Air Flow Simulation around a Bullet using OpenFOAM

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***Abstract*—This Report aims to describe the results obtained from the Airflow Simulation around a Bullet using OpenFOAM (Version-v1612+) and SonicFOAM as the solver.**

***Keywords*—Bullet,Supersonic Flows, OpenFOAM, LaTeX, sonicFoam.**

I. Introduction

We have used AK-47 Bullet for this simulation. An AK-47 bullet with its cartridge has dimensions of 7.62x39mm. This round rimless cartridge was developed during World War II by the Soviets. It functions well in temperatures ranging from -50 to 50 . The AK-47 rifles fired these bullets at speeds of about 750 m/s. For purpose of simplification, we have done performed 2D simulations for the AK-47 Bullet.

Figure 1: AK-47 Bullet

A. Geometry

The geometry of the AK-47 bullet was created using Solidworks and meshing was done using ANSYS. The total length of the geometry is 300 mm and the height is 75 mm . Within the geometry, a 2-D model of the bullet is placed. The bullet has a height of 6.73 mm and a length of 26.45 mm.

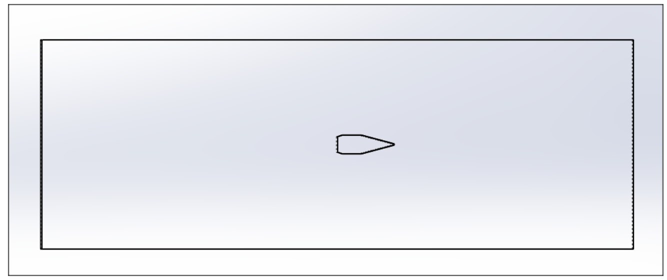


Figure 2: Model of Bullet with its computational domain

B. Meshing

The meshing for the simulation is done using ANSYS 16.1. The mesh were created with different sizing to check the effect of bullet sizing on the simulations and the values obtained. The main sizings used are 1mm , 0.9 mm and 0.8 mm.

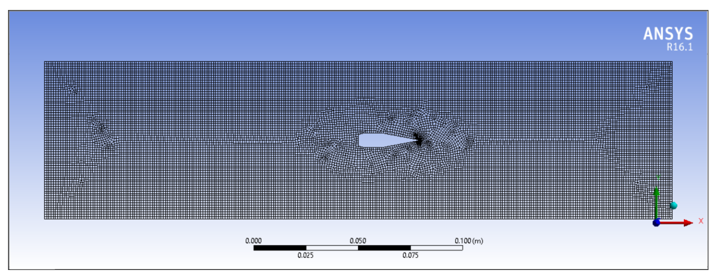


Figure 3: Side View of Mesh

II. ANALYSIS

The CFD analysis of the airflow over theAk-47 Bullet was done using the software OpenFOAM (Version-2.0).

A. Boundary Conditions

Air enters the computational domain at a freestream velocity of $u_\infty = 750 m/s$. Simulations for the bullet are done at velocities from Mach 2 to Mach 4.5 (1543.5 m/s) The Pressure outlet is kept fixed and at atmospheric pressure. The top and bottom surfaces were modelled as walls and the side faces were modelled as empty.

B. sonicFoam Solver

In this case, we wanted to analyze the transient turbulent flow of compressible gas (air) over a bullet surface, hence we have used sonicFoam solver. sonicFoam is a Transient solver for transonic/supersonic, turbulent flow of a compressible gas. This solver is based on the PIMPLE algorithm.

C. Thermo Physical Properties

The Following are the details on the properties of the surrounding fluid (air in this case) are used. They are entered in the file - thermophysicalProperties in the constant folder.

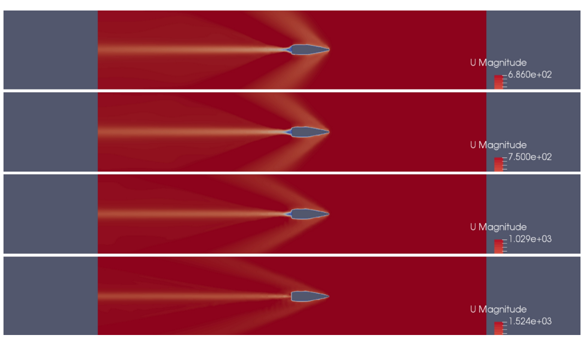
Molecular Weight	28.9
Cp	1005
Mu (Coefficient of Viscosity)	2e-05
Pr (Prandtl Number)	0.7

D. Simulations

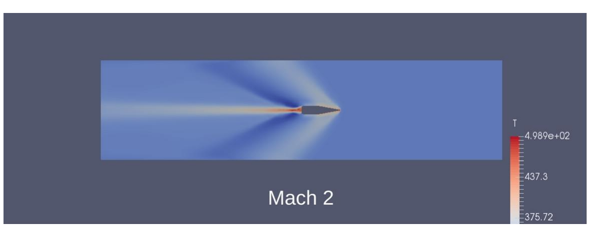
Simulations were majorly done for 3 grid sizes and 4 different free stream velocities. The time for simulations was found to have increased with decrease in the grid sizing. To convert the ANSYS mesh (.msh) files, the fluentMeshToFoam command was used. The following table gives details about the mesh parameters used in various simulations. The simulations gave the transient state values for pressures, velocity as well as temperatures for the air flow over bullet.

