Protection of IFE First Wall Surfaces from Impulsive Loading by Multiple Liquid Layers

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Several inertial fusion energy reactor designs incorporate liquid jets or sheets to protect the first wall and to absorb energy for heat removal from the ICF capsule implosions. These flowing liquid sheets will be accelerated by the hydrodynamic shock and the vaporization due to impact and absorption of the energetic particles. As a consequence, the impulsive pressure load on the reactor first wall is not exclusively due to the hydrodynamic effects of the shock wave from the fusion reaction, but it is also due to the impact of the shock-accelerated liquid layer. This impulsive force along with the hydrodynamics of the break of the liquid protection sheets is studied with the aid of a large vertical shock tube. The shock tube is used to simulate the hydrodynamic shock resulting from the fusion reaction, which makes contact with a water layer suspended in the shock tube. The water sheet is accelerated upon shock contact and begins to break up due to instability growth and vaporization. The degree of breakup and the impulsive end wall force are discussed in this paper. Two different depths of water layer, 6.4 mm and 12.8 mm, are tested at two Mach numbers, 2.12 and 3.20. The pressure histories at various positions along the length of the shock tube and on the end wall are recorded. It is found that the speed of the transmitted shock wave is reduced by about 30% after passing through the liquid layer; however, the peak pressure at the end-wall of the shock tube is significantly increased up to 8 times higher due to the high impulsive force of the liquid layer. X-ray radiography techniques are used to image the breakup of the water layer alloying a quantitative measure of the mass fraction distribution of water after shock impact. It is found that the water layer is significantly disrupted and partially vaporized by the impact even at these low mach number shocks. An apparent mixing and spreading of the water layer is on the order of 20 for a single 12.8 mm initially deep of water layer (4.5 ms after contact with Mach 2.12 shock wave). As many reactor designs involve multiple liquid layers, investigations with multiple water layers are conducted with the goal of understanding the absorption of the hydrodynamic energy in the different layers. It is found that the end-wall peak pressure is indeed reduced up to factors of 2, compared to the single layer configuration with the same amount of water, as multiple sheets with different layer separations are studied.