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MODELLING AND CFD ANALYSIS OVER A MISSILE BLUNT BODY WITH SPHERICAL AEROSPIKE

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ABSTRACT

High-speed flow over a blunt body generates a bow shock wave which causes high surface pressure and as a result the development of high aerodynamic drags. A blunt body creates a bow shock wave at high Mach number, which produces a very high in pressure in the forward region of the hemispherical region which leads to an increase of high wave drag during the projectile's flight through the atmosphere. It is advantageous to have a vehicle with a low drag coefficient in order to minimize the thrust required from the propulsive system during the supersonic and hypersonic regime. The dynamic pressure on the surface of the blunt body can be substantially reduced by creating a low pressure region in front of the blunt body by mounting a spike. A spike is simply a slender rod attached to the stagnation point of the vehicle's nose. Spherical aerospike which is recognized as more effective in reducing drag force for conducting flow analysis on the aerospike with different length to diameter ratios on a missile blunt body at mach number 7 tested to determine its performance and results are presented.

Keywords: Aerospike, Blunt Body, Mach number, Missile.

I. INTRODUCTION

Hypersonic flights have become a dominant feature of aerodynamics. Aerodynamicists mostly use slender pointed body. More pointed and slender the body, the shockwave attached to the nose will be weaker and the wave drag associated with the body will also be less. But when the flights are in hypersonic speeds, there will be sudden change in certain factors, like in intercontinental ballistic missiles (ICBM).These vehicles are designed to cruise outside the earth atmosphere. When these vehicles reenter the earth atmosphere, the cruise speeds will approximately be of 20000 to 22000 ft/sec. At this hypersonic speeds, aerodynamic heating is the severe problem and it will give quite influence over the design of the proper nose cone and vehicle. So aerodynamicists prefer the blunt body concept for thevehicles with supersonic speed . At the outer edge of the atmosphere, due to its velocity and altitude, the supersonic vehicles have high amount of kinetic and potential energies. But near the earth surface, thesonicvehicles have less kinetic energy and approximately zero potential energy. Here all the energy changes to heat energy. Some energy goes to heat the airflow and some to vehicle. We know that in the supersonic flow, the shock waves are generated in the flow and a large temperature gradient is generated. And at the same time, the body gets heated by the frictional dissipation in the boundary layer adjacent to the body. But by the using some special type of bodies, we can dump the energy into the air flow. These bodies are called blunt bodies which creates a stronger shock wave.

The forces acting on a missile in flight consist of aerodynamic, propulsive (i.e., thrust), and gravitational forces. These forces can be resolved along the missile's body-axis system (X_b, Y_b, Z_b) and fixed to the missile's center of gravity (CG). The reference axis system standardized in guided weapons is centered on the CG and fixed in the body. Thus, any set of axes fixed in a rigid body is a body-fixed reference frame.

The conventional in aerodynamics is to resolve the sum of the normal (or pressure) forces and the tangential (or viscous shear) forces that act on the surface due to the fluid motion around a vehicle into three components along axes parallel and perpendicular to the free-stream direction. These forces are lift (L), drag (D), and side force (Y).

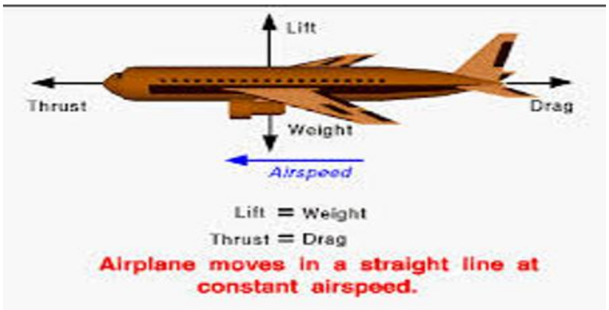


Fig. 1. Forces Acting On Missile

Lift is the component of the resultant aerodynamic force that is perpendicular (i.e., upward) to the relative wind (direction of flight) or to the undisturbed free-stream velocity. The aerodynamic lift is produced primarily by the pressure forces acting on the vehicle surface. Also, the lift force is perpendicular to the missile's velocity vector in the vertical plane. Drag is the component of the resultant aerodynamic force that is parallel to the relative wind. In other words, it is net aerodynamic force acting in the same direction as the undisturbed free-stream velocity. The aerodynamic drag is produced by the pressure forces and by skin friction forces that act on the surface. The drag force is measured along the velocity vector, but in the opposite direction. The different types of drag acting on missile surface are skin friction drag, wave drag, and pressure drag.

