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Drag Reduction in Hypersonic Vehicles -A Case Study

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Abstract:

The use of the hypersonic vehicles increases day by day and improvement in the design and getting maximum efficiency is a key factor. To have the maximum efficiency wave drag need to be the major consideration. Detachment of the wave drags from leading edge decrease the drag co-efficient and increases the L/D ratio. The evolving method to short out the issue is spike in the frontal cone. Attachmentof the spike at the leading edge various the stagnation point position and varying the drag co-efficient value. This case study shows the advantage of using spike in different frontal cones. Variation in the L/D with respect to the length of the spike is discussed.

Introduction:

The space vehicles place a problem of re-entry to the atmosphere at higher velocity. Whenever it reaches the atmosphere due to density of the air it experiencing more wave drag at the leading edge. Decrement in the altitude increases the density of the air, due to high dense air intensity of the wave drag increases rapidly. Generation of the wave drag increases the drag co-efficient value and decreases the L/D ratio. Generally high L/D ratio increases the response time and efficiency, so we need to incorporate this problem to attain maximum efficiency in space vehicles. Researchers deployed many technics to solve this problem but this spike design is one of the efficient and trending one. Spikes at the leading edge increases the efficiency by delaying shock wave from the object. The length of the spike alters the impact of the shock waves over the leading edge. For different cross-section the spike has been incorporated and tested in shock tunnel. In an advanced method coolant injection from the spike further more reduced the temperature at the nose cone. The effect of enthalpy layers over the object also various. In a general case ablative materials has been used for cooling purpose. Further usage of ablative material with spikes totally changes the temperature level in the space vehicles. The process of ablation erode the material present outside the object, the material will

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be totally converted into liquid form due to high temperature. The effect of ablative will also vary with respect to altitude.

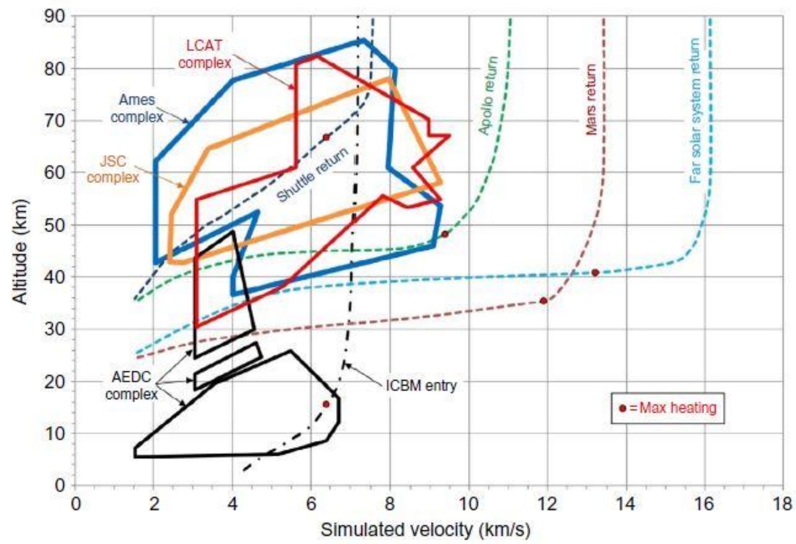

Fig. 1 Performance with several nominal Earth return trajectories[4]

The result shows that if the velocity of the space vehicle depends on the altitude. The altitude variation shows the amount of changes in the velocities. This shows the ranges of the changes in velocities for different frontal cones has shown in the above figure.

