

Abstract

The diffraction of shock waves has been explored in many contexts in which either the shock wave is plane and the confining volume has complex geometry or where the shock wave has some non-plane geometry, typically something like spherical since this is the approximate shape of the waves generated by blasts. However, these studies have not considered more complex initial wave shapes or exit geometries. This study therefore addresses this deficiency in two ways.

The dynamic conical shock wave was originally proposed as a mechanism for the initiation of fusion whereby the focusing of the shock wave near the axis of symmetry would produce the high temperatures and pressures required. This was explored numerically and theoretically, as no experimental method was considered viable, and it was found that the regular reflection of a shock wave defined by conical wave geometry is not stable and will revert to an irregular reflection pattern at the axis. Three primary geometries were identified distinguished by the number of irregular reflections formed and influenced by the induced vortical flow. The current study used a developed experimental apparatus to study conical shock waves and an additional, new reflection pattern, named the von Neumann type (vN-type) for the similarity to the von Neumann reflection of weak plane waves, was identified. In addition, instability of the conical shear layer present as a result of the irregular reflection at the axis of the shock wave was identified experimentally which resembles the Kelvin-Helmholtz instability previously only studied in two-dimensional configurations of compressible flow. Dynamic bending of the central jet from the reflection axis was also tested as a function of upstream occlusion in the shock tube and this suggests possible future work in compressible jet actuation.

The current study also considered the diffraction of plane shock waves at the inclined or curved exits of shock tubes, which are more general examples of duct interaction of the sort that might be found in engines or ventilation systems. This was done experimentally using novel, open test sections for a conventional shock tube and for a limited number of computational cases. These flows are characteristically different from the diffraction of shock waves from tubes of complex cross-section studied to date where the exit plane is still

normal to the direction of travel of the wave. This is because the shock wave still undergoes simultaneous diffraction at all points around the edge of the tube in such a case while in this study the wave diffracts at different times around the tube periphery. This affects the strength of both the emerging incident wave and the diffraction and thus an atypical formation of the jet and vortex takes place.

In the case of the inclined plane exit of the shock tube, two primary phenomena were noted: deflection of the jet and change of the jet cone angle; and variations in the vortex diffraction behaviour. For the former effect a large inclination of the exit from the normal increased the spread of the jet and the inclination away from the tube axis. Also, a system of secondary shock waves forms in the jet due to the expansion fans formed at the diffraction edge, typical of underexpanded jets but becomes weaker as exit surface inclination increases. The second effect noted is of the increased curvature as a function of time after diffraction for higher inclinations, due to the much stronger induced velocities for the portion of the vortex shed on the obtuse upstream edge. The vortex loop also loses coherence with increasing inclination because of the weak vortex shedding at the downstream edge of the tube.

The results for the curved exit are similar although the effects are not as extreme since the limiting diffraction angles are lower than for the extreme plane cases due to the characteristics of circular geometry. In the extreme case of part of the shock tube exit being tangent to the exit surface, the vortex again does not form a closed loop but rather terminates in the exit surface. This was particularly tested here with a plane section at the tangent point. However, the secondary reflection of the diffracted shock wave due to the curvature of the surface toward the diffracted wave, which tends to disrupt the vortex, means that an internal diffraction with a fully closed tube would result in a short-lived vortex loop.

In both of the latter cases the vortex loop, or arch if it cannot close into a loop, is part of the physical mechanism whereby a jet flow exiting a pipe adjusts to being a diffuse flow along the exit surface. This is accomplished by the spreading of the sheet of vorticity, which is the boundary layer in the pipe and the jet boundary outside of it, by the origination of turbulence in the breakdown of the vortex arch or loop.

The diffraction of shock waves from non-orthogonal apertures demonstrates features previously unidentified and suggests complex flow patterns which simplified two-dimensional analysis cannot describe.