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A Review on Effect of Aero Spike in Supersonic Vehicles

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ABSTRACT

When an aerodynamic body travels through air at high Mach number it experience high drag, heat flux, shock wave interaction and so on. With these, the efficiency of the vehicle get reduces. There are many techniques evolved in order to reduce these effects such as aero spike, counter flowing jets, aero disc, energy dissipation, forward facing cavity. This paper details about the use of aero spike in supersonic vehicles to reduce the effect due to drag and increase the efficiency of a vehicle. This is a review where all recent studies of the aero spike are provided.

INTRODUCTION

In recent times, the aerospace industry is growing very fast and more innovative designs are evolving for both commercial purposes and for other operations too. Any aerodynamic body flying above the ground experience drag. The body which is moving at very high speed experience shock waves.

To limit the limitations of drag, heat flux or shock interactions there are many techniques apart from the entire design modulation. They are aero spike, counter flowing jets, aero disc, energy dissipation, forward facing cavity. Out of all the aero spike is the technique which is simple and can be easily integration with the model and occupies less space.

Aero spikes have always been used to solve the difficulties of drag and surface heating faced by re-entry vehicles and bodies traveling in hypersonic medium. As a result, the design of aero spike is important and aids in improvement of space vehicle aerodynamics and research. The parameters involved are the length, Mach number, test configuration and design modulation of spike.

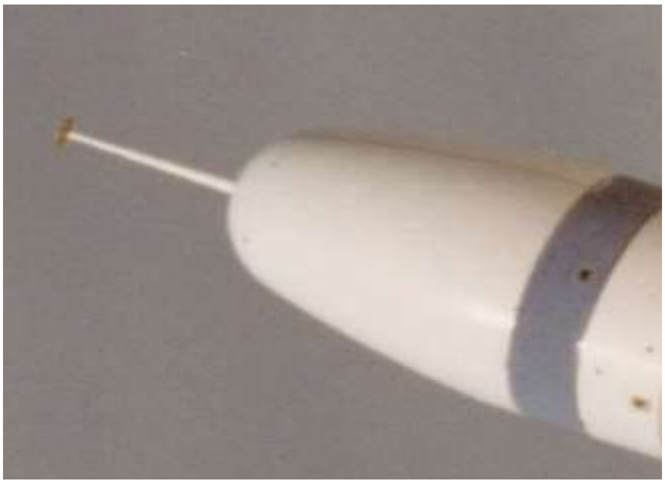


Fig 1: Aero spike with disc attached [1]

The above figure is the pictorial representation of aero spike with the disc attached to the aerodynamic body.

Generally aero spike reduces the drag when installed in supersonic vehicle. The bow shock gets converted to conical oblique shock due to spike which makes the shock weaker and low pressure is created near stagnation region which reduces the dynamic pressure on the blunt body. The detached shock again gets attached to the blunt body at the sides. This again can be reduced by varying the spike length and its geometrical design.

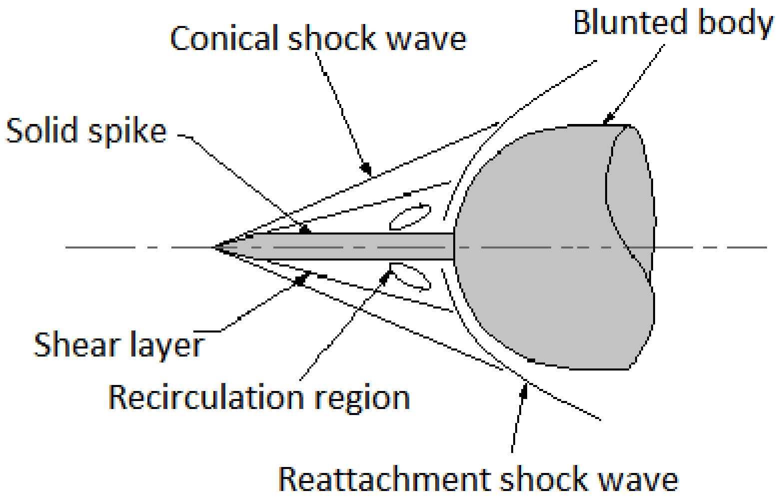


Fig 2: shock wave interaction [2]

The above fig is taken from the journal 2, Review of drag reduction techniques in supersonic vehicles.

The maximum drag comes from the nose part of the vehicle where it nearly covers 33% of overall drag.

Effect of shape of the spike on drag reduction

The comparision of sharp and hemispherical head of a spike is carried at at Mach number 6 using FLUENT[4].

