Validation of the FLASH Code:
Two- and Three-Dimensional Simulations of Shock-Cylinder Interactions

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Overview

We study the interaction of a shockwave and a column of Sulfur Hexaflouride (SF_6) in air as part of the validation program of the FLASH code. Because SF_6 is significantly more dense than air, vorticity is deposited baroclinically at the air-SF_6 interface as the shock traverses the diameter of the column. The subsequent development of the flowfield is driven by this vorticity. A counter-rotating vortex pair forms; and instabilities develop on the interface. The experiments are conducted at Los Alamos National Laboratories.

One difficulty we have encountered in our validation effort is that the flowfield development is highly sensitive to the initial conditions, and the experimental initial conditions are not well characterized. In particular, the maximum mole fraction of SF_6 is not known precisely, because of diffusion between the air and SF_6. To address this issue, we performed simulations of the SF_6 falling through the test section before the shock arrives. These simulations show that the profile and maximum mole fraction vary with height in the tunnel (with distance from the nozzle where the SF_6 enters the test section,) and are highly sensitive to the velocity and purity of the SF_6 at the nozzle.

During the experiment, all the measurements and flowfield images are taken in a single spanwise plane (perpendicular to the axis of the column.) Similarly, all previous simulations have been two-dimensional. Using the simulations of the SF_6 falling through the test section as initial conditions, we perform three-dimensional simulations of the shock-cylinder interaction and flowfield evolution. The simulations reveal large axial flow velocities in the cores of the counter-rotating vortices. Because the strength of the vortices decreases going from the top of the test section to the bottom, a pressure gradient exists along the axes of the vortices. The pressure gradient is compounded by the SF_6, which wraps around the predominantly air-filled cores; the air is preferentially accelerated because it is lighter than the SF_6.