Shock Mitigation Studies in Voided Liquids for Fusion Chamber Protection
Mark Anderson, Jason Oakley, Ed Marriott, Jesse Gudmundson, Kumar Sridharan, Virginia Vigil, Gary Rochau, Riccardo Bonazza
Fusion Technology Institute, University of Wisconsin-Madison
Sandia National Laboratories, Albuquerque, NM

Abstract

A liquid pool, with and without void fractions, was subjected to dynamic compression testing in a vertical shock tube to model the bubbly-pool concept being considered for use in an inertial fusion energy reactor. Water and oil were used to model the Flibe coolant that collects at the bottom of the chamber and serves as first wall protection at that location. The experiments (shock strengths M=1.4, 2.0, and 3.1) were conducted in atmospheric pressure argon, and argon was bubbled through the liquid to achieve void fractions of 5-15% in the 30.4 cm deep pool. The presence of the gas voids in the liquid had a strong effect on the dynamic pressure loading but did not reduce the shock impulse significantly at the low and intermediate Mach numbers, but did exhibit a mitigating effect at the higher shock strength. Polished stainless steel witness samples, placed at the bottom of the pool, experienced a high degree of surface abrasion/pitting when subjected to the shock loading. A very high void fraction foam was also studied that resulted in a 22% reduction of the shock wave impulse.

Scaling with ICF

The pressure traces (right) are from a 1D Bucky radiation-hydrodynamics simulation for a 3 GJ target yield, with an initial argon gas pressure of 12 mtorr. The contact pressure for the blast wave with the Flibe is 1 MPa (just after ~115 ns) and the reflected wave off the Flibe is 23 MPa. This compares with a pressure load from a shock tube experiment, M=2.85 in argon, of 1 MPa contact, but 4.2 MPa reflected. Thus, the pressure loading for the shock tube hydrodynamic experiments are on the same order as in the ICF reactor.

Bubbly-pool Results

The two pressure trace plots (below) show the late and early time behavior for void fractions of 5, 10, and 15% for a M=1.4 shock wave in water. The late-time behavior is similar to the 1D gasdynamics prediction while the early time shows oscillations due to the gas voids. The impulse results for water (table) show little difference at the low and medium Mach numbers, but a significant reduction is measured for M=3.1.

Conclusions

The shocked bubbly-pool experiments exhibited different behavior in the pressure traces, although the average pressure load did not change much. A noticeable impulse reduction was observed for the high Mach number experiments. High void-fraction experiments showed the greatest reduction in impulse (22%). The corrosion/erosion of a wetted surface, enhanced by being repeatedly exposed to shock waves, will need to be considered for first-wall material selection.

Acknowledgements
This work sponsored by the Z-pinch IFE program, U.S. Department of Energy and Sandia National Laboratory, contract number 426334.