EXPERIMENTAL STUDY ON THE EFFECT OF INTAKE AIR TEMPERATURE ON THE PERFORMANCE OF SPARK IGNITION ENGINE FUELED WITH HYDROGEN PEROXIDE BLENDED WITH GASOLINE

MUHAMMAD ASNAWI BIN OMAR

PROJEK SARJANA MUDA

Supervisor: DR. ADNAN BIN ROSELI

2nd Examiner: PROF. MADYA DR. MUSTHAFAH BIN MOHD TAHIR

FACULTY OF MECHANICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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'I have read this thesis

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Signatures : ....

Name of Supervisor : DR. ADNAN BIN ROSELI

Date : ....

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Signatures : ……………………………………………

Name of Author :MUHAMMAD ASNAWI BIN OMAR

Date : ……………………………………………

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ABSTRACT

The aim of this experiment is to investigate the effect of intake air temperature. It will measure the performance of petrol engine running under alternative fuel. The alternative fuel that has been chosen is hydrogen peroxide and it will be blended with gasoline. Some of the characteristics of hydrogen peroxide are it portrays as a strong oxidizing agent however, it is a weak acid when immerse in water. The process of the mixture will be using a device called magnetic stirrer. The specimen used for the test is 5 vol% of hydrogen peroxide + 95 vol% gasoline and 10 vol% hydrogen peroxide + 90 vol% gasoline. Experiment was conducted by using generator engine Precision GX420 single cylinder with 4 strokes. The temperatures chosen for the whole test were 40°C and 60°C respectively. The temperatures were controlled by hot air gun where it will be attached at inlet of the engine. Pressure sensor and crank sensor have been installed on the engine to determine pressure, volume and crank angle. The data obtained was recorded and shown in DEWESOFT data acquisition system.

ABSTRAK

Tujuan eksperimen ini adalah untuk mengkaji kesan suhu udara pengambilan. Ia akan mengukur prestasi enjin petrol yang berjalan di bawah bahan bakar alternatif. Bahan bakar alternatif yang telah dipilih adalah hidrogen peroksida dan ia akan diadun dengan petrol. Sesetengah ciri hidrogen peroksida yang digambarkan sebagai agen pengoksidaan yang kuat, bagaimanapun, ia adalah asid lemah apabila terbenam dalam air. Proses campuran akan menggunakan peranti yang dikenali sebagai pengaduk magnet. Spesimen yang digunakan untuk ujian adalah 5 vol% daripada hidrogen peroksida + 95 vol% petrol dan 10 vol% hidrogen peroksida + petrol 90 vol%. Eksperimen dijalankan dengan menggunakan silinder tunggal Precision GX420 enjin penjana dengan 4 lejang. Suhu yang dipilih untuk keseluruhan ujian ialah 40 ° C dan 60 ° C. Suhu dikawal oleh pistol udara panas di mana ia akan dipasang di enjin enjin. Sensor tekanan dan sensor engkol telah dipasang pada enjin untuk menentukan tekanan, jumlah dan sudut engkol. Data yang diperolehi dicatatkan dan ditunjukkan dalam sistem pemerolehan data DEWESOFT.

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LIST OF ABBREVATIONS

RPM	=	Revolution per Minute
DAS	=	Data Acquisition System
H_2O_2	=	Hydrogen Peroxide
GA	=	Gasoline Alone
TDC	=	Top Dead Centre
BDC	=	Bottom Dead Centre
CO	=	Carbon Monoxide
CO_2	=	Carbon Dioxide
H_2O	=	Water
CH_4	=	Methane
CI	=	Compression Ignition
SI	=	Spark Ignition
NO_x	=	Nitrogen Oxide
ISFC	=	Indicated Specific Fuel Consumption
Q_{HV}	=	Data Heating Value
pH	=	Potential of hydrogen

LIST OF SYMBOLS

T	=	torque (Nm)
V_d	=	volume of cylinder (m^3)
v	=	volume (dm^3)
Π	=	2.134
S	=	Stroke
B	=	Bore
P_0	=	front of throttle pressure (Pa)
ISFC	=	gram per kilo Watt hour (g/kW.hr)
L	=	Liter
Km	=	kilometer
%	=	percentage
J	=	Joule
W	=	Watt
°C	=	Degree Celsius
N	=	number of revelation per minute (rev/min)
R	=	gas constant (0.287 kJ/kg K)
Cp	=	centipoise
OHV	=	Overhead valve

CHAPTER 1

INTRODUCTION

1.1 Overview

Petrol engines or gasoline are the type of engine that we has known. The calling for term is spark ignition engines that be refers to internal combustion engine. The petrol engines takes place during the combustion process where the process of the air fuel mixture is ignited by a spark plug. This process is has been take a flammable mixture of air and petrol when the charge is compressed. The four stroke spark-ignition (S.I.) engine was built by Nicolaus August Otto in 1876. He was a self-taught German engineer at the Gas-motoreufabrik Deutz factory near Cologne, and also experienced in many years in the largest manufacturer of internal-combustion engines in the world. It was one of Otto's associates - Gottlieb Daimler - who later developed an engine to run on petrol which was described in patent number 4315 of 1885.

Hydrogen peroxide appears colourless in a dilute solution. Despite it is a weak acid, hydrogen peroxide has strong oxidizing properties, and powerful bleaching agent. It commonly used as disinfectant, antiseptic, oxidizer and rocketry as a propellant. Characteristics of hydrogen peroxide are strong oxidizing agent and a weak acid in water. The formula is similar to water, only it is added with hydrogen peroxide.

1.2 Problem Statement

Nowadays, engine petrol has become the favourite choice by customer to be using. That people choice these petrol car as their favourite there are many a lot of benefits. It because the engine type of petrol is more efficiency to the vehicle. Besides that, these engine can also protect to our environment from damage or pollute.

However, the increase of gasoline fuel cost becomes the main talk in consumer. This comes into their thought where the price of the fuel is unreasonable to the consumer. Hence, from this issue, I want to introduce the alternative way to solve this problem. The alternative is to mix the hydrogen peroxide as the additive to the combustion engine. From this alternative way, it will save the usage of the petrol fuel as the main fuel. Besides that, the hydrogen peroxide (H_2O_2) is suitable for germicidal agent composed only of water and oxygen. From the fact, hydrogen peroxide is considered the world's safest all natural effective sanitizer.

1.3 Objective

i. To study the optimum air temperature for better performance of an engine.

ii. To study the ratio of petrol blended with hydrogen peroxide with respect to air temperature.

iii. To study the effect of air temperature on performance of petrol engine fuelled with hydrogen peroxide

1.4 Scope of Project

For the scope of project, we has using several tools during running the experiment. Firstly, it will stand by the material that using such as hydrogen peroxide as additive and gasoline. From these material it has several ratio that will be follow before starting the experiment. Secondly, the experiment will be running using engine generator. This engine generator has used single cylinder. The result that will get from this experiment is indicated power, indicated work, indicated specific fuel consumption, thermal efficiency and heat release rate. The experiment will be running in three time, where we has using the different specimen ratio for gasoline + hydrogen peroxide and different temperature for each experiment. In first experiment, the specimen that will be using during this experiment is 100% of gasoline and using temperature 40°C and 60°C. In second experiment, the specimen that will be using is 95 vol% gasoline + 5 vol% hydrogen peroxide and using temperature 40°C and 60°C. In final experiment, the specimen that will be using is 10 vol% hydrogen peroxide + 90 vol% gasoline and using temperature 40°C and 60°C.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, engine petrol is becoming the power source in automobile and transport system. People use this vehicle as daily usage. The gasoline type is a suitable type fuel that can use into the vehicle. Temperature in combustion engine is very important to ensure good performance of the engine. This is because, during the intake process, there is a lot of air from the outside enter combustion engine. The temperature of air is the main factor which can give the best result to engine performance. To test the performance of the petrol engine, hydrogen is blended into this petrol engine. The type of hydrogen that will be tested in this experiment is hydrogen peroxide. This hydrogen peroxide will be blended with the gasoline. From the experiment, we can observe the performance of the petrol engine during intake air temperature.

2.2 Characteristics of Hydrogen and Hydrogen Peroxide

2.2.1 Hydrogen

Characteristic of hydrogen such as wide temperature and pressure ranges. Besides that, it has high flame propagation rates within the engine cylinder in comparison to other fuels. Hydrogen can have a high effective octane number mainly because of its high burning rates and its slow pre-ignition reactivity. Hydrogen engine operation can be associated with less heat loss than with other fuels.

The reaction rates of hydrogen are sensitive to the presence of a wide range of catalysts. This feature helps to improve its combustion and the treatment of its exhaust emissions. Hydrogen high burning rates make the hydrogen fuel engine performance less sensitive to changes to the shape of the combustion chamber, level of turbulence and the intake charge swirling effect. Internal combustion engines can burn hydrogen in a wider range of fuel-air mixtures than with gasoline. Hydrogen with wider flammability limits and higher flame speed make it more efficient in stop and start driving.

The concept of using hydrogen as an alternative fuel for CI engine has gained a lot of attraction recently. Hydrogen has many advantages over conventional fuels for internal combustion engine. It is a very clean energy source, its amount is practically unlimited, and it is considered as a high octane numbered fuel. Therefore it is very easy to implement hydrogen into the conventional spark ignition engine with a relatively higher compression ratio (White, Steeper, & Lutz, 2006).

2.2.2 Hydrogen Peroxide

Hydrogen peroxide is a liquid that can be mixed with the gasoline. One of its characteristics is it colourless appearance in dilute solution. It is a weak acid along with strong oxidizing properties, and powerful bleaching agent. Other than that, Hydrogen peroxide comes as a pale blue liquid, slightly more viscous than water, which appears colourless in dilute solution. It is a weak acid along with strong oxidizing properties, and powerful bleaching agent. It commonly used as disinfectant, antiseptic, oxidizer and rocketry as a propellant. species (Khan, Ahmed, Mutalib, & Bustum, 2013). Next, it also has strong oxidizing agent and a weak acid in water. The formula is similar to the water, with has added extra of hydrogen peroxide (Nagaprasad K. S., 2012).

Additionally, hydrogen peroxide is viable, alternative energy storage medium, competing with hydrogen gas, biogas, biodiesel and alcohol. Hydrogen peroxide can be used as energy dense fuel that burns the hydrogen, but requires no oxidizer as it is included inside the fuel. It will decompose with a release of tremendous energy, close to the energy per mole of hydrogen.

There are some advantages of hydrogen peroxide which as listed below:

i. Stable storage.

ii. Relatively easy to produce.

iii. High energy output.

iv. Only emits water vapour and oxygen.

Table 2.1: Properties of Hydrogen Peroxide

Appearance	Colourless liquid
Density	1110 kg/m^3
Boiling point	226℃
Freezing point	-27℃
Viscosity	1.81 cp
Specific gravity	1.11 kg/m^3

The viscosity of hydrogen peroxide is lower and after blended with the fuel, the density will be increased. It has been mentioned from study, the density of the fuel blended increase slightly with hydrogen peroxide composition due to the lower viscosity value of the hydrogen peroxide. Density is the main factor of the fuel property; it has given the effect to the engine performance characteristics. If the density of hydrogen peroxide is higher it will also increase the density of the fuel blends (Khan et al., 2013).

The pH value of hydrogen peroxide is much lower; subsequently the addition of hydrogen peroxide improved the acidic nature of the fuel blended. From study the pH of the diesel fuel blend demonstrates larger effect where it decrease linearly as the amount of hydrogen peroxide is increased in the fuel blend respectively(Khan et al., 2013).

2.3 The Performance of Hydrogen Peroxide in an Engine

From previous studies, experiments had been carried out and the results obtained shown that the performance of hydrogen peroxide gave impact to the engine. The impact of using a small amount of hydrogen peroxide mixture as an additive on the performance of a four cylinder diesel engine was evaluated. The required amount of the mixture was generated using electrolysis of water considering on board production of hydrogen peroxide mixture. Hydrogen has nine times higher flame speed than diesel has the ability to enhance overall combustion generating higher peak pressure closer to TDC resulting in more work (Bari & Mohammad Esmaeil, 2010).

The principle of hydrogen peroxide is similar to that of nitrous oxide system. Both promote power by increasing the oxygen content in per unit mass of gas. The hydrogen peroxide enhancement takes hydrogen peroxide as its working medium, the heat produced both in the decomposing process of hydrogen peroxide and combustion of fuel and oxygen which is emitted in the decomposing process will improve the energy of gas, and therefore the power of engine will boost in a minute. The hydrogen peroxide enhancement apparatus can increase oxygen content of unit air inflow by jetting hydrogen peroxide into the cylinder, so the output power of engine can be improved while the displacement and weight is still remain constant.

There is some effect to promote the auto ignition in the engine. Hydrogen peroxide has significant effect on promoting the auto ignition of hydrogen. The thermal decomposition reaction of hydrogen peroxide is the most important reaction for the production of hydroxide radicals which promotes hydrogen auto-ignition (Jeon & Bae, 2013).

2.4 Hydrogen Peroxide as Alternative Fuel

Hydrogen Peroxide can be an alternative fuel source. However high costs and the dangers surrounding its transport and production has discouraged any attempts of using it other than in rocket engines. New developments in the production of hydrogen peroxide that are safer and use less energy could change the equation. During hydrogen peroxide is used as a fuel, energy is released in the form of heat during the rapid decomposition of H_2O_2 to H_2O, creating steam and oxygen. In the case of high H_2O_2 concentration, much of the energy takes the form of enormous thrust propulsion as demonstrated by the jet car and rockets. Ho Teng et al. conducted experiments on using dimethyl ether as an alternative fuel for C.I. Engine and claimed that dimethyl ether spray pattern in the engine cylinder will affect the mixing and combustion process in engine cylinder, and also influence emission from combustion engine.(Nagaprasad K. S., 2012).

Hydrogen peroxide is generally considered to be an effective combustion promoter for different fuels. Hydrogen peroxide is used for two different conditions, first as the oxidizer substituent by partial replacement of air and second as an oxidizer supplier by using different concentration of H_2O_2. However, addition of hydrogen peroxide increases CH4 consumption rate and CO production rate, but it reduces production of CO_2.

Hydrogen peroxide under normal temperature is in liquid state making it easy to handle. After chemical dissociation, hydrogen peroxide produces only oxygen and its exothermicity is equal to 2884.6 kJ/kg without toxic products. To improve the combustion process, mixture of methane as auto ignition in air with 5% until 10% of hydrogen peroxide. Besides that, by replacing the air temperature with hydrogen peroxide, it is also an effective measure to burn the velocity. In combustion engine, flame with 20% of air which replaced by hydrogen peroxide has higher adiabatic flame temperature due to the reduction of nitrogen dilution and heat release from thermal decomposition of hydrogen peroxide(Chen, Li, Cheng, Hsu, & Chao, 2011).

Based on studies by scientist, a two-stroke engine can operate on ethanol water stabilized hydrogen peroxide blend, however with not more than 10 % water and 10 % hydrogen peroxide in ethanol. The presence of hydrogen peroxide significantly increases the temperature in combustion. Furthermore, this approach would require different materials resistant to hydrogen peroxide for carburettor membranes since the existing materials are dramatically weakened by the presence of hydrogen peroxide (Ć & Oros, 2012).

Hydrogen peroxide as an oxidant can substantially increase the theoretical voltage of fuel cells and improve the cell performance. The fuel cell that has using the hydrogen peroxide can operate with the absence of oxygen environment such as outer space and underwater conditions. During using electron transfer, hydrogen peroxide offers the low activation loss of the reduction reaction. Moreover, it can avoid the flooding problem during intrinsically liquid phase. As an alternative oxidizer, hydrogen peroxide has recently received ever-increasing attention, primarily because of its several unique characteristics as opposed to the gaseous oxygen.(Zhang, Ji, & Wang, 2014)

2.4.1 Revolution of Hydrogen Peroxide and Water

Hydrogen Peroxide will be an alternative fuel source in vehicle. However, due to high cost and potential dangers surrounding its transport and production has discouraged any attempts of using it other than in rocket engines. New developments in the production of hydrogen peroxide that are safer and use less energy could change the equation.

From the results of scientist, they changed the word of decomposition but they said the fuel is burned. This is mainly because when hydrogen peroxide is used as a fuel, energy is released in the form of heat during the rapid decomposition of hydrogen peroxide to water. In that situation, hydrogen peroxide changed to water, which then creates steam and oxygen. In case of high concentration hydrogen peroxide, most of the energy takes in the form of enormous thrust propulsion as demonstrated by the jet car and rockets.

During the process of hydrogen peroxide decomposes into pure water, there is a change in molecule structure. The H_2O_2 molecule changes into H_2O+ 1 free O (water + 1 free oxygen atom) creating a lot of heat in the process. During World War II, hydrogen peroxide was used as fuel for underwater torpedoes. The reason is because of its ability to burn without presence of air. During the launching process, there was a trail of air bubble that can be seen behind hydrogen peroxide. It was evidence during the decomposition of hydrogen peroxide into water, free oxygen was released.

H_2O_2 decomposition releases pure oxygen as a product. Scientists found that the pure oxygen as a product could be used for burning carbon. In process of H_2O_2 decomposition, the heat causes the carbon and free oxygen making it to ignite and burn. In this way, the heat energy of the H_2O_2 fuel can be increased significantly.

2.5 Important of Air Temperature in SI Engine and CI Engine.

In internal combustion engine, there is normal combustion process occurs in three stages which are initiation of combustion, flame propagation, and termination of combustion. In addition, there are a few flows or steps of combustion; firstly, the initial of combustion normally starts across the spark plug gap when the spark is discharged. The fuel molecules in and around the spark discharge zone are ignited and a small amount of energy is released. The important criterion for the initial reaction to be self-sustaining is that the rate of heat release from the initial combustion be larger than the rate of heat transfer to the surroundings. The factors that play an important role in making the initial reaction self-sustaining, and thereby establishing a flame kernel, are the ignition energy level, the spark plug gap, the fuel air ratio, the initial turbulence, and the condition of the spark plug electrodes. After a flame kernel is established, a thin spherical flame front advances from the spark plug region progressively into the unburned mixture zone.

Secondly, flame propagation is supported and accelerated by two processes. The combined effect of the heat transfer from the high-temperature flame region and the bombardment by the active radicals from the flame front into the adjacent unburned zone raises the temperature. Then, it accelerates the rate of reactivity of the unburned mixture region directly adjacent to the flame front. This helps to condition and prepare this zone for combustion. The increase in the temperature and pressure of the burned gases behind the flame front will cause it to expand and progressively create thermal compression of the remaining unburned mixture ahead of the flame front. It is expected that the flame speed will be low at the start of combustion, reach a maximum at about half the flame travel, and decrease near the end of combustion. Overall, the flame speed is strongly influenced by the degree of turbulence in the combustion chamber, the shape of the combustion chamber, the mixture strength, the type of fuel, and the engine speed.

Thirdly, when the flame front approaches the walls of the combustion chamber, the high rate of heat transfer to the walls slows down the flame propagation and finally the combustion process terminates close to the walls because of surface quenching. This leaves a thin layer of unburned fuel close to the combustion chamber walls which shows up in the exhaust as unburned hydrocarbons (Saraswat, Gadi, Gandhi, Arora, & Bansal, 2015). Air flow rate decreased and fuel flow rate increased with an increase of inlet air temperature, which reduced the air-fuel ratio of the engine. With the increase of the air temperature, the engine efficiency will be decreased and the exhaust gas temperature will be increased. Besides that, the fuel consumption of fuel also increase by the increase of air temperature (Alam, Song, & Boehman, 2005). The increase of inlet temperature led to the reductions of in-cylinder trap mass. Therefore, the capacity of oxygen and heat capacity of air charge was significantly reduced. This has resulted in an increase of brake specific fuel consumption at low load but slightly lowered the brake specific fuel consumption at part load when the charge air temperature is increased (Mamat, Abdullah, Xu, Wyszynski, & Tsolakis, 2010).

2.6 Improvement of Hydrogen Peroxide in Internal Combustion Engine

Every internal combustion engine has wanted to improve the performance of the engine. There is a piston that creates a mechanical energy and transfer to internal energy by expansion stroke in the cylinder. Some of the internal combustion engine is fixed on their displacement and thermal efficiency. So the alternative way to improve the power is by increasing the amount of air inlet and internal energy of the gas. Such examples are turbocharging and applying nitrous oxide system.

Previously, there were several types on how to improve the process in internal combustion engine. As we know, there are famous of turbocharging and applying the nitrous oxide system. From the turbocharging process, it will improve the performance of the engine. And nowadays, there are a few of idea to improve the performance of engine. Besides that, using this additive, it can protect the environment before pollution occurs.

The concept of hydrogen peroxide is similar with nitrous oxide system as both of it increase the oxygen content in per unit mass of gas. Besides that, heat is also produced during the decomposing process of hydrogen peroxide and combustion fuel. In relation to that, the oxygen is also emitted in decomposition process hence improves the energy of gas and boosting the engine power in a minute.

As compared to the working principal of nitrous oxide system, the enhancement of working hydrogen peroxide is more stable. At room temperature, the decomposition rate of hydrogen peroxide in liquid form is no more than 1%. From there, hydrogen peroxide is relatively easier for storage because there is no need for using high pressure cylinders. Additionally, hydrogen peroxide is nontoxic and non-volatile. If it leaks out, its oxidability can be greatly reduced by diluting with water.

