THE DEVELOPMENT OF SMALL GAS TURBINE ENGINE

By

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DECLARATION

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T	Temperature	Ft	Feet
S	Entropy	N	Newton
º	Degree	Lb	Pounds
ºC	Degree Celsius	Hp	Horse Power
°F	Degree Ferrenheit	*T*	Torque
K	Kelvin	F	Force
RPM	Revolution per Minute	r Radius	
V	Volt	RM	Malaysian
DC	Direct Current	Ringgit	
Pa	Pascal		
Atm	Atmospheric Pressure		
Kg	Kilogram		
m	Meter		
Inch	Inches		

Abstract

The design, fabricate and test of a small gas turbine and all other systems are presented in this report. This report is focused on making the combustion chamber, ignition system, lubrication system, and fuel injection system. Other than that this report also focuses on the development of the system after the first design to improve the system.

In this report, designing and fabrication methods of the combustion chamber and also its development process is presented. The combustion chamber and its flame tube were designed and constructed. The combustion takes place inside the chamber should remain in the chamber. The test of the combustion chamber shows that the combustion only remains inside the combustion chamber and did not enter the turbine.

Next, designing and fabrication methods of the ignition system and fuel injection system are presented in this report. The ignition system is followed the conventional spark plug system of a car. The fuel system uses a normal butane gas used at home, and its nozzle is made manually. The methods of the development process of both ignition system and fuel injection system are presented in this report. The tests for both systems show that the minimum voltage to create combustion is 30V.

Lastly, designing and fabrication method of the lubrication system is presented in this report. Lubrication system is needed for the rotating shaft to cool down the shaft and to reduce friction. The test of the lubrication system using a gear pump driven through gear and chain shows that the viscosity of the oil feed to the shaft must be very low. In this system, the Mobil ATF 220 high performance automatic transmission fluid was used.

Abstrak

Rekabentuk, fabrikasi dan ujikaji sebuah turbin gas dan sitem-sistem lain diterangkan dalam laporan ini. Laporan in difokuskan pada penghasilan ruangan pembakaran, sistem pengapian, sistem pelincir, dan sistem pembekal bahan api. Selain dari itu laporan ini juga difokuskan dalam penambahbaikkan sistem tersebut dari rekabentuk asal untuk meningkatkan kebolehan sistem tersebut.

Dalam laporan ini, rekabentuk dan kaedah fabrikasi ruangan pembakaran dan juga proses penambahbaikkan dipersembahkan. Ruangan pembakaran dan tiub api direkabentuk dan dibina. Pembakaran yang terhasil didalam ruangan tersebut mesti berada didalam ruangan itu. Ujian ruangan pembakaran menunjukkan pembakaran tersebut hanya berada didalam ruangan pembakaran dan tidak memasuki turbin.

Seterusnya, rekabentuk dan kaedah fabrikasi bagi sistem pengapian dan sistem pembekal bahan api dipersembahkan dalam laporan ini. Sistem pengapian tersebut mengikut sistem pengapian konvensional dari kereta. Bahan api yang digunakan adalah gas butane biasa dan mulut pembekal bahan api dibuat sendiri. Kaedah penambahbaikkan untuk kedua-dua sistem pengapian dan sistem pembekal bahan api dipersembahkan dalam laporan ini. Ujian untuk kedua-dua sistem menunjukkan voltan minima untuk pembakaran terhasil adalah 30V.

Akhir sekali, rekabentuk dan kaedah fabrikasi untuk sistem pelincir dipersembahkan dalam laporan ini. Sistem pelincir diperlukan oleh rod berputar untuk menyejukkan rod tersebut dan untuk mengurangkan geseran. Ujian sistem pelincir ini menggunakan pam gigi melalui gigi dan rantai menunjukkan kelikatan minyak yang disalurkan ke rod berputar mestilah sangat rendah. Dalam sistem ini, minyak penghantaran automatik Mobil ATF 220 berprestasi tinggi digunakan.

CHAPTER ONE: INTRODUCTION

1.1 Background

This final year project is titled as "THE DEVELOPMENT OF SMALL GAS TURBINE ENGINE". The small gas turbine engine is made out of a car turbo charger. The concept of the turbo charger of a car is same with a gas turbine used in aircraft engine. The turbojet engine of an aircraft consists of three components which are compressor, combustion chamber, and the turbine. The turbo charger of a car consists of two components which are compressor and the turbine. The only component needed is a combustion chamber if we want to make a gas turbine. In a car, the combustion chamber is actually replaced by the engine. It is because the engine will burn a mixture of air and fuel and then release a hot gas to the exhaust. This concept is same with a combustion chamber.

