PERFORMANCE OF 2-SHAFT GAS TURBINE USING LIQUID PETROLEUM GAS (LPG) AS A FUEL FEEDER

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A thesis report submitted to Faculty of Mechanical Engineering in partial fulfillment of the requirement for the award of Bachelor's Degree of Mechanical Engineering (Thermal- Fluid)

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November 2005

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluid)"

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Date : 15 December 2005

I declare that this report entitled "PERFORMANCE OF 2-SHAFT GAS TURBINE USING LIQUID PETROLEUM GAS (LPG) AS A FUEL FEEDER" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

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ABSTRACT

This thesis is the compilation of all the knowledge, activities including gathering information, data and analysis all the related resources due to the main scope which is a study of 2-Shaft Gas Turbine performance using LPG as a feeder. This report is part of the components presented for the Final Year Project (PSM 2) beside the weekly report (log book).

This thesis consist two parameters or factors concerned that are very critical which are the gas turbine engine performance and the effect of the fuel that is going to be use as a feeder.

At the beginning of the report, I briefly introduced the literature review and background of the gas turbine including the theory and the analysis that have been made to review the performance of the gas turbine. Then the scope of the project are touched in details followed by basic law and all the calculation and equation that will involve during this project such as the thermodynamics law, cycles analysis and performance of gas turbine engines. This information is useful to analyze the effect of the gas turbine performance. After doing the literature study, there are many parameters and assumption that have been made to get the equation needed.

ABSTRAK

Tesis ini merupakan kompilasi semua pengetahuan, maklumat dan aktiviti yang dijalankan termasuk mengumpul maklumat, data dan menganalisis kesemuanya yang berkaitan dengan skop tesis iaitu kajian terhadap prestasi 2-shaft turbin gas menggunakan beberapa LPG sebagai bahannapi. Tesis ini merupakan sebahagian daripada Projek sarjana Muda (PSM 2) termasuk laporan buku log.

Tesis ini merangkumi dua perimeter dan faktor penting iaitu prestasi enjin 2-shaft turbin gas dan juga ciri-ciri penting bahanapi yang akan digunakan LPG dan kesannya terhadap keseluruhan prestasi gas turbin.

Di awal tesis ini, kajian penyelidikan dan pengenalan kepada turbin gas termasuk teori dan analisis yang akan diguna pakai dinyatakan. Tesis ini juga menyentuh secara terperinci tentang skop projek di ikuti dengan pengiraan-pengiraan serta rumus-rumus yang akan digunakan semasa menjalankan tesis ini. Antaranya ialah Hukum Termodinamik, analisis kitaran dan juga prestasi turbin gas itu sendiri. Maklumat ini amat penting untuk menganalisa prestasi turbin gas. Selepas menjalankan kajian penyelidikan banyak perimeter dan andaian yang perlu dibuat dan diambil kira.

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LIST OF SYMBOLS

REGULAR	DEFINATION
Q	Heat
W	Work
T	Temperature
P	Pressure
V	Velocity
g	Acceleration of gravity 9.81m/s^2
ρ	Density
R	Gas constant for 1 kg of dry air
Cp	Specific Heat at constant pressure
Cv	Specific Heat at constant volume
η	Efficiency
k	Ratio of specific heat c_p/ c_v
G%	Gas Flow Rate
G	Generator Load
$\dot{m}_{air}$	Air mass flow rate
$\dot{m}_{gas}$	Gas mass flow rate
λ	Air ratio
r_p	Pressure Ratio
P_{T2}	Turbine power output
b_{fuel}	Specific fuel consumption

SUBSCRIPT	DEFINATION
th	Thermal
C	Compressor isentropic
T	Turbine isentropic

g	Gas
D	Fuel Gas Nozzle Pressure
atm	Atmosphere
comp	Compressor
turb 1, out	Turbine 1 Output
turb 2, out	Turbine 2 Output
bw1	Back Work
1	Properties at front of intake
2	Properties at the end of intake and correspond to the face of the first stage of the compressor
3	Properties at the end of the compressor stage
4	Properties at the end of the burner and correspond to the face of the first stage of the turbine
5	Properties at the end of the turbine stage

ACRONYMS	**DEFINATION**
SFC	Specific Fuel Consumption
ETH	Thermal Efficiency

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CHAPTER I

INTRODUCTION

1.0 INTRODUCTION TO GAS TURBINE

A turbine is any kind of spinning device that uses the action of a fluid to produce work. Typically fluids are: air, wind, water, steam and helium. A gas turbine has a compressor to draw in and compress gas (most usually air); a combustor (or burner) to add fuel to heat the compressed air and a turbine to extract power from the hot air flow. In addition, the areas where the air enters the engine and the exhaust leaves the engine are also important. The gas turbines are an internal combustion process and are continuous-flow engines that develop steady aerodynamics and flame kinetics. These features reduce the constraints placed on fuel properties for combustion and provide a considerable margin for clean combustion.

