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Spherical Blunted Tangential Ogive Nose-Cone for Hypersonic Vehicle

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Abstract:- The vehicle moving at hypersonic speed experience forces which leads to slow-down of the vehicle. This flow of fluid which makes it slow is known as drag which plays important role while designing hypersonic rockets for mars mission. Air drag is also plays an important role in the designing of the vehicle. The objective of the aerospace industry is to develop the nose cone that can travel at high speed by producing optimum value of air drag & force. This investigation deals with computational analysis of the spherical blunted tangent ogive nose cone profile of rocket at hypersonic velocity. The outcome of nose-cone design on the drag is studied at hypersonic flow. The paper aim is recognize specific aerodynamic characteristics with minimum drag at particular Mach number with considering density, temperature, viscosity, pressure, velocities for the hypersonic flight. The area of this paper is to develop some profile with outstanding aerodynamic qualities and low cost for use in construction projects for hypersonic mission by improving their efficiency and effect on target. The present problem is analysed in ANSYS fluent software. Flow over a body is observed in numerical simulation for particular Mach number for spherical blunted tangent ogive nose cone profile & the parameters such as critical design aspects and performance characteristics of the selected nose cone are presented.

***Keywords**:- Mach Number, Hypersonic Flows, Nose Profiles, Aerodynamic, ANSYS Fluid Fluent.*

I. INTRODUCTION

From many years aerospace projects involve designing, manufacturing and launching rockets and missiles with payload that perform to reach apogee up to mars, moon. But in hypersonic condition nose cone play an important role reducing drag force on entire body and not allowing flow separation which are adversative effects on efficiency of rocket. And I strongly believe that efficiency of rocket can be increased by producing minimum drag on rocket. The development of hypersonic vehicles is mainly limited due to characteristics of the hypersonic flow. When vehicle exceeds speed of Mach 5, the stream flow causes many uncertainties for the vehicle. One of the major difficulties is the creation of high temperature flow bringing non equilibrium chemical flow properties such as dissociation and ionization. This process chemically reacts with material at the surface level of the hypersonic vehicle degenerates the material faster in this process causing distortion of the hypersonic vehicle shape and increasing drag coefficient. Such a unique environment in the hypersonic flow makes the survivability of such vehicles a unique challenge.

The purpose of this paper is designing of the nose cone producing least drag on the rocket for mars mission. In this paper I am going to discuss the performance of the spherical blunted tangent ogive nose cone for the hypersonic velocity condition at different Mach number using computational fluid dynamics. Flow phenomena observed in numerical simulations during Mach 5, 5.02, 5.04 for spherical blunted tangent ogive nose cone. Spherical blunted tangent ogive nose cone profile gives higher critical Mach number and least drag coefficient which is desirable for the hypersonic flow.

II. PHYSICAL MODEL

Spherical Blunted Tangent Ogive:

The shape profile is formed by a circle segment like the vehicle body which tangent to the curves of nose cone at the base. The vogue of this shape is largely due to the simplicity of building its profile as shown in figure.

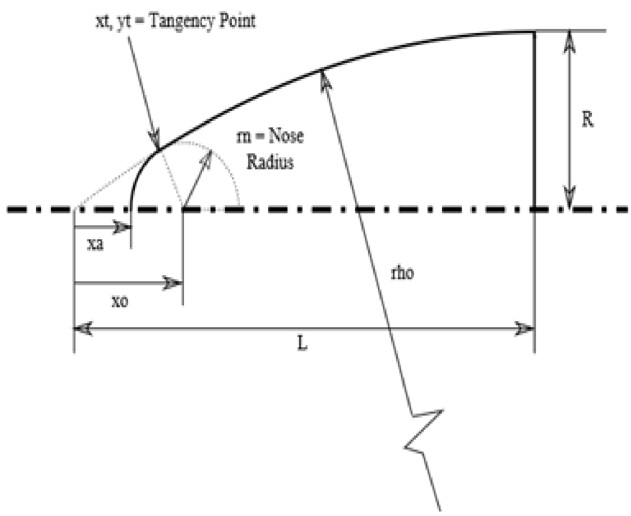

Fig 1.1 Spherical blunted tangential ogive nose cone profile

The profile of nose cone with spherically blunted tangent ogive shape is created by placing a spherical section on the front part of nose cone having tangent ogive shape.