Hydrogen peroxide solution has high concentration by the dual-carburettor system through the intake airflow and increases the intake gas mass. After entering the cylinder, the solution absorbed the heat in the compression stroke, which can decrease the compression work of engines. Compared with normal engines, it can burn more fuels with the help of hydrogen peroxide and produce more heat, which consequently contributes to an increase in output power of engines (Ć & Oros, 2012).

2.7 Emission of Hydrogen Peroxide

The levels of hydrogen peroxide emitted when the exhaust valve opens are very low and do not show any respond. It is not exactly clear how high levels of hydrogen peroxide can be generated in the combustion gases. One of the ways is by improving the decomposition of hydrogen peroxide.

In order to assess the relative importance of these reactions in hydrogen peroxide emission, calculations were carried out at different temperatures for the engine conditions as described earlier. The calculations revealed that the result obtained is around 700°K and above the dominant mode of hydrogen peroxide. Normally in an engine, temperature around 700°K appears only towards the end of the expansion process and it is unlikely that hydrogen peroxide will be emitted from the region in high concentration in such a short time. This can be assumed that there would be possibility where low temperature may appear.

The process of heat transfer predominates in boundary layer where it occurs near the cylinder walls. Gases trapped in the crevices undergoing partial oxidation. In both of these cases, part of the gases can be at a comparatively lower temperature during most of the expansion process. It is believed that such a condition may result in higher levels of H_2O_2 (Varde & Lewis, 1977).

Hydrocarbon emissions decrease and NO_x emissions will increase by increasing the inlet air temperature. Particular matter emissions decrease at low inlet air temperature and opposite happens at high inlet air temperature (Alam et al., 2005).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this chapter is to explain and to show the flow of the experiment. The specification of the engine and the device to conduct this experiment will be explained more details on this chapter.

3.2 Flow Chart of the Methodology

In order to conduct this experiment, there are several steps that should be done before proceeding to the experiment. There are four main tasks that have been planned which are material or temperature selection, testing of material, comparison of material and analysis.

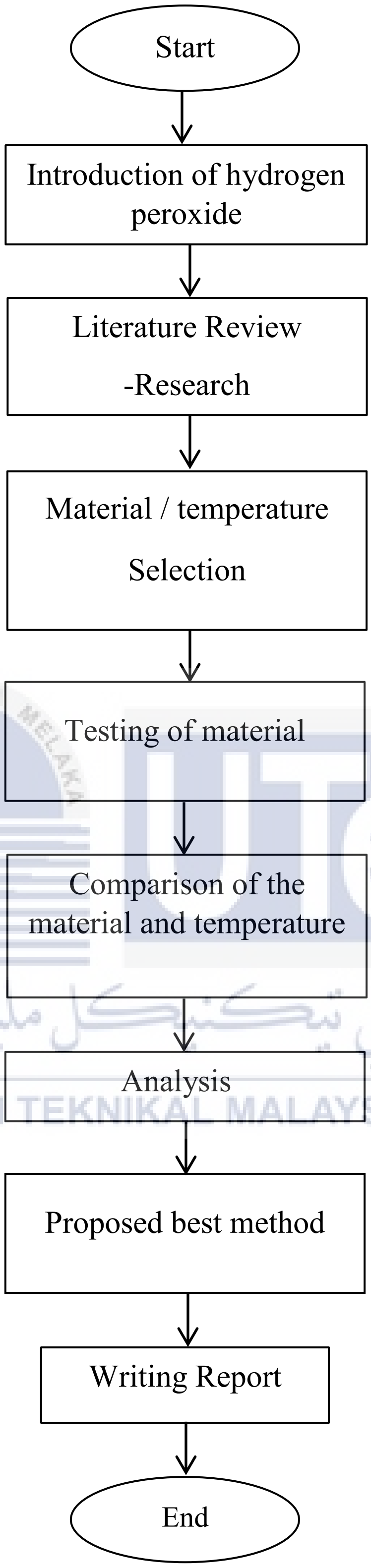


Figure 3.1: Flow Chart of Methodology

3.3 Equipment

To conduct the experiment, below is some equipment listed for experimental apparatus. The equipment are chosen based on advice and guidance from project supervisor.

3.3.1 Engine Generator

The type of engine used in the experiment is a single cylinder engine. This single cylinder engine is a basic piston engine of an internal combustion engine. This single engine is familiar with surrounding. This engine has been often seen on many uses in portable tools and garden machinery. Some single cylinder automobiles and tractors have been produced, but hardly seen nowadays due to developments in engine technology.

The experiment was conducted on a petrol engine. The specification of engine is shown in table below.

Table 3.1: Specification of Engine

Engine model	SHV6000EXE
Engine type	4 stroke, air cooled, overhead valve OHV
Number of cylinder	1
Bore, mm	90
Stroke, mm	66
Compression ratio	9.4 : 1
Max power output	15 HP

Figure 3.2: Engine generator

3.3.2 Hydrogen Peroxide as an Alternative Fuel

The characteristics of hydrogen peroxide are viable, alternative energy storage medium, competing with hydrogen gas, biogas, biodiesel and alcohol. Hydrogen peroxide can be used as energy dense fuel that burns the hydrogen, but no oxidizer includes inside the fuel. It will decompose with a release of tremendous energy, close to the energy per mole of hydrogen.

For this experiment, we used specimen ratio between gasoline and hydrogen peroxide. In first experiment, we used 100% gasoline without any mixture with hydrogen peroxide. Meanwhile in second experiment, gasoline was blended with hydrogen peroxide which it needs to achieve 5 vol% hydrogen peroxide + 95 vol% gasoline and 10 vol% hydrogen peroxide + 90 vol% gasoline.

For the temperatures, the temperatures that have been chosen are 40°C and 60°C respectively. The temperatures were controlled by hot air gun where it will be attached at inlet of the engine.

Table 3.2 below shows the properties of hydrogen peroxide used in this experiment.

Table 3.2: Properties of Hydrogen Peroxide

Appearance	Colourless liquid
Concentration, %	50 %
Boiling point	114°C
Freezing point	-52 °
Specific gravity	1.20 kg/m^3

3.3.3 Data Acquisition System

DAS is the process of measuring the voltage of electrical, temperature, pressure or sound. The system will be synchronized with a computer. This device contains a sensor, the measurement of the system and programmable software. This device has been used widely in industry because of its powerful, productivity and cost effective measurement solution.

This device is the process of real world physical conditions and conversion of the resulting sample into digital numeric values that can be manipulated by a computer. DAS typically involves the conversion of analogue waveforms into digital values for processing.

Figure 3.3: Data Acquisition System DEWESOFT

For this experiment, this device was connected between the signal terminator and data acquisition system. From the signal terminator, it sent the soundwave data to data acquisition system and the data will be displayed on laptop.

Figure 3.4: Signal Terminator

3.3.4 Magnetic Stirrers

Magnetic stirrers are also known as magnetic stir plates. This device is commonly used for experiment related in chemistry and biology. This device is very useful because of its ability to mix the component in liquid form. The function is it can stir the liquid in order to improve mixture. The device is driven by high temperature micro magnet motor where it can produce mixture in the container to achieve the solution.

For this experiment, this device was used to blend the specimen; gasoline and hydrogen peroxide. The specimen is 95 vol% gasoline + 5 vol% hydrogen peroxide and 90 vol% gasoline + 10 vol% hydrogen peroxide.

Figure 3.5: Magnetic Stirrer

3.3.5 Spot Light

Spot light is used in universal place, for examples, houses and outdoor places. The purpose of the spot light is to be used as a load for engine generator.

For this experiment, the spot light was attached with engine petrol. There was a plug box attached on engine generator. This spot light is easier to use as it gives load to the engine. The loads used for this experiment were 500 Watt, 1000 Watt, 1500 Watt and 2000 Watt.

Figure 3.6: type of spot light

3.3.6 Hot Air Gun

Hot air gun is a device that release hot air flow. The temperatures for this device are around 100°C and 550°C. The operation of this device is similar with hair dryer, where, it has a fan that will rotate to drive out an electric heating by using air flow and it exits through a nozzle. Finally, the heated air is directed to the inlet of engine.

During this experiment, we used temperatures of 40°C and 60°C. The specification of the hot air gun is shown in Table 3.3 below.

Table 3.3: Specification Hot Air Gun

Product name	Skil F0158006JP
Weight without cable	0.75 kg
Air flow setting	250 l/min – 500 l/min
Rated power input	1800 W
Working temperature	50 °C- 570 °C

Figure 3.7: Hot Air Gun

3.4 Experiment Procedure

For this project, it consists of two experiments. For the first experiment, the specimen used was 100% gasoline. For second experiment, the percentage is 95 vol% gasoline + 5 vol% hydrogen peroxide and final experiment is 10 vol% hydrogen peroxide + 90 vol% gasoline.

For temperature, the temperature used was 40°C and 60°C respectively. The temperature was controlled by hot air gun where it will be attached to the inlet of engine. This hot air gun will increase the temperature from 40°C to 60°C.

3.4.1 Flow Chart of Experimental Procedure

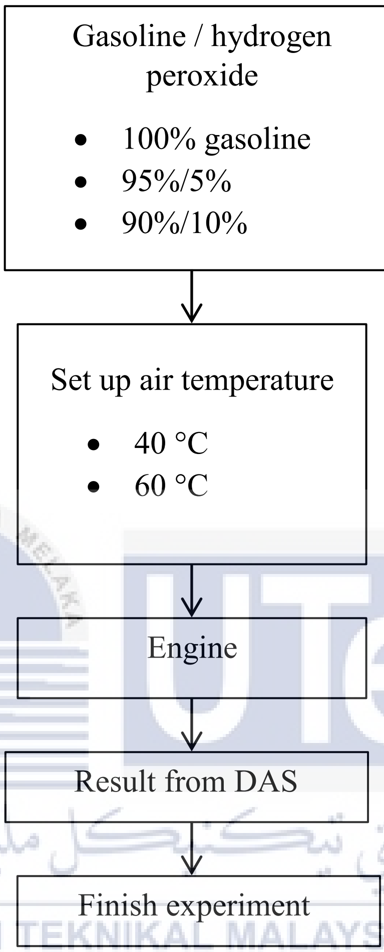


Figure 3.8: Flow Chart of Procedure

CHAPTER 4

RESULTS AND DISCUSSIONS

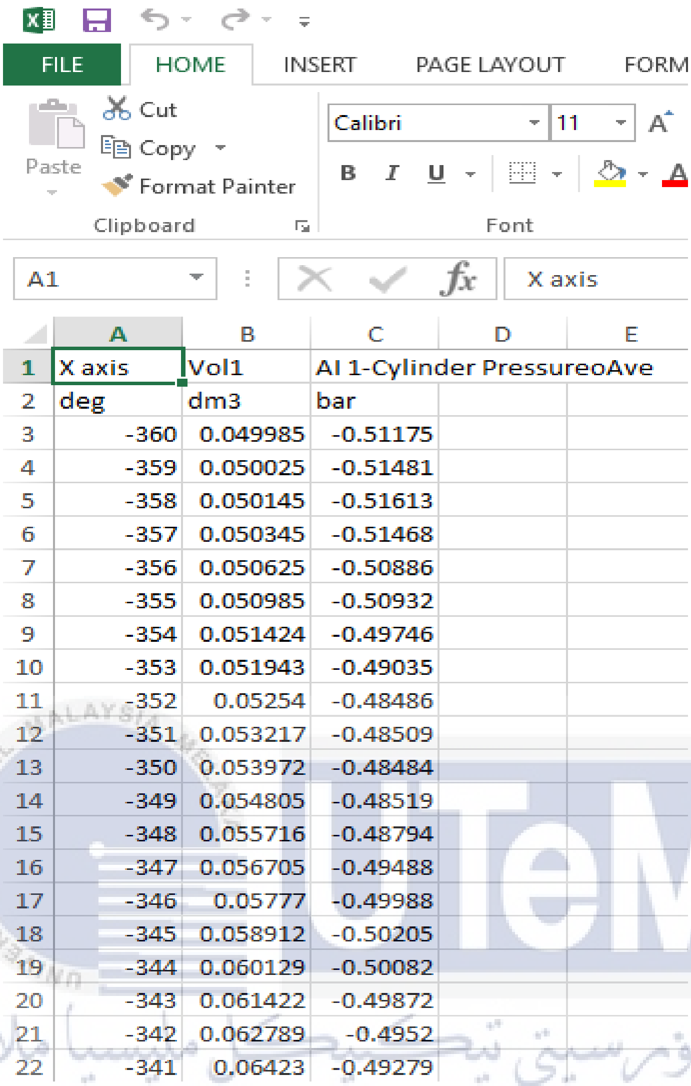
4.1 Introduction

The results of the experimental are presented where analysis and conclusion arrived at this chapter. Discussions are made based on the experiments that were carried out in the previous chapter. In this chapter, the performance of air temperature will be presented in details. The results obtained are comparison between gasoline alone and gasoline mixed with hydrogen peroxide.

4.2 The Raw Data from DEWESOFT Software

For the results of the experiment, software is used to record the data namely DAS system by DEWESOFT software. The software recorded the results from TDC until BDC.

For this experiment, the results are divided into several parts such as volume, pressure and crank angle. From there, it is easier to plot a graph of pressure vs volume and pressure vs ɵ (crank angle). Table below shows the example that will be obtained from DEWESOFT.



	A	B	C	D	E
1	X axis	Vol1	AI 1-Cylinder PressureoAve		
2	deg	dm3	bar		
3	-360	0.049985	-0.51175		
4	-359	0.050025	-0.51481		
5	-358	0.050145	-0.51613		
6	-357	0.050345	-0.51468		
7	-356	0.050625	-0.50886		
8	-355	0.050985	-0.50932		
9	-354	0.051424	-0.49746		
10	-353	0.051943	-0.49035		
11	-352	0.05254	-0.48486		
12	-351	0.053217	-0.48509		
13	-350	0.053972	-0.48484		
14	-349	0.054805	-0.48519		
15	-348	0.055716	-0.48794		
16	-347	0.056705	-0.49488		
17	-346	0.05777	-0.49988		
18	-345	0.058912	-0.50205		
19	-344	0.060129	-0.50082		
20	-343	0.061422	-0.49872		
21	-342	0.062789	-0.4952		
22	-341	0.06423	-0.49279		

Figure 4.1: Example data from DAS

Figure 4.2: Result from Pressure Sensor

4.3 : Fuel Consumption of Oil

4.3.1 : Gasoline Alone

i. Temperature 40°C

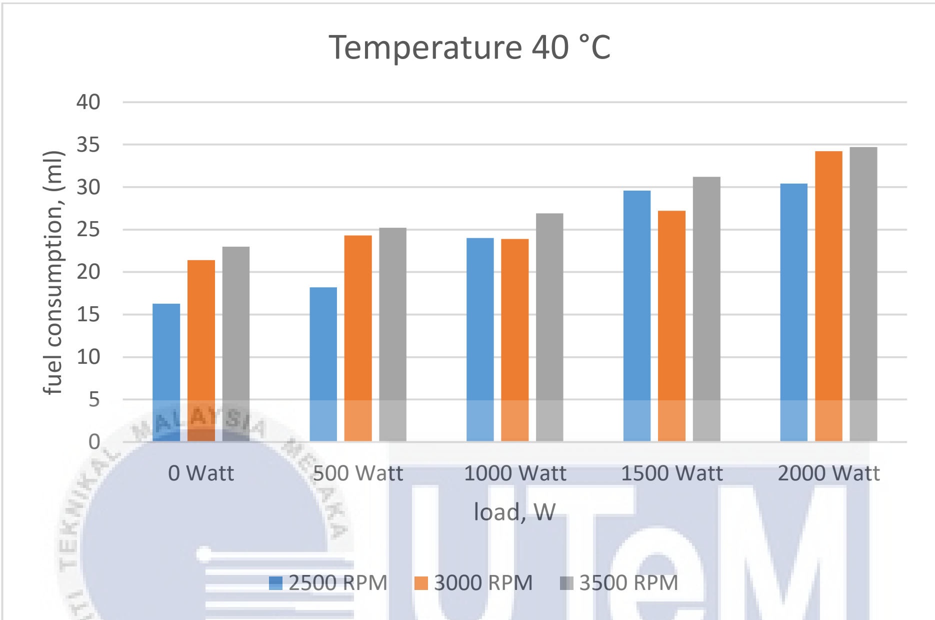


Figure 4.3: Gasoline Alone

ii. Temperature 60°C

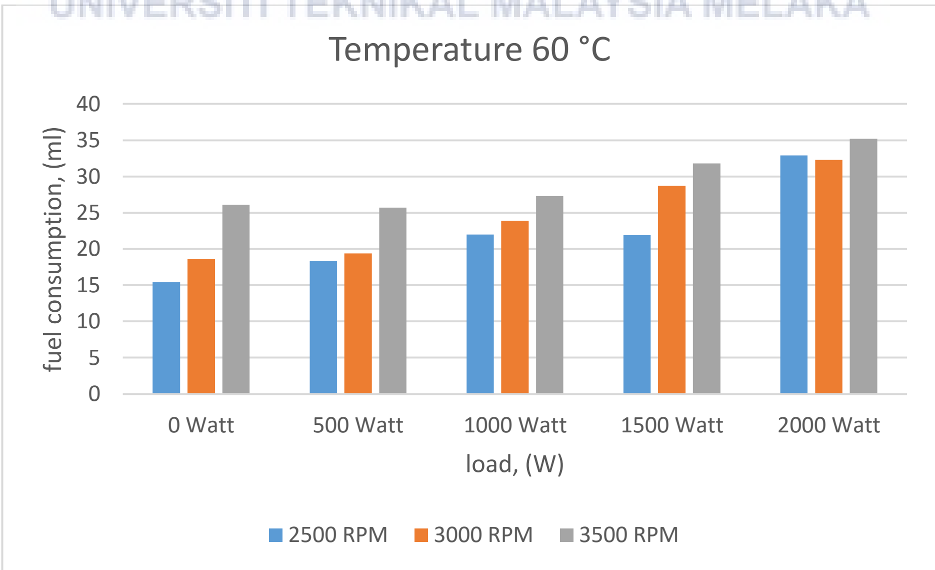


Figure 4.4: Gasoline Alone

From the graphs above, it show the fuel consumption for 100% gasoline at temperature of 40°C and 60°C. The trend shows increase in values from 0 Watt to 2000 Watt. The values increase because different temperature was used during the experiment and from different temperature it was generated more in fuel consumption.

4.3.2 : 5% Hydrogen Peroxide

i. Temperature 40°C

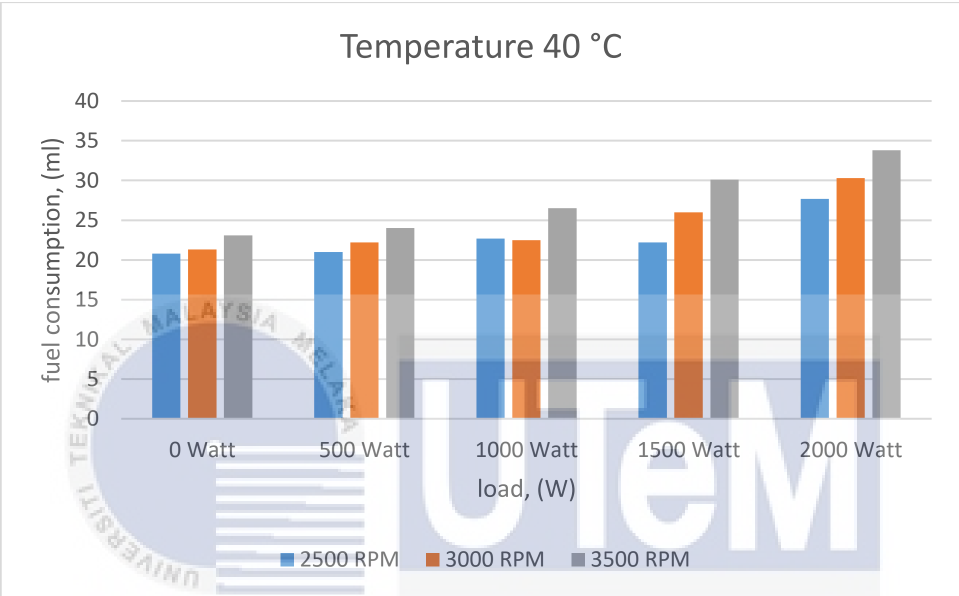


Figure 4.5: 5% Hydrogen Peroxide and 95% Gasoline

ii. Temperature 60°C

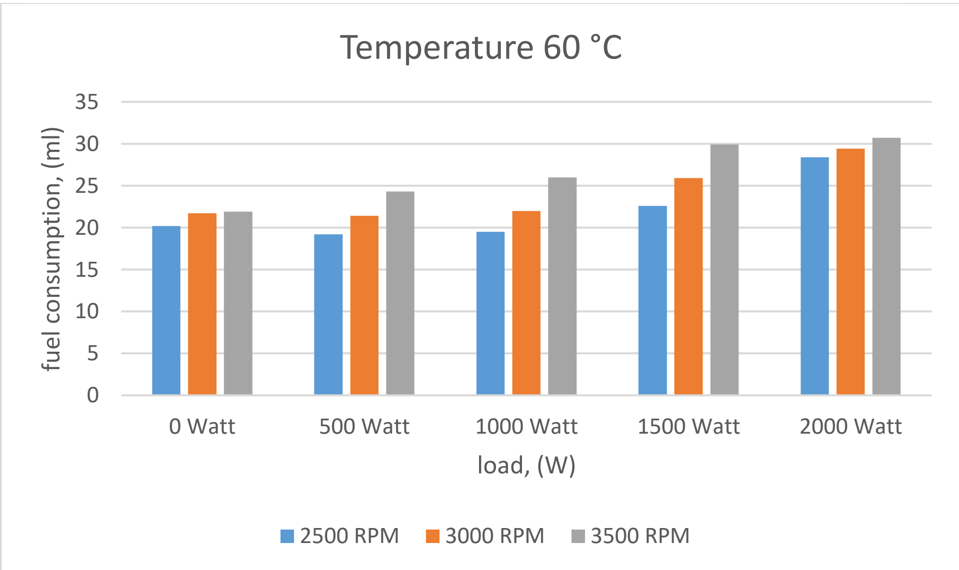


Figure 4.6: 5% Hydrogen Peroxide and 95% Gasoline

From the graphs above, it shows the fuel consumption for 5 vol% hydrogen peroxide and 95 vol% gasoline at temperature 40°C and 60°C. The trend shows that the values increase from 0 Watt until 2000 Watt. The values increased due to different temperature during the experiment. At 40°C, it is highest than 60°C because of the percentage of mixture between gasoline and hydrogen peroxide. This mixture quickly vaporized and it generated more fuel consumption in engine.