Minimization of drag and aerodynamic heating are among the most important design requirements for hypersonic vehicles. Reducing the aerodynamic drag enables increasing the range, economizing the fuel usage, simplifying the propulsion system requirements, and maximizing the ratio of payload to take off gross weight. It is desired to use a pointed slender geometry to minimize the drag during the takeoff (ascent) phase. On the other hand, a blunt design is advantageous during the descent phase to reduce the excessive aero heating levels during re entry and to generate the desired vehicle deceleration. The spike is simply a slender cylindrical rod mounted at the stagnation point of the blunt body and projected in the upstream direction. The spike introduces two major modifications to the flow field upstream of the blunt body. Firstly, it replaces the strong detached shock wave with a system of weaker oblique shock waves. Secondly, it acts as a "flow separator"; the spike encourages the separation of the boundary layer from its surface and the creation of a shear layer. An aero disk mounted at the tip of a spike of a fixed length has the role of providing further reduction in both drag and aerodynamic heating over a wider range of Mach numbers and incidence angles. It can also compensate the drag reduction in cases when a shorter spike is necessary for design.

Fig. 2. Nosecones Shape

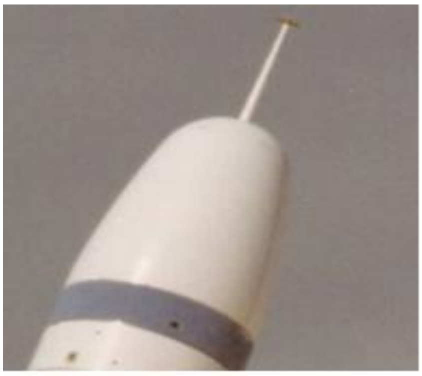


Fig. 3. Aerospike on Blunt Body

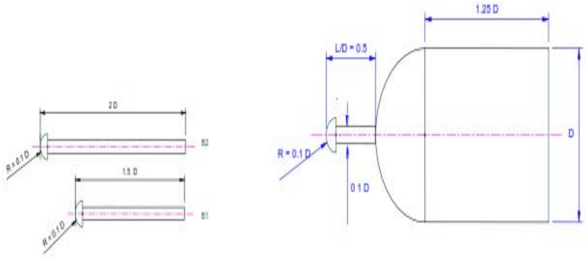
A drag-reducing aero spike is a device used to reduce the fore body pressure drag of blunt bodies at supersonic speeds. The aero spike creates a detached shock ahead of the body. Between the shock and the fore body a zone of re circulating flow occurs which acts like a more streamlined fore body profile, reducing the drag. Aero spike consists of a flat circular plate mounted on an extensible boom which is deployed shortly after the missile breaks through the surface The use of the aero spike allowed a much blunter nose shape, providing increased internal volume for payload and propulsion without increasing the drag. This has the advantage over a structural aero spike that the air density is lower than that behind a shock wave providing increased drag reduction. Aerospace Sciences Meeting it was reported that tests were performed at an aero spike-protected missile dome to Mach 6, obtaining quantitative surface pressure and temperature-rise data on the feasibility of using aero spikes on hypersonic missiles.

II. LITERATURE REVIEW

B.Kaleeswaran, S.Ranjith Kumar, Jeniwer Bimro.N.[1] tells about the aerodynamic study over 2D supersonic nose cone models of missiles. First a Spherical nose cone model was tested with a Mach speed of 3 and then with the same Mach speed another Spherical model with a parabolic nose cavity was tested. Md.Akhtar Khan, Karrothu Vigneshwara, Suresh Kukutla[2] investigated and analyzed the flow field over an aerofoil section integrated with spikes at supersonic speed (Mach numbergreater than 1). Lawrence D. Huebner NASA Langley Research CenterAnthony M. Mitchelland Ellis J. BoudreauxWright[3] Laboratory/Eglin Air Force Base conduted experiment on feasibility of an aerospike for hypersonic missiles, series of wind tunnel tests have been performed on an aerospike-protected missile dome at a Mach number of 6 to obtain quantitative surface pressure and temperature-rise data, as well as qualitative flow visualization data. R. C. MehtaNanyang[4] tells significantly changes in its flow field and influences aerodynamic drag and wall heat flux in a high speed flow. The effect of the spike length, shape, and spike nose configuration on the reduction of drag and heat flux is numerically evaluated at Mach 6 at zero angle of attack and different aerospike shape. Dennis M. BushnellLangley[5] discusses Advanced Aircraft configurationally approaches, across the speed range, which are either enabled, or greatly enhanced, by clever Flow Control. Snežana S. Milicev, Miloš D. Pavlovic,Slavica Ristic[6] worked in order to eliminate the appearance of a strong shock wave at a supersonic flight of a missile, which considerably increases the drag during its flight through the air, a spike is mounted on its nose. D. Sahoo, S. Das, P. Kumar and J. K. Prasad[7] Experimented and computational studies have been made to obtain the effect of a spike on the flow over blunt body with different shapes at supersonic speed of Mach number of 2.The spike used had sharp tip, spherically blunt tip, and flat aero-disk tip. One such attempt is made in this work to model the missile blunt body with spherical aerospike with different length to diameter ratio using solidworks software. CFD analysis of model part is carried out using Ansys- Fluent.

