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Design & Development of Hybrid Electric Jet Engine

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Abstract:- Hybrid electric jet engines without turbines, in which the compressors are powered by fuel cells rather than the turbines, are a potential and evolving technology for unmanned aerial vehicles. The hybrid electric jet engine combines the benefits of fuel cells and turbo-electric engines. The hybrid engine produces high specific thrust and excellent thermal efficiency.

Keywords:- *Jet Engine, Hybrid, Turbine-Less, Aircraft, Design.*

I. INTRODUCTION

A. Background

This paper presents a hybrid electric jet engine which can serve as an alternate means of propulsion for the jet engines. This is environment friendly and has better performance in comparison of other hybrid electric jet engine in its range.

A hybrid electric jet engine is an innovative propulsion system that combines traditional gas turbine technology with electric propulsion components to improve the efficiency, reduce emissions, and enhance the environmental sustainability of aircraft. This concept has gained significant attention in recent years as the aviation industry seeks to reduce its environmental impact and increase energy efficiency.

B. Motivation

The development of hybrid electric jet engines represents a groundbreaking leap forward in aviation technology and sustainability. By combining traditional jet propulsion with electric power, these engines hold the promise of significantly reducing carbon emissions and decreasing our reliance onfossil fuels. This innovation is not only driven by environmental concerns but also by the need for more efficient and cost-effective air travel. Hybrid electric jet engines have the potential to revolutionize the aviation industry, offering quieter and cleaner flight experiences while expanding the range and efficiency of aircraft. As the world increasingly looks for eco-friendly solutions, these enginesinspire hope for a greener and more sustainable future in air travel, addressing both our environmental concerns and our desire for more efficient transportation.

C. Objective

Our aim was to build wind turbine less jet engine which canproduce 400N thrust at a better efficiency. We want to manufacture a turbine less jet engine which can carry the load of 5Kg better than conventional jet engines. By building this project we want to drive the attention of aviation industriesthat the prototype turbine less jet engine would be able to carry a load to particular distance with less emission and better efficiency then the conventional jet engines.

II. CONCEPT

A concept for a turbine-less jet engine represents a groundbreaking innovation in aviation technology. Unlike traditional jet engines that rely on complex turbines to compress incoming air, this novel design leverages alternative principles, such as air compression through novel mechanical systems or propulsion technologies like pulse detonation engines. The absence of turbines simplifies the engine's construction and reduces maintenance requirements,potentially leading to more cost-effective and reliable propulsion systems. Moreover, turbine-less jet engines may have the potential to enhance fuel efficiency and environmental sustainability, making them an exciting prospect for the future of aviation, as they push the boundariesof traditional propulsion systems.

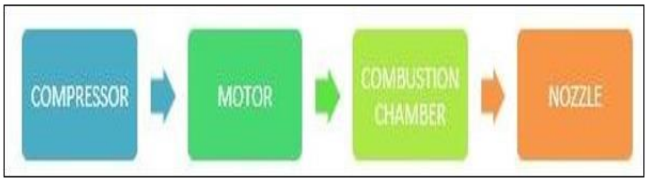

Fig 1: Block Diagram

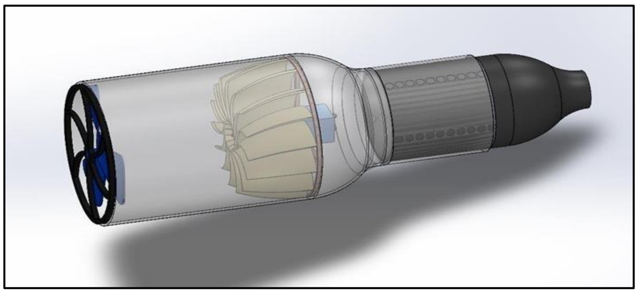

Fig 2: Conceptual Design

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III. COMPONENTS INVOLVED

A. Compressor

A compressor is a mechanical device that increases pressure while decreasing the volume of a gas. Axial type compressor is what we are using.

Axial air compressor use is not usually seen in construction projects. They are typically found in the powerful engines of ships and aircraft, though. Due to its high cost and high efficiency rate in comparison to other types of air compressors, axial compressors are most frequently utilised in aeronautical applications.