4.3.3 10% Hydrogen Peroxide

i. Temperature 40°C

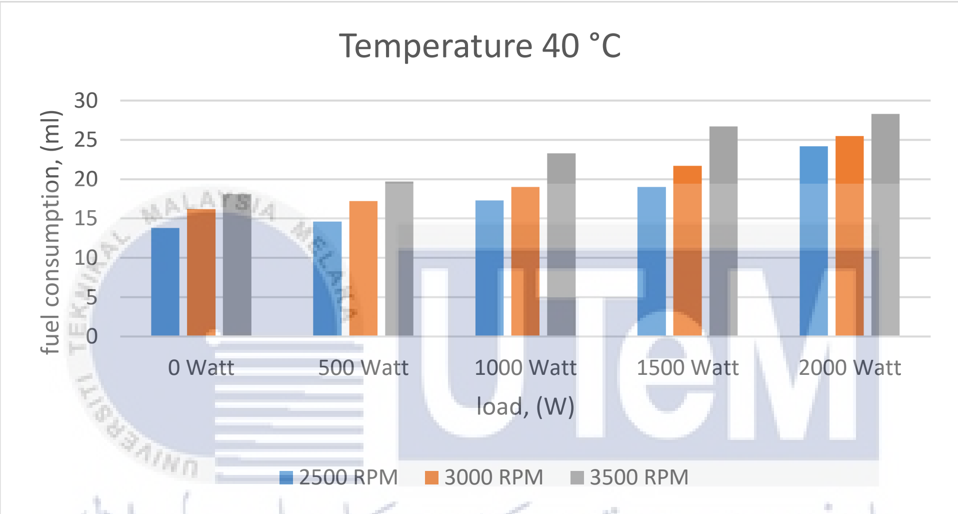


Figure 4.7: 10% Hydrogen Peroxide and 90% Gasoline

ii. Temperature 60°C

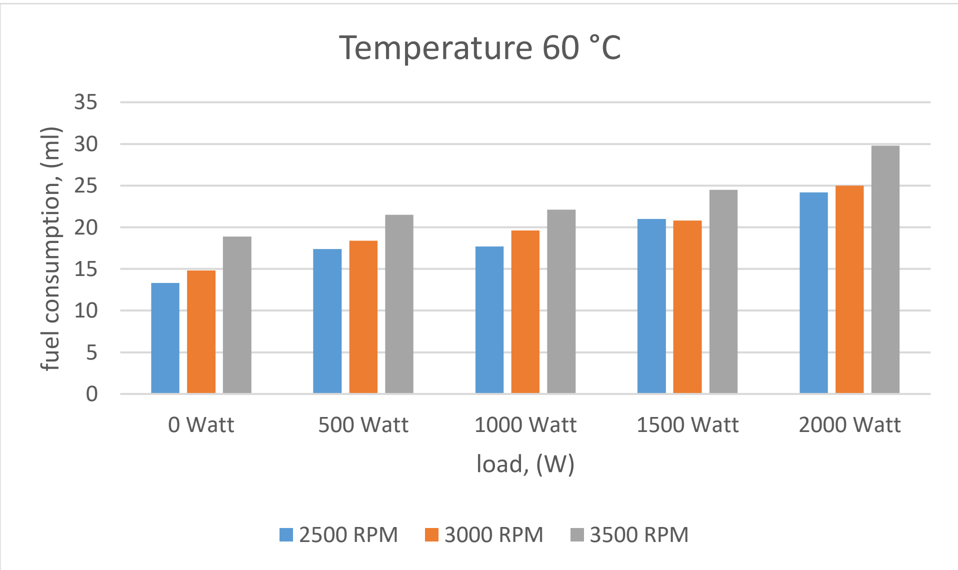


Figure 4.8: 10% Hydrogen Peroxide and 90% Gasoline

From the graphs above, it show the fuel consumption for 10 vol% hydrogen peroxide and 90 vol% gasoline at temperature 40°C and 60°C. The trends show increased in values from 0 Watt until 2000 Watt. This is because different temperature was used during the experiment. The value obtained at 60°C is highest than 40°C because of the percentage of mixture between gasoline and hydrogen peroxide. This mixture is faster to vaporize and generates more fuel consumption in engine.

4.4 Properties of Fuel Blend

There are two types of fuel used in the experiment, which are gasoline from Caltex RON 95 and gasoline blended with H_2O_2. The properties collected from this experiment were energy content, Q_{HV} of fuel and the density of difference type of fuel blend. The experiment of properties finding was conducted at Chemical Lab, Faculty of Mechanical Engineering. The result of density and energy content of fuel is tabulated as shown in Table 4.1.

Table 4.1: Results of density and energy content of fuel

Type of Fuel	Density (kg/m^3)	Energy Content, Q_{HV} (kJ/kg)
Gasoline Alone	735	38102
5% of H_2O_2 + Gasoline	755	33474
10% of H_2O_2 + Gasoline	765	28845

From Table 4.1, the result shows the density and energy content of fuel. The result shows different values of density an energy contents. The density of 10% hydrogen peroxide is higher than gasoline alone. Besides that, the value energy content for 10% hydrogen peroxide is lesser than energy content for gasoline alone. This reduction of energy content on H_2O_2-gasoline blend due to the extra atom of oxygen in H_2O_2 is suspended in water and placed in unstable condition where the oxygen are trying to escape unless held under slight pressure that keeps in stored (Charles P.Cox, 1981).

4.5 Discussions

4.5.1 Introduction

This part elaborates the results from the experiment. There is major comparison between temperature of 40 °C and 60 °C due to engine. The experiment was conducted on three types of liquid; gasoline alone, 5% of hydrogen peroxide and 10% hydrogen peroxide. As for engine, the speeds used were 2500RPM, 3000RPM and 3500RPM with load attached to the engine. Additionally, there were five sets of load, 0 kW, 500 kW, 1000kW, 1500kW and 2000kW.

4.5.2 P-θ Diagram

The cylinder pressure was measured using DEWESOFT pressure transducer and this input data was organized by DAS to visualize P-θ diagram while running the experiment. The figure shows an example of the variation of in cylinder pressure with crank angle and pressure at the gasoline alone with speed at 3500RPM and 1kW load with temperature 40°C and 60°C.

The results show that all curves move upward with the same pattern before top dead center (TDC) which normal combustion without pre-ignition. The pressure of the 10% H_2O_2 is highest than the pressure of gasoline alone (GA) and 5% of H_2O_2. The pressure curves for 10% is shift to the right and the pressure for GA and 5% is range from 20 degree to 45 degree.

There is an effect to promote the auto ignition in the engine. Hydrogen peroxide has significant effect on promoting the auto ignition of hydrogen. The thermal decomposition reaction of hydrogen peroxide is the most important reaction for the production of hydroxide radicals which promotes hydrogen auto-ignition (Jeon & Bae, 2013).

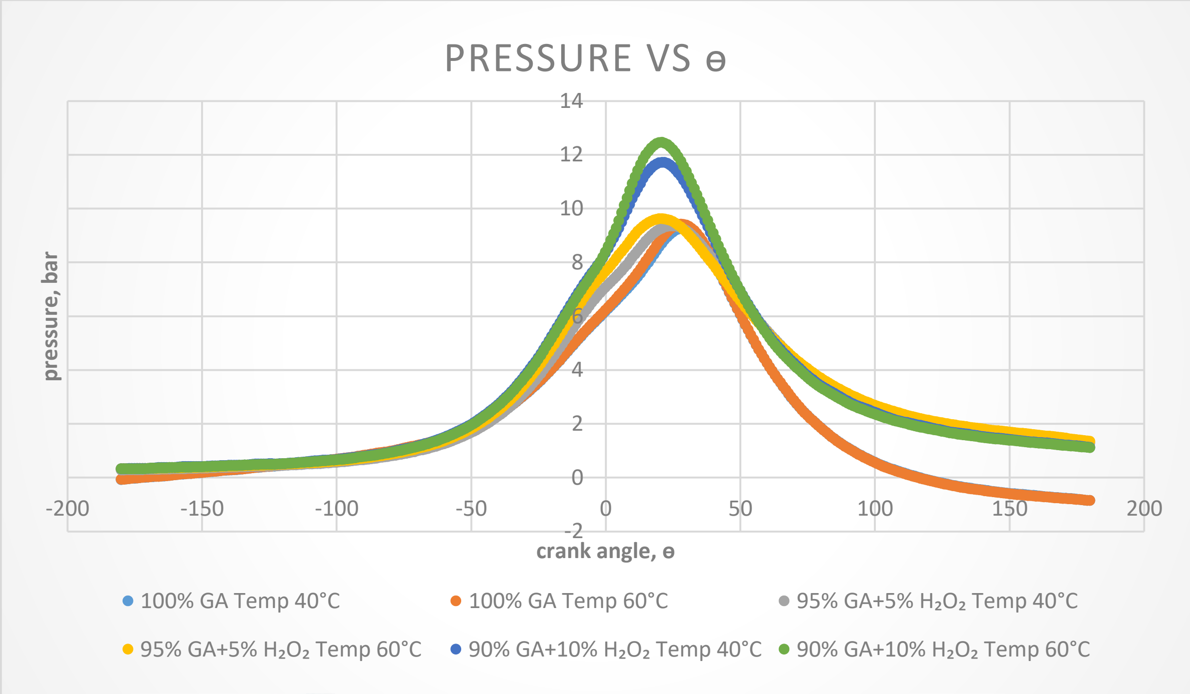


Figure 4.9: Pressure with Different Temperature and Percentage at 3500RPM.

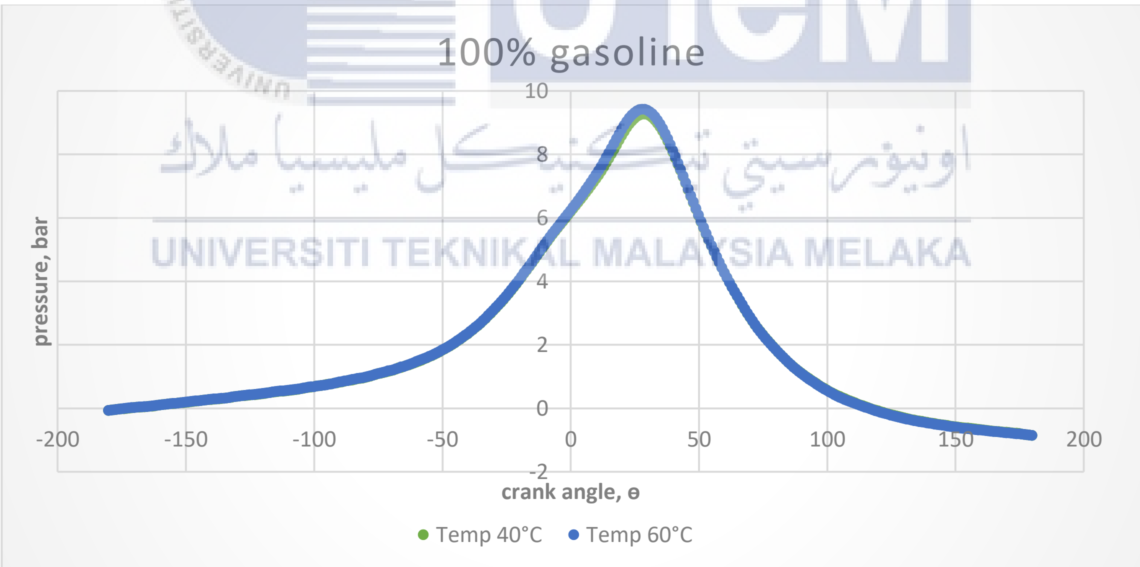


Figure 4.10: Gasoline Alone with Different Temperature

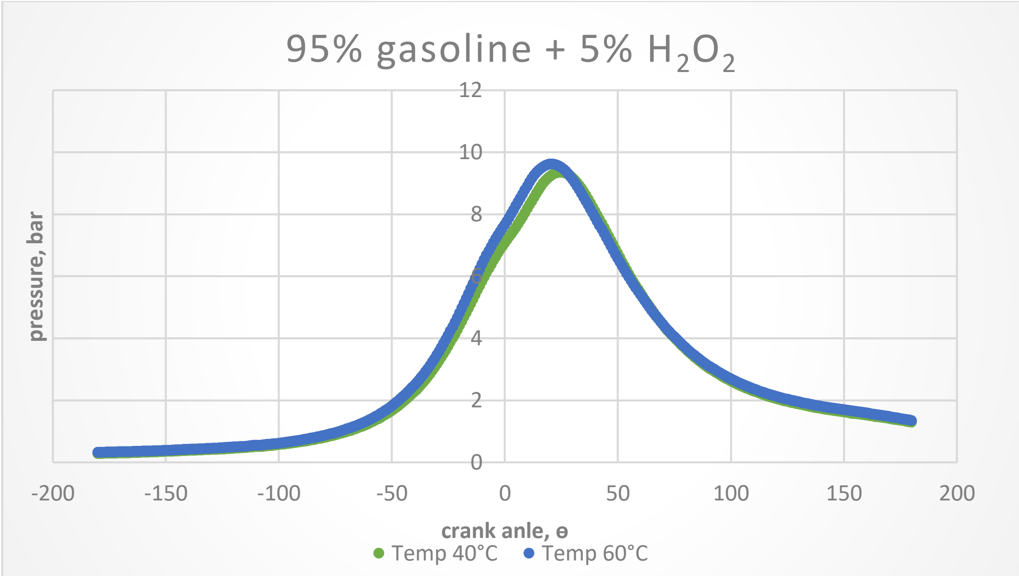


Figure 4.11 : 5% H_2O_2 with Different Temperature

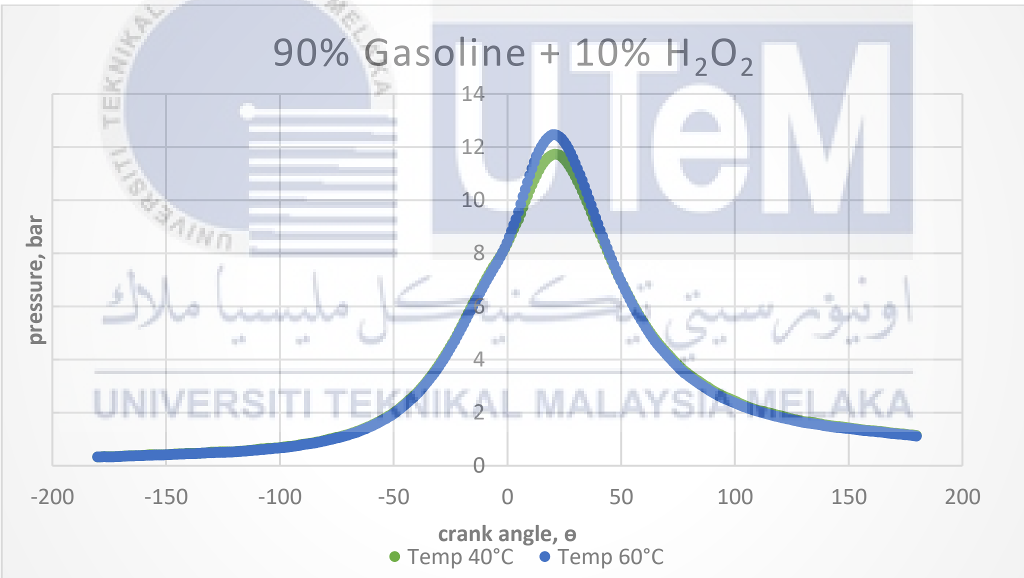


Figure 4.12: 10% H_2O_2 with Different Temperature.

4.5.3 P-V Diagram

For the p-v diagram, the data recorded from BDC to TDC where it ranges from -360 to 360. From the P-V diagram, the result of the work nett then obtained. The formula used in order to get the data of crank angle ranges between -180 to +180 is by calculating the area under the graphs. The parameters involve are pressure and volume, while the result measurement was calculated in (kPa.m3) unit.

The formula to find volume is shown below:

$$v \equiv \frac{\pi b^2 s}{4} \quad (1)$$

S = 6.7 cm

B = 9.1 cm

This formula is used to find the volume and to draw the P-V diagram.

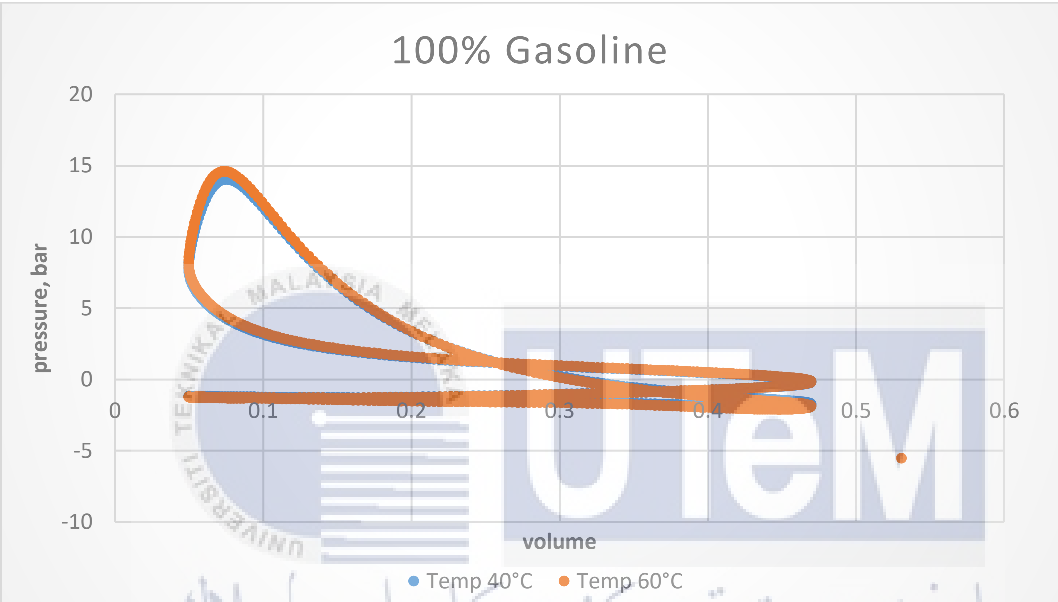


Figure 4.13: P-V graph 100% gasoline

From Figure 4.13, the pressure for temperature 60°C obtained is higher than the temperature 40°C. This is because at temperature 60°C, the highest pressure is supplied to engine. At higher temperature, the area under the graph and the result for the work nett are different. The work nett for temperature 40°C is $0.07 kPa.m^3$. Meanwhile, for temperature 60°C is $0.06 kPa.m^3$.