The point at which the tangent ogive intersects with the sphere is called the Tangency point. The tangency point is determined using:

$$X_t = X_c - \sqrt{r_n^2 - y_t^2}$$

$$y_t = \frac{r_n(\rho - R)}{\rho - r_n}$$

Here,

X_c is centre of spherical nose

$$X_c = L - \sqrt{(\rho - r_n)^2 - (\rho - R)^2}$$

L represents the length of nose cone

X_t represents the X-coordinate of tangency point

y_t is Y- coordinate of tangency point

r_n is the ogive radius

Using these equations, the apex point can be determined using:

$$X_a = X_c - r_n$$

This nose cone shape is designed to travel through compressible fluid medium. In case of spherically blunt profile, we observe highest mean pressure value on surface of body. Thus, to attain minimum tip temperature, parabolic nose shape is preferred. To attain the lowest value of mean temperature on the surface, we prefer the tangent ogive nose design. Also, by using tangent ogive shape for the nose cone, we obtain minimum value of mean shear stress at the surface.

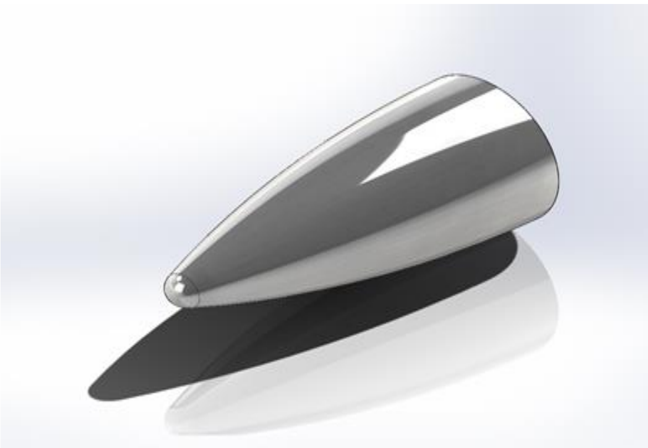

Fig. 1.2 CAD model of spherical blunted tangential ogive nose cone

Design and Computational Methodology:

In this paper spherical blunted tangential ogive nosecone shape is planned utilizing Solid works software. The initial step is to create 2D model. Simulation is done in three steps i.e.

i) Pre-processing - Design, Create Mesh, Set the Boundary condition as per requirement and apply Numerical method,
ii) Processing – In this all the governing equation are solved by using numerical method. In this we have use density based solver.
iii) Results – In this we can get results in all the forms such as graphs, contour, animation which helps us to understand the results easily.

These steps are used for Ansys Workbench were the boundary condition are kept as:-

- Mach No.- 5
- Pressure – 1 ATM
- Temperature – 300K
- Solver Set to 2nd Order Discretisation
- Monitors are set to 10^{-6}.

III. RESULT AND DISCUSSION

The results we got from Ansys Fluents for our simulation after post-processing are discuss below. As the incoming flow was set at hypersonic speed, the bow and attached shocks were visible in contour.

