ELK ASIA PACIFIC JOURNAL OF MECHNICAL ENGINEERING AND RESEARCH
ISSN 2349-9368(Online) EAPJMER /ISSN.2454-2962/2016;Volume 6 Issue 2 (2020)

# DESIGN AND ANALYSIS OF BULLET BY USING CFD AND EXPLICIT DYNAMICS

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**ABSTRACT**

*This article aims to present the best design iterations of the bullet by changing the shape of the bullet to enhance its accuracy and stability by reducing drag force. To check the results, CFD and Explicit Dynamics are utilized as a tool because it provides most accurate results and observed much improvement in the behaviour of the bullet in the air at its maximum traveling velocity approximate 890 m/s, conjointly tested the impact of the most improved designed bullet on concrete wall. This work shows the flow of air around the bullet surface creating pressure & velocity contours, streamline flow which shows the difference between the various designs. Finally, velocity & pressure of air at every segment, drag force of the bullet body are to be noted and also the impact of the bullet on the wall is obtained.*

**Keywords: -** Bullet (7.62mm), CFD fluent, drag force, Explicit Dynamics, Impact force, Thrust force.

## Introduction:

In case of bullet many factors that affect the stability and accuracy in the motion of the bullet to reach it towards the targeted position so there should be an approach to minimize an error and to make the motion of the bullet stable so there is a thought about some possible improvement can be done on the bullet design. Here the original design of the 7.62 bullets is being tested and then by modifying its design, the difference is to be observed that which works better in comparison with other design iterations. The velocity and pressure contour and streamline flow around the body of the bullet by using CFD fluent. By this, the improved shape of the bullet with lesser drag will help to improve the aerodynamic shape and stability of the bullet. The impact test of the bullet with a pointed tip and blunt tip on the concrete sheet is to be checked & a better one will create more damage on the wall.

## Literature Review:

1. This literature shows a part of a larger research effort to characterize the aerodynamic performance of finned shaped bullet (FSB) and design them to achieve the best performance for various requirements of different types of missions. The FSB structure is made to be fired from smoothbore gun barrels, once the lightweight weapon is desired to extend the accuracy of putting the bullet on a target from long vary (*e.g. 2000 meters and beyond*). It's a self-guided to a target lighted by an optical device target designator. To

compute the control effects of micro-actuators, a series of CFD simulations were performed to finish the study of the pre-program feasibility for the FSB aerodynamic configuration which can provide the control authority. The rare micro-actuator for FSB is selected because of the main subject used for all mechanism simulation and prediction studies throughout this paper. [1]

2. The major interest of this literature is to analyse the effect of flow over the bullet and advantage of its shape in terms of range and penetration. Therefore, here different shapes are taken and tried to analyse the flow over the geometries. [2]

**Research and methodology:**

The designs of the bullets have been developed by using NX software. The dimensions used are according to the dimensions of 7.62*39 mm bullet (Fig.1) then tried to modify it accordingly. The design requirements of the bullet should be according to its dimension so that it could easily be used in all 7.62 mm supportive weapons & helps to improve the ability of the weapon.

Drag force plays a vital role to scale back to reduce the efficiency of the bullet. Drag force is the force that opposes the body to travel in fluid through this force is generated when the solid body moves in the fluid at a certain velocity; it is aerodynamic friction on the body. When air flows over anybody it creates a disturbance in the flow of velocity and pressure over the body and induces the change in momentum of the molecules and the forces are produced. The magnitude of the force can be determined by integrating the local pressure times the surface area around the entire body. The aerodynamic force of the body that is opposed to the motion is the drag; the lift is the component perpendicular to the motion, both the lift and drag force act through the centre of pressure of the object [3].

