EXPERIMENTAL INVESTIGATION ON THE EFFECT OF FUEL TEMPERATURE ON THE PERFORMANCE OF SPARK IGNITION ENGINE WITH HYDROGEN PEROXIDE-GASOLINE BLEND

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**This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Automotive)**

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Experimental Investigation On The Effect Of Fuel Temperature On The Performance Of Spark Ignition Engine With Hydrogen Peroxide-Gasoline Blend" is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

This thesis is dedicated to my mother, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my sister, who taught me that even the largest task could be accomplished if it is done one step at a time.

ABSTRACT

There are many experiments and research about additive that added to the gasoline in spark ignition in order to increase the performance of the engine in many aspects, such as hydrogen, LPG, ethanol and many more. Therefore, this project was carried out to study other additive, which is hydrogen peroxide (H_2O_2), one of the chemical that rarely use in research and with different fuel temperature to examine the optimum blend and fuel temperature for performance of the spark ignition engine. Then, the project experiment is running with 100% of gasoline and mix fuel blend by 5% and 10% of H_2O_2 with 45° Celsius and 60° Celsius of fuel temperature at generator engine with carburetor and by collecting the data using DEWESOFT software as to find crank angle and pressure in-cylinder. This experiment is focus to determine the properties of peak pressure, heat release rate, indicated thermal efficiency, fuel consumption, indicated specific fuel consumption, and gross indicated work at performance of the single cylinder engine. The experiment is running at FASA B, Vehicle Green Technology Laboratory. There are also including the Chemistry Laboratory at Technology Campus, which is to find all the chemical properties, which is Density and Energy Content of gasoline alone and fuel blend for 5% and 10% of H_2O_2.

ABSTRAK

Banyak eksperimen dan kajian mengenai bahan penambah yang digunakan pada minyak petrol di dalam enjin palam pencucuh untuk meningkatkan prestasi enjin dalam banyak aspek, seperti hidrogen, LPG, ethanol dan banyak lagi. Justeru itu, projek ini dijalankan bagi mempelajari bahan penambah yang lain, iaitu hidrogen peroksida ($H_2 0_2$), *salah satu bahan kimia yang sangat jarang digunakan dalam kajian dan dengan berlainan suhu minyak untuk mengkaji gabungan minyak dan suhu yang paling optimum untuk prestasi enjin palam pencucuh. Selepas itu, projek eksperimen ini dijalankan dengan 100% minyak petrol dan campuran minyak petrol bersama 5% dan 10%* $H_2 0_2$*.bersama suhu 45° Celsius dan 60° Celsius suhu minyak di generator enjin yang menggunakan carburetor dan mengumpul data menggunakan perisian DEWESOFT untuk mencari sudut engkol dan tekanan di dalam silinder. Eksperimen ini menfokuskan untuk mengenal pasti puncak tekanan, kadar pembebasan haba, kecekapan haba, kadar penggunaan minyak, kadar penggunan tentu, dan kadar kerja pada prestasi enjin palam pencucuh. Eksperimen ini dijalankan di FASA B, Makmal Kenderaan Teknologi Hijau. Selain itu, Makmal Kimia, Kampus Teknologi juga digunakan bagi mencari ketumpatan dan kandungan tenaga untuk 100% petrol dan campuran minyak 5% dan 10%* $H_2 0_2$.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Dr. Adnan Bin Roseli for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank a senior named Taufiq Jumadi and Lee for spending his time to guide me. They would share his knowledge in the internal combustion engine with me and guide me to do experiment. Also, I would like to thank laboratory assistant, En. Junaidi and Pn Rosni for his kindness in suggesting me the suitable time to use laboratory equipment for his action saved me a lot of time.

I would like to express my gratitude towards my members for their support and their kind co-operation and encouragement, which help me in completion of this project. Finally, I would like to most thank to my family for their support and give motivation for me.

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LIST OF ABBREVIATIONS

H_2O_2	Hydrogen Peroxide
BMEP	Brake Mean Effective Pressure
BP	Brake Power
IP	Indicator Power
MEP	Mean Effective Pressure
SFC	Specific Fuel Consumption
BSFC	Brake Specific Fuel Consumption
NO_X	Nitrogen Oxide
H_2	Hydrogen Gas
LPG	Liquefied Petroleum Gas
NGV	Natural Gas Vehicle
RON	Research Octane Number
BTDC	Before Top Dead Center
BDC	Bottom Dead Center
TDC	Top Dead Center
GA	Gasoline Alone
CASE 1	Gasoline with 5% of Hydrogen Peroxide
CASE 2	Gasoline with 10% of Hydrogen Peroxide
CA	Crank Angle
HRR	Heat Release Rate

LIST OF SYMBOL

ρ_a	=	Inlet air density
m_a	=	Steady-state flow of air into the engine
V_{disp}	=	Displacement volume
N	=	Engine speed
W_b	=	Brake power
$\dot{m}_f$	=	Rate of fuel flow to the engine
Δv	=	Different volume BDC to TDC

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The crisis of energy and the problem of environment issues that identified to the utilization of fossil fuels in the engine expand the competitive to the world. Furthermore, the expanding vitality request, exhausting oil saves and ecological contamination issues connected with the utilization of fossil fuels have started restored enthusiasm to discover other clean fuels.(Pan et al, 2015). The majority of energy requirements in transportation are still addressed by fossil fuels. The fast consumption of fossil fills and the consistent increments of oil costs are convincing engine manufactures makes to find another option fuel. Besides, it is an unavoidable need to create fuel because of the harm to the earth and to people brought about by the utilization of oil. (Sandalci et al, 2014).

The non-renewable nature and restricted assets of petroleum powers has turned into a matter of incredible concern. The monetary and political variables are significantly connected with their appropriation. The ignition of these energizes in SI engine causes pollution. Every one of these perspectives has attracted the thought to preserve and extend the oil assets by method for option fuel research

Internal Combustion Engine is most strength utilized engine as a part of car field to change over the chemical energy into the valuable mechanical movement to move the vehicle. Considerable measures of option fuels have been all through to supplant the utilization of current essential energizes that are gas and diesel in other to improve the output performance of the engine. There are some researchers towards other sources and not only dependable on fossil fuels (Yunus et al, 2015).

Such as, NGV, Hybrid System, biodiesel (Shehata, 2013), LPG (Sulaiman et al, 2013), and Electric Car like Tesla. However, there are researchers that still dependable on the fossil fuels but in order to reduce the vitality of using one sources there are use addition to the fuel as their alternative. Researchers are struggling to find the alternative fuel and additive to the diesel or gasoline engine towards the optimum performance and lower emission. Some researcher tended towards, addition of ethanol in gasoline (Schifter et al,2011), addition hydrogen blend with gasoline (Shivaprasad et al, 2014), and addition hydrogen peroxide blend with diesel (Khan at al, 2013).

Investigation had been made on various type of fuel in recent years form improving the quality and performance of gasoline fuel. Significant attention has been given to option fuel with predominant physiochemical properties for protect the environment and improving the fuel effectiveness viewpoint, especially the alcohol based fuels. One of the research is more consideration has been given to ethanol due to its outstanding properties. Mixes of methanol and ethanol in gasoline utilized as a part of fuel, with an emphasis on mixes containing 85% alcohol (M85 and E85) were assessed as option light-duty vehicle fills (Khan et al., 2013).

Besides that, there are some researchers tests fuel using hydrogen peroxide that also enhances the performance of the engine. Hydrogen peroxide has the criteria of highly reactive and storable fluid oxidizer; this specialty puts hydrogen peroxide forward in alternative fuel. (Sabourin et al, 2008). In previous research, H_2O_2 has been used as additive in other fuels like LPG. H_2O_2, is reported that will be the renewable fuel and will be label as low emission high quality of alternative fuel when it is blend with LPG. (Muhammad Saad Khan et al, 2009).

H_2O_2 also has been used for additive in diesel engine and according to ASTM Standards fuel tests they reported that hydrogen peroxide are fit to improve the fuel diesel properties(Khan et al., 2013). They are also found the advantages of hydrogen peroxide on methane premixed flame, H2O2 were considered as easy ignited fuel and effective for improvement flame temperature. In addition, H_2O_2 is responsive stimulator or an oxidizer compound pathways and to further upgrade substance radicals.(Chen et al, 2011).

1.2 PROBLEM STATEMENTS

Hydrogen peroxide have been used with previous research with gasoline or diesel because of it is in the weak acid category along with much stronger oxidizing properties. Hydrogen peroxide and water charge supplies extra oxygen to guarantee complete combustion of the hydrocarbon fuel and at the same time the high vitality content present in the hydrogen peroxide serves to support the power yield of the engine. As the development of hydrogen is difficult to achieve that brings hydrogen economy is also difficult to attain. Hydrogen peroxide is move beyond as the alternative fuel that can give competitive to the hydrogen gas.

However, there are some issues that we had to face through this experiment. Some of the research like there use the 30% purity of hydrogen peroxide in their research. As we know this situation happen because of the market price of H_20_2 is expensive. This will be lead to the limitation in this research where the pure 100% of H_20_2 will not be tested. In this experiment, we will use almost 30% of the hydrogen peroxide and blend with the gasoline.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To study the optimum ratio of gasoline blended with hydrogen peroxide with respect to the fuel temperature.
2. To investigate the effect of fuel temperature on petrol engine with hydrogen peroxide-gasoline blend.
3. To study the optimum fuel temperature for better performance.

1.4 SCOPE OF PROJECT

The scope of this project will be covering the performance of the engine. The parameters that will involve in this project are peak pressure, heat release rate, indicated thermal efficiency indicated work, and indicated specific fuel consumption. All these results will show in several test fuel temperatures from 50° to 60° of fuel blend. The experiment will be run with the 4-stroke single cylinder engine and give the different loads to look the different in the result. In this experiment, gasoline is use from RON 95 Caltex and 50% purity hydrogen peroxide will use. There will be various ratios of fuel blend will be made as to look the different of parameters result. In addition, this experiment is use to get the optimum performance of engine result from the several ratios of fuel blend with the respect of the fuel temperature.

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical Background Engine Performance

There are a few of parameter that have to be considered in the experiment that involve with the performance of engine. Mostly, all the data is collect from the Data Acquisition System (DAS) that adjusted from Dyno Machine. These include the mechanical output parameters of work, torque and power, the input requirements of air, fuel and combustion, efficiencies and emission measurement of engine exhaust (Heywood, 1988; Pulkrabek, 2004)

2.1.1 Brake Power

Outputs of the engine are measured by developing the power into a brake dynamometer in the output shaft. Dynamometers measure the speed and the torque of the shaft. Power is defined as the rate of work of the engine. The brake power is expressed as Eq. (2.4) (Pulkrabek, 2004)

$$y = mx + c \tag{2.1}$$

$$\dot{W} = 2\pi n\tau \tag{2.2}$$

$$\dot{W} = (\frac{1}{2n})(mep)A_p\bar{U}_p \tag{2.3}$$

$$\dot{W} = (mep)A_p\bar{U}_p/4 \tag{2.4}$$

Where N is the shaft speed in rev/s, T is the torque in Nm

2.1.2 Mechanical Efficiency

This tells us how much of the indicated power is converted into brake power. The difference between them us due to frictional between the moving parts and the energy taken to run the auxiliary equipment as the fuel pump, water pump, oil pump and alternator.

$$H_{mech} = \text{B.P./I.P} \tag{2.5}$$

2.1.3 Brake Specific Fuel Consumption

Brake specific fuel consumption (BSFC) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft, power. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. It is the rate of fuel consumption divided by the power produced.

$$bsfc = \dot{m}_f / \dot{W}_b \tag{2.6}$$

Where $\dot{m}_f$= rate of fuel flow into engine

The literal meaning of BSFC is how much fuel is consumed in one hour to produce one kilowatt brake power. Brake Specific Fuel Consumption as a function of engine speed. Fuel Consumption decreases as engine speed increases due to shorter time for heat loss during each cycle. At higher engine speeds fuel consumption again increases because of high friction losses. As compression ratio is increased fuel consumption decreases due to greater thermal efficiency.

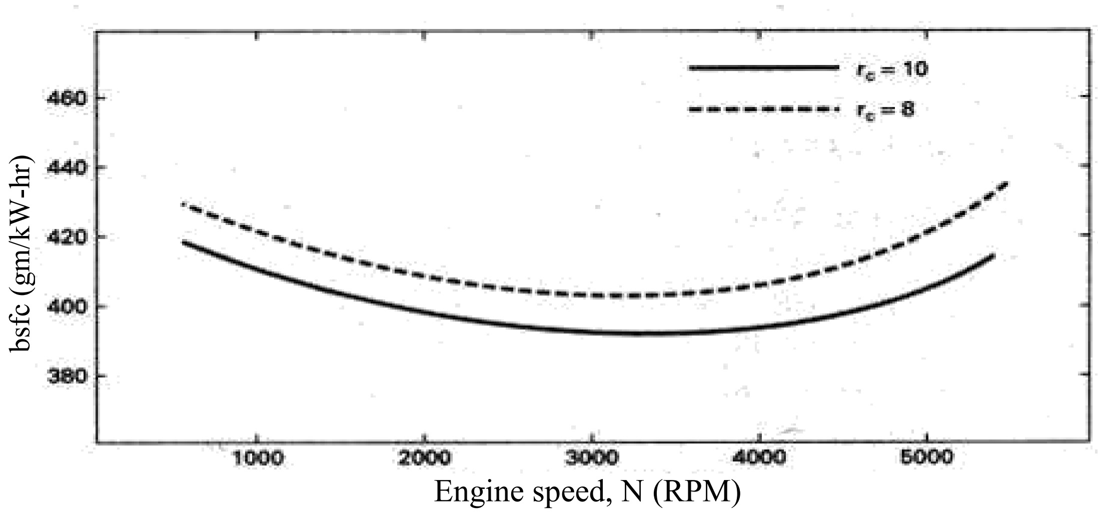


Figure 2.1: BSFC versus Engine Speed due to different of compression ratio (Pulkrabek, 2004)

2.1.4 Mean Effective Pressure

The average pressure exerted on the piston during each power stroke, and is determined from a formula. These are two kinds of MEP, Indicated Mean Effective Pressure which is developed in the cylinder and can be measured, and brake mean effective pressure (BMEP) which is compute from the brake horsepower (BHP) delivered by the engine.

$$BMEP = w_b / \Delta v \tag{2.7}$$

$$BMEP = 2\pi n \tau \; / \; V_d \tag{2.8}$$

Where $\Delta v = v_{bdc} - v_{tdc}$

Mean effective pressure is a good parameter to compare engine for design or output because it is independent of engine size or speed. If torque is used engine compression, a larger engine will always look better. If power is used as the comparison, speed becomes very important.

2.1.5 Thermal Efficiency

When transforming thermal energy into mechanical energy, the thermal efficiency of a heat engine is the percentage of heat energy that is transformed into work.

Thermal efficiency is defined as:

$$n_{th} = \frac{W_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} \tag{2.9}$$

Where, n represent the efficiency, W_{out} , represent work done, suffix Q_{in}, stands for Heat Input, Q_{out}, stands for Heat Output.

2.1.6 Fuel Efficiency

Fuel efficiency is a form of thermal efficiency, meaning the efficiency of a process that converts chemical potential energy contained in a carrier fuel into kinetic energy or work. Overall fuel efficiency may vary per device, which in turn may vary per application. In the context of transport, "fuel efficiency" more commonly refers to the energy efficiency of a particular vehicle model, where its total output (range, or "mileage") (HPF, 2005). The emissions of an engine are determined by the operating conditions of the engine. The main emissions of an engine are nitrogen oxides, carbon oxides, and unburned hydrocarbons.

2.1.7 Volumetric Efficiency

This is used as an overall measure of the effectiveness of a four-stroke cycle engine and its intake and exhaust system as an air-pumping device. It is calculated as:

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_{disp} N/2} \quad (3.0)$$

Where:

ρ_a = the inlet air density

$\dot{m}_a$ = the steady-state flow of air into the engine

V_{disp} = displacement volume

N = engine speed

2.1.8 Engine Brake Torque

This is a good indicator of an engine's ability to do work. It is defined as the force acting at a moment distance and has units of N-m. Torque (τ) is related to work (Pulkrabek, 2004)

$$2\pi\tau = W_b = (bmep)V_d/n \quad (3.1)$$

Where:

W_b = brake work of one revolution

V_d =displacement volume

n = number of revolution per cycle

2.1.9 Indicated Thermal Efficiency

Brake thermal efficiency, (η_{th}) is the ratio of energy in the indicated power (ip) to the input fuel energy in appropriate units (Ganesan, 2003). Solving for thermal efficiency:

$$\eta_{th} = \frac{ip}{mass\ of\ fuels\ x\ calorific\ value\ of\ fuel} \qquad (3.2)$$

2.2 Characteristics of Hydrogen Peroxide

Hydrogen peroxide is a pale blue liquid, slightly more viscous than water, and appears in colourless in dilute solution. It is weak acid with strong oxidizing properties and powerful bleaching agent. H_2O_2 are widely as antiseptic, oxidizer, disinfection, and rocketry propellant. The oxidizing is so strong that it is a highly reactive oxygen species (Khan et al, 2013). Dilute hydrogen peroxide solutions (3-30%) are used for bleaching (pulp, paper, straw, leather, hair) and to treat wounds. At higher concentration (70-98%) of hydrogen peroxide is used as a monopropellant in rocket engine. It is also be used as an oxidant with organic compounds, such as kerosene, in a biopropellant rocket engine.

In context of combustion from the hydrogen peroxide, it is reactive stimulator or an oxidizer chemical pathways and to further enhance chemical radicals. Besides, H_2O_2 is considered as an easy-ignited fuel and helpful for increasing flame temperature (Chen et al, 2011). In addition, hydrogen peroxide is highly reactive and storable energetiv liquid oxidizer that has been applied to many combustion application (Sabourin et al, 2008). Moreover, hydrogen peroxide and water charge supplies additional oxygen to insure complete combustion of hydrocarbon fuel and simultaneously the high energy content present to boost the power output of the engine. The hydrogen peroxide in the charge is decomposed so as to produce additional oxygen which enables more complete combusiton of the mixture fuel (James R.Dissmore, 1981).