There are lots of turbo chargers on the market and many company like Mitsubishi, Subaru, Nissan, and others has produced an engine with build in turbo charger. For this project, we bought a turbo charger came from a Nissan engine. This turbo charger is Garrett A/R 80. This turbo charger is previously used in a Nissan 240sx, one of Nissan best car used for racing development. Turbo charger involving a very high revolution and thus it needs lubrication. It doesn't come with lubrication and yet we must design the lubrication. Figure 1.1 and figure 1.2 shows the turbocharger that was bought for the final year project purpose and the Catia design of it. [1]

Figure 1.1 Garrett Turbo A/R 80

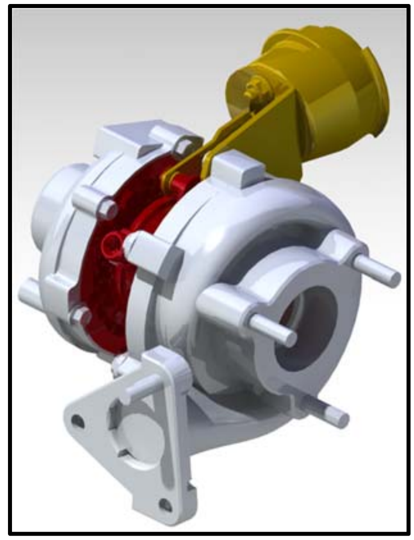

Figure 1.2 Garrett Model

The Combustion chamber is the climax part of this final year project. The combustion chamber is used to burn a mixture of air and fuel and also to deliver the resulting gases to the turbine at a temperature which will not exceed the allowable limit. The combustion chamber must add sufficient heat energy to the gases to accelerate their mass which enough to produce the desired thrust for the engine and power for the turbine. There are three criteria for acceptable burner. First is pressure loss of the gas passes through the combustion chamber must be held to a minimum. Second is the combustion efficiency must be maintained at high level. Lastly there must be no tendency for the combustion chamber to blow out of the turbine. A perfect combustion process must take place within the chamber and no burning should occur after the gases leave the chamber outlet. The gases temperature-distribution must satisfy the limit and have an acceptable maximum temperature as they enter the turbine. There are many components that need to be designed and fabricated in the combustion chamber such as the chamber itself, the flame tube, the fuel injectors and the spark plug for initiating the combustion process. [2]

The fuel is basically used for the combustion process after being mixed with compressed air. There are many fuel that can be used for combustion these days such as gasoline that was used by cars, butane gas that is used in house for cooking purposes, propane that is used as fuel in furnaces for heating, in cooking, as a energy source for water heaters, laundry dryers, barbecues, portable stoves, and motor vehicles, methane that is used for cooking purposes, vehicle fuel, and rocket fuel. For this project, we might want to use a cheap, reliable, and easy to find type of fuel. In Malaysia, the most easily to find is the butane, and second is propane. As this project move on, we will test both gases as fuel for the combustion process. [3] [4]

1.2 Problem Statement

Small gas turbine made from old car turbocharger is mostly known as homemade gas turbine or homemade turbojet engine in other countries such as United States of America. Currently in Malaysia, there are no people who tried to do this project and hopefully this final year project gives a good result and is the first in Malaysia. There are five initial questions that need further study for this project.

The first problem is about the combustion chamber. The main problem about this is the design. As we all know that the combustion must take place within the combustion chamber only and yet this is one of the problem because this need research and development process to get a complete combustion in the chamber. Another question is what type of metal we can use to make the chamber. As we know it must have high melting point temperature so that it does not melt when the combustion takes place. In this case the only available material we can use is Aluminium, Mild Steel and other type of Steel. The best material can be used is Mild Steel because it is easier to find and it is the cheapest price of Steel in Malaysia. Other than that is the Fuel Injection System. The fuel must be mixed with air completely before it undergoes burning process. The chamber must be designed to create enough turbulence to mix the fuel and air before burning. If the chamber cannot create enough turbulence, the air and fuel did not mix well enough and can contribute to incomplete combustion process, and the combustion process will extend after the turbine. If this happens, the turbine will be exposed to extremely high temperature. We do not want this thing to happen because it can damage the turbine blades, the bearings and the shaft. Common symptoms are leaking of the lubricants, loosen shaft and blade failure.

Second is the spark plug. The question is where to put the plug so that it will not contribute to melted fuel injector, how to build a conventional spark plug used by cars and motorcycles. If we are trying to use conventional sparkplug like the one being used by cars and motorcycles, we might want to use other components to generate enough power to ignite the sparkplug. The components of the car for the sparkplug are 12V battery, magnetic coil, point distributor, and a spark plug. There might be more components for different cars or motorcycles.

Third is the flame tube. The flame tube is one of the most important things inside a combustion chamber. This is where the combustion takes place. One of the questions is what design it should be, how many holes so that it can perform a complete combustion process in the flame tube and how long the flame tube should be designed to get a complete combustion. There are many possibilities which it may produce incomplete combustion or excess combustion. Incomplete combustion can produce hazard gas and it can damage the ozone. Thus it will contribute to global warming. Excess combustion can contribute to damage the turbine and overheat of the shaft. Eventhough the casing is made out of cast iron, but the blades may expand. This can damage the blades. That is why we need a complete combustion inside the chamber so that there is no excess heat transferred to the turbine.

