"Design and Thrust Analysis of Compact Jet Engine"

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Abstract

With gas turbine engine testing becoming very expensive because of the increasing complexity involved with the engine, engine subsystems, and test support systems, a low-cost Turbo Jet Engine is proposed. In the present study, The Turbo jet engine should built with modularity as a key design consideration to allow for flame-tube patterns and augmented sections to be changed quickly for combustion. Experiments that have gained impetus due to combustion anomalies/instabilities inherent with future military engine augmentors. This model allows for an effective way to test new analytical techniques before full scale testing at low-cost and quick schedule turnaround. The compact model should complete using a minor financial investment when matched to comparable capabilities.

INTRODUCTION

We found out that the application of a jet engine is very limited as due to its working and some other problem such as fuel consumption and stability. So what we were seeking it as make it in a compact size of the vast utilization of the thrust produced by the jet engine. So, this project involves building a ground based gas turbine engine for use as a technology demonstrator that has been given the title, Turbine Engine model.

This project involves building a ground based gas turbine engine for use as a technology demonstrator that has been given the title, Turbine Engine model. The data and control system is easily adaptable to meet future test requirements. The Turbo engine is a highly modular system that allows components to be changed out and can be modified easily. The components are analysed for the proper failure modes, and performance is predicted using a combination of hand calculations and engine performance prediction software. The compressor performance is predicted using turbomachinery relationships and geometry, then compared with experimental data.

LITRATURE REVIEW

Gas Turbine

Development of Gas, or combustion, turbines was originally started in the 18th century. The first patent was issued to England's John Barber in 1791 for a combustion turbine. Patents for modern versions of combustion turbines were awarded in the late nineteenth century to Franz Stolze and Charles Curtis, however early versions of gas turbines were all impractical because the power necessary to operate the compressors outweighed the amount of power generated by the turbine. To achieve positive efficiencies, engineers would have to increase combustion and inlet temperatures beyond the maximum allowable turbine material temperatures of the day. It was not until the middle of this century that gas turbines evolved into practical machines, primarily as jet engines. Although some prototype combustion turbine units were designed, the developments that led to their practical use were a result of World War II military programs. The actual race for jet engines was prompted by World War II and therefore government started subsidization on R&D. Later gas turbines for power generation were to emerge to from these military advances in technology. Only Germany's Junkers and Great Britain's Rolls- Royce were successful to enter general production with their engines during the war. Only GE was especially able to transfer knowledge between its ongoing aircraft engine and power generation turbine businesses. The beginning of gas turbine power generation "packages" occurred early 1960s when GE and Westinghouse engineers were able to standardize (within their own companies) designs for gas turbines.

Combustor Design

The simultaneous involvement of evaporation, turbulent mixing, ignition, and chemical reaction in gas turbine combustion is too complex for complete theoretical treatment. Instead,large engine manufacturers undertake expensive engine development programs to modify previously established designs through trial-and-error.They also develop their own proprietary combustor design rules from the experimental results of these programs.

