Topic: EX-D

Toroidal asymmetry of divertor heat deposition during the ELM and 3-D field application in NSTX

J-W. Ahn[1], K. Gan[2], F. Scotti[3], R. Maingi[1], J.M. Canik[1], T.K. Gray[1], J.D. Lore[1], A.G. McLean[4], A.L. Roquemore[3], and V.A. Soukhanovskii[4]

[1] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[2] *Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, People's Republic of China*
[3] *Princeton Plasma Physics Laboratory, Princeton, NJ 08543, USA*
[4] *Lawrence Livermore National Laboratory, Livermore, CA 94551, USA*

It is found in NSTX that asymmetries in the toroidal distribution of peak heat flux (q_{peak}) and heat flux width (λ_q) become largest at the peak of ELM heat flux; the higher the peak heat flux, the stronger the degree of asymmetry. This can pose a serious challenge to the tile design and cooling requirement in future machines as they are usually based on a 2-D axisymmetric calculation.

The 2-D heat flux data calculated by TACO [1,2] allowed for the evaluation of toroidal arrays of peak heat flux (q_{peak}) and its width (λ_q), with each array representing toroidally distributed data for the corresponding radial location. This was achieved by re-mapping the (x,y) coordinate of the 2-D data to the r and Φ. Then the toroidal asymmetry of q_{peak} and λ_q at each radial location was quantified by taking standard deviation (σ) of q_{peak} and λ_q over data in each toroidal array. In order to compare changes in asymmetries for multiple ELM periods, σ_{qpeak} and $\sigma_{\lambda q}$ were normalized by the mean values of q_{peak} and λ_q. In case of ELMs and 3-D field application, the helical heat deposition naturally produces scatter of data around mean values and the fractional σ_{qpeak} and $\sigma_{\lambda q}$ can be interpreted as the degree of toroidal asymmetry of each quantity. The degree of asymmetric heat deposition is highest at the ELM peak times, while it becomes lower toward the later stage of the inter-ELM period. This dependence of the degree of asymmetric heat deposition on the ELM cycle is also related to the absolute value of peak heat flux. That is, higher peak heat flux leads to stronger degree of asymmetric q_{peak} and λ_q. The correlation between fractional σ_{qpeak} and $\sigma_{\lambda q}$ is the strongest at the ELM peak times and becomes weaker later in the ELM cycle.

A wide angle, 2-D fast visible camera with capability of viewing nearly full divertor surface [3] is also being used to study the toroidal and radial structure of the divertor flux profile. The 2-D data is remapped to the (r,Φ) plane and facilitates the comparison with modeling. The strike point splitting pattern in the 2-D plane during the n=1 and n=3 field application agrees well with the vacuum field line tracing [4]. The divertor heat flux profile during the ELMs triggered by the applied 3-D fields are found to have the same spatial structure (in both r and Φ directions) as that for the profile during the inter-ELM period in the presence of applied 3-D fields [5]. Data for the intrinsic and applied 3-D fields as well as for the triggered and natural ELM filaments from different ELM types have been obtained, and first results from a 3-D edge transport code, EMC3-Eirene, show that the observed asymmetric divertor flux is qualitatively reproduced [6]. This work was supported by the US Department of Energy, contract numbers DE-AC05-00OR22725, DE-AC02-09CH11466, and DE-AC52-07NA27344.

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