The Drag force is depending on the following parameters:

1) The shape of the body: Size & Shape of the body

2) The motion of fluid: Velocity and the inclination of the body towards the flow

3) The fluid itself: Viscosity, Mass & Compressibility of the fluid

A force acting on the body while traveling in the air that helps to balance the drag force-generating on the body, these forces make easier to understand & gives some insight knowledge. In an ideal situation, a body could sustain a constant speed and level flight in which the weight would be balanced by the lift and the drag would be balanced by the thrust. The closest example of this condition is airliner.

The weight of the aircraft decreases as fuel burns, the change is very small relative to the total weight of aircraft. In this situation, the aircraft will maintain a constant velocity as per Newton's first law of motion.

$F = m * a$; where,

a: acceleration,

m: a mass of the body,

F: net force acting on the body.

When the weight is decreased while the lift held constant, the body will rise:

Lift > Weight - Body Rises

When the lift is decreased while the weight is constant, the body will fall:

Weight > Lift - Body Falls

Similarly, increasing the thrust while the drag is constant will cause the body to accelerate:

Thrust > Drag - Body Accelerates

And increasing the drag at a constant thrust will cause the body to slow down:

Drag > Thrust - Body Slows [4]

So, in bullet the weight is compensated by using different materials to it usually bullet is composed of two different parts Shell (Jacket) & Core. The shell is made of hard material and the core is made of bit softer or lighter material. Materials like lead and lead alloy are mainly used for the core as it is lighter in weight and density. Jackets are made of copper or gilding metal, an alloy of copper and zinc including bronze, aluminium, plastic, rubber steel, tin tungsten, bismuth [5].

Harder the material of the bullet further it penetrates and softer the material greater the impact of the bullet by expanding on the targeted body, change in the properties of the jacket alters the amount of expansion and the penetration phenomena of the bullet or it can be said that heavier the bullet greater the penetration. In bullet different parts are made differently such as:

1) The nose of the bullet can be sharp, blunt, or flat for the amount of penetration required.

2) Shank of the bullet can be cylindrical, tapered, grooved.

3) Body Tail can be flat, tapered, or grooved for greater accuracy and precession.

Following are the design iterations have been shown up:

1) Bullet 1 shown in Fig. 2 is the normal and simplest design of the bullet and is commonly used in rifles.

2) Bullet 2 shown in Fig. 3 having fins are been added on the shank portion.

3) Bullet 3 shown in Fig. 4 shows fins with positive curvature on the shank diameter at the end and to the required diameter. To keep the diameter unaffected fin size and curvature are extended to limit.

4) Bullet 4 shown in Fig. 5 shows negative curvature is added at the end & with the more pointed tip.

5) Bullet 5 shown in Fig. 6 shows fins added on the curved surface.

6) Bullet 6 shown in Fig. 7 shows a bullet continuous twist and tapered to the shank portion.

**Results and Analysis:**

Now the CFD fluent is used to see the effect of the airflow on the following bullets and it takes the following steps to get results.

1. Geometry:

In this step the geometry is to be imported in the STEP file from the NX Software then the enclosure is to be made around the body and Boolean operation is to be applied between the enclosure and the bullet.

2. Meshing:

The meshing of the object is to be created by using the tetrahedral method so it divides the body into multiple numbers of nodes and elements, that help the software to perform its calculation according to it. Then different boundary conditions are to be applied on different faces of the enclosure. The meshing of the bullet shown in Figure 8 & Table 1 shows meshing input.

After meshing of all different bullets number of nodes and elements is to be determined. Table 2 shows nodes, elements, and domain of all bullets & Table 3 shows boundary conditions.

3. Setup:

The solution is based on pressure and absolute velocity formulation with steady time.

In Models multiphase is off, energy is on, viscous is laminar, and else are off.

In materials Fluid is air and solid is aluminum.

Cell zone conditions are solid with fluid type.

The solution method is simple solution initialization is hybrid.

Boundary conditions are the same for all the Bullets in traveling fluid (air).

4. Results of CFD:

In results the contour on a plane placed on to axis of the bullet, the streamlines start from the Isosurface with sampling at face centre, and variable subjected to velocity & pressure in a forward direction a shown.

