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FLOW ATOMISATION EFFECT ON AN ICBM MISSILE FUEL INJECTOR

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Abstract: This study investigates the influence of flow atomization on fuel injectors specifically designed for Intercontinental Ballistic Missiles (ICBMs). Given the high-speed, long-range nature of ICBMs, ensuring uniform combustion through fine fuel atomization is critical. Key metrics such as spray cone angle, droplet size distribution (SMD), and flow uniformity are analysed. Results show that optimized atomization significantly enhances combustion stability, reduces ignition delay, and minimizes unburned propellant. Comparisons with traditional injectors reveal that advanced swirl-assisted designs provide the most effective atomization for ICBM operational demands.

***IndexTerms* - ICBM, Atomization, Fuel Injector, Spray Dynamics, Combustion Stability.**

I. INTRODUCTION

Intercontinental Ballistic Missiles (ICBMs) operate under extreme conditions, requiring highly efficient and stable propulsion systems to ensure mission success. A key component in achieving this is the fuel injector, which must atomize liquid fuel into fine, uniform droplets. Proper atomization facilitates rapid vaporization and thorough mixing with oxidizers, directly impacting combustion efficiency, ignition reliability, and overall thrust stability. Inadequate atomization can lead to incomplete combustion, pressure fluctuations, and potential propulsion failure.
By analyzing factors such as droplet size distribution, spray cone angle, and flow uniformity, this study aims to identify injector configurations that offer optimal performance for ICBM applications. The findings support the development of advanced swirl-assisted injectors that enhance atomization quality, reduce ignition delay, and ensure consistent propulsion across varied operating conditions.

II. AIM AND OBJECTIVE

AIM:

To analyze the effect of atomization characteristics on ICBM fuel injector performance using experimental setup.

OBJECTIVES:

- Design a swirl-assisted fuel injector tailored for ICBM engines.
- Study the influence of cone angle and injector pressure on droplet dispersion.
- Compare performance with traditional showerhead and pintle injectors.
- Propose recommendations for optimized injector configurations.

III. METHODOLOGY / DESIGN APPROACH

a. INJECTOR GEOMETRY

The designed injector uses a swirl chamber and tangential entry ports to induce rotational flow. The geometry was created in PTC Creo Parametric, focusing on achieving a cone angle of 60–75° for optimal dispersion.

b. CAD MODEL

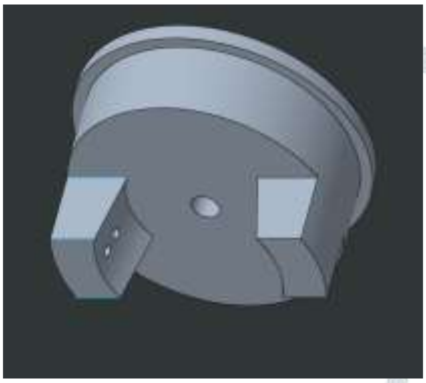

Fig. 3.1: – Oxidiser Nozzle

Fig. 3.2: – Fuel Nozzle

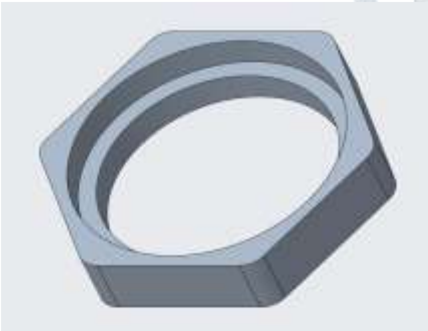

Fig. 3.3: – Lock Nut

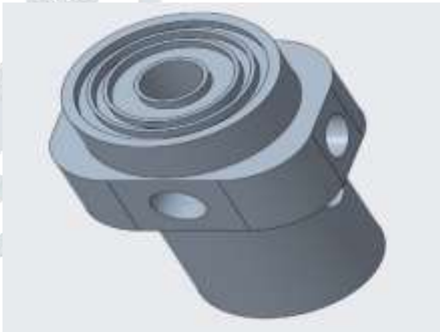

Fig. 3.4: – Pressure casing / Housing

IV. EXPERIMENTAL SETUP

The experimental setup was used to validate the numerical results by comparing them with experimental observations conducted at Prime Tooling, Bangalore. The setup includes components such as oxidizer and fuel nozzles, a lock nut, and a pressure casing/housing, which are part of the injector geometry. Images of the experimental setup show pressure tanks, hoses, and the injector assembly spraying a mist.

V. COMPARISON OF INJECTOR CONFIGURATIONS

Table 5.1: Comparison of Various Injectors

Parameter	Swirl Injector	Showerhead Injector	Pintle Injector
Atomization Efficiency	Very High	Moderate	Low–Moderate
Cone Angle Control	Excellent	None	Limited
Droplet Size (SMD)	20–35 µm	40–60 µm	50–70 µm
Pressure Loss	Moderate	Low	High
Suitability for ICBM	High	Moderate	Low

VI. COST ANALYSIS

Table 6.1: Cost Analysis of Various Injectors

Injector Type	Manufacturing Cost	Maintenance Complexity	ICBM Suitability
Swirl	High (1.7 – 8.3 Lakhs)	Moderate	Very High
Showerhead	Low (80k - 4 lakhs)	Low	Moderate
Pintle	Moderate (1.2 - 6 lakhs)	High	Low

VII. ACKNOWLEDGMENT

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