In particular, heavy-duty gas turbines can operate on a large number of primary fuels that are available in many branches of the industry. These accessible fuels include natural gas (NG) and diesel fuel (DF), as well as a number of industry byproducts generated by the refining and petrochemical sectors, coal and oil and gas activities, steel and mining branches and by agricultural industry (biofuels). This fuel flexibility enhances the existing qualities demonstrated by gas turbines, such as efficiencies, reliability, versatility in applications (mechanical drive, simple and combined cycle, combined heat and power, and low emissions.

Gas turbines are always used in situations where high power density, low weight and rapid start up are required. A gas turbine is very similar the expanding hated gas acts upon a turbine wheel which can be used to provide power. In a gas turbine, air is compressed using a rotating impeller, which is driven by the turbine.

The main difference between a piston engine and gas turbine is that the processes in gas turbine are simultaneous and continuous. Aerodynamics also play a key role in gas turbine operation, the flow of gases around turbine blades and compressors is crucial to the efficient operation.

As the moving parts in a gas turbine are only subject to rotary motion, given good balancing, almost vibration free running is possible. A disadvantage is the high noise level caused by the high gas speeds and the simultaneous direct link to the atmosphere.

1.1 TYPES OF GAS TURBINE ENGINE

There are many types of gas turbine engine available today for aircraft propulsion used. Below are some of the classifications of gas turbine engines.

1.1.1 TURBOJET ENGINE

The turbojet is the basic engine of the jet age. Air is drawn into the engine through the front intake. The compressor squeezes the air to many times higher than the normal atmospheric pressure and forces it into the combustor. Here, fuel is sprayed into the compressed air, is ignited and burned continuously. The burning gases expand rapidly rearward and pass trough the turbine. The turbine extracts energy from the expanding gases to drive the compressor, which intakes more air. After leaving the turbine, the hot gases exit at the rear of the engine, giving the aircraft its forward reaction.

1.1.2 TURBOPROP/TURBOSHAFT ENGINE

A turboprop engine uses thrust to turn a propeller. As in a turbojet, hot gases flowing through the engine rotate a turbine wheel that drives the compressor. The gases then pass through another turbine, called a power turbine. This power turbine is coupled to the shaft, which drives the propeller trough gear connections.

A turboshaft is similar to a turboprop engine, differing in the function of the turbine shaft. Instead of driving the a propeller, the turbine shaft is connected to a transmission system that drives helicopter rotor blades, electrical generators, compressors and pumps, and marine propulsion drives for naval vessels, cargo ships, high speed passenger ships, and other vessels.

1.1.3 TURBOFAN ENGINE

A turbofan engine is basically a turbojet to which a fan has been added. Large fans can be placed at either the front or rear of the engine to create high bypass ratios for subsonic flight. In the case of a front fan, a second turbine, located behind the primary turbine that drives the main compressor drives the fan. The fan causes more air to flow around (bypass) the engine. This produces greater thrust and reduces specific fuel consumption.

1.1.4 ULTRA HIGH BYPASS ENGINE

A logical approach to improving fuel consumption is even higher bypass technology. Mechanical arrangements can vary. During the 1980s, GE developed the Unducted Fan UDF engine which eliminated the need for a gearbox to drive a large fan. The jet exhaust drives two counter-rotating turbines that are directly coupled to the fan blades. These large span fan blades, made of composite materials, have variable pitch to provide the proper blade angle of attack to meet varying aircraft speed and power requirements.

1.2 OBJECTIVES

The objective of this thesis is to study on the 2-shaft gas turbine performance by using LPG (Liquid Petroleum Gas) as a feeder. For this study the interest is to monitor, learned and also observed the 2-shaft gas turbine engine performance with variable fuel properties. It is hoped that this project will be beneficial to the reader especially at an introduction level. Also, this thesis could be a beginning for the further study in gas turbine industries.

