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Design and Analysis of Nose part for Re-entry vehicle considering Magnus effect over the Blunted Double Cone Configuration in the region of the Shock Wave Boundary Layer Interaction.

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Abstract: When the fluid velocity is much larger than the velocity of sound in the flow field(M>1.2, M<5) is supersonic flow. When the vehicle is moving faster than the speed of sound Shock waves will occur which makes bombs have more chances of explosion. If the shock wave moves much faster than the energy of the bomb, fades away quickly. Increasing the shock wave on the surface and improving the interaction between shock wave and boundary layer will design the nose part of the re-entry vehicle. Designing the nose part (Blunted double-cone configuration) for a Re-entry vehicle and analysing by including the Magnus effect over the blunted double-cone configuration in the region of the Shock wave boundary layer interaction (SBLI) in supersonic condition considering (M=3). To obtain the better interaction between shock wave and boundary layer by involving the spinning effect over the surface and analysing the result through computational fluid dynamics (CFD). Considering the result of spinning effect over the blunted double cone and comparing the result with without spinning effect over the blunted double-cone configuration through CFD to provide the data that attain in an efficient manner. Determining the result to attain minimum drag, surface temperature and other factors act on the nose part while re-entering into the atmosphere. Determining the result to attain maximum efficiency, minimizing bombs and comparing the result through CFD.

Keywords: Shock wave, Boundary layer, SBLI, Magnus effect, Supersonic flow, CFD.

1. INTRODUCTION

Shock wave boundary layer interaction (SBLI) is a main phenomenon of aerodynamics. Most probably SBLI creates a consequential issue in a flow field; Significantly proves that hypercritical or even design limitation problems are raised. Shock wave carries energy and can propagate through a medium and are characterized by a sudden, change in pressure, temperature, and density of the medium[1]. A boundary layer is a thin layer of fluid that comes in contact with a surface. Boundary layer interaction is the process when the fluid (gas/air) comes in contact with a solid surface nose part of the Re-entry vehicle (Blunted double-cone configuration) the fluid produces the shockwave, the process also known as Shock wave boundary layer interaction (SBLI)[2]. The present work focuses on the utilization of the Magnus effect to decrease the drag value, temperature value, and other factors acting over a blunted double-cone configuration. Magnus effect is the fundamental phenomenon by which the spinning object flies in a fluid creates a whirlpool of fluid around itself. It will experience a force perpendicular to the line of motion. By Bernoulli's principle, we get the Magnus effect. Aeronautics' main application is the Magnus effect and is also used for generating the lift. It was described by Isaac newton in 1671. By using the Magnus effect will go to improve the efficiency and minimize the drag and surface temperature values. To provide more understanding into the computed results, can also experiment through a supersonic wind tunnel and collect the data and compare the result. An attentive presentation is needed to find some control techniques applied to shock wave boundary layer interaction on the supersonic vehicles. However, the application of interaction control on re-entry vehicles was not seriously examined until the recent development. Hence, we have a considerable renewal of interest in drag reduction techniques and, in this context, the reduction of the drag rises due to strong shock forming on re-entry vehicle nose part at off-design conditions as well as the increase of buffet boundary can be of vital importance. To increase the shock wave boundary layer interaction the Magnus effect will support and also fade the bombs which provide when the vehicle is moving in supersonic condition. For improving the efficiency of the vehicle and reducing the drag produced in the vehicle so many experiments are done in the wind tunnels, using CFD and also numerically.

The descriptive explanation about SBLI and Magnus effect in different papers in different methods are explained below.

