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NUMERICAL ANALYSIS OF DRAG ON BLUNT BODIES WITH THE USE OF DIFFERENT CONICAL SPIKES AT SUPERSONIC SPEED

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Abstract- **Aerospace vehicles such as re-entry vehicles, satellite launching vehicles, missiles, rockets move at very greater speed with variations in properties around the flow pattern. Greater amount of heat and drag are associated with these vehicles. Different spikes, bleeding devices, trailing flatters have been designed to reduce drag formed on aero-vehicles due to pressure, wave, skin friction factors. In present study, 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, 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**.

Keywords- Blunt Body, Conical spike, Supersonic speed, drag

I. INTRODUCTION

Aero vehicles usually travel through high temperature and pressure atmosphere at sonic as well as supersonic speed. The effect on performance is due to strong bow shock wave formation at vicinity of blunt nose. Also high aerodynamic heating causes damage of different sensitive parts present in the dome. So to reduce these shock waves, one can convert the normal shock waves into oblique shock waves by introduction of front facing spikes. These spikes tend to reduce the amount of aerodynamic drag created on the blunt body. Different spikes as sharp spike, flat head aerodisk spike, hemispherical tip spike etc. are used to reduce the drag effect on blunt nose of aerodynamic bodies. The phenomenon behind these spikes is that it creates weak shock wave on the blunt body.

II. LITERATURE REVIEW

Huang et al. [1] have studied the flow fields around a blunt cone with and without aerodisk flying at hypersonic Mach numbers are computed numerically, the reduction in drag of the blunt body is proportional to the length of the spike and the diameter of the aero disk, and the maximum aerodynamic drag reduction is 54.92%. Sebastiana et al. [2] have computationally studied the hypersonic flow over a spiked blunt body. Here the hemispherical tip spike is used to reduce the drag force at a Mach number 6 of blunt body. Also L/D ratio of spike is 1.5 and 2 for same spike. D. Sahoo et al. [3] have experimentally and computationally studied the effect of spike on a blunt body at Mach number 2 and zero angle of attack. Here the sharp spike reduces the drag by 30% of total value whereas the blunt spike reduces the drag value by 45%.V. Siva Kanna et al. [4] have experimentally studied the effect of drag on the blunt bodies and blunt bodies with spike and it is found that the spike reduces the radius of curvature of streamline approaching the blunt body. L/W=1 is best spike for the blunt body configuration as shown by the experimental results. Yu Ma et al. [5]589 have numerically investigated unsteady flow around the spiked blunt body and concluded that concluded that the inflation, withhold processes are corresponding to the decrease of the drag curve. Sujesh.G et al. [6] studied computationally the effect of blunted aerodisk spike on blunt body which create a drag reduction of 58%at hypersonic speed for L/D=2. Ramesh Repaka et al. [7] have numerically concluded that the effective spike length by diameter ratio is 2 which effectively reduce the pressure drag on the blunt body for both triangular as well as hemispherical type of spike. M. Barzegar Gerdoodbary et al. [8] have investigated the flow and effect of opposing jet on blunt body of D = L= 100 mm and also drag reduction by using hemispherical disk spike on the same at Mach number 5.75 and temperature of 250k. Kamyar Mansur and Mahdi khorsandi [9] have numerically investigated the flow over hemispherical spike blunt body at freestream Mach number 6 and have concluded that hemispherical tip spike reduces 40% of total drag formed on the main body.