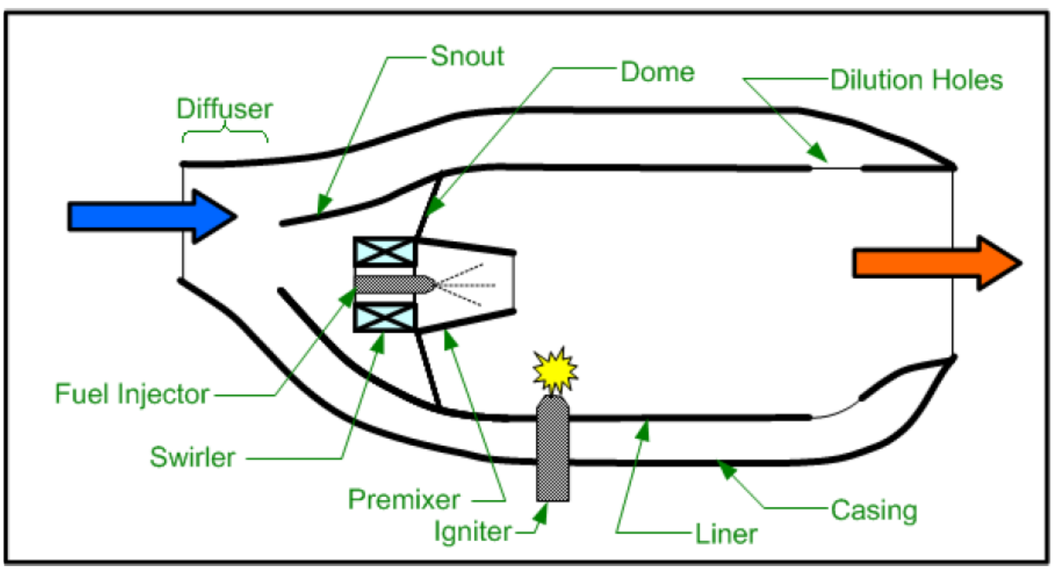

Figure 2.1: Modern combustor components.

These design rules provide a means of specifying the combustor geometry to meet a set of requirements at the given inlet conditions .Combustor designers without access to proprietary design procedures must derive their own methods from the literature or from experimentation. Numerous published empirical, semi empirical, and analytical tools have been developed to reduce the need for costly experiments. Analytical methods, less accurate in comparison to empirical methods, are much more flexible as they are only restricted by the simplifying assumptions

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
May 2018

necessary to reduce their complexity and computation time. Hybrid semi-empirical tools combine both empirical and analytical methods to provide a reasonable balance between accuracy and computation time.

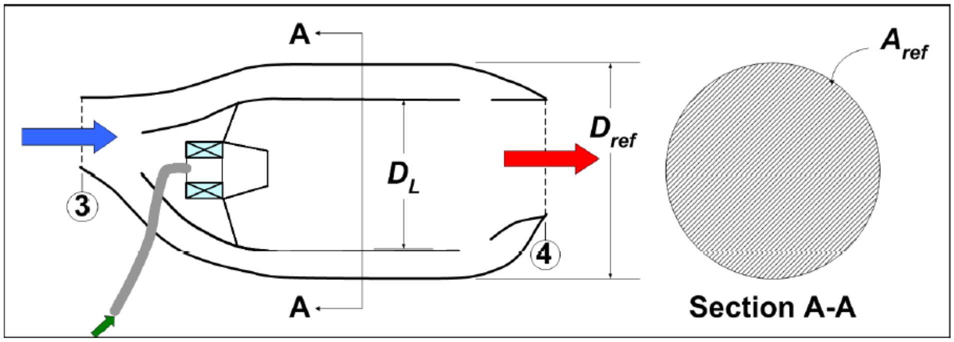

Figure: Reference dimensions.

2.3. Gas Turbine Combustor Model

Basic material on combustion theory and models can be found in the paper, Some
Fundamentals of Combustion, which provides the idea about the modeling of combustor.Numerical procedures used to be based on the SIMPLE algorithm and rectangular gridsystems approaching the turbine.The flow field exiting the combustor has highly non-uniform pressure and temperature variations in both the radial and circumferential directions as well as high turbulence levels. as illustrated by the highly popular TEACH code and its derivatives .

It may be noted that other techniques are available however these have not found wide spread use in combustor simulation because of lack of flexibility, robustness and experience. Only the broad features of such flow field have been simulated with TEACH-based codes. It is not trivial, however, to improve the fidelity of these simulations. The models for turbulence and chemistry and the numerical procedures are together responsible for the problems encountered.Performance enhancements and control of heat transfer in high pressure gas turbine vanes and rotors is dependent on understanding the flow and thermal fields

2.3. Summary of literature Survey

On the basis of literature review it can be concluded that the fluid flow has very complex and essential to observe it for proper combustion of fuel. Prediction of flow in gas turbine combustor has been a subject of several investigations owing to the fact that aerodynamics plays a key role in dictating the performance of gas turbine combustor. The estimation of pressure drop is very much required for effective combustion of fuel inside the combustor. The air distribution through different zone holes has very much effect on the mixing the fuel and its combustion. The velocity in all directions is also gives the information of mixing and burning of fuel. For stability of flame the flow pattern of air and fuel is very essential.

