λ_q than the empirical scaling for ITER at the same poloidal magnetic fields.

In addition to the high-B_p measurements, we have assembled a database of λ_q measurements consisting of over 300 shots that span nearly the entire operating space of Alcator C-Mod (L-, H- and I-modes) under attached divertor conditions. As seen in earlier studies [5], λ_q at fixed values of poloidal magnetic field exhibit significant scatter that appears related to the core plasma confinement quality, i.e., discharges with the highest stored energy tend to have the smallest λ_q. Using the extended database, we are presently exploring correlations of λ_q with global plasma parameters and with conditions in the pedestal; we will report on the latest results at this meeting. In addition, the database now includes a composite of measurements made by surface thermocouples and Langmuir probes, both benchmarked against calorimetry. These sensors have much better spatial resolution and heat flux dynamic range than IR thermography, allowing for more accurate fits of λ_q to the measurements and resolving the role of heat flux spreading into the private flux region. We find that the standard analytic form [1] that assumes a symmetric, diffusive-like spreading of heat toward private and common flux regions is not appropriate under many conditions. Instead, we find that a 2-decay length model for both the private and common flux regions is a more appropriate empirical description.

[1] T. Eich, *et al.*, Nucl. Fusion **53** (2013) 093031. [2] R.J. Goldston, *et al.*, Nucl. Fusion **52** (2012) 013009. [3] C.S. Chang, *et al.*, Nucl. Fusion **57** (2017) 116023. [4] B. Chen, *et al.*, APS 2017, paper in progress. [5] B. LaBombard, *et al.*, Phys. Plasmas **18** (2011) 056104.

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