Results in numbers and figures are provided in Appendix A & Appendix B showing a difference in thrust produced by different bullets which leads to drag performance of the bullet.

5. Information collected from the explicit dynamics simulation:

In an explicit dynamic test, bullet 2 & bullet 4 are tested because of the major difference in designing the tip of the bullet to test penetration and damage done on the wall by the bullet. Table 4 shows statistics of bullets, Table 5 shows the material of bullets, Table 6 shows meshing information, Table 7 shows definitions, Table 8 shows step control, Table 9 shows the result of explicit dynamics.

The below Fig.9, Fig.10, Fig.11 & Fig.12 shows the amount of Equivalent elastic strain, Total deformation was done by these two bullets on the wall with similar inputs and is observed that the bullet 4 is better than the bullet 2 in terms of penetration because of the major difference in the design. In Fig. 10 and Fig. 11, the isosurface view of equivalent stress is provided to watch closely the amount of stress generated by the bullet on the wall.

**Conclusion:**

From all results, the main focus is on overall configuration and the aerodynamic behaviour of the bullet while traveling in air at a velocity of 890m/s with and without the fins on the bullet as there are series of computational fluid dynamics simulations of all 6 bullets are done and the difference in the flow path of air streamlines is been identified.

1) The thrust forces produced by the bullet is as follows: Bullet 5 > Bullet 3 > Bullet 4 > Bullet 6 > Bullet1 > Bullet 2. The improved aerodynamic shape is with Bullet 5 as it produces a more thrust force and thus produces lesser drag force.

2) The fins provide a higher spin rate to the bullet hence it makes the bullet more stable and accurate as a result of simulation of streamline flow over the bullet.

3) It is also concluded that sharper the nose of bullet greater the penetration in the wall under the same input conditions with the impact or the total deformation comparison between bullet 4 and bullet 2.

**References:**

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**List of Figures:**

ISSN 2349-9368(Online) EAPJMER /ISSN.2454-2962/2016;Volume 6 Issue 2 (2020)