METHODOLOGY

All air breathing gas turbine engines have four major components in common: the compressor, combustor, turbine, and nozzle. A typical non-augmented turbojet engine cross-section is shown in Figure 4.1 with the main components. The compressor takes the free-stream ambient flow and compresses it to a higher enthalpy state to prepare it for combustion in the combustor where the air and fuel are mixed together and ignited to form hot high pressuregas.

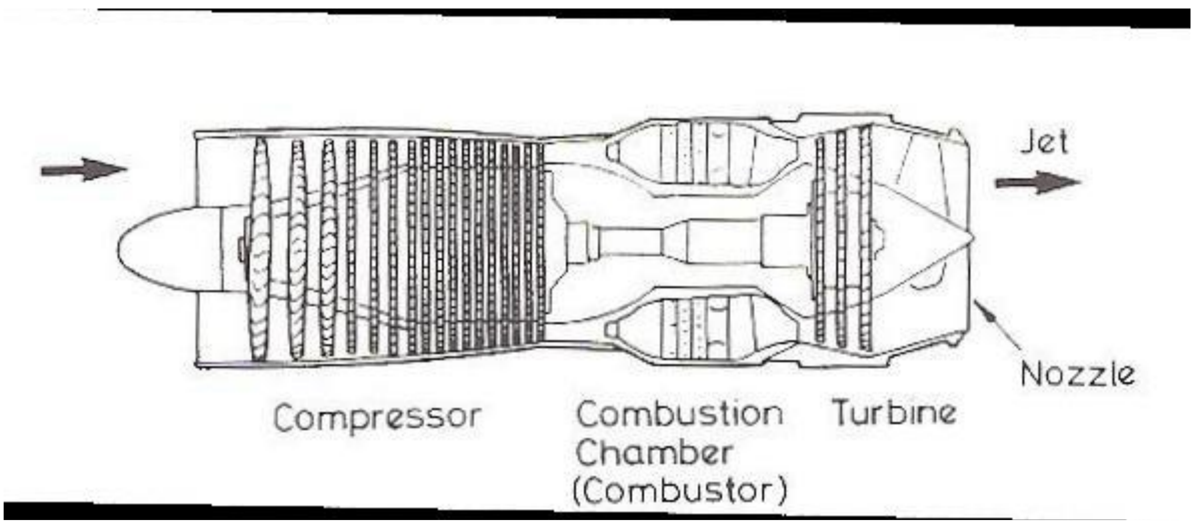

Figure: Typical turbojet engine showing four main components

The gas is next expanded across turbine blades that extracts a portion of the energy from the flow to drive the compressor through the engine shaft. Downstream of the turbine, the flow is accelerated by the nozzle and according to Newton's 3rd law creates thrust. If the engine is augmented (afterburning), as within the current testbeds capability, there is another region for combustion, after additional fuel has been added, downstream of the last turbine stage to increase the temperature and therefore the enthalpy of the fluid flow before being accelerated through the nozzle. The augmentor is a way to add power output for a given compressor pressure ratio. The gas turbine engine operates using the Brayton cycle for thermodynamics. The T-s diagram for a 'real' (with component efficiency losses) afterburning turbojet engine is shown in Figure 4.1. Note that the 'AB Operation' region increases the useful work (Thrust, *F)* of the engine. This increase in useful work comes at a large increase in fuel consumption. It is assumed that the reader has some background with thermodynamics and turbo-machinery as well as basic understanding of engineering design.