III. MODELLING OF BLUNT BODY

The modeling of the blunt bodies of the missiles with nosecones or aerospikes is done using Solid works 2012 by taking dimensions from a flow field computations over a conical,disc and flat spiked bodies at mach no 6[8] . This is a solid model over which the external flow analysis is done. Some of the sketch commands used in this particular aircraft modeling are line, arc. And the feature commands used are revolve. The blunt body with different length to diameter (L/D) ratio aerospikes are modelled.



(b) Hemispherical disk spike

Fig. 4. Spherical Blunt Body 2D Diagram With Dimensions

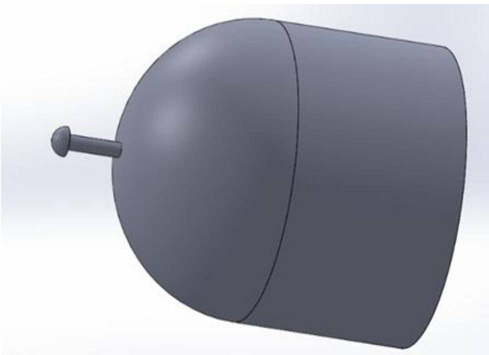


Fig. 5. Spherical Spike with L/D Ratio Of 0.5

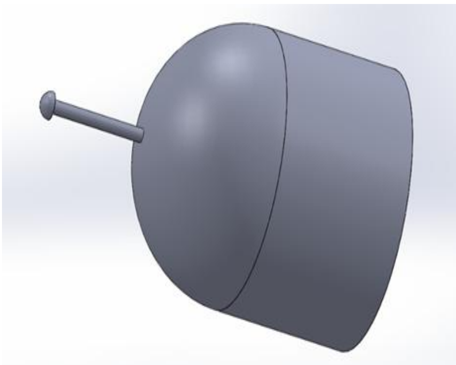


Fig. 6. Spherical Spike with L/D Ratio Of 1.0

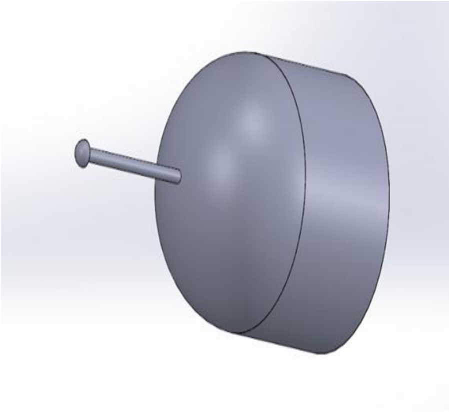


Fig. 7. Spherical Spike with L/D Ratio Of 1.5

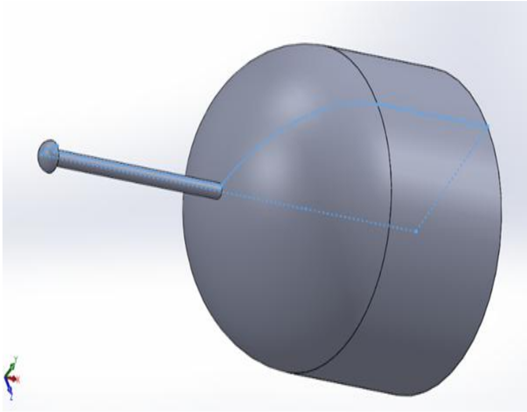


Fig. 8. Spherical Spike with L/D Ratio Of 2.