1.3 SCOPE

The scopes of this thesis are as follow:

- i- Study on 2-shaft gas turbine engine performance
- ii- Selection of importance equations that govern the performance of gas turbine engine performance.
- iii- Running the gas turbine with Liquid Petroleum Gas (LPG).
- iv- Gathering all the data performance
- iii- Analysis

1.4 PROBLEM STATEMENT

As mentioned before the main purpose of this thesis is to study and to find the overall 2-shaft gas turbine performance, ET 794 Functional Gas Turbine Model that has been provided in Thermo Lab using Liquid Petroleum Gas (LPG) as a feeder. The understand of application concept of 2-shaft gas turbine, turbine characteristic and fuel consumption are the various parameter that have to be consider during this thesis.

1.5 PROBLEM ANALYSIS

Some of the approach that has to be considers overcoming the problem statement mentioned above:-

i- Identify all the problem statement and try to overcome it.

ii- Design and develop an experiment based on the problem.

iii- Study on the gas turbine performance and characteristics.

iv- Familiarized with all the equations, concept and theory related to the problem.

v- Collecting data from the experiment and try to overcome the data.

vi- Study the mathematical simulation of the gas turbine.

CHAPTER 2

LITERATURE RIVIEW

2.0 RESEARCH IN GAS TURBINE

In this thesis several researches was done base on the journals related on the topics. This is done due to analyze the accomplishment of the project that have been done and as main resources to fulfill this thesis.

i) The reasons why the maximum thermal efficiency not to be at the highest temperatures are because of the non-linear correlation between fuel air ratio and temperature increase in the burner. Neither the temperature dependence of specific heat nor the water vapor content of the combustion gas are the reason for the maximum thermal efficiency existing at fuel air ratios lower than the stoichiometric value. Increasing burner exit temperature is not a way to increase thermal efficiency as it was in the past. Increasing pressure ratio yields a moderate improvement potential and true improvements in thermal efficiency are possible with alternate gas turbines configurations, (Joachim Kurzke, Oct 2002).

ii) Using an alternative gas turbine liquid fuels, such as volatile or low viscosity fuels like gas condensates, kerosene, methanol, ethanol, or low lubricity distillate fuels; light cycle oil (LCO), or synthetic fuels are quite interesting for their ability to be fired in heavy duty gas turbines. However, the effect of using these fuels creates specific issues such as low lubricity properties which can affect sensitive key components like fuel pumps and flow dividers. This journal also included many practical aspects of using fuel lubricity additives for reduced component wear in gas turbine fuel systems, and for reliability and successful plant operation on these alternative gas turbine liquid fuels, (Jean Stalder and Phil Roberts, June 2003).

iii) Crude and heavy fuel oils are most common fuels use for combustion in gas turbines because of the competitive pricing of these fuels. However, crudes and heavy fuels usually contain significant levels of metallic contaminants usually Vanadium which cannot be removed before combustion, results in the formation of low melting point corrosive deposits on the turbine blades. It also can cause severe operational problems in gas turbines if appropriate action is not taken. To prevent this from happen is the use of Magnesium containing additives. The crude and heavy fuel oils are also always contaminated with sodium and potassium which greatly increase turbine blade corrosion. It is therefore essential to reduce the level of both these metals to a minimum, (Dr Phil Roberts, April 1999).

2.1 GAS TURBINE ENGINE COMPONENTS

The inlet, compressor, combustor, turbine and nozzle are the main components of the gas turbine engine.

2.1.1 INLETS

An inlet reduces the entering air velocity to a level suitable for the compressor. The air velocity is reduced by compression process which increases the air pressure. The operation and design of inlet are described in terms of efficiency of the compression process, the external drag of the inlet, and the mass flow into the inlet. The design and operation of the inlet depend on whether the air entering the duct is subsonic or supersonic.

2.1.2 COMPRESSOR

The function of the compressor is to increase the pressure of the incoming air so that the combustion process and the power extraction process after combustion can be carried out more efficiently. By increasing the pressure of the air, the volume of the air is reduced, which means that the combustion of the fuel/ air mixture will occur in smaller volume.

2.1.3 COMBUSTOR OR MAIN BURNER

The combustor is design to burn mixture of fuel and air and to deliver the resulting gases to the turbine at a uniform temperature. The gas temperature must not exceed the allowable structural temperature of the turbine. Less than one-half of the total volume of air entering the burner mixes with the fuel and burns. The rest of the air-secondary air is simply heated or may be thought of as cooling the products of combustion and cooling the burner surfaces.

2.1.4 TURBINE

The turbine extracts kinetic energy from the expanding gases which flow from the combustion chamber. The kinetic energy is converted to shaft horsepower to drive the compressor and the accessories. Nearly three-fourths of all the energy available from the products of combustion is required to drive the compressor.

