Numerical and Experimental Analysis of Drag and Lift Forces on a Bullet Head

Drilling is performed at the rear side of the bullet head from the radial drill. The jig is mainly used for guiding the cutting tool and the fixture is used to support the cutting tool. To avoid slanting and dislocation during the drilling operations both jig and fixtures (hole and busing) are used and machining operations are performed by efficient and experienced machinists. Drilling is performed just to Aline or regulates the explosion of the gun power towards the bullet head. Following are some pictures of the drilling operations along with the utilized jig and fixtures.

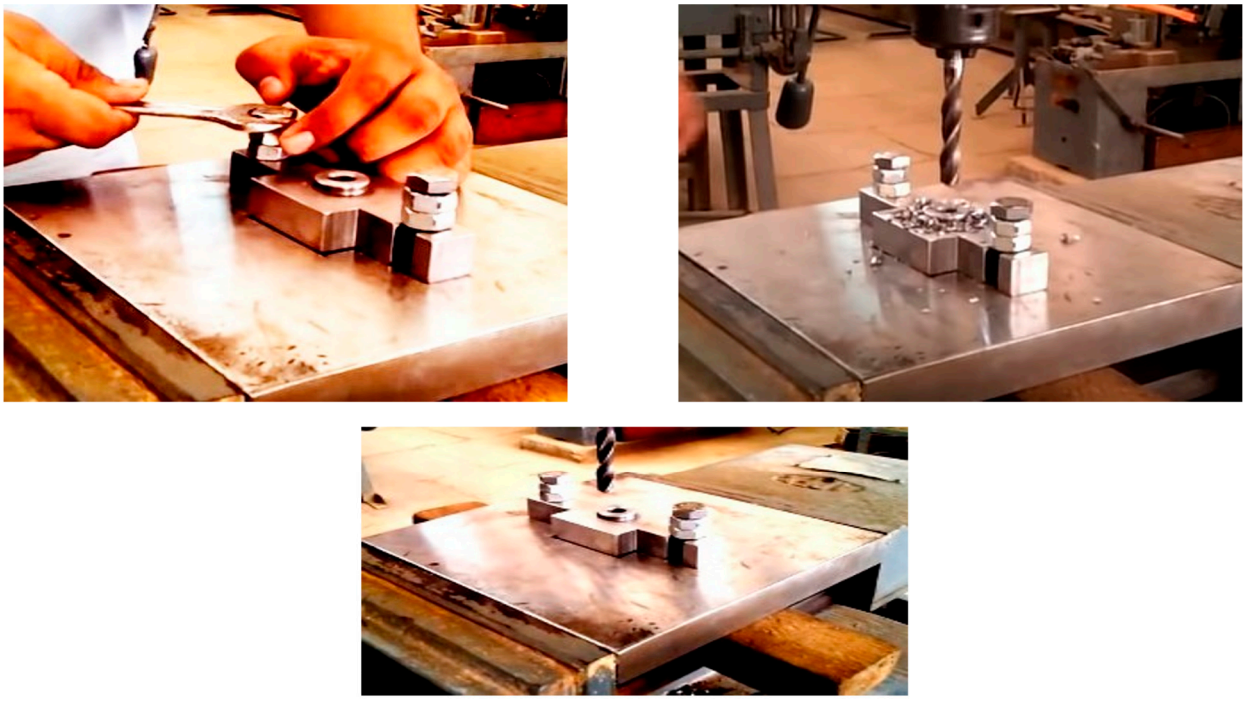

Figure S1a. Jig and Fixture utilized in the drilling

Procedures that are adopted for the fabrication of the bullet heads are described in the following lines.

- **Parting** (Cutting of the aluminum rod into the required dimensions) is performed at the lathe machine.
- **Turning** (To adjust the diameter to the required dimensions) is performed by the CNC lathe machine.
- **1st Taper Turning** (To Aline the diameter at the significant taper) performed at the CNC milling machine.
- **2nd Taper Turning** (To Aline the diameter at the minor taper) is performed at the CNC milling machine.
- **Champer Turning** (To machine the tip of the bullet head) is performed at the CNC milling machine.