In previous research there are many experiment regarding to the mixing fuel involving hydrogen or hydrogen peroxide. There are different infrastructure between hydrogen and hydrogen peroxide, hydrogen gas is very hard to achive, similary acquiring a hydrogen economy also difficult to attain. However, H_2O_2 is viable, alternatively energy storage medium, competing with hydrogen gas. It is also energy-dense fuel that burns as cleanly as H_2 , but requires no oxidizer as it is included inside the fuel (Muhammad Saad Khan et al, 2009).

In terms of emission that produce by hydrogen peroxide is, charge produces a washing effect on the engine combusiton chamber which enables combustion to proceed at a lowered temperature which results in lowered NO_x content of the exhause gas. Besides that, The water present by reason of the aqueous hydrogen peroxide solution turns to steam additionally supply an increased vapor pressure within the combustion chamber to increase the power or torque therof and additionaly in effect wash down the cylinder walls so as to produced a coolong effect that somewhat reduces the operating temperature within the chamber so as to minimize the amount of NO_x produced (James R.Dissmore, 1981).

Actually, hydrogen peroxide it does not burn it decomposes, with a release of tremendous energy, close to the energy per mole of H_2. It is like water, so it does not need a pressure vessel to contain it. Over about 80% H_2O_2, where H_2O_2 is the impurity, it is explosive and extreme mechanical shock or heat can set it off. It is "burned" in jets and other devices by catalytic decomposition. They can get 3500-psi steam out of it. Helicopters have flown with rotors containing H_2O_2 jets on their blade tips - no tail rotors are needed and no central engine. Very affordable and simple fuel is possible with peroxide(Muhammad Saad Khan et al., 2009).

These are properties of hydrogen peroxide in table 2.1:

Table 2.1 Properties of Hydrogen Peroxide

Appearance	Colourless Liquid
Density	1110 kg/m^3
Boiling Point	226^{c}C
Freezing Point	-27^{O}C
Viscosity	1.81cp (0.004m3)
Specific Gravity	1.11

2.3 Effect of Hydrogen Peroxide Blend with Fuel

In previous research there are researcher are throughout injecting hydrogen peroxide into the diesel engine. Diesel engine has higher emission and exhaust gas temperature and the experiment are been made by conducted at a different load, 10%, 20%, 30%, 40%. The engine speed is maintained constant at 1500 rpm. After every load the engine is allowed to attain steady state for duration of about 15 minutes. The in jection pressure is kept constant at 150 bar with an injection timing 10° BTDC and 15° BTDC. The results on this experiment stated that The brake thermal efficiency of the engine is increase due to th presence of hydrogen peroxide in fuel which start decomposing and releasing a large amount of oxygen. The oxygen are also helps to reduce the ignition lag as well as assisting complete combustion. There are about 15.48% of efficiency is observed at 50% of load when the engine used 5% of hydrogen peroxide (K.S & Madhu, 2012).

Besides, previous researcher is blend hydrogen peroxide with the LPG. LPG is burnt in the conventional diesel engine there is a difficulty in self-ignition because of its lower cetane number. If LPG is to be used as an alternative to diesel, the cetane rating needs to be improved with additives or other positive means of initiating combustion. Adding a cetane number improver to LPG is one method to improve its cetane number and its ignition quality. One of additive that suggested is hydrogen peroxide that can improve the ignition property. Hydrogen peroxide can be run automobiles and it is worked as an alternative or replacement of hydrogen gas. The experiment had been set up with Material includes the H_2O_2 with the concentration of at least 50% from MERCK Company from Germany. LPG contains 30% butane and 70% of propane. They claimed the result could be hydrogen peroxide could decrease the ignition temperature and burn off temperature of LPG evidently for a wide concentration range. The initial and final temperature may decreases continuous with the increase of hydrogen peroxide. For one volume percentage LPG combustion, the initial and final temperature could be decreases to 40°C and 37°C when the H_2O_2/LPG is equal to 0.05. The initial and final temperature could be decreases about 130°C and 140°C when the H_2O_2/LPG ratios are 2.5.

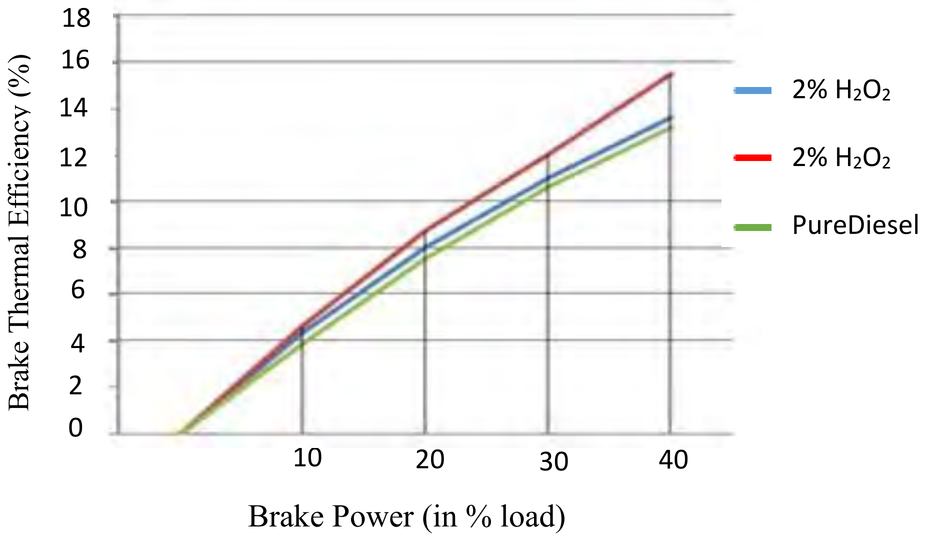


Figure 2.2: Brake thermal efficiency versus brake power for different of H_2O_2
(K.S & Madhu, 2012)

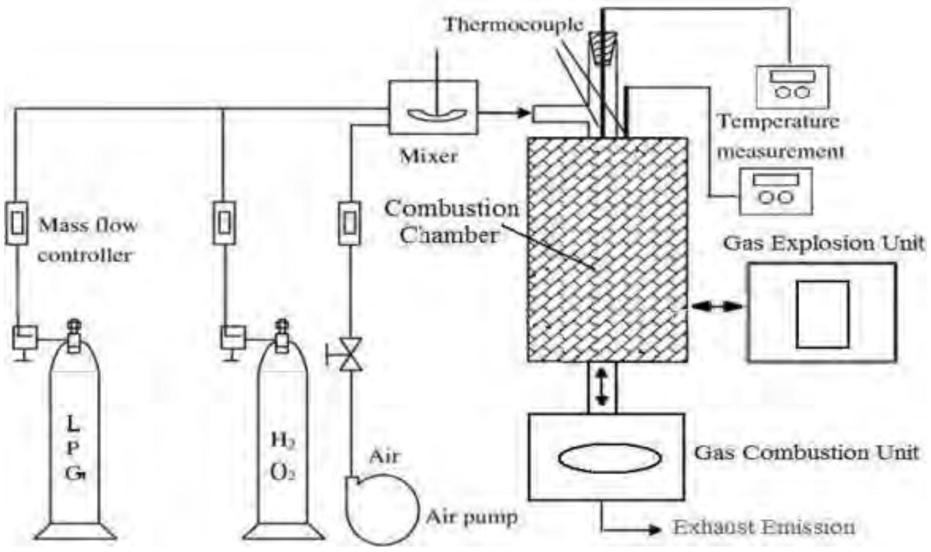


Figure 2.3: Schematic flow diagram LPG/ H_2O_2 combustion system
(K.S & Madhu, 2012)

Previous research in blending hydrogen peroxide is blend with the diesel to further looks in characterization on that blend fuel. In this research method, diesel fuel was acquired from PETRONAS fuel station while the commercial hydrogen peroxide (30%) was gotten from the Chemical Company of Malaysia Berhad (CCM). All tests are repeated three circumstances for consistency and the average reading was used. The emulsifier was arranged in a matter of seconds preceding the blending between the reference diesel and the H_2O_2 to shape the diesel mix fuel. In addition, this research using of American Society for Testing and Materials (ASTM) for the fuel testing according to the table 2.2.

Table 2.2 ASTM for the fuel testing

S. No	Property	ASTM Method
1	Density	ASTM D-1298
2	Viscosity	ASTM D-445
3	Flash Point	ASTM D-93
4	Ph	ASTM D-4539

Density is a key fuel property, which specifically influences the engine performance attributes. Numerous performances attributes, for example, cetane number and warming worth, are identified with the density of fuel. The density of the fuel mixes showed expanding value with the expanded in hydrogen peroxide piece in the blend because of higher density of H_2O_2, having an estimation of 1.130 g/cm3. However, the thickness of the fuel mixes does not build much when the hydrogen peroxide surpassed more than 15%. Because of the lessening in the energy content after the addition of the hydrogen peroxide, more fuel injection into the burning chamber is required. Then, such weakness is compensated back through the higher cetane number of the fuel mixes with the addition of hydrogen peroxide. Higher cetane number of the fuel mixes will prompt to cleaner combustion thus bringing down the discharge of carbon monoxide from the engine (Khan et al, 2013).

There are research on the performance and emission of a diesel engine at B20 blend with addition of hydrogen peroxide. In this study, use of B20 as the working medium that 20% Bio-diesel and 80% diesel as the optimum ratio and looking on the performance and emission with different value of injecting hydrogen peroxide. The working method are used in this research bio diesel is extracted from hinge oil is taken as test sample and is mixed with standard fossil derived fuel in ratios of 20% Bio-diesel and 80% fossil derived diesel. Then, this mixture which we commonly term as B20, H_2O_2 is added in the ratios of 2, 5 and 10% and the characteristics of the engine are plotted. In this research are to studied the fuel consumption, brake power generated, exhaust gas temperature, brake thermal efficiency, and the emission from the experiment. The result of this research are according to Figure 2.4 and Figure 2.5 (B, 2014).

The result shows that in figure the brake thermal efficiency is higher when 0% of H_2O_2 at low loads, but decreases as the loads go higher. Then, the result of brake thermal efficiency is lower for 2, 5 and 10% H_2O_2 at low loads but starts to take effect and goes higher once the load is increased, where 10% H_2O_2 exhibits the highest thermal efficiency at maximum load. For the SFC result, Specific fuel consumption has a peak at low loads and tends to constantly decrease for higher load levels. The SFC being the highest for 2% H_2O_2 and is higher than 0% H_2O_2 for all loads. This is due to the extra heat absorbed by H_2O formed during the decomposition of H_2O_2 in the combustion chamber.

In the result of load against brake power, there were no significant improvement in the brake power over different levels of H_2O_2 and is mostly dependent on load exhibiting a linear increase over increase of load. Then, the effects on exhaust gas temperature do not show any promise of significant decrease, but does show decrease at constant rate of increase in H_2O_2 ratio.

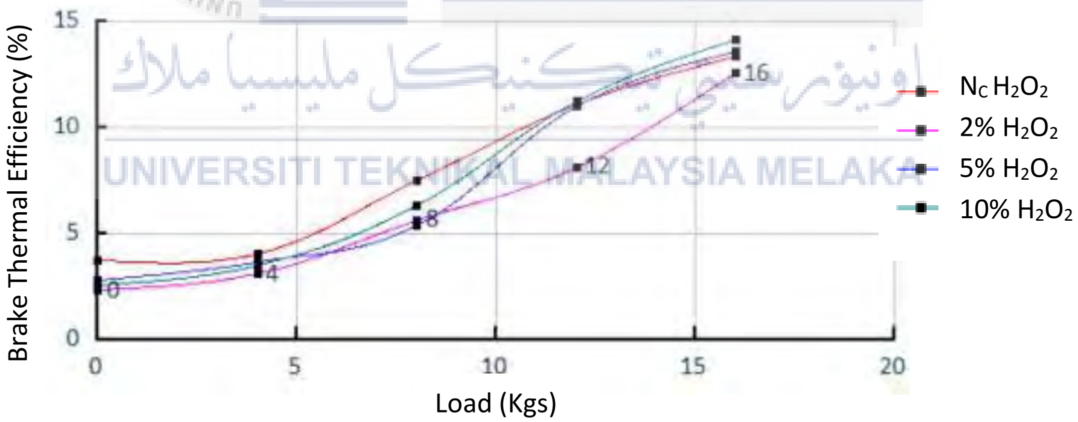


Figure 2.4: Brake thermal efficiency versus load versus with various percentage of H_2O_2 (B, 2014)

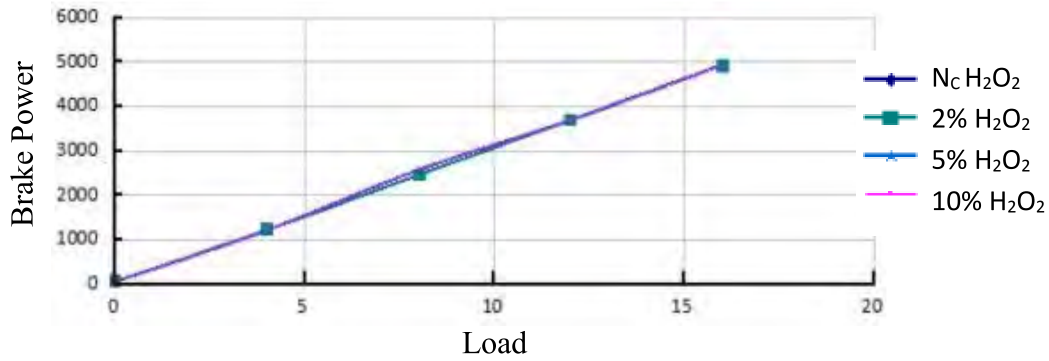


Figure 2.5: Brake power versus load with various percentage of H_2O_2 (B, 2014)

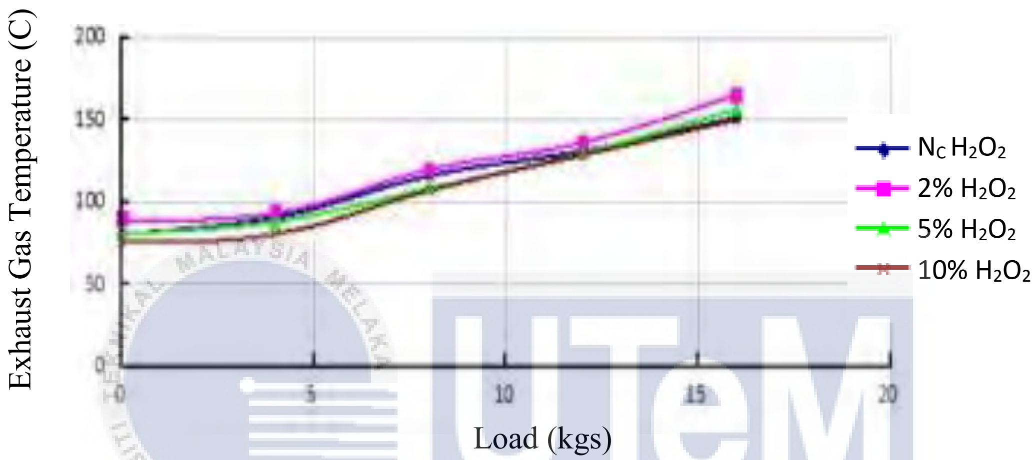


Figure 2.6: Exhaust gas temperature versus load with various percentage of H_2O_2 (B, 2014)

2.4 Effect of Different Fuel Temperature on Blend Fuel Experiment

Previous experiment there is study about the influence of fuel temperature on diesel engine performance operating with biodiesel blend. This paper shows the simulating that carried by the diesel engine that conducted by full load condition where the temperature given are from 300 to 500 K. In this simulation, the development of a four cylinder, four stroke direct-injection (DI) diesel engine in one dimensional simulation. The condition of environment pressure is adjusted to the (1bar) and the environment temperature is at standard 298 K. The paper are to measure the performance engine include volumetric efficiency, engine brake torque, brake power, brake mean effective pressure, and brake specific fuel consumption. In this study the method show that, using the added 5% of blend fuel between diesel and biodiesel the temperatures are starting from 300 K reaching the maximum 500 K, the tests were conducted by varying speed from 1000 rpm to 4000 rpm. Higher fuel temperatures to tend to produce higher injection pressure. The highest injection pressure causes the lowest ignition delay, which results in the increase of brake power. A shorter ignition delay causes the early start of combustion. It is also, effects on energy level that as the fuel temperature is decrease the energy level also decreased. The brake thermal efficiencies at a temperature of 300 K are lower than at a temperature of 500 K. The most reduced temperature created the energy content to diminish, bringing about the least brake thermal efficiency. The efficiency is enhanced when the fuel temperature is expanded.

According to the Figure 2.7 and Figure 2.8, that shows the engine performance to the different of fuel temperatures.

