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Analysis of Drag Reduction over Different Types of Blunt Bodies at Different Angle of Attack

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Abstract:- The main intention of this project is to do relative analysis of Drag Reduction over Blunt Bodies at varied Angles of Attack in Supersonic Flow. In this project we have taken plain blunt body attached with different types of spikes which are like as 1. Blunt nose 2. Conical spike 3. Flat faced aero disc 4. Hemispherical spike 5. Breathing Blunt nose. For competitive analysis and results based on the different angle of attack with 0, 5 and 8 on that blunt body with spikes. Numerical simulation was carried out using CFD with SST k-omega model adopted. The hemispherical body is found to be efficient for reducing pressure in vicinity of blunt nose, while the flat plate found to be efficient in reducing peak pressure in compare to other. However, from the values of drag coefficient for all configuration the conical body is observed to have effective drag reduction compare to other bodies.

Keyword:- *Shock wave, drag, Spikes, Blunt body, Breathing blunt nose.*

I. INTRODUCTION

A. What is aero spike ?

The aero spike also known as spike is originally used as “flow separation spike”, which is caused by the adverse pressure gradient in the boundary layer region near the aero spike. However, the effect of drag and heat transfer reduction depend on the flow conditions, blunt body shape ,and spike geometry.

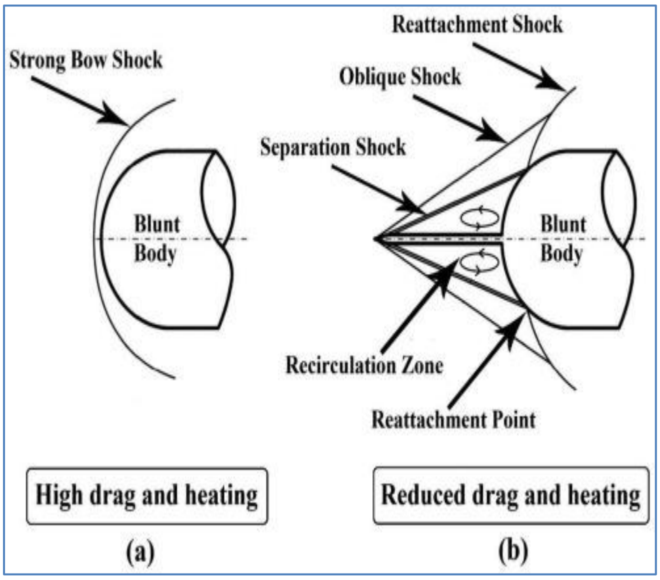

Fig. 1: Blunt body

A drag-reducing aerospike is a device used to reduce the forebody pressure aerodynamic drag of blunt bodies at supersonic speeds. The aerospike creates a detached shock ahead of the body. Between the shock and the forebody a zone of recirculating flow occurs which acts like a more streamlined forebody profile, reducing the drag.

B. Types of aerospike

- *Blunt nose*

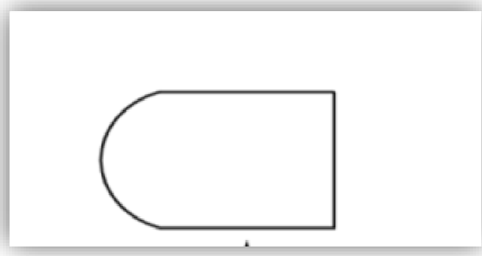

Fig. 2: It is a simple blunt body which is use for the drag reduction in supersonic missile

- *Conical aerospike*

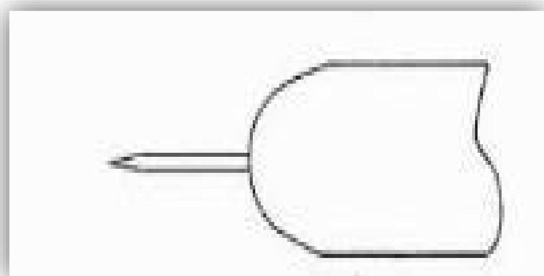

Fig. 3: The sharp conical shaped spike which is attach in fore section of the blunt nose to reduce the drag

- *Flat faced aerospike*

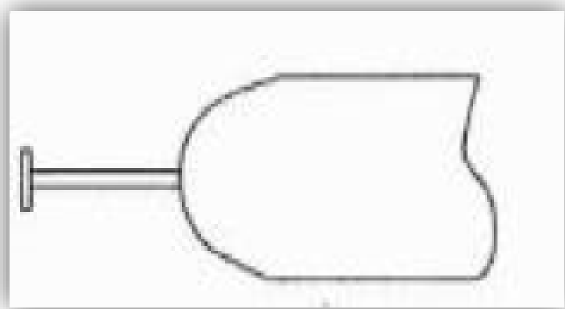

Fig. 4: The flat faced spike which is attach in fore section of the blunt nose to reduce the drag

➢ *Hemispherical aerospike*

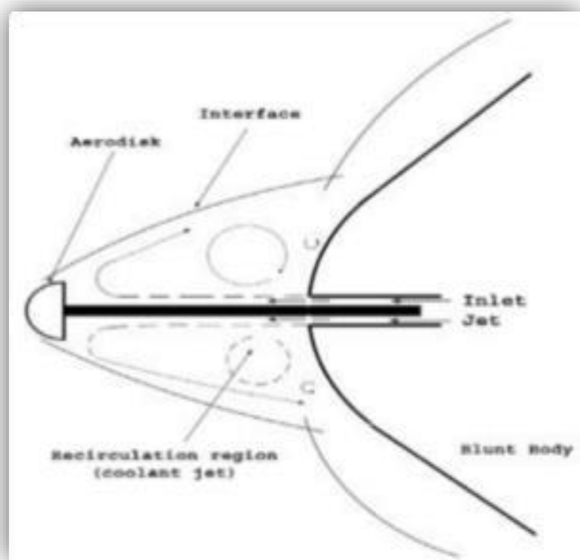

Fig. 5: The hemispherical spike which is attach in fore section of the blunt nose to reduce the drag

➢ *Breathing blunt nose*

In this type of configuration breathing blunt nose is used for drag reduction by taking the atmospheric air in the body.