Fourth is the fuel. The main question about fuel is what type of fuel we want to use for combustion process. There are many type of fuel that can be used for combustion such as butane, propane and even a gasoline can be used for combustion in the chamber. Then question is how to supply the fuel to the fuel injectors. Many precautions is needed, we do not want leaking on the fuel lines because it might contribute to explosion. After that is what are the components needed for the fuel system other than fuel regulators. We need to know the status of the fuel such as the pressure, fuel flow rate, and more. This is needed for calculating the remaining fuel in the tank so that we can prepare when to replace the fuel supply tank with a new one.

Fifth is the lubrication. A lubricant is a substance introduced between two moving surfaces to reduce the friction between them, improving efficiency and reducing wear. A lubrication system is a must to avoid the shaft that connects the compressor and the turbine from failing. The main components of this lubricating system are lubrication oil, oil pump, oil cooler and oil filter. One of the problems regarding this lubrication system is the oil. There are lots of lubricants on the market and they are classified between its own category which its viscosity, density and its heat transfer efficiency. For a turbojet engine used in aircraft, they basically used a synthetic oils such as Polyalpha-olefin (PAO) and Synthetic esters. The problem is to find the lubricant and for sure it is expensive if we want to use a synthetic oil of a turbojet engine. The best way is to test the lubrication oil that is cheap on the market such as lubrication oil for a piston engine for a motorcycle or a car. Too much oil being feed, reducing the efficiency of the rotating shaft which means the shaft will not rotate at a maximum revolution per minute. Too less oil feeding to the shaft, there will be friction that can cause the shaft to fail. Therefore, the oil feeding must be synchronized with the shaft rotation so that the oil feeding is in normal rate.

1.3 Mission Statement

Design, develop and construct a small gas turbine engine from primarily turbocharger and other relevant components.

1.4 Objective

There are many objectives on this project but the most important objectives are set to five main objectives. Below shows the objective aligned according to its priority:

1) To design, fabricate and test combustion chamber.
2) To design, fabricate and test ignition system for combustion process.
3) To design, build and test fuel injection system for combustion process.
4) To design, build and test Lubrication system for the gas turbine.
5) To assemble all systems, testing the gas turbine, and apply technical and engineering skills.

1.5 scope of work

The various scope of this project which cover as follows:

1) To study the basic concept of a turbocharger and its components.

2) To study the basic concept of gas turbine engine and its operations.

3) To design a combustion chamber using Catia V5R19.

4) To apply technical and engineering skills such as using tools and machines for fabrication process.

5) To fabricate small gas turbine using car turbocharger.

CHAPTER TWO: LITERATURE REVIEW

2.1 Review on Brayton Cycle concept and theory [1]

This final year project consists of many components of design and fabrication process. The components are turbo charger, combustion chamber, fuel and lubrication. The first knowledge needed is the basic concept of the turbo charger. The engine used is based on the Brayton Cycle concept. First, the air is compressed by the compressor and then being mixed with fuel, and then heat is generated in the combustion chamber. After that high temperature and pressure gases will be released as an exhaust to the environment after passing through the gas turbine. The turbine is then generates work by the exhaust gas and rotates the shaft. This process is shown in a figure 2.1.

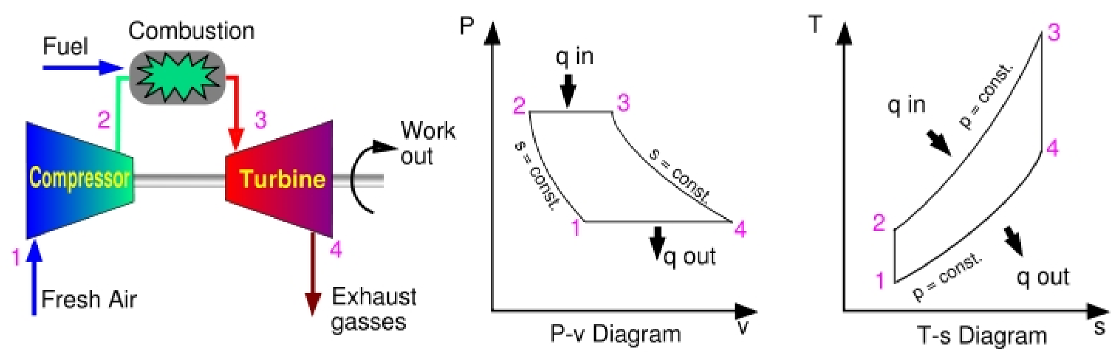

Figure 2.1 Idealized Brayton Cycle [17]

From the figure above, process 1 to 2 is the process of isentropic compression of air and no heat is supplied. This is the part where the air is supplied to the compressor. Process 2 to 3 is the process of constant pressure combustion, the heat is supplied and no work done. This is point where the mixture of fuel and air ignited and combustion process occur. Process 3 to 4 is a process of isentropic expansion of air in the turbine and no heat is added. This is the final point where the exhaust gases after combustion being released to the environment. This is the basic knowledge of how the Brayton Cycle is applied on a turbojet engine.