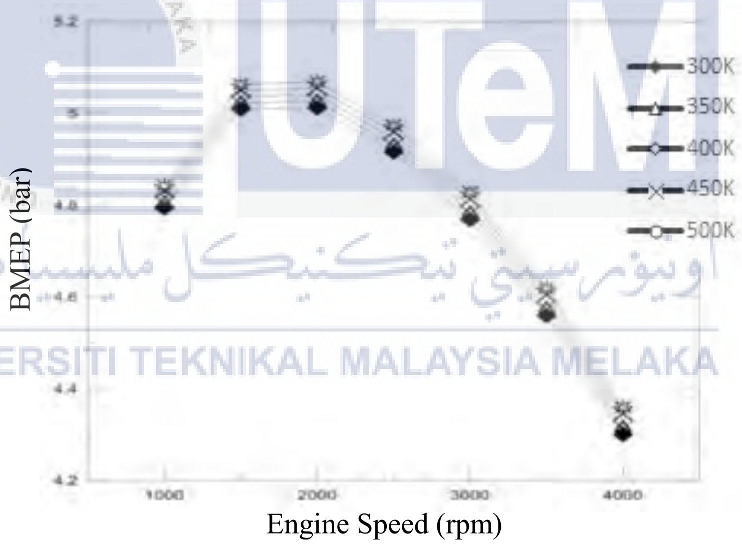


Figure 2.7: BMEP versus engine speed with various percentage of temperature (Rahim; et al., 2012)

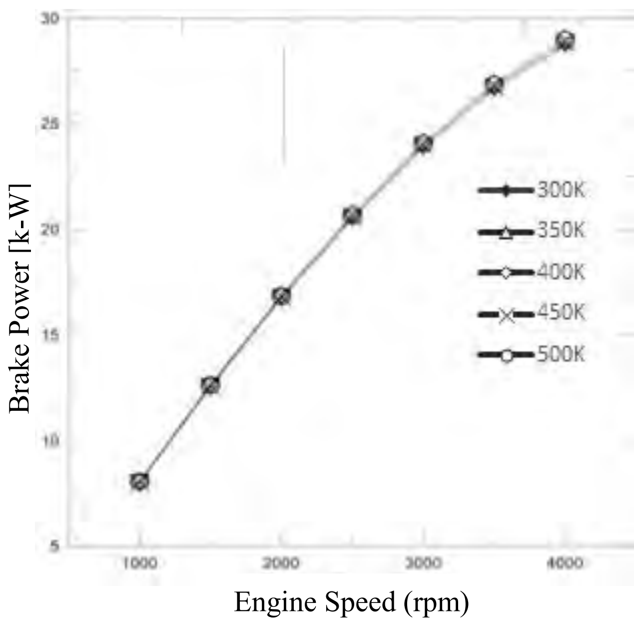


Figure 2.8: Brake power versus engine speed with various percentage of temperature (Rahim; et al., 2012)

The conclusion from this outcome it results that the most elevated fuel temperature causes the most injection pressure, bringing about a shorter ignition delay. In addition, the shorter ignition attributed to the early start of burning, prompting to a higher in-cylinder pressure. At that point, the expansion of fuel temperature speaks to higher energy content, bringing about lower BSFC, as is clearly desired (Rahim et al, 2012).

There is one article that studied about effect on fuel temperature on diesel engine performance and emission using cotton seed based bio-diesel ad additive Ac2010a, highlighted there are referring to the effect of fuel temperature that may give the different to the performance and emission to the engine. The inlet of the temperature is setting to the upper limit for the tested is 80^{o}C. In this study, engine performance that shows in the result is brake thermal efficiency, brake specific fuel consumption according to different loads, and the emission are been used 12% of additive with different temperature to further look on hydrocarbon, carbon dioxide and nitrogen oxide. These are the results according to the different temperature and percentage of additive in Figure 2.9 and Figure 2.10.

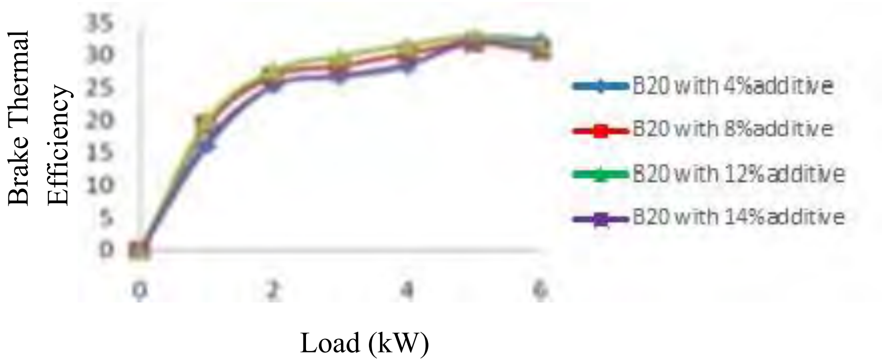


Figure 2.9: Effect of percentage additive on brake thermal efficiency with load (Kanna et al., 2014)

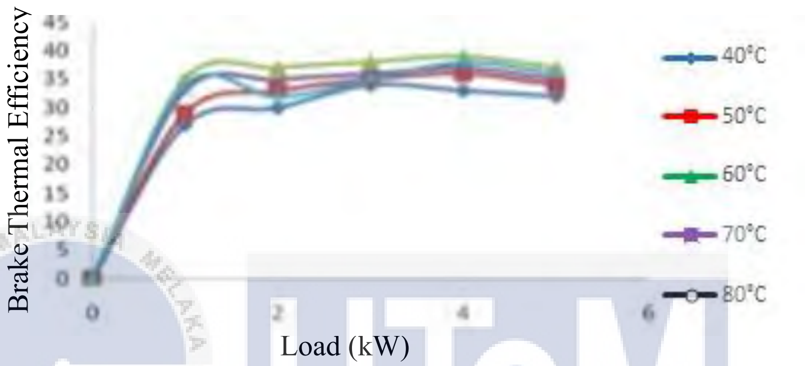


Figure 2.10: Effect of 12% additive on brake thermal efficiency with load at various temperatures (Kanna et al., 2014)

conclusion in this research study, it prove that warming of the cotton seed bio-diesel with added substance before infusion into the engine's ignition chamber brings about a diminishment in viscosity, prompting to better atomization and enhanced execution and decrease emission. Uniform or better ignition is happened because of preheating of inlet fuel, which brings about lower engine noise (Kanna et al,2014).

2.5 Research in Gasoline Engine with Other Additive

Besides focusing on gasoline to the hydrogen peroxide, this research is tended to look the behaviour of gasoline to the other additive that may be able to enhance the performance of the engine. There are many researches that using the hydrogen as the additive to the diesel or gasoline engine. One of the researchers are made the experiment to investigate the performance and emission of the gasoline engine to the effect of hydrogen addition. The tests were done at motor rates of 2000 to 4000RPM with an addition of 500RPM. Hydrogen energy division on volume premise of 5%, 10%, 15%, 20% and 25% was balanced with the assistance of controller. The present examination is gone for investigating the performance and emission attributes of hydrogen enriched high speed SI engine with ECU controlled MPI framework.

From this result, the additive of the hydrogen in the gasoline engine can be obtained that the expansion of hydrogen helps in enhancing bmep. The greatest bmep acquired at 20% mix of hydrogen for an engine working at 3000RPM speed. Besides, the addition of hydrogen is viable on enhancing engine brake thermal efficiency. An expansion of brake thermal efficiency was seen until a hydrogen division of 20%. Past this, the brake thermal efficiency is declined because of decrease in air amount (Shivaprasad et al, 2014).

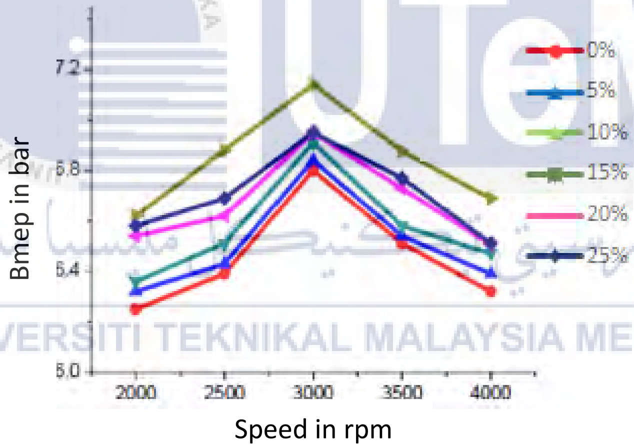


Figure 2.11: Variation of bmep with speed for various hydrogen volume fractions (Shivaprasad et al., 2014)

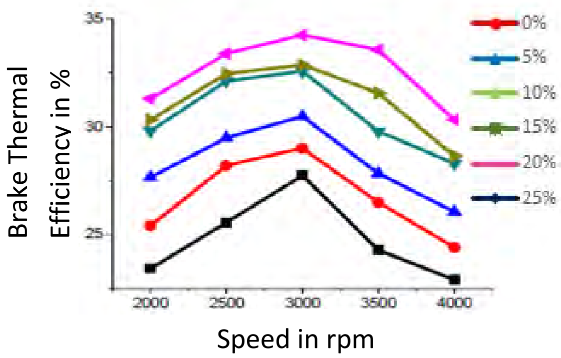


Figure 2.12: Variation of brake thermal efficiency with speed for various hydrogen volume fractions (Shivaprasad et al., 2014)

CHAPTER 3

METHODOLOGY

3.1 Equipment

In this section, all the equipments that have been used during the experiment such as generator engine, magnetic stirrer, bomb calorimeter, data acquisition system will be elaborated. This section also discusses on how to experiments were carried out.

3.1.1 Generator GX420 Gasoline Engine

In this experiment, the test is run by using generator GX 420, 6.8hp, with 4 stroke gasoline engine. The specification of the engine is shown in Table 3.1 and its respective figure is shown in Figure 3.1.

Table 3.1 Specification of generator GX 420

Engine Model	GX 420
Engine type	6.8hp, Air cooled
Number of cylinder	One
Spraying pressure	20/35 bar
Fuel tank capacity, litre	30
Weight, kg	85
Stroke to bore	90mm/66mm
Maximum power, kW	3.3 @ 3600rpm

Figure 3.1: GX420 Generator Single Cylinder

This generator has been through some modification for reaching the objective to find the crank angle and cylinder pressure for this generator. The generator have install with cylinder pressure sensor, name as PCB Piezotronics like in Figure 3.2 and had been placed through head of the engine like in the Figure 3.3. Then, to identify the crank angle of the shaft in the generator the crank angle sensor have installed like in Figure 3.4.

Figure 3.2: PCB Piezotronics

Figure 3.3: Place of cylinder pressure sensor

Figure 3.4: Place of crank angle

3.1.2 Generator Load

Load is applied for the generator is using bulb 500W, 1kW, and 2kW. The load is checked by using voltmeter to ensure the exact amount of load had been applied from the generator. In Figure 3.5, shows on how the load is install in that generator and some modification to ensure the power meter is continuously check the voltage, ammeter, and current that produce by bulb that installed.

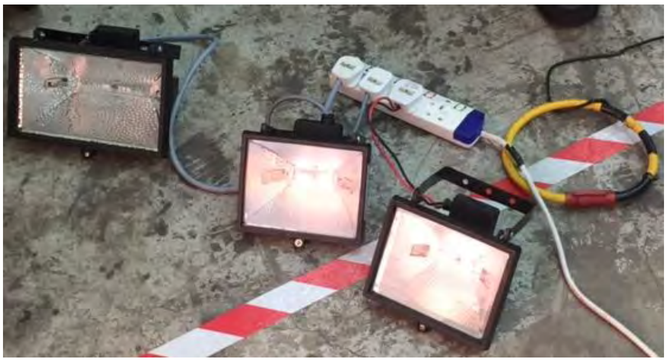


Figure 3.5: Load for the generator

3.1.2 Magnetic Stirrer

This test is carried out by looking the result on different temperature of the mixed fuel between hydrogen peroxide and gasoline. In order to mixed gasoline and hydrogen peroxide is by using magnetic stirrer. Magnetic stirrers are very common in experimental chemistry and biology. They are used to mix components like liquid and liquids and also solids and liquids to get homogeneous liquid mixtures. Besides, magnetic stirrers minimize the risks of contamination since only an inert magnet bar, which can easily be cleaned, is put inside the sample/fluid. In addition, using a magnetic stirrer rather than manual stirring is critical for consistent, reproducible mixing or mixing over long time scales. Then, it can rotate an internal magnet at variable speeds, mixing volumes up to one litre. Glassware with a stir bar is placed directly on top of the stirrer unit. The device is battery-operated and largely isolated from spills by its plastic case and gasket. There are few of ratios that will be testing on this experiment and there are give the different density on that mixed fuel. There are the example of magnetic stirrer in Figure 3.6 and its specification of magnetic stirrer on Table 3.2.

Figure 3.6: Magnetic Stirrer

Table 3.2: Magnetic Stirrer, IKA C-MAG HS-7

Power input	1020W
Motor rating output	1.5W
Speed control	Scale 0-6
Speed Range	100-1500RPM
Heat output	1000w
Heating temperature range	50-500°C
Voltage	230/120/100v

3.1.3 Hydrometer

In this case, there are a few of properties need in order to have a different result in aspect of ratios. The properties of density there are use for hydrometer to check the density of the gasoline alone and mixed fuel on every ratio. The hydrometer is the highest reading that can achieve is 1 g/cm^3. The sample of liquid should be in the temperature at 15°C before it can be check the exact density of the liquid in the beaker using hydrometer as in Figure 3.7

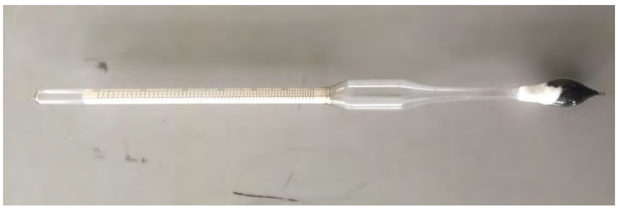


Figure 3.7: Hydrometer

3.1.4 1341 Plain Jacket Bomb Calorimeter

Besides, the bomb calorimeter is also use to check the energy content on the mixed fuel for the 1g blend. There are specification on bomb calorimeter in Table 3.3 and its respective figure is shown in Figure 3.8 and Figure 3.9.

Table 3.3: 1341 Plain Jacket Bomb Calorimeter

Power input, W	120
Max test per hour, Hour	2
Precision Class,%	0.3
Working time temperature, °C	25 minutes

Figure 3.8: Bomb Calorimeter

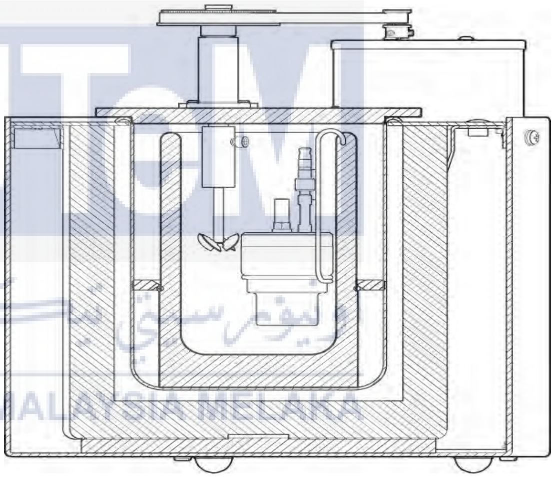


Figure 3.9: Parts inside bomb calorimeter

3.1.4 Heating Element

In order to have different temperature for the mixed fuel, the test will be use heating coil as to increase the temperature. For the heating coil model DKT 1500W Nichrome Heating Element will use in this test as in Figure 3.10. The heating element are put in mixed fuel and measuring by using thermometer as reach the temperature needed, the engine run at different load to see the different in the result. All experiments is repeat three times for the consistency and the average reading used.

Figure 3.10: Heating element

3.1.5 Polysaccharide as Emulsifier

Mix blend fuel between hydrogen peroxide and gasoline will have the problem to mix between with these two liquid. Hydrogen peroxide contains water that cannot be dissolve in gasoline. Therefore, the method that can use is using Polysaccharide chemical as the emulsifier to combine between two liquid. As stated in the journal Poly saccride (PS) based emulsifier reduces the surface tension between the diesel and H_2O_2 and stabilizes the blend for longer period (Khan et al., 2013). The blends in the Figure 3.11 shows that mixture of gasoline and hydrogen peroxide are completely blended.

Figure 3.11: Blends using polysaccharide as emulsifier

3.1.6 Data Acquisition System (DAS)

DAS is the main role in this experiment for gain RAW data and calculated performance of the engine. The DAS use in this experiment is DEWESOFT software the modal name of Sirius as in the Figure 3.12. The model is install by two parameters according to the requirement, which is crank angle sensor and cylinder pressure sensor. The interface of DAS system can be modify as our need for the performance that required for that engine. As in Figure 3.13 is the interface of DEWESOFT that including RPM meter, Time, Cycle, Pressure and much more.

Figure 3.12: Model Sirius in DEWESOFT

Figure 3.13: Interface of DEWESOFT software

3.2 Methods and Procedures

The methods and the procedures of the experiment has been carried out will be explained in this particular section. Method use for hydrometer is blended fuel between hydrogen peroxide and gasoline, put about 1L there are three sample of fuel which is gasoline alone, 5% of hydrogen peroxide, and 10% hydrogen peroxide. Then, put every sample in the beaker and using magnetic stirrer about 60 minutes. Then, transfer the mixed fuel on small test tube and put on fridge about to have 15^{o}c the test it with hydrometer to identify the density of that ratio fuel. The entire test is referring from ASTM standards method for the fuel testing in Table 3.4. For the experiment work, the reference gasoline fuel was obtained from CALTEX RON 95 fuel station whilst the commercial grade hydrogen peroxide is 50% that obtained from Poly Scientific. Sdn. Bhd. All tests are conducted at a different load 500W, 1kW, and 2kW and the engine speed also in different RPM which is 2500RPM, 3000RPM, and 3500RPM. After every load engine is allow to attain steady state for duration about 1 minute before collect data.

Table 3.4: ASTM standard for fuel testing

Test	ASTM
Density	ASTM D-1298
Viscosity	ASTM D-445
Flash point	ASTM D-93

For the first, the gasoline is tested 100% fully on the generator to get the reference result as to compared it with others mix fuel blend. The test is run by two sample of mixed fuel, there are 5% and 10% of hydrogen peroxide and the rest are from gasoline. The experiment was analysed at different fuel temperatures, starting at a temperature of 45°C and 60°C. Higher fuel temperatures tend to produce higher injection pressure.

