Anomalous First-Wall Heating Due to Instability-Related Ion Loss During QH-mode

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QH-mode is of interest for long pulses without edge localized modes (ELMs) in a high-power tokamak, which would lengthen the lifetime of the divertor plate. However, during many QH-mode discharges, we detected localized heating of the upper outer baffle far outside the strike point in DIII-D upper single-null discharges. The peak heat flux calculated from infrared camera measurements is in many cases comparable the heat flux at the outer strike point, and so could be a significant cause of first-wall damage in a higher-power machine.

We attribute this heating to impact by moderate energy (~5 keV) ions lost from the core plasma, with supporting data from charge exchange recombination (CER) measurements and fixed Langmuir probes. We find a class of QH discharges in which the power deposited in this area of the upper outer baffle depends linearly on core β, and another class in which the baffle heating is lower by more than a factor of three and does not depend on core β. The β-dependent case occurred in discharges in which less-tangential neutral beams were injected at 75 keV for the full-energy component. The beta-independent case had the less-tangential beams at 70 keV. Variation of the energy of more-tangential beams did not have an observable effect on the ion loss. This sensitivity to less-tangential beam energy is not what would be expected for prompt beam ion loss from the periphery of the plasma.

The dependence of the anomalous power loss on core β and beam energy suggests that a core instability is responsible for the ion loss. In far infrared scattering data, we find signatures of the reversed shear Alfvén eigenmode (also known as the Alfvén cascade). However, this mode is seen in the majority of discharges in both cases, and so does not correlate well with the ion loss. Some discharges also exhibit toroidal Alfvén eigenmodes, whose presence also does not correlate with the ion loss. The strong effect of less-tangential beams may be an indication of the importance of trapped particles in the loss mechanism. There is as yet no obvious reason the anomalous particle loss should be specific to QH-mode, but it has not been observed in other high-performance regimes such as weak or reversed central shear, hybrid, edge localized mode-free, or VH modes. We will examine other instabilities such as core tearing modes that may be causing the observed ion loss.

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