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ACTIVE AERODYNAMICAL FIN OPTIMIZATION PGK FUZE IN 155MM ARTILLERY SHELLS

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Abstract : The Precision Guidance Kit (PGK) revolutionizes conventional 155mm artillery by converting unguided shells into smart munitions. This is achieved by replacing the standard fuze with a PGK unit that integrates a Global Positioning System (GPS) receiver and aerodynamic fins. This innovation dramatically reduces the Circular Error Probable (CEP) from over 200 meters to under 50 meters, often reaching as low as 10 meters. Such enhanced precision significantly boosts battlefield effectiveness, reduces ammunition expenditure, and alleviates logistical burdens. For safety, a crucial fail-safe mechanism disarms the fuze if GPS signal is lost or the round deviates off-course, minimizing collateral damage. The PGK provides near-precision accuracy, comparable to more expensive fully guided systems, at a substantially lower cost by retrofitting existing ammunition stockpiles. Its affordability and ease of integration establish the PGK as a vital asset for modern artillery, enhancing both precision and sustainability for military operations.

IndexTerms **- PGK (Precision Guidance Kit), 155mm Artillery Shells, Aerodynamic Fins, Fin Optimization, Active Control, Guidance and Control (G&C), Trajectory Correction, Course Correction.**

I. INTRODUCTION

Precision Guidance Kit (PGK) - The **Precision Guidance Kit (PGK)** fuze is a GPS-enabled guidance system that transforms conventional artillery rounds into precision-guided munitions. Designed primarily for 155mm shells such as the M795 and M549A1, the PGK replaces the standard fuze and incorporates GPS technology and aerodynamic control surfaces (fins or canards) to steer the shell toward its target during flight.

This guidance capability dramatically improves accuracy. Traditional unguided artillery rounds can have a circular error probable (CEP) exceeding 200 meters at long range, which means a large area must be targeted to ensure a hit. With PGK, the CEP is reduced to less than 50 meters, often reaching as low as 10–30 meters. This allows forces to engage targets more precisely, using fewer rounds and reducing collateral damage.

The PGK also includes a built-in fail-safe mechanism. If the GPS signal is lost or the shell drifts too far from its intended trajectory, the PGK will prevent the round from detonating, further enhancing battlefield safety and limiting unintended damage.

One of the key advantages of PGK is cost-effectiveness. Instead of procuring new guided artillery systems like the more expensive M982 Excalibur, militaries can retrofit existing stockpiles with PGKs to gain near-precision capability. This reduces logistics burdens and allows artillery units to adapt quickly to evolving battlefield needs.

Overall, PGK fuzes significantly increase the effectiveness and efficiency of artillery fire. By enhancing the accuracy of traditional rounds, they provide a valuable middle ground between unguided munitions and high-cost, fully guided weapons. Widely adopted by the U.S. military and allied forces, PGKs are an essential component in modernizing artillery capabilities while maintaining affordability and operational flexibility.

Artillery - Artillery refers to large-caliber weapons designed to launch projectiles over long distances to support ground forces in combat. These include cannons, howitzers, mortars, and rocket systems. Artillery is used to destroy, neutralize, or suppress enemy forces, fortifications, and equipment, often from positions far behind the front lines.

Modern artillery systems can fire shells, rockets, or missiles, and may be towed or self-propelled. They are typically crew-operated and supported by spotters, radar, and targeting systems. Artillery is a key component of combined arms warfare, offering both offensive and defensive firepower.

Artillery rounds can be explosive, smoke, illumination, or precision-guided munitions. With technological advancements, artillery has become more accurate, mobile, and deadly. Precision systems like the Excalibur or PGK-equipped shells allow for accurate strikes with minimal collateral damage. Artillery remains a decisive force on the battlefield due to its range, power, and ability to deliver sustained fire over time.

