Abstract

The cardinal aspects of supersonic and hypersonic propulsion intake design involve understanding the internal shock wave structures forming therein. A study was conducted to explore the effects of internal surface curvature and entry deflection angle on steady axisymmetric shock waves. Very little is known about these influences with only Curved Shock Theory, produced by Mölder, providing analytical insight directly after a curved shock wave.

The shock waves and accompanying flow fields which were generated were studied via experimental and numerical means. Radius normalised internal radii of curvature of 1, 1.5 and 2 with entry deflection angles of 0°, 4° and 8° were investigated between a Mach number range of Mach 2.4 and 3.6. Experimental results were produced using a blow down supersonic wind tunnel facility and were captured via shadowgraph and schlieren flow visualisation techniques. The numerical simulations were validated using the experimental results.

A self similar curved shock wave shape equation was presented with an empirical model which uses flow Mach number and internal radius of curvature in order to produce the resulting curved shock shape. Curved Shock Theory streamlines were used to try predict the internal surfaces that produced the curved shocks but results did not correlate. This was due to extreme streamline curvature curving the streamlines when the shock angle approached the Mach angle. Very good agreement was however found between the theoretical and numerical streamlines at lower curvatures. The higher the internal surface curvature and entry deflection angle, the greater the flow fields were impacted. Steeper characteristics formed as a result, curving the shock wave more noticeably. Both the internal surface curvature and entry deflection angle were found to have an effect on the trailing edge expansion fans which then altered the shape of downstream shock wave structures. The highest curvature models produced steady double reflection patterns due the flow being turned in onto itself by the imposed internal surface curvature. The effects of conical and curved internal surfaces were explored for additional insight into the presence of flow-normal curvature and the curving of the attached shock waves.