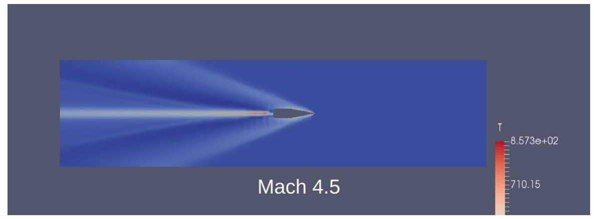
E. Flow Visualization

The period of simulation for the transient flow is given in the controlDict file. For many simulations the following are the details of the simulation



The following images show distribution of Temperature for various velocities.





III. Data Analysis and Results.

For all the Simulations the Boundary Layer Thickness in the external flows and the values of CD were the parameters that were measured. Boundary Layer Thickness refers to the distance from the body of the bullet to the point where the velocity of the stream reaches 99% of the free stream velocity.

A. Boundary Layer Thickness

Plot showing variation of boundary layer thickness with increasing velocity. Here we can observe that with the increase in free stream velocity of the simulation, the value of boundary layer thickness at a specific location decreases.

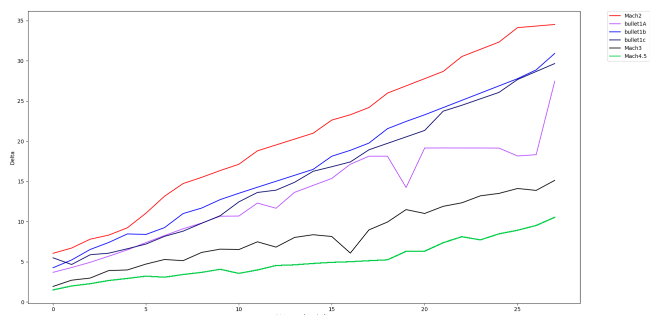


Figure 9 : Boundary Layer Thickness Plot

Also the graphs in shades of blue color indicate the same velocity but different mesh sizing. Bullet1a , bullet1b and bullet1c marks on the legend refers different mesh sizing being used with the number of nodes in each mesh increasing.
In the graph, we can observe that the variations between bullet1b and bullet1c are quite less if compared with bullet1a. Hence on increasing the mesh sizing and with more nodes, the values obtained as a result of simulations have less errors and also tend to the actual solutions.

B. Coefficient of Drag

$$Cd = \frac{D}{0.5 * \rho * V^2}$$

The following graph shows variation of drag coefficient over the body during the duration of the simulation. In this graph, we can observe that with increasing free stream velocity, the maximum value of the drag coefficient decreases.

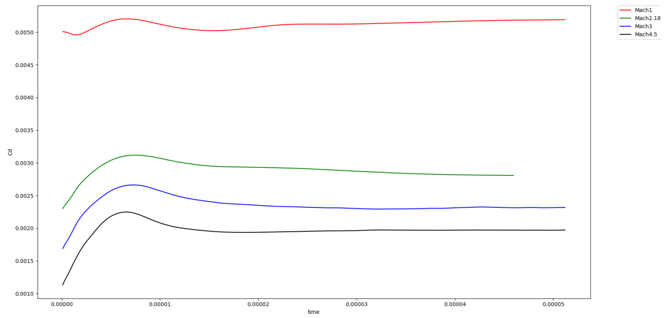


Figure 9 : Variation of Cd with Time

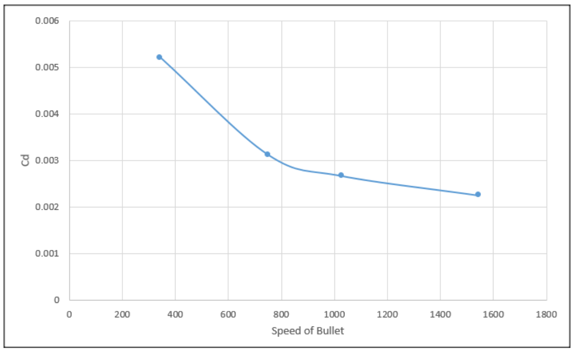
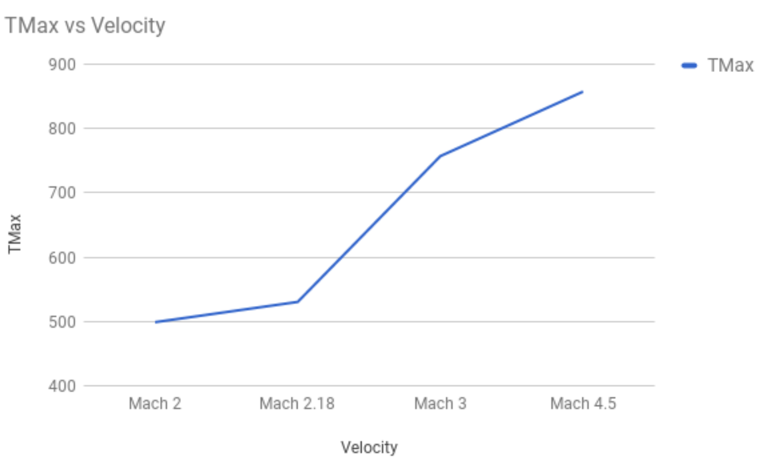


Figure 10 : Variation of Cd with Speed of Bullet

C. Temperature

The following graph gives the relationship between maximum Temperature and the free stream velocity



From the above graph, we can conclude that the maximum temperature increases with increase in the speed of the bullet.

Reference

[1] https://cfd-freelancing.com/portfolio/bullet-