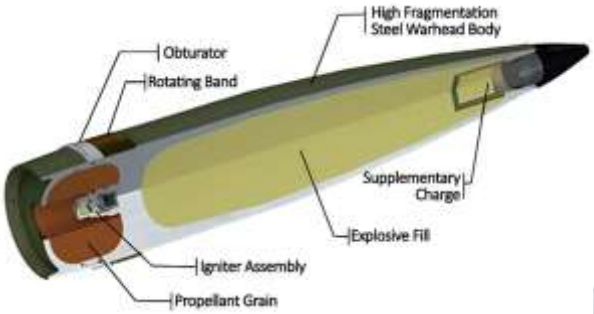

Fig. 1:- Artillery

II. Types Of Precision Guidance Kit Fuze

There is one main type of Precision Guidance Kit (PGK) fuze in service, but it has gone through different developmental blocks or versions. These reflect upgrades in performance, reliability, and compatibility with newer artillery systems.

a. PGK Increment 1 : (XM1156 / M1156)

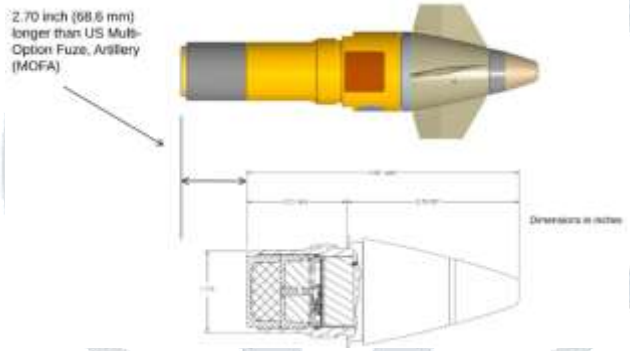

Fig. 2:- PGK - M1156

Primary fielded version used by the U.S. and allied militaries.
Replaces standard fuzes on 155mm artillery rounds.
Provides GPS-based guidance with course-correcting fins.
Reduces Circular Error Probable (CEP) to <50 meters.
Features a fail-safe mechanism to prevent detonation if the round strays off target.
Compatible with standard shells like M795 and M549A1.

b. PGK Increment 2 : (Planned/Future Version)
Currently under development or evaluation.
Expected improvements:
Better resistance to GPS jamming or spoofing.
Improved accuracy (potential CEP <10 meters).
Compatibility with additional types of artillery rounds.
May include Anti-jam GPS, Data link updates, or Inertial navigation backup.

c. 105mm PGK Fuze (concept / Prototype):
Purpose: For lighter artillery platforms using 105mm shells
Smaller fuze.
Uses micro-canards or control rings due to size limitations
Intended for airborne units and light artillery systems
Currently in R&D and testing phases in the U.S. and NATO.

d. Other Variants (Experimental/Foreign Concepts):
Some countries (e.g., South Korea, Germany, Australia) are developing similar GPS fuze systems or license-producing PGK-type kits.
South Korean PGK Fuze (Hanwha)
Being developed for K9 Thunder and other platforms.
Similar to XM1156 but optimized for Korean and export shells.
Uses digital GPS module and ruggedized body.

Turkish PGK Concept (ROKETSAN/Aselsan)
Fuze-based guidance for 155mm T-155 Fırtına.
Integrates GPS/INS + potential future laser guidance.
Still under technical validation.

China's Smart Fuze Programs
For 122mm, 152mm, and 155mm shells.
Focus on low-cost GPS-guided fuzes. (Details limited due to classification)
NATO-compatible variants may exist with localized adaptations or enhancements.

e. Experimental Dual-Mode PGK Fuzes
Under development by U.S. and allies.
Guidance: GPS + Laser or GPS + EO/IR.
Allows terminal homing on moving targets or GPS-denied environments.
Currently in early prototype stages.

III. Uses Of Precision Guidance Kit Fuze

The Precision Guidance Kit (PGK) fuze is designed to improve the accuracy and effectiveness of conventional artillery. Its primary uses include:

a. Precision Target Engagement -
Enables artillery units to strike specific enemy positions, vehicles, or fortifications with high accuracy.
Reduces the number of rounds needed to destroy a target, increasing efficiency.

b. Minimizing Collateral Damage -
With improved accuracy (CEP <50 meters), PGK reduces unintended damage to civilians, infrastructure, and friendly forces in populated or sensitive areas.

c. Cost-Effective Modernization -
Upgrades existing unguided artillery rounds without needing entirely new munitions.
Offers a cheaper alternative to full precision-guided shells like the M982 Excalibur.

d. Safe Use in Complex Environments -
PGK's fail-safe mechanism prevents detonation if the round veers off course, improving safety during urban or close-combat operations.

e. Supporting Rapid, Responsive Fire Missions -
Allows for accurate fire support with minimal coordination time, crucial in dynamic combat situations or against mobile targets.

f. Force Multiplier -
Enhances the capability of conventional artillery units, allowing fewer guns to achieve more with greater precision and less logistic burden.

