ABSTRACT

Enormous research has taken place in the recent year in order to reduce the aerodynamic drag and heating resulting from high speed and shape of the blunt cone for hypersonic vehicles. These still possess a great challenge in the design of supersonic and hypersonic vehicles as the aerodynamic drag varies with velocity as $(V_\infty)^2$, whereas the aerodynamic heating increases as$(V_\infty)^3$. The increase in heating and drag associated with hypersonic speed had a significant impact on the design of hypersonic space vehicle. Modifying the flowfield structure ahead of the main body can result in substantial reduction both in aerodynamic drag and heating. One such method is the use of spike; a passive flow control device.

Many researches in the past have addressed the reduction in drag and aerodynamic heating with the use of spike. Most of the paper available in published literature reports the effect of *l/D* ratios, but the effect of aero disk size is not studied. It is obvious that size of aero disk significantly modifies the flow field ahead of the blunt body and hence affects the aerodynamic parameters.

Therefore the aerodisk spikes can be regarded as a potential contestant for drag reduction. The effect of spike length, nose configuration, aerodisk radius, and effectiveness of the multidisc aerospikes by varying intermediate positioning of the rearward aerodisk has been studied extensively in the current research.

Detailed numerical simulations have been carried out on commercial available ANSYS FLUENT software to investigate the aerodynamic drag and heating of a hemispherical cylinder with forward facing aerodisks. A wide range of aerodisk viz. hemispherical, flat and flat triangular aerodisk have been investigated for their effectiveness in reducing aerodynamic drag and heating of a hemispherical cylinder. The base configuration is a hemispherical cylinder whose base diameter is 40 *mm* with an overall length of 70 *mm*. The lengths of the spike investigated are 1, 1.5, 2 and 2.5 times the base diameter of the cylinder and the radii of the

aerodisk were varied for 0.05, 0.1, 0.15 and 0.2 times the diameter of the cylinder. Also the effectiveness of the multidisk aerospikes has been investigated in detail by varying the radii and position of the aerodisks by varying the rearmost aerodisk between 0.25, 0.5 and 0.75 of the length between the front and the rearmost disk.

All geometries and grid generation were done using GAMBIT geometry and grid generation software. GAMBIT is a single interface for geometry creation and meshing brings together most of the FLUENT's pre-processing technologies in one environment. The outer boundary of the computational domain is farfield, which is at 0.5*D* in upstream, 1.25*D* in lateral direction and 2.5*D* in top direction to capture shocks properly. The adaptive hybrid mesh generated for the base configuration had all quadrilateral cells 50,000 in number. For subsequent domains around geometries with aerodisks at nose, the cell count varies from 50,000 to 60000 quadrilateral cells depending on length of the spike. During the course of solution these grids are further adapted, based on flowfield gradients, so as to increase the cell count to 80,000 to 140,000 for various configurations. The structured prismatic layer of cells near the surface are highly stretched and fine and the distance of the first cell centre from the body is 1e-07 such that the non-dimensional cell wall distance from the body, $y^+ \approx 1$. For all the configurations investigated, the surface pressure and heat flux distribution were observed at zero degree angle of attack through a time marching solution of the axisymmetric Navier-stokes equation using the FLUENT code. All the computations were done with second order upwind spatial discretization while the inviscid fluxes are computed using modified Advection Upstream Splitting Method (AUSM+). Since the unit Reynolds number are high enough to have turbulent flow, the Splalart - Allmaras one equation model which incorporates both the strain and vorticity based production has been used for modeling the turbulent stresses.

The steady state results show that the use of multidisk aerospike favourably reduces the aerodynamic drag and aerodynamic heating to the main body. A reduction in the drag was observed with the increase in l/D ratio. For a single disk aerospike, the hemispherical aerodisk gives a reduction in drag of about 60% at l/D =1 to 67% at l/D=2.5 for 6 *mm* aerodisk radius. For the same configuration the flat aerodisk gives a reduction in drag of about 57% at l/D =1 to 70% at l/D=2.5. The flat triangular single aerodisk gives the most favourable reduction in drag of 57% at l/D=1 and 70% at l/D=2.5 for aerodisk radius of 4 *mm*. A reduction of about 45% in peak reattachment heat flux is observed for hemispherical aerodisk of radius 6 *mm* at l/D=2.5, which goes to 60% for flat triangular aerodisk and 61% for flat triangular aerodisk. For double and triple disk aerospikes, both the aerodynamic drag and heating are highly dependent on the position of intermediate aerodisk. It has been observed that that drag gradually decreases as rear aerodisk moved forward which is similar for all double disk configurations. The drag reductions in flat aerodisk are considerably higher as compared to hemispherical aerodisk with reduction of about 40% to 78% compared to base configuration. The optimal drag reduction of 78% is observed for flat triangular aerodisk with r_1=6 *mm* and r_2=4 *mm* at l/D=2.5 with rear disk at 0.75l. The flat triangular triple disk gives a very desirable result for drag reduction of about 75% to 78% with the disk size of r_1=4 *mm*, r_2=6 *mm* and r_3=8 *mm* at l/D=2.0 and 2.5 with l_2/l' at 0.50.

The hemispherical double disk aerospike offers up to 65% reduction in peak reattachment heat flux at an l/D of 2.5 with rear disk at 0.75l of the total length of spike. For flat aerodisks, these reductions improve to 68% for r_1=8 *mm* and r_2=6 *mm*. For an l/D ratio of 2.5, a single flat aerodisk of radius 4 *mm* gives a reduction of 47% in peak reattachment heat fluxes which increases to 54% for two disks and goes up to 63% for the three flat disk configurations at the same l/D ratio. With an l/D=2.5, the hemispherical aerodisks offer reductions up to 8% with single aerodisk, 19% with double disks and 27% for the three aerodisk configurations, in the total heat transfer rates to the main body. The flat aerodisk spiked configurations with same front disk radius of 4 *mm* offers reductions up to 27%

with single disk, up to 34% with double disks and up to 39% with treble disk in the total heat transfer rates to the main body.

It has been observed that the multiple aerodisk spikes are advantageous for the purpose of reduction both aerodynamic drag and heating at hypersonic speed. The two aerodisk spiked configurations show better results in terms of aerodynamic heating and drag in comparison to the single disk aerospikes while the three disk spiked configurations yield only a marginal reduction in aerodynamic drag over the two disk configurations. For reduction of heat fluxes and heat transfer rates though, the three disk configurations are extremely advantageous and give much larger reductions are compared to the two disk configurations.