II. LITERATURE REVIEW

Gaurav Kunal Jaiswala and Mrinal Kaushikb (2017) Innovative Techniques of Drag Reduction over Blunt Bodies at varied Angles of Attack in Supersonic Flow.

In the present investigation, the flow field over a forward facing conical spike, hemispherical aero-disk and flat faced disk attached to the blunt nose and over breathing blunt nose carried out at Mach 2.0 flow regime. The efficiency of these different configurations on the reduction of drag is presented through contours and graphs at Mach 2 with angles of attack 0, 5 and 8 degrees. Numerical simulation is carried out using CFD software with SST − turbulence model adopted. From this paper we conclude that The Flow Field is function of the Shape of the Aerospike.The Shock Strength is markedly weaken in the case of conical spike.The conical spike has a higher lift to drag ratio as compared to other designs and hence it is more efficient at higher angle of attack.

Parag P. Mangave, Vivek P. Warade and A. P. Shah (2018) numerical analysis of drag on blunt bodies with the use of different conical spike at supersonic speed.

The blunt body drag is computed numerically by using Spallart-allmaras turbulence model for different angle of attack i.e. 0,2,4,8 degrees at supersonic speed of Mach number 2 and conical spiked blunt body for L/D ratio of 1, 1.5, and 2 at zero angle of attack has been computed. The front facing conical spike reduces the strong bow shock at front part of blunt body by converting it into oblique shock and shifting the reattachment point for different L/D ratio. From this paper we conclude that As angle of attack increases the peak pressure force acting on a body is increases. The reduction in drag is by 53.93% as compared to that of body without spike. The least drag is found for l/d=1.5 because the force created by the intensity of the oblique shock is less on the blunt body compared to other bodies.

AVashishtha and E Rathakrishnan (2008) Breathing blunt-nose concept for drag reduction In supersonic flow. This paper presents the results and the physics behind the process which results in the reduction of pressure drag of blunt-nosed body by passive control in form of breathing Nose at a supersonic Mach number. The drag of a blunt-nosed body with and without breathing nose at Mach 1.96 is compared. From this paper we conclude that The breathing blunt nose is efficient in reducing the drag of the body at mach 1.96.The shock at the nose becomes weaker when the nose is open.

R. Kalimuthu, R. C. Mehta and E. Rathakrishnan (2008) Experimental investigation on spiked body in hypersonic flow.A spike attached to a hemispherical body drastically changes its flow field and influences aerodynamic drag in a hypersonic flow. It is, therefore, a potential candidate for drag reduction of a future high-speed vehicle. The effect of the spike length, shape, spike nose configuration and angle-of-attack on the reduction of the drag is experimentally studied with use of hypersonic wind-tunnel at Mach 6. The effects of geometrical parameters of the spike and angle-of attack on the aerodynamic coefficient are analyzed using schlieren picture and measuring aerodynamic forces. From this paper we conclude that The flow fields show different flow features between the conical spike, the hemispherical aerodisk and the flat-faced aerodisk.A forward facing spike attached to a hemispherical body alters significantly the structure of the flow field and serves to reduce drag by the formation of a recirculation region around the stagnation point of the blunt body.

R. Kalimuthu, R. C. Mehta and E. Rathakrishnan (2010) Drag reduction for Spike Attached to blunt –nosed body at Mach 6.

Experimental study of the fluid flow structure and aerodynamic characteristics of a spike attached to blunt body at Mach 6. This Note analyses the aerodynamic effects of the spike attached to the blunt body by using schlieren flow visualization and measured aerodynamic forces and moments. Experimental results of the research on a hemispherical blunt nose body with and without spike at L=D ratio of 1.5 and 2, angle of attack from 0 to 8°, with a 1° step.

From this paper we conclude that The hemispherical spike attached to the blunt body is serves to reduce the drag coefficient by forming a recirculation region around the stagnation point. The drag coefficient is reduce to 62% for L/D =1.5 and 78% for L/D= 2.0 .

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III. METHODOLOGY

It includes modeling of the different types of spikes by taking its dimensions from reference research paper and by using the CATIA software we generate its design. After that mesh is generate on all configuration of spikes by using k-omega model for setup to analysis. And using fine mesh is taken for the transition SST model analysis at different angle of attacks. Finally we have generate pressure contours and graphs of cd vs. angle of attack.

IV. ALCULATION OF VELOCITY

Mach number: 2
M=velocity / speed of sound
2=velocity / (1.4× 287× 300) ^0.5
Velocity=694.3774 m/s
α = 5°
X=Vcos α = 694.3774 × cos 5 ° =691.73 m/s
Y=Vsin α = 694.3774 × sin 5 ° = 60.5 m/s
α = 8°
X=Vcos α = 694.3774 × cos 8 ° =687.61 m/s
Y=Vsin α = 694.3774 × sin 8 ° = 96.69 m/s
Mach number: 4
M=velocity / speed of sound
4=velocity / (1.4× 287× 300) ^0.5
Velocity=1338.75m/s
α = 5°
X=Vcos α = 1338.75 × cos 5 ° = 1383.465 m/s
Y=Vsin α = 1338.75× sin 5 ° = 121.0 m/s
α = 8°
X=Vcos α = 1338.75× cos 8 ° = 1375.23478 m/s
Y=Vsin α = 1338.75× sin 8 ° = 193.2766 m/s