Following are some pictures of the machining of the bullet heads.

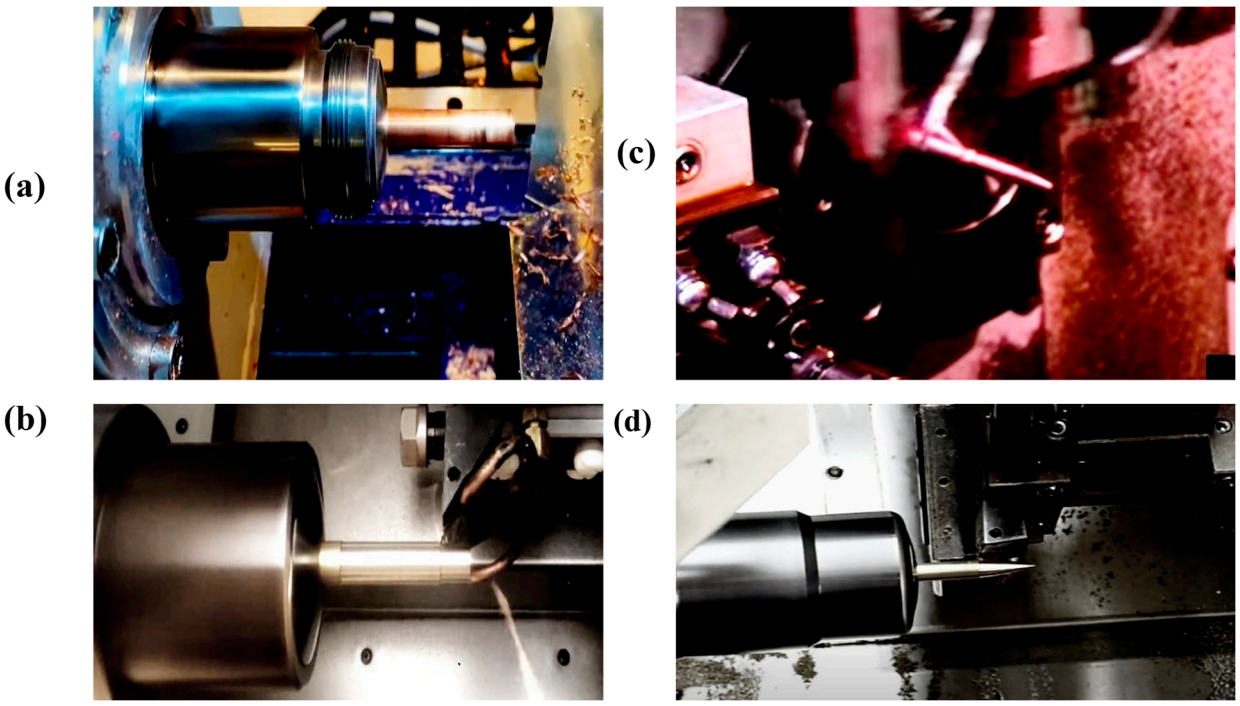

Figure S1b. Multiple processes in the fabrication of the bullet head

$$A_{Total} = Total\ Active\ Projected\ Area\ (A_1 + A_2 + A_3 + \cdots) \qquad \textbf{(a)}$$

The following equation calculates the total area by considering the bullet as a combination of different shapes.

$$Area = \frac{\pi r^2}{2} + (2\pi r) * (r + h) + \frac{h(a+b)}{2} + \pi r^2 + \pi rs + \pi r^2 + \pi rs \qquad \textbf{(b)}$$

