Impact of 3-D fields on divertor detachment in NSTX and DIII-D

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Increasing input power and plasma current in present and future tokamaks naturally leads to more serious divertor and first wall heat flux problem. This is true for both the steady state and the transient ELM heat deposition. Therefore, ELM control using the 3-D fields and peak heat flux reduction with the divertor detachment must be compatible. Partial divertor detachment both on the inboard and outboard sides has been demonstrated in the high performance H-mode plasmas in NSTX and DIII-D. Results from NSTX have shown that partially detached divertor plasma can be re-attached by applying 3-D fields (n=3). However, this can be avoided when the detachment is enhanced by puffing sufficient gas into the divertor region.

A large amount of deuterium (D_2) gas is puffed into the lower divertor area in NSTX, for naturally ELMy H-mode plasmas, to produce partially detached divertor condition. 0.2kA n=3 error field correction was applied as a baseline, followed by super-position of the n=3 perturbation field (-0.5kA) for the 2nd half of the gas puff period. Two divertor gas puff rates were tested; low (~$7\text{x}10^{21}$ D/sec) and high gas puff (~$1.1\text{x}10^{22}$ D/sec). Heat flux profile before the gas puff is peaked near the strike point in both cases, which indicates that the divertor plasma is attached. After the detachment onset (by gas puff), the peak heat flux is reduced by ~70 % compared to those in the attached regime. However, it is seen that the profile becomes peaked again in the low gas puff case after 3-D fields were applied to the detached plasma, i.e. the divertor plasma re-attaches, while it remains detached in the high gas puff case. Therefore, the 3-D fields can re-attach weakly detached plasma but this can be avoided by enhancing detachment with higher gas puff.

A similar experiment was carried out at DIII-D to investigate the impact of n=3 3-D fields by I-coils on divertor detachment, which was established by upstream D_2 gas puffs. 4 kA coil current, with both even and odd parities, was applied to high density ($\bar{n}_e$>$7\text{x}10^{19}$ m^{-3} and $\nu_e^* > 1$) H-mode discharges. It was found that the plasma did not respond to the applied 3-D fields, *i.e.* there was no striation observed either in the heat or particle flux profile, although the pedestal collisionality was high enough compared to the value reported necessary ($\nu_e^* > 0.5$) to achieve heat flux striations in a previous study. Field line tracing using TRIP3D-MAFOT with and without the use of data from M3D-C[1] shows that plasma response can significantly alter the pattern of striations predicted by vacuum modeling. Work is in progress to fully explain experimental observations by implementing 3-D edge transport calculation by EMC3-Eirene.

Characterization of 3-D field spectra and shape parameters regarding their impact on detachment conditions, along with comparison of results from NSTX and DIII-D, will be presented. This work was supported by the US Department of Energy, contract numbers DE-AC05-00OR22725 (ORNL), DE-AC02-09CH11466 (PPPL), DE-FC02-04ER54698 (GA), DE-AC52-07NA27344 (LLNL), and DE-FG02-05ER54809 (UCSD).