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Assessment of Divertor Heat Load with and without External Magnetic Perturbation & Elimination of the Non-Axisymmetric inter-ELM Heat Flux Generated by Resonant Magnetic Perturbations in Detached Divertor Conditions

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A. Studies of the steady state scrape-off layer heat transport with and without external magnetic perturbation in ASDEX Upgrade L-Mode are shown. It is found that the heat transport perpendicular to the magnetic field is within the uncertainty unaffected by external magnetic perturbation. The observed heat flux pattern is explained by heat flux calculations using the vacuum field of the external magnetic perturbation. It is seen that the intensity of the lobes to generate a toroidally non-uniform power deposition pattern is largely reduced with increasing divertor broadening S.

For type-I ELMs a multi machine scaling using data from three devices based on the pedestal pressure prior to the ELM crash is presented. The presented multi machine scaling for the ELM induced thermal load onto the target includes data from JET, ASDEX Upgrade and MAST with unmitigated and mitigated ELMs. The mitigation techniques used are external magnetic perturbation (MP) and kicks which is a fast vertical movement of the plasma column. The leading quantity detected in the scaling is the pedestal pressure prior to the ELM crash.

An approach to scale the thermal load of ELMs without the need to scale the ELM wetted area is presented. An approximately linear dependence of the peak ELM energy density with the pedestal top electron pressure and minor radius and a square root dependence on the relative ELM loss energy, is found in JET operating with CFC and ILW, ASDEX Upgrade operating with carbon and tungsten plasma facing components and MAST.

Results from ELM mitigation experiments using magnetic perturbation in JET, ASDEX Upgrade and MAST and aiming to induce higher ELM frequencies as well as experiments using kicks in JET are in agreement with the scaling. Here it is observed that the reduced thermal load due to ELMs is correlated to the loss of pedestal pressure. These new findings will be discussed for the operation of ITER and the access to ELM divertor heat load mitigation.

B. In DIII-D, measurements show that at high densities, above the onset of divertor detachment, the non-axisymmetric heat flux striations between ELMs created by resonant magnetic perturbation (RMP) fields are eliminated and the heat flux profile is nearly identical to that measured without RMPs. Measurements show that the RMPs continue to affect the particle balance even when there were no measurable perturbations to the heat flux structure. ELM mitigation was seen when the RMPs were applied, but not ELM suppression. Previous results from DIII-D showing that increasing density can cause heat flux to the striations to increase, [1] as well as results from NSTX showing that heat flux in the striations can remain high during detachment [2], have caused concerns about the compatibility of RMPs and the divertor operation in ITER. In this work, density has been raised beyond that previously used to study RMP effects in DIII-D. It is shown that above the onset of detachment, striations in the heat flux gradually decreased with increasing density and are effectively eliminated at 90% of the Greenwald density. Eliminating these striations could dispense with the requirement that RMP fields on ITER rotate to distribute the non-axisymmetric heat flux.

When RMPs are applied, the density in the main plasma drops and the peak inter-ELM heat flux to the divertor is observed. Peak heat flux generally scales inversely with the plasma density even without RMPs. When gas puffing is used to increase the main plasma density to pre-RMP levels the peak inter-ELM heat flux returns

to a value at or below the pre-RMP value. The 3D edge code EMC3-EIRENE [3] is used to explore the relative contributions of changes in particle transport, source and sink effects. Measurements of electron temperature made using divertor Thomson scattering show that a structure similar to that predicted by EMC3-EIRENE appears when RMPs are applied. The structure in the electron temperature generated by the RMPs does not extend to the floor tiles in detached conditions where striations in the heat flux profile were also eliminated.

[1] M.W. Jakuboski, et al., Nuc. Fus., 49, (2009) 095013 [2] J.W. Ahn, et al., PPCF, 56, (2014) 015005 [3] Y. Feng, et al., J. Nuc. Mat., 241-243, 930 (1997)

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