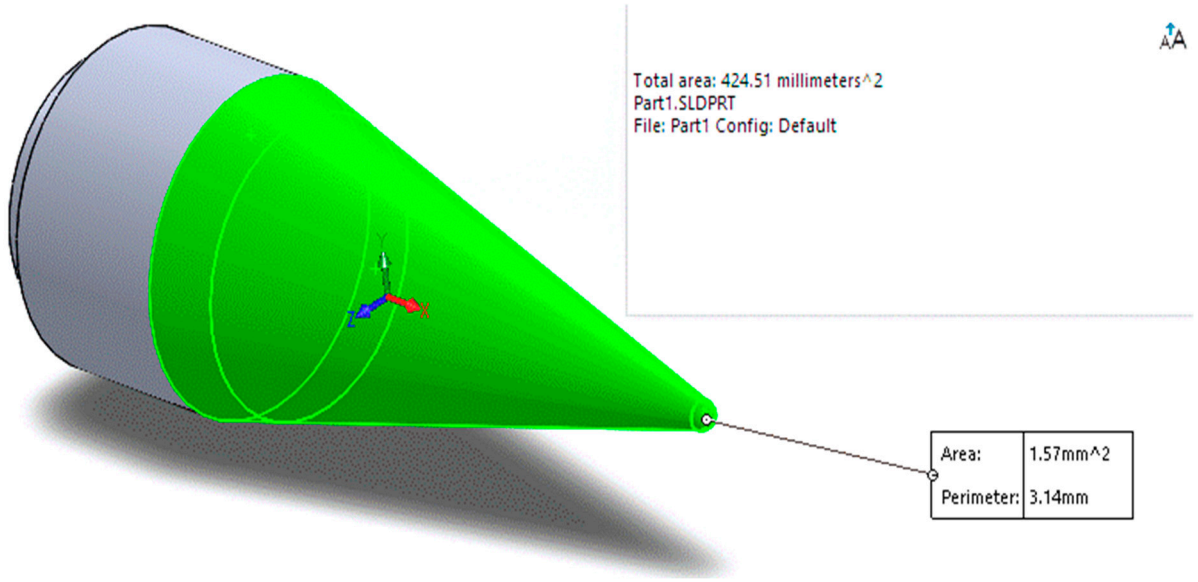

Figure S2 Projected area of Design I by SOLIDWORKS.

The projected area of each bullet head segment was calculated by CAD modeling in SOLIDWORK software (Fig. 5a and Fig. 5b). Bullet heads were sectioned into 30 strips, and a 3D drawing was drawn to attach the top and bottom of the projectiles. The area of all segments was not considered as they could not be seen from the front of the plane facing the wind. Hence, the pressure difference in those areas varied due to turbulence and was not reliable.

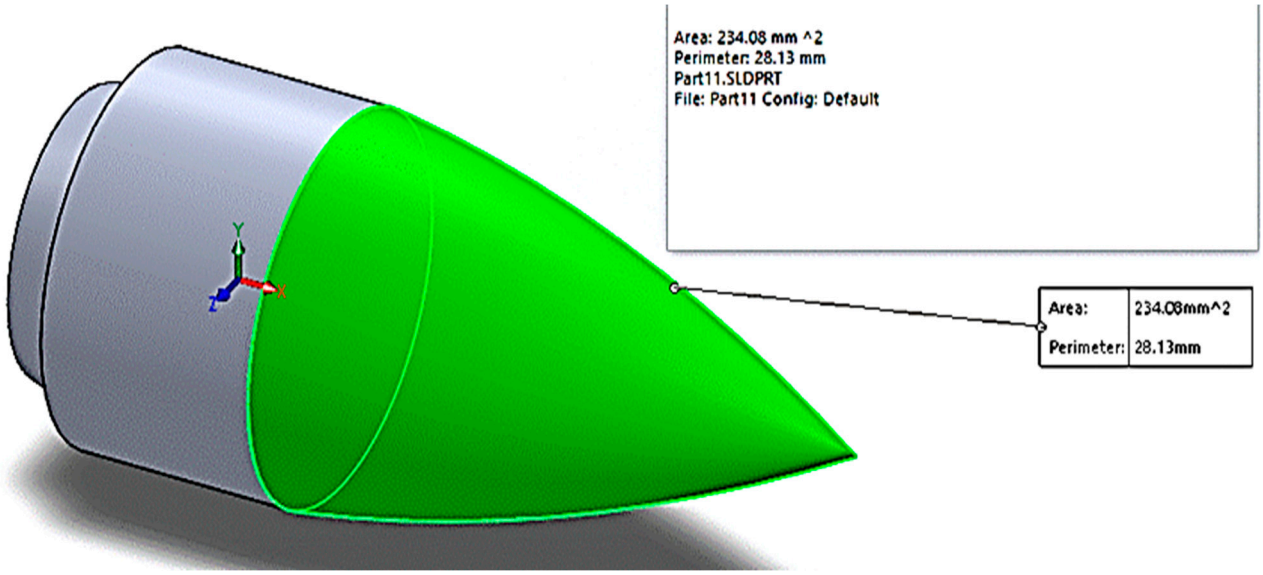

Figure S3 Projected area of Design II by SOLIDWORKS.

