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Analysis of Missile Bodies with Various Cross sections and Enhancement of Aerodynamic Performance

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Abstract: In order to optimize the geometry of the missile's cross-section for transportation purposes and also to obtain higher aerodynamic efficiencies, non-circular bodies have gained substantial attention by many researchers. In this work, we have compared the aerodynamic characteristics of three missiles having the same cross sectional areas, but different shapes (one circular, one square with round corners and one hexagonal with round corners). In order to differentiate the non-circularity and the fin effects, we have considered the bodies with no fins. A three dimensional, compressible, stationary, viscous, turbulent flow has been simulated using the FLUENT CFD code with the standard $k-\epsilon$ model. Our results indicate that, even though the square section missile has more friction drag, it produces less overall drag, similarly the hexagonal section has more frictional drag than square model, it produces less overall drag compared to both the square and circular section. Also, its lift is higher than that of the circular and square case and thus has a higher aerodynamic efficiency. Moreover, the rate of increase of the aerodynamic efficiency with increasing of the angle of attack is higher than that of circular and square section.

keywords: Missiles configurations, CFD Analysis, Hexagonal Missiles

1 General Introduction

With increasing concern over security and exploitation of space plays a major role in the advancement of new technologies that are challenging each and every country in the field of rockets and missiles.

Various studies about the missiles are carried out in area to increase its efficiency and range of operation. In this content aerodynamic analysis of missile with different cross-sectional shapes in one such important task that helps to increase the ways for obtaining greater range and better aerodynamic efficiency.

1.1. Missile Introduction.

Missiles are generally categorized by their launch platform and intended target. In broadest terms, these will either be surface (ground or water) or air, and then sub-categorized by range and the exact target type (such as anti-tank or anti-ship). Many weapons are designed to be launched from both surface and the air, and a few are designed to attack either surface or air targets (such as the ADATS missile). Most weapons require some modification in order to be launched from the air or ground, such as adding boosters to the ground launched version.

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Nomenclature

α	angle of attack
C_L	coefficient of lift
C_D	coefficient of drag
M_∞	free stream mach
C_p	pressure coefficient

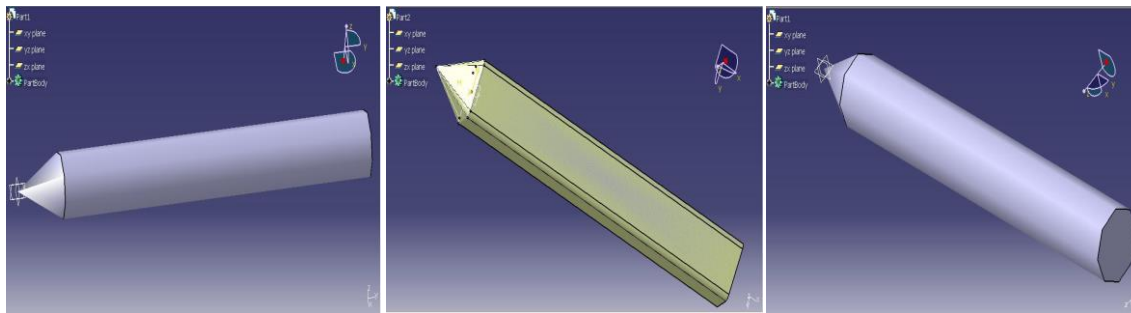
2. Design of Missiles

figure.1(a) circular missile

figure.1(b) . square missile

figure.1(c) hexagonal missile

First, a 3d missile model without fin was created in CATIA with the dimensions as shown in the fig.2.1.the non dimensional length of the missile is 36.44 including the conical region. The diameter is kept as 4.8. The non-dimensional scale considered is 1mm as the length scale and free stream velocity as the velocity scale

3.Computational analysis

The flow considered here is three-dimensional, compressible, stationary, viscous, turbulent and singlephase . The fluid is air, for which the viscosity is obtained using Sutherland relation.