Conducted the experiment in a ballistics range to find various carbonaceous material properties, calculations of nose tip flow fields, and calculations of laminar boundary layer development. To analyses transition data for flow over transition surface, Reynold number for transition. conducting the nose tip transition experiment to collect the data and comparing the data with existing wind tunnel data to correlate both the data. The roughness-dominated transition on blunt bodies in hypersonic flows is identified while conducting an experiment. Various material properties are identified through this experiment[3].Conducted experiment on LENS I and XX shock/expansion tunnel to identify the properties of boundary layer while interaction occurs. Surface heat transfer and pressure measurements are made in laminar separated regions in high enthalpy flow over the double cone and hollow cylinder/ fare configuration. Here we conducted the experiment and compared the experimental data with defined boundary conditions of Navier- stoke computations[4]. Velocities from 8000 to 22000 ft/s to take. Freestream conditions are also taken from Navier-stoke computation. provide information on various properties of shock wave interaction which included thermal transport and convective heat transfer. Provide information about turbomachinery components' environment and conditions. Also, practical and design information of aerospace and aeronautical components and environments and conditions. It also provides information on the characteristics of shock wave information.

- It is generated in a constant-area duct, a diverging nozzle, or multiple passage test sections.
- Development of devices and technologies for the implementation of specific control strategies.
- Determination of thermal transport and related surface heat transfer effects
- Consideration of the origin and propagation of shockwave interaction unsteadiness[5].