2.2 Review on combustion chamber design and process

The Combustion Chamber is only used for combustion process. There are several components in this part which is chamber, flame tube, fuel injector, and spark plug. The most important thing about combustion chamber is the combustion must take place within the chamber itself. For complete combustion, there should be no excess combustion process after the chamber other than hot gas. The Combustion Chamber is used to burn mixture of air and fuel. It is also functioned to deliver resulting gases to the turbine at a temperature which will not exceed the allowable limit. It must add sufficient heat energy in the chamber itself to the gases to accelerate their mass which is enough to produce the desired thrust for the engine and power to turn the turbine. It is said that the heat released per cubic foot in a combustion space in a turbojet engine is several thousand times more than the heat released per cubic foot of burner space in an ordinary home heating oil burner. [2]

There are several criteria for an acceptable burner. First is the pressure loss as the gas passed through the chamber must be at most lowest. Second is the combustion efficiency must be maintained to be the highest possible. And third is there must be no tendency for the chamber to explode or blow out by the combustion process. A complete combustion process must take place within the burner section itself which is inside the combustion chamber only. There should be no burning occurring after the gases leave the burner section and burning should not enter the turbine section. The gases that get into the turbine must have a satisfied temperature-distribution and acceptable maximum temperature as they enter the turbine so that it can be no harm to the turbine. The best combustion chamber design must consist of all these criteria. If all of these conditions are achievable, then engine will be suitable for a continuous operation. **[2]**

A turbojet Combustion Chambers may be can type, annular type or can-annular type. These types of combustion chamber show that the total volume of air entering the chamber has only less than a third that mixes with the fuel. Normally the total air to fuel ratio for a different type of engines varies from 40 to 80 parts of air to one part of fuel, by weight. A ratio 60 part of air to one fuel is an average air to fuel ratio. Of the 60 parts of air, only 15 parts are used for the combustion process. Another 45 parts of air will bypass the fuel nozzles and bypass the flame tube cooling the burner surfaces and to mix with and cool down the burned gases before they enter the turbine. [2]

Most combustion chamber design contains subsonic diffuser or supersonic diffuser. This two different types depends on the speed of the air entering the compressor. In aeronautical sense of word, a diffuser is a device which reduces the velocity and increases the static pressure of a fluid, such as a gas or air passing through a gas turbine engine. A diffuser operates on the principle of Bernoulli's Theorem which says that at any point in a tube (or a gas passageway) through which a liquid (or gas) is flowing, the sum of pressure energy, the potential energy and the kinetic energy is a constant; that is, if one of the energy factors in a gas flow changes, other variables must also change in order that the total energy may remain constant. Specifically, if velocity decreases, the pressure increases. [2]

2.2.1 Subsonic Diffuser

At Subsonic velocity, the rate of change in volume of a gas is proportional to the rate of change in velocity, and diffusion takes place when the cross-sectional area of a tube, duct or enclosure through which a gas (or air) is passing progressively increases in size. The divergent shape of the passage serves to convert the kinetic energy of a moving gas to static pressure energy. As the velocity of the gas decreases with the expanding shape of the divergent duct, its static pressure increases, although the total pressure remains the same. Total pressure in this case, is the sum of the static pressure and the pressure due to ram, which results from the velocity of the gas, itself. Static pressure can be defined as the pressure of the gas at rest, neglecting motion or velocity. The ram pressure decreases as the velocity decreases, so the static increases, to maintain a constant total pressure. Because the velocities within a gas turbine engine are normally less than Mach 1.0, a typical diffuser will be shaped in a manner similar to that shown in figure 2.2 below. [13]

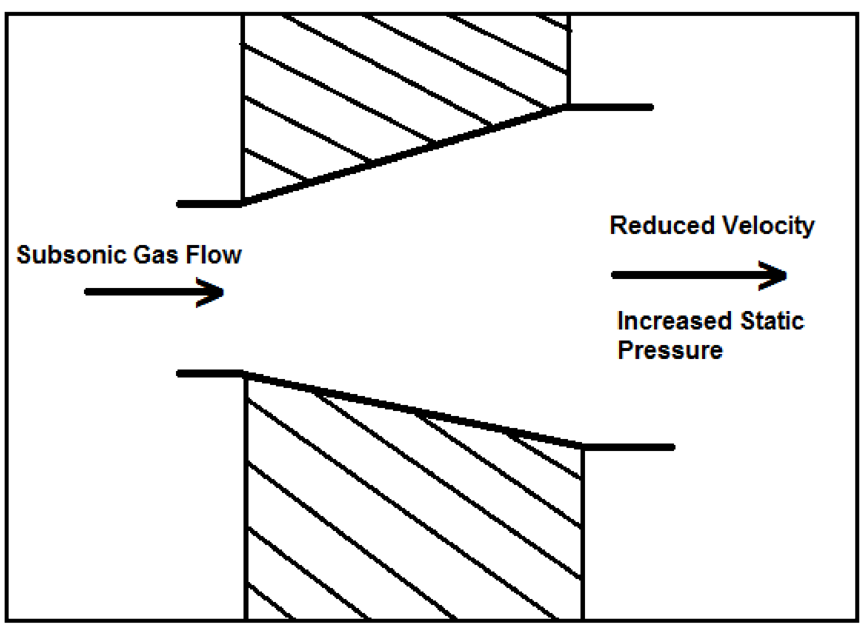

Figure 2.2 Subsonic diffuser

2.2.2 Supersonic Diffuser

Airplanes have many classes, and some of the classes can fly at supersonic velocity. It is necessary to apply the diffusion process to air or gases flowing at supersonic velocity. The most common example of this for a gas turbine engine is probably the air-inlet-duct configuration used on some supersonic fighter aircraft. The physical laws for a gas stream flowing at supersonic velocity are different from those which apply below mach 1.0, a convergent passage rather than a divergent one must be used to produce a diffusion effect. Figure 2.3 below shows the supersonic diffuser. [13]