V. MODELING OF AEROSPIKE

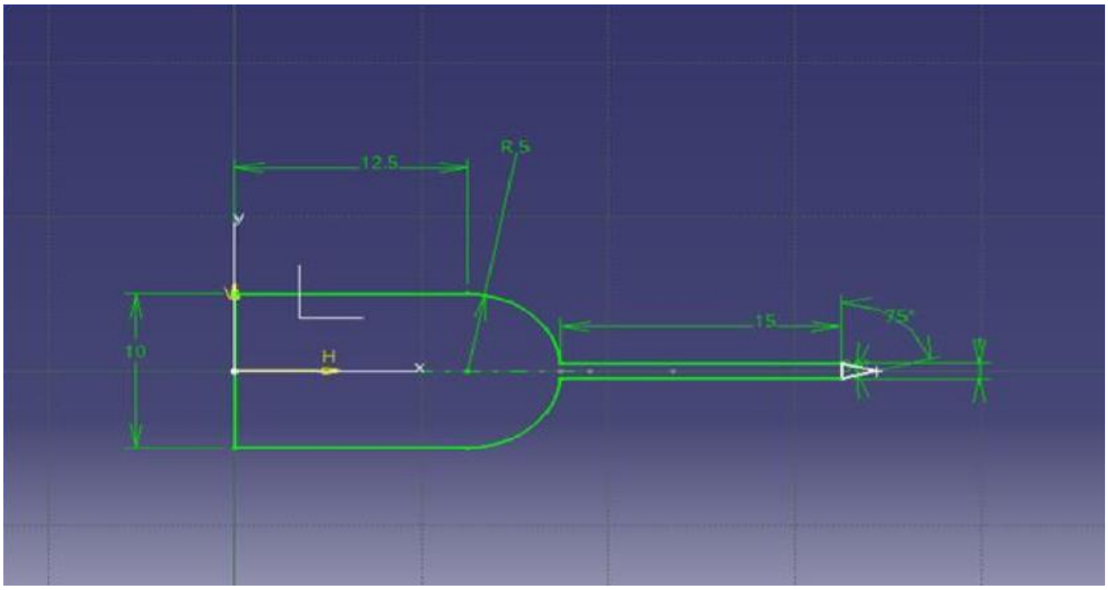


Fig. 6(a)

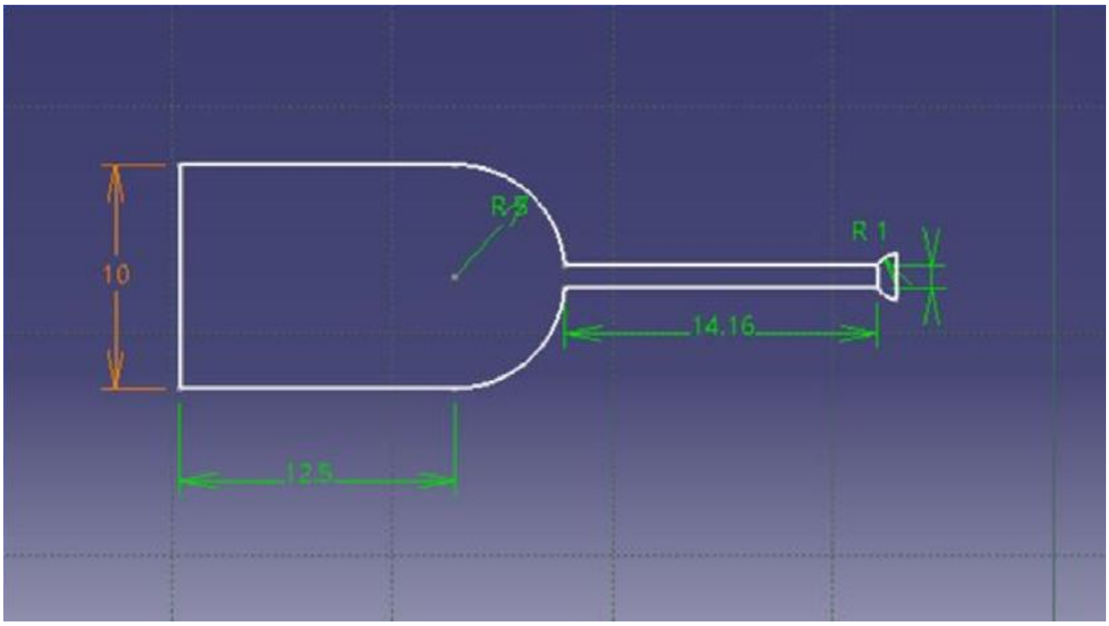


Fig. 6(b)

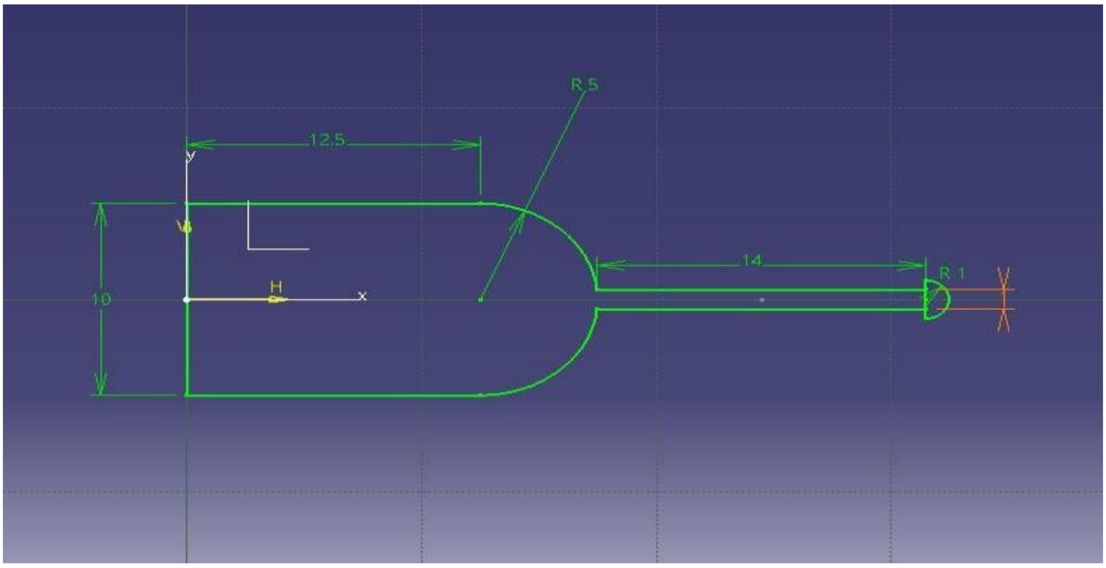


Fig. 6(c)