3.3 Experimental Setup

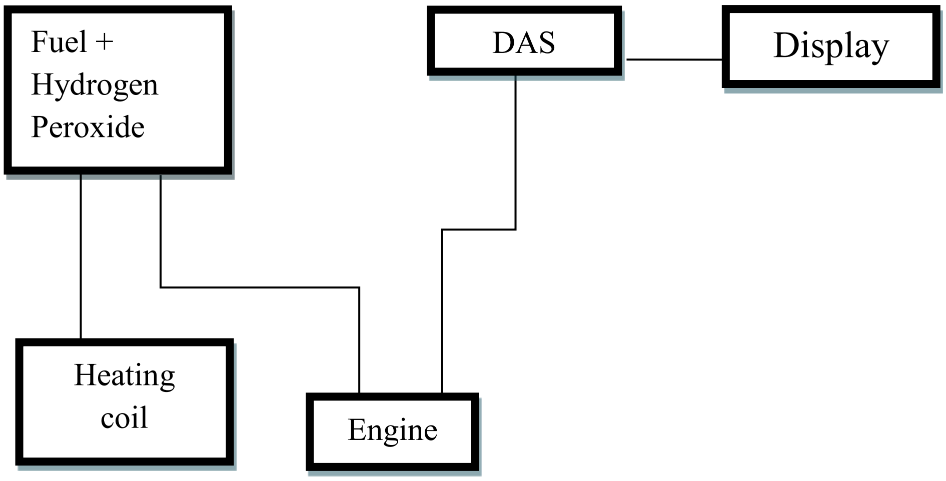


Figure 3.14: Experimental set up equipment

The experiment will be tested with blend gasoline and hydrogen peroxide with 5% and 10% of ratios and gasoline alone. The change of temperature of fuel blend by using a heater in order to increase the temperature at 45°C and 60°C. There are ratios that have plan to the test in this experiment in the Table 3.5.

Table 3.5: Ratio of blends in the experiment

H_2O_2 (%)	C_7H_{12} (%)
0	100
5	95
10	90

The parameters of performance in the engine that will be collect In DAS system is P-ϴ, P-V, and pressure in cylinder. Then, from collected data the performance that can calculate is peak pressure, indicated work, indicated thermal efficiency, heat release rate. All the result with the different of fuel temperature and the data will show it on the graph. The graph will show the reading of parameters with respect to the fuel temperature for each ratios of blend. At the end of this experiment there will have the complete data and find the optimum ratio of fuel blend as the optimum performance of the engine that can be achieve form this experiment. The methodology of this study is summarized in the flow chart as shown in Figure 3.15.

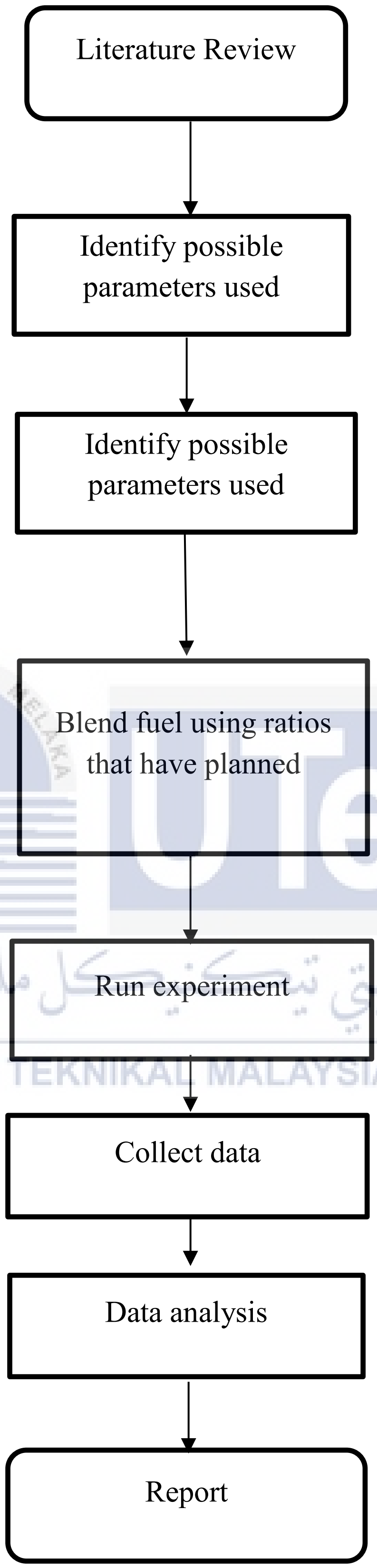


Figure 3.15: Flow chart of the methodology

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The results of the experimental and numerical investigations are presented, analysed and conclude arrived at in this chapter. Discussions are made based on the experiments and analysed had been discussed in the previous chapter. In this chapter, performance of the single cylinder engine by using mix blend fuel between gasoline and hydrogen peroxide, along with the effect of various temperature. Experimental results pertaining to performance characteristics of single cylinder engine and mix blend fuel with different temperature, which is 45°C, and 60°C are presented in detail. It is compared with gasoline alone (GA) and 5% of hydrogen peroxide (CASE 1), and 10% hydrogen peroxide (CASE 2). Brief comparison between these studies with other researchers are also presented in order to acknowledge the available research gaps even though most of the works are dissimilar.

4.2 Experimental Data

4.2.1 Chemical Properties of Fuel

The experiment of chemical properties for fuel blend between gasoline and hydrogen peroxide is gain from Tribology Laboratory, FKM, Kampus Teknologi, UTeM. From the experiment, the density and energy content for gasoline alone and blend fuel for 5% of hydrogen peroxide and 10% hydrogen peroxide blend with gasoline.

Table 4.1: Table of density and energy content

Types	Density (g/cm^3)	Energy content (kJ/g)
Gasoline alone	0.735	38.102
5% of H_20_2 + gasoline	0.75	33.474
10% of H_20_2 + gasoline	0.765	28.845

As the result, the experimentally measured values of densities for the fuel blend are presented in Table 4.1, 10% of $\mathrm{H_20_2}$+ gasoline showed higher values than reference gasoline. Although the density of hydrogen peroxide is much greater, the energy content is apparently lower both on a mass and volume basis when compared to the reference gasoline fuel. The result is same as the fact of, due to the reduction in the energy content after the addition of the hydrogen peroxide, more fuel is through into the combustion chamber is required (Khan et al., 2013). This will lead to the more consumption of fuel in this experiment. Nevertheless, such disadvantage is compensate back through the higher cetane number of the fuel blends with the addition of hydrogen peroxide.

Two combined effects can cause the almost unchanged temperature profile in the case of $\mathrm{H_20_2}$/water in-ejection: the energy being required for spray evaporation is compensated by the exothermal of the gas phase $\mathrm{H_20_2}$ decomposition and/or by the heat release of the heterogeneous reaction of soot and OH (Franz & Roth, 2000).

4.2.2 Engine Testing Data

The data is collect from DAQ system, which is using DEWESOFT software. The data is gain from cylinder pressure sensor and crank angle sensor that install to the generator. The data is gain from the software is crank angle, pressure in the cylinder and displacement volume cylinder for 1 minute. All these data is export to excel and gain the RAW data to find other characteristic for the performance in single cylinder engine. The figure shows in

Figure 4.1 is the screenshot from excel that exported from DEWESOFT software and the data is gain from average cycle that gain from 1 minute of an experiment.

X axis	Vol1	AI 1-Cylinder PressureoAve
deg	dm3	bar
10	0.053972118	4.7459288
11	0.054805394	4.6138592
12	0.055716433	4.4875073
13	0.056704797	4.3619304
14	0.057770025	4.2361073
15	0.058911607	4.1102362
16	0.060129002	3.9804125
17	0.061421636	3.8675787
18	0.062788896	3.7470558
19	0.064230137	3.6327741
20	0.065744668	3.5187671
21	0.067331791	3.4041302
22	0.068990752	3.2943206
23	0.070720762	3.1899326
24	0.072521031	3.0872564
25	0.074390687	2.9868112
26	0.076328866	2.8889933
27	0.078334659	2.7939725
28	0.080407135	2.7047057
29	0.082545325	2.6185806
30	0.084748238	2.5325003
31	0.087014839	2.4448326

Figure 4.1: Example of raw data exported to Microsoft Excel

From Table 3.2 to Table 3.4, shows the fuel consumption of fuel for gasoline alone and fuel blend 5% of H_20_2 and 10% of H_20_2. The consumption of fuels was recorded with respect to different loads, engine speed and fuel temperature of fuel blend.

Table 4.2: Fuel consumption of gasoline alone

RPM/LOAD	T=45°C			T=60°C		
	2500	3000	3500	2500	3000	3500
0	17.9	18.1	26.9	28	20	19.1
500	27.5	26.7	27.4	26.1	28.4	30.2
1000	27.3	29	32.5	26	44.7	46.3
1500	32.8	33.7	41.1	32.3	28	35.2
2000	35.1	34	42.6	34.2	35.1	36.5

Table 4.3: Fuel consumption of 5% H_2O_2

RPM/LOAD	T=45°C			T=60°C		
	2500	3000	3500	2500	3000	3500
0	26.2	26.9	32.6	15.7	19.7	24.7
500	16.3	19.5	23.5	18.8	23.1	26.5
1000	19.4	18.8	27	22.8	21.9	25.9
1500	21.8	24.8	31.5	22	24.4	28.2
2000	26.2	26.9	32.6	27.5	24.5	28.2

Table 4.4: Fuel consumption of 10% H_2O_2

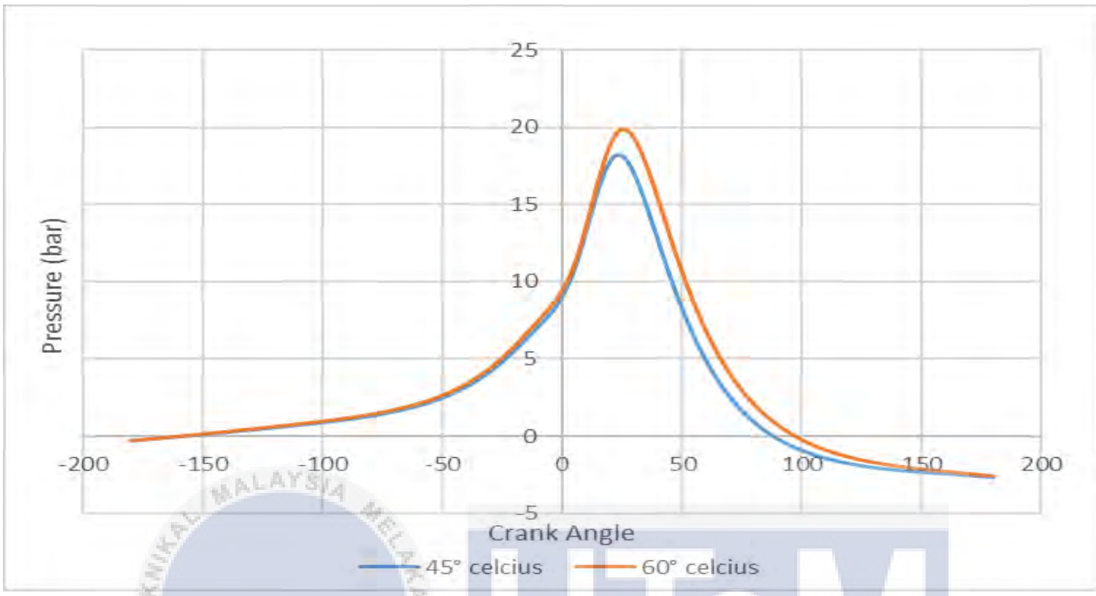
RPM/LOAD	T=45°C			T=60°C		
	2500	3000	3500	2500	3000	3500
0	12.5	15.3	20.5	13.7	16.2	18.2
500	16.7	21	20.5	13.5	17.2	23.3
1000	17.4	18.5	26.3	18.9	22.2	25.2
1500	21.2	21	28.9	23.8	27.7	31.6
2000	24.5	25.5	32	24.5	25.5	30.8

4.3 Performance Analysis

This section discusses experimental results on performance of single cylinder engine with gasoline alone, 5% of H_20_2 and 10% of H_20_2 according to 45° Celsius, and 60° Celsius fuel temperature. The selected chart that represents similar pattern for each performance characteristics will be interpreted and discussed. The extensive charts on performance of single cylinder engine for gasoline alone (GA), gasoline with 5% of H_20_2 (CASE 1) and gasoline with 10% of H_20_2 (CASE 2) operations are presented in Appendix F.

4.3.1 Crank Angle and Pressure Cylinder

The crank angle and pressure cylinder was measured using DEWESOFT cylinder pressure sensor and crank angle sensor as to be the input of the data and it well organized by DAS to visualize P-Ө diagram while running the experiment. Figure 4.2 shows an example of the variation of cylinder pressure with crank angle at the speed of 2000RPM and 2kW load for gasoline alone (GA) operation. The GA graph shows the temperature at 60°C reaching the highest pressure 20 bar at 20° crank angle wheres the temperature at 45° Celcius reach at 17 bar at 19° crank angle. The highest pressure that produce due to the elevated of temperature of fuel and increasing of pressure in carburetor into the cylinder.



The GA, CASE 1 and CASE 2 in the Figure 4.3, pressure curves has the tendency to shift to the right where the peak pressure for single cylinder engine operation occurs in the range of 3° to 5°CA later than that of GA operation throughout all engine speeds. The delay in peak pressure of CASE 1 and CASE 2 operations is due to the oxygen are also helps to reduce the ignition lag as well as assisting complete combustion (K.S & Madhu, 2012).

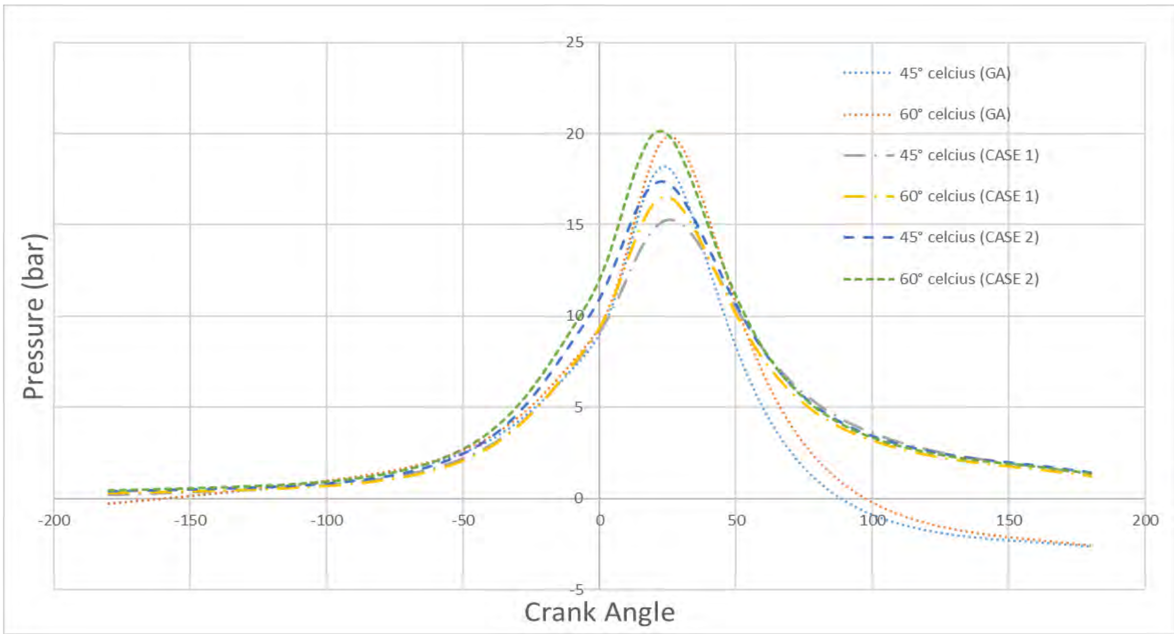


Figure 4.3: Variation of blend fuel with crank angle vs cylinder pressure 2000RPM at 2kW

4.3.2 Peak Pressure

The peak pressure was obtained from P-θ diagram for every speed and load during experiments. The analysis of peak pressure is justification in determining maximum force applied on the engine piston and cylinder. The Figure 4.4 shows results of GA, the peak pressure for the temperature 60°C and 45°C at 2500RPM, 3000RPM and 3500RPM, pattern is almost same. The highest peak pressure of GA is when giving from 2kW of load with 20 bar for temperature 60°C and 18 bar for temperature 45°C. Increasing of RPM will decrease the peak pressure of cylinder. The shorter ignition delay attributed to the early start of combustion, leading to a higher in-cylinder pressure (Rahim; et al., 2012).

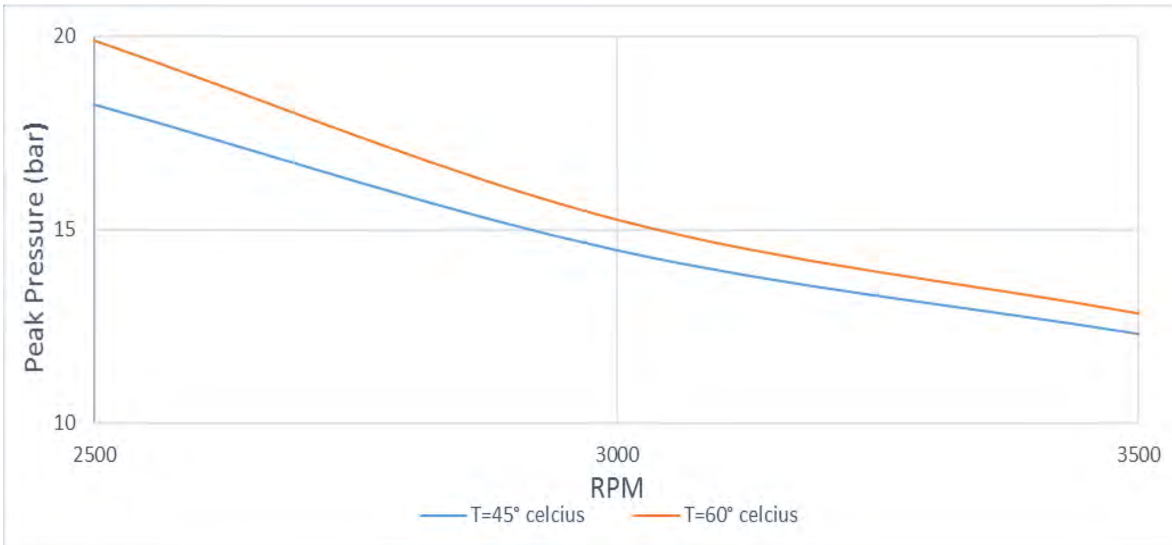


Figure 4.4: Peak pressure of gasoline alone at 2kW

In the Figure 4.5, the comparison of peak pressure of single cylinder operation for all cases at 2kW and different RPM. The results observed that CASE 2 with highest temperature at 60° Celsius reach the highest peak at 22 bar compared between CASE 1 and GA reach at 14 to 17 bar. It is because of presence of H_2O_2 is because it decomposes, with a release of tremendous energy, close to the energy per mole of H_2. Water content in H_2O_2 will evaporate the heat from the cylinder charge is needed for its evaporation. Then, it shows that this can related to stronger heat release and more complete combustion as the effects from optimum equivalent ratio of the cylinder charge with hydrogen peroxide.