Rajesh Yadav et al. [10] have investigated by simulation about drag reduction in a blunt body of base diameter 40mm and overall length 100m with double hemispherical disk spike and concluded that Long length spikes offer better drag reduction than shorter spikes i.e., 44% reduction in body drag. M. Venkatesan et al. [11] have conducted experiments and computation for blunt body and blunt body with sharp spike, hemispherical spike, flat tip spike, aerodisk spike, hemispherical tip larger than stem of spike, blunt conical spike models for drag reduction of blunt body. Roberto Roveda [12] have obtained Steady state results from numerical simulations of compressible flow using two state of the- art Computational Fluid Dynamics codes (CFD++ and Cobalt) were compared to previous CFD simulations (Fluent) and experimental data. R. Kalimuthu, R. C. Mehta, E. Rathakrishnan[13] have experimentally investigated flow field computation on drag reduction of blunt bodies at hypersonic speed by use of three different aero-flat disk, circular disk, conical tip. Jonathon P. Baker and C.P. van Dam[14] by using structured grids have numerically investigated that splitter plate can reduce the drag of blunt cone airfoil and the plate angle did not have an effect of drag but effected lift considerably. Hiroyaki Kobayash et al. [15] have used multi row disk spike on a blunt body for decreasing the effect of drag on blunt body. It was concluded that by increasing the number of stabilizer disk the drag, zero lift drag, induced drag can be reduced. M. Asif et al. [16] found that increase in length resulted in increase in lift coefficient and pitching moment coefficient, but also resulting an adverse effect on the static stability at the same time. Menezes et al. [17] have experimentally, numerically investigated and concluded that At higher angles of attack, the drag on all spiked bodies increases as a result of the inward shift in the point of bow reattachment on the windward side of the cone. Milicev and Pavlovic [18] have experimentally investigated and concluded that the spike with hemispherical tip has the lowest amount of drag generated on blunt body. All the models used in the experimental study were made of steel with great surface finish. Harvey Album [19] has studied the utility of using spikes on blunt bodies. author also concluded that the spikes blunt body has lesser heat generation and greater stability in structure. Drag reduction was an effective reason behind the spike used at the blunt bodies which has lead to utilisation of spike in the blunt bodies

III. NUMERICAL MODEL

In- house developed compressible implicit RANS solver of CFD Expertlite™ by Zeus Numerix Pvt. Ltd. Pune, India has been used for the simulations which use basic governing equations of continuity, energy, momentum for solving the problem. Compressible, LUSGS implicit time step, green Gauss gradient, Spalart Allmaras i.e one equation turbulence model for turbulent eddy viscosity is used for solving the above aerospace problem to compute the drag coefficient.

3.1 Geometry And Mesh Details

Figure 1 shows detailed dimensions of the blunt body[3] and conical spiked blunt body[10]. 3-D Hybrid meshes were created using ICEM CFD 15.0.Here hybrid mesh is created i.e prism layers are also created in order to resolve the flow over the body. First cell height is 1.5 x 10^{-3} mm and y+ falls below unity i.e 0.8 for the body. A total of 23 prism layers were created to capture the boundary layer phenomenon. Also the growth ratio of 1.2 is given to create a denser mesh near the body and as it approaches the domain the mesh elements get coarser. Also, all the quality parameters are above 0.2 value in aspect ratio, skewness, quality of mesh elements.

For solving the above problem pressure farfield boundary condition for domain and stationary wall boundary condition for spike, tip and blunt body were given. The created mesh was numerically analysed at Reynolds number 3.5 x 10^5 on base diameter of blunt body and at Mach number 2. The free stream conditions for pressure and temperature are 53486 Pa, 303.15 K.

IV. RESULTS AND DISCUSSION

The results were obtained after all the residuals were having a three order fall in all the residues of continuity, momentum, energy equations. Also all the forces i.e pressure, friction forces were monitored and converged. Coefficient of drag is calculated by using equations of drag force which is given by,

$$F_d = (1/2)\,\rho V^2 A\ C_d \qquad (1)$$

$$F_l = (1/2)\,\rho V^2 A\ C_l \qquad (2)$$

$$F_d = F_x \cos\alpha + F_y \sin\alpha \qquad (3)$$

$$F_l = -F_x \sin\alpha + F_y \cos\alpha \qquad (4)$$

Where, ρ = mass density, F_d, F_l = drag and lift force ,V = velocity of object, A=area of cross-section, α = angle of attack, C_d, C_l = aerodynamic coefficient of drag and lift.

4.1 Validation and Grid independence

A total of three different meshes coarse, fine, very fine (0.9, 2.1, 2.6 million) hybrid meshes consisting of triangular, prism and tetrahedral elements were taken into consideration for monitoring drag on blunt body. Fine and very fine mesh showed less than 5 % of variation in aerodynamic drag coefficient value. Also the computational results agree with experimental results with less than 4% difference hence it can be said that the computational results are validated for the above computational problem [3].