Experimental Methodology

A bullet head is clamped in a wind tunnel with the help of a thin aluminum road inserted along the axis of a head in the same way as in a real framework. A wind tunnel test helps in verifying the numerical results with an experimental one and identifies the areas where improvement is required. The **TA 300/ 300 C** wind tunnel is computer controlled subsonic wind tunnel it is operated easily with the help of a computer**.** The authors have measured the lift and drag forces of both the geometries of a bullet in a wind tunnel by the following steps.

1. Switch on the power supply and open the **SCADA** software on the computer.
2. Open the home interface of a SCADA and then select the surface force module.
3. In surface forces, select the drag force as the x-axis force and the lift force as the y-axis force.
4. The angle of attack of a bullet head in the wind tunnel is changed manually by changing the orientation of its clamping.
5. Switch On the actuator and adjust the velocity of air by rotating the knob that appeared on the screen.

6. Analyze the convergence graph to validate that the measured results are accurate.
7. At least take two or three readings at each angle of attack to reduce the chances of error.

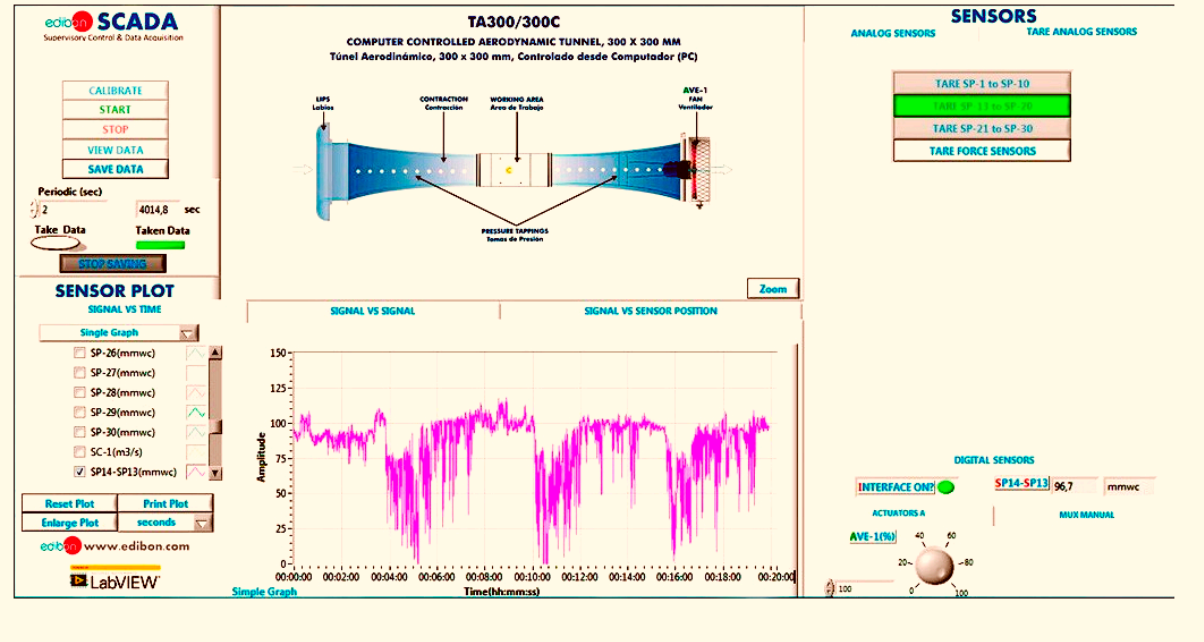

Figure S4. SCADA interface of the Wind Tunnel

Figure S5. Bullet head clamped in the wind tunnel

Whereas the specifications of the experimental apparatus are determined in the following table.

