Influence of surface tension on macroscopic erosion of castellated tungsten surfaces during repetitive transient plasma loads

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Understanding of plasma-surface interaction (PSI) effects during the transient events in future fusion reactors requires dedicated R&D activity in plasma simulators used in close connection with material characterization facilities as well as with numerical modeling. This report is focused on the analysis of surface tension contribution to the erosion features of tungsten resolidified surfaces and resulting material response to large number of repetitive plasma impacts. Experimental investigations of erosion processes on castellated tungsten surfaces in conditions relevant to ITER ELMs have been performed within powerful quasi-stationary plasma accelerator QSPA Kh-50. The surface energy load measured with a calorimeter was varied between the melting (0.6 MJ/m^2) and evaporation (1.1 MJ/m^2) thresholds, the plasma pulse duration was 0.25 ms. Observations of plasma interactions with exposed W surfaces, analysis of dust particle dynamics and the droplets monitoring have been performed with a high-speed digital camera. Development of surface pattern and material modification in results of plasma exposures have been studied with optical and SEM microscopy, profilometry and XRD.

Repetitive plasma loads above the melting threshold led to formation of melted and resolidified surface layers. Networks both macro and intergranular cracks appeared on exposed surfaces. Cracks propagate to the bulk mainly transversely to the irradiated surface. The splashing of dust/liquid particles has been analyzed in the course of repetitive plasma pulses. It was revealed that mountains of displaced material at the edges of castellated units are primary source of the splashed droplets. The solid dust ejection dominates by cracking processes after the end of pulse and surface resolidification.

Due to the continuously growing crack width (from fraction till tens μm) with increasing number of pulses the initially uniform melt pool on the castellated units became disintegrated into a set of melt structures separated by cracks. As result, a number of ejected particles essentially decreased after first hundred plasma pulses. Further increase of repetitive plasma impacts (above 200) led to considerable qualitative changes of surface morphology. Each cell of the crack network is strongly subjected to the surface tension that minimizes melt pool area. After large number of exposures the progressive corrugation of the surface occurred due to the capillary effects on exposed W surfaces.

Results of simulation experiments for castellated targets and developed surface structures are compared with repetitive plasma exposures of flat tungsten surfaces. Important contribution of surface tension to the erosion processes under the ELM relevant repetitive loads and it influence on suppression of droplets splashing is discussed.