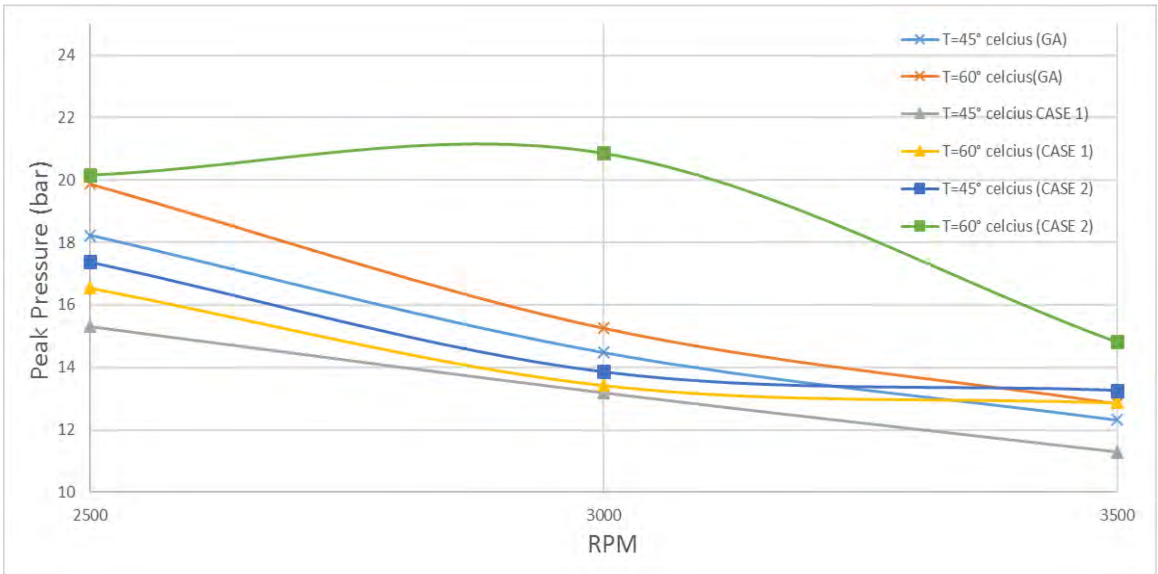


Figure 4.5: Peak pressure of gasoline alone at 2kW

4.3.3 Heat Release Rate

Heat release rate (HRR) was calculated from the average pressure with respect to crank angle. It is important in identifying the rate of chemical energy released from combustion of fuels. Figure 4.6 demonstrates the heat release rate of single cylinder engine in present investigation running on GA with temperature 45°C and 60°C at 3500RPM and 2kW. The maximum HRR obtained with GA with 45°C is 9.2 J/deg and for GA with 60° Celsius it is 10 J/deg. This is due to rapid heat release from gasoline GA with 60° C that closed to the flash point by virtue of the fast flame speed of as GA with 60°C compared to GA with 45°C (Navale et al, 2017). It also effects on energy level that as the fuel temperature is decrease the energy level also decreased. The trends of HRR for GA is where peak heat release rate decreases and combustion duration increases as combustion phasing retards. Reduced peak heat release rate and increased combustion duration are more pronounced for gasoline compared to E40, a trend previously (Szybist & Splitter, 2017).

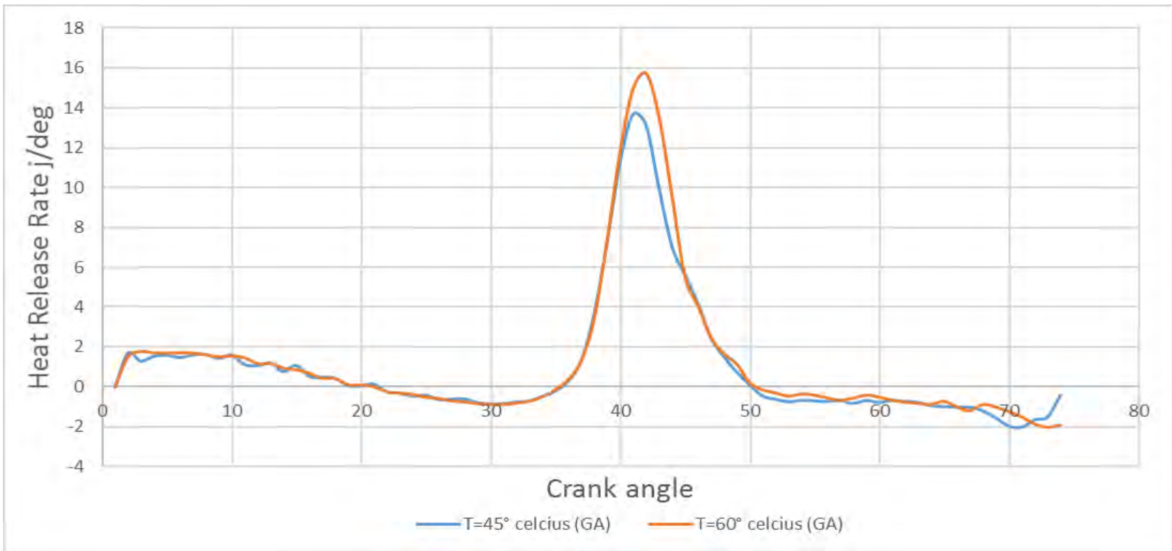


Figure 4.6: Heat release rate for gasoline alone 3500RPM and 2kW

The Figure 4.7 is shows the comparison between GA, CASE 1, and CASE 2 with 45° Celsius and 60° Celsius at 3500RPM and 2kW. The pattern is almost the same for all cases. It is observed that the curves are similar in shape, indicating a rapid premixed combustion phase followed by a slower diffusion combustion phase (Guangxin et al, 2013) The highest peak, which is for CASE 1 at temperature 60°C with 11.8 J/deg and the lowest peak at CASE 1 at temperature 45°C with 7.8 J/deg. As the graph shows the higher % of hydrogen peroxide the higher heat release rate produce. This means that lowered peak heat release rate (PHRR) due to decreasing of energy level during premixed combustion phase as compared to temperature at 60°C operation. Faster burning speed of fuel blend caused relatively high rate of heat release in a small time interval (Navale et al., 2017)

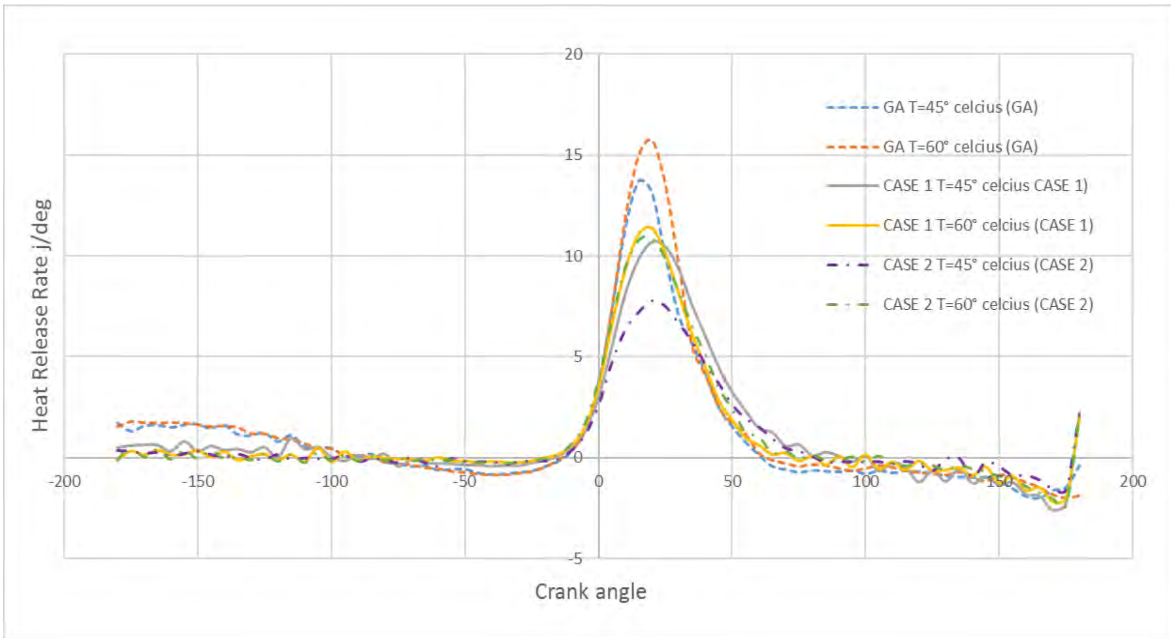


Figure 4.7: Variation of Heat release rate for all cases at 3500RPM and 2kW

4.3.4 Gross Indicated Work

Gross indicated work is known as work delivered to the piston during compression and expansion strokes namely crank angle in between 180°BTDC and 180°ATDC. It also known as shaft work for an engine. It can be determined from area under the graph area on PV diagram as shown in Figure 4.8 and figure 4.9 shows the pattern of indicated work in Joule for all cases at 3500RPM and 2kW and it compared with the same temperature, which is 45°C and 60°C.

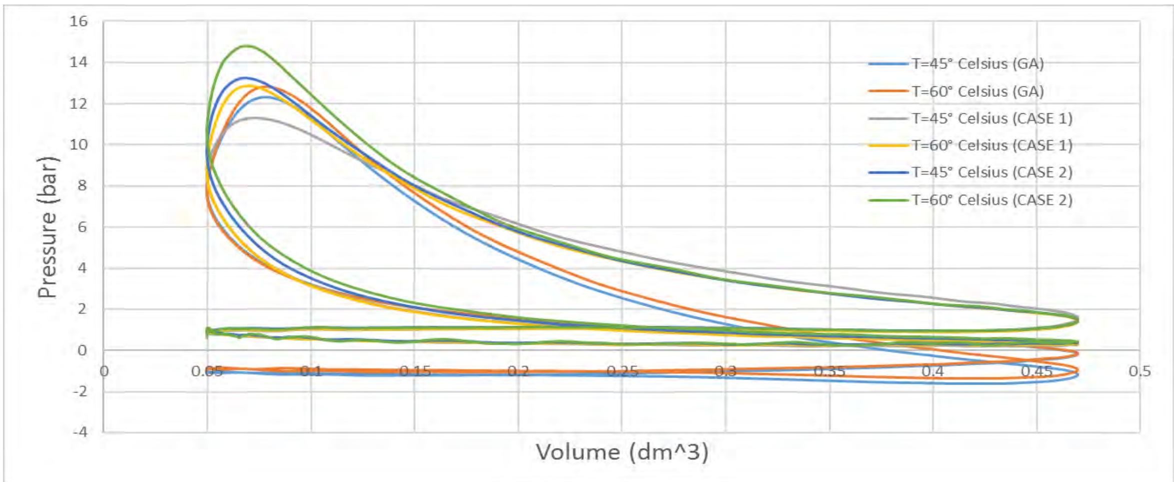


Figure 4.8: PV diagram at 3500RPM and 2kW for all cases

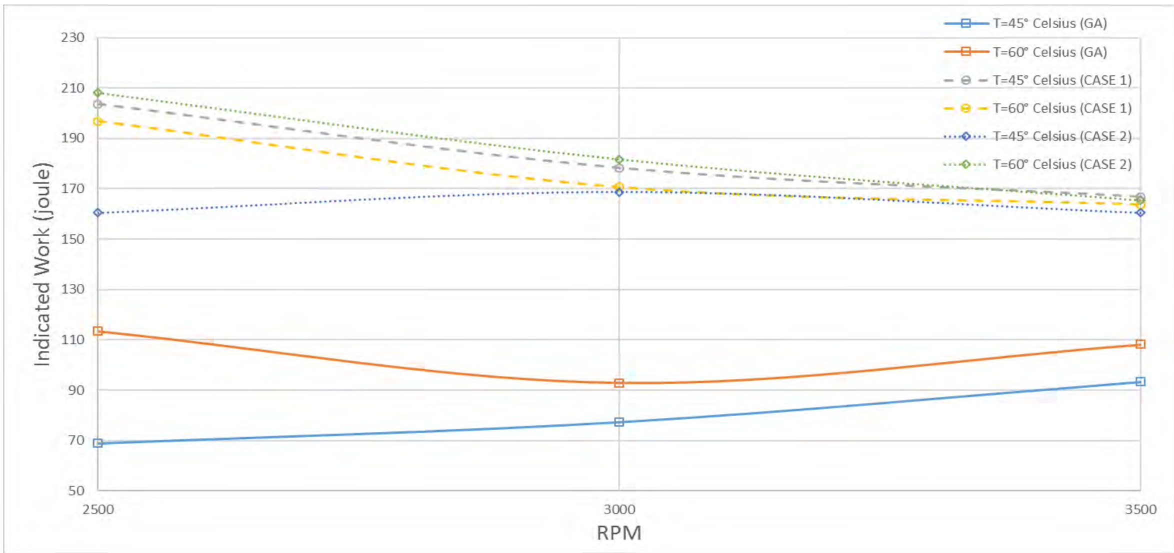


Figure 4.9: Variation Indicated work at 2000W for all cases at 2kW and 3500RPM

It can observed that CASE 2 at temperature 60°C is the highest gross indicated work reach 210 joule and the lowered indicated work is for GA at temperature 45°C 70 joule. CASE 1 observed that at temperature 45°C the indicated work is higher than at temperature 60°C. It is due to the higher pressure is produce in the cylinder and increase the energy level of the blend fuel. In this observation, hydrogen peroxide blend could increase the indicated work for the engine almost 40% of the reference work. It shows that the blend fuel is produce better combustion quality as the duty of hydrogen peroxide and water charge supplies additional oxygen to insure complete combustion of hydrocarbon fuel and simultaneously the high energy content present to boost the power output of the engine (James R.Dissmore, 1981). Besides, operating engines incorporating such fuel system such that increased power and fuel efficiency is achieved in part by the more complete combustion of the fuel mixture.

4.3.5 Indicated Thermal Efficiency

Indicated thermal efficiency (ITE) is determined from the ratio of gross indicated work and total heat generated from combustion of fuels. Figure 4.10 illustrates the variation of ITE for all cases at 2500RPM, 3000RPM, and 3500RPM at 1kW of load. It can see that higher ITE for CASE 2 temperature at 45° Celsius for 41% of ITE and produce the same pattern of graph at temperature 60°C at 39% of ITE. For the CASE 1 at temperature 45°C, it produce 27% of ITE shows higher ITE than CASE 1 at temperature 60° Celsius for only 24% ITE. This oxygen helps in reducing the ignition lag as well as assisting complete combustion of the fuel (K.S & Madhu, 2012). The thermal efficiency is drop by increasing the RPM of the engine this statement is support by research; It is evident that the get decreases with the increase of temperature and the trend is more obvious under the high engine loads (Guangxin et al., 2013)

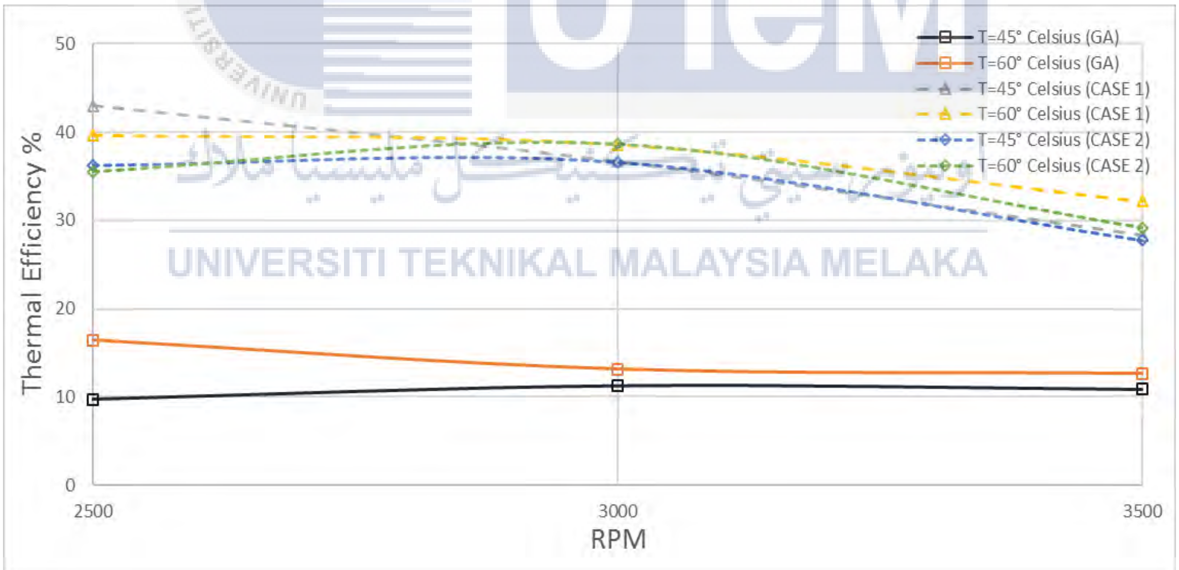


Figure 4.10: Indicated thermal efficiency at 1kW for all cases

4.3.6 Indicated Specific Fuel Consumption

Figure 4.11 shows the variation of ISFC (indicated specific fuel consumption) according to the GA, CASE 1, and CASE with temperature 45°C and 60°C at 2kW. It can observed that the CASE 2 have the lowest ISFC at 291 g/kwh at 3500RPM at 60°C. These is due to the lean combustion in the cylinder engine that produces a lower temperature from the H_2O release from H_2O_2 properties. This also due to the higher efficiency that produce. As the facts in fundamentals of internal combustion engine, Combustion of mixtures leaner than stoichiometric produces products at lower temperature, and with less dissociation of the triatomic molecules CO_2 and H_2O (Heywood, 1988). The highest ISFC is reach by GA at temperature 45°C. This results can shows that the combustion is lead to the rich combustion because of there are 100% of gasoline and due to dissociation at the high temperatures following combustion, molecular oxygen is present in the burned gases under stoichiometric conditions, so some additional fuel can be added and partially burned (Heywood, 1988).