Table S1. Specifications of the Wind Tunnel T300/300C

Specification	**Detail**

Brand	Edibon
Operating Range	Ranging from the 0.1 to 0.9 Mach Number
Working	Replicate the flow by blowing high-pressure air on it.
Specimen Dimensions	The specimen diameter must be less than 12 inches and the object mass must be less than 400 grams.
Operating System	Supervisory control and data acquisition (SCADA) is a control system comprising computers, networked data communications, and graphical user interfaces for high-level supervision of machines and processes.
Controls	Totally operated and controlled by the computer whereas the orientation of the the specimen is changed manually by adjusting its clamping according to the flow.
Accuracy	To assure the precision in the results every single experimental value is noted by performing the experimentation three times and then its average is taken.
Blockage Effect	The blockage effect of the wind tunnel is reduced by decreasing the fan cross-section

	area and by enhancing the wind tunnel cross-section area.

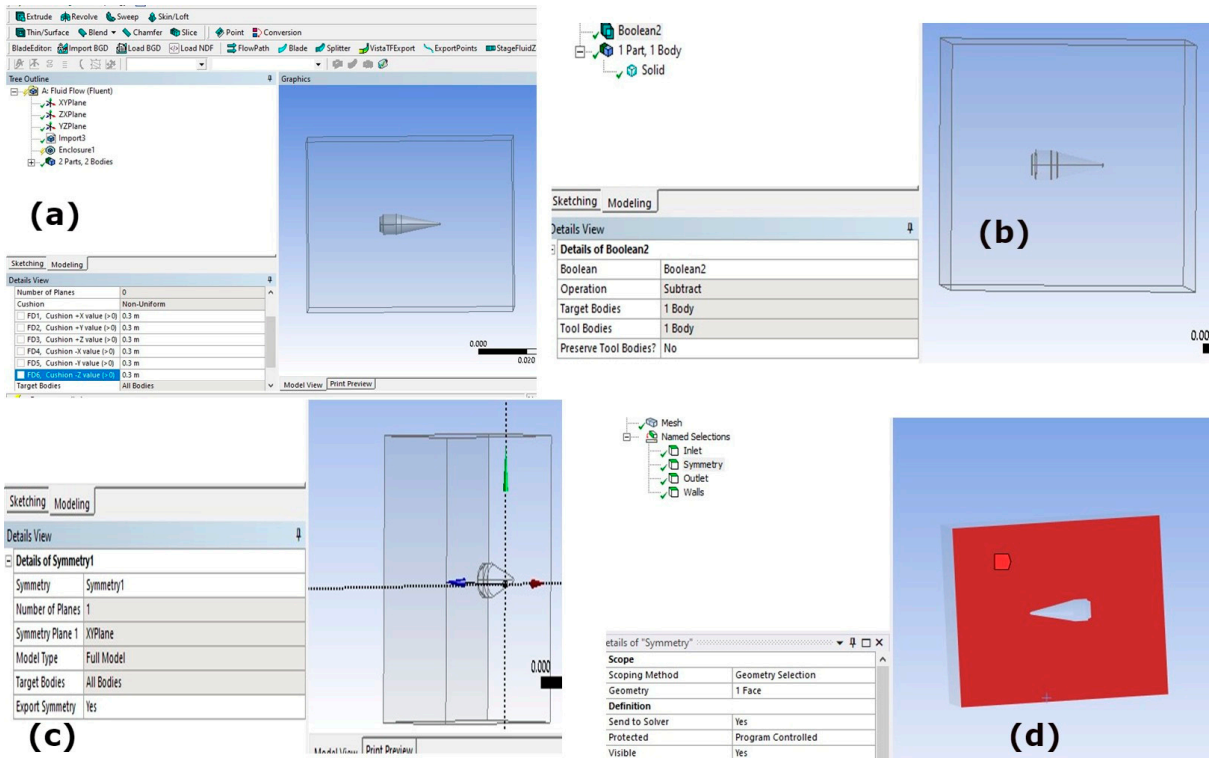

Figure S6 (a) Enclosure accomplishing **(b)** Boolean creation **(c)** Applying symmetry **(d)** Applying the boundary conditions