- **Pressure**

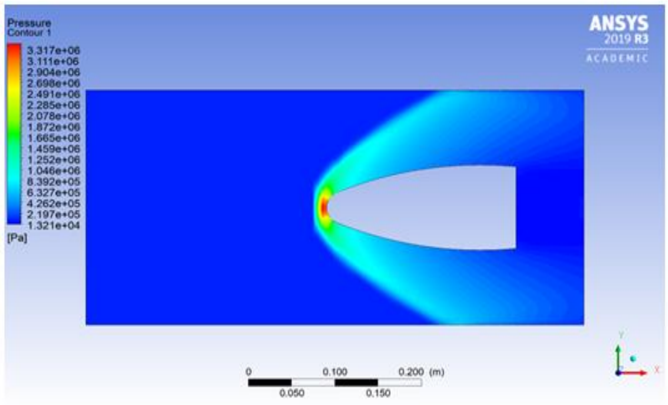

Fig 1.3 Pressure Contour spherical blunted tangential ogive nosecone

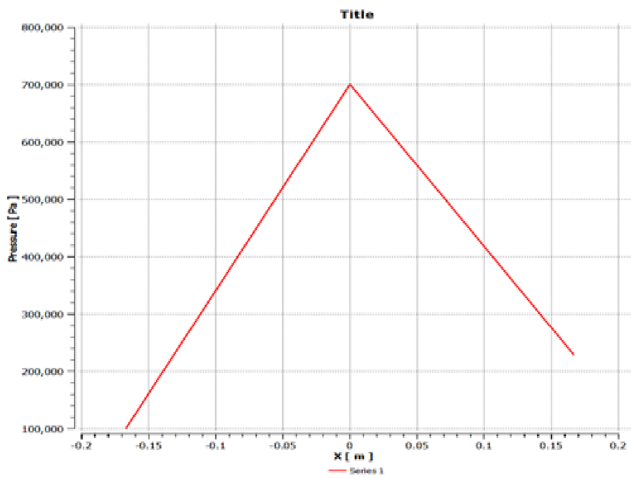

Fig.1.4 Simulation Result Graph of pressure for spherical blunted tangential ogive nosecone

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For spherical blunted tangential nosecone for hypersonic flows, there is presence of large amount of pressure present at the tip of noce cone and the layer near the blunted surface surrounded by high total pressure layer, this was due to the variation of shock wave, indicating 3D flow characteristics. This can also seen it the above graph. Spherical blunted nosecone, there is existence of least pressure instantly downstream of the nosecone. In this we can see that the shock wave form at the nose cone it little away from nosecone surface and this type is called detached shock wave.

- **Density**

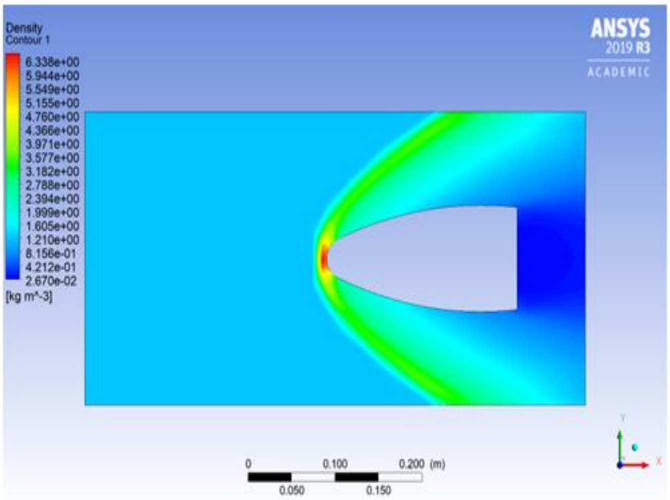

Fig 1.5 Density Contour spherical blunted tangential ogive nosecone

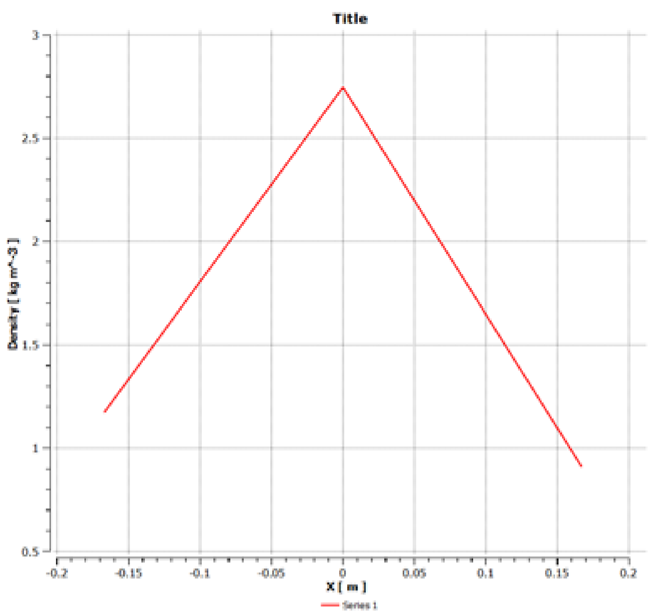

Fig.1.6 Simulation Result Graph of Density for spherical blunted tangential ogive nosecone

Travelling at higher speed region, nose cone experiences sudden change in the properties of fluid. Temperature, pressure and density across the shockwave's front changes in downstream condition of the shockwave. The static pressure rises in the downstream of the shocks as a result increases the pressure and temperature. The sudden interaction between the nose cone body & the air flow cause disturbance. And this disturbance cause the density variation in the medium which also changes the temperature. It also cause equilibrium flow disturbance which will be higher than ideal gas. As we can see in the above graph that the sudden rise in the density is cause due the nose cone & also we can see the formation of shock wave.

