Study of tungsten plate bending during transient heat load possible in ITER

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One of the key problems of the ITER project is the erosion of tungsten divertor armor caused by pulsed thermal loads associated with ELMs. Fast heating of the tungsten is the reason of the appearance of tensile stresses in the thin surface layer of the metal, which cause deformation and cracking of the surface during cooling. A residual bending was measured in experimental simulation of transient thermal loads effect on tungsten samples on the BETA facility \cite{1} at the Budker Institute of Nuclear Physics. It correlates with the evaluated residual stress. To characterize the stresses, a non-contact, non-destructive diagnostic system has been developed. It allows \textit{in situ} observing the dynamics of deformations of a tungsten plate during the heating and cooling stages.

The operational principle of the system is based on observing a change of the position of the focal point of the laser beam reflected from the polished surface of the tungsten plate, which is opposite to the heated surface. Curvature radius of the plate surface is considered as a parameter characterizing the deformation. The front side of the plates with thicknesses from 2 to 4 mm is heated by an electron beam with duration of 1 ms, having a Gaussian shape with FWHM of about 20 mm and creating a heat flux factor of $10 - 40 \text{ MJ} \cdot \text{m}^{-2} \cdot \text{s}^{-0.5}$.

The experimental results show that the residual curvature of the surface of the tungsten plate (as well as the curvature at the maximum bending at the end of heating) correlates with the magnitude of the heat load. It grows with increasing load, as do the residual tensile stresses that arise in the surface layer. When irradiated with a constant power and pulse duration, the residual curvature is set to a constant value after several acts of exposure. Cracking of a tungsten target is accompanied by a decrease in the absolute value of the residual deformation, which indicates partial stress relief. A theoretical study of the process of deformation and stress accumulation was carried out, which results are consistent with the experimental data obtained at the BETA facility. Investigations of samples with different thicknesses under different scenarios and heat load values are carried out.

\cite{1} L.N. Vyacheslavov et al., Phys. Scripta 93 (2018) 035602