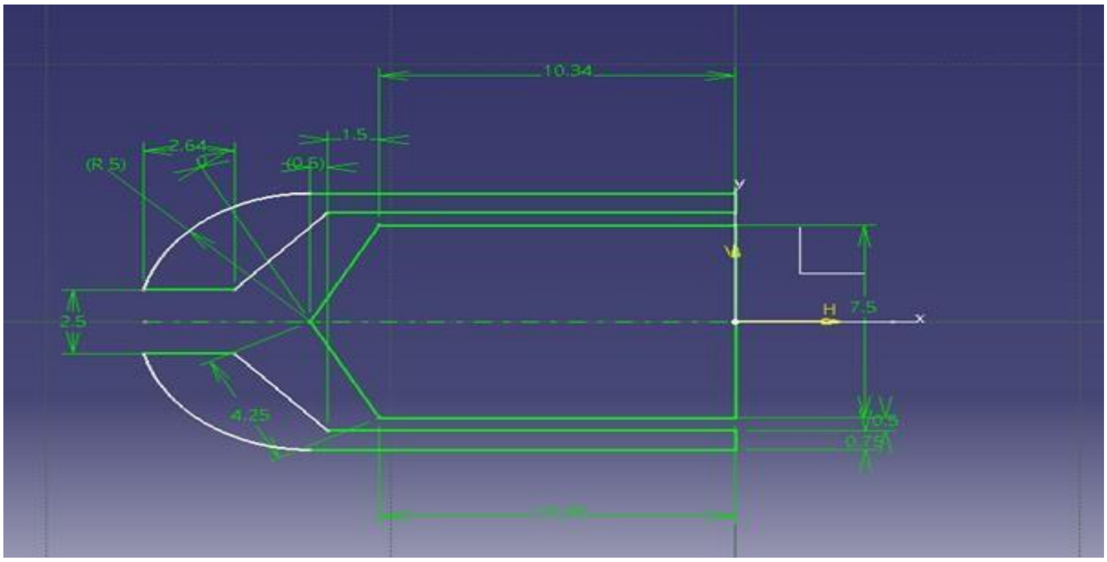


Fig. 6(d)

Fig. 6(a) shows the geometry of conical, 6(b) shows the geometry of flat plate, 6(c) shows the geometry of hemispherical disk and 6(d) shows the geometry of breathing blunt nose

VI. MESHING OVER AN AEROSPIKE

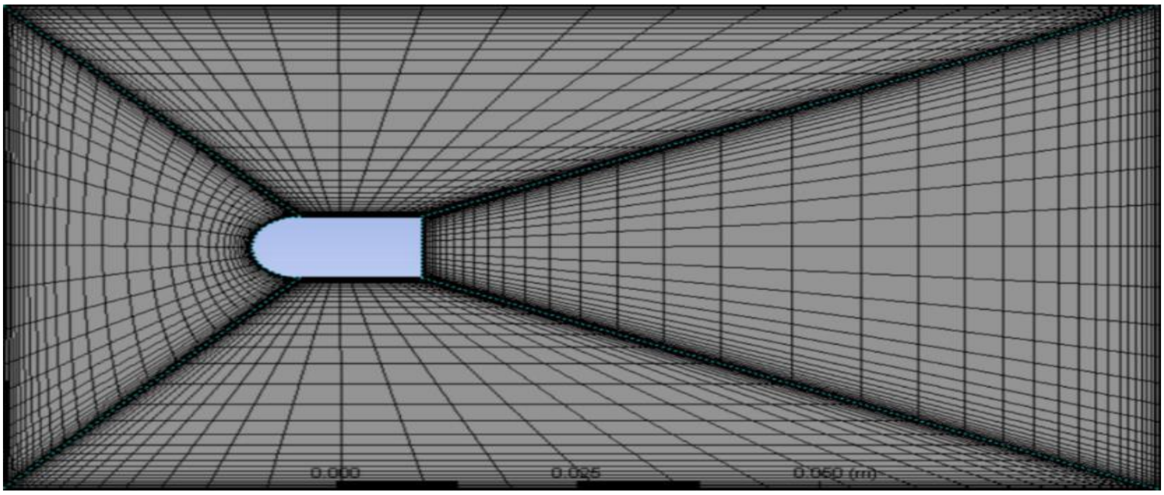


Fig. 7: No. of nodes : 6640 and No. of elements : 6438

VII. BOUNDARY CONDITIONS

- SST k-omega model
- Po : 101325 pa
- Temp : 300k
- Mach number : 4
- Pb(static pressure at outer flow) : 101325pa
- Non slip
- Adiabatic
- Viscous : 2D-equation SST-k-omega model
- Enable the Energy equation
- Ideal gas
- Iterations : 1000

