Abstract

Shock–waves (shocks) exist in various shapes; restricted to two dimensions some examples are planar, cylindrical, parabolic and elliptical. However, most shock–wave research has been focussed mostly on plane shocks. In this research, the scope is expanded to cylindrical shock–wave segments where a plane shock can be viewed as a cylindrical shock segment (referred to as a cylindrical shock) with a large radius of curvature; with this view, the expectations are that cylindrical and plane shocks behave similarly although with quantitative differences.

Whereas plane shocks have constant orientation, constant strength and can be imagined to extend unbounded, cylindrical shock segments demand that both ends be bound; this leads to spatial constraints, shock strength varying with respect to radius and shock orientation being non-constant. Three shock phenomena were investigated: diffraction, reflection and propagation in converging diverging nozzles. Shock–tube experiments were run for shocks with a radius of 165 mm and strength between Mach numbers 1.2 and 1.7. Complementing these were Computational Fluid Dynamics (CFD) and Geometric Shock Dynamics (GSD) simulations where GSD relies on Whitham's equations.

On shock diffraction, cylindrical shocks were shown to behave qualitatively like plane shocks. Upon encountering a sharp corner, expansion waves propagate along the shock. However, after reflecting off the opposite wall they become compression waves and form a 'Mach reflection (MR)' like configuration on the shock front. A method for calculating the locus of the expansion waves based on Whitham's theory is presented, which on comparison with CFD simulations gives good correlation. Comparisons of shock profiles calculated using Whitham's theory and CFD is also made; it showed good correspondence before the formation of MR like configurations after which the profiles differ.

The reflection of cylindrical shocks was investigated from both an experimental and numerical perspective. Shock–tube experiments were run for shocks propagating on concave cylindrical walls with radii of 100 mm, 180 mm, 140 mm and 82 mm, the range was expanded by use of CFD. An expression for calculating the locus of the MR that forms on the shock front was derived which generalises onto plane shocks. Two limits were recognised, one where shock radius is much greater than wall radius and another where shock radius is much smaller. The former corresponds to a cylindrical shock on a plane wall while the latter a plane shock on a cylindrical wall as illustrated by the data gathered.

Cylindrical shock propagation in converging-diverging nozzles was also investigated. In this case, the phenomena at play are diffraction, reflection and focusing, a combination which results in a complex evolution of the shock front. Two types of channels were investigated, one formed from a 3^{rd} order polynomial and another from circular arcs. In both cases, wall signal were generated on either side of the shock which split the shock–front into three sections. The decreasing channel cross–section area causes the shock strength to increase resulting in very weak MR formation on the shock front. Channels from circular walls exhibit a single peak in the centre line shock strength while that from polynomial profile walls results in a double peak. This was then related to type of wall disturbance generated.