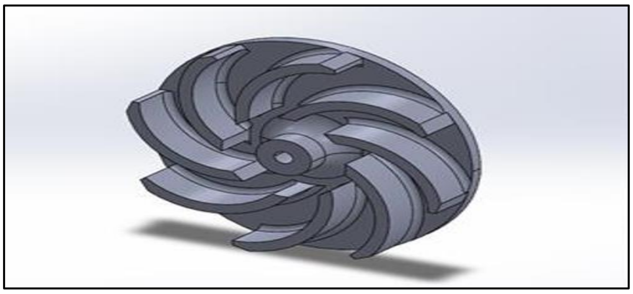

Fig 3: Solid Works Model of Compressor

B. Motor

Brushless direct current electric motors, often referred to as BLDC motors or BL motors, are also known as electronically commutated motors, or ECM/EC motors, as well as synchronous DC motors. These motors operate on direct current (DC) power and utilize electronic controls to supply DC current to the motor windings. This current generates a magnetic field, effectively rotating in space as the permanent magnet rotor follows suit. To control the speed and torque of the motor, the controller adjusts the phase and amplitude ofthe DC pulses. This method of control serves as a replacement for the mechanical commutator (brush) found in many conventional electric motors.

Brushless motor systems share similarities with permanent magnet synchronous motors (PMSM) in design, although theycan also be induction (asynchronous) motors or switched reluctance motors. Additionally, they can come in the form of axially outer rotors, where the stator surrounds the rotor, or axially inner rotors, where the rotor surrounds the stator. In some cases, neodymium magnets are used, resulting in a flat and parallel rotor and stator configuration.

Brushless motors offer several advantages over brushedmotors, including a high power-to-weight ratio, high speed, close RPM and torque matching, high efficiency, and low maintenance costs. These motors find applications in various devices such as handheld power tools, model airplanes, automobiles, and computer peripherals like floppy disk drives and printers. Moreover, modern washing machines have adopted direct drive solutions powered by brushless DC motors, eliminating the need for rubber belts and gears.

Table 1: Motor Specifications

Sr. No	Components	Specification
1	MOTOR	BLDC
2	BATTERY	NIPPO

C. Combustion Chamber

Combustion takes place in the combustion chamber of a gasturbine, ramjet, or scramjet engine. Other names for it are burners, combustors, and flame holders. Gas turbine engine compression systems deliver high pressure air to the combustor or combustors. It then heats the air in the combustion chamber while keeping the pressure constant. Theair heated in the combustion chamber travels from there through guide vanes in the nozzle to the turbine. Ramjet and scramjet engines send air directly to the nozzle.

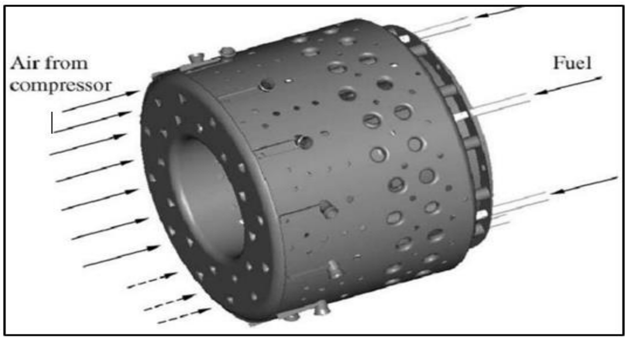

Fig 4: Combustion Chamber

Annular combustors feature a continuous liner and casing, which eliminates separate combustion zones (the annulus). Circular combustion offers several advantages, including more consistent combustion, reduced weight, and a smaller overall footprint. Moreover, annular combustors tend to maintain stable exit temperatures and exhibit minimal pressure drop, typically around 5%.

The annular design is straightforward, although testing often requires full-size equipment. Turbofan engines operate on a fundamental principle. They incorporate a large front-mounted fan that draws in air. The additional air entering the engine, known as bypass air, follows the compression of the air entering the compressor, which is achieved through a set ofrotating fan blades.

Within the combustor, the fuel-air mixture ignites, generating hot gases that rapidly expand rearward, propelling the engine forward. In the event of a malfunction, such as an unforeseen obstacle, a fan blade could potentially break loose, spin off, and damage other engine components. Therefore, fancasings must be robust enough to contain detached blades and protect against potential harm, ensuring they can endure the impact of a loose blade.

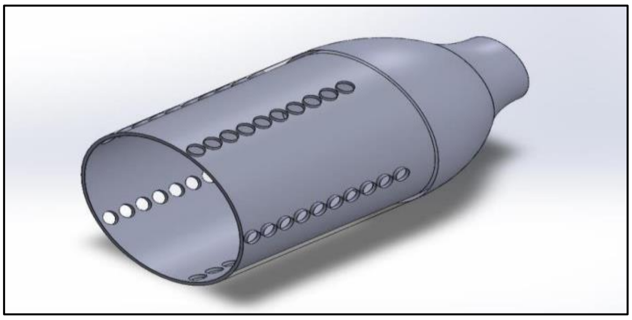

Fig 5: Solid Works Model of Combustion Chamber

D. Nozzle

Nozzles are an essential component of a jet engine that help convert the high-energy exhaust gases into a high-velocity jet of exhaust to produce thrust.