- **Velocity**

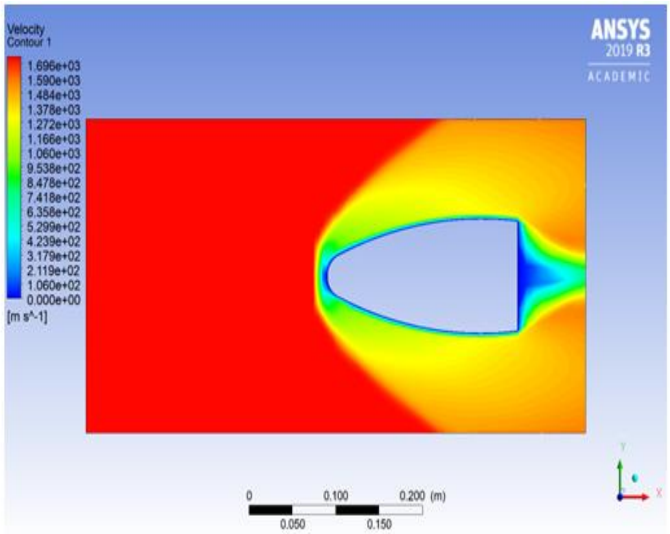

Fig 1.7 Velocity Contour spherical blunted tangential ogive nosecone

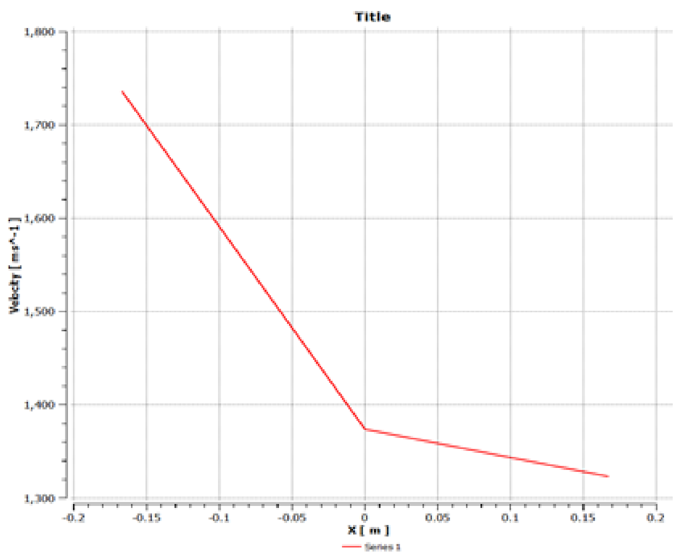

Fig.1.8 simulation results of velocity for spherical blunted tangential ogive nosecone

The sudden change of flow will generate drag and shock wave at the surface of nose cone which can be seen in the fig.1.7. The formation of shock wave changes the properties of the flow which stops the vehicle to travel fast in the atmosphere & can also damage the vehicle. Now when we talk about traveling to other planets we need the rockets which can travel at high speed such as hypersonic which will also cause major changes in the shape of rocket in different atmosphere. And this will increase the shock wave force on the rocket and to reduce it we will need more aerodynamic efficient nose cone. For body to sustain the hperpersnoic velocities we need to keep the shock wave away from the main body & which can be only done in Bluff body due to its large surface area. Bluff body design in aerodynamics and structural aspects become more crucial factor in hypervelocity vehicle. As flight velocity reaches to very high velocity, shockwaves start forming on the spacecraft, which further increases the velocity and pushes the shock front closer to the body. Hence, the body design plays very important role as it directly influence the shockwave contour. The De-attached shocks which are generated on body basically nose cone part of aircraft or spacecraft travelling at higher velocity region has some phenomenal use in aerospace industry. As the bow shock generate away from the surface, higher velocity was achievable. Blunt body design nose cone, re- entry vehicle experience bow shock during the operations.