Considering the problem and giving accurate solutions to the problem by using direct numerical simulation data. Separation points and wall pressure points we can find by using the direct numerical simulation data. Analysis of the characteristics and properties of the free stream flow and characteristics of frequencies. We also find the shock motion and various properties of shockwave band turbulent boundary layer interaction using this numerical data[6]. Conducting an experiment in the transonic wind tunnel to find the transonic flow of the shock wave pattern and pressure distribution of the boundary layer. And also find the change of flow from laminar to turbulent in the same Mach number while conducting the experiment. In this paper, they are conducting the experiment to find the various properties of the transonic flow while interacting between the boundary layer and shock wave[7]. Conduct experiments to find various Problems of turbulent boundary-layer separation (not even solved in incompressible flow) is included in shock/boundary-layer interactions by using the most advanced CFD codes validate codes against hypersonic shock/boundary-layer interactions. Specifically, the coverage of the present database collection and assessment effort with respect to shock/ boundary-layer interactions includes both supersonic (M 3-5) and hypersonic data (above M 5), both two-dimensional (2-D) and three-dimensional(3-D) data, and both unseparated and separated turbulent boundary layers (though the emphasis is on the latter). Consideration - 4 +, also includes not only perfect-gas behavior, but real gases and (where appropriate) chemically-reacting flows as well. Also mentioned were the experiment details conducted by various persons which were successful[8].It is an experiment conducted on existing shockwave boundary layer interaction having sufficient quality to guide turbulence modeling and code validation. By using CFD we find solutions for Hypersonic issues. Various boundary layer interaction experiments are to be done to know about the various properties in turbulent shock situations. some tests can't be done fully in-ground base situation then, it will be done by using CFD methods. So, pre-installation of the body to be designed in a manner that could eradicate this vibrational disturbance. For this proper experimentation to be done. Here the analysis is taken as Mac 3 then after the section, it is observed that Mac 3-5 is the operating range for supersonic and above Mac 5 is the operating range for Hypersonic conditions[9].Collecting numerical values from large-eddy simulations of SBLI to know the complex mechanisms which would play a major role while designing propulsion systems. By using the result of CFD code validation of supersonic shock boundary interaction has been done. We observed the dynamic interaction of boundary is observed from the data. We were also able to predict the wall pressure, temperature fluctuation, density profile, root mean square of velocity, Reynold's shear profile. Comparing the flow of SBLI from numerical data to experimental data of 3D flow[10].Considering some basic properties of the interaction are considered for a 2D adiabatic flow developing on the flat surface. upstream interaction length, incipient shock-induced separation, and evolution of the boundary layer properties can get by conducting the experiment. SBLI has guided by two categories; acting on the boundary layer properties before it enters the shock region and shock foot region. Conducting mathematical experiments and analyzing data to find various properties of the shock wave boundary layer while interacting. By using two methods of control techniques, it has been done[11]. Finding the better solution for a numerical issue of impinging the shock wave and laminar boundary layer. Determining the pressure by using the Prandtl-Meyer formula. Comparing the experimental data and theoretical data to various properties of the boundary layer on the plate. They conclude that the compressible boundary layer equation has an appropriate result for the shock wave laminar boundary layer equation. Theoretical data is hard to find due to the parabolic equations involved[12].SBLI research is involved in four areas: i) understanding low-frequency unsteadiness, ii) heat transfer prediction capability, iii) phenomena in complex (multi-shock boundary layer) interactions and iv) flow control techniques. By correcting minor things in the design to achieve maximum accuracy and conduct the experiment to find the various properties in mentioned areas accordingly. Achieve maximum accuracy for forecasting and solving the problem through two-dimensional flow interaction and can't be achieved in three-dimensional flow interaction due to RANS/LES methods have shown promising results. Achieved by numerical data and experimental data through CFD data validation[13].Conducting an experiment to observe the glancing interaction between oblique shock wave and thermal boundary layer through a supersonic wind tunnel. It has two different viscous layers. Whereas, (i) the side-wall boundary layer growing along the flat surface; (ii) the induced layer originating on the shock-generator surface near the root and crossing the path of the wide-wall layer. Comparing the theoretical data with experimental data to achieve accuracy. It also provides information about various properties and characteristics of the flow which includes oil flow pictures, vapor and smoke-screen photographs, wall-pressure distributions, and local heat-transfer measurements. Conducting the experiment to achieve by mounting the wedge in the supersonic wind tunnel[14].Comparison of the result of numerical solution to CFD solution for a given problem. Conclude that we also find an accurate solution using the numerical solution. Although it will take time to do the whole calculation gives the accurate solution in linear and non-linear problems. Although the solution can proceed at larger time steps, is the computation time per step correspondingly greater also[15].A shock tunnel experiment has been conducted to study the interaction of boundary layer developed together with a rocket to a bow shock generated by a booster. Booster configurations were employed to change the strength of the bow shock. The distribution of heat flux and static pressure were measured along the rocket surface in order to examine the character of the interaction region and correlated both peak values. By the experiment, the three-dimensional shock boundary layer interaction flow field was also visualized by the oil flow method and schlieren photography. Hereby using this we understand the heat flux and static pressure[16].Modifying the design to double cone configuration and conducting the experiment to find the various properties of flow stream through Lens XX tunnel. Free Stream has been selected through CFD calculations. Properties which include pressure, Mach number, and temperature of flow field should be predicted through this experiment. It also includes experiments on flow chemistry. It combined both experimental data and numerical to find appropriate techniques for the double cone configuration. By the experiment, we also find the chemical properties and reactions. It also provides information effects of flow chemistry on the characteristics of the laminar region of shock boundary layer interaction. Provide exact data related to the model which they have taken. Design the double cone configuration and conduct test in Lens xx tunnel to find various things and by using CFD find some chemical characteristics[17]. To predict the unsteady flow and the Magnus effect over a spinning finned projectile an unsteady algorithm-based grid movement has been developed. Compared the numerical results with experimental results which were satisfied[18]. The investigation of the flow mechanism of the Magnus effect for supersonic conditions by the numerical simulations of flow over a spinning finned projectile at an angle of attack ranging from 4° to 30.3°. by using numerical simulation method investigating the Magnus effect of a finned projectile in supersonic flow based on RANS equation, combining the dual-time stepping method and different turbulence models. Comparing the result of Magnus force between the finned body projectile and nonfinned body projectile[19]. Describe the physical mechanisms governing the Magnus effect. A small incidence of spinning projectiles and yawing induces a weak asymmetry of the boundary layer profiles as well as high incidences, increased cause the separated vortex to be altered. By using the numerical prediction validated the flow phenomena (CFD methods, Reynolds-averaged Navier-strokes ((RANS) and unsteady rans (URANS) equations, and hybrids RANS/LES). Compared the result of supersonic wind tunnel tests and CFD results. RANS method for supersonic flow condition is well predicted[20].Review the application of the Magnus effect, concepts used in aeronautical that have been investigated by various researchers in different applications. Concluded that the advantages of a Magnus effect device are high-lift forces or rather high wing-loading and stall resistance. The general barrier for the usage of the Magnus rotor is the lack of design information, aerodynamics modeling, and the basics of flight mechanics of rotor airplanes[2]. Analyzing the Magnus effect in the cylindrical surface and the dumbbell-shaped by using the CFD for ducted fan UAV. Response surface methodology (RMS) and Genetic algorithm (GA) methods are adopted for multi-objective optimization. Compared to the analysis result of the cylinder and the dumbbell, experienced the higher Magnus force on the dumbbell than the cylinder at the same wind speed and rotational speed[21].