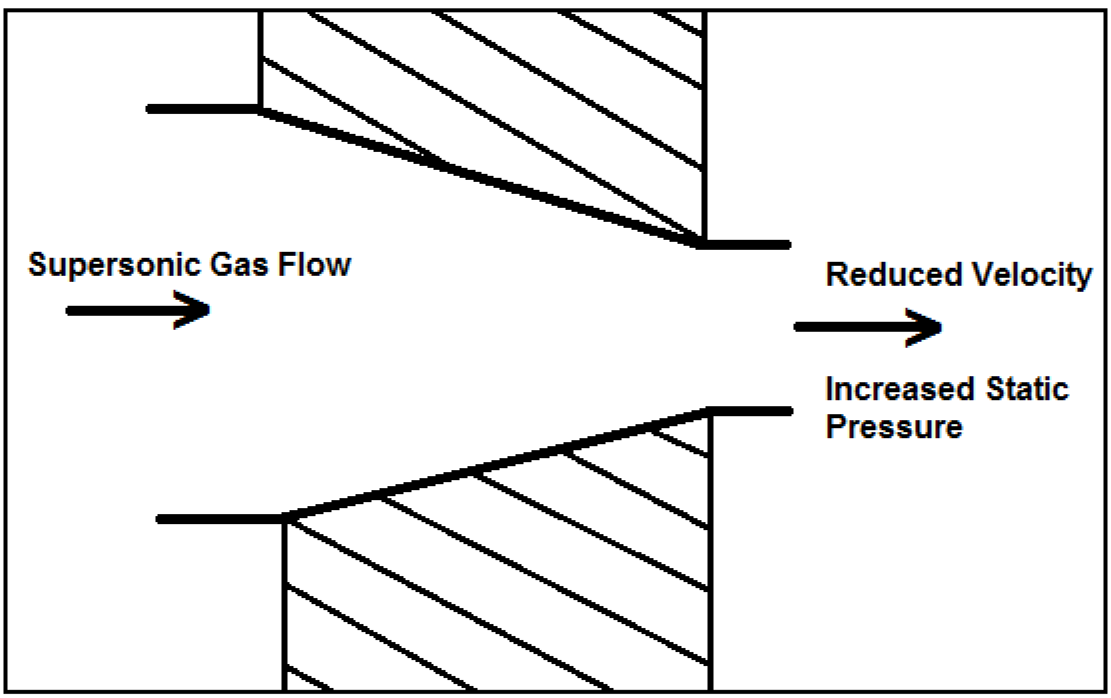

Figure 2.3 Supersonic diffuser

At supersonic flow rates, the rate of change in volume of a gas is greater than the rate of change in velocity. When a gas is increasing in velocity after supersonic velocity is reached the gas expands more rapidly than it accelerates. The gas flow through a supersonic exhaust nozzle would be an example of this. The reverse is true if a gas is decreasing in velocity, as would be the case in a diffuser. To ensure that a constant weight or volume of a gas will flow past any given point in a supersonic diffuser while air or gas is still at supersonic velocity, the aft part of the diffuser must decrease in cross-sectional area to adjust the area to reducing weight or volume of a gas as the velocity decreases. Thus, a supersonic diffuser employs progressively decreasing area similar to that shown in figure 2.3, rather than an expanding one such as that required by a subsonic diffuser. The rate of decrease in velocity which proportionally matches the decrease in weight or volume of gas at any given point. The static pressure, therefore, increases as the gas proceeds through the diffuser, in the same way that it does within a subsonic diffuser at velocities below Mach 1.0. [13]

2.3 Reviews on Ignition System.

Spark plug systems are most commonly used in cars or in a piston engine. The spark is made out of several thousand volts with a very small amount of current. This spark is ignited when the piston are at a position of maximum stroke which the air and fuel mixed and compressed. When it sparks, the mixture will explode pushing the piston back downward and then go back up and ignite again. The timing for the whole engine must be right at all times to get the most efficient cycle. If the timing of the spark is late or earlier than the exact moment it suppose to, then the power and torque of the piston engine will be reduced. The spark is produced when the electricity is supplied to the spark plug at a specific voltage, the current jumps between the electrodes. This is the spark and it ignites the air-fuel mixture in the combustion chamber. A very high voltage is needed so that the highly compressed gas inside the combustion chamber can be ignited. A conventional car batteries supply a 12 volts. From these 12 volts, the magnetic coil generates about 40,000 volts to make the current jump from one electrode to another. [10]