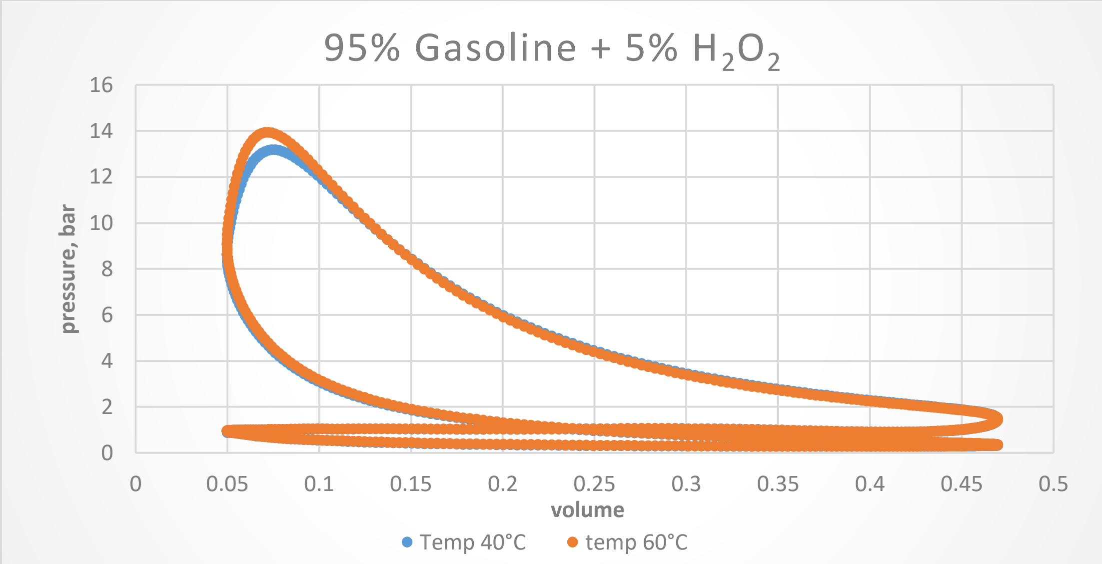


Figure 4.14: P-V graph 95% gasoline + 5% H_2O_2

From the Figure 4.14, the pressure for temperature 60°C is higher than the temperature 40°C. The pressure for temperature 60°C is around 14 bar and for temperature 40°C is 13 bar. The work nett for temperature 40°C is $0.1731 kPa.m^3$. Meanwhile for temperature 60°C is 0.1735 $kPa.m^3$. Temperature at 40°C is lower compared to temperature 60°C due to lower pressure supplied to the engine.

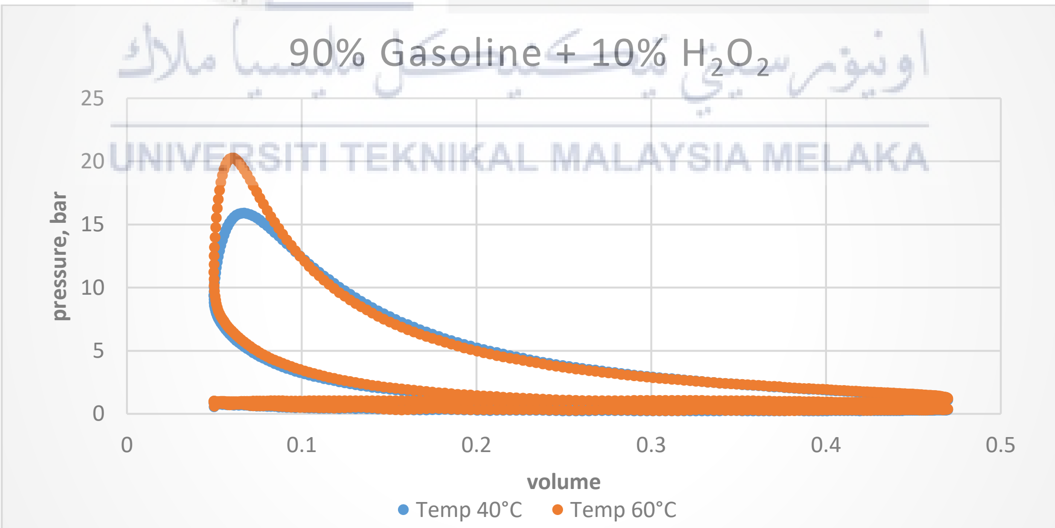


Figure 4.15: P-V graph 90% gasoline + 10% H_2O_2

From the Figure 4.14, the pressure for temperature 60°C is higher than the temperature 40°C. The pressure for temperature 60°C is around 21 bar and for temperature 40°C is 17 bar. The work nett for temperature 40°C is 0.1636 $kPa.m^3$. Meanwhile, for temperature

60°C is $0.1735\ kPa.m^3$. The temperature 60°C is lower than temperature 40°C because the specimen 10% hydrogen peroxide is higher than 5% hydrogen peroxide.

4.5.4 Peak Pressure

The peak pressure was obtained from P-θ diagram for each speed and during experiment. The analysis of peak pressure is significant in determining maximum force exerted on the engine piston and cylinder prior to identifying the best material for engine fabrication.

From Figure 4.16, it shows the peak pressure for each material such as GA, 5% H_2O_2 and 10% H_2O_2 is reduced during increment of engine speed from 2500 RPM to 3500 RPM. As shown, the different temperature will affect pressure. Besides that, the ratio is the main factor which causes increase of the different pressure. If the temperature is high, it will result in increase of pressure. For temperature 40°C, the pressure is lower than the pressure for temperature 60°C. Higher pressure produced at 10% of H_2O_2, which can be found at temperature 60°C.

For GA, at speed engine 2500 RPM, the pressure for temperature 40 °C is 18.41 bar and temperature 60°C is 19.77 bar and the values decrease until 3500 RPM with 11.86 and 12.86 bar. For 5% of H_2O_2 with temperature 40 °C and 60 °C, the pressure for 2500 RPM is 17.42 bar and 16.94 bar. The pressure still drop until 3500rpm in value 12.33 bar and 12.88 bar. For 10% of H_2O_2 with temperature 40 °C and 60 °C, the pressure for 2500 RPM is 19.31 bar and 26.54 bar. The pressure still drop until the 3500 RPM in value 14.80 bar and 18.87 bar.

The impact of using a small amount of hydrogen peroxide mixture as an additive on the performance of a four cylinder diesel engine was evaluated. The required amount of the mixture was generated using electrolysis of water considering on board production of hydrogen peroxide mixture. Hydrogen has nine times higher flame speed than diesel has the ability to enhance overall combustion generating higher peak pressure closer to TDC resulting in more work (Bari & Mohammad Esmaeil, 2010).

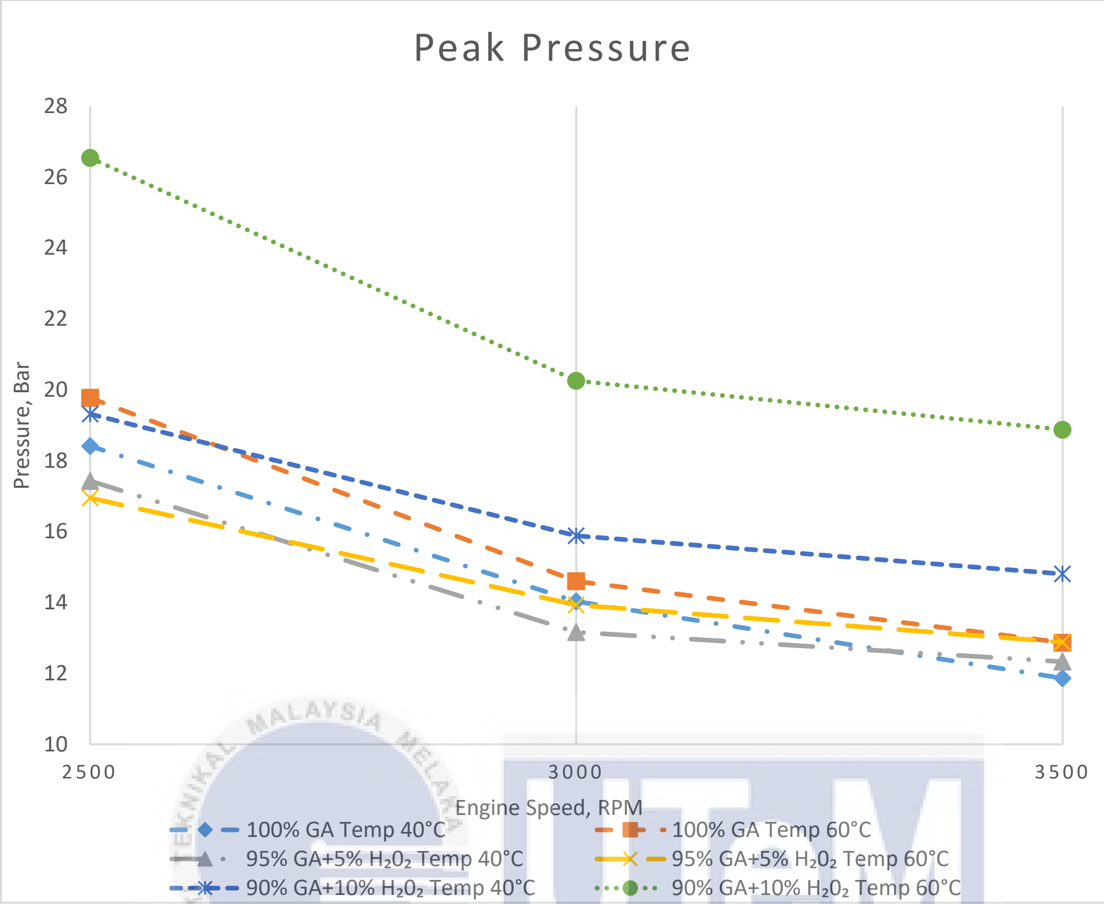


Figure 4.16: Graph Peak Pressure and Engine Speed (RPM)

4.5.5 Indicated Work

Work is the output of any heat engine and in a reciprocating internal combustion engine this work is generated by the gases in the combustion chamber of the cylinder. Work is the result of force acting through a distance. Force due to gas pressure on the moving piston generates the work in an internal combustion engine cycle.

Figure 4.16 shows the value of the work nett that created by engine. There is different value if there is a change in temperature. Besides that, when using gasoline alone only, the value increased. As example, for the result of gasoline alone in 3500 RPM with temperature 40°C, the value is 90.69 Joule. Meanwhile, with same properties for 5% H_2O_2 and 10% H_2O_2 is 168.1739 Joule and 155.69 Joule.

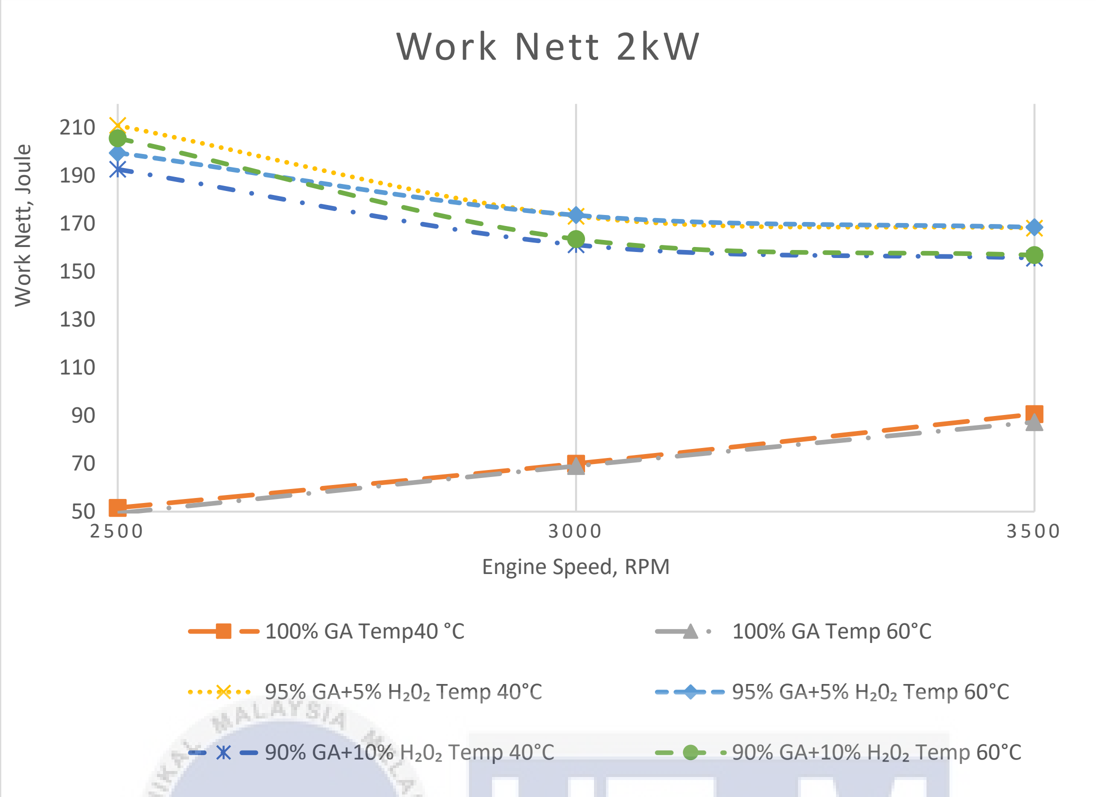


Figure 4.17: Graph Work Net for GA, 5% And 10%

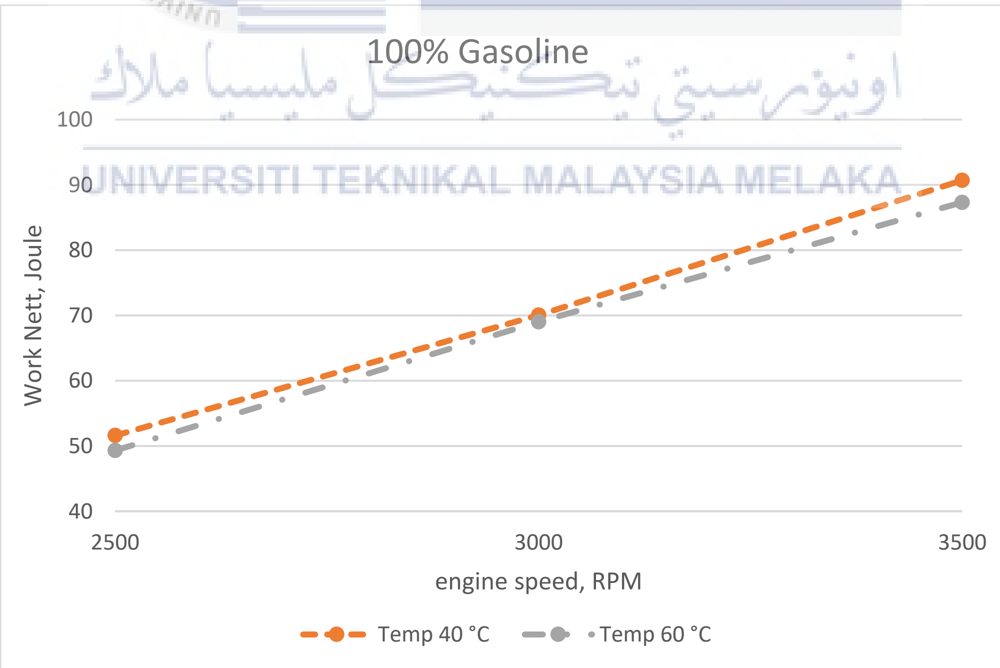


Figure 4.18: Graph of Gasoline Alone

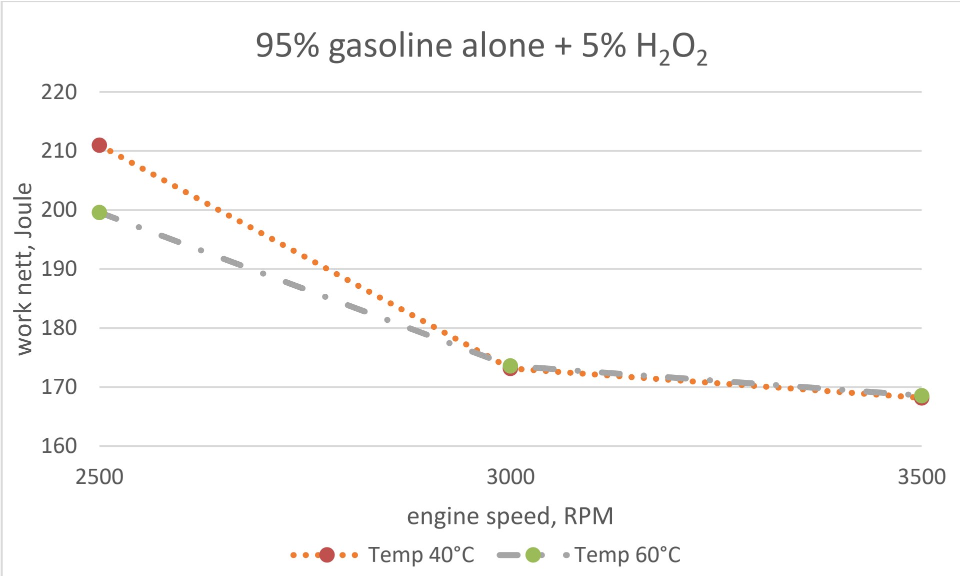


Figure 4.19: Graph 5% H_2O_2

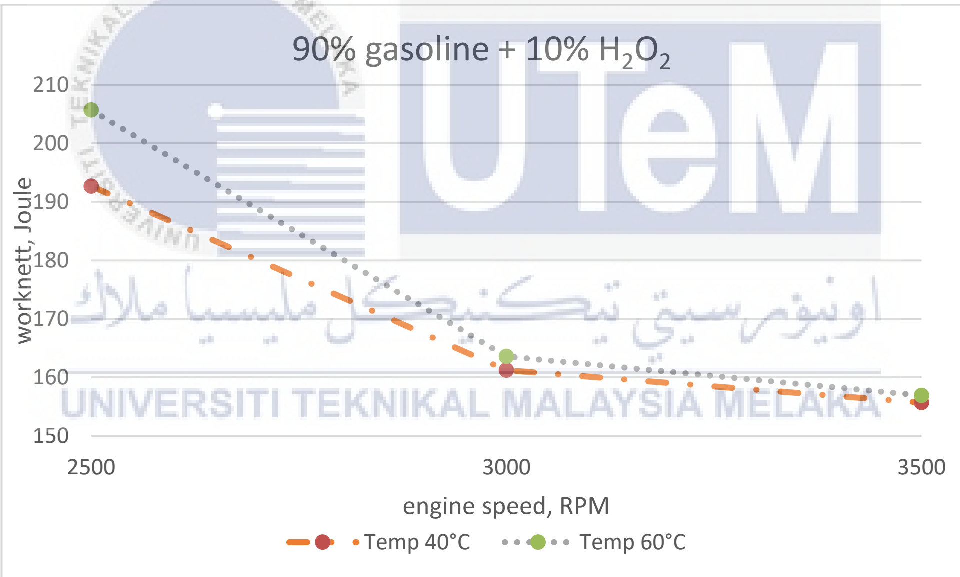


Figure 4.20: Graph 10% H_2O_2

4.5.6 Indicated Power in kW

From Figure 4.21 shows the result of the indicated power for the gasoline alone, 5% of H_2O_2 and 10% of H_2O_2. For each of the material, the temperature measured is temperature 40°C and temperature 60°C respectively. For engine speed, there are three different speed which are 2500RPM, 3000RPM and 3500RPM.

For gasoline alone, the result of the power increase from 2500RPM until 3500RPM with using temperature 40°C. When using different temperature which is temperature 60°C, the result of power is lower than the temperature 60°C.

For 5% of H_2O_2, the result is still increase when using temperature 40°C and temperature 60°C. But, the result of the power for the temperature 60°C is higher than using temperature 40°C. For 10% of H_2O_2, the result at different temperature is differed. This is because, at temperature 60°C, the result is higher than temperature 40°C.