Sr.no	Method	Aerodynamic drag coefficient(C_d)
1	Experimental [3]	0.793
2	Computational	0.76

Table no. 1 Comparison of computational results with experimental results.

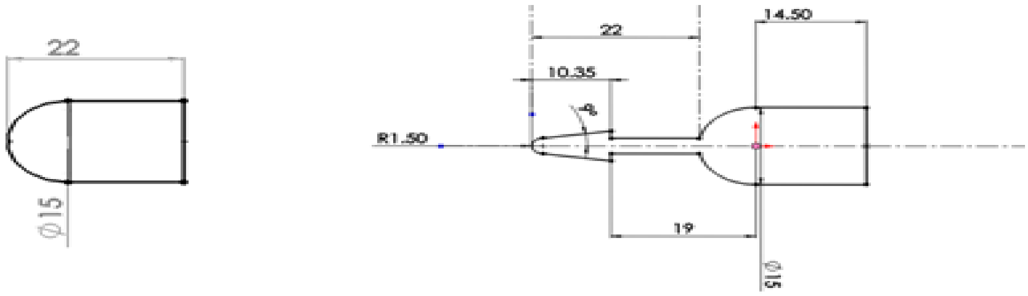


Fig.1. Dimensions (in mm) of blunt body and blunt body with conical spike

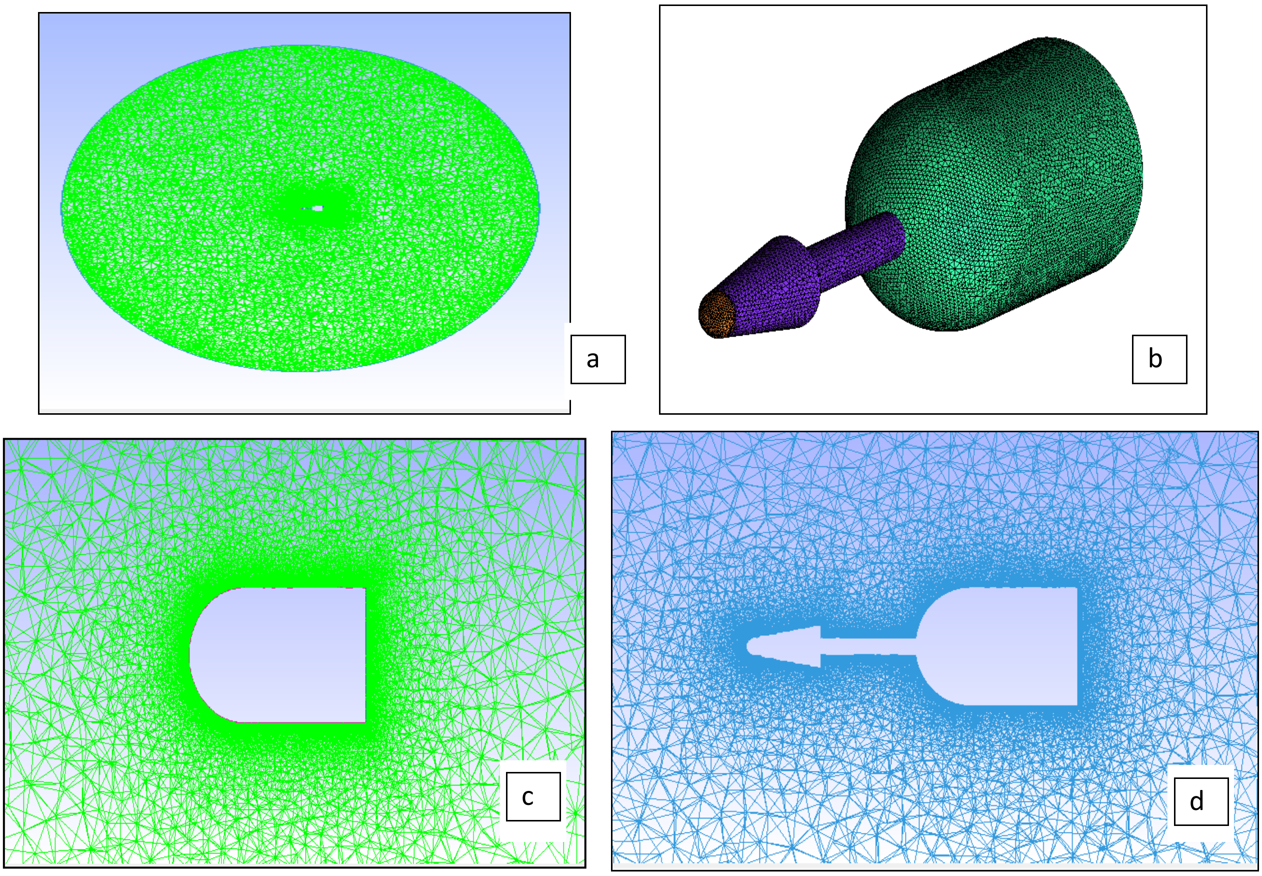
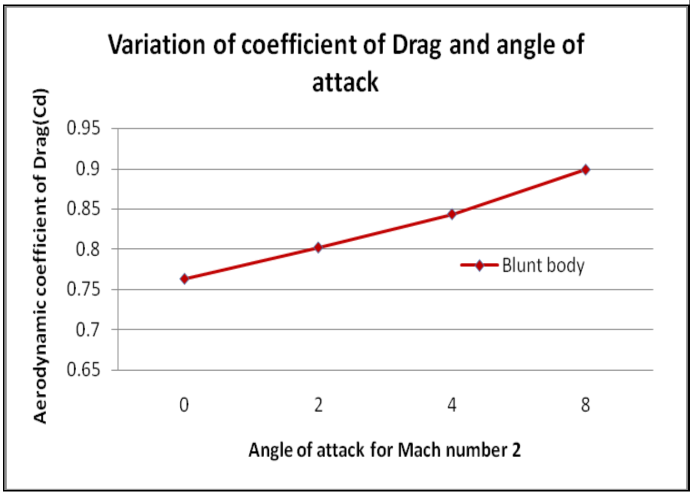