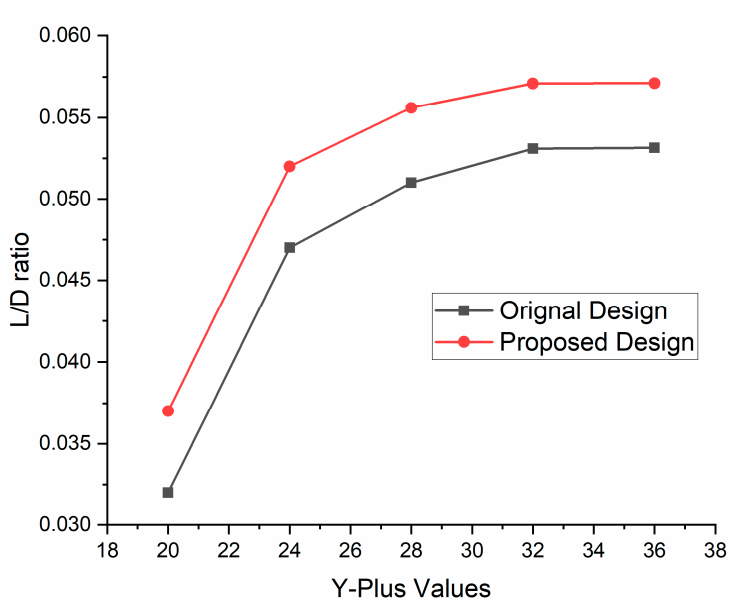

Figure S7. Line plot of the y+ values against L/D ratio

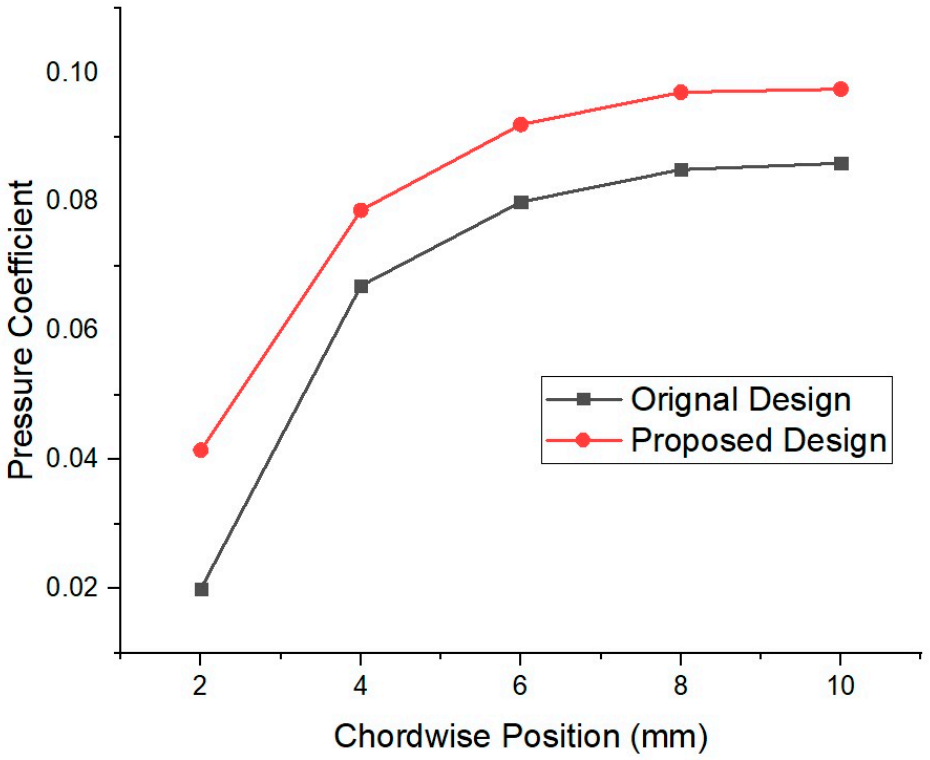

Figure S8. Distribution of the pressure coefficient along the chordwise bullet length