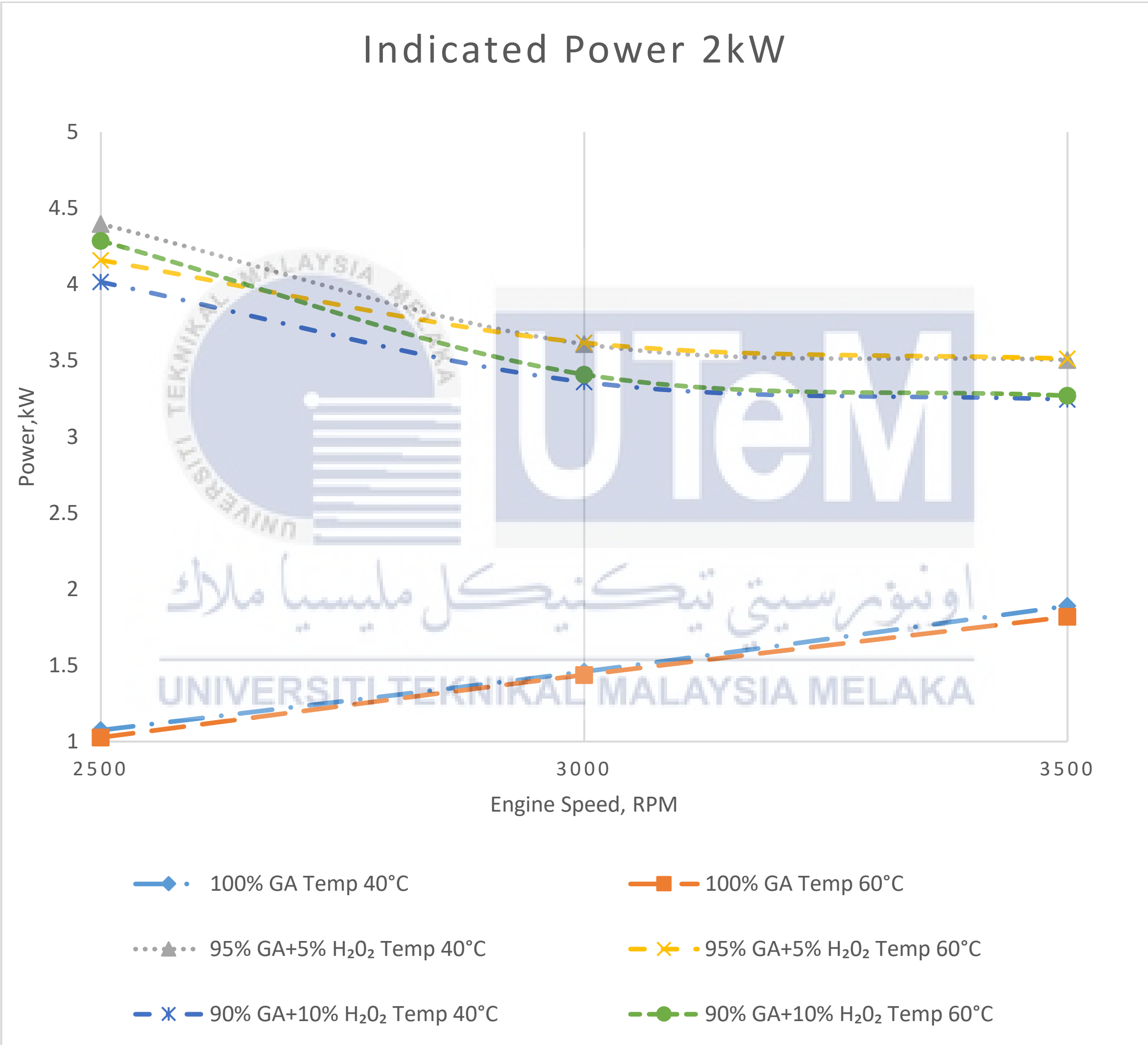


Figure 4.21: Graph Indicated Power for Load 2 kW

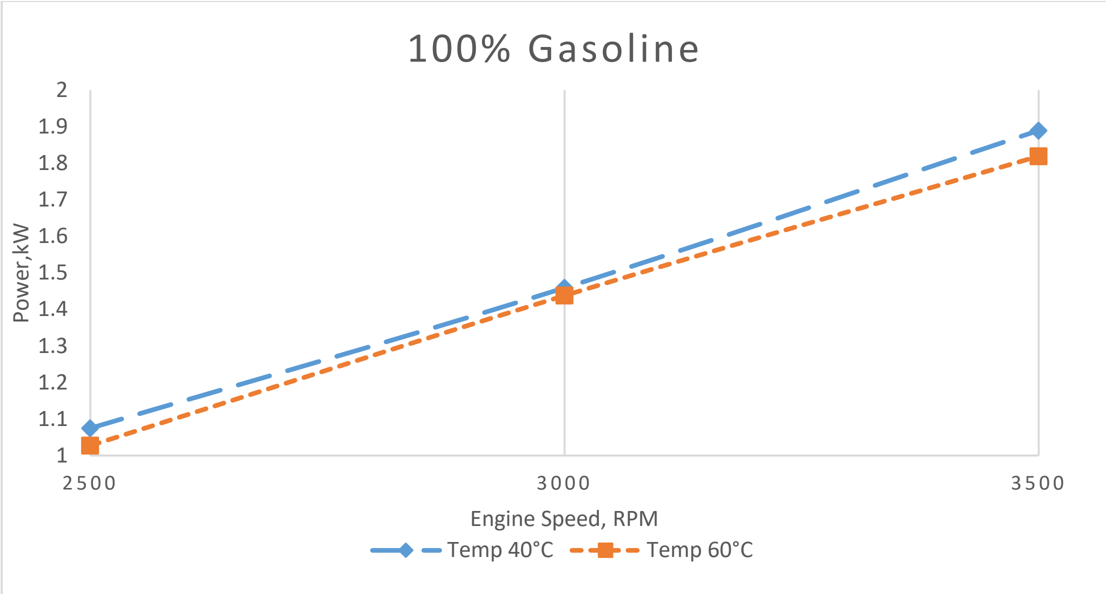


Figure 4.22: Graph 100% Gasoline

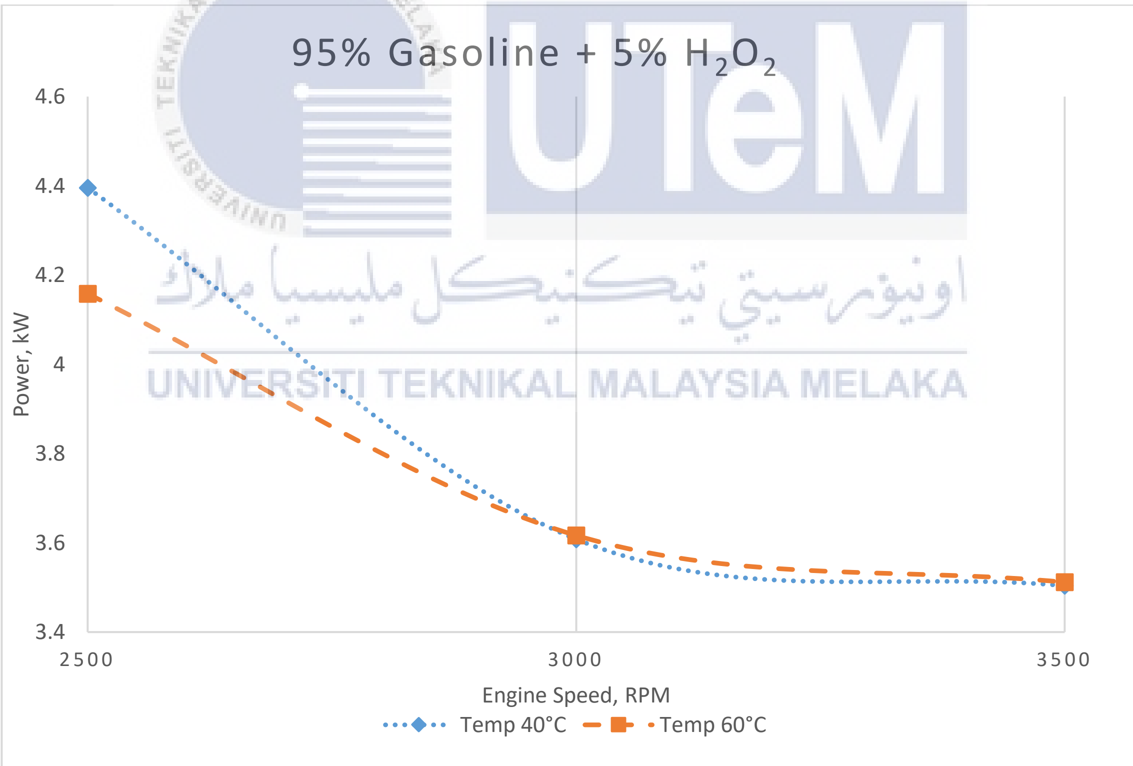


Figure 4.23: Graph 95% Gasoline + 5% H_2O_2

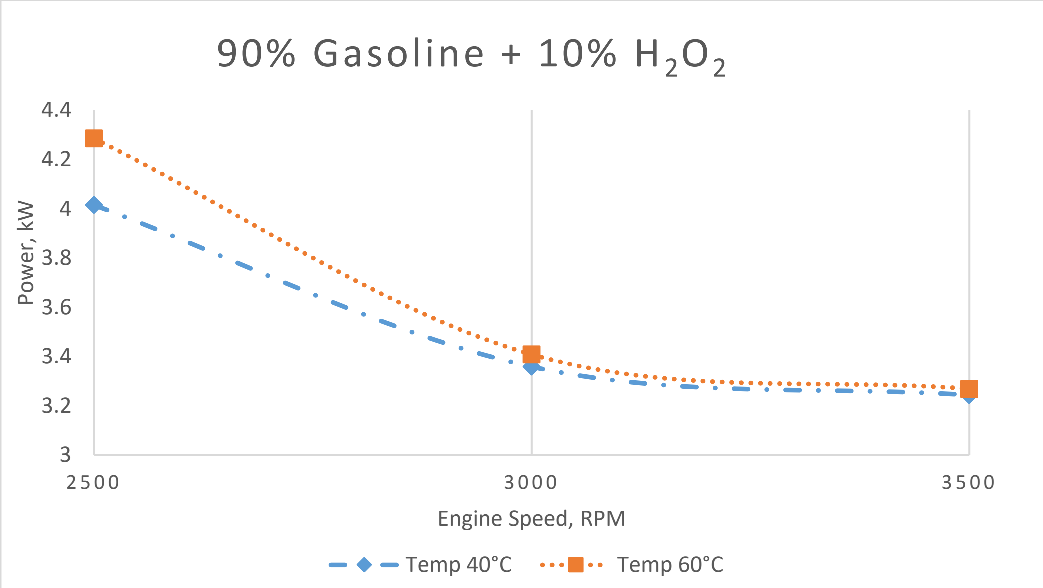


Figure 4.24: Graph 90% Gasoline + 10% H_2O_2

4.5.7 Thermal Efficiency

Figure 4.25 shows the result of thermal efficiency for load 2kW. For this result, there are two different temperature for measurement which are temperature 40°C and temperature 60°C. For the properties of gasoline alone, temperature 40°C is higher than temperature 60°C where the value is 12.96% than 12.30% at engine speed 3500RPM. However, for engine speed 3000RPM, the percentage for temperature 60°C is higher than temperature 40°C which the value is 10.59% than 1.15%.

For 5% H_2O_2, temperature 60°C is greater than temperature 40°C at engine speed 3500RPM as the value is 27.67% than 24.67%. Meanwhile, at engine speed 2500RPM the result for temperature 40°C is higher than temperature 60°C with the value 37.77% than 34.85%. The decreasing factor is caused by increase of inlet charge temperature (Pan et al, 2015).

Finally, for 10% H_2O_2, when using temperature 40°C the result is higher than temperature 60°C with the value is 27.28% than 26.11%. For the engine speed is using 3500 RPM. However, when using engine speed 2500 RPM, the result when using temperature 40°C is lower than using temperature 60°C with the value is 39.49% than 42.15%.

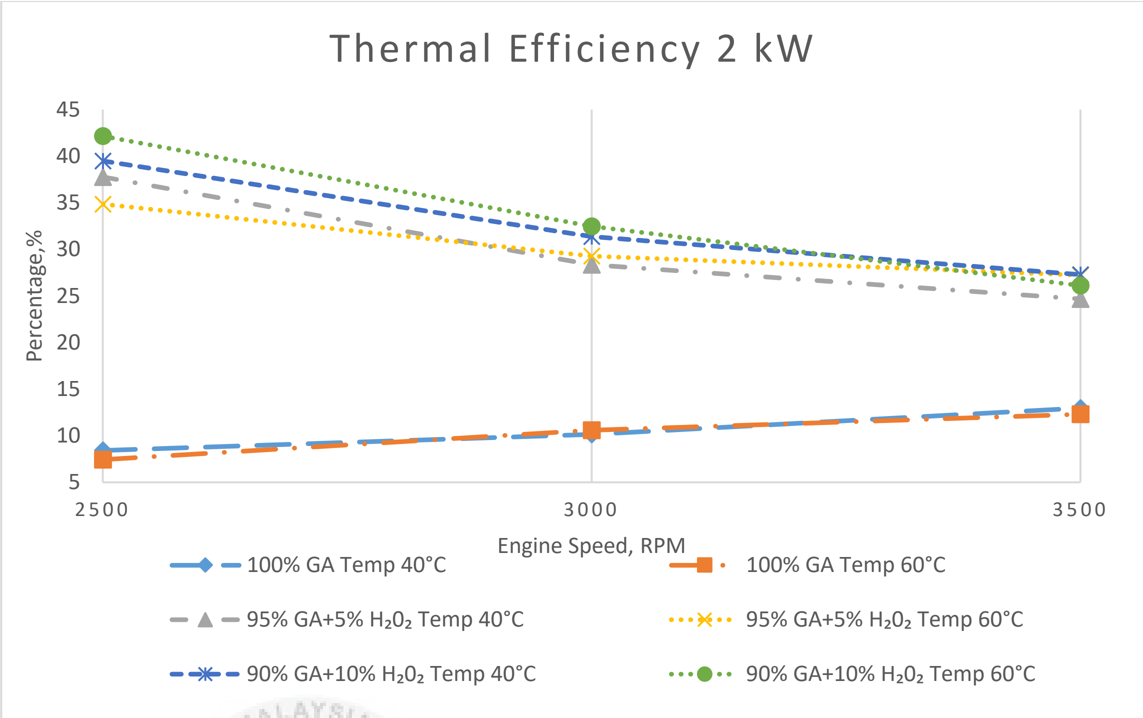


Figure 4.25: Graph Thermal Efficiency Load 2kW

4.5.8 Indicated Specific Fuel Consumption

Specific fuel consumption is generally given in unit of g/kW-hr or lbm/hp-hr. For transportation vehicle it is common to use fuel economy in terms of distance travelled per unit of fuel, such as miles per gallon (mpg). In SI units it is common to use the inverse of this, with (L/100km) being a common unit.

Besides that, to decrease air pollution and depletion of fossil fuels, there has law have been enacted requiring better vehicle fuel economy. From this act, most automobiles got less than (15.7L/100km) using gasoline. Nowadays, many modern automobiles using only at (7.8 L/100km) and some small vehicle using (3.9 L/100 km).(Pulkrabek, 1986.)

For the result of ISFC, especially for gasoline alone, the result showed that for temperature 60°C is higher than temperature 40°C with using engine speed 2500RPM. The result is the same with using engine speed 3500RPM. However, during using engine speed 3000RPM the result of temperature 40°C is higher than using temperature 60°C.

For properties 5% H_2O_2, the result for using temperature 40°C is higher than temperature 60°C. This result is same between engine speed 3000RPM and 3500RPM. Meanwhile, for temperature 40°C is lower than temperature 60°C when using engine speed 2500RPM.

For properties 10% H_2O_2, based in using temperature 40°C the result shows higher value than using temperature 60°C with using engine speed 2500RPM and 3000RPM. Meanwhile, the result for temperature 40°C is lower than temperature 60°C with using engine speed 3500RPM.

This can be concluded that 10% hydrogen peroxide has the best ISFC because less used of fuel for engine output during highest engine speed. This can be proved by the best value of ISFC for SI engine are about 400 g/kWh (Heywood, 1988).

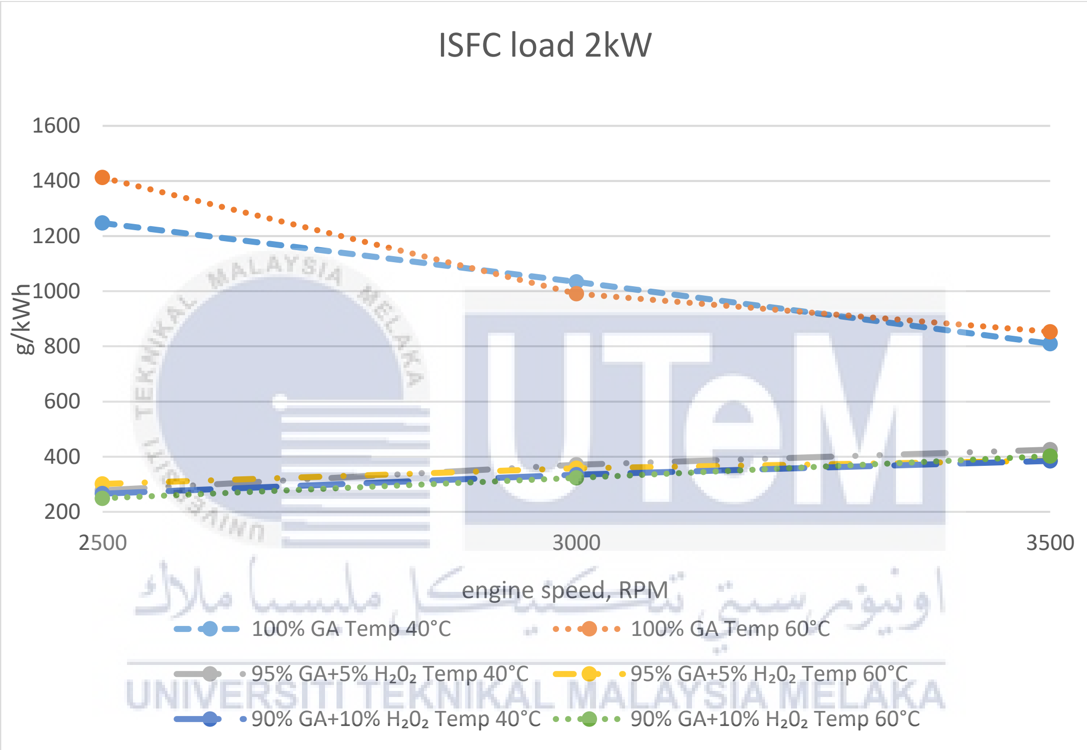


Figure 4.26: Graph ISFC with Load 2 Kw

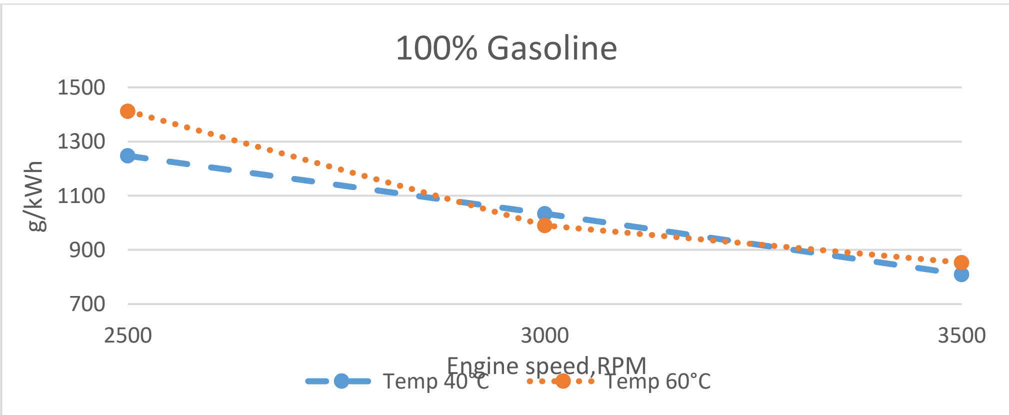


Figure 4.27: ISFC Gasoline

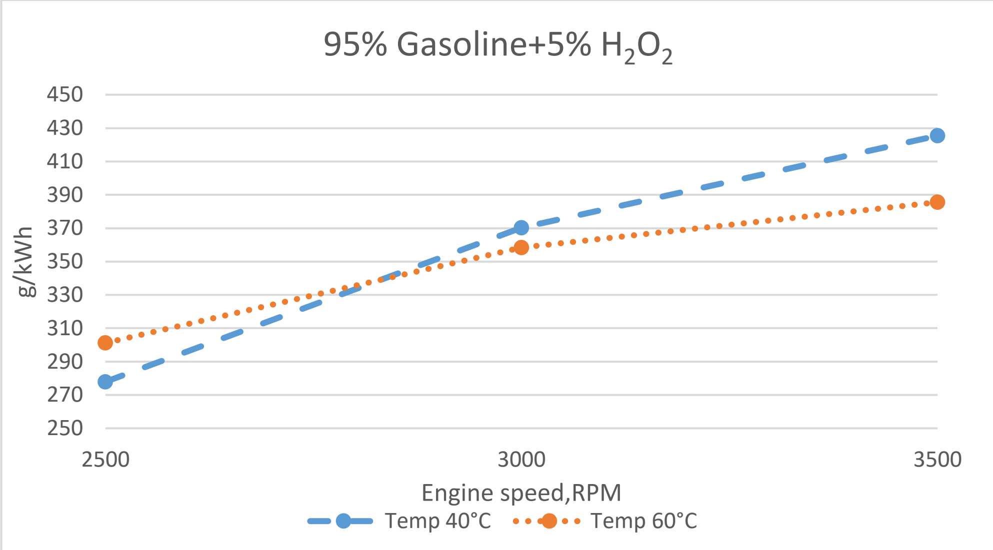


Figure 4.28: ISFC 5% H_2O_2

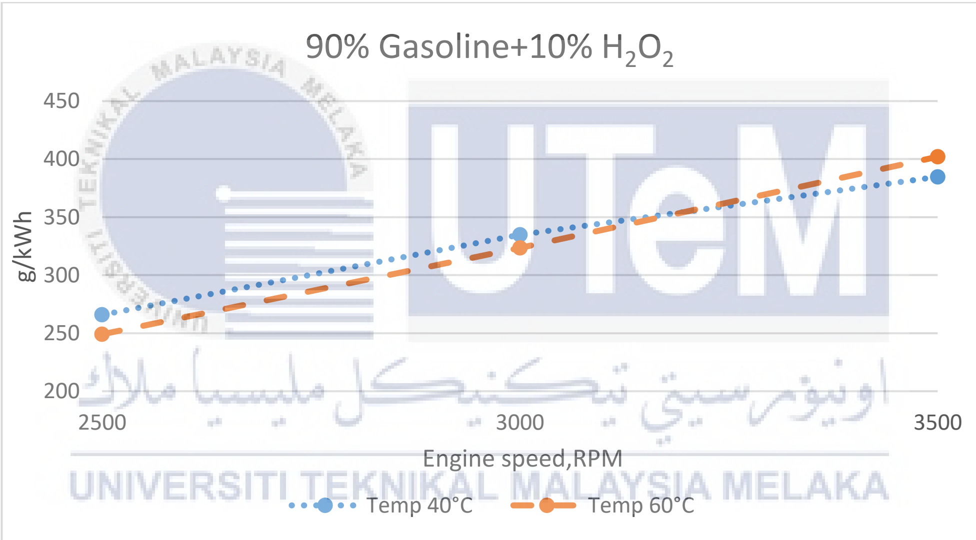


Figure 4.29: ISFC 10% H_2O_2

4.5.9 Heat Release Rate

Heat release rate was calculated from the average pressure with respect to crank angle. It is important to identify the rate of chemical energy release from combustion of fuels. Through all data results, negative heat release rate has been observed before to TDC where the pressure of the gasoline and the H_2O_2. This can be seen in result of load 2kW with engine speed is 3500RPM.