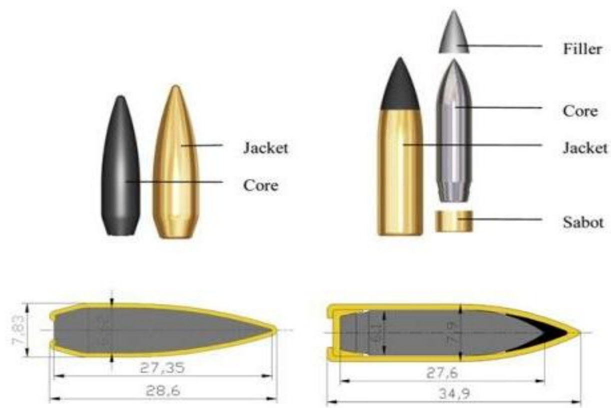



**Figure 1: Original dimensions of 7.62*32 bullets with body parts [4]**

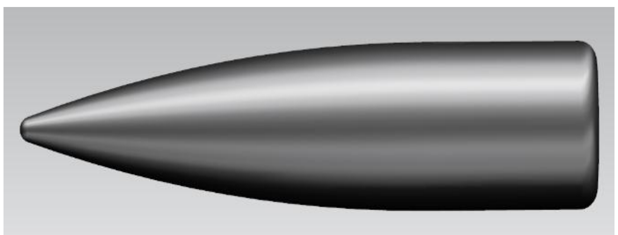


**Figure 2: Bullet 1**

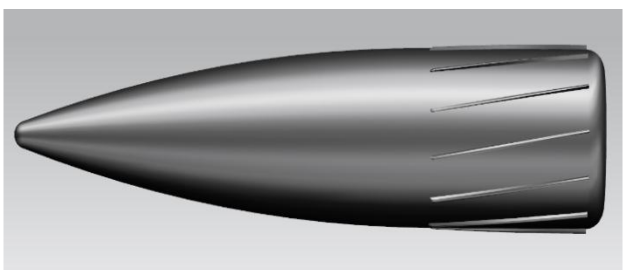


**Figure 3: Bullet 2**

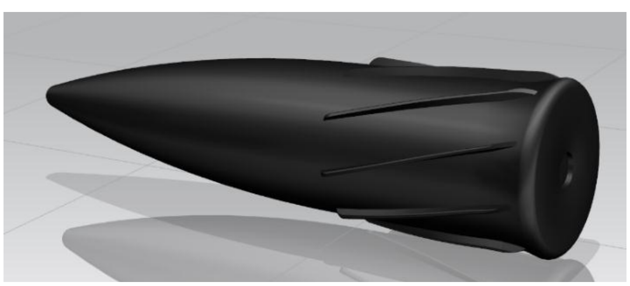


**Figure 4: Bullet 3**

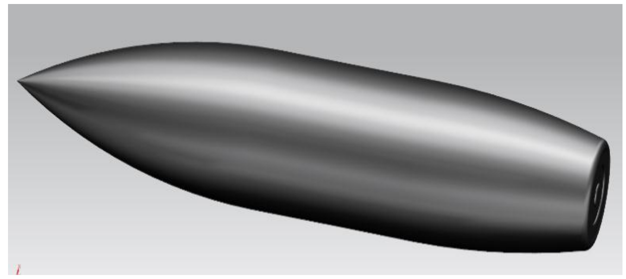


**Figure 5: Bullet 4**

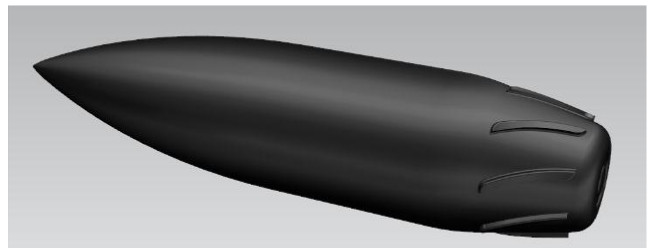


**Figure 6: Bullet 5**

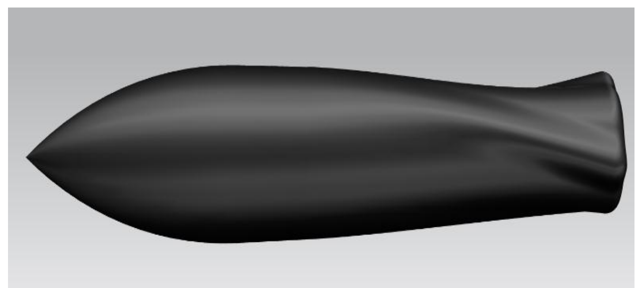


**Figure 7: Bullet 6**

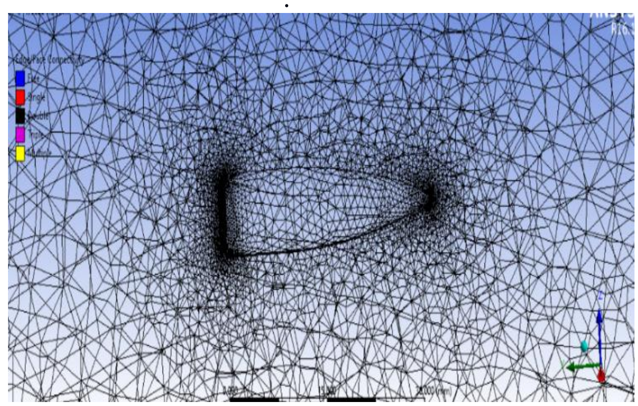


**Figure 8: Meshing of body**

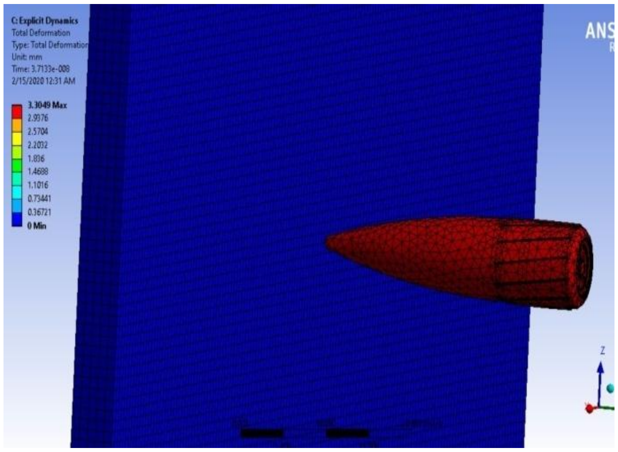



**Fig 9: Total deformation of bullet 2**

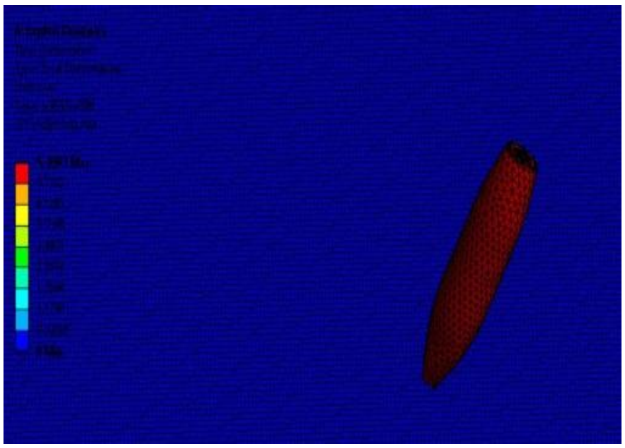


**Fig 10: Total deformation of bullet 4**

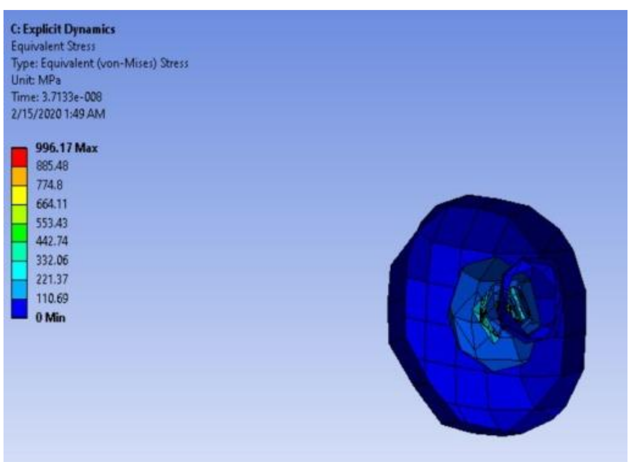



**Fig 11: Equivalent Stress of Bullet 2 Isosurface view**

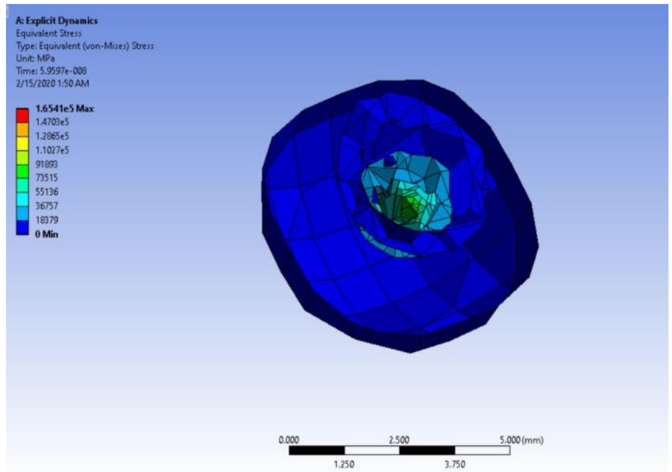



**Fig 12: Equivalent Stress of Bullet 4 Isosurface view**

## List of Tables:

| Sizing | |
|---|---|
| Use Advance Size Function | On: Curvature |
| Relevance Centre | Medium |
| Initial Size Seed | Active Assembly |
| Smoothing | Medium |
| Transition | Slow |
| Span Angle Centre | Fine |
| Curvature Normal Angle | Default (18.0”) |
| Min Size | Default (4.1743e-002 mm) |
| Max Size | Default (8.34860 mm) |
| Growth Rate | Default (1.20) |