IV. Design approach, implementation, working and parts in it

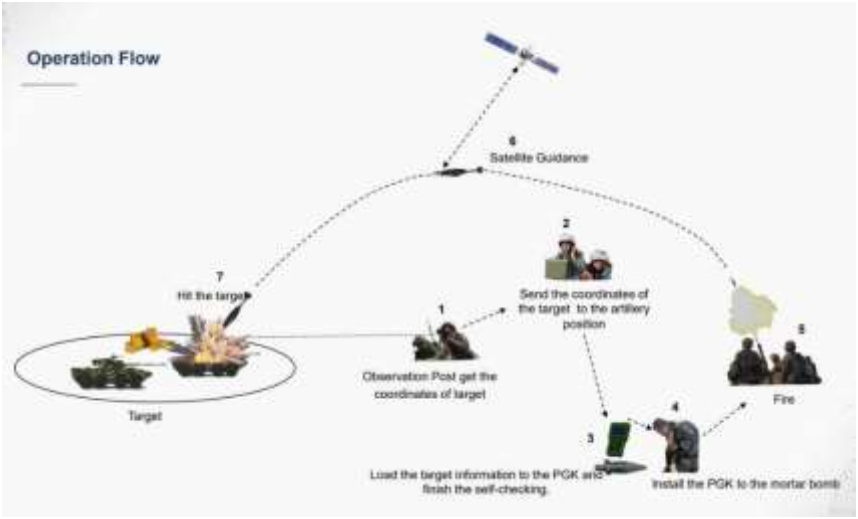

Fig. 3: – Operation Flow

a. GPS Receiver -
Function: Receives signals from GPS satellites to determine the shell's location and trajectory in real time.
Purpose: Enables mid-flight course correction toward the programmed target coordinates.

b. Inertial Sensors (IMU)

Function: Tracks the shell's motion (acceleration and rotation) when GPS is unavailable.
Purpose: Helps maintain accuracy if GPS signal is degraded or briefly lost.

c. Canards (Control Fins)
Function: Small aerodynamic fins near the nose that adjust during flight.
Purpose: Steer the shell by altering its path based on GPS guidance updates.

d. Power Supply (Battery)
Function: Provides electrical power to GPS, control systems, and electronics.
Purpose: Activates during firing and powers the system until impact or detonation.

e. Electronic Control Unit (ECU)
Function: The central processor that interprets GPS data and controls fin movements.
Purpose: Calculates course corrections and executes commands to guide the shell.

f. Safe and Arm Mechanism
Function: Ensures the fuze only arms under proper conditions (e.g., spin rate, distance).
Purpose: Prevents premature or accidental detonation.

g. Settable Target Coordinates Interface
Function: Allows the gun crew to input GPS target coordinates before firing.
Purpose: Ensures the shell is guided to the correct location.

