Simulation of Stress Waves Induced by Pulsed Heavy Ion Beams in Thin Graphite Targets*

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Graphite is used as material for production targets for in-flight radioactive ions and neutrino facilities. At the future Super-FRS at FAIR and at several neutrino facilities, the driving beam will be a pulsed beam. Failure of the targets is a combined effect of radiation damage and fatigue due to cyclic thermo-mechanical loads. This work is part of the efforts to understand and mitigate the effects of beam-induced stress waves on the lifetime of the graphite targets. A Finite Element method (FEM) simulation using a simplified model of the target is applied to describe the thermo-mechanical behaviour [1].

FEM simulations require realistic input parameters on the beam spot in particular with respect to the temperature distribution [2]. We therefore performed irradiation experiments with 45-µm thin SGL R6650 graphite foils (density of 1.84 g/cm^3 [3]) mounted on Al frames with a radius of 1.5 cm . The foils were exposed to 1.14-GeV ^{238}U ions (0.7 Hz, 0.15 ms pulse length). The energy deposition by the ions induces target heating within the beam spot localised in the foil centre. A fast FLIR SC7500 infrared (IR) camera recorded the spatial distribution and time profile of the temperature on the target.

Thermal expansion within the beam spot causes a compressive stress wave that spreads out and reflects at the foil frame. The succeeding waves interfere leading to high stress amplitudes within the material. The temperature distribution as recorded by the IR camera was mapped onto the generated mesh of the target as shown in Figure 1 (a). The rise of thermal load *T(t)* to a recorded maximum temperature T_{max} = 820K was fitted by a sin^2 function (Fig. 1 (b)). The simulation used a temporal temperature profile with one temperature rise after the other to save calculation time.

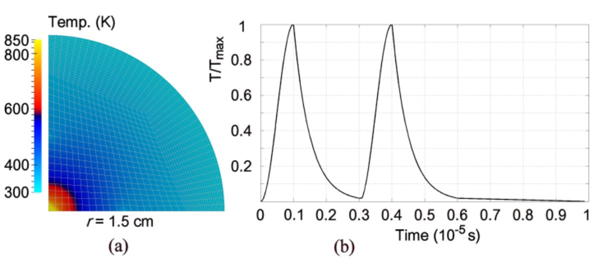

Figure 1: (a) Radial temperature distribution caused by a single ion beam pulse superimposed on the FEM mesh. (b) Simulated temporal evolution of temperature induced by two consecutive beam shots in the centre of the target.

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The FEM simulations are limited to a linear elastic behaviour [4]. The material properties are inserted as constants, i.e. changes with temperature were neglected. The distribution of the stress amplitude was calculated and plotted as function of target radius. Stress wave reflexions at the foil frame and their interferences were simulated, without considering damping. To save comuting time, the calculations used axial symmetry of the target-beam configuration. Figure 2 shows the magnitudes of the shear and compressive stress caused by the initial beam pulse (blue lines) and the amplitude of the stress caused by interferences with a second pulse (red lines).

To simulate the response of the irradiated target to beam-induced stresses, a future approach will take into account different material properties within the beam spot under the effect of radiation damage.

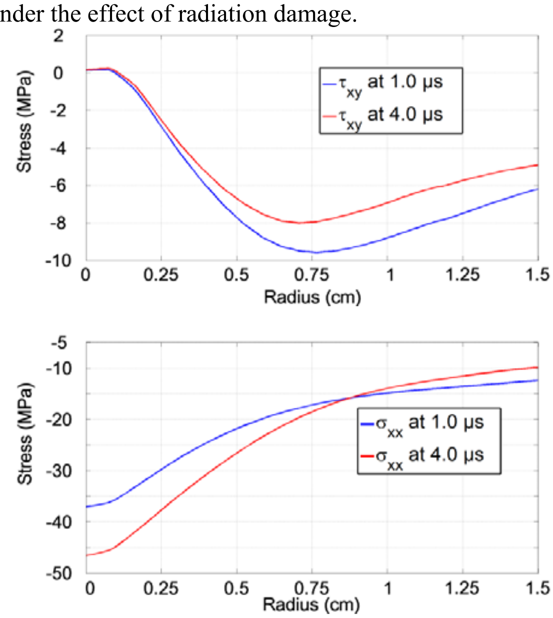

Figure 2: Distribution of shear stress (top) and compressive stress (bottom) after initial ion pulse (blue) and after second pulse (red)

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