| Minimum Edge Length | 3.65620 mm |
| Inflation | |
| Use Automatic Inflation | None |
| Inflation Option | Smooth Transition |
| Transition Ratio | 0.272 |
| Maximum Layers | 5 |
| Growth Rate | 1.2 |
| Inflation Algorithm | Pre |
| View Advance Options | No |

**Table 1: Meshing Input**

| Bullet No. | Bullet 1 | Bullet 2 | Bullet 3 | Bullet 4 | Bullet 5 | Bullet 6 |
|---|---|---|---|---|---|---|
| Nodes | 91153 | 139904 | 308016 | 20308 | 54849 | 156542 |
| Elements | 496686 | 767928 | 168586 | 98320 | 254032 | 851995 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 0 | | | |
| Domain | Solid | Solid | Solid | Solid | Solid | Solid |

**Table 2: Meshing Results**

| Boundaries | Type | Domain |
|---|---|---|
| Boundary - inlet | Velocity inlet (890 m/s) | Solid |
| Boundary - outlet | Pressure outlet | Solid |
| Boundary - wall | Wall | Solid |
| Boundary - wall solid | Wall | Solid |

**Table 3: Boundary Conditions**

| | |
|---|---|
| Bodies of bullets | 3 |
| Active Bodies of bullets | 3 |
| Nodes of bullet 2 | 186139 |
| Elements of bullet2 | 163088 |
| Nodes of bullet 4 | 275991 |
| Elements of bullet 4 | 237584 |
| Mass of bullet 2 | 0.34791 kg |
| Mass of bullet4 | 0.52147 kg |

**Table 4: Statistics of Bullets**

| | Jacket | Core | Wall |
|---|---|---|---|
| Bullet materials | Stainless steel | Magnesium | Concrete |