Literature review:

Drag reduction in the hypersonic vehicles concentrated throughout the study. To achieve the prescribed lift to drag ration spikes been built at the leading edge and the vehicles has been tested with different angle of attack. The author changes the enthalpy range from minimum to maximum level in order to see the flow field variation with and without spikes. Length of the spikes with respect to Disc diameter is taken as ¼ D. The variation in the enthalpy range is (1.1 $\pm$ 0.02 and 1.5 $\pm$ 0.03 MJ/kg)

With different shock tunnel minimum and maximum enthalpy conditions drag values has been identified for normal and spike blunt body and graph has been plotted

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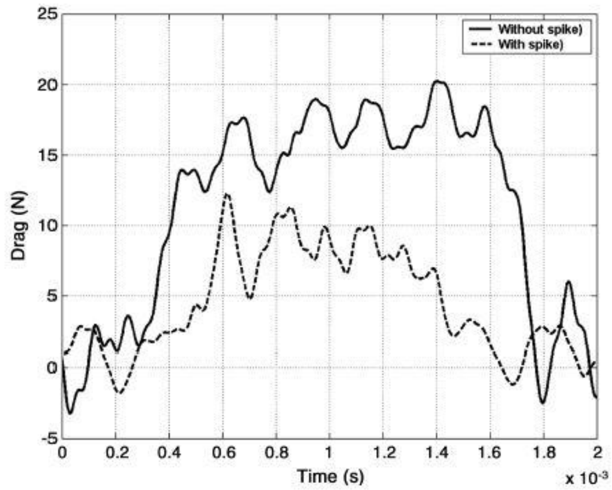

Fig. 2 Recovered drag signals with and without spike[1]

Bluntphasewith apex angle of 120^o with spike produces 57% of better performance comparing to normal one.

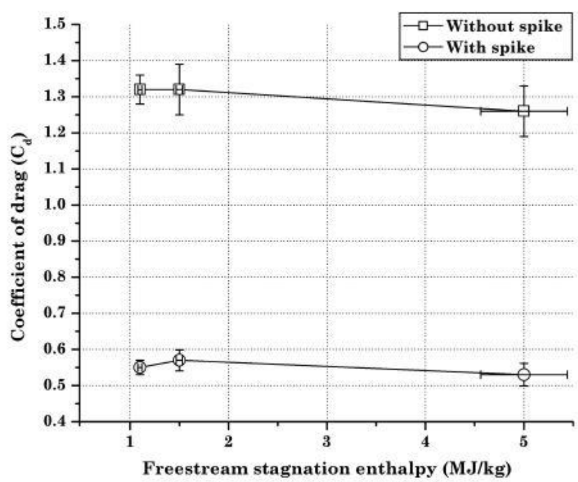

Fig. 3 Variation of drag co-efficient with free stream stagnation enthalpy[1]

Hemispherical body hypersonic analysis with and without spike:

Hemispherical body considered as a base design, and it has been analyzed with and without spike at hypersonic range. Whenever the spike is present at zero angle of attack the effect is very low. Change of angle produces better performance and high L/D ratio. The overall drag reduction of 63% to 78% is possible.

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For a better specific fuel consumption low drag co-efficient and high L/D is required for better performance.

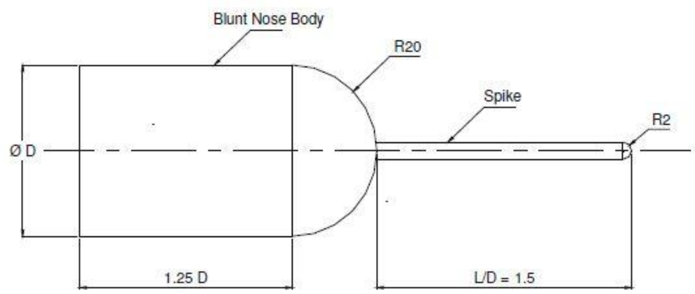


Fig. 4 Force Measurement Model details[2]

The design is tested in free jet apparatus and the result shows the variation in drag co-efficient with and without spike.