Fig.2.a.b.c.d Cut section of Hybrid Meshing for blunt body and blunt body with conical spike

4.2 Effect of Angle of attack on blunt body

Figure 3 shows the drag computed for various angle of attack i.e 0,2,4,8 degrees. It indicates that as the angle of attack increases more area of the blunt body gets in contact with pressure forces. So as the angle of attack increases the drag coefficient also varies linearly with respect to angle of attack. The value of drag coefficient for blunt body at zero angle of attack is 0.76 it increases to 0.91 with 8 degrees of angle of attack. The major reason for drag is pressure drag and wave drag that is created due to supersonic speed of this blunt body in fluid medium which creates shock waves near the vicinity of blunt body. Lift coefficient also increases as angle of attack increases. The major reason behind increase is force acting in vertical direction on blunt body increases with increase in angle of attack.



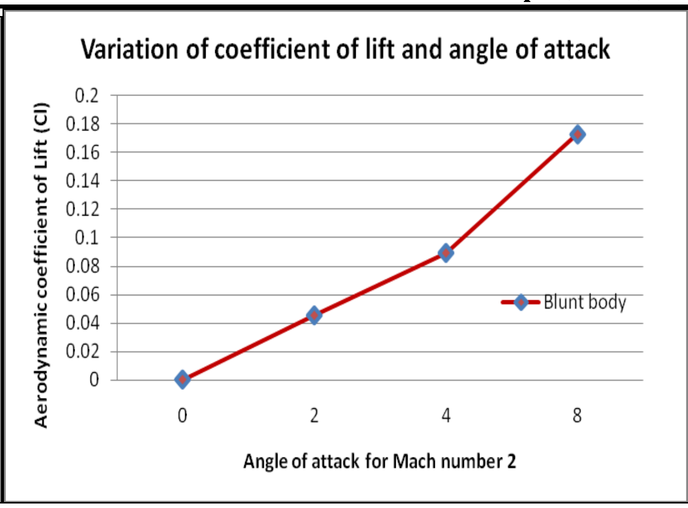


Fig.3.a Variation of aerodynamic coefficient of drag with angle of attack for blunt body,
3.b. Variation of lift coefficient with angle of attack for blunt body at Mach number 2

4.3 Effect of L/D Ratio:

Fig 5 and fig 6 show variation of static pressure, temperature and Mach number around the body with different ratio of L/D from 1, 1.5, 2. The pressure exerted on the tip of the spike varies as the spike length varies[6]. Also strong shock is formed when body is with spike of L/D-1 more pressure force is exerted on main body as compared to that of L/D-1.5 and the pressure again increases for L/D-2. Also the reattachment of shockwave point is found near to the tip for spiked body with L/D 1 and L/D 2 as compared to the other one.