2. Design

The design of the Re-entry vehicle nose part (Blunted double-cone configuration) is shown in figure no. 1.

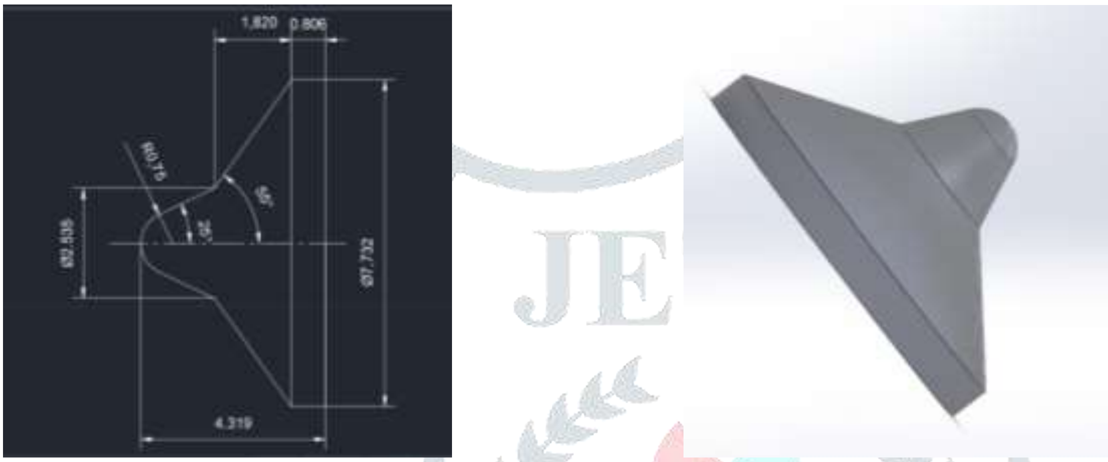

Figure 1. New Design of blunted double cone configuraton by including magnus effect