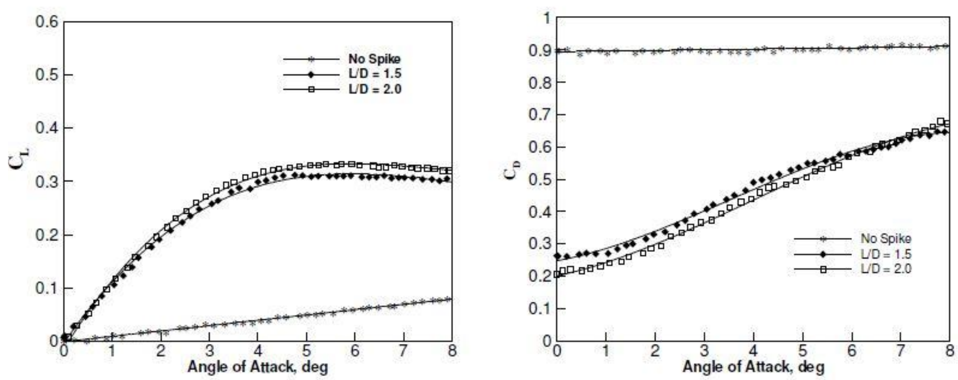
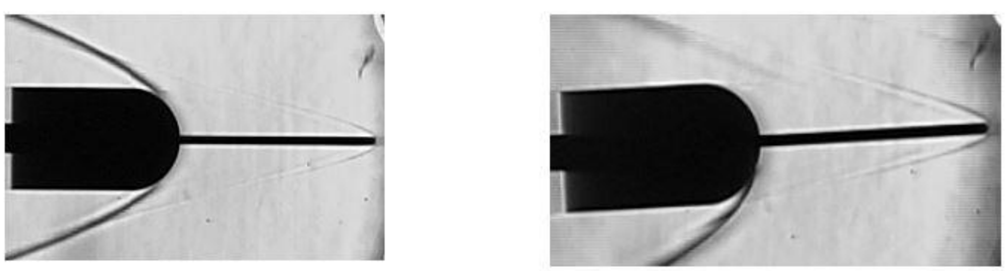


Fig. 5 Variation of C_l and C_d with different angle of attack.[2]

Variation in the schlieren image shows the intensity variation with respect spike.



(a) $\alpha = 0°$ (b) $\alpha = 5°$

Fig. 7 Shock pattern for hemisphere aerospike of L/D = 2.0

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Single and Twin spike:

In order to reduce the drag and increase the aerodynamic efficiency of the space vehicle spike has been incorporated in hypersonic vehicles. Single and double spike flow analysis was carried out for different flow condition. Axisymmetric model was chosen as a base design. Five different cross-section spike designs were followed and best one taken out into account.

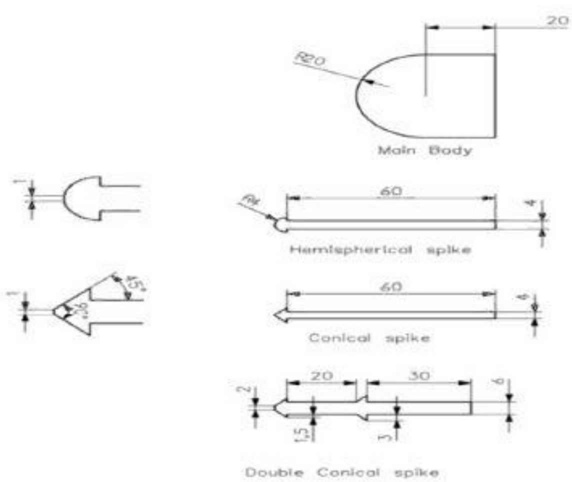

Fig. 8 Different spike cross-section[3]

Reynolds number of 1.72×10^6 per unit length is taken into account and the analysis carried out using ANSYS. The drag co-efficient reduced to 44 % to 66 % of its own result.

Table. 1 Heat flux and drag reduction for the model[3]

Model	% reduction in peak heat flux	% reduction in CD
Single conical spike without jet	31	59
Single hemispherical spike without jet	27	61
Single conical spike with jet	33	47
Single hemispherical spike with jet	29	44
Twin-conical-spike	44	46

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Conclusion:

From the above study we can justify that when cross section increases wave drag intensity and heat flux stated increasing, but in small cross sectional area the space for disperse not there. So to achieve the high performance with stability the stagnation points need to be dislocated from the leading edge. This spike technic is one of the best one to achieve the efficiency with performance. The spike dislocates the position of the stagnation and decrease the effect of heat over the object. In advanced injecting coolant through spikes is most efficient then other technics.

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