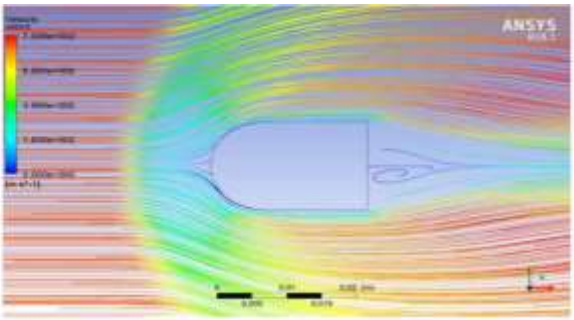


Figure 3. Flow visualization of blunt nose

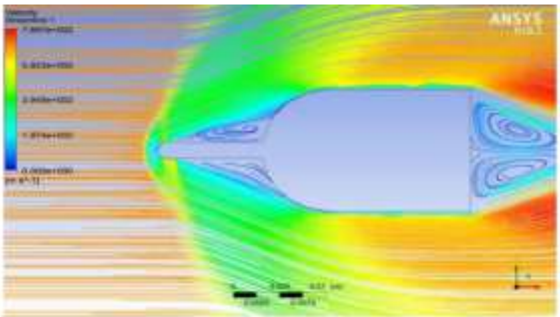


Figure 5. Flow visualization of hemisphere aerospike

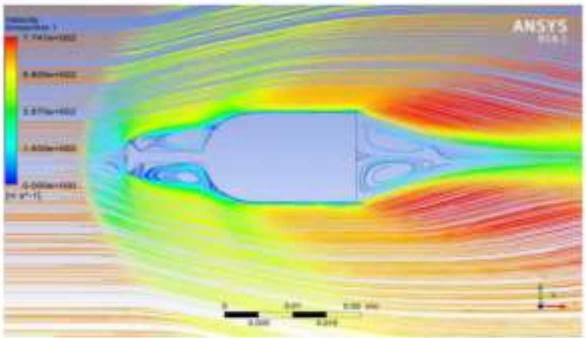


Figure 4. Flow visualization of aerodisk

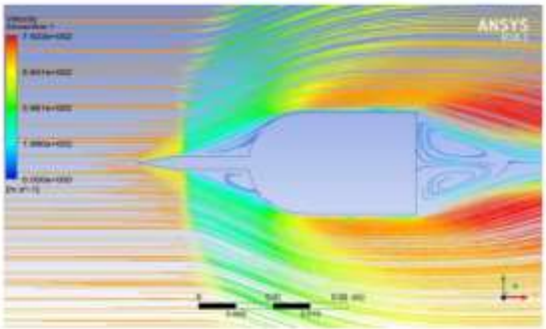


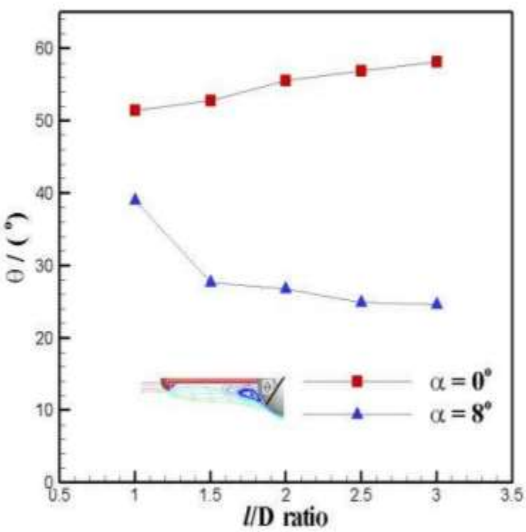
Figure 6. Flow visualization of sharp aerospike

Sharp spike exhibits a maximum drag reduction of 69.5%, while the hemispherical head spike has a maximum drag reduction of 81.5%. The drag reduction of 81.5% is only due to change of the shape of spike tip.

It is recommended to use hemispherical shaped spike as it reduces more drag when compared to sharp one. Apart from this, the disc spike also reduces drag where double disc gives more drag reduction than single disc [3].

Effect of drag due to Spike L/D ratio

Here the spike length to diameter ratio and its inclination to the main body is illustrated. As the angle of reattachment increases the pressure drag also get decreased and L/D ratio is inversely proportional to the pressure drag until a particular value of given Mach [3].



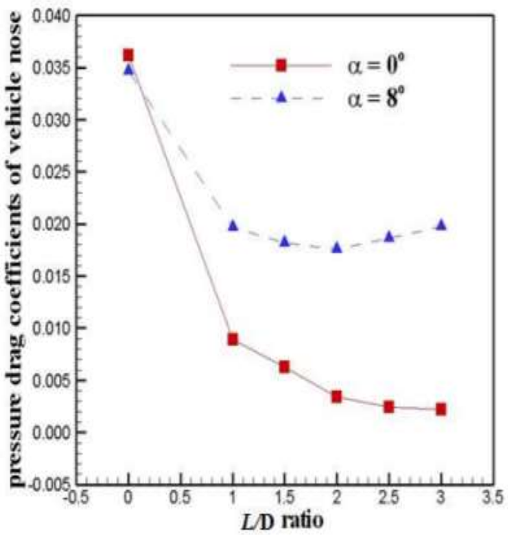


Fig 7: reattachment angle with L/D [2]

Fig 8: L/D ratio with pressure drag [2]

The drag reduction is more at 0 AOA but the vehicle moves at greater angles during glide so other than 0 angle, 8 AOA is chosen where L/D ratio 2 serve the purpose of drag reduction at Mach 6.

Effect on heat flux

As the shock wave directly touches on head of the spike, the heat generated would be high. The spike need to with stand the continuous heat generation of a shockwave. The tip of the spike sometimes generate excess heat due to its small area of cross section. The thermal protection need to be higher. The spike reduces the drag whereas it increases the heat flux.

As use of spike alone has some limitations, therefore a combination of techniques can be used. Use of spike with counter flowing jets or spike with energy dissipation or spike with forward facing cavity. Out of which spike with counter flowing jets give more benefit to reduce the heat flux and pressure drag. The counter flowing jets makes the shock to move far from the spike which helps the spike from the effect of heat flux. It also helps in delaying the reattachment shock on the sides of the main blunt body.

CONCLUSION

Supersonic vehicles when moving at high speed experience drag, heat flux and shock waves due to which it efficiency gets reduced. The maximum drag comes from the nose part compared with other parts of the body which is 33%. Therefore reduction in drag at the front brings considerable decrease in overall drag. Application of spike on blunt body reduces the drag. The low pressure area depends on the length to diameter ratio and the L/D ratio of 2 at angle of attack 8 with Mach number 6, the drag gets reduced by 49.3% at nose and overall 4.39%. Use of hemispherical head spike is recommended than the sharp one which reduces the drag as well as heat flux. To reduce more amount of heat flux, a combination of techniques can be used where the limitations of spike can be avoided.

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