VIII. RESULTS

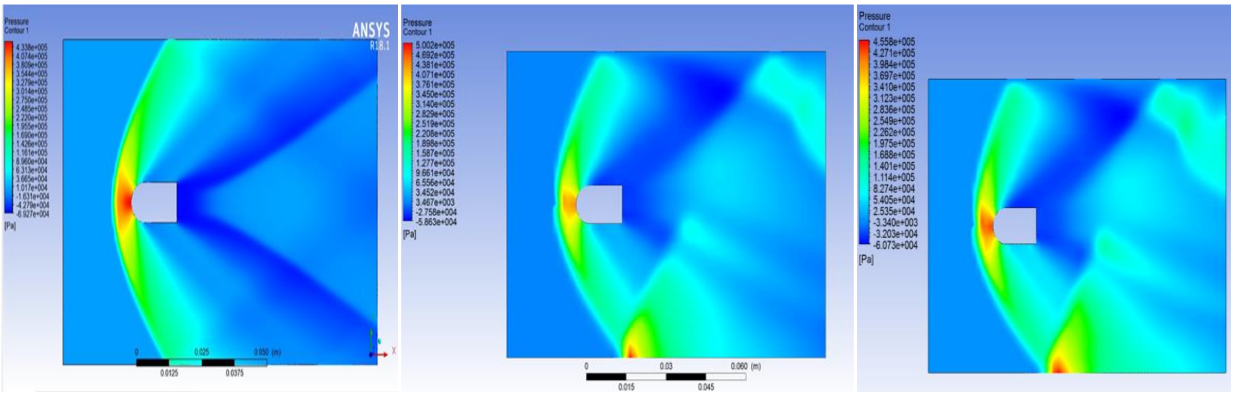


Fig.8(a): Plain Blunt body (Mach No.2)

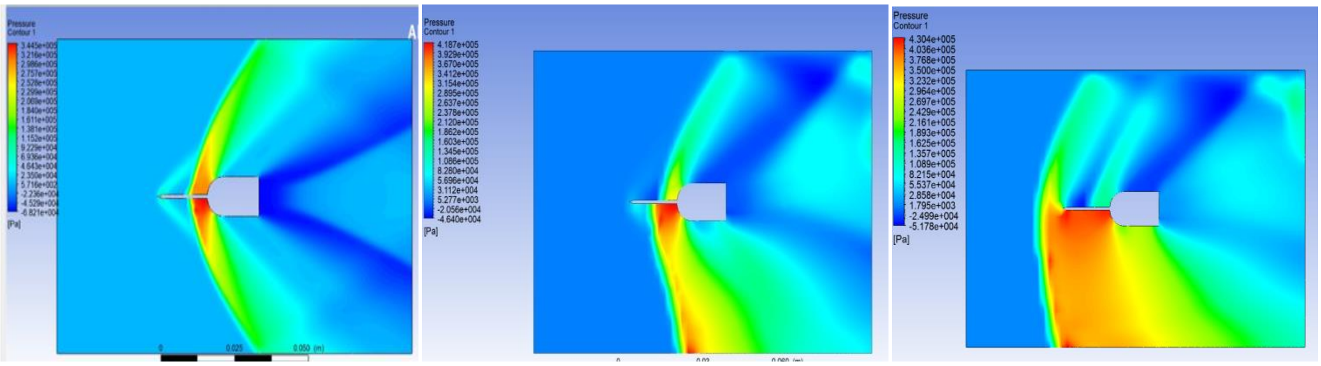


Fig.8(b): Conical spike attached to blunt nose(Mach No.2)

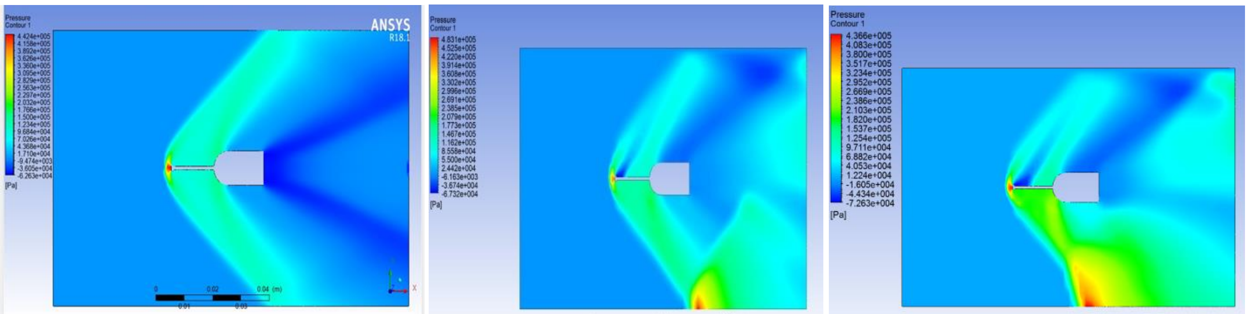


Fig.8(c): Flat faced aerodisk attached to blunt nose(Mach No.2)

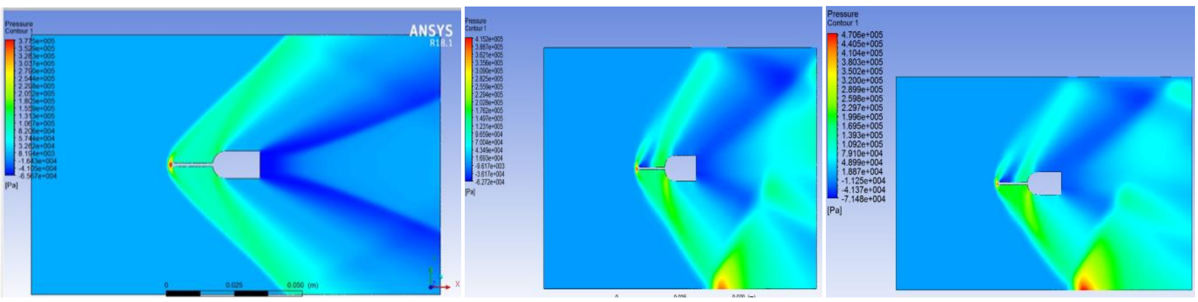


Fig.8(d): Hemispherical Aerodisk attached to blunt nose(Mach No.2)