Figure 4.31 is gasoline alone, shows the value of heat after maximum power, it goes down and reach before negative point. The value continues until end of the crank and to BDC. Figure 4.32 is 5% H_2O_2, shows the value before the maximum power is at positive point, until it reaches TDC. After reach to TDC it continuous consistent at positive point and until reach at 150 degree of crank, it values goes to negative point until end of the crank angle. Figure 4.33 is 10% of H_2O_2, shows the value at TDC for temperature 40°C is higher than the temperature 60°C. When using temperature 60°C, the engine having difficulty to reach to its maximum at TDC. This is because, upon arrival at TDC, combustion has extra air that give to the lean combustion. Besides that, negative heat release rate has been observed before the start of ignition due to gasoline fuel and hydrogen peroxide droplet initiates its vaporization process resulting in heat absorption from the cylinder charge.

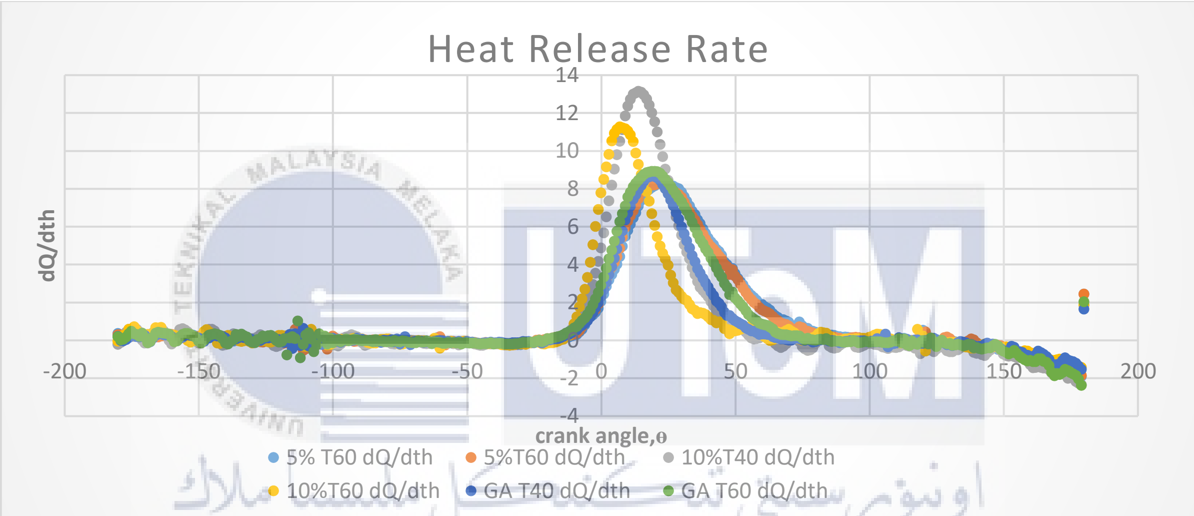


Figure 4.30: Graph Heat Release Rate

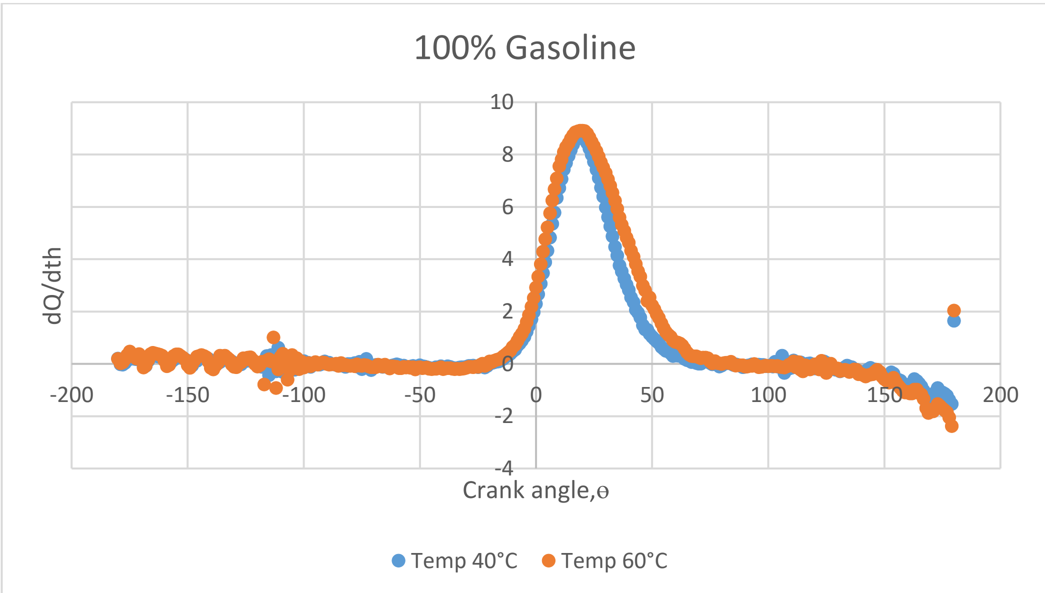


Figure 4.31: HRR Gasoline Alone

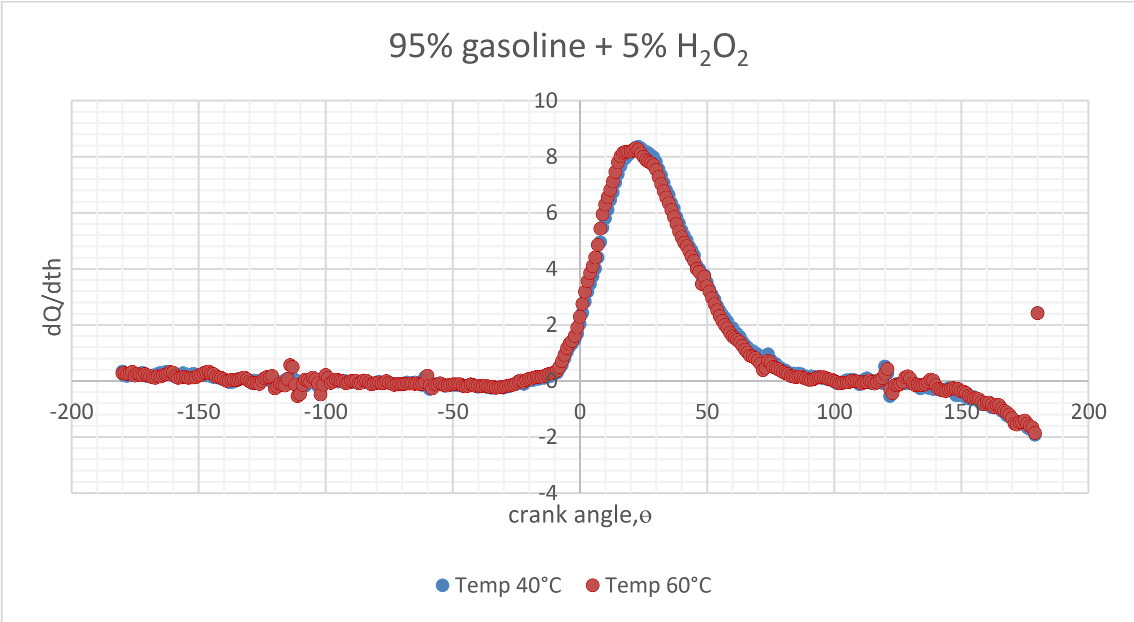


Figure 4.32: HRR 5% H_2O_2

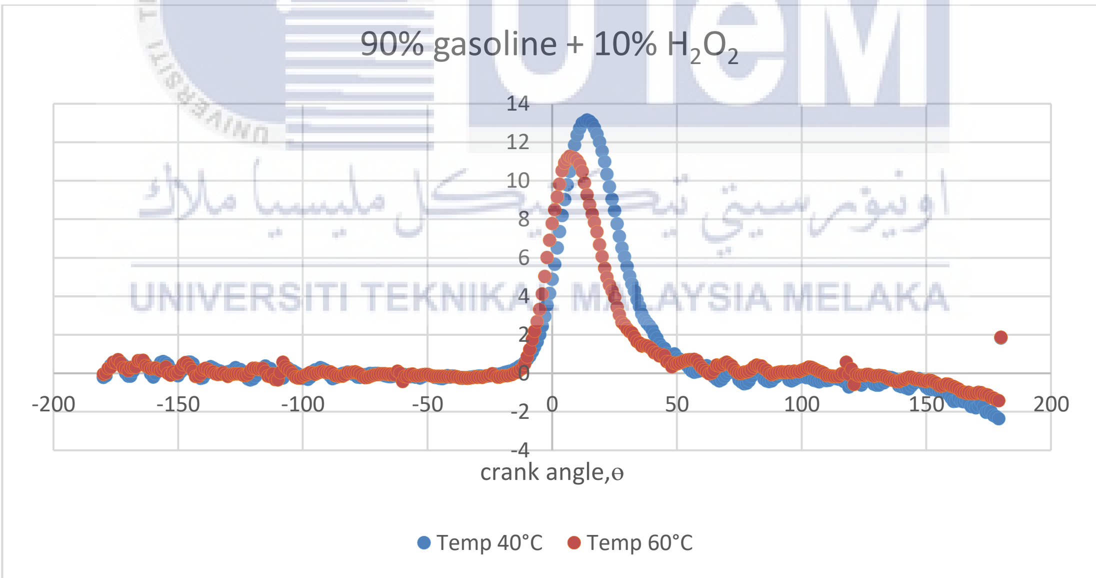


Figure 4.33: HRR 10% H_2O_2

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, the objectives of this experiment were successfully achieved. This is because the different of air temperature that was due to the engine has given the performance to engine. The result from experiment, it has shown the temperature 40°C is greater than temperature 60°C. The air temperature was the factor to give great performance to engine.

Besides that, the ratio for petrol blended with hydrogen peroxide is important to determine the suitable ratio that will due to engine. From result of experiment, the suitable ratio for engine is 95% gasoline with 5% of hydrogen peroxide which it gives great performance to engine compared to 90% gasoline with 10% of hydrogen peroxide.

Finally, the air temperature affected engine performance. From the experiment, engine at temperature 40°C is easier to conduct as compared at temperature 60°C because this specimen of hydrogen peroxide evaporated more.

5.2 Recommendations

There are some recommendations for further research for the chemical hydrogen peroxide. The specimen percentage for hydrogen peroxide should not more than 10% hydrogen peroxide. This is because to avoid stuck during combustion process and it has higher viscosity during intake process. Related to that, this specimen is easier to evaporate and the solution decreases slightly. Besides that, it is also to promote the alternative fuel with good ratio between gasoline and hydrogen peroxide. From the alternative fuel, we can generate the best chemical for the engine and can be used widely.

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APPENDICES

APPENDICES A

FIGURE OF EXPERIMENT PROJECT

The DAS Dewesoft

The Inlet Carburettor of Engine

Location of Pressure Sensor

Type of Load

APPENDICES B

THERMAL EFFICIENCY

100% gasoline

i. Temperature 40°C

Engine Speed 2500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	0.5931	1.2119	0.0284	38102	11.985	0.0866
500W	0.0002	0.6327	1.2684	0.0304	38102	13.377	0.0828
1000W	0.0003	0.0997	10.614	0.0048	38102	17.64	0.0099
1500W	0.0004	0.9606	1.3588	0.0461	38102	21.756	0.0773
2000W	0.0004	1.0748	1.2473	0.0516	38102	22.344	0.0842

Engine Speed 3000RPM

Load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0 W	0.0002	0.7260	1.2998	0.0348	38102	15.729	0.0807
500 W	0.0003	1.0446	1.0258	0.0501	38102	17.860	0.1023
1000W	0.0003	0.9488	1.1108	0.0455	38102	17.566	0.0945
1500W	0.0003	1.1603	1.0337	0.0556	38102	19.992	0.1015
2000W	0.0004	1.4590	1.0337	0.0700	38102	25.137	0.1015

Engine Speed 3500RPM

Load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	0.9506	1.0669	0.0456	38102	16.905	0.0983
500W	0.0003	1.1427	0.9724	0.0548	38102	18.522	0.1079
1000W	0.0003	1.3552	0.8753	0.0650	38102	19.771	0.1199
1500W	0.0003	1.6720	0.8228	0.0802	38102	22.932	0.1275
2000W	0.0004	1.8895	0.8098	0.0906	38102	25.504	0.1296

ii. Temperature 60°C

Engine Speed 2500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0001	0.5378	1.2626	0.0258	38102	11.319	0.0831
500W	0.0002	0.5351	1.5080	0.0256	38102	13.4505	0.0696
1000W	0.0002	0.6996	1.3865	0.0335	38102	16.17	0.0757
1500W	0.0002	0.5740	1.6823	0.0275	38102	16.0965	0.0624
2000W	0.0004	1.0273	1.4122	0.0493	38102	24.1815	0.0743

Engine Speed 3000RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	0.7439	1.1025	0.0297	38102	13.671	0.0952
500W	0.0002	0.6711	1.2746	0.0322	38102	14.259	0.0823
1000W	0.0002	1.3040	0.8082	0.0625	38102	17.5665	0.1298
1500W	0.0003	1.2422	1.0188	0.0596	38102	21.0945	0.1030
2000W	0.0003	1.4376	0.9908	0.0690	38102	23.7405	0.1059

Engine Speed 3500RPM

load	fuel mass flowrate-kg/s	indicated power-Kw	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0003	1.4641	0.7861	0.0501	38102	19.1835	0.1335
500W	0.0003	1.2325	0.9195	0.0591	38102	18.8895	0.1141
1000W	0.0003	1.3620	0.8839	0.0653	38102	20.0655	0.1187
1500W	0.0003	1.5839	0.8853	0.0760	38102	23.373	0.1185
2000W	0.0004	1.8192	0.8532	0.0873	38102	25.872	0.1230

5% hydrogen peroxide + 95 % gasoline

i. Temperature 40°C

Engine Speed 2500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0003	3.5933	0.3043	0.1724	33474	18.6	0.3847
500W	0.0002	2.3732	0.3902	0.1139	33474	15.75	0.3000

1000W	0.0002	4.9152	0.2036	0.2359	33474	17.025	0.5749
1500W	0.0002	3.61586	0.2707	0.1735	33474	16.65	0.4325
2000W	0.0003	4.39555	0.2779	0.2109	33474	20.775	0.4213

Engine Speed 3000RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0003	3.5184	0.3158	0.1688	33474	18.9	0.3707
500W	0.0002	2.3351	0.4192	0.1120	33474	16.65	0.2793
1000W	0.0002	4.6958	0.2113	0.2253	33474	16.875	0.5542
1500W	0.0003	5.4964	0.2086	0.2638	33474	19.5	0.5613
2000W	0.0003	3.6079	0.3703	0.1731	33474	22.725	0.3161

Engine Speed 3500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0 W	0.0002	3.8525	0.2644	0.1849	33474	17.325	0.4428
500 W	0.0002	2.3407	0.4521	0.1123	33474	18	0.2589
1000 W	0.0003	4.8602	0.2404	0.2332	33474	19.875	0.4870
1500W	0.0003	5.4690	0.2427	0.2625	33474	22.575	0.4824
2000W	0.0004	3.5036	0.4254	0.1681	33474	25.35	0.2752

ii. Temperature 60°C

Engine Speed 2500RPM

load	fuel mass flowrate-kg/s	indicated power-Kw	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	1.9340	0.4605	0.0928	33474	15.15	0.2542
500W	0.0002	2.3562	0.3593	0.1130	33474	14.4	0.3258
1000W	0.0002	2.9432	0.2921	0.1412	33474	14.625	0.4007
1500W	0.0002	3.5554	0.2803	0.1706	33474	16.95	0.4177
2000W	0.0003	4.15817	0.3011	0.1995	33474	21.3	0.3887

Engine Speed 3000RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	2.2087	0.4332	0.0883	33474	16.275	0.2702

500W	0.0002	2.1798	0.4329	0.1046	33474	16.05	0.2704
1000W	0.0002	2.6139	0.3711	0.1254	33474	16.5	0.3155
1500W	0.0003	3.1441	0.3632	0.1509	33474	19.425	0.3223
2000W	0.0003	3.6166	0.3584	0.1735	33474	22.05	0.3266

Engine Speed 3500RPM

Load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	2.7880	0.3464	0.0955	33474	16.425	0.3380
500W	0.0002	2.3066	0.4645	0.1107	33474	18.225	0.2520
1000W	0.0003	2.6419	0.4339	0.1268	33474	19.5	0.2698
1500W	0.0003	3.1050	0.4246	0.1490	33474	22.425	0.2757
2000W	0.0003	3.5116	0.3855	0.1685	33474	23.025	0.3037

10% hydrogen peroxide + 90% gasoline

i. Temperature 40°C

Engine Speed 2500RPM

Load	fuel mass flowrate-kg/s	indicated power-Kw	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	1.9987	0.5251	0.0959	28845	17.969	0.2570
500W	0.0001	2.4765	0.2599	0.1188	28845	11.023	0.5192
1000W	0.0002	2.7542	0.2769	0.1322	28845	13.0615	0.4873
1500W	0.0002	3.1711	0.2642	0.1522	28845	14.345	0.5109
2000W	0.0002	4.0147	0.2658	0.1927	28845	18.271	0.5078

Engine Speed 3000RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0003	1.5574	0.7418	0.0747	28845	19.781	0.1819
500W	0.0002	2.2108	0.3430	0.1061	28845	12.986	0.3934
1000W	0.0002	2.5599	0.3273	0.1228	28845	14.345	0.4124
1500W	0.0002	2.9897	0.3200	0.1435	28845	16.3835	0.4217
2000W	0.0003	3.3589	0.3347	0.1612	28845	19.2525	0.4032

Engine Speed 3500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0004	1.6749	0.8978	0.0803	28845	25.7455	0.1503
500W	0.0002	2.2324	0.3891	0.1071	28845	14.8735	0.3468
1000W	0.0002	2.6409	0.3890	0.1267	28845	17.5915	0.3465
1500W	0.0003	3.0095	0.3912	0.1444	28845	20.1585	0.3450
2000W	0.0003	3.2437	0.3847	0.1556	28845	21.3665	0.3508

ii. Temperature 60 °C

Engine Speed 2500RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0001	1.8729	0.3131	0.0898	28845	10.0415	0.4310
500W	0.0002	2.2772	0.3369	0.1093	28845	13.137	0.4006
1000W	0.0002	2.8125	0.2775	0.1350	28845	13.3635	0.4864
1500W	0.0002	3.6543	0.2534	0.1754	28845	15.855	0.5326
2000W	0.0002	4.2850	0.2490	0.2056	28845	18.271	0.5420

Engine Speed 3000RPM

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0001	2.0763	0.3143	0.0830	28845	11.174	0.4294
500W	0.0002	2.1904	0.3704	0.1051	28845	13.892	0.3644
1000W	0.0002	2.5818	0.3347	0.1239	28845	14.798	0.4032
1500W	0.0002	2.8920	0.3171	0.1388	28845	15.704	0.4256
2000W	0.0003	3.4084	0.3233	0.1636	28845	18.875	0.4173