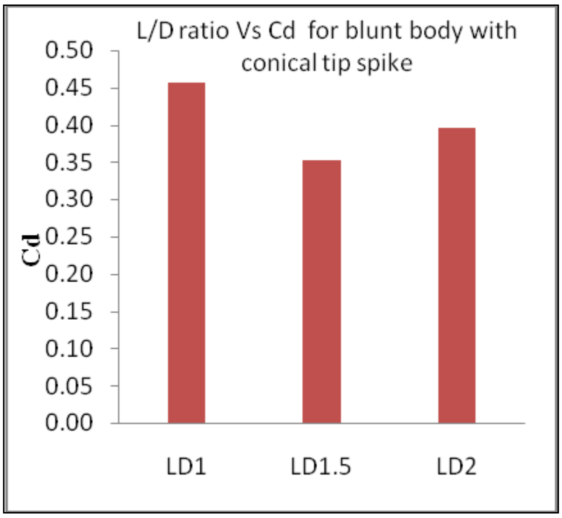
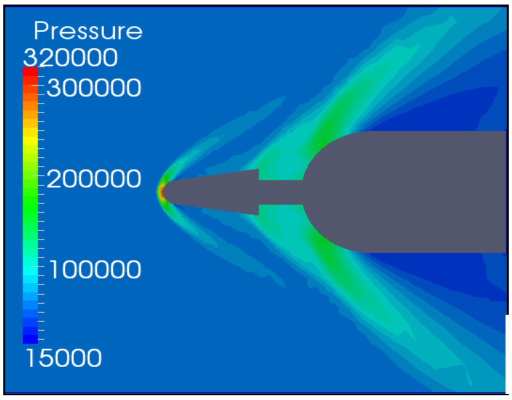
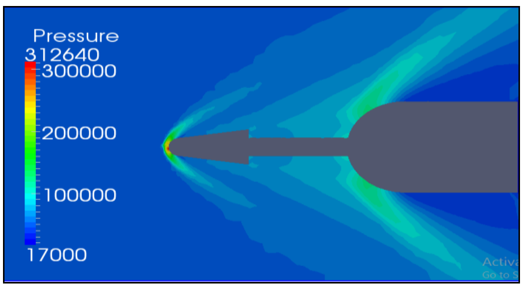


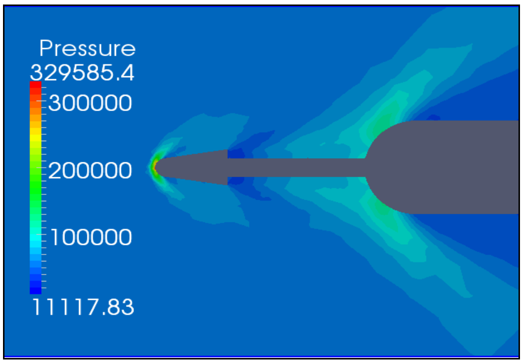
Fig.4. Aerodynamic coefficient of drag (C_d) for different L/D ratio of blunt body with conical spike



5.a



5.b



5.c

Fig.5.a,b,c Variation of static pressure for L/D ratio 1,1.5,2 respectively for blunt body with conical spike at Mach number 2.