V. CAD MODEL

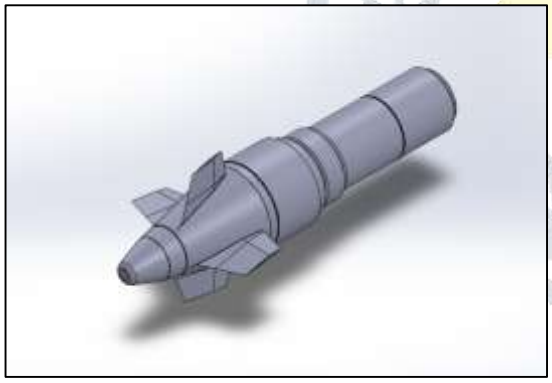

Fig. 5.1: – Isometric View

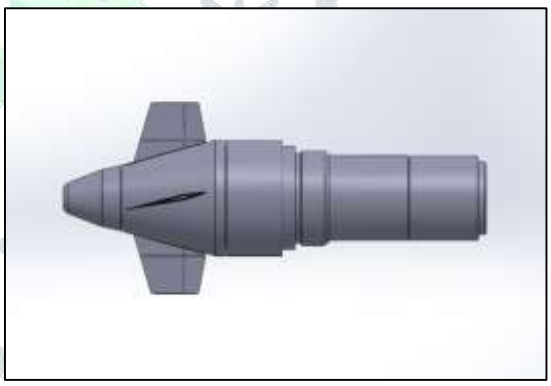

Fig. 5.2: – Top View

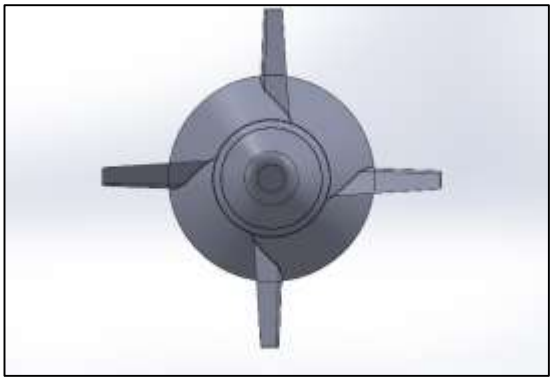

Fig. 5.3: – Front View

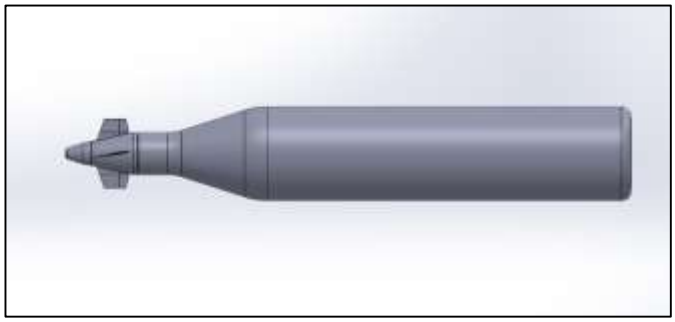

Fig. 5.4: – PGK attached to Artillery

VI. CFD ANALYSIS DETAILS

a. Input Parameters:
Inlet Conditions: Mach: 0.6
Outlet Conditions: Pressure Gauge: 101325 Pa (atmospheric pressure assumed).

b. Solver:
Type: Pressure-based solver
Reason: Suitable for low-speed compressible and incompressible flows where pressure-velocity coupling is critical.

c. Turbulence Model:

k-ε (k-epsilon) Model

Widely Validated: One of the most commonly used turbulence models for engineering applications, particularly for flows with high Reynolds numbers.

Robust and Stable: Handles a variety of flow problems, including boundary layers, recirculation, and free shear flows.

Computationally Efficient: Balances accuracy with computational cost compared to more complex models like k-ω SST or LES.

d. Reasons for Model Choices:

k-ε Model:

Provides good predictions for:

High-pressure turbulence in mixing zones (fuel and oxidizer interaction).

Boundary layer development in the conical section and outlet zones.

Less sensitive to near-wall odelling than k-ω SST, making it simpler to implement for your geometry.

e. Pressure-Based Solver:

Required to resolve the significant pressure gradients (1.5 Mpa and 2 Mpa to 101325Pa) efficiently.

Best for cases where pressure coupling drives the flow, like in fuel injectors or jet engine components.

f. Meshing :

