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# A Short Review on Efficiency of Rotating Detonation Engine

Lalith Veeramanikandan*

*Intern, Acceleron Aerospace, Bangalore, Karnataka, India – 560037*
**ORCID-0009-0008-8307-3876**

**Abstract:** The rotating detonation engine (RDE) is a revolutionary propulsion technology with the potential to significantly enhance the efficiency of propulsion systems. This paper provides an in-depth review of the RDE's efficiency, its advantages over pulse detonation engines (PDEs) and deflagration concepts, as well as its applications in rocketry. The historical development of detonation engines, specifically RDE, is discussed, along with various research methodologies applied in both atmospheric and vacuum conditions. The challenges and potential solutions for utilizing RDE in space missions are also explained in this paper.

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## 1. Introduction

The rotating detonation engine (RDE) represents a groundbreaking advancement in propulsion technology. In comparison to pulse detonation engines (PDEs) and deflagration concepts, RDEs offer up to 25% higher efficiency. This paper aims to examine the principles, applications, and efficiency of the RDE, shedding light on its potential to revolutionize the field of propulsion.

## 2. Historical Development of Detonation Engines

The concept of utilizing detonation waves for propulsion was first introduced by Professor James Arthur Nicholls at the University of Michigan in the 1950s. His pioneering work led to the creation of the pulse detonation engine (PDE). In the 1960s, he theorized the Continuously Rotating Detonation Engine (CRDE), which laid the foundation for modern RDE development. A prototype of RDE engine developed by NASA is shown in the figure-1. This engine was tested successfully at NASA's Marshall Spaceflight Center on 25-January-2023, which produced 44kN [1-8].

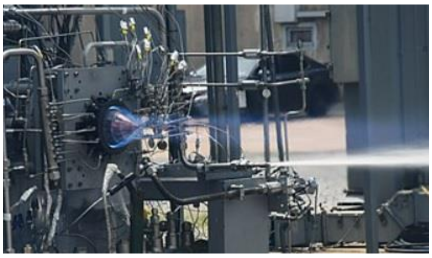

**Figure-1 RDE Test [Courtesy: NASA]**

## 3. RDE Architecture and Working Principles

The RDE consists of micro nozzles positioned between the inner and outer cylinder. Upon ignition, the flame front of the detonation travels in a circular motion, producing supersonic speeds and high thrust. The detonation process effectively burns fuel and air between the cylinders, resulting in enhanced thrust within a smaller volume. An additional efficiency enhancement can be achieved by incorporating an aerospike nozzle, which optimizes specific impulse up to 16%, albeit with altitude constraints [1-8].

### 3.1. RDE in Flight

Integrating RDEs in rocketry's first stage at altitudes ranging from 60 km to 80 km poses several challenges, such as stability, heating, and noise. Controlling the frequency of the RDE becomes crucial inside and outside the

*Intern, Acceleron Aerospace, Bangalore, Karnataka, India - 560037. **Contact**: veeramanikandanlalith@gmail.com.
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atmosphere. Strategies for ensuring stability, including the use of booster engines for directional control, are explored. Furthermore, the potential of utilizing RDEs with low frequency and mild thrust outside the atmosphere is considered, facilitating the separation and reuse of primary RDE engines [1-8].

### 3.2. RDE in Vacuum

After successful launch and primary RDE separation, the secondary RDE is employed in the second stage of separation. Control mechanisms, such as micro nozzles and RCS thrusters, are examined for direction adjustments during orbit. The specific requirements for RCS thrusters in small and large vehicles are highlighted, and the importance of accessing the minimum frequency for the main RDE in satellite flight is emphasized.

## 4. Challenges and Future Prospect

The short review paper identifies key challenges in the widespread implementation of RDE technology. Issues like stability during launch, altitudinal constraints with aerospike nozzles, and frequency control require further investigation and practical solutions. The potential of RDEs to enhance space missions, reduce costs, and increase payload capacities is discussed. In addition, we have comprehensively summarized the development of RDE engines by organizations, tested year, fuel used, and its objectives in the table-1.

**Table-1 Development of RDE Engines throughout Space Agencies [1-8]**

| Organization/Agency | Tested Year | Fuel Used | Comments |
|---|---|---|---|
| **US Navy (NRL)** | 2012 | NA | To reduce fuel consumption in ships |
| **Aerojet Rocketdyne** | 2010 | NA | To power launch vehicles |
| **NASA** | 2023 | NA | To power launch vehicles |
| **Energomash** | 2018 | Methane/Oxygen | To power space launch vehicles |
| **Purdue University** | 2016 | Hydrogen/Oxygen | To power drone and launch vehicles |
| **University of Central Florida** | 2020 | Hydrogen/Oxygen | To power defense systems |
| **JAXA** | 2021 | Solid Propellant | To power rockets |
| **Institute of Aviation** | 2021 | Liquid Propellant | To power rockets |

## 5. Conclusion

The rotating detonation engine (RDE) represents a highly promising propulsion technology, offering substantial efficiency gains over traditional propulsion systems. This short review paper explores the principles of RDE operation, its historical development, and various recommendations for utilizing RDEs in both atmospheric and vacuum conditions. By addressing the challenges and future prospects, this paper sets the stage for further advancements in RDE technology and its potential applications in space exploration and beyond.

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## 7. Biography

Lalith Veeramanikandan, an Aerospace Intern at Acceleron Aerospace, is a driven figure from Karaikudi, Tamil Nadu, and India. With an ardent interest in Aerospace Propulsion and RDE Engines, he navigates intricate aerospace innovations. Lalith's focus on the transformative Rotating Detonation Engine (RDE) technology showcases his attention to detail and determination to enhance propulsion efficiency. His research extends to broader aerospace domains, reflecting his commitment to shaping the future of space exploration. Rooted in Karaikudi, Lalith's journey epitomizes dedication to aerospace advancement, making him a notable contributor to the field's evolution.

## 8. Acknowledgement

I extend profound appreciation to my family and mentor, whose steadfast support, encouragement, and guidance have been instrumental in shaping my journey.

## 9. Conflict of Interest

The author have no conflict of interest to report.

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