**Table 5: Material of Bullets**

| | Sizing of bullet 2 | Sizing of bullet 4 |
|---|---|---|
| Use Advanced Size Function | Off | Off |
| Relevance Centre | Medium | Medium |
| Element Size | 1.0 mm | 1.0 mm |
| Initial Size Seed | Active Assembly | Active Assembly |
| Smoothing | High | High |
| Transition | Fast | High |
| Span Angle Centre | Medium | Medium |
| Minimum Edge Length | 1.4015e-004 mm | 2.84240 |

**Table 6: meshing information**

| | |
|---|---|
| Input Type | Velocity |
| Coordinate System | Global Coordinate System |
| X Component | 0. mm/s |
| Y Component | -8.9e+007 mm/s |
| Z Component | 0. mm/s |

**Table 7: Definitions**

| | |
|---|---|
| Resume from Cycle | 0 |
| Maximum Number of Cycles | 100 |
| End Time | 1. s |
| Maximum Energy Error | 0.1 |
| Reference Energy Cycle | 0 |
| Initial Time Step | Program Controlled |
| Minimum Time Step | Program Controlled |
| Maximum Time Step | Program Controlled |
| Time Step Safety Factor | 0.9 |
| Characteristic Dimension | Diagonals |
| Automatic Mass Scaling | No |

**Table 8: Step Control**

| Bullets | Equivalent elastic strain | Equivalent (von-Mises) Stress | Total deformation |
|---|---|---|---|
| Bullet 2 maximum | 0.19542 mm/mm | 996.17 MPa | 3.3049 mm |
| Bullet4 maximum | 1.8435 mm/mm | 1.6541e+005 MPa | 5.3083 mm |

