A Study on Passive Aerothermodynamic Flow Control Methods for Hypersonic Lifting Body Configurations

論文内容の要旨

Dissertation Abstract

論文題目 Title:
A Study on Passive Aerothermodynamic Flow Control Methods for Hypersonic Lifting Body Configurations（極超音速揚力飛行体形状に対する非能動的熱空気力学的流れ制御に関する研究）

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With the retirement of conventional space shuttles and the emerging interest in the space tourism, the efforts to design and investigate various geometrical configurations added with different techniques for ensuring safe, reliable and economical travel have paced up. The increased drag and convective heating associated with flow at hypersonic speeds have a significant impact on the design of vehicles. Together with optimization design study, techniques for simultaneous control aerodynamic flow field have been researched for a long time, which can be classified into Active (requiring a dedicated energy source) and Passive Control Methods (manageable with simple modification in the geometry). Considering significant design and application complexities of Active control methods, Passive flow control techniques of using a forward-facing aerospike and breathing blunt nose concept were chosen as the potential candidates for the current investigation.

A forward-facing spike attached at the nose of a blunt-body has been established as a means to favorably modify the flow field with a significant influence on the aerodynamic characteristics in hypersonic flow and can be regarded as a prospective option for drag reduction and increase of (lift/drag)-ratio of blunt nosed flying vehicles. The various parameters to be considered includes spike length, shape, spike-nose configuration and angle of attack. However, the studies have been conducted only on simple axisymmetric geometries and not on representative lifting body shapes. Therefore, as a first of its kind study, the efforts were focused on

analysis of using forward-facing aerospikes and its effectiveness with varying angle of attack (-10° to +10°) and spike-nose configuration, on key aerothermodynamic parameters of drag and heat reduction for prospective application to two type of lifting body configurations, with leading edges swept at 70° forming a delta shape, one with a non-axisymmetric forward stagnation surface and another with an axisymmetric nose. Flow visualization was carried out using the schlieren technique. Measurements made at freestream Mach number 7 with six-component force balance system revealed a large increase in the Lift/Drag Ratio and marginal increase in pitching moment coefficient compared to no-spike case, together with overall reduction in the nose surface area exposed to heating, with aerospikes proving worthy at high angles of attack; thereby indicating their practical feasibility for eventual future applications to spacecrafts.

Breathing blunt nose concept study, proposed for drag reduction, by bleeding the air from nose and discharging it at the base, in an attempt to increase the pressure at the base of the body, hence reducing the contribution from base drag against the direction of motion. This concept also has been studied on simple basic geometries only, therefore it has been investigated for practical feasibility and application on lifting body configurations with the help of wind tunnel experiments carried out at Mach 7 on a 70° swept-back lifting body shape forming a delta shape, with axisymmetric nose, and using shallow water channel visualization technique. The visualization results highlights the similarity between the flow field estimated by the two methods, and the latter provides an insight into the flow physics of inside the channel with an assumption of quasi one-dimensionality. The aerodynamic measurements at the wind tunnel demonstrated that with the breathing blunt nose, the drag can be fairly reduced without adversely affecting the stability of the basic body, proving it worthy of practical utility, and underlines the existence of limit of bleeding from the nose.

Both the techniques have been proven to be worthy of favorably modifying the flow field resulting in the improvement of aerodynamic characteristics over the basic reference configuration. The only issues that needs to be addressed, for aerospikes, includes optimum selection of aerospike for a specific body for avoiding any reattachment of shear layer on the body and to curb the extra normal force component acting on the spike nose at higher angles of attack which needs to be taken

into consideration. For the breathing blunt nose concept, the design of the channel, for carrying and discharging the high pressure and high temperature air from the nose to the base, needs dedicated study for maximizing the drag reduction and to bear the heat load of the from the air bled and moving inside the channel. The results obtained by investigating the flow features around various configurations, by varying the geometric parameters, are valid within the parameters investigated here.