Ph.D. Thesis Abstract

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Shock-shock interactions appearing around hypersonic vehicles are generally complex and often lead to high values of localized pressures and temperatures. This increase in temperature is associated with exceedingly high heating rates on the surface of the flying vehicle and it may have serious influence on the performance and safety of the vehicle. A blunt body with a spike attached to its stagnation point is a typical configuration around which shock-shock interaction appear. The shocks also interact with the boundary layer on the sur-face of the spike, leading to boundary layer flow separation.

The present work focuses on the study of high speed flows over spiked blunt bodies. The two main design requirements for any hypersonic vehicle are minimum drag and minimum aerodynamic heating. A blunt body design of large nose radius is preferred for reduced aerodynamic heating during the re-entry phase and a sharp slender forebody design for reduced drag during the atmospheric flight phase. The addition of a spike to the stagnation point of the blunt body offers a partial solution to the above-mentioned design problem. Though the use of the spike as drag reduction tool has been studied at length, most of the experimental investigations used very simple configurations. Hence, very little is known about the flowfield around a realistic geometric con-figuration with aerospikes. The present work aims to study the effect of spike as a drag reduction tool on the Hypervelocity Ballistic Models (HB1 and HB2). The HB models are standard AGARD models and represent generic missile configurations.
The addition of a spike changes the flowfield around the blunt body, re-placing the existing bow shock wave with a system of weaker shocks. This results in generation of a separated flow region ahead of the blunt body, which screens a larger portion nose surface from the oncoming hypersonic freestream. This leads to considerable reduction in drag and heat flux. This mechanism maximizes missile performance by transforming the aerodynamic characteristics of a blunt nose in to a more streamlined shape.

Experiments on force measurements are conducted to study the influence of spike geometry in enhancing the aerodynamic characteristics of the missile configurations. Two different spikes are used; one with a conical tip and the other has hemispherical disk attached to its tip. Based on the experimental results, the performance of the spike with aerodisk is better than the conical spike at higher angles of at-tack tested. The present study uses a 3-component accelerometer based force balance system to measure the aerodynamic forces acting on the model. Direct force measurements over such realistic configurations are very little in the literature.

For certain combinations of flow conditions and geometric parameters, the flow around the spiked body configuration becomes unstable. This flow unsteadiness leads to severe pressure and heating loads. In earlier studies on flow instability around spiked bodies at hypersonic Mach numbers, the high speeds are not simulated, which is the measure of the kinetic energy of the flow. The presents study uses a flat cylindrical model with a variable length spike to understand the influence of the unsteady separation zones on the pres-sure fluctuations using a shock tunnel flow, where along with Mach and Reyn-olds number, the enthalpy of the flow will also be simulated. Two distinct un-steady flow modes, namely pulsation and oscillation are observed. Pulsation mode includes very violent shock oscillations, whereas the oscillation mode is relatively less severe, and the amplitude of pressure fluctuations is much smaller than that obtained with pulsation mode. Transition between the two modes is observed at a spike length equal to that of the body diameter. Basic methods for passive suppression of the flow unsteadiness by varying the geometric parameters are suggested to supress or eliminate the flow oscillations. These experiments also demonstrate that impulse ground test facilities like shock tunnels can be used for studying unsteady flow phenomena of moderate to high frequencies.