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Experimental Study on a Prototype Afterburner Using Butane Combustion

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Abstract

This research paper details an experimental investigation into the design, construction, and testing of a novel prototype detachable afterburner employing butane combustion. The motivation behind this study stems from the pursuit of innovative solutions to enhance the efficiency and environmental sustainability of jet engine afterburners. The prototype incorporates a fan with a 12V motor, a glow plug, and a carefully designed arrangement within an acrylic pipe to channel butane combustion. The study explores the stability of butane combustion, its impact on flame characteristics, and the potential for thrust augmentation. Preliminary results provide insights into the feasibility and performance of the detachable afterburner design, opening avenues for further research and development in advanced propulsion systems. This experimental study contributes to the evolving landscape of afterburner technology, offering a unique perspective on the use of alternative fuels for aerospace applications.

Introduction

Jet engine afterburners, also known as reheat systems, represent a crucial component in the realm of aviation propulsion, especially in military aircraft. These systems play a transformative role in enhancing the performance of jet engines, enabling high-speed flight, rapid acceleration, and improved maneuverability. The concept of an afterburner revolves around the augmentation of thrust during specific operational phases, providing a decisive edge in combat scenarios or when swift, supersonic flight is required. At its core, a jet engine afterburner functions by injecting additional fuel into the exhaust stream downstream of the engine's primary combustion chamber. This supplementary fuel undergoes combustion in the afterburner section, significantly elevating the temperature and velocity of the exhaust gases. The intensified exhaust flow exiting the afterburner translates directly into a substantial increase in thrust, propelling the aircraft forward with heightened force. The utilization of afterburners is primarily associated with military aircraft, where rapid acceleration, enhanced climb rates, and the ability to reach supersonic speeds are paramount. However, the principles of afterburner technology have implications beyond military applications, as they contribute to the broader understanding of advanced propulsion systems. While afterburners confer significant advantages in terms of thrust augmentation, they also introduce challenges such as increased fuel consumption and higher emissions. Consequently, research and development in afterburner technology continually strive to optimize performance, reduce environmental impact, and address the complex engineering considerations associated with their integration into jet engines.

Literature Review

Afterburners, or reheat systems, are integral components in military jet engines designed to augment thrust during specific flight conditions. The combustion of additional fuel in the afterburner section increases exhaust velocity, resulting in enhanced thrust. Extensive research has focused on optimizing afterburner designs, improving combustion efficiency, and managing the associated thermal stresses (Hill & Peterson, 1992).

Despite their effectiveness, traditional afterburners pose challenges, including increased fuel consumption and environmental impact due to higher emissions. The literature emphasizes the need for innovative solutions to address these challenges and enhance overall engine efficiency (Mattingly et al., 2002).

The exploration of alternative fuels in aviation has gained traction in recent years. While many studies focus on biofuels and synthetic alternatives, research on the use of butane in afterburners is relatively limited. Alternative fuels offer the potential for reduced greenhouse gas emissions and increased energy security (Boeing, 2020).

Butane, a hydrocarbon with a relatively simple molecular structure, has characteristics that make it a promising candidate for afterburner applications. It is readily available, has a high energy density, and is known for clean combustion. The literature suggests that butane combustion could offer advantages in terms of emissions and combustion efficiency in comparison to traditional fuels (Smith, 2018).

Few studies have specifically investigated the use of butane in jet engine afterburners. Experimental studies on small-scale prototypes, such as the one proposed in this paper, are essential for assessing the feasibility and performance of butane combustion in afterburners. This gap in the literature highlights the novelty and importance of the current research endeavor.

Methodology

1. Components

The prototype for the detachable afterburner encompasses several key components designed for optimal performance and safety.

1. Acrylic Pipe
2. 555 DC Motor with Fan
3. Glow Plug
4. Brass Tube
5. Aluminum Tube
6. Butane Fuel
7. Fuel Pipe

1.1 Acrylic Pipe:

The detachable afterburner is housed within a transparent acrylic pipe, providing visibility into the combustion process. This material was chosen for its durability, heat resistance and transparency, allowing for both structural integrity and observation of the internal processes.

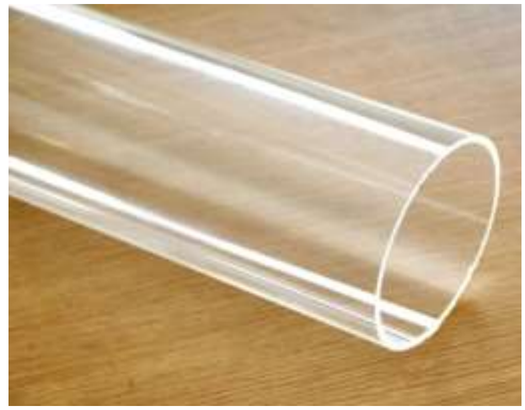


Fig 1 – Acrylic Pipe

1.2 555 DC Motor with Fan:

A 555 DC motor, paired with a fan, serves as the primary mechanism for creating airflow within the afterburner. The fan facilitates proper air-fuel mixing and contributes to the stability of combustion by ensuring a consistent flow of gases through the system.