IV. CFD ANALYSIS ON BLUNT BODY

Computational Fluid Dynamics, more commonly known as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

Tthe geometry file is imported from the solid works. And the required model is selected (which is saved in IGES format). For a CFD analysis the body should be enclosed in a continuum where in the boundary conditions are applied. This enclosure around the body is made in ANSYS Workbench 14.5.The enclosure is uniform in dimensions in all sides Then the body is subtracted from the enclosure to get the complete continuum. Enclosure is for defining control volume flow over the body

FLUENT will display the details of the mesh file on the screen. Once the meshing of the continuum is done it is then exported to ANSYS Fluent 14.5, where in the flow analysis over this blunt body with spherical aerospike is done. The problem considered here is high speed compressible flow so we choose density based solver.

The material used for the study of the blunt body is Titanium alloys. In the boundary conditions the material used is air.

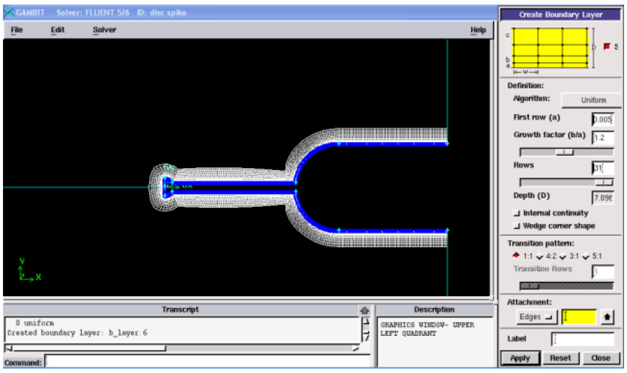


Fig. 9. CFD analysis on missile blunt body with aerospike

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V. RESULTS AND DISCUSSION

The performance of the modelled part is analyzed in ANSYS Fluent 14.5 with the various L/D ratios of the spherical aerospike by applying the material and applying the various boundary conditions such as inlet, outlet, zone boundary and type wall conditions. Then the velocity, temperature and the pressure contour plots are obtained and the XY plots of various parameters are obtained as shown in the figures 10 to 29.

For L/D 0.5:

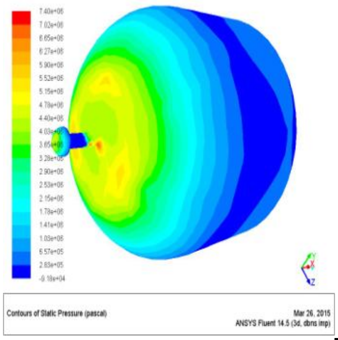


Fig. 10. Pressure contour

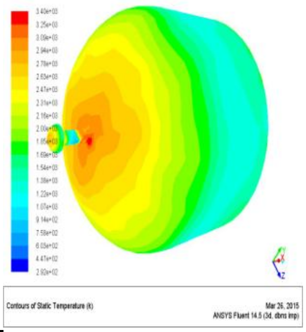


Fig. 11. Temperature contour

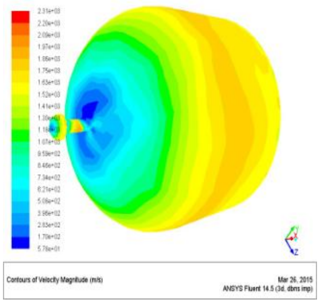
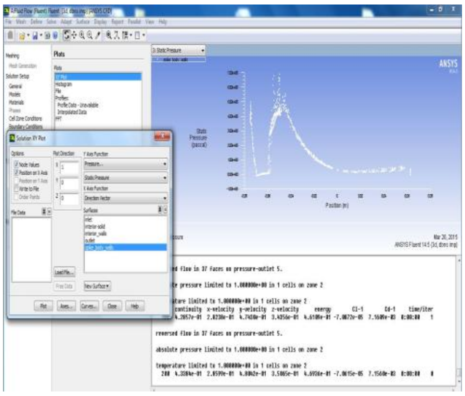