**Table 9: Result of Explicit Dynamics**

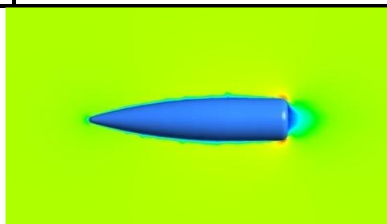
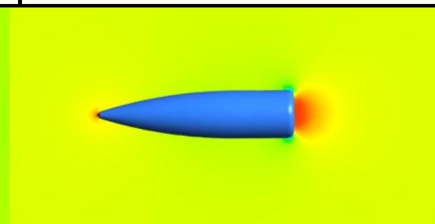
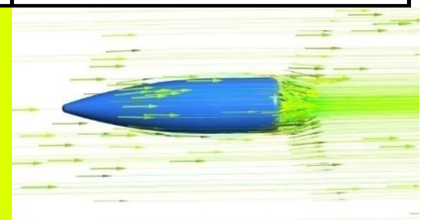
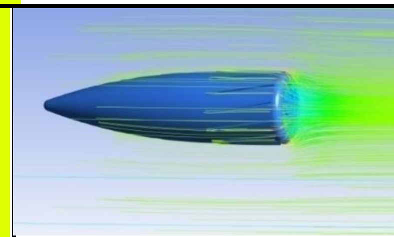
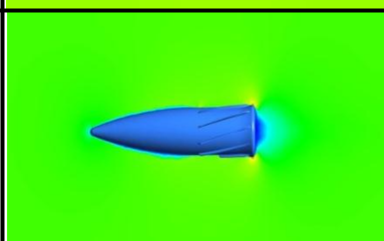
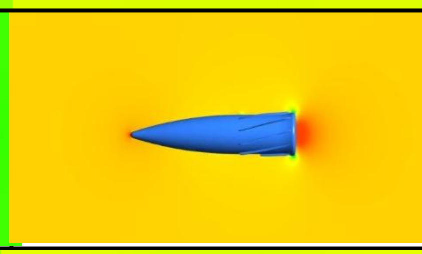
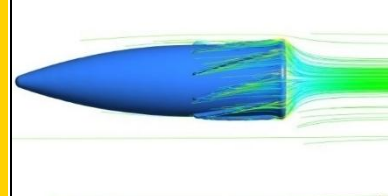
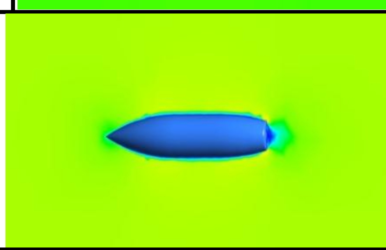
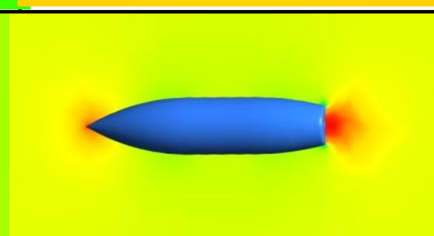
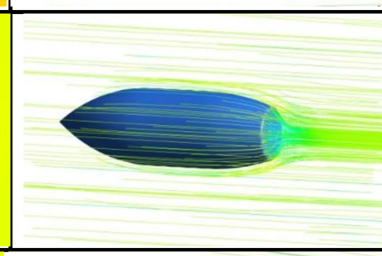
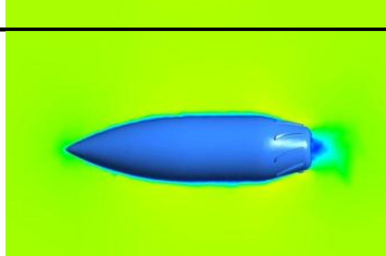
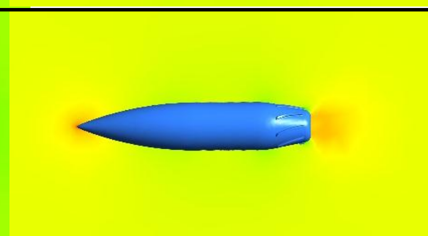
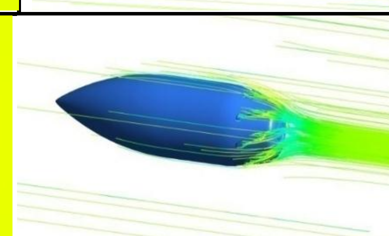
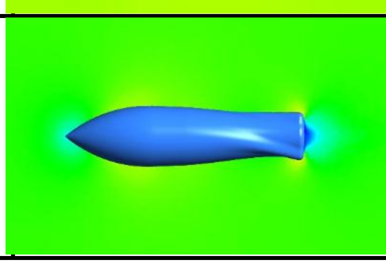
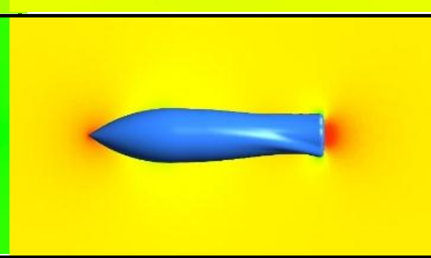
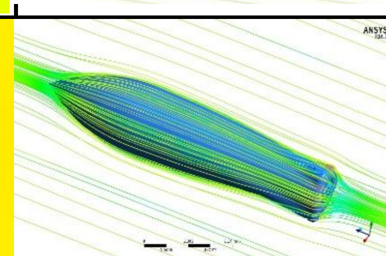
**Appendix A**

