Numerically Designed Facility for Optimized Liquid Dispersion

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Abstract: Several research areas require modeling of liquid jets or droplet cloud ignition and combustion upon interaction with a shock or blast wave. Typical past droplet cloud production tests used small explosive charges centrally embedded within liquid-filled plastic or glass bottles. Upon charge detonation, the liquid is dispersed, and the fast-propagating bulk liquid jet breaks down to blobs, which in turn break into large droplets. The droplet breakdown cascades further as the large droplets break into ever smaller droplets. The droplet break-down terminates when the drag force between the droplets and the flow about them becomes zero. It is at this stage when a second large external charge is detonated, enabling the study, experimentally or computationally, of droplet break-down, vaporization and ignition under extreme pressure and temperature gradients.

To better understand the physical processes controlling this event, we applied a coupled CFD and CSD methodology to the study of liquid dispersal from bottles by internal charges. A small detonator is placed within a plastic bottle containing liquid. To provide jet directionality to a specific angle (rather than a spherical dispersion), the bottle is placed within a steel holder containing a slot. The coupled methodology first modeled the driving of the liquid by the RP80 commercial detonator, which consists of a small PETN charge enclosed within thin aluminum and copper shells. Coupling of CFD and CSD codes is necessary for modeling as past experiments have demonstrated significant explosive energy loss required to break the shell and accelerate the fragments. Next, the coupled code models the detonation products bubble expansion within the liquid, the shock propagation through the liquid and its impact on the plastic bottle; the plastic shears under internal pressure upon contact with the slot corners, and the liquid combined with the "slotted" plastic eject through the open slot in the steel bottle holder. As the liquid jets out at high speed, the jet thins, breaks down to blobs of liquid that eventually break into large-size droplets, that continue breaking to small size droplets, all slowing down due to aerodynamics drag.

The full paper will describe the design of an optimal charge and slotted bottle-holder combination, as well as a sample of jet break-up, and droplet dispersion, vaporization and combustion under interaction with an external blast load.