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COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF MISSILE WITH GRID FINS

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ABSTRACT: *This paper presents the results of a study demonstrating an approach for using aerodynamic coefficients for a missile with grid fins. A grid fin is an unconventional lifting and control surface that consists of an outer frame supporting an inner grid of intersecting planar surfaces of small chord. The calculations were made at a mach number of 0.2 and angle of attack 0° for a missile with grid fins. The simulations were also successful in calculating the flow structure around the fin in the separated-flow region at the higher angles of attack. This was evident in the successful calculation of the nonlinear behavior viscous computational fluid dynamic simulations to calculate the flow field and for that fin, which showed negative normal force at the higher angle of attack. The effective angle of attack is negative on either part of the entire top grid fin for the higher angle of attack. The modeling of unconventional grid fin missile is done in CAD software called CatiaV5. The meshing of geometry is in a pre processor called Gambit. And the solving and post processing is done in a solver called Fluent.*
KEYWORDS: *aerodynamic coefficients, grid fin, CatiaV5, Fluent*

INTRODUCTION

Over the years much of the research efforts are directed to improve the aerodynamics of flows in the unconventional grid fin missile by conducting experimental and theoretical studies. This led to the formulation of empirical models, which established a relationship with parameters like Mach number, pressure, aerodynamic coefficients to the overall performance of the missile [1]. But due to the growing demand for high performance and reliable unconventional grid fin missile more fundamental approach viz. evaluation of flow fields, aerodynamic coefficients and species concentration throughout the domain of interest is needed. Hence the development of computational methods for predicting flow fields in unconventional grid fin missile has evolved. Investigations have been carried out earlier through experimental, theoretical and CFD methods by many investigators in this particular area [4].

The Guidance system is that part of a missile which decides when, and by how much, the control system must change the trajectory of the missile. A system which evaluates flight information, correlates it with target data, determines the desired flight path of a missile.

GRID FINS

Grid fins have some advantages over conventional, planar fins. One advantage is the ability to maintain lift at higher angles of attack since grid fins do not have the same stall characteristics of planar fins. Another is the very small hinge moment, which can reduce the size of control actuator systems. Since curvature of the grid fins had little effect on their performance, folding down the fins onto the missile body is a storage design advantage [10]. The main disadvantage was higher drag than that of planar fins, although techniques for minimizing drag by altering the grid fm frame cross-section shape were demonstrated (Miller and Washington 1994). These studies also showed that grid fins experience a loss in control effectiveness in the transonic regime due to flow choking in the individual cells [9].

DESIGN CHARACTERISTICS

Conventional "planar" control fins are shaped like miniature wings. By contrast, grid fins are a lattice of smaller aerodynamic surfaces arranged within a box. Their appearance has sometimes led them to be compared to potato mashers or waffle irons.

Grid fins can be folded against the body of a missile more easily than planar fins, allowing for more compact storage of the weapon; this is of importance for craft which store weapons in internal bays, such as stealth aircraft. Shortly after release, the fins are swiveled into place for use as control surfaces [7].

In the case of the MOAB, grid fins allow the weapon to fit inside a C-130 cargo bay for deployment while the craft is in flight. Grid fins have a much shorter "chord" (the distance between leading and trailing edge of the surface) than planar fins, as they are effectively a group of short fins mounted parallel to one another. Their reduced chord reduces the amount of torque exerted on the steering mechanism by high-speed airflow, allowing for the use of smaller fin actuators, and a smaller tail assembly overall.

Their small chord also makes them less prone to stall at high angles of attack, allowing for tighter turns. Grid fins perform very well at subsonic and supersonic speeds, but poorly at transonic speeds; the flow causes a normal shockwave to form within the lattice, causing much of the airflow to pass completely around the fin instead of through it and generating significant wave drag. However, at high Mach numbers, grid fins flow fully supersonic and can provide lower drag and greater maneuverability than planar fins [7].

DESCRIPTION OF THE GEOMETRY

Missile has been designed by using Catia v5 and the implementation of grid fins with the missile carried *out carefully. Planar fins are totally different from grid fins, which include various lattice arrangements that classified in to following categories. i) Baseline lattice grid fin ii) Coarse lattice grid fin iii) AFIT lattice grid fin. It is believed that the AFIT design would be better than the other lattice grid fins because this layout doubles the area of the cells in the main body of the fin while retaining a similar shape. The geometry of missile is shown in the below figure1&figure2 respectively.*