- **Temperature**

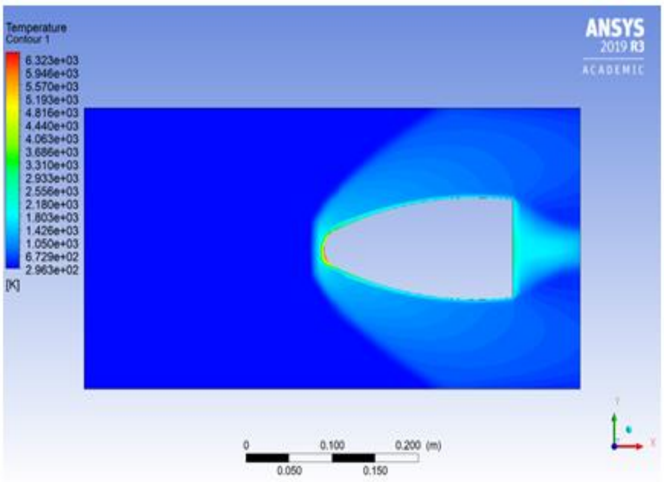

Fig 1.9 Temperature Contour spherical blunted tangential ogive nosecone

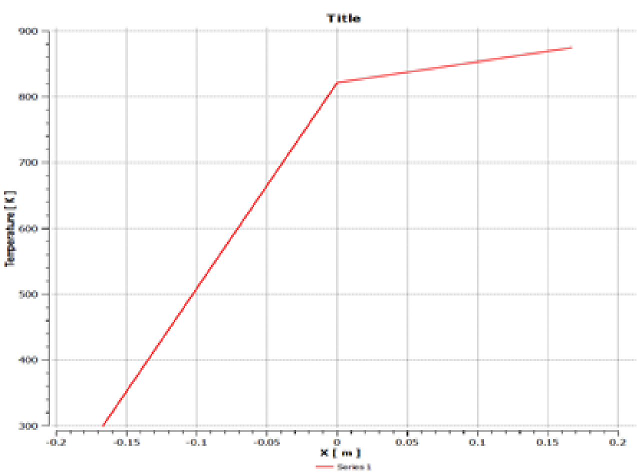

Fig.1.10 Simulation Result Graph of temperature for spherical blunted tangential ogive nosecone

Temperature plays an important role while design the rocket nose cone. It depends on the aerodynamics nature of the body. In the above fig. 1.9 we can we that there is sudden rise in the temperature at the tip of the nose cone which can damage the nose cone & also can change the shape of the nose cone. This rise in temperature helps in the selection of the material of the rocket. Sometimes due to rise in temperature there is layer present of Space Banket at the surface of the nose cone. Nose Cone is defined as the Front-most part in an aircraft, Missile or Rocket. Its purpose is to withstand extremely high temperature due to Atmospheric Drag.

IV. CONCLUSION

The reason for this paper is to help the researcher while selecting the nose cone for the hypersonic vehicle and also for performance improvement of hypersonic flight nosecone using spherical blunted tangential ogive nosecone. By referring above outcomes of spherical blunted tangential ogive nosecone for higher critical Mach number which is desirable for hypersonic flows as stated in problem statement. This paper demonstrations the flows characteristics, such as aerodynamic drag, pressure, velocity, Temperature and attached shock wave formed ahead of the spherical blunted tangent ogive cone at zero angle of attack near the nose cones.

REFERENCES

[1]. "A. Hemateja, B. Ravi Teja , A. Dileep Kumar , Rakesh S.G", "IOP Conference Series: Materials Science and Engineering", "2017".

[2]. "Niranjan Sahoo", "16th Australasian Fluid Mechanics Conference", "2007".

[3]. "Ashish Narayan, S Narayanan and Rakesh Kumar", "Simulation: Transactions of the Society for Modeling and Simulation International", "2017".

[4]. "Manjunatha H, C. N. Nataraj", "International Journal of Science and Research (IJSR)", "2014".

[5]. "N. S. Harshavardhan .R; Sanjana .K; Sai Sharan .K ; Srinivas .G", "International Journal of Scientific & Engineering Research, Volume 5, Issue 5", "May-2014".

[6]. "Guillaume Grossir, Fabio Pinna, Olivier Chazot", "AIAA Journal", "1999".

[7]. "W. Schuyler Hinman, Craig T. Johansen", "Aerospace Science and Technology", "2016".