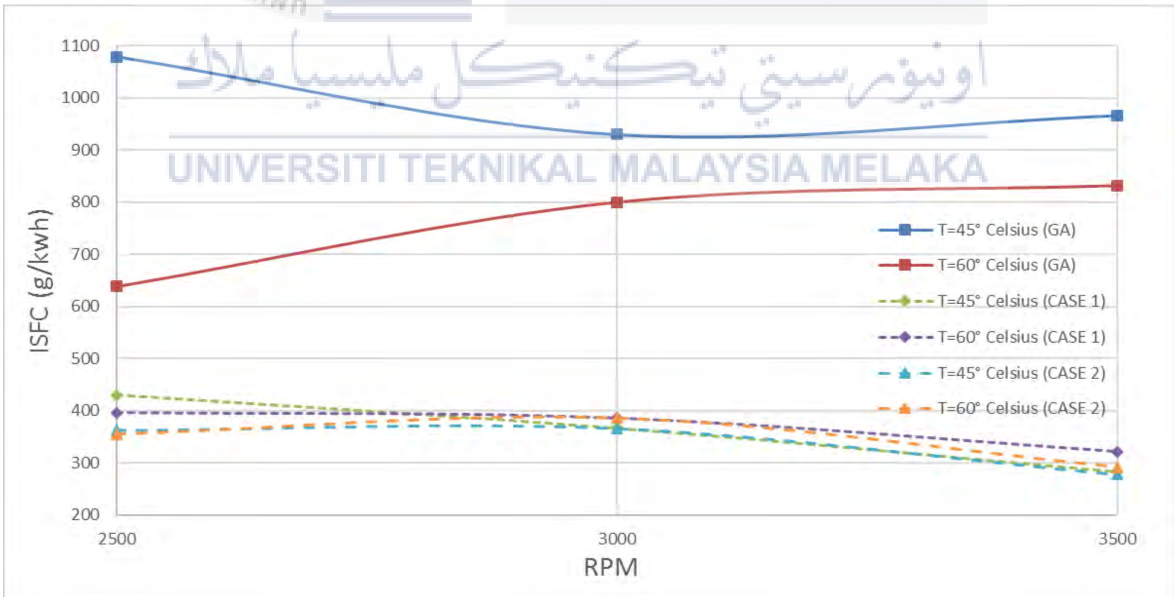


Figure 4.11:ISFC at 2kW for all cases

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

As conclusion, a few aspects have to be considered before using the hydrogen peroxide as the additive in the single spark ignition engine. From the data of performance of the engine shows, positively that hydrogen peroxide could increase the pressure of the cylinder as the fuel temperature increase. This can be concluded that with the increasing of H_2O_2 and fuel temperature the pressure in cylinder increase. When it is comparing the graph GA, CASE 1, and CASE 2 there are delay in peak pressure of CASE 1 and CASE 2 operations is due to the oxygen are also helps to reduce the ignition lag as well as assisting complete combustion (K.S & Madhu, 2012).

Then, the performance at peak pressure that relate to the crank angle and pressure in cylinder. It also gives the positive value to the pressure as CASE 2 at temperature 60°C until reach to the 22bar. It is because of presence of H_2O_2 is because it decomposes, with a release of tremendous energy, close to the energy per mole of H_2. For the heat release rate, the CASE 1 at 60°C is the highest compared to the GA and CASE 1. It can be concluded that lowered peak heat release rate (PHRR) due to decreasing of energy level during premixed combustion phase as compared to temperature at 60°C operation.

Next, the highest performance for gross indicated work results is CASE 2 at temperature 60°C it shows that CASE 2 produce better quality of combustion than GA and CASE 1. The indicated thermal efficiency the highest thermal efficiency is CASE 2 at 45°C but it is almost same to 60°C. This is due to the oxygen helps in reducing the ignition lag as well as assisting complete combustion of the fuel.

For the indicated specific fuel consumption, the graph is clearly shows that when adding of additive hydrogen peroxide to the gasoline it can help to reduce the consumption of the fuel about 200g/kwh it such as big different almost 50% from the reference GA. As the overall conclusion respective to the objective in this experiment, the optimum blend with gasoline is 10% of hydrogen peroxide by volume of total blend. The optimum temperature is when reach 60°C due to all observation that better performance when the temperature is increase.

However, in the experiment observation the blend fuel have higher evaporation as it cannot stand outside condition in long period. The reaction from the blend clearly shows it really have exciting reaction and fast evaporation that enhancing the performance in the cylinder. This results may have improve with spark advanced ignition that will reduce the ignition timing as the combustion complete before TDC due to reactive from blend fuel.

REFERENCES

B, M. V. (2014). *EFFECT Of Additive Hydrogen Peroxide On The Performance And Emission Of A Diesel Engine At B20 Blend*.

Chen, G., Li, Y., Cheng, T., Hsu, H., & Chao, Y. (2011). Effects of Hydrogen Peroxide on Methane Premixed Flames, 1–6.

Franz, B., & Roth, P. (2000). Injection of a H2O2/ Water Solution Into The Combustion Chamber Of A Direct Injection Diesel Engine And Its Effect on Soot Removal, *28*, 1219–1225.

Guangxin, G., Zhulin, Y., Apeng, Z., Shenghua, L., & Yanju, W. (2013). Effects of Fuel Temperature on Injection Process and Combustion of Dimethyl Ether Engine, *135*(28), 1–5. https://doi.org/10.1115/1.4023549

Heywood, J. B. (1988). *Internal Combustion Engine Fundementals*. *McGrawHill series in mechanical engineering* (Vol. 21). https://doi.org/10987654

James R.Dissmore. (1981). Fuel System For IC Engine, 1–4.

K.S, N., & Madhu, D. (2012). Effect of Injecting Hydrogen P Eroxide Into Diesel Engine. *International Journal of Engineering Sciences & Emerging Technologies*, *2*(1), 24–28.

Kanna, J., Reddy, P. M., & Reddy, K. H. (2014). Effect Of Fuel Temperature On Diesel Engine Performance and Emissions using Cotton Seed Based Bio-Diesel And Additive Ac2010a, *4*(2), 9–13.

Khan, M. S., Ahmed, I., Mutalib, A., & Bustum, A. (2013). Characterization Of Diesel-Hydrogen Peroxide Fuel Blend. *Journal of Energy Technology and Policy*, *3*(12), 273–279.

Muhammad Saad Khan, Hassan, Z. Bin, & Iqbal, A. (2009). Influence of Hydrogen Peroxide on Liquefied Petroleum Gas (Lpg) Performance. *National Conference on Postgraduate Research (NCON-PGR) 2009*, (October), 107–113.

Navale, S. J., Kulkarni, R. R., & Thipse, S. S. (2017). An experimental study on performance , emission and combustion parameters of hydrogen fueled spark ignition engine with the timed manifold injection system. *International Journal of Hydrogen Energy*, *42*(12), 8299–8309. https://doi.org/10.1016/j.ijhydene.2017.01.059

Pan, W., Yao, C., Han, G., Wei, H., & Wang, Q. (2015). The impact of intake air temperature on performance and exhaust emissions of a diesel methanol dual fuel engine. *Fuel*, *162*, 101–110. https://doi.org/10.1016/j.fuel.2015.08.073

Pulkrabek, W. W. (2004). *Engineering Fundamentals of the Internal Combustion Engine, 2nd Ed. Journal of Engineering for Gas Turbines and Power* (Vol. 126). https://doi.org/10.1115/1.1669459

Rahim;, R., Mamat;, R., Taib, M. Y., & Abdullah, A. A. (2012). Influence of fuel temperature on biodiesel engine performance operating with biodisel blend. *Mechanical Engineering and Sciences (JMES)*, *2*(June), 226–236. https://doi.org/http://dx.doi.org/10.15282/jmes.2.2012.10.0021

Sabourin, J. L., Risha, G. A., Yetter, R. A., Son, S. F., & Tappan, B. C. (2008). Combustion characteristics of nanoaluminum, liquid water, and hydrogen peroxide mixtures. *Combustion and Flame*, *154*(3), 587–600. https://doi.org/10.1016/j.combustflame.2008.05.015

Sandalci, T., & Karagöz, Y. (2014). Experimental investigation of the combustion characteristics, emissions and performance of hydrogen port fuel injection in a diesel engine. *International Journal of Hydrogen Energy*, *39*(32), 18480–18489. https://doi.org/10.1016/j.ijhydene.2014.09.044

Schifter, I., Diaz, L., Rodriguez, R., Gómez, J. P., & Gonzalez, U. (2011). Combustion and emissions behavior for ethanol-gasoline blends in a single cylinder engine. *Fuel*, *90*(12), 3586–3592. https://doi.org/10.1016/j.fuel.2011.01.034

Shehata, M. S. (2013). Emissions , performance and cylinder pressure of diesel engine fuelled by biodiesel fuel. *Fuel*, *112*, 513–522. https://doi.org/10.1016/j.fuel.2013.02.056

Shivaprasad, K. V, Raviteja, S., & Chitragar, P. (2014). Experimental Investigation of the Effect of Hydrogen Addition on Combustion Performance and Emissions Characteristics of a Spark Ignition High Speed Gasoline Engine. *Procedia Technology*, *14*, 141–148. https://doi.org/10.1016/j.protcy.2014.08.019

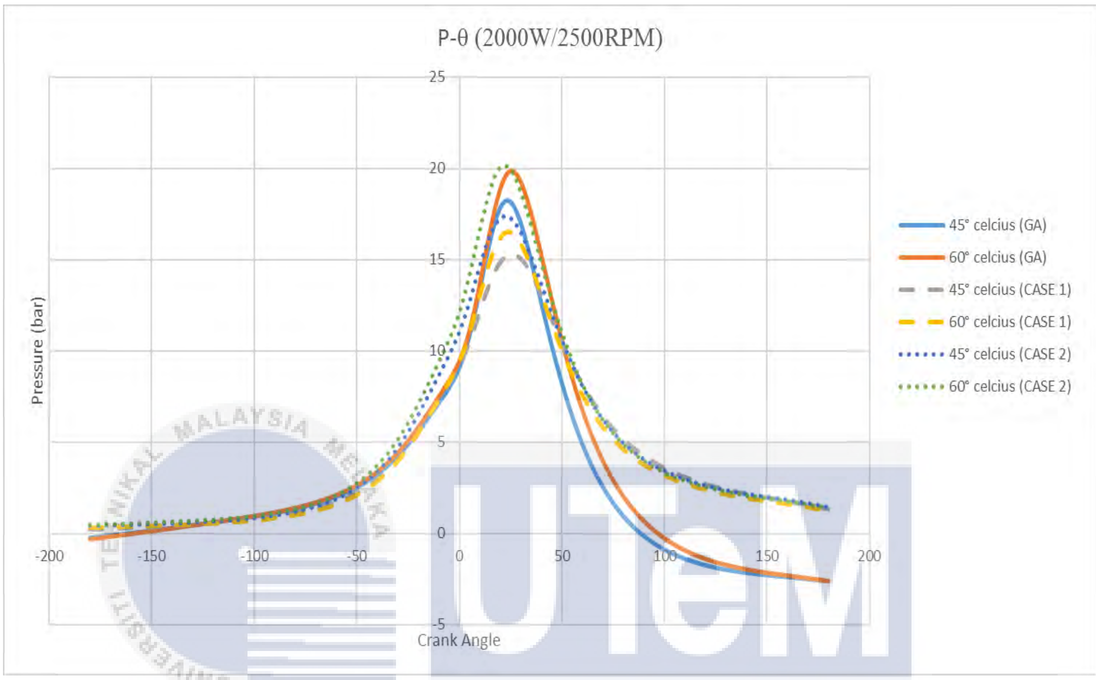
Sulaiman, M. Y., Ayob, M. R., & Meran, I. (2013). Performance of single cylinder spark ignition engine fueled by LPG. *Procedia Engineering*, *53*, 579–585. https://doi.org/10.1016/j.proeng.2013.02.074

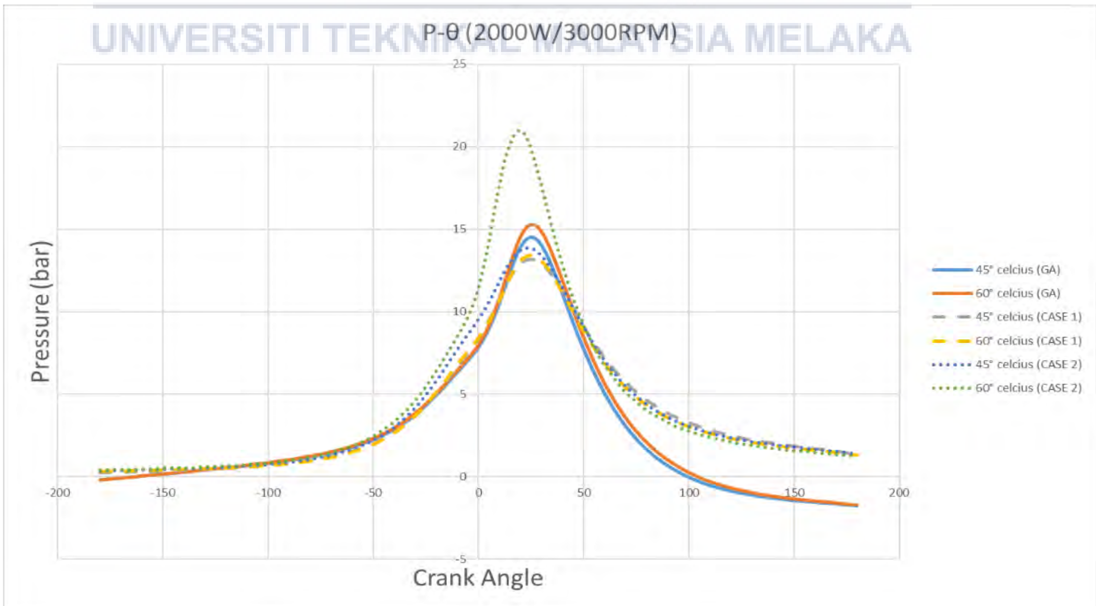
Szybist, J. P., & Splitter, D. A. (2017). Pressure and temperature effects on fuels with varying octane sensitivity at high load in SI engines. *Combustion and Flame*, *177*, 49–66. https://doi.org/10.1016/j.combustflame.2016.12.002

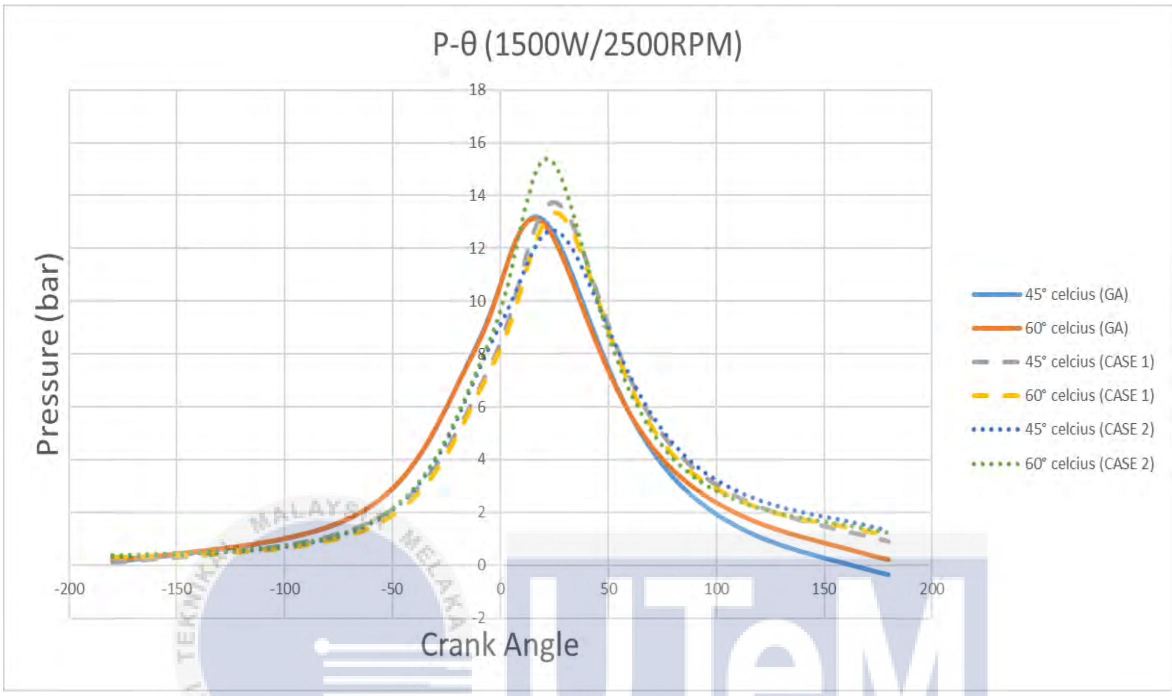
Yunus, M. Z., Musthafah, M. T., & Akop, M. Z. (2015). Study the performance of single cylinder spark ignition engine for gasoline and compressed natural gas. *Proceedings of Mechanical Engineering Research Day 2015,* (March), 121–122.

