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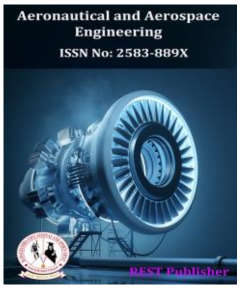

Cycle Analysis of Lox/Lh2 Rocket Engine

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Abstract: *This paper presents a comprehensive cycle analysis of a LOX/LH_2 rocket engine operating on a gas-generator cycle. The methodology integrates spreadsheet-based power matching and NASA CEA (CEARUN) thermodynamic tools to evaluate engine performance. Key engine parameters such as chamber pressure, mixture ratio, thrust, and specific impulse were studied under various conditions. Results demonstrate the critical impact of chamber pressure and mixture ratio on performance, while power balance equations validate the turbopump efficiency and turbine work requirements.*

1. INTRODUCTION

Liquid rocket engines offer high performance and reusability for space missions. Among the various cycles, the gas-generator cycle is widely used due to its simplicity and reliability. This study focuses on evaluating the performance of a LOX/LH_2 rocket engine using thermodynamic and fluid dynamic modelling techniques.

2. LITERATURE REVIEW

Extensive research has been conducted in the field of liquid rocket engine cycles. Huzel and Huang (1992) laid foundational principles of liquid propulsion, elaborating on cycle selection criteria and performance parameters. Sutton and Biblarz (2001) provided detailed thermodynamic analyses and design considerations for LOX/LH_2 engines, emphasizing trade-offs between efficiency and complexity. NASA's LE-5A engine and ISRO's VIKAS engine are practical implementations of gas- generator cycles with varying oxidizer-to-fuel rations and performance characteristics. More recent studies have used computational methods such as CEARUN to assess combustion properties and optimize nozzle expansion (Kim, 2016; Yadav & Tiwari, 2020). These works validate the importance of iterative design, particularly the use of power matching for pump and turbine design.

3. METHODOLOGY AND DESIGN

The cycle analysis is carried out in five main phases:

- Cycle Selection: Gas generator cycle chosen for its balance of performance and simplicity.
- Thermodynamic Calculations: CEARUN software is used to determine specific heat (Cp), y, and combustion properties.
- Power Matching: Spreadsheet calculations solve turbopump work balance using governing equations.
- Performance Evaluation: Variations in thrust, Isp, and mass flow are analyzed.
- Validation: Comparative analysis against standard engines (e.g., VIKAS, LE- 5A).

4. GOVERNING EQUATIONS AND POWER MATCHING

Key Equations:
Turbine Power:

$$P_{turbine} = m * C_p * T * \eta * (1 - ExpansionRatio)$$

Pump Power:

$$P_{pump} = \frac{m_{propellant} * (P_{out,pump} - P_{in,pump})}{\eta_{pump} * \rho_{propellant}}$$

Thrust:

$$F = Pc * At * Cf$$

Specific Impulse:

$$I_{sp} = \frac{F}{m_{tc} * g_0}$$

5. RESULTS

Three operating cases were studied at MR = 5.5 with chamber pressures of 57, 60, and 65 bar:

TABLE 1

Case	Pc (bar)	Thrust (N)	Isp (s)	Total Pump Power (W)
1	57	188248	476.45	1.75 MW
2	60	198156	476.45	1.82 MW
3	65	214669	476.86	2.23 MW

6. DISCUSSION

The results highlight:

- The sensitivity of Isp to chamber pressure and mixture ratio.
- The importance of specific heat ratio (γ) in choked flow conditions.
- Efficiency increases with optimized power matching in turbomachinery.

7. CONCLUSION

A spreadsheet-based approach, validated by thermodynamic tools like NASA CEA, can provide accurate cycle analysis for LOX/LH_2 gas-generator engines. Future work can implement computational scripts to further improve precision and adaptability to other engine cycles.

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