Nozzle design is critical for optimizing engine efficiency, performance, and fuel consumption. The shape and size of the nozzle are carefully engineered to match the operating conditions of the engine. Divergent section geometry, throat area, and expansion ratio are key parameters in nozzle design.

Proper nozzle design is crucial to optimize engine efficiency, which is often measured by specific fuel consumption (SFC) and thrust-to-weight ratio (T/W). The efficiency of a nozzle directly impacts the overall performanceand capabilities of the aircraft.

Nozzles are exposed to extremely high temperatures and pressures. They are often made from high-temperature, heat- resistant materials such as superalloys. Some nozzles incorporate cooling systems to protect the structure from extreme heat.

Ongoing research focuses on improving nozzle design to increase engine efficiency, reduce emissions, and enhance the overall performance of jet engines. Research also explores innovative materials and manufacturing techniques for nozzles.

Nozzle design can influence the environmental impact ofjet engines. Efforts are made to reduce noise and emissions through nozzle design and other engine technologies. As aircraft propulsion technology advances, nozzles will continueto play a significant role in enhancing engine performance, reducing environmental impact, and increasing safety.

In this instance the nozzle is of convergent type with the inlet diameter of 98mm converging to an outlet diameter of 40mm. The material of the nozzle needs to withstand high pressure and temperature so sheet metal is being used. The design of the nozzle is able to provide a suitable thrust to the model and provide motion to the assembly.

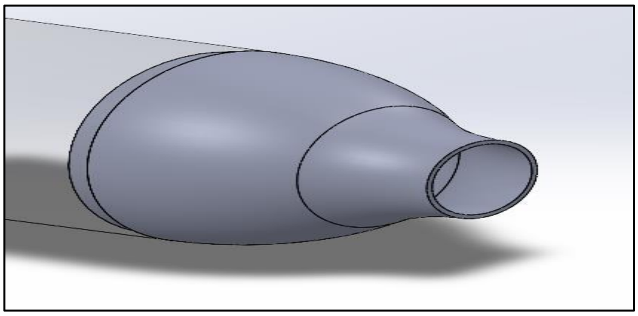

Fig 6: Solid Works Model of Nozzle

IV. ASSEMBLY

In In this assembly, the initial stage involves the intake of ambient air, which subsequently undergoes a multi-stage compression process upon entering the assembly. This processbegins with an inlet compressor designed to elevate the air's pressure and temperature significantly. The compressor unit operates with the aid of a motor situated directly behind it, driving the compression mechanism.

The highly compressed air is then directed into the combustion chamber, a critical component of the assembly. Within the combustion chamber, a precisely controlled mixture of fuel and the pre-compressed air is introduced. This fuel-air mixture undergoes a carefully regulated combustion process, ensuring that the air-fuel ratio remains within an idealrange for efficient and controlled combustion.

As the combustion process unfolds, the high-energy air starts to expand within the confines of the combustion chamber. This expansion occurs at a rapid pace, and the airexhibits a strong desire to escape the chamber through a designated nozzle. The nozzle is a crucial component designed to facilitate the efficient release of the expanding air. At the nozzle outlet, the expanded air-fuel mixture is forcefully expelled into the surrounding atmosphere. This process generates an immense thrust force, a consequence of the high-speed ejection of the combustion products. It is thisgenerated thrust that serves as the primary propulsive forcedriving the entire assembly forward in a controlled andpurposeful manner. This detailed sequence of events elucidates the fundamental principles behind the motion and propulsion of the assembly.

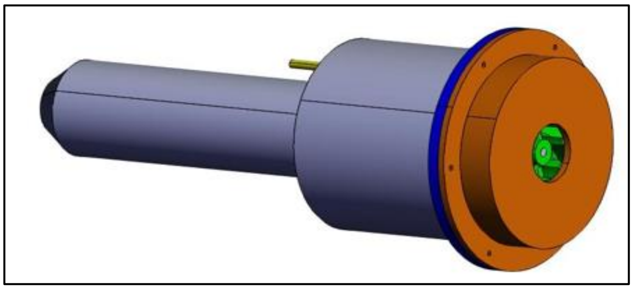

Fig 7: Solid Works Model of Actual Assembly

V. CALCULATIONS

A. *Thrust Calculation*

Actual thrust required to lift/push a weight of 25 kg isgiven as below.