The following table shows the different values of velocities and pressure at different places:

| Sr no. | Bullet 1 | Bullet 2 | Bullet 3 | Bullet 4 | Bullet 5 | Bullet 6 |
|---|---|---|---|---|---|---|
| Velocity at nose [m/s] | 6.231e+02 | 6.231e+02 | 2.973e+02 | 6.386e+02 | 6.436e+02 | 522.385 |
| Velocity at top end [m/s] | 1.184e+03 | 1.184e+03 | 1.460e+03 | 1.093e+03 | 8.765e+02 | 1129.01 |
| Velocity at end centre [m/s] | 4.237e+02 | 4.237e+02 | 1.556e+02 | 8.316e+02 | 7.276e+01 | 89.7507 |
| Pressure at nose [Pa] | 2.393e+05 | 2.393e+05 | 3.767e+05 | 2.162e+05 | 2.194e+05 | 308160 |
| Pressure at top end [Pa] | -3.527e+05 | -3.527e+05 | -8.267e+05 | -1.874e+05 | -1.886e+05 | -288998 |
| Pressure at end centre [Pa] | 3.461e+05 | -3.527e+05 | 3.194e+05 | 6.174e+04 | 1.485e+05 | 332330 |
| Maximum velocity [m/s] | 1382.250 | 1454.77 | 1647.129 | 1403.465 | 1417.62 | 1690.74 |
| Minimum velocity [m/s] | 0 | 0 | 0 | 0 | 0 | 0 |
| Maximum pressure [Pa] | 418161.875 | 443596.625 | 411512.250 | 340513.625 | 423578.50 | 401111 |
| Minimum pressure [Pa] | -1001800.000 | -1069160.00 | -1794960.00 | -855997.00 | -1101340.00 | -1.39922e+06 |
| Thrust by Bullet [N] | 0.739423 | 0.536862 | 1.98679 | 1.48342 | 2.58431 | 1.34584 |

**Appendix B**

And the following results by doing a series of computational fluid dynamics simulations to the bullets have been

| Bullet No. | Velocity contours | Pressure contours | Streamline flow |
|---|---|---|---|
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |   |

obtained.