**ABSTRACT**

Rapid heating by x-rays and ions in Inertial Fusion Energy (IFE) chambers will produce stress waves in dry chamber walls, in some cases leading to damage that will ultimately fail the structure. These waves can affect the surface or propagate to the substrate and produce delamination. Hence, it is important that these waves be understood. Models exist for thermally induced stress waves resulting from surface heating, but models with volumetric heating have not been presented for IFE conditions. In this paper we develop models for elastic stresses caused by rapid volumetric heating in a half-space. The stress wave models are obtained analytically for heating distributions which are both uniform over a finite region and exponentially decaying over the entire depth. These two cases cover the relevant heating for a typical IFE threat. Results are given for both x-ray and ion heating using threats from a direct drive target developed for the High Average Power Laser (HAPL) target.

The wave speed is defined as:

$$ c^2 = \frac{2(1 - \nu)(1 + \nu)}{(1 - 2\nu)^2} \rho $$

Boundary conditions:

$$ u_x(x, t) = 0 \quad \sigma_x(x, t) = 0 \quad \sigma_y(x, 0) = 0 $$

Variables:

$$ g = \frac{1 + \nu}{1 - \nu}, \quad h = \frac{\rho_0}{\rho_p} $$

Laplace-transform of the governing equation:

$$ \frac{c^2}{\rho} \pi(x, s) = \frac{c^2}{\rho} \pi(x, s) + \frac{gb^2}{s - \gamma} e^{-\gamma s} $$

Solution:

$$ \pi(x, s) = C_1 e^{s} + C_2 e^{-s} + \frac{b^2 g}{2\gamma} s \frac{C_1 e^{s} - C_2 e^{-s}}{s - \gamma} e^{-\gamma s} $$

Displacement-stress relations:

$$ \sigma_x = \frac{2\gamma}{1 - 2\nu} \left[ (1 - \nu) \frac{\pi(x, s)}{c} \right] $$

Maximum displacement:

$$ u_{\text{max}} = \left( 1 - e^{s\gamma x} - s\gamma x \right) b g $$

Displacement at fixed times (x-rays):

**Stresses at the wave tip (x-rays):**

In a different case the heat is ramped over time, but still decreases exponentially with depth (case 2):

$$ \lim_{t \to \infty} \frac{\sigma_{\text{surface heating}}}{\sigma_{\text{volumetric heating}}} = 2 $$

Comparing the results for volumetric heating with previous results for surface heating (based on the schematic for case 1), assuming the same total heat is deposited, reveals a ratio of 2 for long times.

**Stresses from case 1 and 2 at fixed times (x-rays):**

COMPARISON

The plots show that the stress caused by a step increase in the volumetric heating is slightly higher than for a ramp increase, assuming the same total heat is deposited over a pulse. In addition, the stresses increase faster for the case of a step increase.

By comparing the stresses at the end of the pulse, one can determine the exact ratio between the stresses in case 1 and case 2. Stepped heating always causes slightly higher stresses than an equivalent ramped case. In the IFE x-ray case, with a 0.5ns pulse length, the ratio is 1.07.

**CONCLUSIONS**

Solutions are developed for thermoelastic stress waves due to volumetric heating. It is found that the stresses induced by volumetric heating are lower than for a case in which the same amount of heat is supplied as surface heat. It is also shown that step heating causes a larger stress than equivalent ramped heating, though the difference is relatively small.

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**REFERENCES**