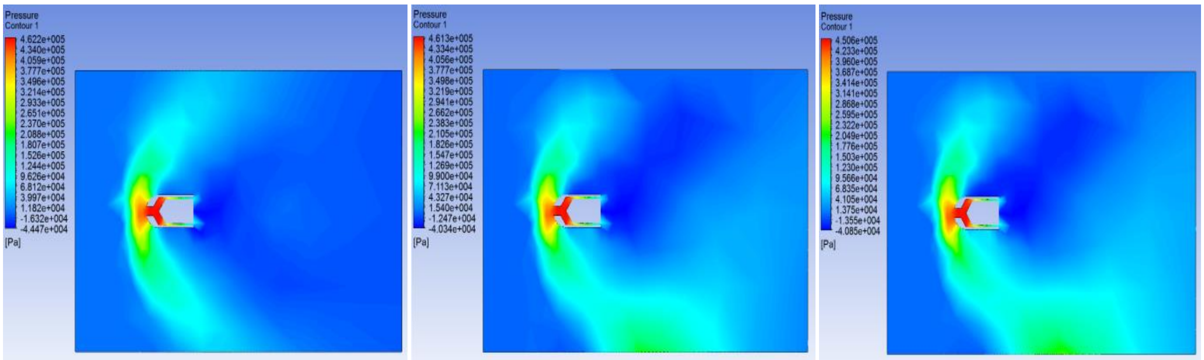


Fig.8(e): Breathing Blunt nose(Mach No.2)

Fig. 8: Pressure (in Pa) contours for various configurations at Angles of Attack 0, 5, and 8 degrees for mach no.4

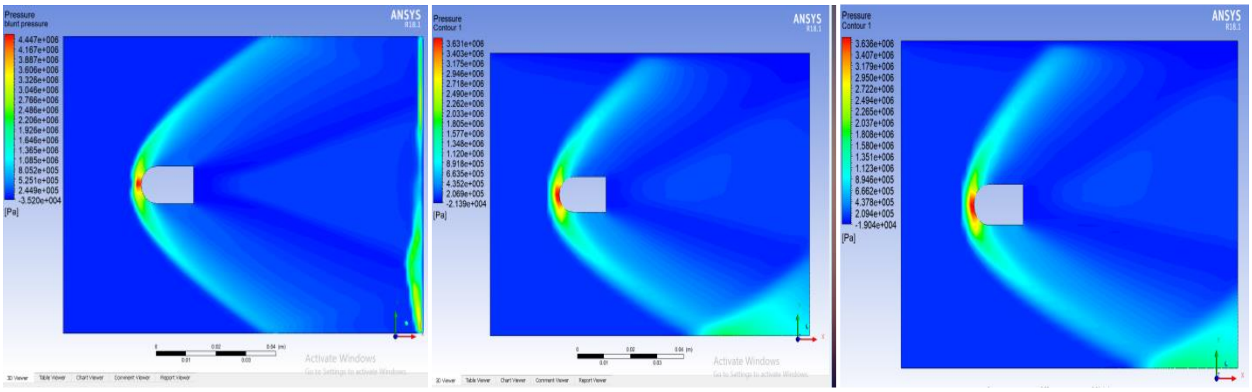


Fig. 9(a): Plain Blunt body (Mach No.4)

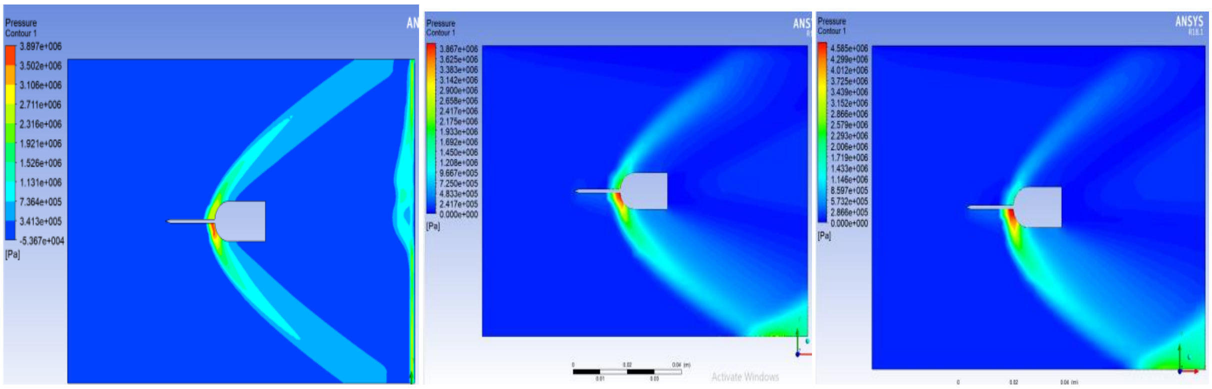


Fig. 9(b): Conical spike attached to blunt nose(Mach No.4)

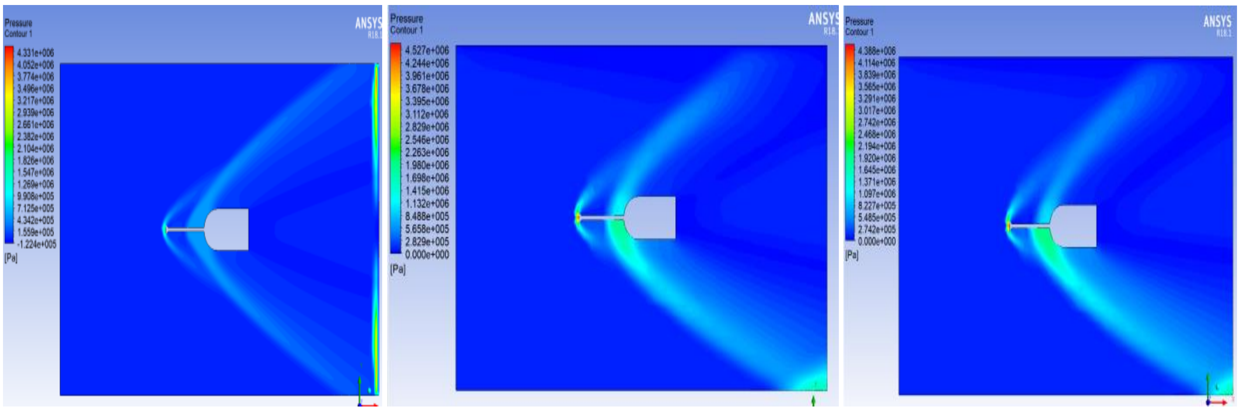


Fig. 9(c): Flat faced aerodisk attached to blunt nose(Mach No.4)