3.1Turbulence modeling

The turbulence model used was a 2-equation model, the standard k- ϵ where k is the turbulent kinetic energy and ϵ is the dissipation rate. This is a semi-empirical model that uses constants determined from air and water experiments (FLUENT, Tannehill). The model assumes that the flow is fully turbulent. K- ϵ model is a two-equation model, in which the averaged Reynolds stress is proportional to the averaged velocity gradient and the proportionality constant (μT) is to be found from the κ and the ϵ equations

3.2.Grid generation

For analysis domain considered is as follows, circumferential outer boundary is at a distance of 15D from the missile and in the axial direction domain boundaries are considered at 5D from the leading edge of the missile to 10D from the end of the missile. The grid over the missile and outer domain grid are generated using GAMBIT. The mesh used is Tri-primitive type(Triangular mesh).



figure 2.(a) . 3D grid of Square missile

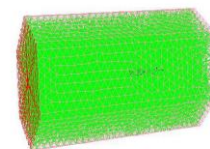


figure 2.(b) 3D grid of hexagonal missile



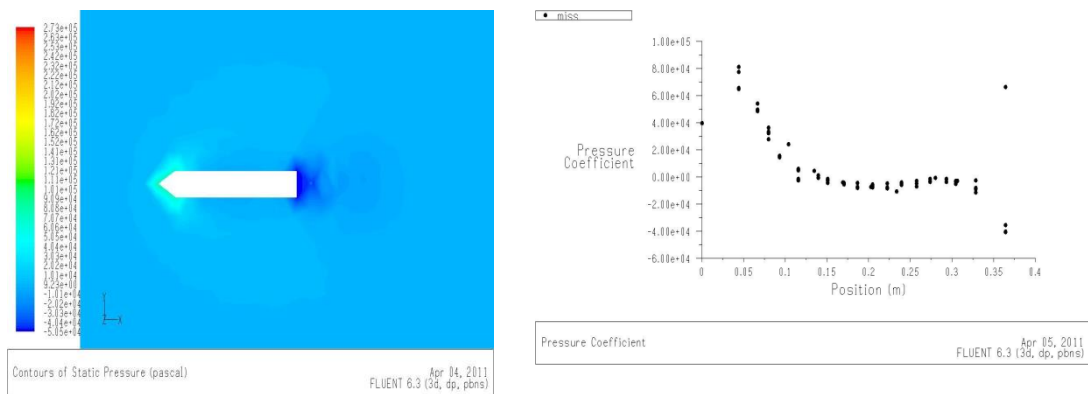
figure 2.(c) 3D grid of circular missile

3.3. 3d Analysis Results

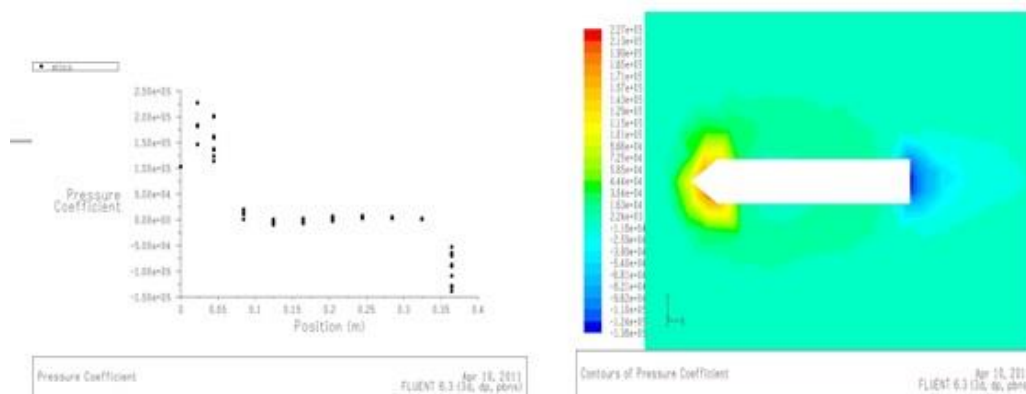
All 3D CFD cases were performed using the Fluent 3D double precision solver. Default criteria were used for most parameters. The convergence criteria for the residuals were again set at $1e-6$. The residual tolerances were never achieved but were set to allow the solver to continue to iterate. The case was stopped after the lift and drag coefficients had reached steady values to at least 4 significant digits. The Courant number used for the cases was one.

3.3.(a) . circular missile

The 3D analysis of all missiles are computed and plotted for various mach numbers. The contours and vectors of all missiles are displayed in the following figures.