3. Meshing

The meshing for blunted double-cone configuration is shown in figure no.2

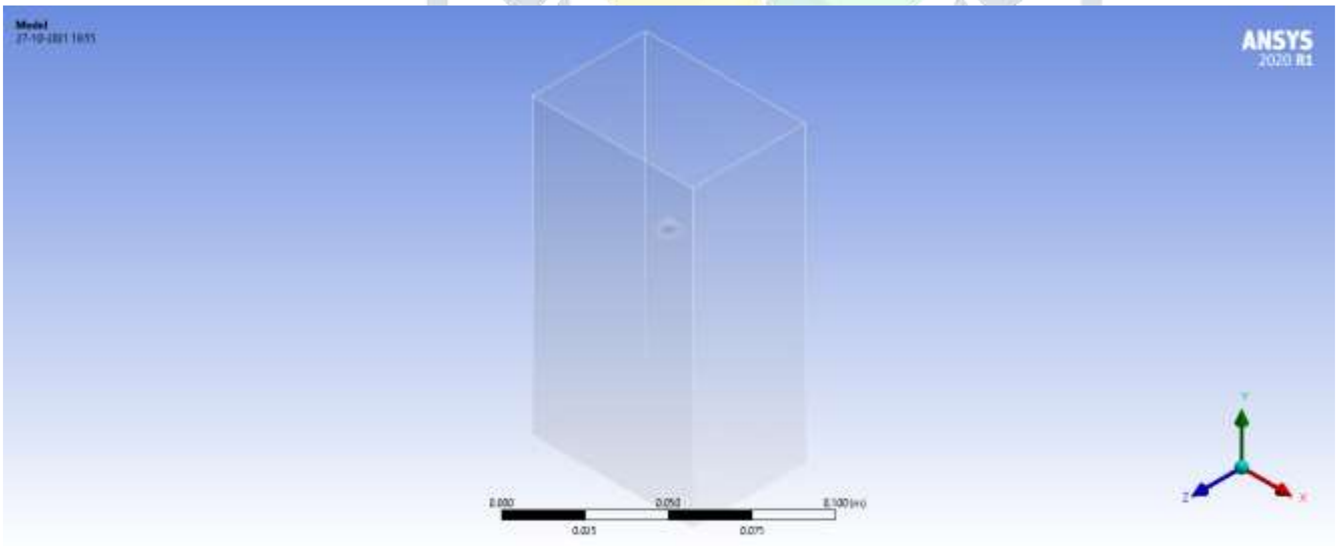

Figure 2. Blunted double cone model configuration meshing

4. Analysis Result

The analysis results of blunted double cone model configuration without Magnus effect and with Magnus effect are shown in the below figures (3,4,5,6). The contours show the result data of pressure and velocity of blunted double-cone configuration. Comparing the both results.

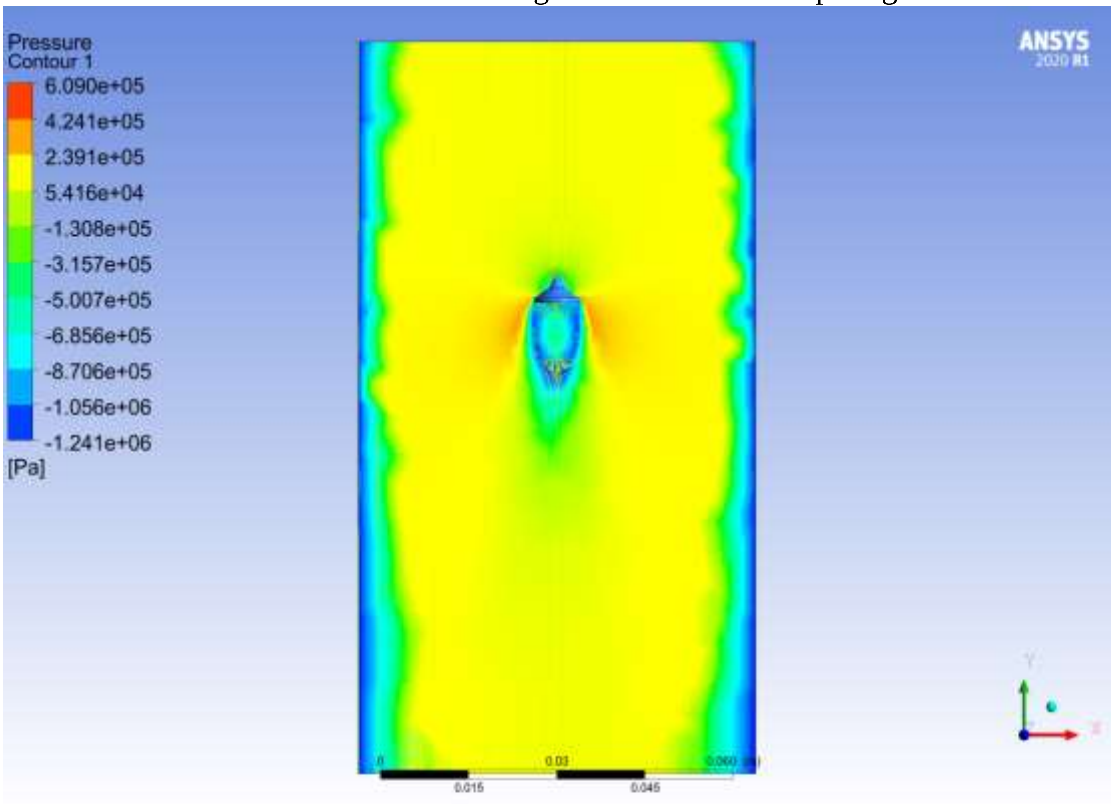

Figure 3. Pressure analysis over blunted double cone configuration without magnus effect