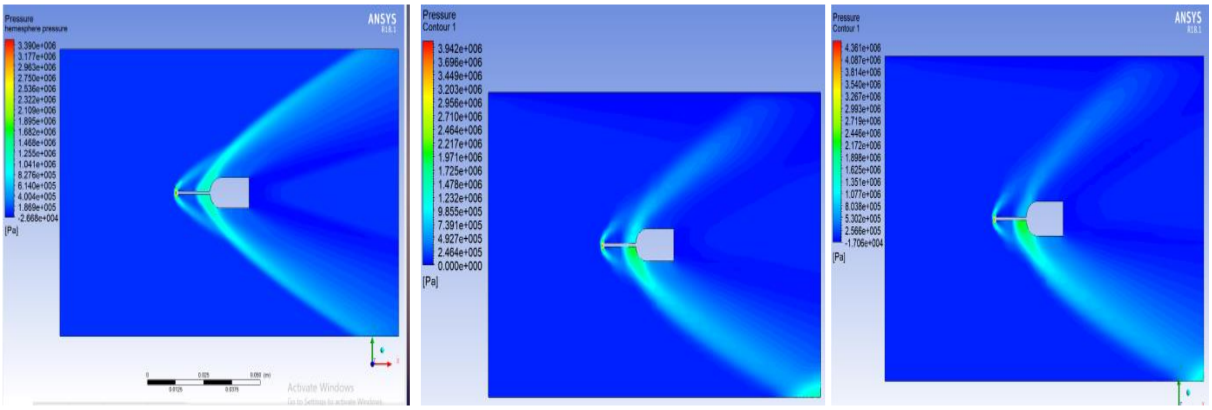


Fig. 9(d): Hemispherical Aerodisk attached to blunt nose(Mach No.4)

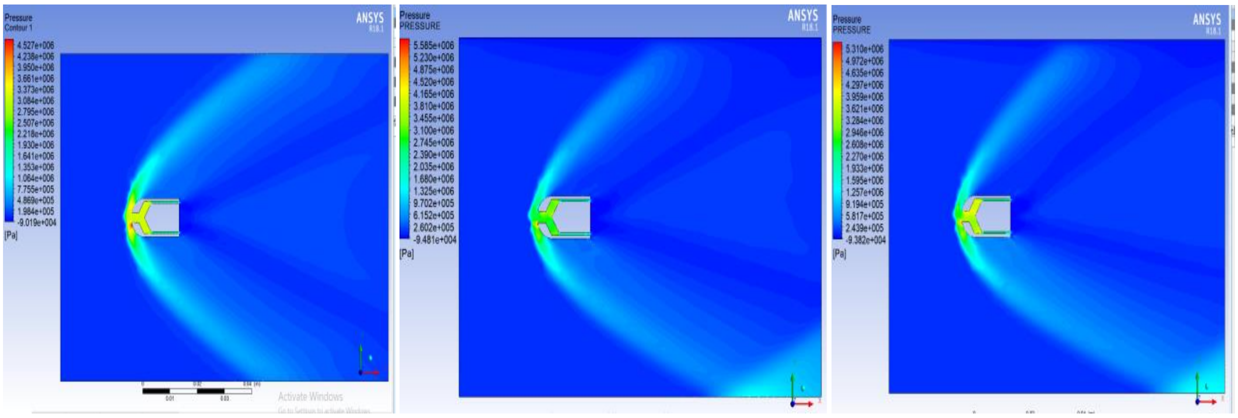


Fig. 9(e): Breathing Blunt nose(Mach No.4)

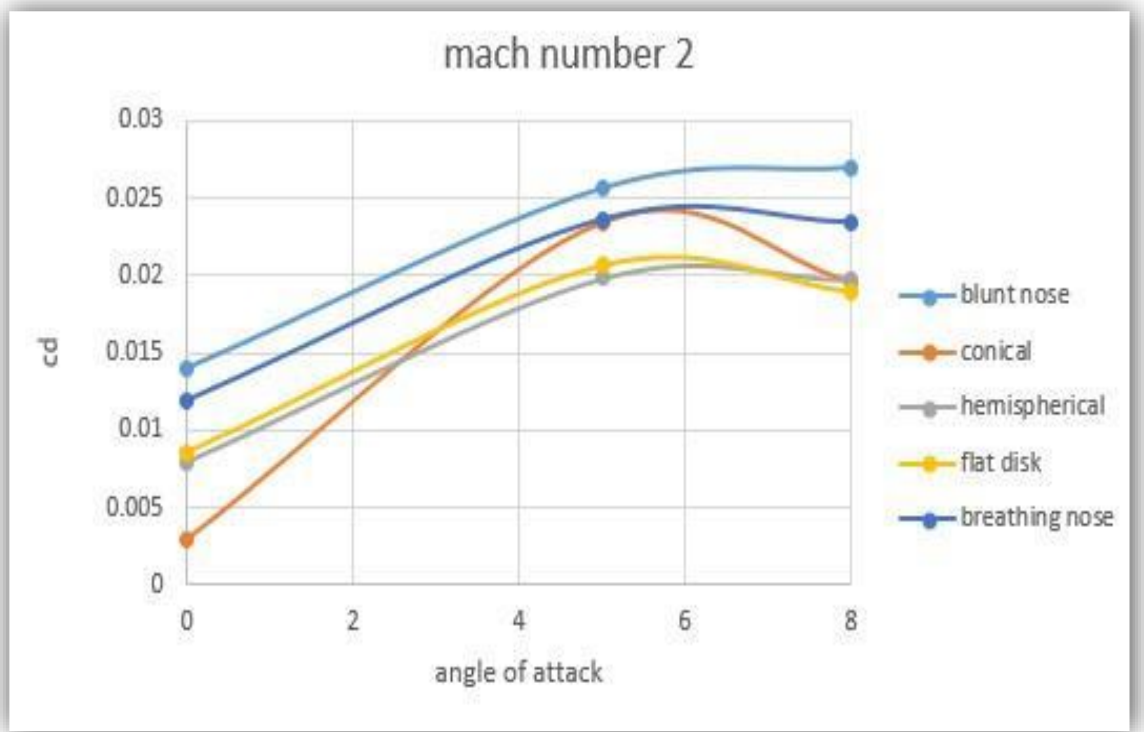
Fig. 9: Pressure (in Pa) contours for various configurations at Angles of Attack 0, 5, and 8 degrees for mach no. 4