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
May 2018

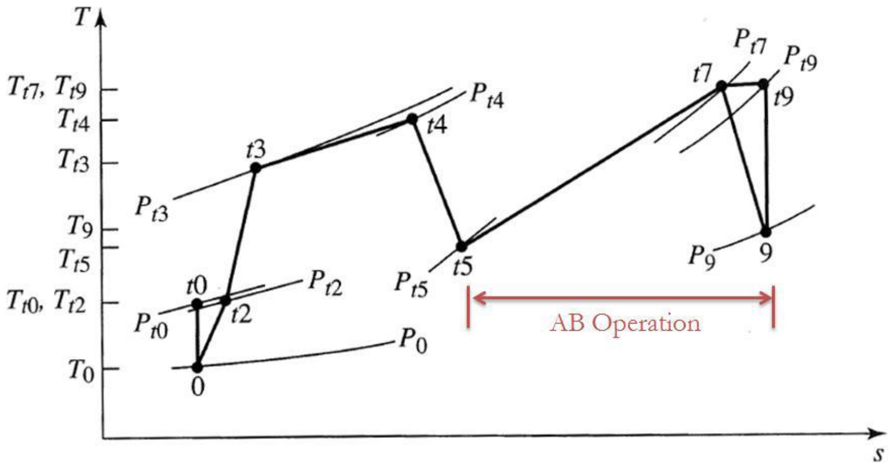

Figure T-s diagram for real afterburning turbojet engine

Table: Table of corrected performance parameters

Parameter	Symbol	Corrected parameter
Total pressure	P_{ti}	$\delta_i = \frac{P_{ti}}{P_{ref}}$
Total temperature	T_{ti}	$\theta_i = \frac{T_{ti}}{T_{ref}}$
Rotational speed	$N = \text{RPM}$	$N_{ci} = \frac{N}{\sqrt{\theta_i}}$
Mass flow rate	$\dot{m}_i$	$\dot{m}_{ci} = \frac{\dot{m}_t\sqrt{\theta_i}}{\delta_i}$
Thrust	F	$F_c = \frac{F}{\delta_0}$
Thrust-specific fuel consumption	S	$S_c = \frac{S}{\sqrt{\theta_0}}$
Fuel mass flow rate	$\dot{m}_f$	$\dot{m}_{fc} = \frac{\dot{m}_f}{\delta_2\sqrt{\theta_2}}$

Result and Discussion

The pressure and temperature are made dimensionless by using the following relationships

$$\delta_i \equiv \frac{P_{ti}}{P_{ref}}, \text{ where } P_{ref} = 14.696\, psia \qquad \theta_i \equiv \frac{T_{ti}}{T_{ref}}, \text{ where } T_{ref} = 518.69°R$$

The corrected engine speed is a function of the upstream total temperature ratiousing the relationship:

$$N_c \equiv \frac{N}{\sqrt{\theta_1}}$$

Challenges During Discussion

- Many interdisciplinary aspects: design, fabrication, and analysis (requires self-education for less proficient areas)
- Parts for the intended use are very expensive and have long lead times (need to be innovative to be successful)
- Large number of custom components requires fabrication techniques that lead to higher costs and longer schedule
- Control system must be robust enough to handle unexpected occurrences while still shutting down the engine safely
- High rotational speeds are a concern for safety along with the use of hydrocarbon fuels
- Keeping the system 'mobile' requires subsystems to be on-board the engine test stand
- Modularity requirement requires that all components be easily changed and replaced with newly 'modified' components

Conclusion and further scope of work

The aim of the designing and constructing scale model of jet engine was to study the working and performance of jet engines.The study showed that jet engines are efficient in converting fuel energy into shaft power.The study revealed that jet engines offer a number of advantages as compared to other heat engines in respect of :

1. High power to weight ratio
2. Higher mechanical efficiency
3. Higher thermal efficiency

4. Lesser Vibrations

5. Simplicity of component

Thus jet engines/ gas turbines can be employed in number of the automotive propulsion and low cost power generation applications.There are some disadvantages of the gas turbines like:

1. Low part efficiency

2. Difficulty in manufacturing

But these disadvantages can be surpassed by extensive research in the field of computational fluid dynamics, combustion dynamics, metallurgy and advancements in the manufacturing techniques. There are number of improvements currently going on in the field of gas turbines which will make them more versatile than other engines. As for future prospective what we are trying to do here by making the jet engine in as possible as compact size and it can be utilized in as many as useful application i.e. for future oriented jet controlled Drones and also as mini jet planes for Military surveillance,by making it fuel efficient,smaller in size.

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