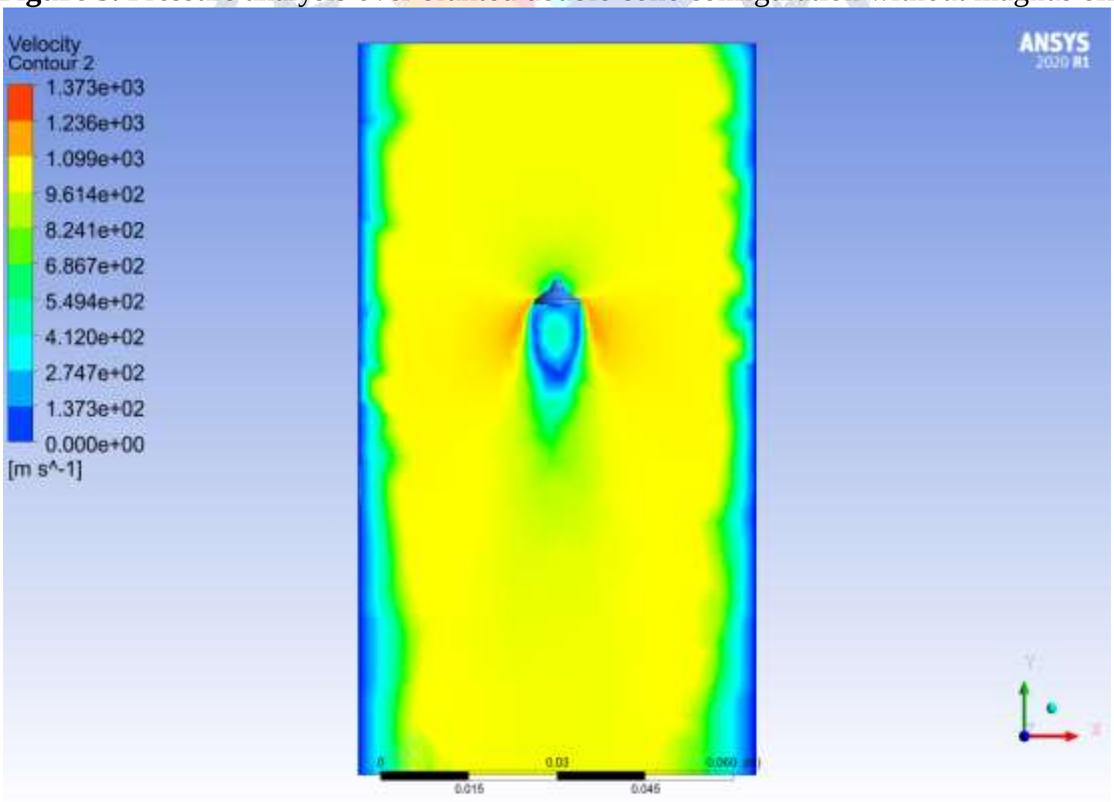

Figure 4. Velocity analysis over blunted double cone configuration without magnus effect

