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Aerodynamic effects of accelerating objects in air.

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Abstract

This is an investigation into the unsteady aerodynamics of accelerating bodies. The main objective of the study is to compare the unsteady flow fields and the aerodynamic forces and moments resulting from acceleration or retardation of various objects with the corresponding steady state results at specific Mach numbers. It is to focus on transonic and subsonic Mach numbers using two-dimensional numerical models of airfoils and axisymmetric bodies. Fluent is used as the computational fluid dynamic (CFD) software with a special technique for handling the unsteady conditions during acceleration. In most cases constant velocity (steady state) simulations were conducted at Mach numbers ranging from 0.1 to 1.6. The objects were then accelerated at 1041 m/s^2 (106 g) and 86.77 m/s^2 (8.845 g), starting at Mach 0.1, and decelerated at -1041 m/s^2 and -86.77 m/s^2, starting at Mach 1.6, through the same range of Mach numbers using time-dependent (unsteady) simulations. Airfoils were used at different angles of attack and occasionally smaller accelerations at lower Mach numbers were used to confirm generality of results. It was found that during acceleration subsonic lift was lower and subsonic drag was higher than the corresponding steady state values at the same Mach number, with the opposite effect identified during retardation. In the transonic regime differences between the steady and unsteady position for the shock waves on the surfaces of the airfoils and axisymmetric bodies were observed. These were used to explain the large differences between the steady and the unsteady aerodynamic forces in the transonic range of Mach numbers. Acceleration dependent behavior for the bow shock, the tail shock and the trailing compression wave were also observed. In conclusion, all differences between steady and unsteady transonic shock wave behavior were found to be predominantly a function of flow history. In the subsonic regime the differences between steady and unsteady lift were attributed to flow history but for unsteady drag these differences were mainly attributed to fluid inertia.