Sr No.	Configuration	Angle of attack	Force (N)	cd
1	Blunt nose	0	7948.8582	0.014019
		5	7275.7702	0.025648981
		8	7653.2183	0.026979258
2	Conical spike	0	6694.1066	0.0029514682
		5	6660.2952	0.023479272
		8	5566.1969	0.019622054
3	Hemispherical spike	0	4500.6688	0.007937478
		5	5625.6281	0.019831
		8	5590.8591	0.019708994
4	Flat disk spike	0	4883.6543	0.0086129196
		5	5852.3034	0.020630891
		8	5366.2669	0.018917257
5	Breathing nose	0	6769.8488	0.011939454
		5	6711.8667	0.023661075
		8	6654.0531	0.023456984

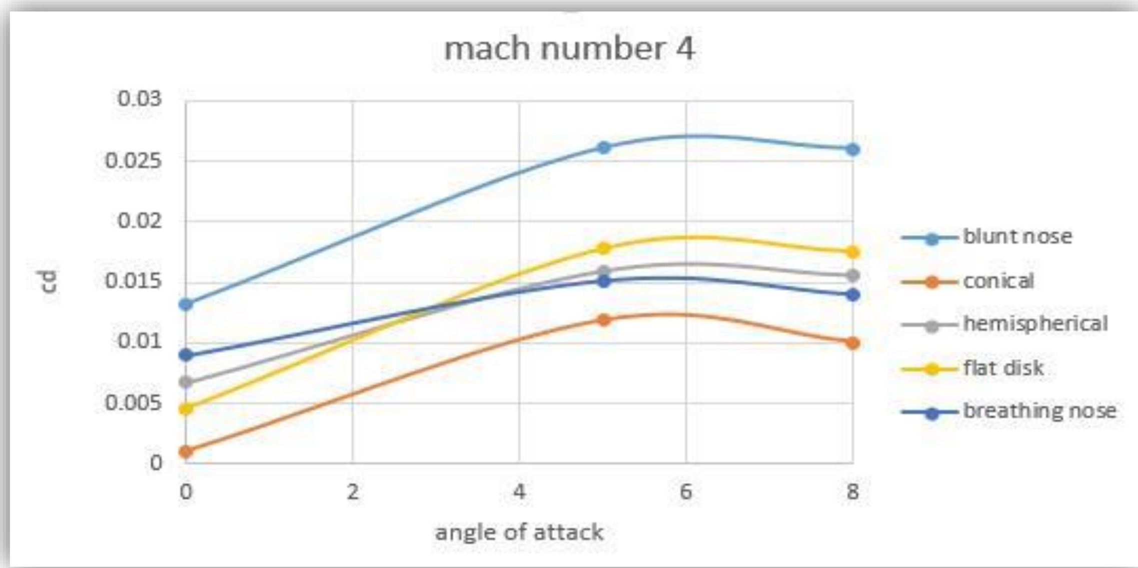
Table 1: Values of cd and force at Mach 2

Sr No.	Configuration	Angle of attack	Force (N)	cd
1	Blunt nose	0	29929.187	0.013195942
		5	29640.898	0.02612278
		8	29570.49	0.026060593
2	Conical spike	0	24317.842	0.0010722
		5	24796.228	0.011853131
		8	26156.194	0.010051559
3	Hemispherical spike	0	15344.043	0.0067652727
		5	18035.534	0.015894864
		8	17639.139	0.015545445
4	Flat disk spike	0	7833.1053	0.004537
		5	20204.835	0.017806696
		8	19930.84	0.017565129
5	Breathing nose	0	25167.31	0.0089856
		5	22260.009	0.01514
		8	21827.304	0.014021

Table 2: Values of cd and force at Mach 4



Graph.1 cd vs. angle of attack for mach 2



Graph 2: cd vs. angle of attack for mach 4

A. *At Mach number 2*

Figure 10. shows the line graph between angle of attack and drag coefficient cd which gives the clear data about the drag reduction over the different configurations of the aerospike at Mach number 2. This graph shows that as α increases the drag coefficient decreases up to some limit but after that it decreases in all configurations. While for the conical the drag reduction is high. That's why the conical spike is considered to be most relevant.

B. *At Mach number 4*

Figure 11. shows the line graph between angle of attack and drag coefficient cd which gives the clear data about the drag reduction over the different configurations of the aerospike at Mach number 4. In this graph with the comparison with Mach 2 the drag reduction is higher in Mach 4 as values of the drag coefficient is getting low in Mach 4 then the Mach 2.

IX. CONCLUSION

- In this project we using five different aerospike i.e. k-omega and transition SST and plot the graph of drag coefficient with different angle of attack with 0, 5 and 8. In that model we get the good result for drag reduction for all configuration of spikes.
- The conical spike reduces the shock angle and thus shock considerably weakens compared to other configuration. The conical spike is noticed to have lower drag coefficient in compare to other configuration and thus can be considered most effectual.(Mach 2)
- For Mach number 4 this boundary condition of Mach number 2 is working, but shock angle is shifted at after end of body.
- We also conclude that as increases pressure distribution in lower portion increase and in upper portion pressure decreases, it creates pressure difference on the surface which results in lift generation.

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