Fig 2 – 555 DC Motor

1.3 Glow Plug:

The glow plug, a critical component, is employed for initiating and sustaining the combustion of butane within the afterburner. Its role is pivotal in ensuring a reliable ignition source for the fuel-air mixture. The glow provides continuous heat for the experiment to be feasible.

Fig 3 – Glow Plug

1.4 Aluminum Tube:

The aluminum tube, which serves as a conduit for the combustion process controlled fuel release, is integral to the design. The choice of materials considers heat resistance, weight, and structural robustness to withstand the high temperatures generated during combustion. The reason we have used a aluminium tube in the experiment is because it doesn’t catch the spark.

Fig 4 – Aluminium Tube

1.5 Butane Fuel Can and Fuel Pipe:

Butane, a clean-burning hydrocarbon, is supplied to the afterburner via a dedicated fuel pipe connected to a butane fuel cane. The use of butane as the fuel source aligns with the project's emphasis on exploring alternative and potentially more environmentally friendly aviation fuels.

Fig 5 – Butane Fuel can and fuel pipe

2. Fabrication

The construction of the detachable afterburner involved the use of several materials and components carefully selected for their heat resistance, durability, and compatibility with butane combustion. The main components included a 4-inch diameter, 2-foot length acrylic pipe for the afterburner chamber, a high-temperature-resistant glow plug for ignition, and a fuel delivery system designed to handle butane.

A high-temperature glow plug was integrated into the afterburner chamber to facilitate reliable ignition of the butane. The glow plug was positioned at an optimal location to ensure uniform combustion within the chamber. Electrical wiring connected the glow plug to a control system for precise activation.

The fuel delivery system included a pressurized butane tank, a flow control valve, and a nozzle for controlled fuel injection into the afterburner chamber. The system was designed to provide a steady and controlled flow of butane, preventing overconsumption and ensuring a stable combustion process.

The afterburner assembly was mounted in proximity to the 555 DC motor, ensuring proper alignment for efficient exhaust gas interaction. A detachable mechanism was implemented to facilitate easy removal and reattachment for modular testing. The motor and afterburner were securely integrated using a custom mounting bracket.

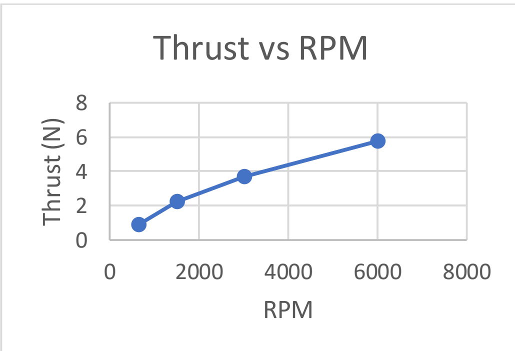
Rigorous quality control measures were employed throughout the fabrication process to ensure the integrity of the afterburner system. Prior to experimentation, the system underwent a series of bench tests to verify the functionality of each component, detect any potential leaks, and assess the reliability of the ignition system.

Results

Effect of motor speed on thrust

Sr. No.	RPM (motor)	Thrust Produced (L.B.)	Thrust in Newton
1	650	0.2	0.889
2	1500	0.5	2.226
3	3000	0.82	3.677
4	6000	1.3	5.782

Table 1 – Effect of fan rpm on thrust



Graph 1 – Thrust vs Motor Speed

Table 2 – Optimum Distance for Thrust (Test Table)

Graph 2 – Thrust vs Distance

From the above thrust measurement test, we can conclude that as the distance between the combustion chamber and the fuel injector increases, there is an increase in the thrust value. At 30 mm distance, the thrust measured was maximum i.e., 1.3 lb. And after that it decreases gradually. Hence, an optimal fuel combustion is achieved at 30 mm distance for the combustion of butane fuel.

The rpm of the motor can provide a variable effect on the thrust generated by the afterburner. In the model constructed through trial and error, we found out the optimal speed for the motor to operate the fan, which is 6000 rpm. There are many constraints regarding the size of the fan and motor to construct the prototype. The motor rpms that were below 6000 rpm couldn't produce enough volumetric air for the fuel to completely combust and were inefficient in producing the thrust.