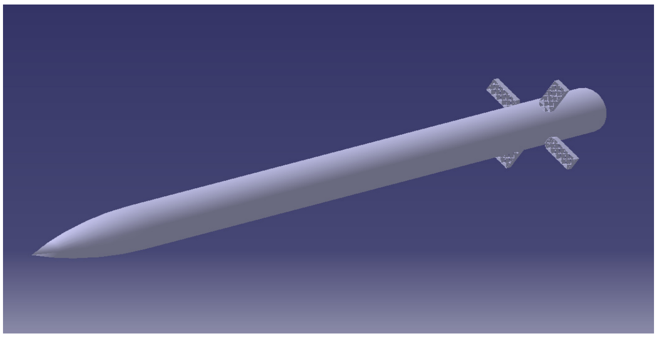

Figure 1. 3D view of the missile

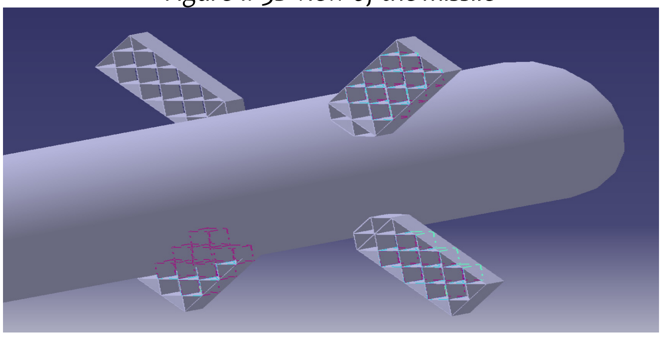

Figure 2. Enlarged view of fins on miss

The mesh has been generated for the missile as well as its domain in terms of various mesh nodes and that is shown in the below figure 4, 5,6,7,8 respectively.

