ELECTRON BEAM SIMULATION OF TRANSIENT HEAT LOADS AT HIGH CYCLE NUMBERS

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Divertor materials for fusion devices have to withstand high heat fluxes, generated by radiation, particles and neutrons. Heat fluxes differ in power density, duration and repetition rate and can lead to roughening, cracking, erosion and melting of the plasma facing materials (PFMs) or to fatigue damage of the joints in the plasma facing components (PFCs). In addition to steady state heat loads of 5-20 MW/m² transient loads in the range of milliseconds and sub-milliseconds deposit power densities of several GW/m². Edge localised modes (ELMs), transients that occur during normal machine operation, have a pulse length of ≤ 0.5 ms, a power density of ≤ 1 GW/m² and a repetition rate of ≥ 1 Hz. This leads to millions of ELM events during the foreseen lifetime of divertor components in the next step fusion device ITER. Up to now only limited data exists regarding the influence of a high number ($> 10^4$) of ELMs on PFM degradation [1].

Therefore this work is aimed at simulating a large number of ELM-like heat load pulses using an electron beam facility that provides a Gaussian shaped e-beam profile with variable beam diameter. The beam diameter is controlled via a magnetic lens system and depends on various parameters, e. g. beam power and vacuum conditions. Since the knowledge of the focussing diameter is crucial to determine the power density, systematic beam shape and diameter measurements were done. As ELMs distribute energy in general homogeneously, special attention has to be paid to the electron beam path on a sample, to the resulting loading pattern and to the interpretation of results.

This paper deals with the electron beam guidance and ELM-simulation results of tests on actively cooled flat tile modules with tungsten brazed to a copper heat sink. These tests were performed at a repetition rate of 25 Hz with power densities in a range up to 0.5 GW/m² with sub-millisecond beam pulses. The experiments ran either with or without an additional steady state heat load of 5 MW/m². For higher thermal loads (≥ 0.4 GW/m²) crack formation has been observed even at low cycle numbers (10^3). At thermal loads close to the damage threshold (0.2 GW/m²) the samples did not show surface modifications after 10^3 cycles, but surface roughening after 10^4 cycles. The roughening increased in case of additional steady state heat load. Samples exposed to weaker ELM-like heat loads of 0.14 GW/m² at 0.5 ms pulse duration (without additional steady state load) showed no surface modifications even at 10^5 cycles.

[1] Linke, J., High heat flux performance of plasma facing components under service conditions in future fusion reactors, Transactions of fusion science and technology, vol. 49 (2T), 2006, pp 455-464