Ignition system for a car consists of 12 volts battery, magnetic coil, condenser, distributor, contact point, and spark plug. Magnetic coil works like the principle of magnetic field. When electricity flows through a wire, a magnetic field will be produced around the wire. When the magnetic field breaks down, an electricity will be generated in any wire around the magnetic field. This principle is similar with the transformers which is used to amplify or degrade a voltage. This coil contains two wires wound tightly around a soft iron core which one of the coil is a low voltage coil which is connected to the battery and it consists of several hundred turns. The secondary coil consists of thousand of turns of fine wire. [9]

Conventional breaker-point ignition is one of the important components inside the ignition system. Cars today are more likely made of electronic ignition system. Older cars, and some new imported cars, use breaker-point ignition systems. The main difference between electronic and a breaker-point ignition is the manner in which the primary current flow to the coil is interrupted. Electronic systems use transistorized electromagnetic or photoelectric devices. In conventional ignition system, the breaker points act as an on-off switch to interrupt the flow of low-voltage current through the primary winding of the coil and thereby induce a high-voltage current in the secondary winding. For electricity to flow, a complete circuit is needed. In an automobile, all the electrical components are connected, or grounded to the car's frame. The engine and frame therefore complete the circuit and provide a path for the electricity to flow back to the battery from the spark plugs, breaker points, and coil. [9]

2.4 Reviews on Fuel System.

The fuel is basically used for combustion process. To reduce time for this part, we will use only butane or propane since it is easy to find in the market. The propane and butane is generally used for cooking purposes and hence it is reliable based on the spare parts available on the market. Butane has a chemical formula C_4H_{10} that is an alkane with four carbon atoms. Butane is a highly flammable liquid that has a maximum adiabatic flame temperature of butane mixed with air is 2,243 K that is 1,970 °C or 3,578 °F. Butane has a Flash point about −60 °C which means at that temperature butane is a volatile liquid at which it can vaporize to form an ignitable mixture in air. It also has an Auto Ignition Temperature about 500 °C. This means that when the mixture of butane and air is reaching 500 °C, the mixtures will combust itself. So to reach idle state of combustion, the engine must reach this 500 °C first before it able to maintain the combustion without any ignition being done to the combustion process. Butane density is 2.48 kg/m3 when it appear in gas at 15 °C and 1 atm, 600 kg/m3. Butane has a Melting point is −138.4 °C or 135.4 K, and its Boiling point is −0.5 °C or 272.6 K. [3]

Propane is an almost similar gas to the butane. It is highly flammable liquid and most of it normally occurs in gas but compressible to a transportable liquid. Similar to butane, people use this gas for home heater, cooking gas, and oven. Propane has a chemical formula of C_3H_8 which is a three-carbon alkane. Propane has a density of 2.0098 kg/m3 when occur as gas at 0 °C and 1013 mbar, and 581.2 kg/m3 when occur as liquid at boiling point. Melting point of Propane is −187.7 °C or 85 K or -306 °F, and its Boiling Point is −42.1 °C or 231 K or -44 °F. Flashing Point of Propane is -104 °C or

169.1 K, and its Auto Ignition Temperature is at 540 °C or 813.1 K. This show a slightly higher temperature of the Auto Ignition for Propane compare to the Butane. This means that there is an advantage of using Butane as a fuel. Propane will ignite itself at 540 °C while Butane ignites itself at 500 °C. Hence Butane should reach it idle state earlier compared to Propane. [4]

Hydrogen is another type of fuel that can be used for combustion process. Hydrogen appears to be colorless and it is highly flammable and has an almost invisible flame, which can lead to accidental burns. This gas has melting point of 14.01 K or -259.14 ºC and its boiling point is 20.28 K or -252.87 ºC. Hydrogen has a chemical formula of H_2 and its density measured at 293 K is 0.0000899 gram per cm^3. Hydrogen has many applications nowadays such as it is used for used in the Haber process which is in the production of ammonia, hydrogenation of fats and oils, methanol production, hydrocracking, and hydrodesulfurization. Other applications for hydrogen are also used in metal refining. Other than that Liquid hydrogen is used as a rocket fuel, for example powering the Space Shuttle's lift-off and ascent into orbit. Liquid hydrogen and oxygen are held in the Shuttle's large external fuel tank. Nowadays, engineers and scientist are trying to develop a new power source which uses hydrogen as a fuel replacing current hydrocarbon the oil, gas and coal. This is because of the hydrogen is much more economic and the production of hydrogen is only through hydrolysis process by the reaction of water to some polymer element. Despite the economical value of hydrogen, combustion energy is produced when hydrogen combusts with oxygen and the only by-product from the reaction is water. This gives a better benefit in terms of environmental friendly. [12]

2.5 Review on Lubrication system for high speed rotation shaft

Lubrication is basically required for a rotating shaft and for this project the turbocharger needs lubrications since it will rotate more than 10 000 revolutions per minute. This is for the health of the turbo itself. The shaft rotates up to twice faster than the rotation of car engine. The turbo is taken from Nissan 240sx which has power of 151 kW (202 hp) or 6000 rpm and torque of 203 lb"ft (275 N"m) @ 4000 rpm. If the Nissan 240sx maximum rotation per minute is 6000 rpm, it will rotate up to 12000 rpm. This can cause wear for the rotating shaft and the bearing. Therefore the best lubricant and lubrication process is needed to avoid this wear. [6]