Fig. 12. Velocity contour



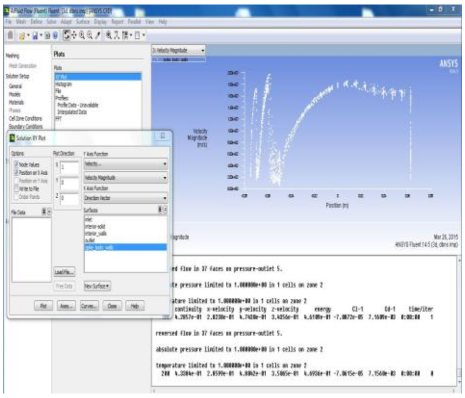


Fig. 14. Velocity Graph

Fig. 13. Pressure Graph

For L/D 1.0:

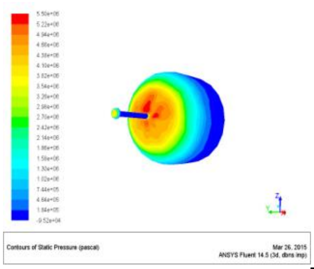


Fig. 15. Pressure contour

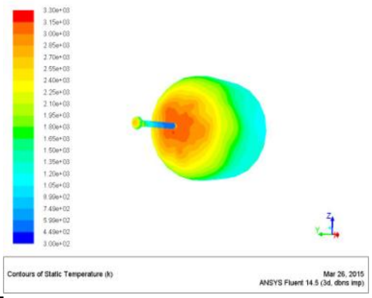


Fig. 16. Temperature contour

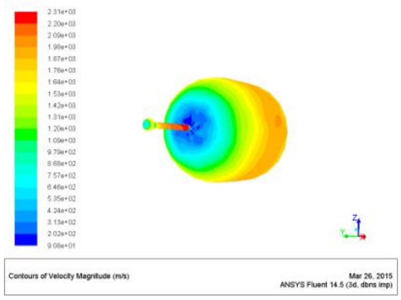


Fig. 17. Velocity contour

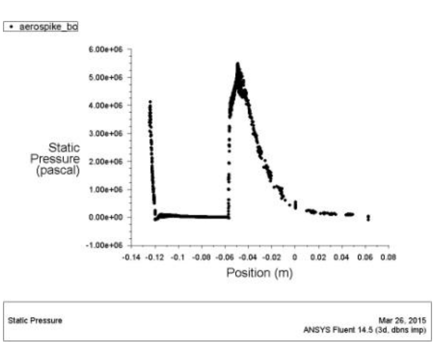


Fig. 18. Pressure Graph

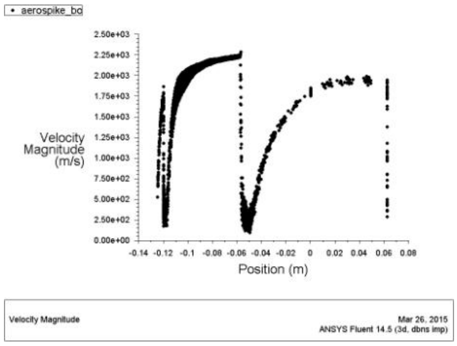


Fig. 19. Velocity Graph

For L/D 1.5:

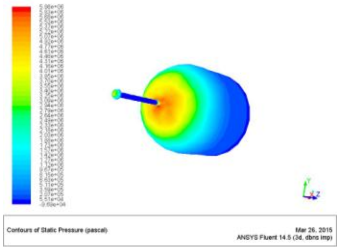


Fig. 20. Pressure contour

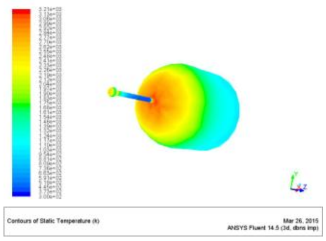


Fig. 21. Temperature contour

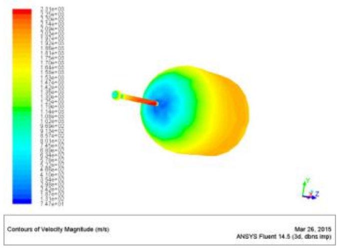


Fig. 22. Velocity contour

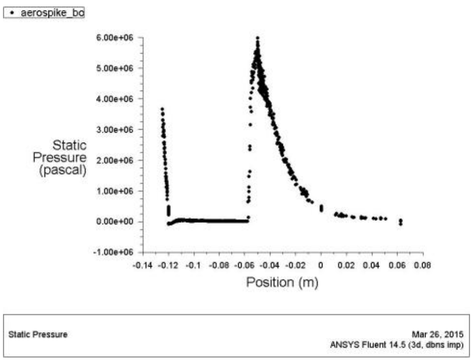


Fig. 23. Pressure Graph

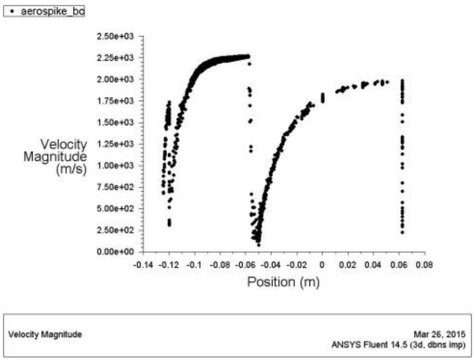


Fig. 24. Velocity Graph

For L/D 2.0:

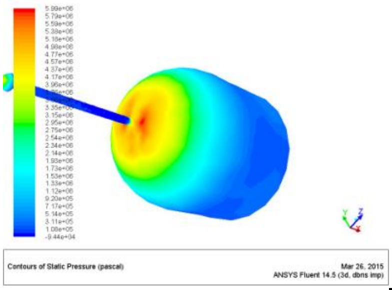


Fig. 25. Pressure contour

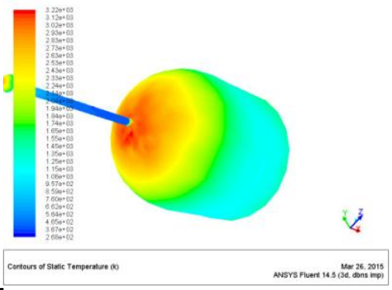


Fig. 26. Temperature contour

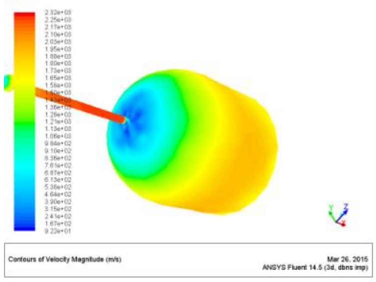


Fig. 27. Velocity contour

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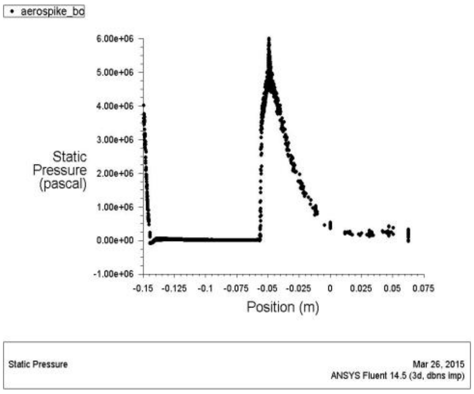

Fig. 28. Pressure Graph

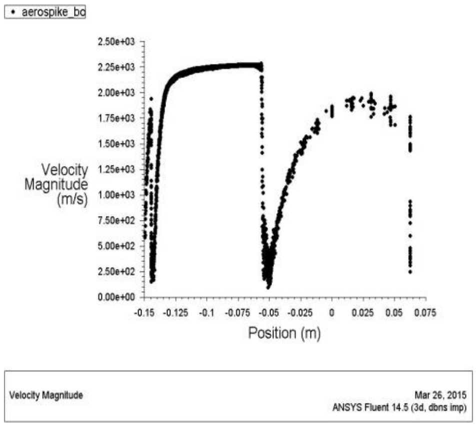

Fig. 29. Velocity Graph

VI. CONCLUSIONS

In this work, it is proposed to enhance the efficiency of a missile blunt body by placing the spherical aerospike of varying L/D ratios such as 0.5, 1.0, 1.5 and 2.0. In all these simulations the various outputs such as pressure, velocity and temperature contours are compared. Similarly the pressure and velocity graphs for all these L/D ratios are also compared. From all the data analysed it is evident that the missile blunt body is efficient when the L/D ratios of the spherical aerospike are 1.0 and 1.5 when compared with the other L/D ratios.

Very little research is going on introducing spike on the hypersonic vehicles. Since no static results exists for a mach number in the range 8-14. Also data on large nose radius do not exist. Using in viscid flow equation over the spike body and analyse drag force and velocity over the spiked blunt body. But there is a chance of using different flow equations over a hypersonic vehicle like turbulence equations, viscous laminar equations during analysis and also with different aerospike shapes. This may vary results and give optimum results for future efforts.

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