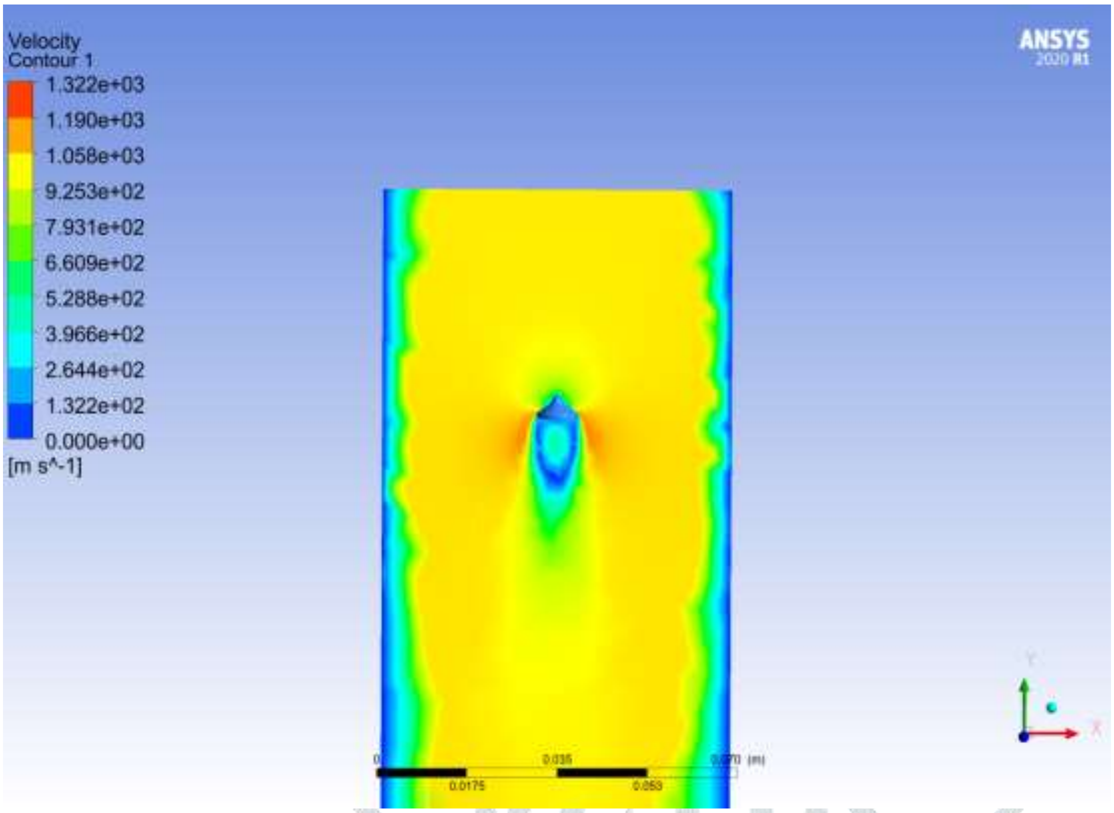

Figure 5. Velocity analysis over blunted double cone configuration with magnus effect