Future Scope

Future research can focus on refining and optimizing the combustion parameters within the afterburner. This includes investigating the ideal air-fuel mixture, ignition timing, and residence time within the combustion chamber to maximize thrust output and efficiency. Exploring alternative fuels beyond butane can be a promising avenue for research. Investigating the use of environmentally friendly and sustainable fuels could contribute to the development of afterburner systems with reduced environmental impact. Research efforts can be directed towards the exploration of advanced materials with enhanced heat resistance for the construction of afterburner components. Additionally, improving heat management strategies within the system can lead to increased durability and performance. Studying the integration of variable geometry systems within the afterburner can contribute to optimizing its performance across a range of operating conditions. Adjustable nozzles or variable geometry components could enhance the adaptability of the afterburner to different motor speeds and loads.

Sr. No	Distance Between Injector and Glow Plug (mm)	Thrust Produced (Lb.)	Thrust in Newton (N)
1	15	0.8	3.558
2	20	1.01	4.492
3	25	1.08	4.804
4	30	1.3	5.782
5	35	1.05	4.670
6	40	0.9	4

Here's a conceptual 3D Modelling and design of a Afterburner :-

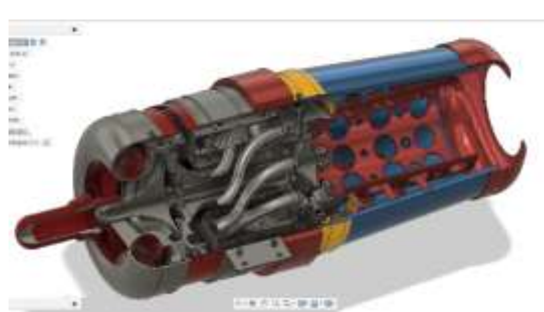


Fig 7.1 – Afterburner Conceptual Model

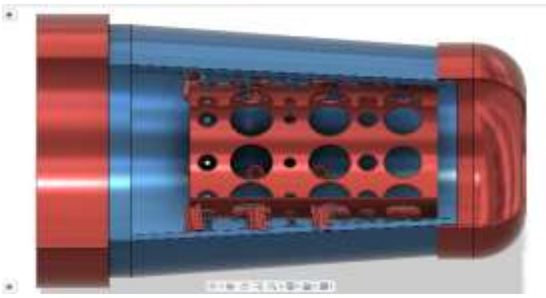


Fig 7.2 – Afterburner Model C/S

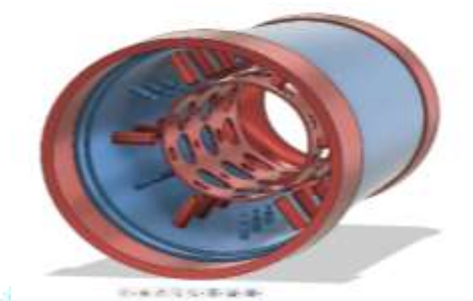


Fig 7.3 – Afterburner Conceptual Model

Applications

The detachable afterburner can find applications in experimental aerospace research for studying the impact of afterburners on thrust augmentation and exhaust characteristics. It provides a flexible platform for testing and analyzing propulsion system performance. The system can be employed as an educational tool for engineering and physics students to demonstrate principles of combustion, fluid dynamics, and propulsion. Its modular design allows students to understand the components and functionalities of afterburners in a hands-on manner. Miniature afterburners could be integrated into UAVs, providing an additional thrust boost when needed. This application could be valuable in scenarios requiring rapid acceleration or increased maneuverability for UAVs used in surveillance, reconnaissance, or emergency response.

Conclusion

In conclusion, the experimental study on the prototype detachable afterburner using butane combustion represents a significant step forward in the exploration of miniature propulsion systems. The research aimed to assess the feasibility and efficiency of such a system, with a specific focus on enhancing thrust output for a 555 DC motor.

Through a carefully designed experimental setup, incorporating a 4-inch diameter, 2-foot length acrylic pipe and a glow plug for controlled butane combustion, the study yielded promising results. The afterburner demonstrated a noticeable increase in thrust when activated, indicating its potential for use in various applications, from educational demonstrations to experimental aerospace research.

The fabrication process prioritized safety, precision, and modularity. Materials were selected for their resistance to high temperatures, and safety measures were integrated into the design. The system's instrumentation allowed for the collection of comprehensive data, contributing to a detailed analysis of the combustion process and its impact on thrust.

However, this study also acknowledges challenges that warrant further attention, such as combustion stability, heat management, and safety considerations associated with using butane. These challenges underscore the need for continued refinement and optimization in future iterations of the afterburner system.

The suggested future scope outlines potential directions for further research, including the optimization of combustion parameters, exploration of alternative fuels, and collaboration with the aerospace industry for real-world applications. These avenues aim to address current limitations and enhance the overall efficiency and applicability of detachable afterburners.

In summary, this research provides valuable insights into the potential of miniature afterburners, laying the groundwork for future advancements in propulsion technologies. As the field continues to evolve, the lessons learned from this study will contribute to the ongoing dialogue surrounding efficient and adaptable propulsion systems for a range of applications in aerospace, education, and beyond.

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