APPENDICES

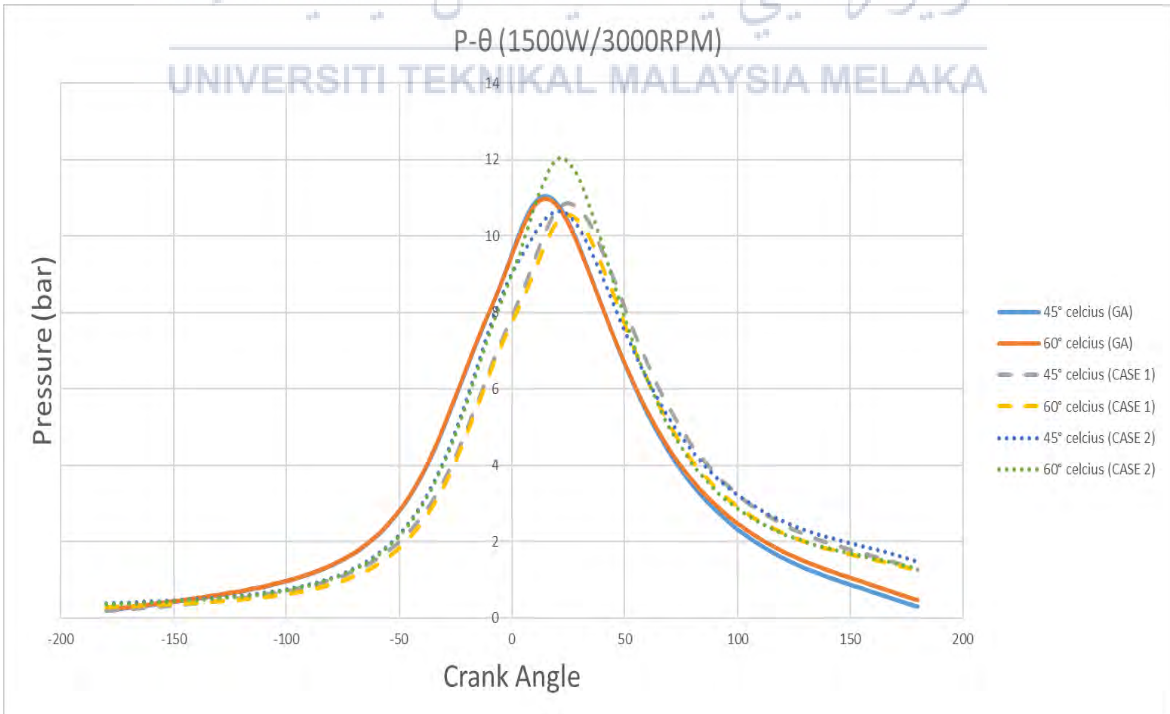
(A) P-Ɵ Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature



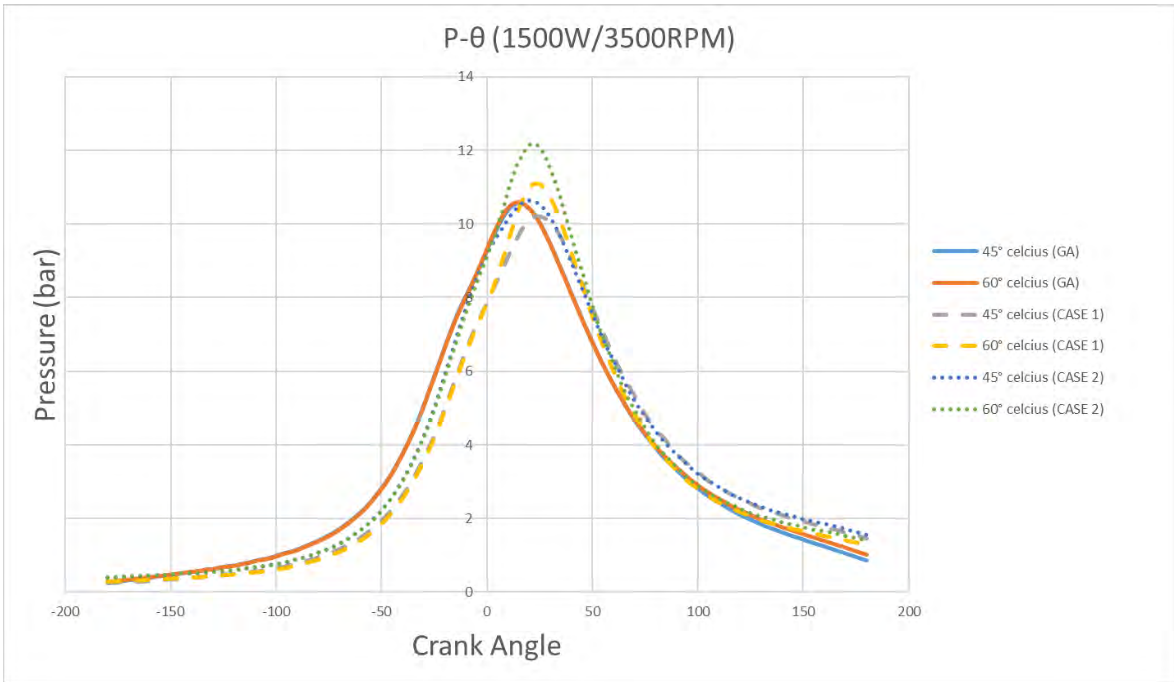




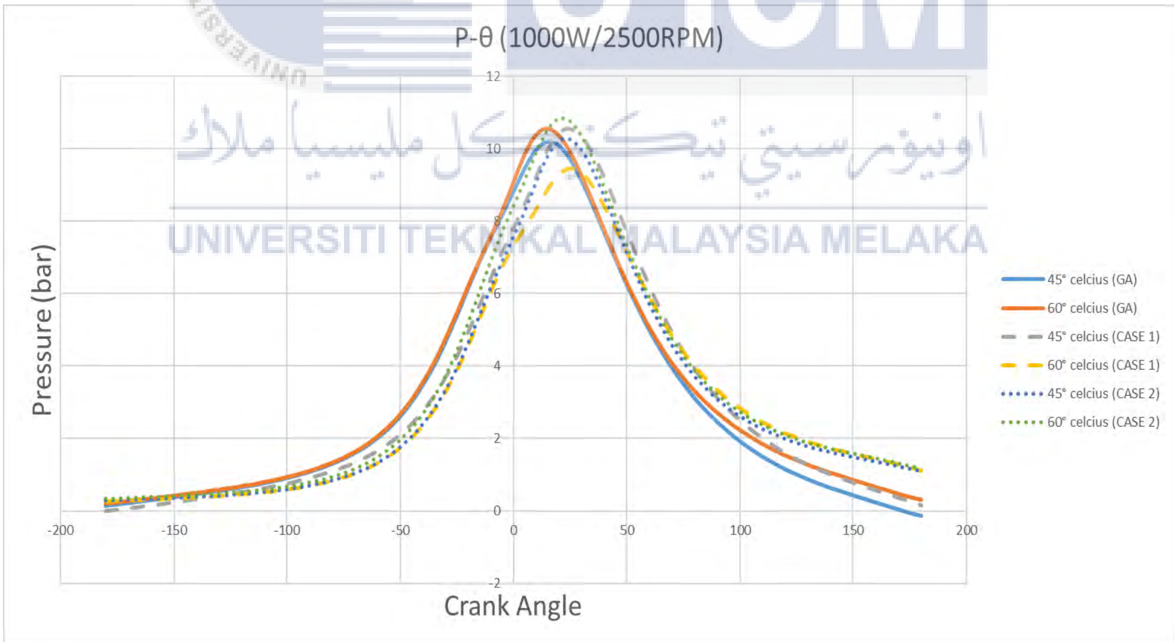
P-θ (1500W/2500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)



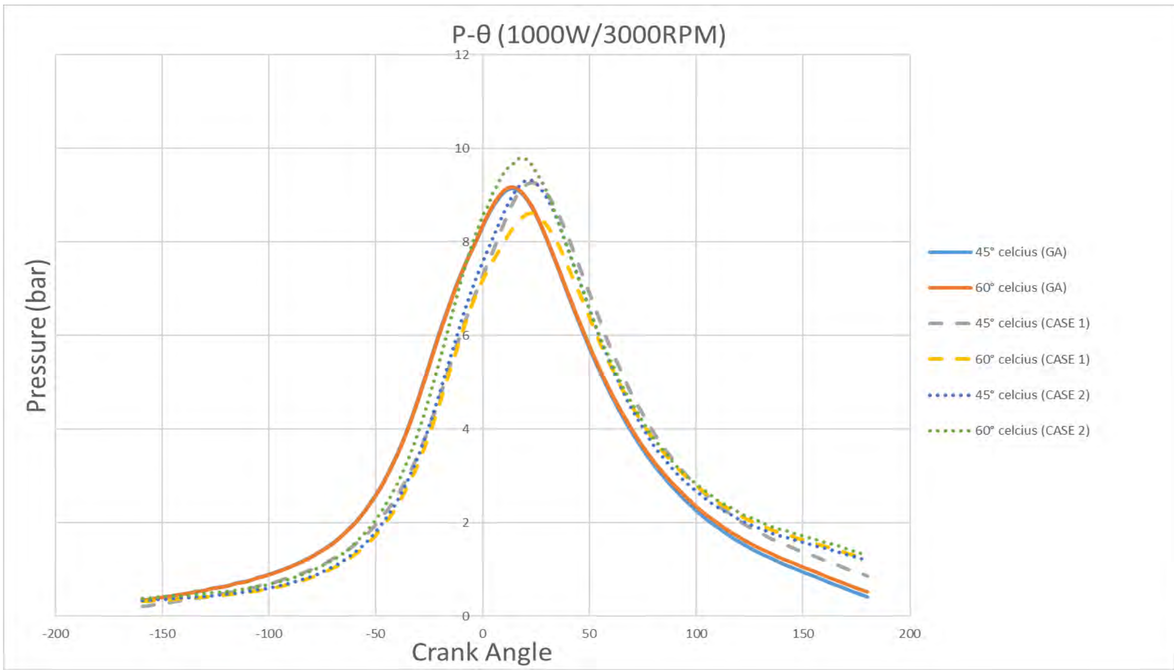
P-θ (1500W/3000RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)



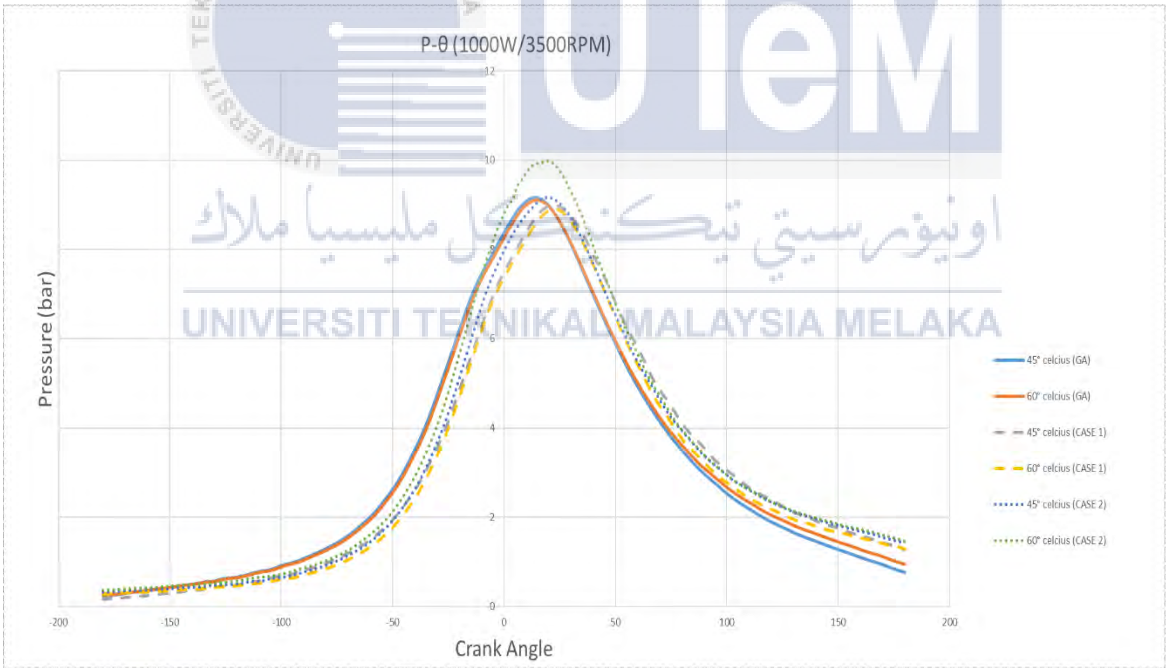
P-θ (1500W/3500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)



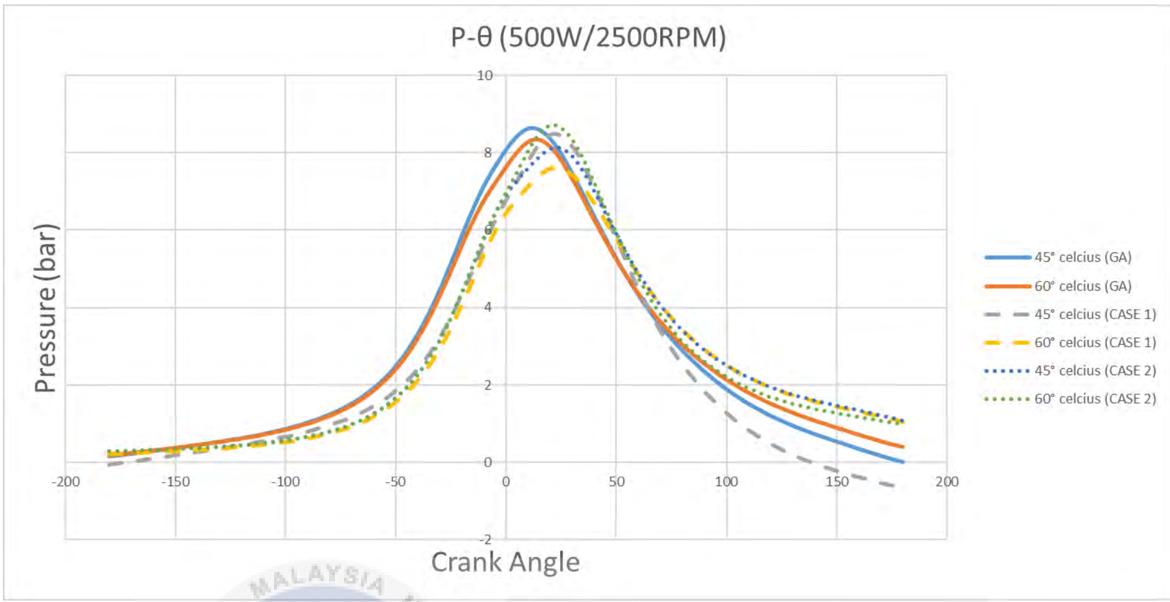
P-θ (1000W/2500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

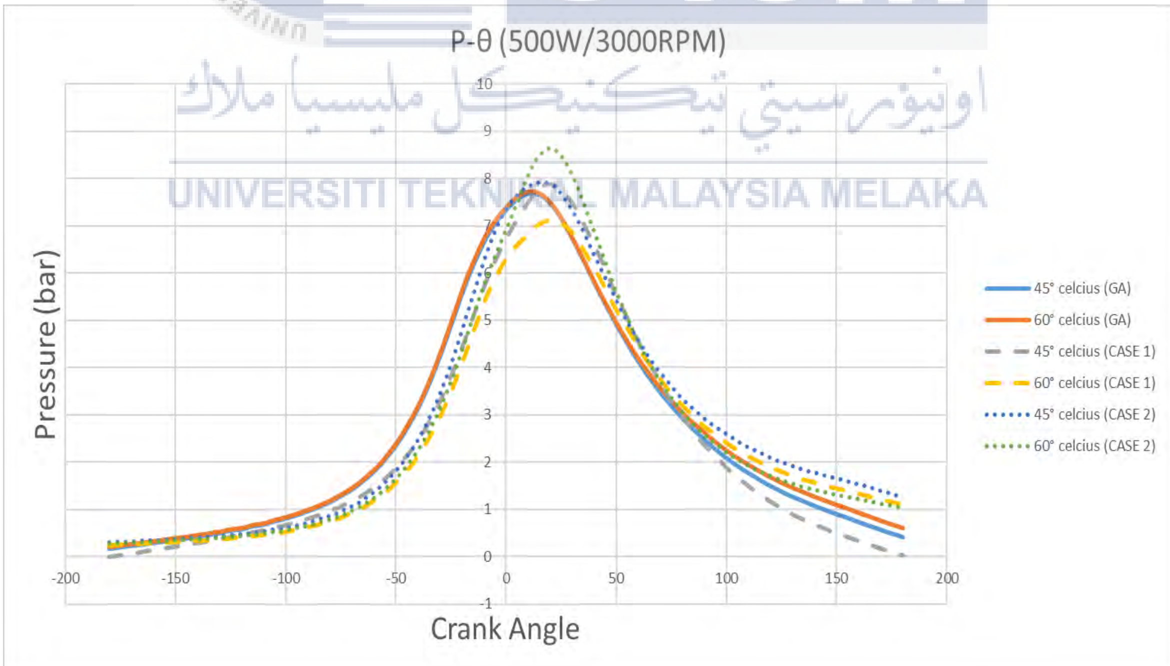


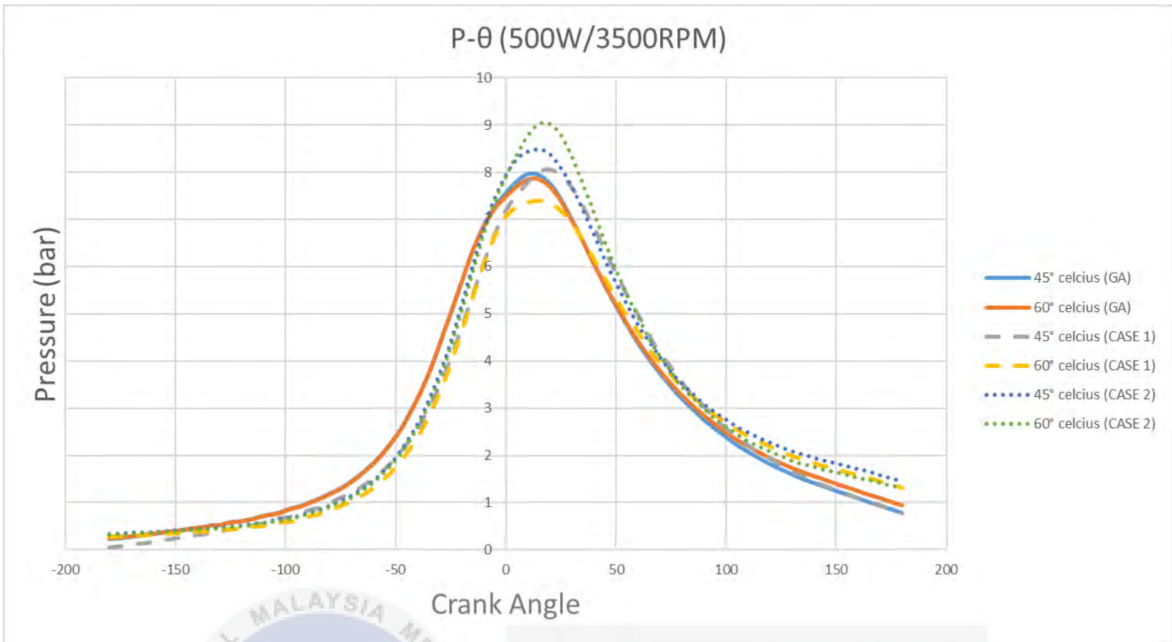
P-θ (1000W/3000RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

