# Abstract

The aim of this thesis is to research the fundamental flow physics arising from expansion fan/shock wave interactions in two- and three-dimensions. Motivation for this research stems from occurrence of such interactions in the practical aerospace applications of supersonic store carriage and release from aircraft, engine inlet design, and formation flying. Additionally, previous investigations into expansion fan/shock wave interactions have considered only two-dimensional interactions analytically and numerically, with specific focus on the effect of the interaction on the downstream shock reflection rather than the flow physics of the interaction itself, therefore there is a gap in the field of knowledge concerning these interactions.

This thesis presents a study of two- and three-dimensional expansion fan/shock wave interactions both numerically and experimentally, where the experimental investigations were conducted in a supersonic wind tunnel and complementary time-averaged Reynolds-averaged Navier-Stokes numerical simulations were performed using a commercial computational fluid dynamics package. The interactions were modelled between two wedges (one generating the oblique shock wave and the other generating the expansion fan) at various wedge compressive flow deflection angles, expansive flow deflection angles, and aspect ratios at various Mach numbers. The numerical simulations resolved all the flow features of interest present in the experimental results and allowed for interrogation of the flow field at various spanwise and chordwise locations, particularly in the study of the three-dimensional interactions.

Results of the investigations show that in a two-dimensional expansion fan/shock wave interaction, the shock is curved toward the upstream direction by the expansion fan, the expansion fan is deflected toward the downstream direction by the shock, and the shock is strengthened and the expansion fan weakened as a result of the interaction. An increase in either compressive or expansive flow deflection angle yields an increase in shock curvature, greater deflection of the expansion fan (increasing the compressive flow deflection angle causes an increase in deflection of both the leading and trailing Mach waves of the expansion fan whereas increasing the expansive flow deflection angle gives rise to an increase in deflection of the trailing Mach wave while the deflection of the leading Mach wave remains constant), strengthening of the shock to a greater extent, and an increase in the amount by which the

expansion fan is weakened. Increasing the freestream Mach number results in a decrease in the concavity of the shock, an increase in expansion fan deflection, greater strengthening of the shock, and a larger extent of weakening of the expansion fan. Flow separation from the expansion generator wedge surface under certain flow conditions has a significant effect on the expansion fan/shock wave interaction, negating the interaction altogether in some cases. Also included in the study of 2D expansion fan/shock wave interactions was modification of an analytical model for such interactions (published previously by other researchers) and validation thereof, where significant agreement with experimental and numerical results was achieved.

The study of three-dimensional expansion fan/shock wave interactions (where 3D flow features dominate the flow field) showed that the interaction involves an incident shock weakened by shock diffraction and an incident expansion fan weakened by circulating flow entrained in the tip vortices, when traversing the wedge span from the centre plane toward the wedge edges. This results in a decrease in shock curvature, less deflection of the expansion fan, strengthening of the shock to a lesser extent, and reduced weakening of the expansion fan toward the wedge edges. Comparison of the three-dimensional expansion fan/shock wave interactions at each spanwise location reveals the same trends as the 2D expansion fan/shock wave interactions for a variation of compressive and expansive flow deflection angles and freestream Mach number. The influence of the 3D flow features on the expansion fan/shock wave interaction can be reduced by either increasing the aspect ratio of the wedges, which gives rise to a two-dimensional flow region and hence 2D interaction unperturbed by three-dimensional flow features around the wedge centre plane, or decreasing the vertical separation distance between the wedges, which shifts the interaction upstream thereby reducing the distance over which the three-dimensional flow features affect the flow field prior to the interaction. Expansion fan/shock wave interactions between wedges with mutually different aspect ratios were also investigated; moving from the wedge centre plane toward the wedge edges, interaction of an expansion fan influenced by three-dimensional effects with a two-dimensional shock wave has the same effects on the shock curvature, expansion fan deflection, shock strength, and expansion fan strength as a two-dimensional interaction with decreasing expansive flow deflection angle, while interaction between a two-dimensional expansion fan and a shock wave affected by three-dimensional flow phenomena follows the trends of a two-dimensional interaction with decreasing compressive flow deflection angle where the shock curvature, expansion fan deflection, shock strength, and expansion fan strength are concerned.

This thesis contributes a comprehensive study of the flow physics involved in expansion fan/shock wave interactions in two- and three-dimensions, characterising the effects of a variation of compressive flow deflection angle, expansive flow deflection angle, Mach number, vertical separation distance, and aspect ratio, to the field of compressible flow.