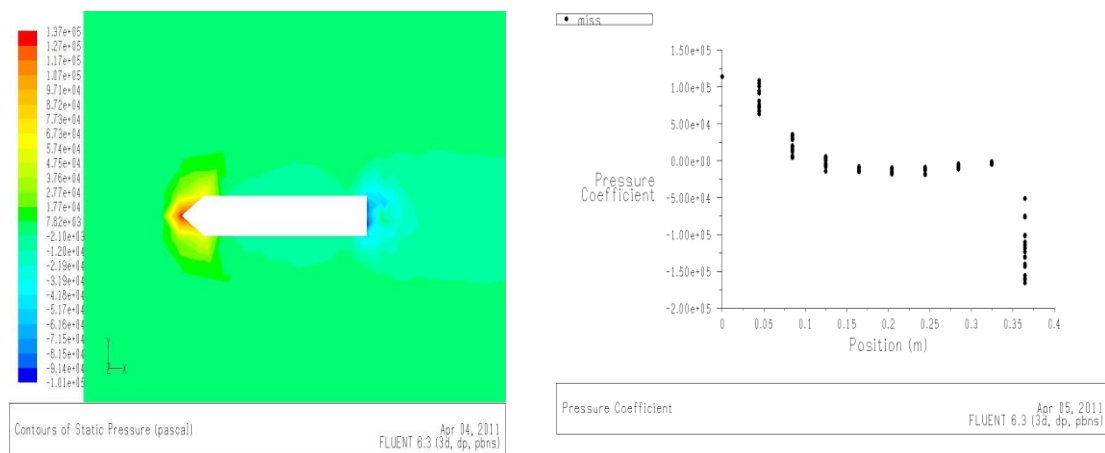


3.3.(b). Square missile



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3.3.(c).hexagonal missiles



Result and discussion

The plots done for pressure distribution at various positions for different speeds. At mach number 1, the maximum C_p occurs at 0.1m. It shows, the velocity is minimum (345 m/s) compared to free stream velocity. This is due to the propagation of shock wave a head of the fore body. The C_p value decreases 0.25m and becomes negative at 0.25m of the missile body and it becomes constant at 0.4m of missile length. This is due to formation of expansion wave at the tail portion of the missile length. The static pressure over the length of missile decreases due to the presence of expansion waves, decreases at a distance of 0.4m from the leading edge of the missile length and the static pressure decreases below the free stream pressure, so C_p becomes negative, which can be obtained from

$$C_p = (P / P_\infty - 1) / (1/2 * \gamma * M_\infty^2)$$

At $M_\infty = 2$ the C_p value increase is low compared to that of C_p at $M_\infty = 1$ and its remains constant throughout the length of the missile body length. This is due to decrease of free stream mach number at the tip of the fore body. It shows the static pressure rise over the missile length. In this circumstance the point of inflection moves towards the downstream.

Further increase of free stream mach number (1 to 4), the C_p distribution shows similarity i.e., the static pressure increases over the fore body. In all the cases the point of inflection keeps on increasing with free stream mach number. It shows that shock also moves with respect to point of inflection, mean while the prandtl-Meyer expansion takes place.

It is very tedious to predict the flow characteristics at $M_\infty = 4$. Because it is a mixed flow of both supersonic and hypersonic flow.

Conclusion

Three missiles circular, square and hexagonal of diameter 4.8cm and length 36.44cm (nose section 4.44cm and body 32cm length) with taper of 5 degree for hexagonal and square section has been tested for supersonic mach number 1 to 4. This study will motivate the need of aerospace industry to quickly and inexpensively determine characteristics of missile without the need of wind tunnel experiments, which are difficult and expensive.

An analysis of the above results, has led to the following conclusions.

1. For all the missile the shock is seen attached as the Mach number increases a detached shock wave is obtained.
2. In the case of circular missile have good lift characteristics but the over all drag is high compared to square missile.
3. As in the case of square missile the nose cone drag is high while the over all drag is low compared to that of the circular missile.
4. The C_p value for the hexagonal missile is low for all mach numbers compared to circular and square missiles.
5. When comparing all the missiles the hexagonal exhibit better aerodynamic characteristics for all the mach numbers.
6. With the attachments of fin a better aerodynamic characteristics and a good result can be obtained.

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