Anomalous Shock Structure in CRASH Simulations

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Introduction

The typical shock structure in the initial CRASH experiments is shown in the radiograph at the right. The primary shock is nearly planar. Radiation propagates ahead of the primary shock, heats the plastic tube, and drives a wall shock toward the center of the tube. The primary shock and wall shock intersect at a triple point.

Simulations of the CRASH experiment differ significantly from the experiment, producing a very non-planar primary shock. The plot below shows the density structure from the "nominal" two-dimensional case, before any attempt was made to decrease the curvature of the primary shock. The anomalous structure results from the interaction of waves propagating inward from the walls of the tube. The structure is not a numerical artifact caused by the convergence of waves toward a symmetry axis. Similar behavior is seen in three-dimensional simulations with no axis of symmetry, as well as in simulations in which the tube was moved off-center to create an asymmetry in the initial conditions.

All two-dimensional simulations described here were performed on a 1200 x 120 grid and are shown at time 16 ns. They were initialized using an output file from Hyades 2d.

Removal of Plastic Tube

For the following two simulations, the plastic tube was replaced by a reflecting boundary in order to eliminate the effects of the wall shock. The shock is nearly planar, but still shows a small bump on the axis.

Small inward velocities were present in the initial conditions obtained from Hyades, causing matter to collide at the symmetry axis. When these are set to zero, the bump on the axis nearly disappears, as shown below.

Elimination of initial vertical velocities

For the next simulation, the reflecting boundary was removed, and the plastic tube was re-inserted. In addition, the initial vertical velocities were set to zero. The results were very similar to the nominal case.

Reduction of Initial Pressure and Energy

The initial conditions generated by Hyades show a very large pressure in the tube walls behind the primary shock. If this calculated pressure is too large, the resulting inward propagating waves could be too strong, possibly creating the anomalous shock curvature. For the following simulation, the initial pressure in the wall was reduced and the initial vertical velocities were set to zero. Radiative heating quickly restores the high pressure in the walls, and strong inward propagating waves are generated. The flow looks slightly different in this case, but the primary shock remains curved.

In order to reduce the initial radiative heating of the walls of the tube, the radiation energy in the initial conditions was reduced by a factor of 1000, keeping the initial wall pressure low and keeping the initial vertical velocities zero. Radiation produced by the propagation of the primary shock quickly restored the large radiation energy, resulting in a flow that looks quite similar to the case shown above.

Asymmetric Initial Conditions

In order to check whether the artificial symmetry present in the numerical simulations was responsible for the anomalous shock curvature, an asymmetry was introduced into the initial conditions. This was accomplished by multiplying the pressure by the factor \([1 + 0.00001(x^2+y^2+z^2)]\) in all zones in which both \(x\) and \(y\) are positive. The asymmetry prevents waves from converging at a line and amplifying. The simulation was performed in three dimensions using a 1200 x 340 x 240 grid. The results are plotted at 16 ns for both the \(y=0\) and \(z=0\) planes. Significant asymmetry can be seen in the results, but the shock curvature remains.

Conclusion

The curvature of the primary shock is an extremely robust feature of the simulations that is very difficult to eliminate. This poster shows only a sample of tests that have been performed. Others have involved modifying the equation of state or opacities of the various materials, using improved physics, such as multi-group diffusion, or modifying the numerics. Most simulations that have resulted in a nearly planar shock do not contain a wall shock. It is unclear if the cause of the shock curvature is incorrect initial conditions, incorrect or incomplete physics in the CRASH simulations, inconsistent physics between Hyades and CRASH, some combination of these, or something else entirely. It does not appear to be caused by numerical errors associated with an axis of symmetry.

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