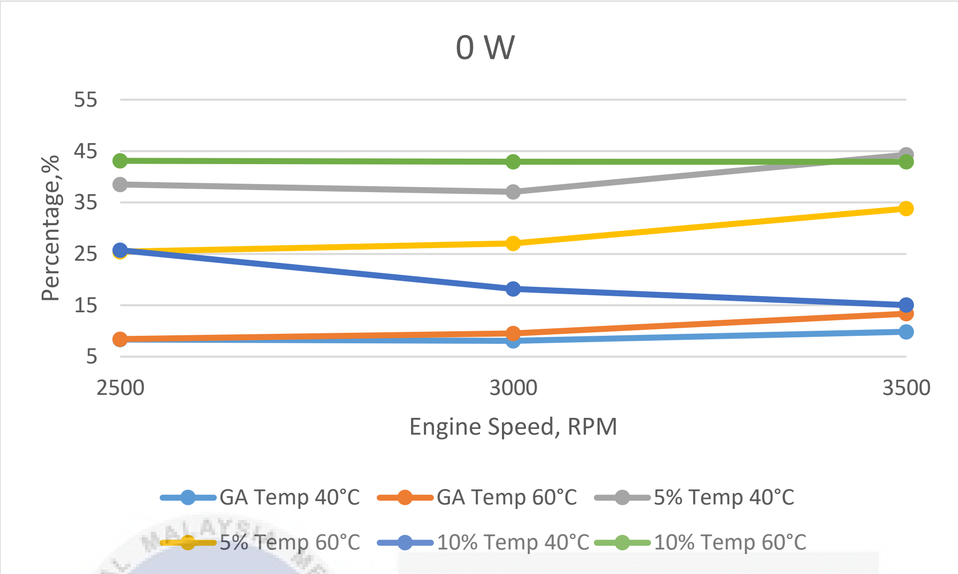
Engine Speed 3500rpm

load	fuel mass flowrate-kg/s	indicated power-kW	ISFC-kg/kWh	indicated work-kJ	energy content	fuel mass-g	thermal efficiency
0W	0.0002	2.6499	0.3145	0.0908	28845	14.2695	0.4292
500W	0.0002	2.3555	0.4025	0.1130	28845	16.2325	0.3353
1000W	0.0002	2.6934	0.3618	0.1292	28845	16.6855	0.3730
1500W	0.0003	2.8797	0.3751	0.1382	28845	18.4975	0.3598
2000W	0.0003	3.2690	0.4020	0.1569	28845	22.499	0.3358

Appendix C

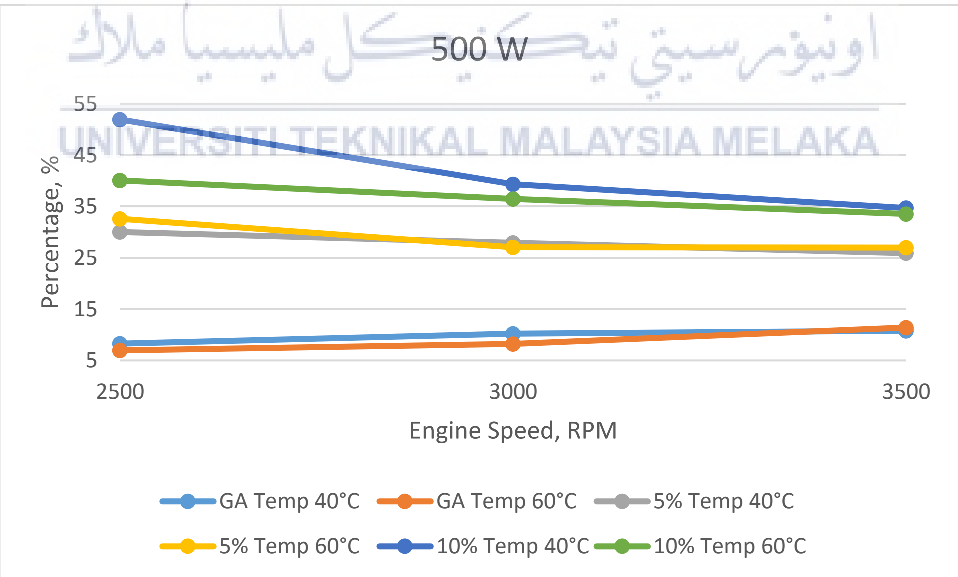
Thermal efficiency

: Result for Zero Load



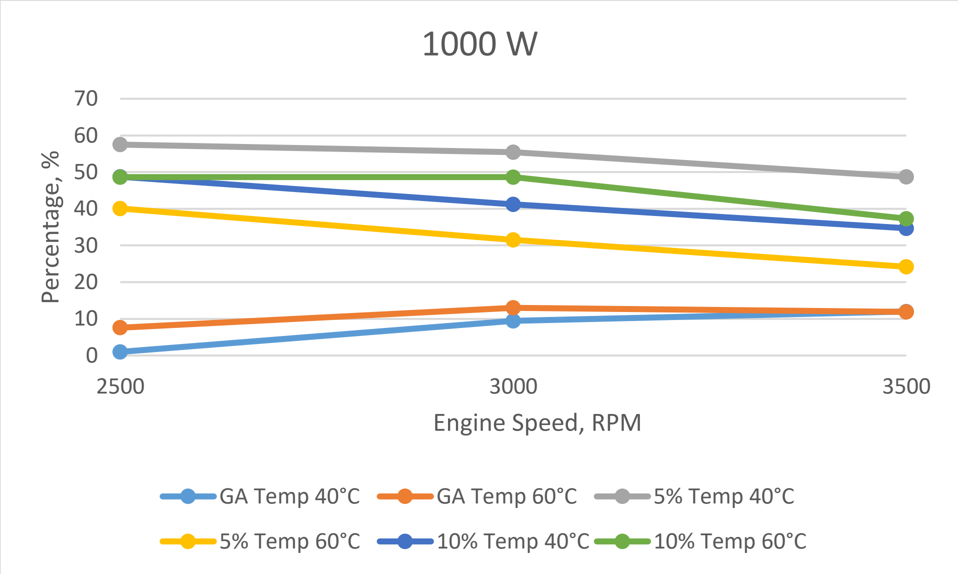
Graph Zero Load

Result for 500 W Load



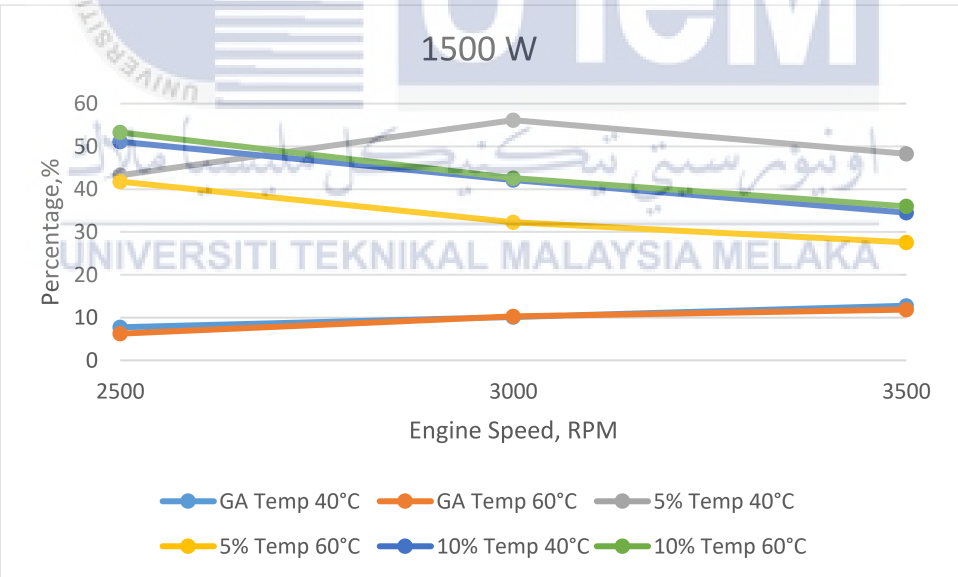
Graph 500 W Load

Result 1000 W Load



Graph 1000 W Load

Result 1500 W Load

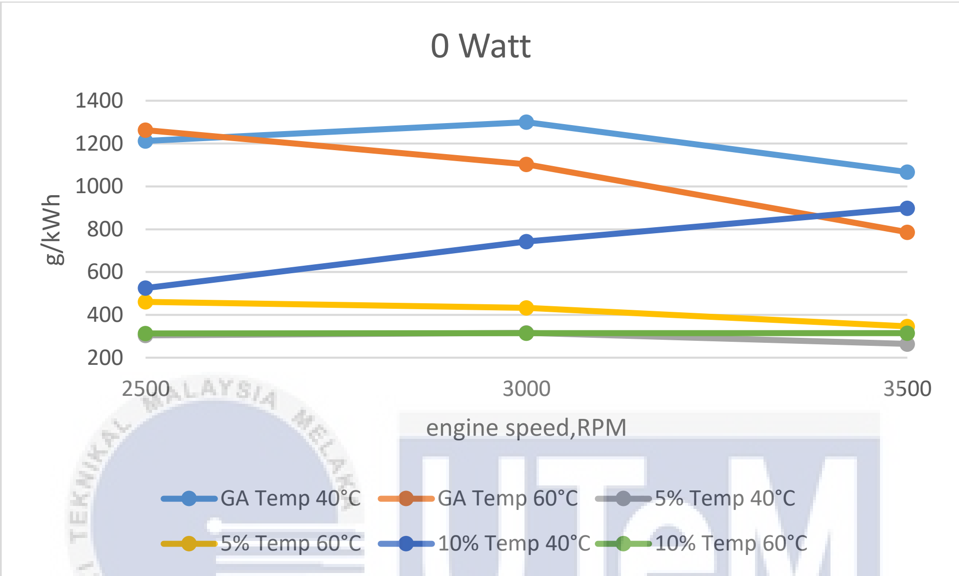


Graph 1500 W Load

Appendices D

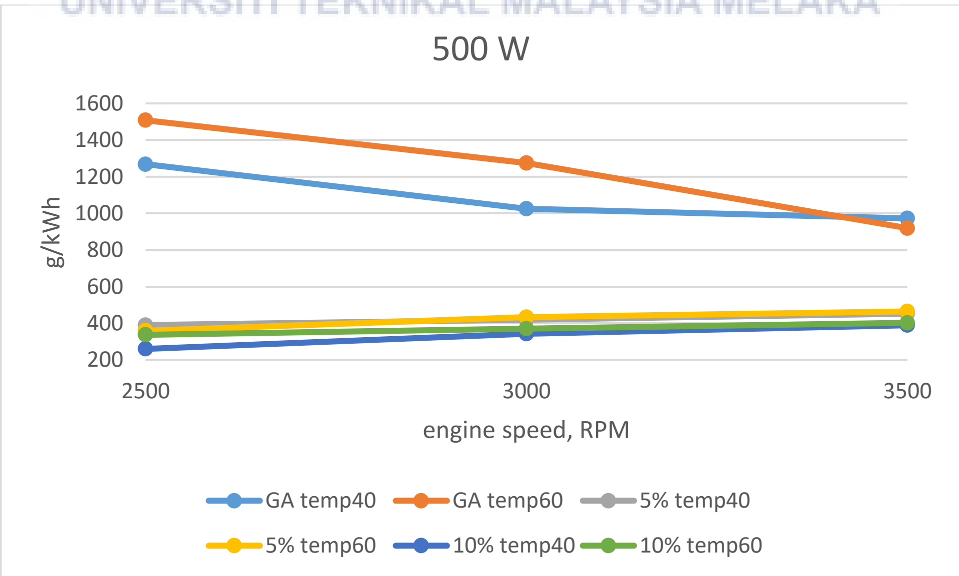
INTEGRATED SPECIFIC FUEL CONSUMPTION (ISFC)