Nodes	–	133646
Elements	–	720433
Elements Size	–	0.1 m

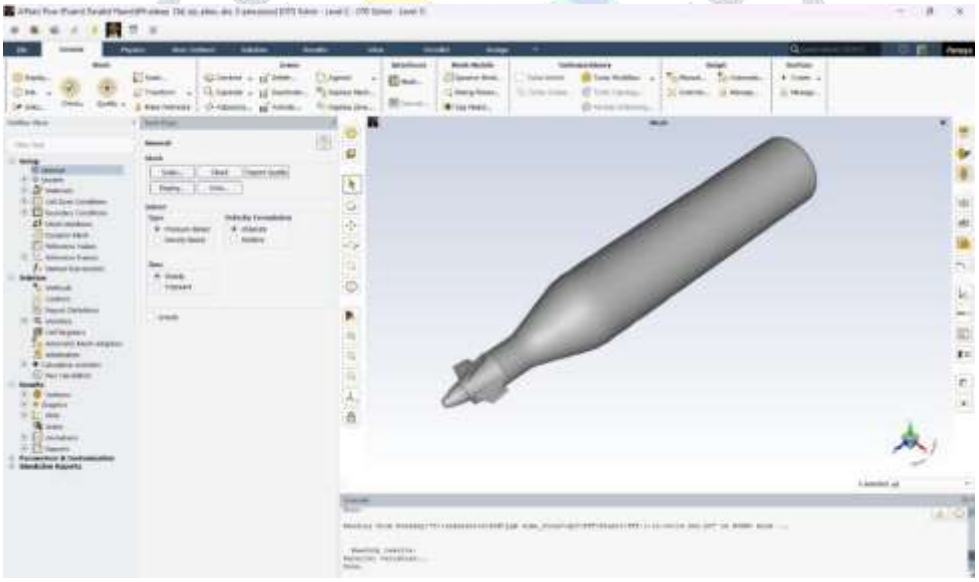

Fig. 6.1: – Meshing Model

VII. RESULTS

a. Contours:

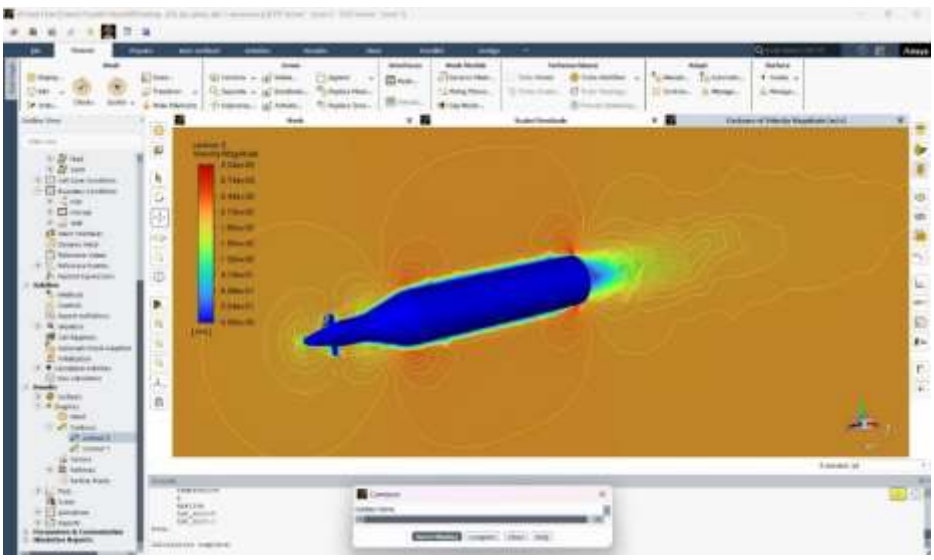

Fig. 7.1: – Velocity Magnitude

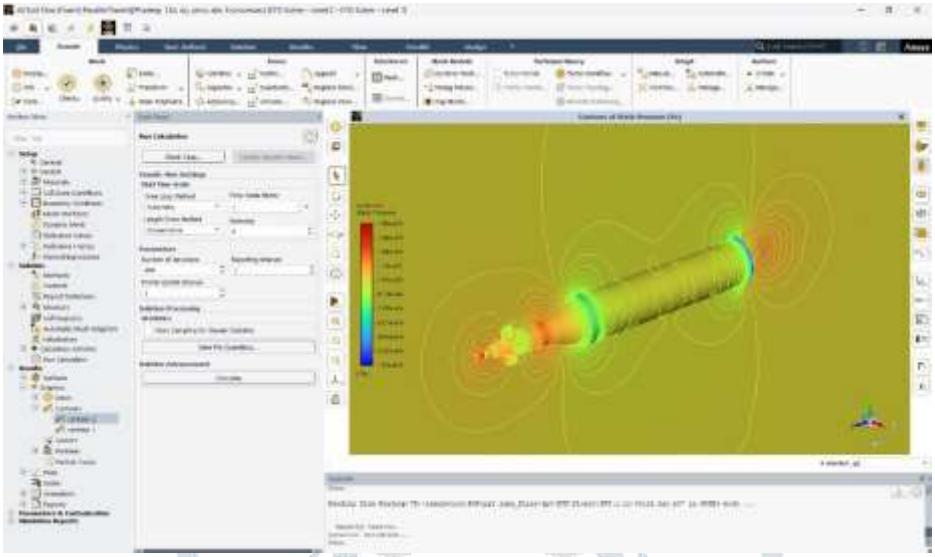

Fig. 7.2: – Static Pressure

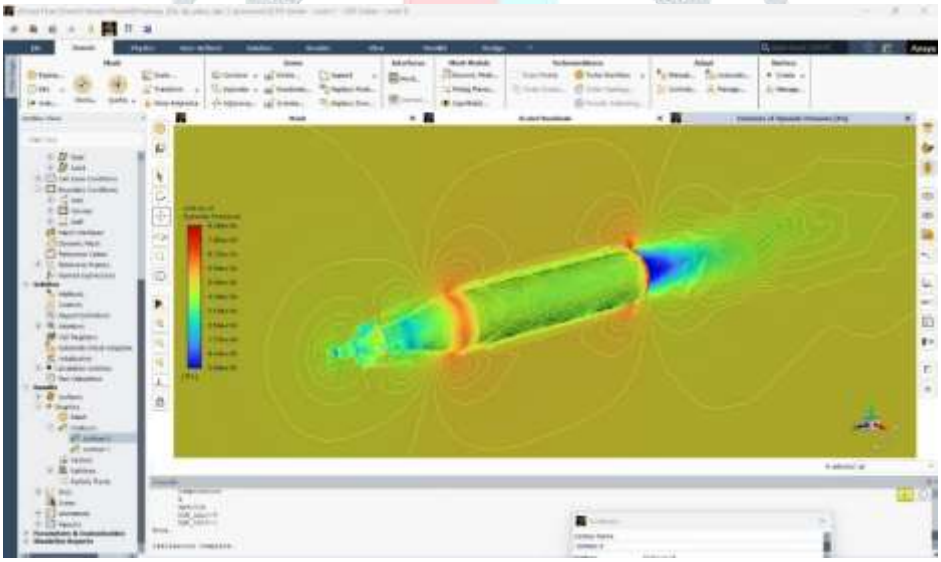

Fig. 7.3: – Dynamic Pressure

b. Pathlines:

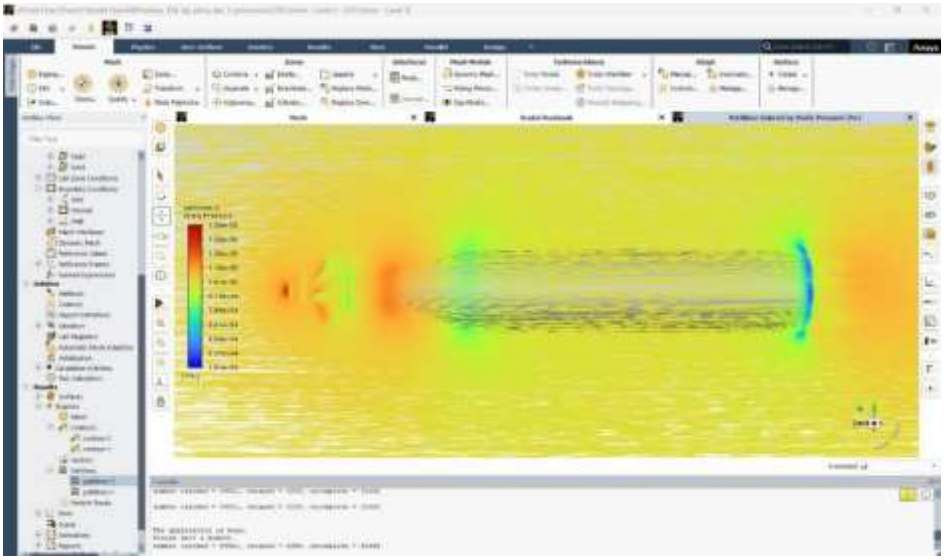

Fig. 7.4: – Static Pressure 1

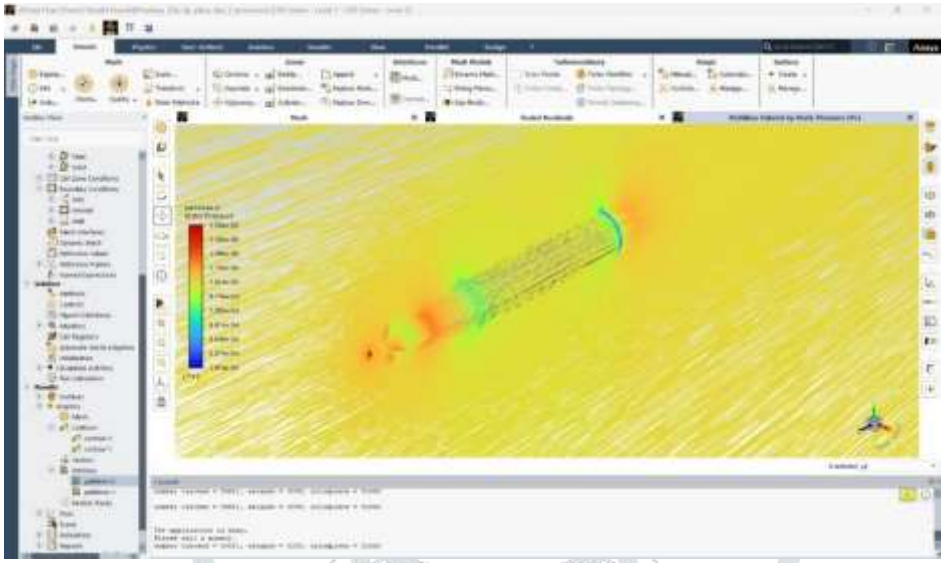

Fig. 7.5: – Static Pressure 2

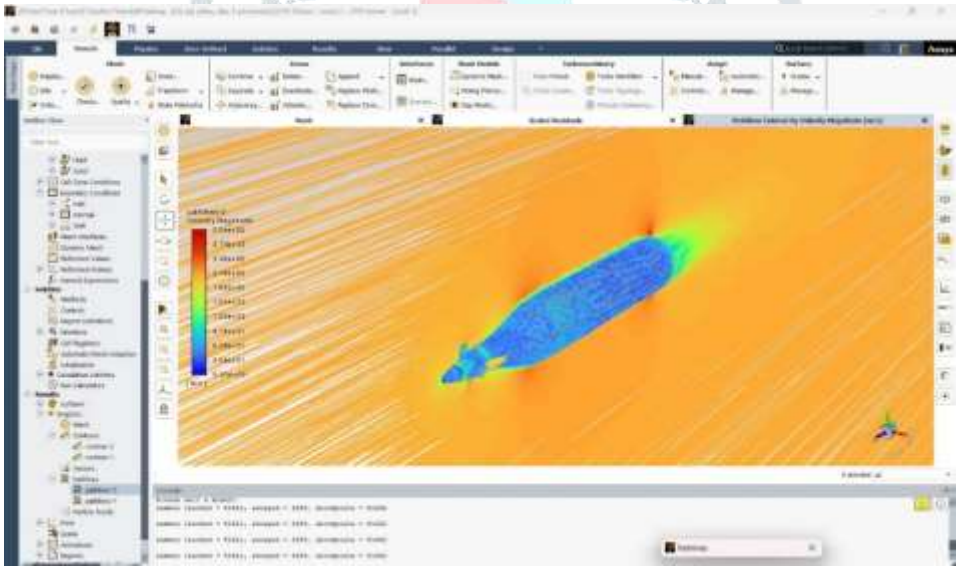

Fig. 7.6: – Velocity Magnitude 1

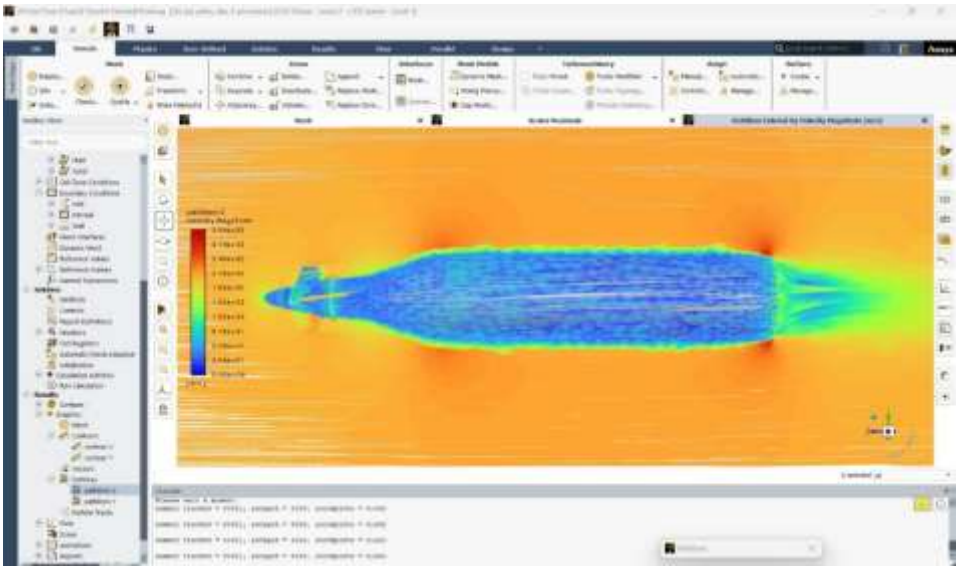

Fig. 7.7: – Velocity Magnitude 2

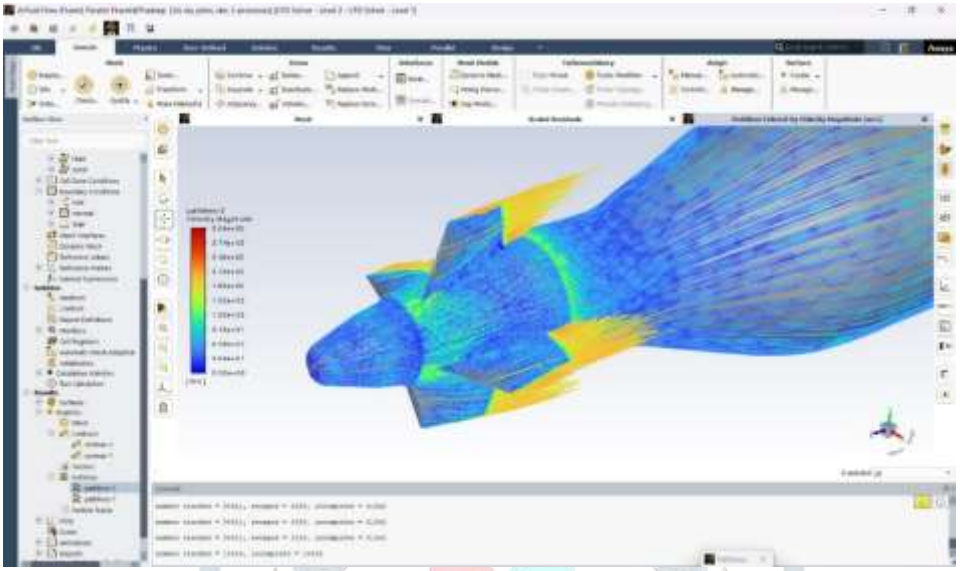

Fig.7.8: – Velocity Magnitude showing less induced drag

VIII. ACKNOWLEDGMENT

I extend my sincere gratitude to my supervisor, Nikhil Gangamkote for their expert technical guidance and continuous support throughout this research on Precision Guidance Kit (PGK) artillery systems. Their insights were invaluable. I am profoundly thankful to Prime Toolings for providing the essential resources and a conducive environment for this study. Special appreciation is extended to Prime Toolings for their invaluable technical contributions to critical components of this research, which were instrumental in its practical execution. Furthermore, I acknowledge the specialized insights and data furnished by military and industry professionals, significantly enriching the analytical depth of this investigation.

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