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Three dimensional shock wave/boundary layer interactions

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Abstract

An investigation into a three-dimensional, curved shock wave interacting with a three-dimensional, curved boundary layer on a slender body is presented. Three different nose profiles mounted on a cylindrical body were tested in a supersonic wind tunnel and numerically simulated by solving the Navier-Stokes equations. The conical and hemispherical nose profiles tested were found to generate shock waves of sufficient strength to separate the boundary layer on the cylinder, while the shock wave generated by the ogival profile did not separate the boundary layer. For the separated flow, separation was found to occur predominantly on the windward side of the cylinder with the lee-side remaining shielded from the direct impact of the incident shock wave. A thickening of the boundary layer on the lee-side of all the profiles was observed. In the conical and hemispherical cases this leads to the re-formation of the incident shock wave some distance away from the surface of the cylinder. A complex reflection pattern off the shock wave/boundary layer interaction (SWBLI) was also identified for the separated flow cases. For comparative purposes an inviscid simulation was performed using the hemispherical profile. Significant differences between the viscous and inviscid results were noted including the absence of the boundary layer leading to a simplified shock wave reflection pattern forming. The behaviour of the incident shock wave on the lee-side of the cylinder was also affected with the shock wave amalgamating on the surface of the cylinder instead of away from the surface as per the viscous case. Test data from the wind tunnel identified two separation lines present on the cylindrical surface of the hemispherical SWBLI generator. The pair of lines were not explicitly evident in the original CFD simulations run, but were later identified in a high resolution simulation.