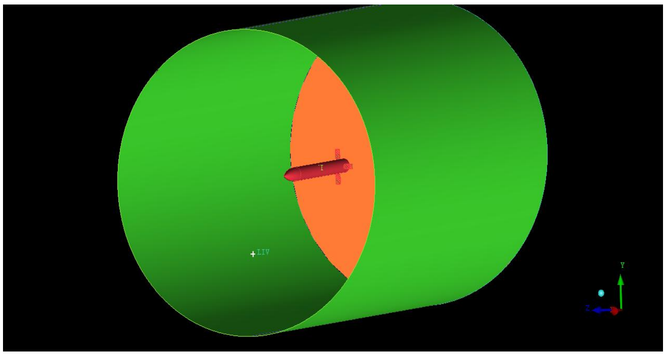

Figure 3. 3D view of missile with domain in ICEM CFD

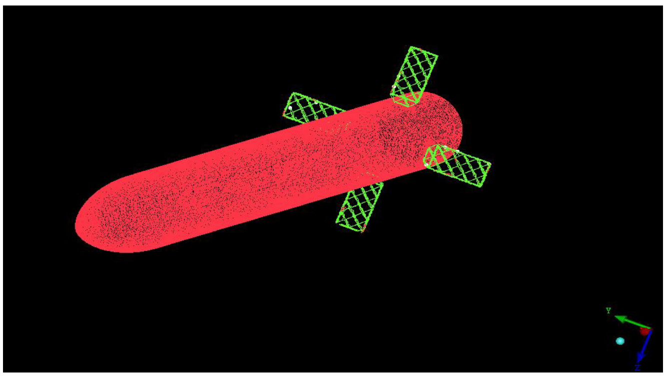

Figure 4.Triangle mesh on missile surface

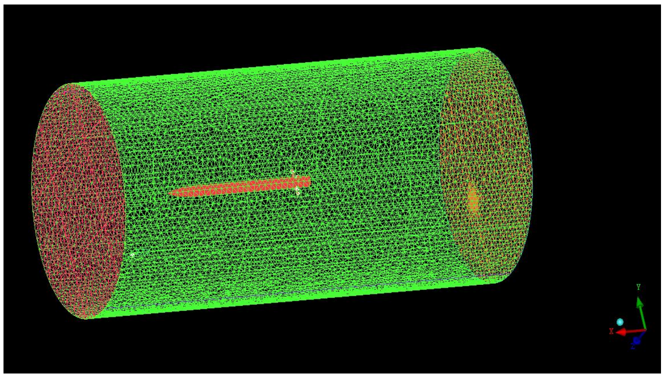

Figure 5. Surface mesh on domain

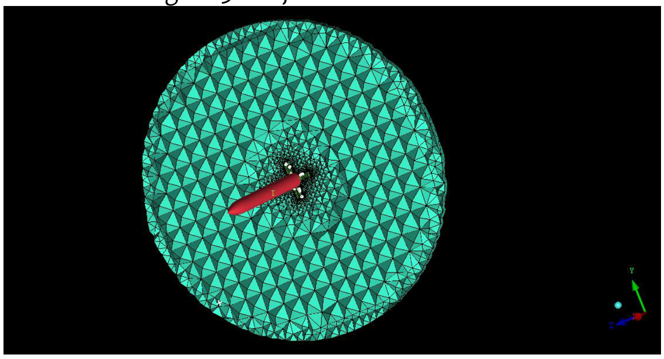

Figure 6. Tetrahedral mesh cut plane on x -axis on domain

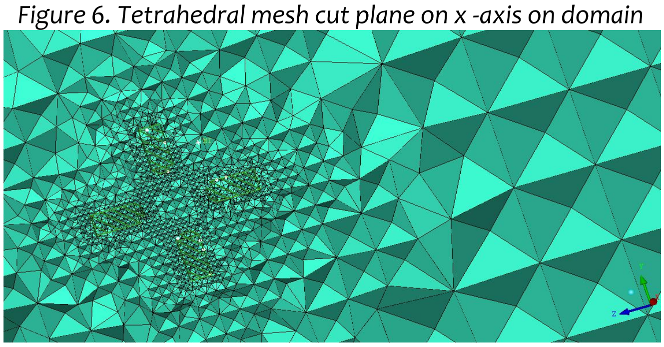

Figure 7. Enlarged view of Tetrahedral mesh cut plane on fins

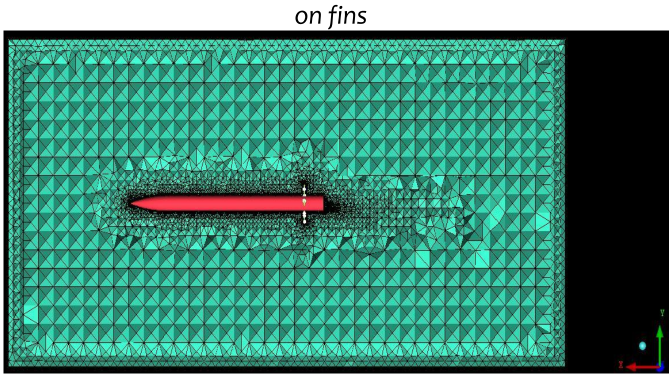

Figure 8. Tetrahedral mesh cut plane on z -axis on domain

DESCRIPTION OF MESHING

The missile geometry created in Catia V5 is imported into ICEM CFD for meshing by using suitable file acceptance format. Surface mesh on missile and fins are created as initiative process. The triangle elements are used for this surface meshing and then whole domain is meshed using tetrahedral cells [8]. The quality of meshing found to satisfactorily by checking criteria like quality, aspect ratio etc. A three-dimensional unstructured tetra grid (mesh) has been generated using the tetra meshing feature of ICEM CFD. The mesh size is 2 million cells; the grid is refined in the near wall regions using prism cells. The three *dimensional view of the full grid in ICEM CFD is shown in the figure below.*

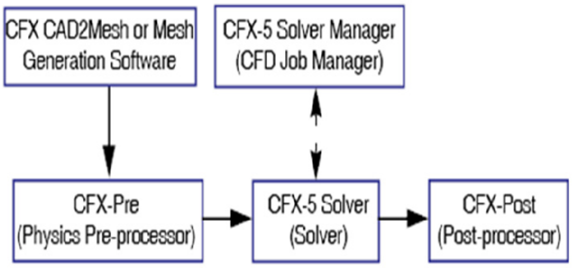

Figure9. The Structure Of CFX

Thus, the tetrahedral mesh for missile geometry is created using ICEM CFD. The tetrahedral elements are used for easy meshing as it is unstructured and requires less time to complete. Total elements: 1711046 and Total nodes: 287557.Thus both constitutes nearly 2 million cells. Then the mesh file is export to suitable solver.

DESCRIPTION OF SOLVER

CFX is a general purpose Computational Fluid Dynamics (CFD) code, combining an advanced solver with powerful pre and post-processing capabilities. The next-generation physics pre-processor, CFX-Pre, allows multiple meshes to be imported, allowing each section of complex geometries to use the most appropriate mesh [11].

CFX includes the following features:

- i. *An advanced coupled solver which is both reliable and robust.*
- ii. *Full integration of problem definition, analysis and results presentation.*
- iii. *An intuitive and interactive setup process, using menus and advanced graphics.*
- iv. *Detailed online help.*

The Structure of the CFX is illustrated in the below figure9 and which explains the steps involvement in the process. The mesh file is to be imported in to CFX solver and boundary conditions were made and that has been shown in the figure 10, 11, 12 respectively.