Oil in an automobile engine basically does more than just reduce friction between its moving parts. The motor oil is usually used to help seal the high pressure combustion gases inside the cylinders, to reduce the corrosion of metal parts, to absorb some of the harmful by products of the combustion, and to transfer heat from one part of the engine to another. For storage, the oil is stored in the oil pan at the bottom of the engine. It is forced by a pump which cause it to move through a filter and then through a series of passages to lubricate the engine's moving parts. While the oil is moving, it also act as a coolant fluid that is used to cool down these parts. Rapidly moving engine parts actually float on a thin film of oil and never make contact with one another. This is called hydrodynamic lubrication, and usually begins when an engine reaches idle state. Oil is fed into the bearing at a point where the clearance is greatest (Usually near the top). The rotation of the shaft pulls the oil around the rotation of maximum pressure (near the bottom), where the clearance is smallest. This creates oil wedge between the spinning shaft and its bearing, and allows high loads to be applied with little or no wear. Insufficient flow of oil will lead to rapid wear or to seizure of the engine's moving parts by allowing metal to grind against metal. It can also cause engine failure by destroying the sealing surfaces of the piston rings and allowing the combustion to escape passes the pistons. [7]

Lubrication in a turbojet engine has two main objectives which is first is to cool down the part and second is for lubricating the bearings. Most turbochargers nowadays use roller bearings and of course it needs lubrications as they rotate at high revolutions per minute. Normally, a turbojet or turbofan engine uses a pressure oil system that carries the oil directly to the point where it is needed. These points are basically the compressor, the turbine, the propeller shaft bearings, reduction gearing and the torque meter. Turbojet engines lubrication system contain so many parts such as oil pressure pump, oil strainers, scavenge pumps, oil boost pump, main pressure regulating valve, boost pump regulating valve, and boost pump relief valve. The oil pressure of this system must be maintained at some predetermined value at any altitude. Which means that the pressure must be constant at any altitude for example it maintained at 10 bar at an altitude of 35,000 feet. In terms of safety when the pressure exceeds the required pressure, the spring-loaded blow off valve acts as a pressure-relief valve for the entire system. The valve will only open if the pressure exceeds a predetermined maximum pressure for the system. [8]

2.6 Gas Turbine Operating Sequence

Gas turbine engines are started by rotating the compressor. In the case of dual axial compressor engines, the high compressor is usually the only one rotated. First, it is necessary to accelerate the compressor to provide sufficient air, under pressure, to support combustion in the burners. Secondly, once the fuel has been introduced and the engine has fired, the starter must continue to assist the engine above the self-accelerating speed of the engine. The torque supplied by the starter must be in excess of the torque required to overcome compressor inertia and the friction loads of the engine.[14]

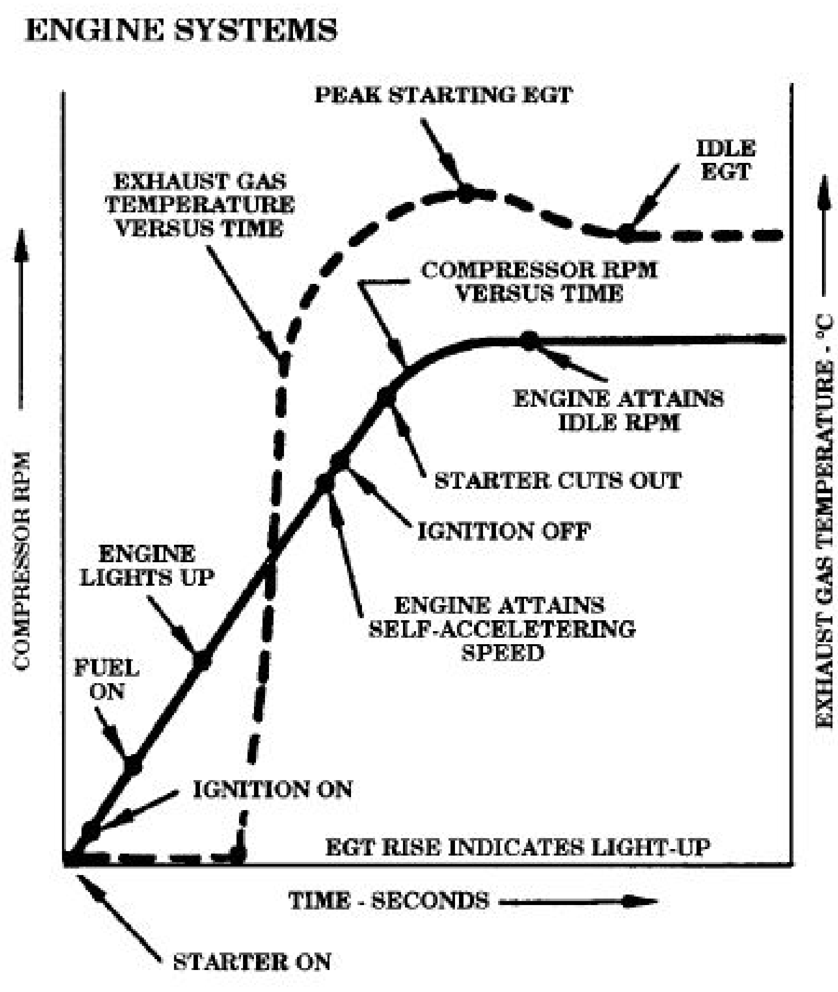

Figure 2.4 Starting sequence for a gas turbine engine [15]