F= 25 × 9.81 = 242.25 say 250 N

So, for safer side designing the engine to be able togenerate 400 N thrust.

- *Calculating Mass Flow Rate of Air*

F=m˙×(Ve−V0) + (Ae−A0) × Pe

400= m˙ × (284-25) + (5.94 × 10^{-3} - 5.67 × 10^{-3}) × 6

So, m= 1.54 kg/s

- *Now Calculating the Thrust based on New Value of MF =1.54 × (284-25) + (5.94 × 10^{-3} - 5.67 × 10^{-3}) × 6*

F = 398.86 N which is greater than required thrust,so design is safe

B. *Compression Ratio*

$$r = \frac{T2}{T1} = \frac{1}{\eta(\frac{1}{r-1})}$$

Where:

r is the compression ratio.

T1 is the initial temperature in Kelvin (convert 25degrees Celsius to Kelvin by adding 273.15).

η is the efficiency of the compressor as a decimal (e.g.,70% as 0.70).

γ is the specific heat ratio (also known as the ratio ofspecific heats or adiabatic index). For air,

γ is typically approximately 1.4. Let's calculate it using your values.

- *Convert the Initial Temperature T1 from Celsius to Kelvin:*

T1(K) = 25+273.15=298.15K

- *Plug in the Values into the Formula:*

$$r = \frac{1}{0.70(\frac{1}{1.4-1})}$$

- *Calculate the Exponent:*

$$r = \frac{1}{0.70(\frac{1}{0.4})}$$

- *Calculate the Compression Ratio:*

r = 1.639

C. *Air Fuel Ratio*

Thrust produced = 398.86 N Assume Weight of the engine= 7 kg

Mass flow rate of air entering the engine = 1.54 kg/s Fuel used is petrol having a C.V = 44.4 MJ/Kg Assuming the temperature and pressure of air is at

Atmospheric level
Cp of air = 1.4 KJ/kg K

To calculate the air fuel ratio for the given turbine less jet engine, we can use the following.

formula: $\frac{mass\ flow\ rate\ of\ air\ \times[\text{specific heat ratio of air }(T2-T1)]}{mass\ flow\ rate\ of\ fuel\ \times\ heating\ value\ of\ fuel}$

To determine T2, we need to make some assumptions about the compressor efficiency and the pressure ratio across the compressor. Let's assume that the compressor is 70% efficient and that the pressure ratio across the compressor is 1.5.

T1 = temperature of air at the compressor inlet (assuming atmospheric temperature of15°C, which is 288 K)

Using these assumptions, we can calculate T2 as follows:

$$\frac{p_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{(1{\cdot}4/0{\cdot}4)} \qquad 1\cdot 63 = \left(\frac{T_2}{298}\right)^{(1{\cdot}4/0{\cdot}4)}$$

T2 = 342.64K

Now we can plug in the values and calculate the air fuel ratio:

Air Fuel Ratio= $\frac{1.54\ \times[1.4\ (342.64-298)]}{0.253\ \times\ 44.4}$ = **8.56**

Therefore, the air fuel ratio for the given turbine lessjet engine is 8.56.

VI. CONCLUSIONS

The present work deals with the design of hybrid electric jet engines with the analysis of the individual components. The project is being made by following a specific procedure i.e.:

- Literature Review: Papers of reputed authors were referred to set a standard and give us a strong base to work on further such as, Zhixing Ji; Jiang Qin; Kunlin Cheng; Chaolei Dang; Silong Zhang; Peng Dong,(”Thermodynamic Performance Evaluation of a Turbine-less Jet Engine Integrated with Solid Oxide Fuel Cells for Unmanned Aerial Vehicles”) Zhixing Jiab, Marvin M. Roknib , Jiang Qina , Silong Zhanga , Peng Donga, (“Energy and configuration management strategy for battery/fuel cell/jet engine hybridpropulsion and power systems on aircraft”).
- Focusing on certain parts of engine such as motor compressor and combustion chamber.
- Understanding the working of individual parts and knowing the mechanism when assembled.
- Calculation of thrust, compression ratio, mass flow rate of air, air fuel ratio was carried out.
- After completing our necessary calculations, we carried on with our Solid Works model of compressor, motor, combustion chamber, compressor casing and experimental setup.
- As we have completed the following set of procedures this semester, we are ready to start manufacturing our well-designed model.
- By following this set of procedures, we were able to complete our calculations and designing at the specified time.

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