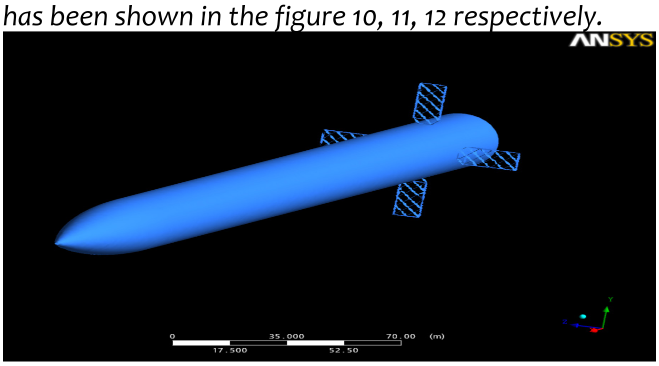

Figure 10. Missile geometry in CFX

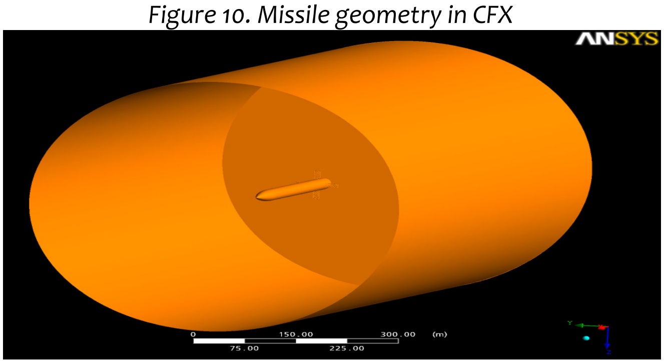

Figure 11. Missile and its domain in CFX

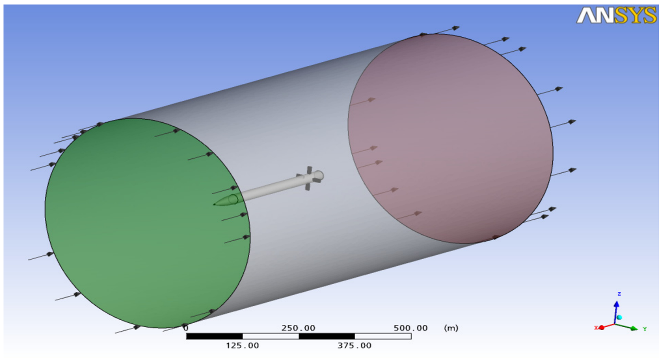

Figure 12. Boundary conditions

The following boundary conditions are used in this analysis.

1) For inlet, Velocity = 75 m/s. Static temperature = 300K.

2) For outlet, Static pressure = 0 Pa.

For missile and other parts of flow domain are considered as adiabatic wall (i.e.) no transfer of heat The various contour for velocity and pressure has generated with respect to boundary layer condition that is shown in thefig13,14,15,16,17,18 respectively .

