On the convergence of cylindrical shock wave

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ABSTRACT The technique of shock focusing is an efficient way of producing localized high-pressure and temperature conditions in the laboratory. This high energy density in mediums can be used in biomedicine, initiation of nuclear fusion reactions, fragmentation of kidney stones (shock wave lithotripsy), etc. The present study is an experimental and numerical investigation of the phenomenon of shock convergence. The experiments were performed in shock tube operated by a fast-opening valve. The test gas in the experiments was Argon. The study shall present high temporal data of cylindrical shock convergence. Along with experiments, numerical simulation of the flow is performed for comparison.

Figure 1 shows the shadowgraph images (taken at 2 million fps) of the convergence of the cylindrical shock up to its focus. The first image shows the shock when the cylindrical convergence of the shock starts, with shock Mach number (M_0) of 4.6. The last shadowgraph image is at the instant just after the reflection of the shock. The flash of light can be observed at the focus.

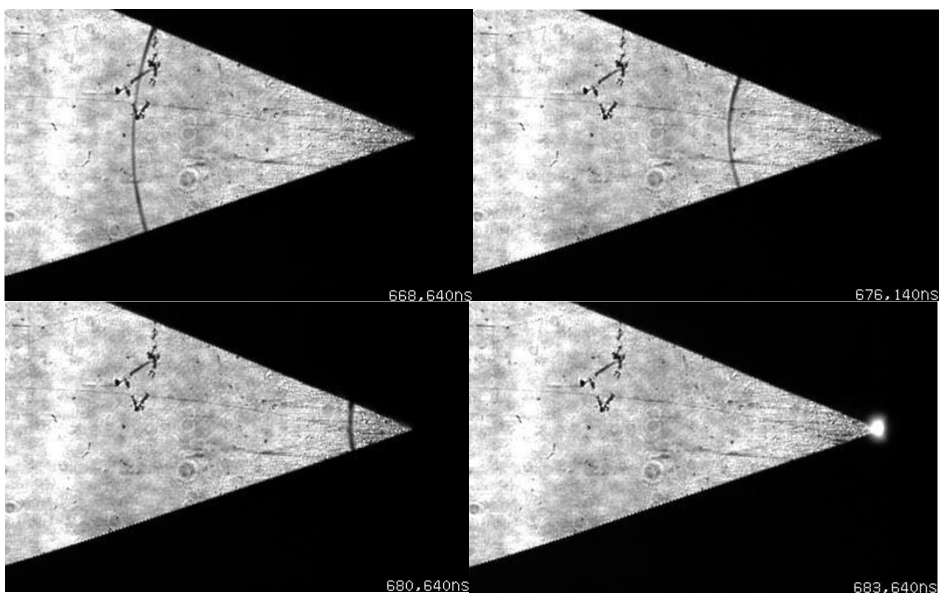

Figure 1. Shadowgraph images of convergence of cylindrical shock wave of Mach 4.6.

In the study, the shock location from the shadowgraph images is tracked and trajectory of the cylindrical shock is traced. In figure 2, the non-dimensional radius of the shock (normalized with initial radius (r_0) of 25.6 mm) is plotted with non-dimensional time (normalized by the time at the instant of shock focusing (t_0)). Along with the experimental data, numerical data, and self-similarity solution of Guderley[1] are plotted. The analytical relation by Guderley is given as:

$$\frac{r}{r_o} = \left(1 - \frac{t}{t_o}\right)^{\alpha}$$

where, r and t are instantaneous radius and time. The exponent α is the similarity exponent. For Argon and cylindrical shock convergence, it is 0.81562. Overall, a fairly good match of the data is obtained.

It is not expected that the experimental and computational data should match the analytical relation due to two main reasons. First, the Guderley solution assumes that the convergence of the shock is self-similar. Previous works in the literature[2] suggest that the Guderley solution is an 'intermediate asymptotic' solution and is applicable only very close to the focus of convergence. Second, the downstream disturbances of the flow travelling on C_+ characteristics influences the motion of the converging shock.

These two phenomena shall be described in more detail to understand the mechanisms of shock convergence. Along with this, the data from experiments and computations performed for a range of Mach numbers shall be presented. An interesting trend in the exponent of convergence for different initial shock strength is observed which shall also be presented in the full-length paper.

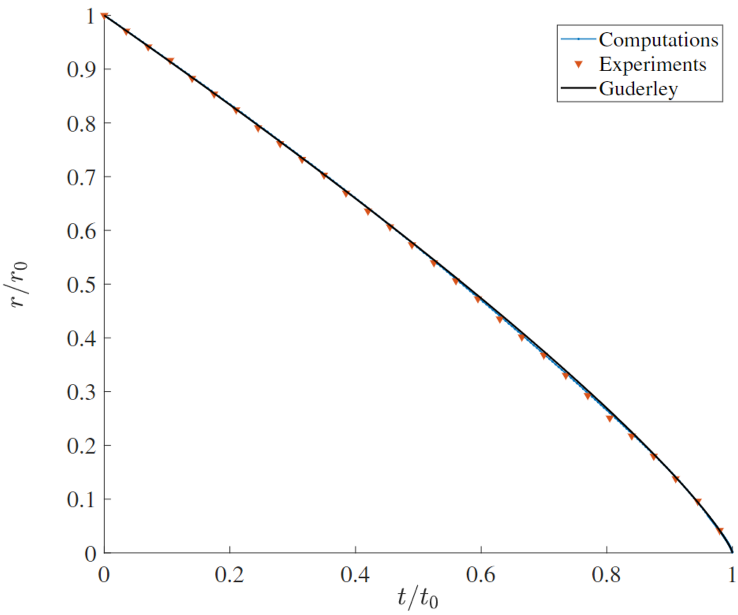

Figure 2. Comparison of the trajectory of cylindrical converging shock.

REFERENCES

[1] G. Guderley, "Starke kugelige und zylindrische verdichtungsst oe in der n ahe des kugelmittelpunkter bzw. der zylinderachse." Luftfahrtforsch 19 (1942).
[2] Y. Nakamura, "Analysis of self-similar problems of imploding shock waves by the method of characteristics," Phys. Fluids 26, 1234 (1983).