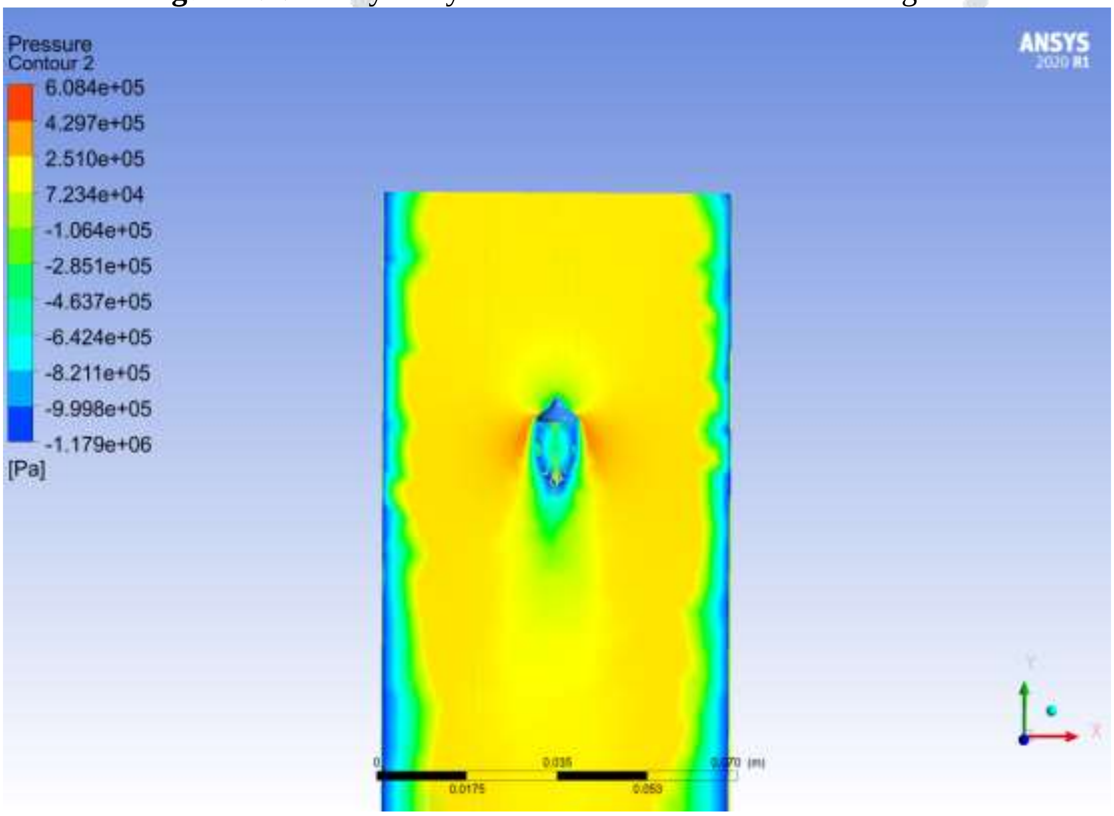

Figure 6. Pressure analysis over blunted double cone configuration with magnus effect

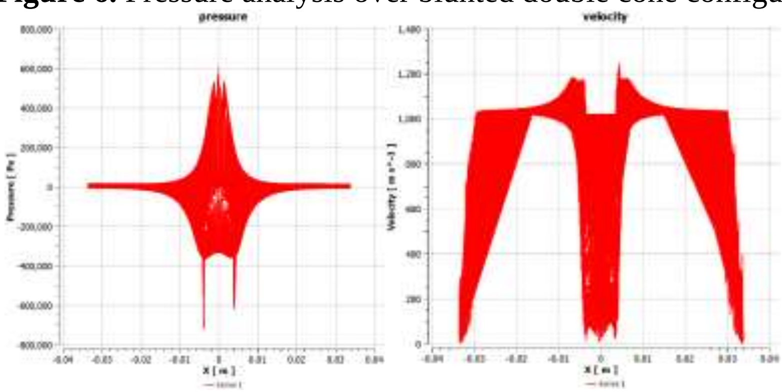

Figure 7. Result of Pressure and temperature over a blunted double cone without magnus effect

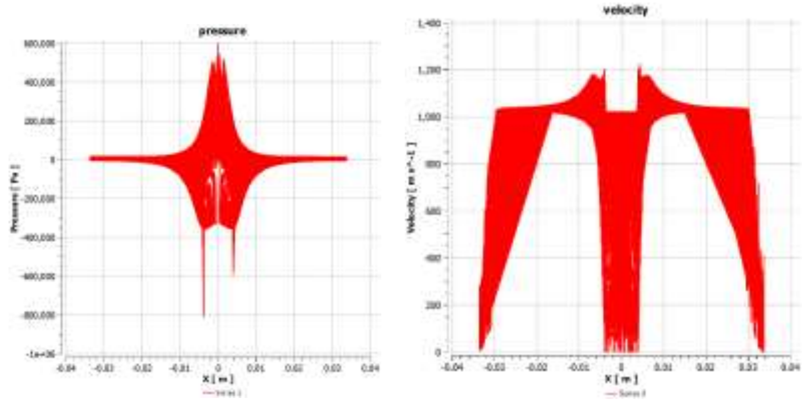

Figure 8. Result of Pressure and temperature over a blunted double cone with magnus effect

5. Result

Comparing the results through the CFD the result of velocity is **Figure 4** having high velocity compared through **Figure 5** although it is minor it having great impact and also the pressure of cone while re-entry into atmosphere having high value **Figure 6** compared to without applying magnus effect **Figure 3**

6. Conclusion

Concluding that the result by applying the magnus effect over the blunted double-cone configuration achieving the better efficiency then the normal one. The shock wave moving faster than the energy of the bomb to minimise it which cause explosion while entering into the atmosphere. Further can done experiment to shown the accurate result by using the supersonic wind tunnel. The result attain through CFD shows that the minimising factors acts on nose part of re-entry vehicle while entering into earth's atmosphere.

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