A Theoretical Approach for Transient Shock Strengthening in High-energy-density Laser Compression Experiments*

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In high-energy-density shock compression experiments, a desired state of compression can be achieved by passing a shock though a sequence of materials with different acoustic impedances [1,2]. In this study, a theoretical approach for transiently strengthening such shocks is examined. A method based on characteristic analysis semi-analytically solves the problem of a shock passing from one material to another through a region of non-uniform density. By appropriately designing this region, a greater shock strength can be achieved in the second material for a finite duration than in the absence of this region. The method is applied to the design of shock-compression experiments exploring the behavior of planetary mixtures at the conditions thought to exist within the interiors of Jovian planets like Uranus and Neptune [3]. These studies utilize an anvil platform like the diamond anvil cell [4]. With an anvil-based platform, an experimental target is isentropically compressed using the vice-like anvil. A shock wave is then generated via laser-plasma interactions in an ablated material which subsequently passes through the anvil and into the precompressed target. It is found that the shock wave passing into the experimental target can be strengthened by bridging the density jump between the anvil material and the target with intermediate density steps. This strengthening is shown in Figure 1 (between solid lines) and is maximized when the density of the intermediate step is equal to the geometric mean of the densities of the anvil and the experimental target (dashed line). Furthermore, it is demonstrated that an exponential density profile between the two materials yields the most effective shock strengthening. The potential shock strengthening is calculated for a wide range of density ratios and incident shock Mach numbers, and the limiting behavior of the strengthening is examined.

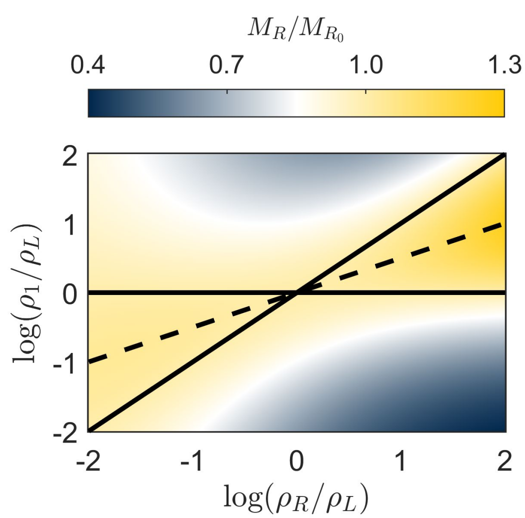

Figure 1 – The shock strengthening, i.e. the ratio of the shock Mach number in the experimental target with and without an intermediate density step, versus the overall interface density ratio and the density of a single intermediate step.

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References

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