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FOAMED LIQUID METAL SHOCK ATTENUATION ANALYSIS FOR Z-IFE*

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Foamed liquid metal is being investigated as a potential material for shock mitigation and energy absorption in the IFE Z-Pinch Power Plant concept. This material is a critical part of the plant design because it absorbs the energy that will be converted to electricity, generates tritium, and protects the containment structure. Foamed liquid metal is being considered as a shock mitigating material because of its low density. The importance of a low density material that absorbs the energy and breeds tritium is evident using the following equation, which was derived from the Snowplow model.

$$I = \frac{\rho D V_{shock}}{\alpha}$$

where the impulse, I, is the time integrated pressure and has units of Pa-s, α is the void fraction, ρ is the density, D is the material sheet thickness, and V_{shock} is the shock velocity. It is clear that for constant shock conditions a material with a low density or a high void fraction decreases the impulse and is more effective at attenuating the shock.

However, for inhomogeneous materials, such as a liquid with gas bubbles, a low density mixture can be obtained using various configurations or sizes of gas regions. A series of simulations using ALEGRA modeled three different configurations of liquid with gas regions to investigate the effect of bubble size on shock mitigation. The 2D simulations exposed a 1m x 1m square containing 50% liquid and 50% gas to a pressure pulse of 500 GPa. The models contained 9, 25, or 100 equally distributed circular gas regions, which were sized to cover 50% of the area. The ideal gas law was used to model the helium gas regions, and the Mie-Grüneisen equation of state was used for the liquid regions. These simulations initially used water as the liquid; then the pertinent parameters such as density, sound speed, and specific heat were modified to reflect the behavior of liquid lithium. The results indicate that ALEGRA can model the behavior of strong shock waves in inhomogeneous mixtures of liquid and gas, and that for foamed liquid metal the material configuration has an impact on the shock attenuation capability. In particular, increasing the number of gas regions from 9 to 100 while maintaining a 50/50 mixture reduced the pressure at the wall from 28 to 2 GPa. These simulations and continued investigations will be used to determine the properties of foamed liquids that are relevant to shock mitigation, and the pertinent relationships will be addressed.

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