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Shock wave-induced flow features in concave profiles

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Abstract

This work provides an in-depth study into the development of a complex two-dimensional flow field resulting from the interaction of a plane shock wave in air with concave profiles. Of particular interest are the development of reflection patterns of the incident shock wave at the profile wall and the process of gas dynamic focus. These principal flow features are examined across a wide range of different reflector shapes using both experimental and CFD approaches. The size of the various reflector shapes were specified by varying their depth-to-aperture where models ranged from 0.2 to 1. Model apertures for numerical test pieces were fixed at 160 mm; experimental test pieces ranged from $140 \le A \le 160$ mm. The strength of the incident plane shock wave was limited to $1.2 \le M_S \le 1.45$.

The principal flow features were established and examined experimentally using qualitative and quantitative flow visualization techniques supplemented with numerical results. Time-resolved high-speed imaging was used to capture the interaction providing the unique ability to track the various transient flow features over the course of the interaction. The variation of the principal flow features were examined by testing a large group of profiles using an experimentally-validated Euler-based CFD code.

The depth-to-aperture ratio of the profile and the incident shock strength were shown to be the two primary factors that influenced the maximum pressure amplification at focus and the focus mechanism. Increases in the depth-to-aperture ratio increased the maximum pressure amplification observed at focus. This occurred due to a combination of factors including: the strengthening of the individual shock waves involved in focus; the duration of focus and the strengthening of a compressive flow field that develops adjacent to the shock system during focus. The compressive flow field adjacent to the shock system at focus was shown to be of great importance to the focus process. Parabolic or weighted catenaries with depth-to-aperture ratios between 0.7 and 0.75 developed a new focus mechanism consisting of multiple foci. This new focus mechanism was shown to produce significant peak pressure amplifications. Recommendations for further study include high resolution experimental and/or CFD studies of gas dynamic focus in deep profiles.