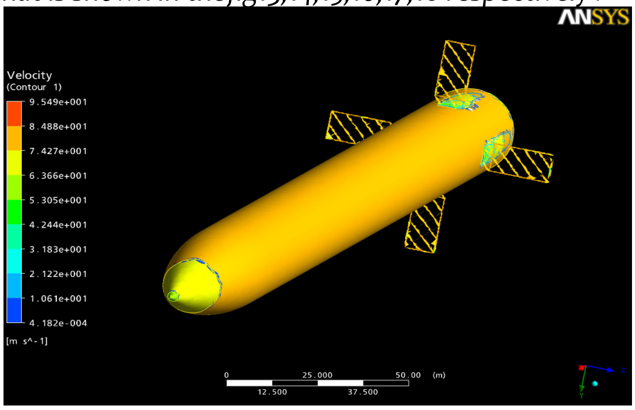

Figure 13. Velocity contour on Missile

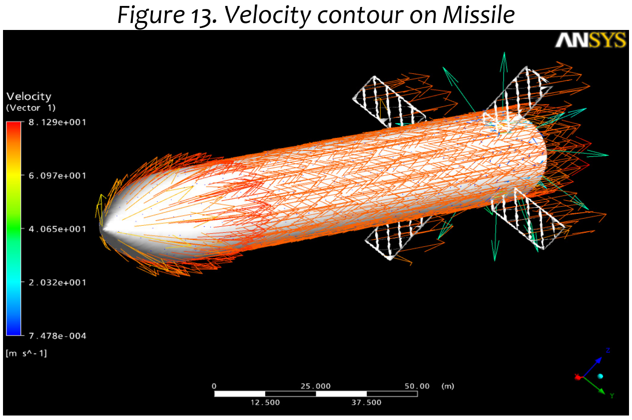

Figure 14.Velocity vector on Missile

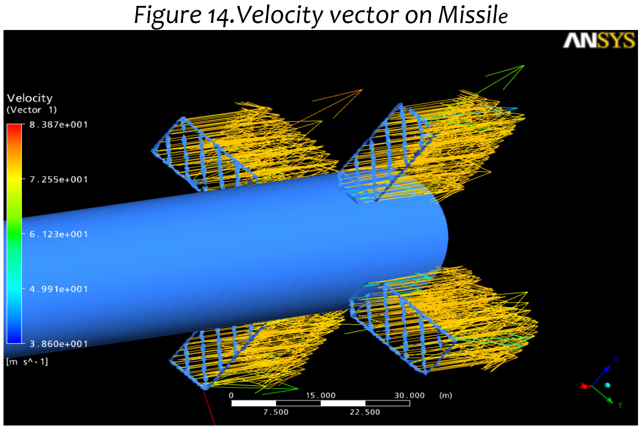

Figure 15.Velocity vector behind fins

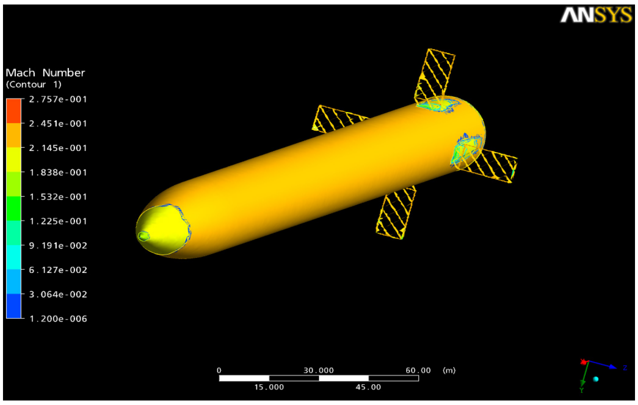

Figure 16. Mach Number contour on Missile

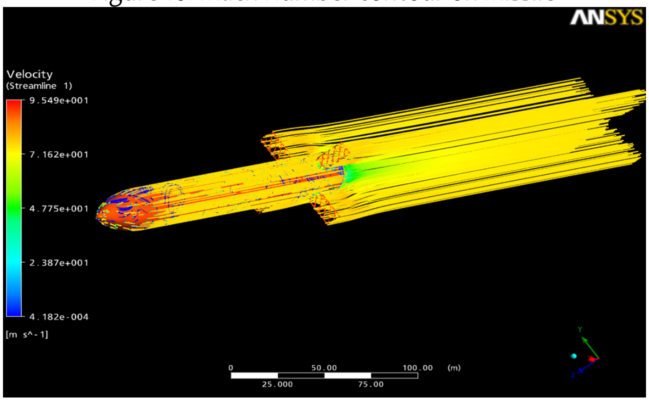

Figure 17. Stream Line Plot

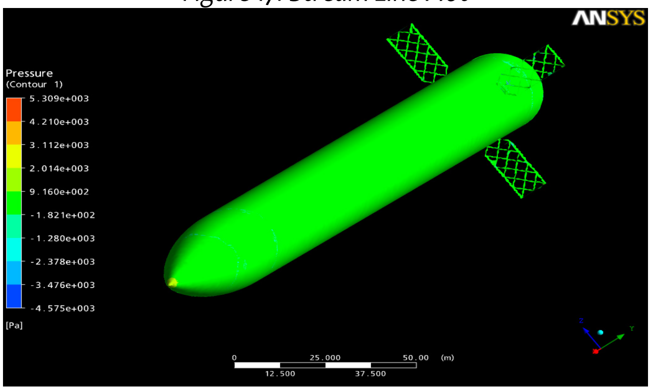

Figure 18. Static Pressure Contour On Missile

CONCLUSIONS

The velocity contour shows color which differs from region to region. The maximum velocity acceleration due to the presence of fins and the body dimensions were indicated in leading edge (front side-yellow color) and the ones which has maximum velocity decelerations were indicated in trailing edge(backside-blue color)as shown. Stream plot is drawn over the missile with grid fin to view the flow visualization for zero angle of attack. The average mach number over the missile is 0.21(i.e) subsonic as per as assumption. Thus, the flow over missile is found to be satisfactory.

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