Isfc 0 Watt



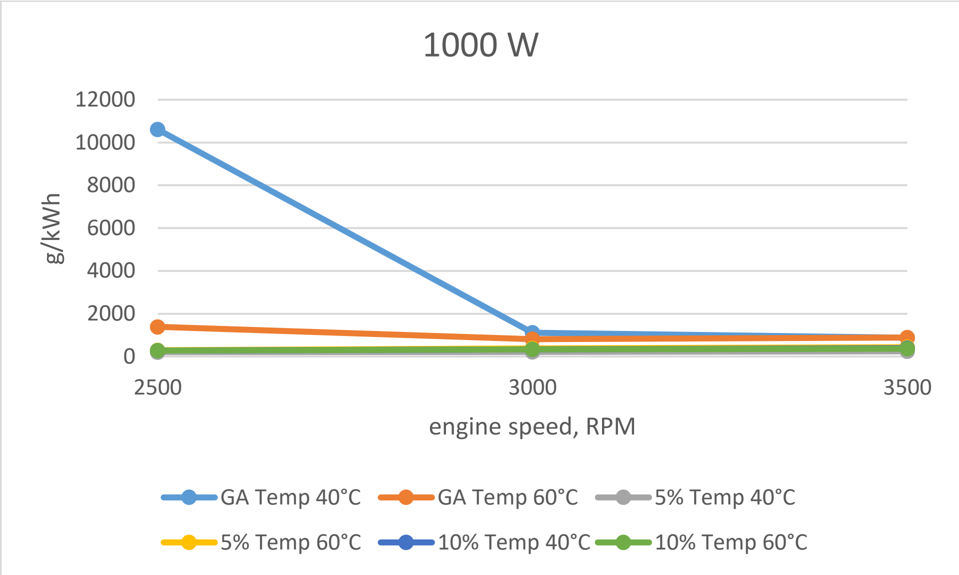
Graph ISFC 0 W

ISFC Result for 500 W



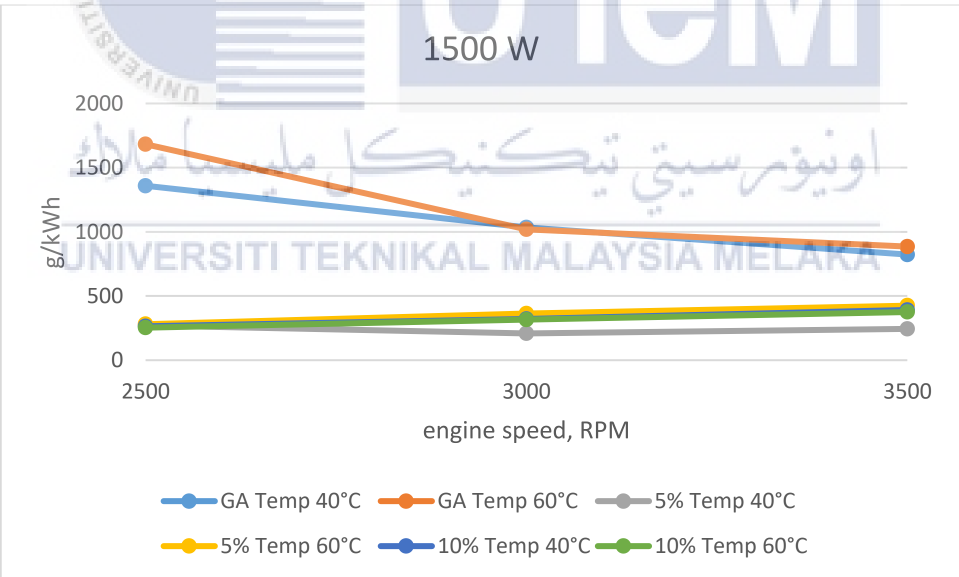
Graph Load 500 W

ISFC 1000 W



Graph for ISFC 1000 W

ISFC 1500 W

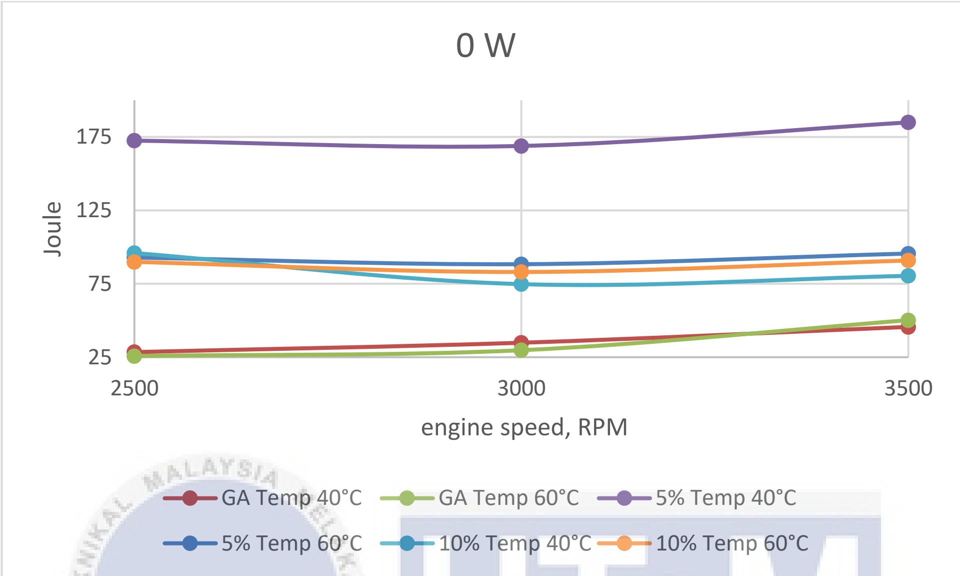


Graph ISFC 1500 W

APPENDICES E

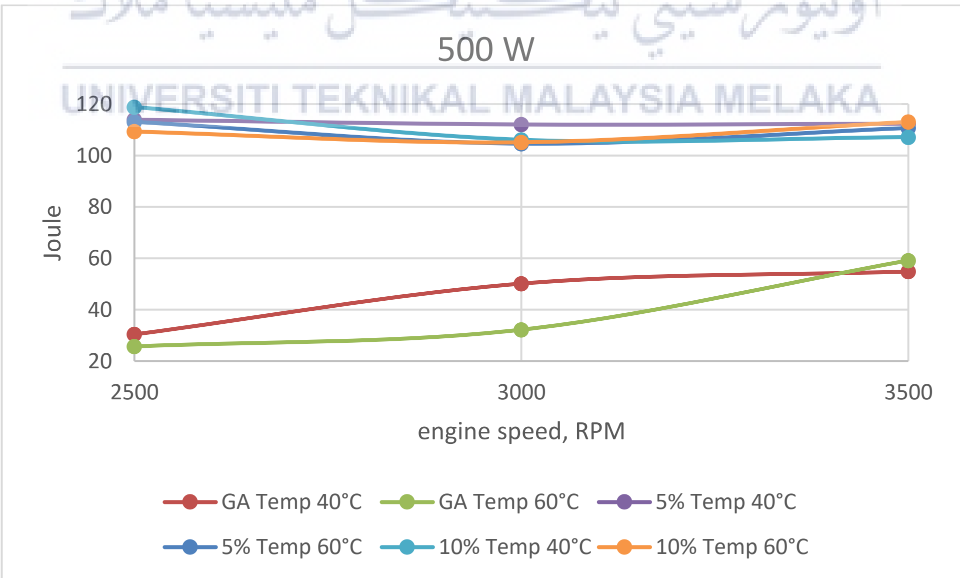
INDICATED WORK

Work nett 0 W



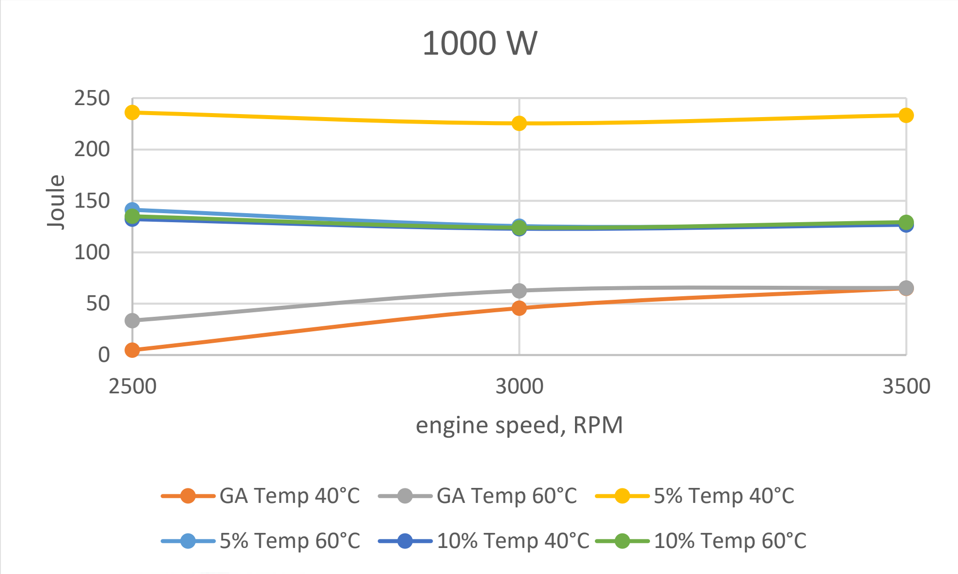
Graph Work Nett 0 W

Work nett 500W



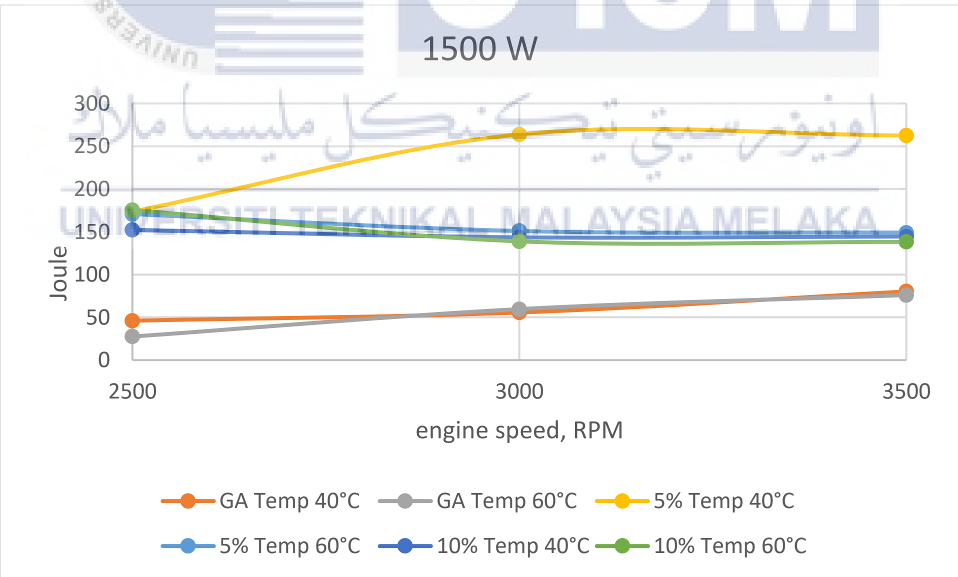
Graph for Work Nett 500 W

Work nett 1000 W



Graph for Work Nett 1000 W

Work nett 1500 W

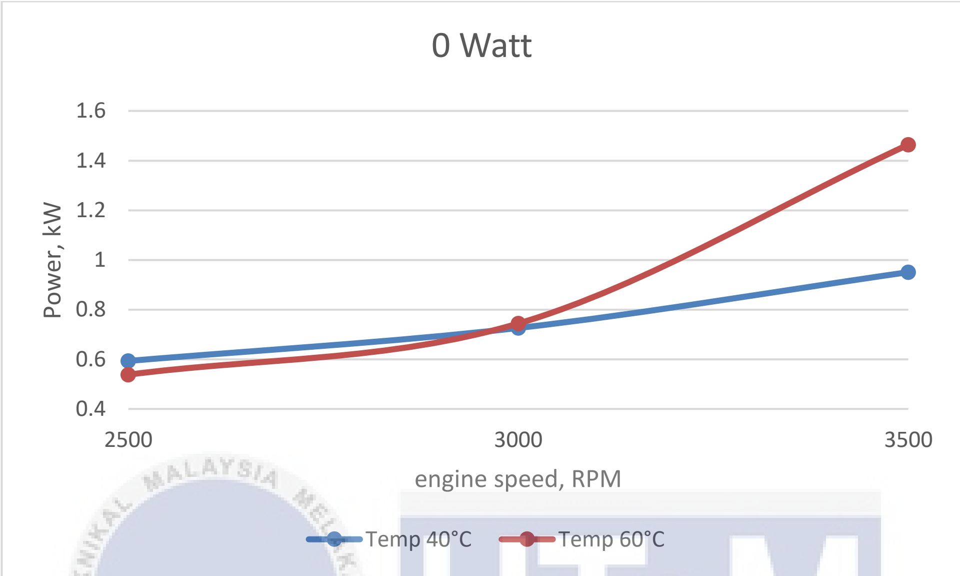


Graph for 1500 W

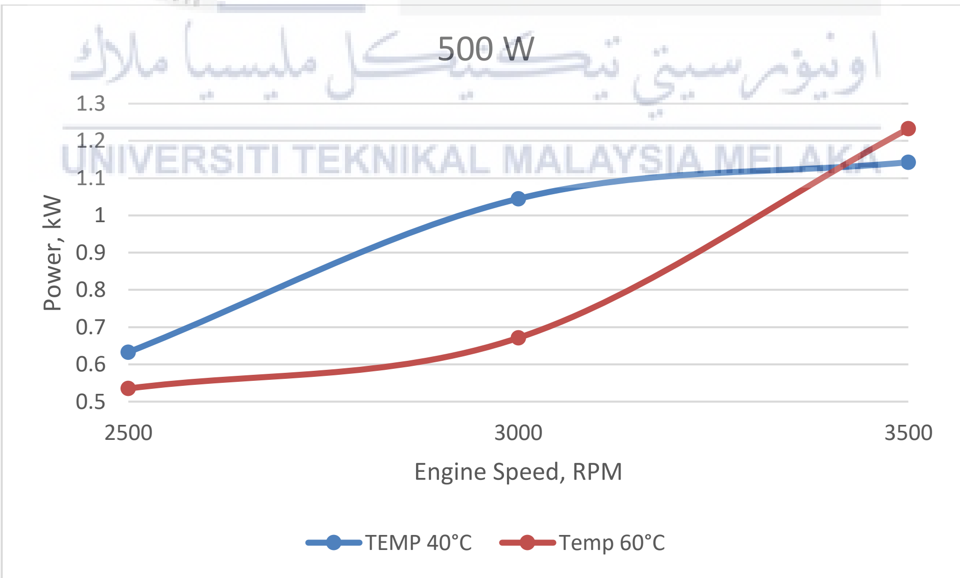
APPENDICES F

RESULT FOR POWER VS RPM

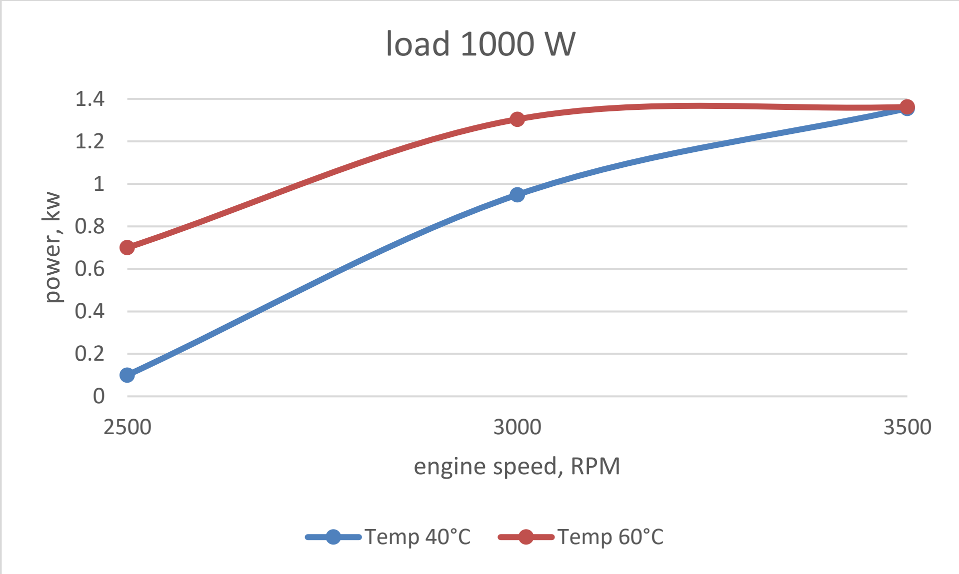
i. Gasoline alone



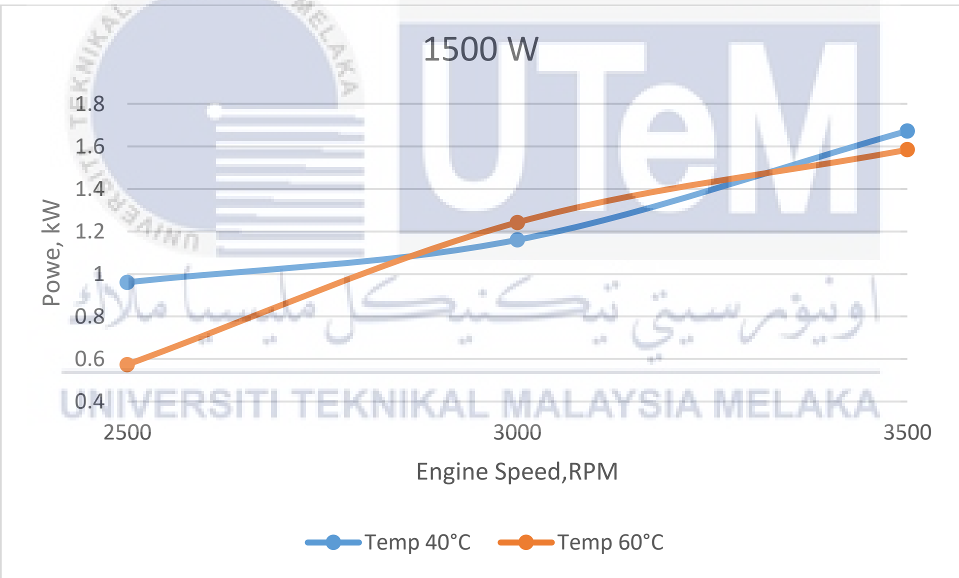
Graph for Zero Load



Graph for Load 500 W

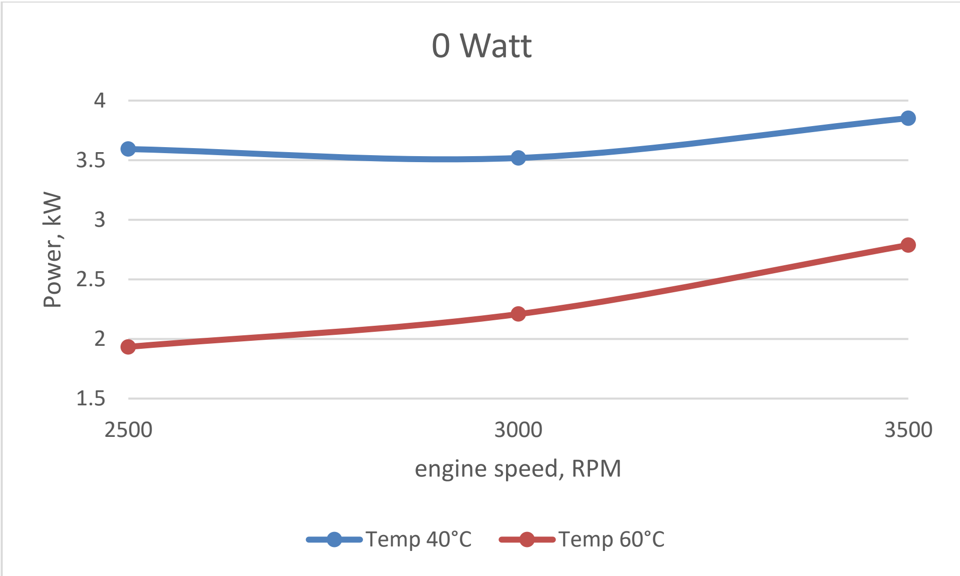


Graph for Load 1000 W

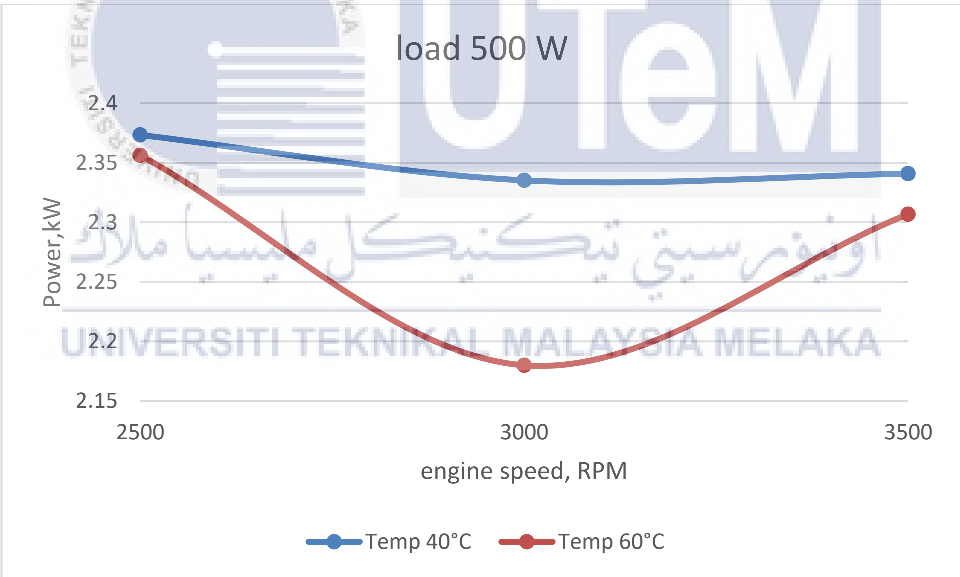


Graph 1.5 kW

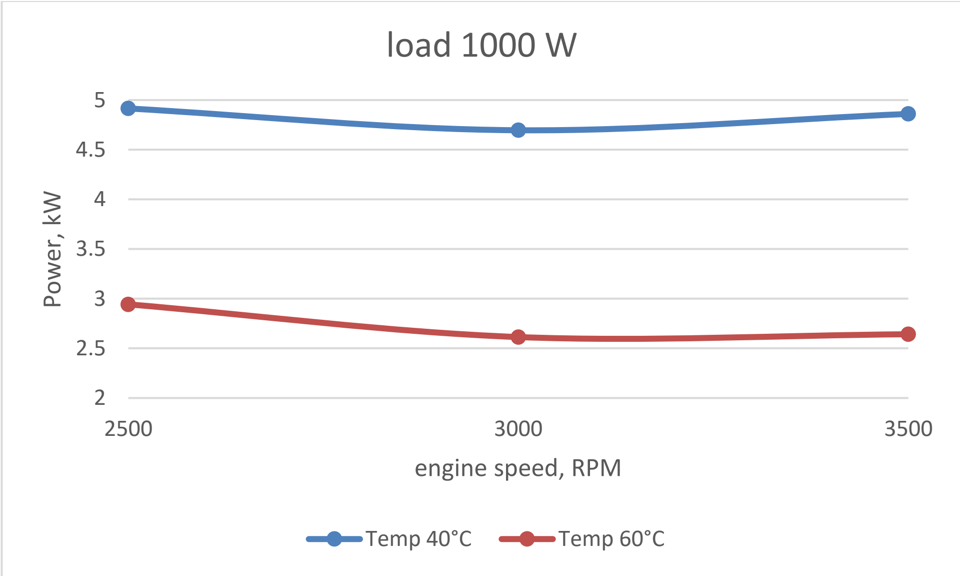
ii. 5% hydrogen peroxide



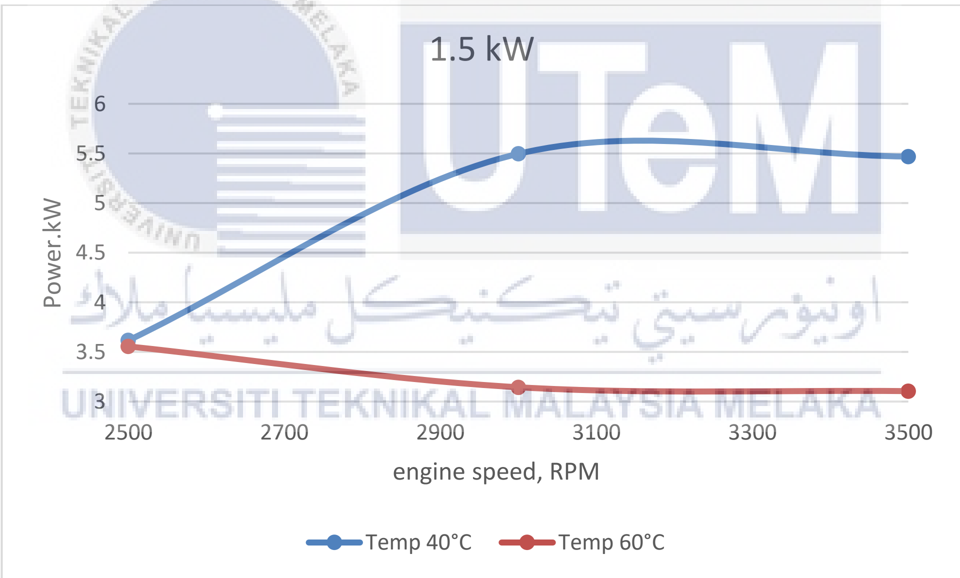
Graph 0 W



Graph 500 W

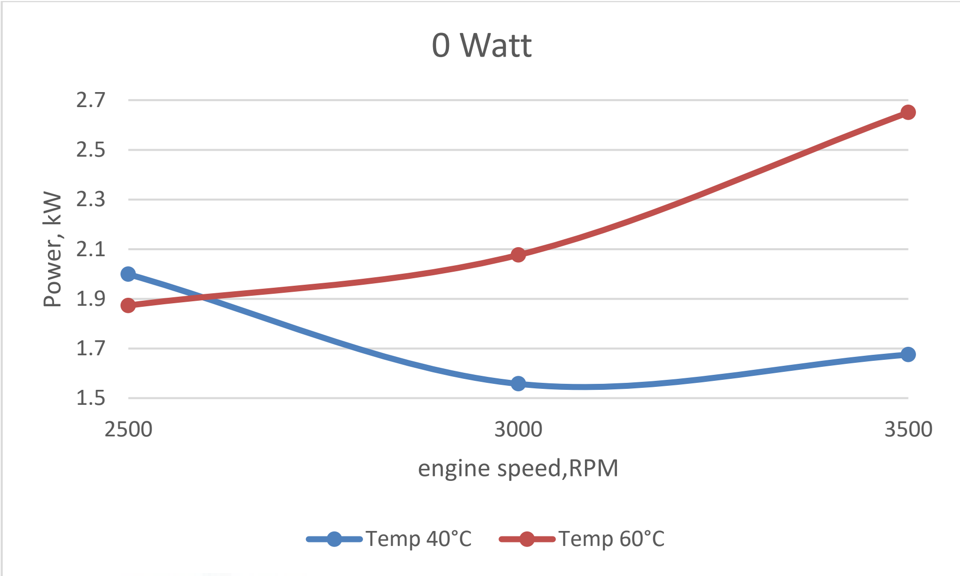


Graph Load 1000 W

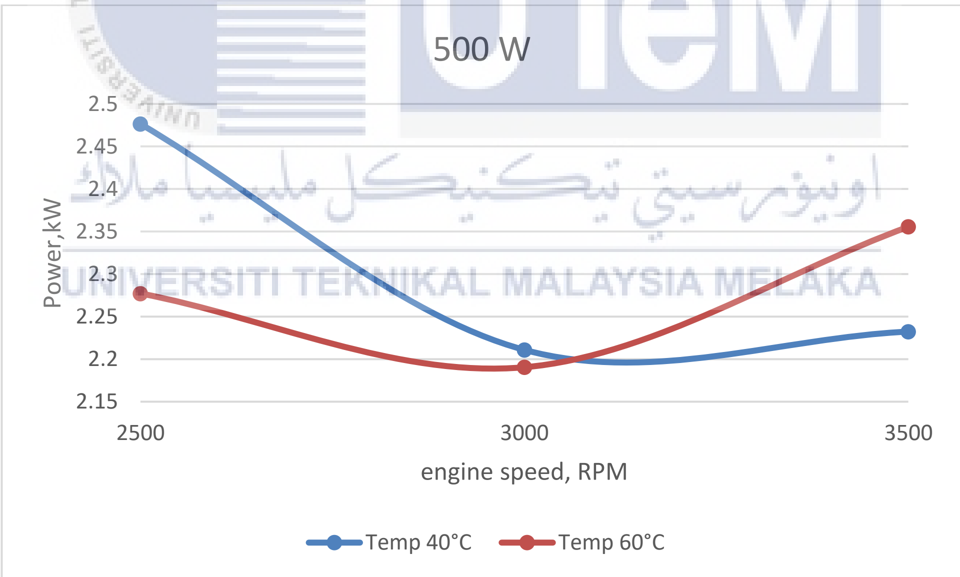


Graph for 1.5kW

iii. 10% hydrogen peroxide

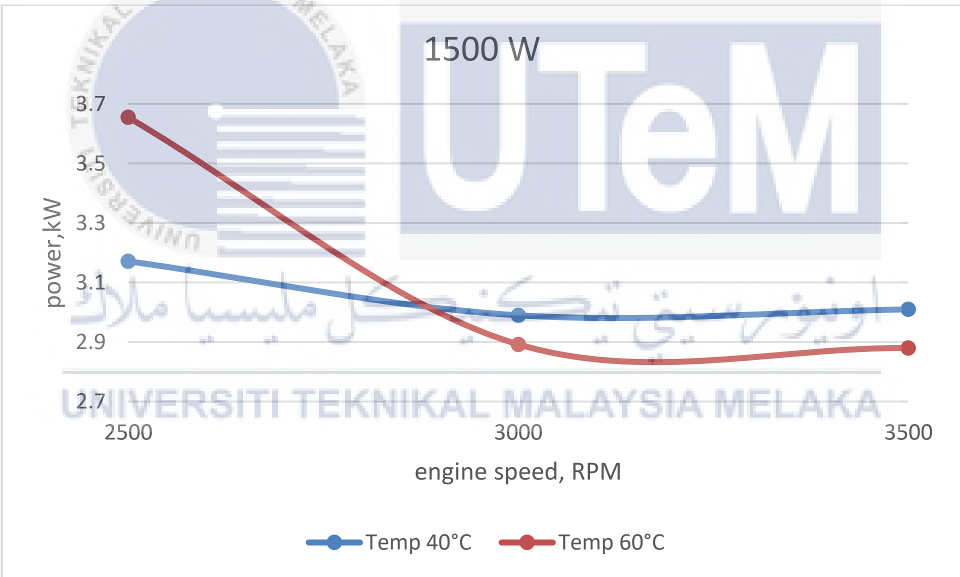


Graph for 0 W



Graph 500 W

Graph for 1000 W



Graph for 1500 W