H-Mode Threshold and Pedestal Issues related to magnetic configuration

Amanda Hubbard, July 3, 2002

A difficulty in uniform assessment of ITER, FIRE and Ignitor is that they all have different magnetic configurations; ITER will have a single-null divertor, FIRE is being designed for double-null operation and Ignitor has no divertor. Almost all of the best documented H-mode pedestal and threshold studies, including the ITPA databases, are for single null diverted plasmas so that much less is known about the other configurations.

Very few tokamaks have achieved H-mode with a wall-limited configuration, indicating that its L-H power threshold must be significantly higher. Indeed, several experiments have found the threshold in diverted increases with small wall-separatrix separation [1]. Such discharges are often eliminated from threshold scalings. The required gap may depend on characteristic scrape-off lengths; recent scans on C-Mod found that the threshold varied only weakly down to 3 mm gaps, but was *at least* 70% higher for limited discharges (no H-modes were achieved with the power available) [2,3]. Given the higher power threshold, and the high density and field of Ignitor, it is unlikely that a limiter H-mode could be achieved with the auxiliary power available. The few limiter experiments which have achieved H-mode, notably TFTR, have found that the confinement improvement over the pretransition plasma is modest, typically ~ 20% [4]. While no well resolved pedestal measurements are available, one clearly cannot expect either pedestals or global confinement to reach the empirical H-mode scalings for divertor plasmas.

Given this background, the Ignitor scenarios assume an L-mode edge in the full current (11 MA) , limited discharges and propose an alternative configuration with internal X-points in order to explore H-mode. The plasma current in this case is limited to 9 MA. A similar configuration was in fact used for the first H-mode experiments in JET, which did not originally have a divertor [5,6] These H-modes, with I_p up to 5 MA in single null and 3 MW in double null, had global confinement approximately double the L-mode scalings, and displayed global and local threshold scalings quite similar to those in divertor plasmas. One can thus expect scaling laws derived from diverted plasmas to apply in configurations with an internal X-point. Power handling of the surfaces near the strike point will likely be a serious issue, which might limit input power and duration. Impurity influxes and accumulation will also be critical; these issues are being assessed by the boundary physics working group (P5).

Systematic studies of double-null vs single null H-modes in diverted tokamaks are rather incomplete. Some comparisons on DIII-D indicated a higher power threshold with double null, as compared with a single null having favorable drift direction [7]. However, more recent comparisons indicate that this may be an indirect effect of shaping changes [8]. It is not clear to what degree, or even in what direction, the pedestal parameters would be different in double null plasmas. It seems likely that the effect will be modest, comparable to those produced by varying plasma shape. Given that this is an important issue for predicting performance on FIRE, comparisons of thresholds and pedestals in single and double-null plasmas are in progress or planned on both DIII-D and C-Mod.

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