2.1.5 EXHAUST NOZZLE

The purpose of exhaust nozzle is to increase the velocity of the exhaust gas before discharge from the nozzle and to collect and straighten gas flow from the turbine. In operating, gas turbine engines convert internal energy of the fuel to the kinetic energy in the exhaust gas stream. For large values of specific thrust, the kinetic energy of the exhaust gas must be high, which implies a high exhaust velocity. The nozzle supplies a high exit velocity by expanding the exhaust gas in an expansion process which requires a decrease in pressure. The pressure ratio across the nozzle controls the expansion process, and the maximum thrust for a given engine is obtained when the exit pressure equals the ambient pressure.

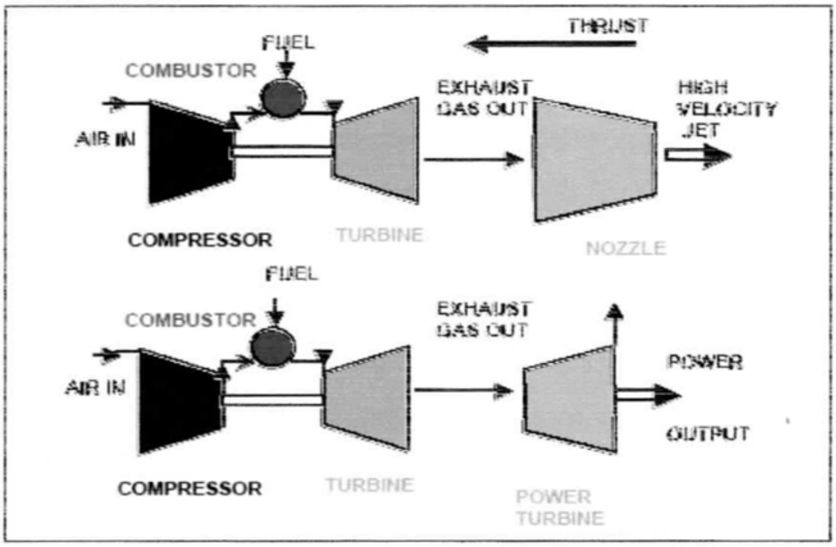

Figure 2.1 : ***Simple Cycle Gas Turbines as Aircraft Engines and Land Based Prime Movers. The compressor-combustor-turbine part of the gas turbine is commonly termed the gas generator*, (Rainer Kurz, 2001)**

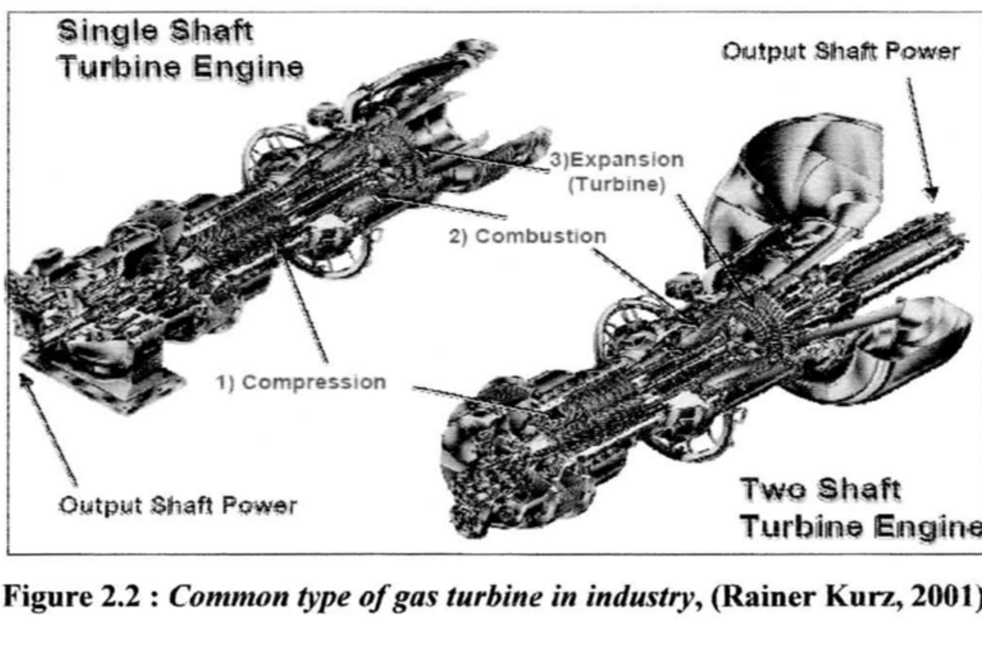

Figure 2.2 : ***Common type of gas turbine in industry*, (Rainer Kurz, 2001).**