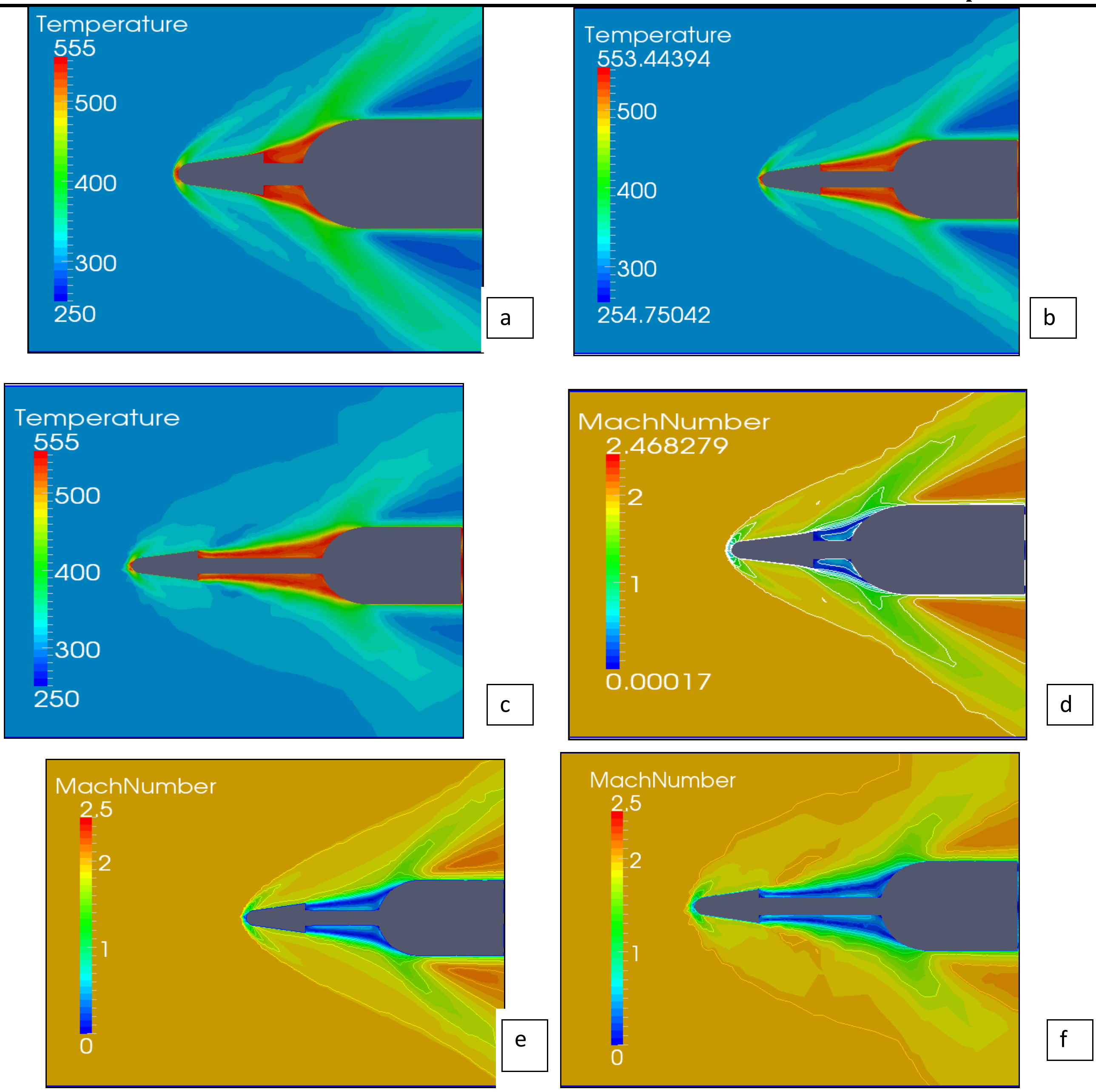


Fig.6.a, b,c Variation of static Temperature & 6.d,e,f variation of Mach number for L/D ratio 1,1.5,2 respectively for blunt body with conical spike at Mach number 2.

V. CONCLUSION

Supersonic flow visualisation for Mach number 2 is studied for blunt body at 0, 2, 4, 8^0 angle of attack and conical spike blunt body for different length to diameter (L/D) ratio i.e 1, 1.5, 2 at zero angle of attack are numerically simulated using CFD Expertlite™. Pressure variation, Mach number variation plots were studied to compute the drag coefficient. Peak pressure force acting on the body increases as angle of attack increases. Least amount of drag is found for L/D ratio 1.5 because the intensity of oblique shock creates less force on blunt body as compared to other ratios. Also, the reduction in drag is by 53.94 % as compared to that of body without spike. The present model is being further used to study effect of angle of attack for spiked body at different angle of attack.

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