Figure 2.4 above graphically illustrates a typical starting sequence for a gas turbine engine. As soon as the starter has accelerated the compressor sufficiently to establish airflow through the engine, the ignition is turned on, and then the fuel. The exact sequence of the starting procedure is important because there must be sufficient airflow through the engine to preclude the danger of an explosion before the fuel/air mixture is ignited. The fuel flow rate will not be sufficient to enable the engine to accelerate until after self-accelerating speed has been attained. If assistance from the starter were cut off below the self-accelerating speed, the engine would either fail to accelerate to idle speed, or might even commence to decelerate because it cannot produce sufficient energy to sustain rotation or to accelerate during the initial phase of the starting cycle. The starter must therefore continue to assist the engine considerably above the self-accelerating speed to avoid a delay in a hot or false start, or a combination of both. At the proper point in the sequence, the starter and, usually, the ignition will be automatically cut off. The higher the rpm before the cut out, the shorter will be the total time required for the engine to attain idle rpm, because the engine and the starter are working together to furnish torque above the self-accelerating speed. [14]

CHAPTER THREE: METHODOLOGY

Methodology is a description of process, or may be expanded to include a philosophically coherent collection of theories, concepts or ideas as they relate to a particular discipline or field of inquiry. In this project, my method of doing the project is by dividing the project into sections. The section is Preliminary Study, Survey Parts, Designing, Fabricate, and Research and Development.

3.1 Preliminary Study

The first section is the preliminary study. This part is to study the whole project from basics to intermediate knowledge of the project. The studies include the basic function of the turbochargers and its components. The basic function of a turbocharger in a car is to increase the car engine's power and torque. This component consists of a compressor and a turbine which is connected through a shaft. Both compressor and the turbine will rotate together and has its own function. Basically, the compressor is used to compress air into the turbo and the turbine will use the exhaust gas to generate work and rotate the compressor. Figure 3.1 and figure 3.2 shows the compressor and the turbine.

Figure 3.1 Compressor

Figure 3.2 Turbine

Second are the fuel types and fuel injection system. There are so many types of fuel that can be used for the combustion process such as butane, propane, methane, hydrogen, and even a standard Ron95 or Ron97 petroleum used for a car. Some fuel have higher output as they generates more heat during the combustion. Thus using corresponding fuel to the type of material used for the combustion chamber is prominent. For this project a regular butane gas used for house cooking is chosen and it is shown in figure 3.3 below.

Figure 3.3 Petronas regular butane

Fuel injection is needed to make sure the fuel is completely distributed around the combustion chamber and mixed with the air. The narrower the injection, the more efficient it mixes with air. The materials of the injector can be copper, Aluminium, Mild Steel and others. For this project the material is an Aluminium filling tube that is used for filling air inside a ball which shown in figure 3.4 below.

Figure 3.4 Aluminium Filling Tube

Third is lubrication system, lubrication oil and its viscosity. The lubrication system is used mostly in rotary and sliding parts of a machine. The rotation is very high and it can produce a catastrophic failure for the shaft without a lubrication system. This failure is because of the amount of heat generated due to friction between the rotating shaft and the bearings. Without lubrication it generates heat that can create volume expansion and thus generates more frictions and more heat until it fail. Different oil can give different results and this is because all oil has its own viscosity. Different types of application need different type of properties. For a very high revolution speed it needs specific oil with a low viscosity so that it can go through the shaft at high revolution per minute (rpm). The best oil for this application is fully synthetic oil. This oil is very expensive in the market and average price is approximately RM200. For this project a Shell Helix 10W 30 is picked as the lubrication oil. Figure 3.5 below shows the lubrication oil.

Figure 3.5 Shell Helix 10W-30

Next is combustion chamber or burner with its flame tube. The combustion chamber is one of the important parts of the gas turbine. Generally it consist of flame tube and its chamber. The combustion will take place inside it and amount of heat and pressure due to combustion is very significant. Therefore type of material used for the combustion chamber is very important so that it can sustain the pressure and the heat generated. Most common material is mild steel, titanium, and other types of steel. For this project mild steel is chosen because of its availability in Malaysia and it is cheap. Mild Steel is also known as low carbon steel and it has young's modulus of 210,000 MPa and has a melting point of 2730 ^{o}F. This type of steel has a very cheap price for a reasonable strength and reasonable melting point. Figure 3.6 below show the mild steel. [16]