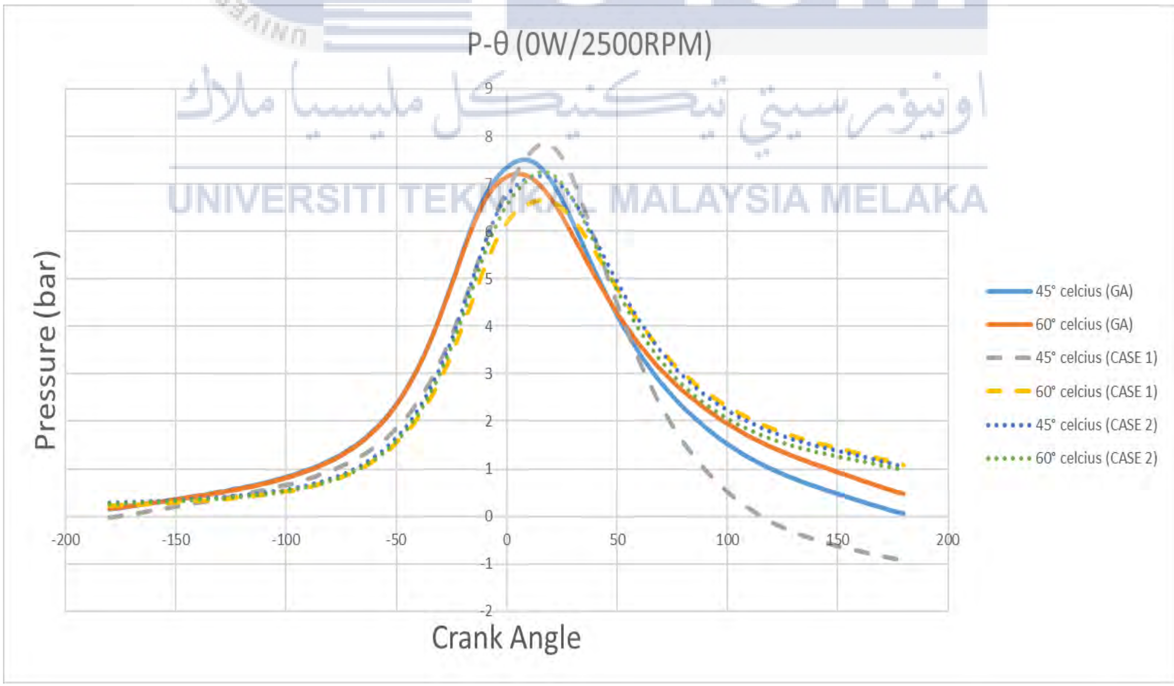


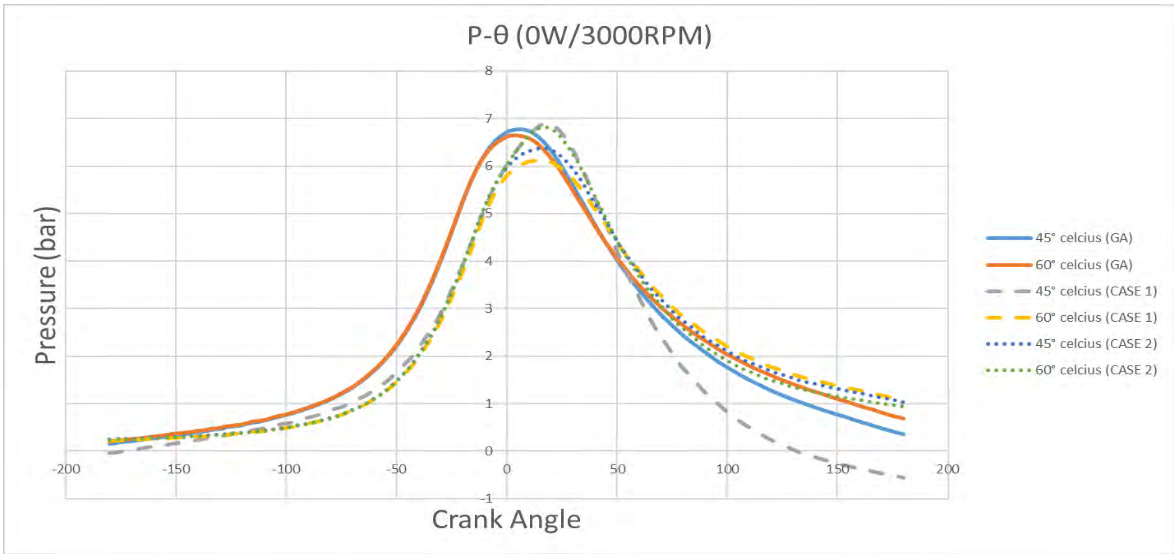
P-θ (1000W/3500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

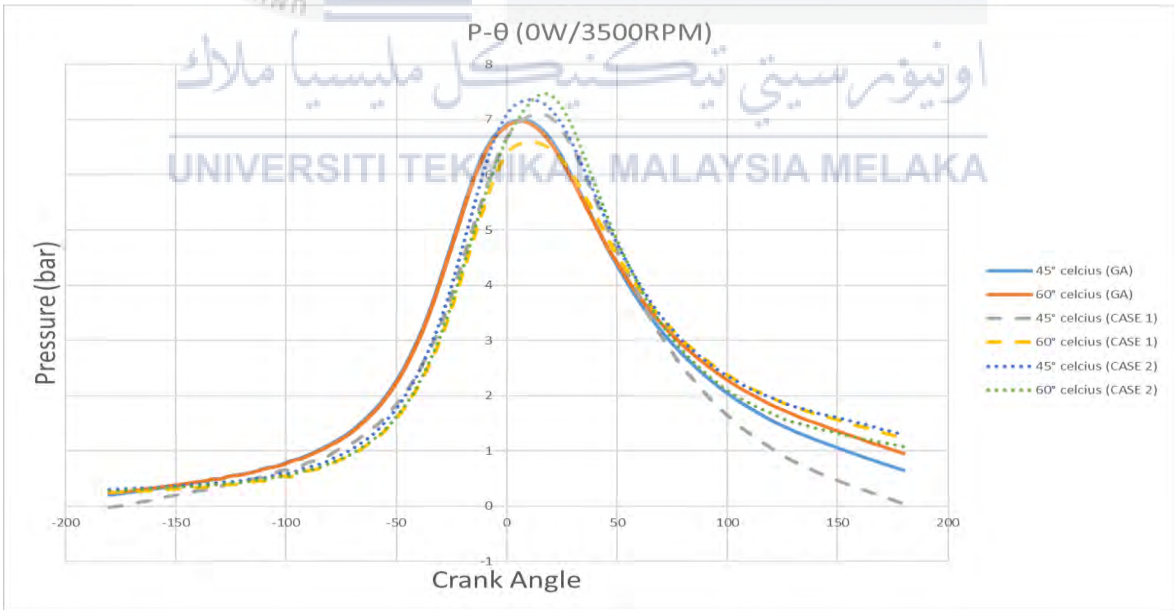

P-θ (500W/2500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)


P-θ (500W/3000RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

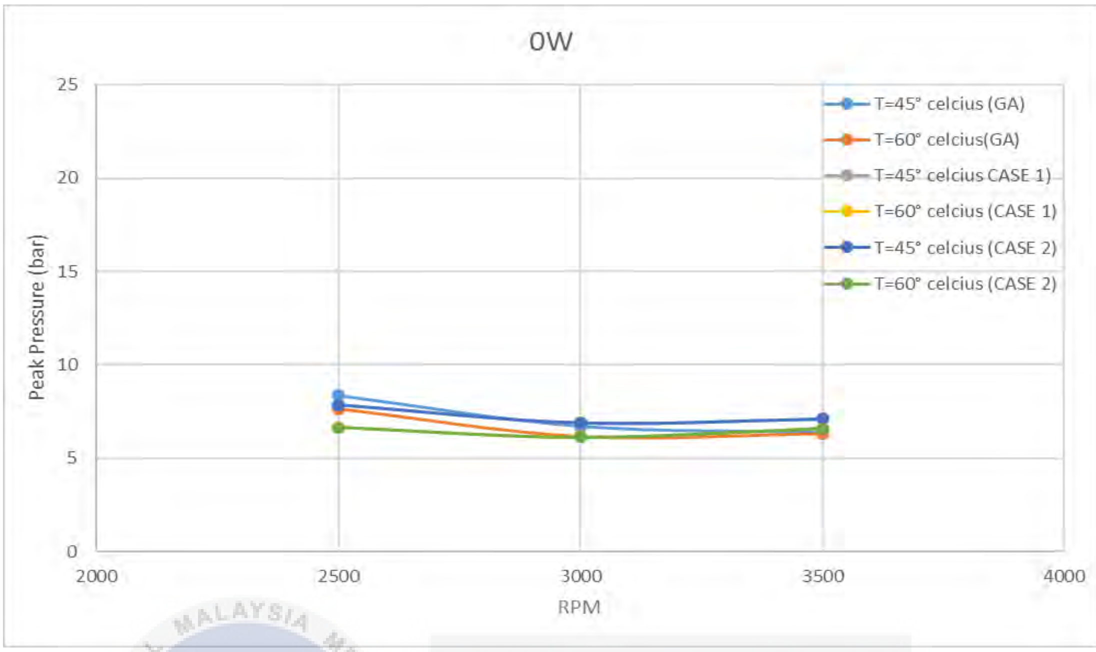

P-θ (500W/3500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

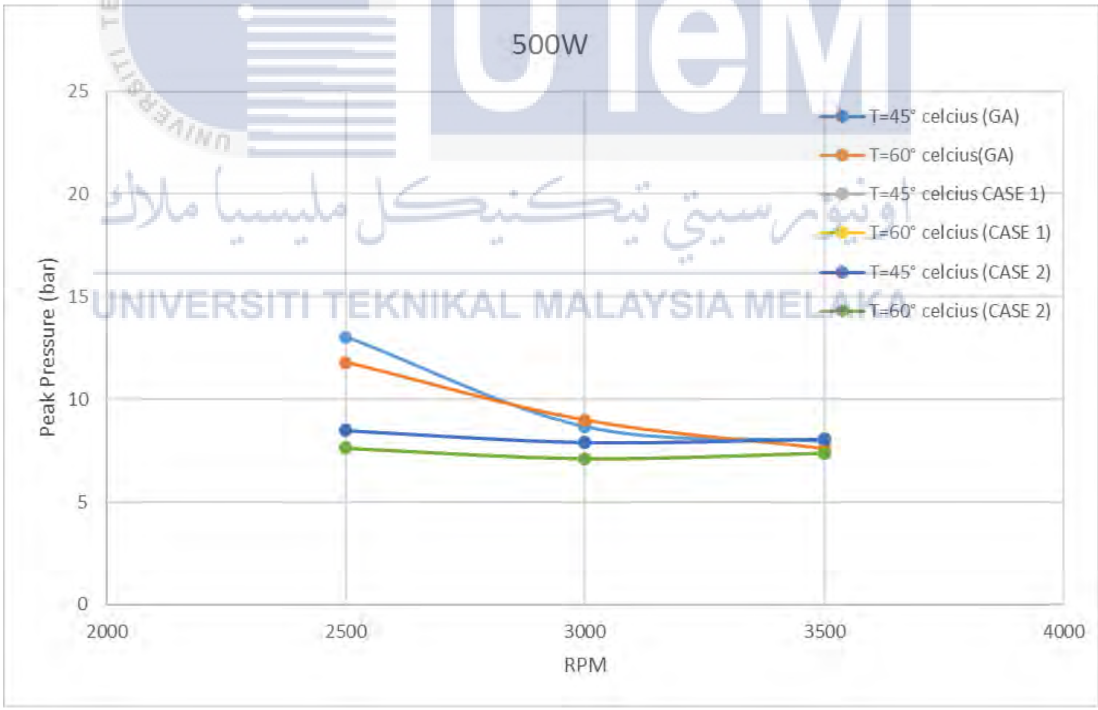

P-θ (0W/2500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

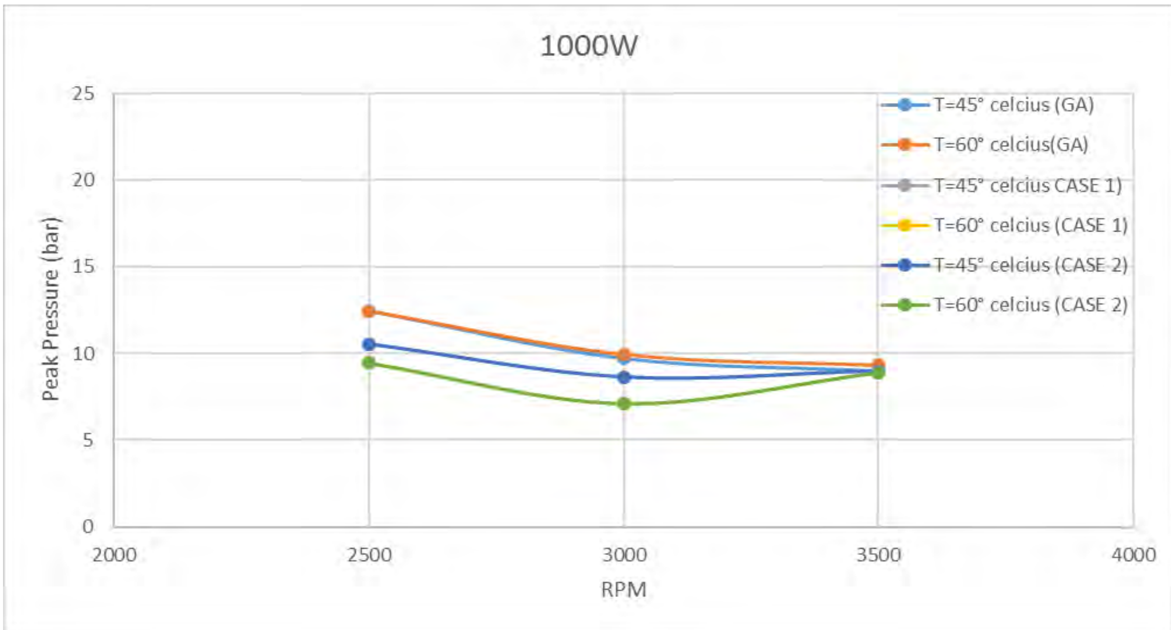

P-θ (0W/3000RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)


P-θ (0W/3500RPM)
Pressure (bar)
Crank Angle
45° celcius (GA)
60° celcius (GA)
45° celcius (CASE 1)
60° celcius (CASE 1)
45° celcius (CASE 2)
60° celcius (CASE 2)

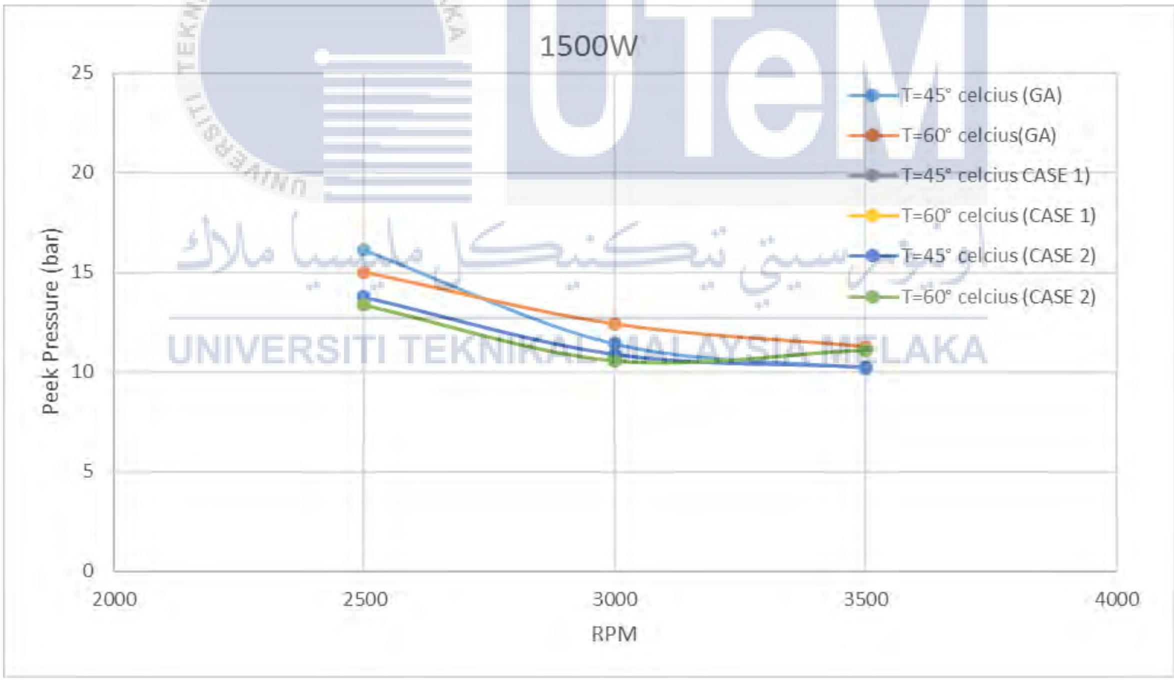
(B) Peak Pressure Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature



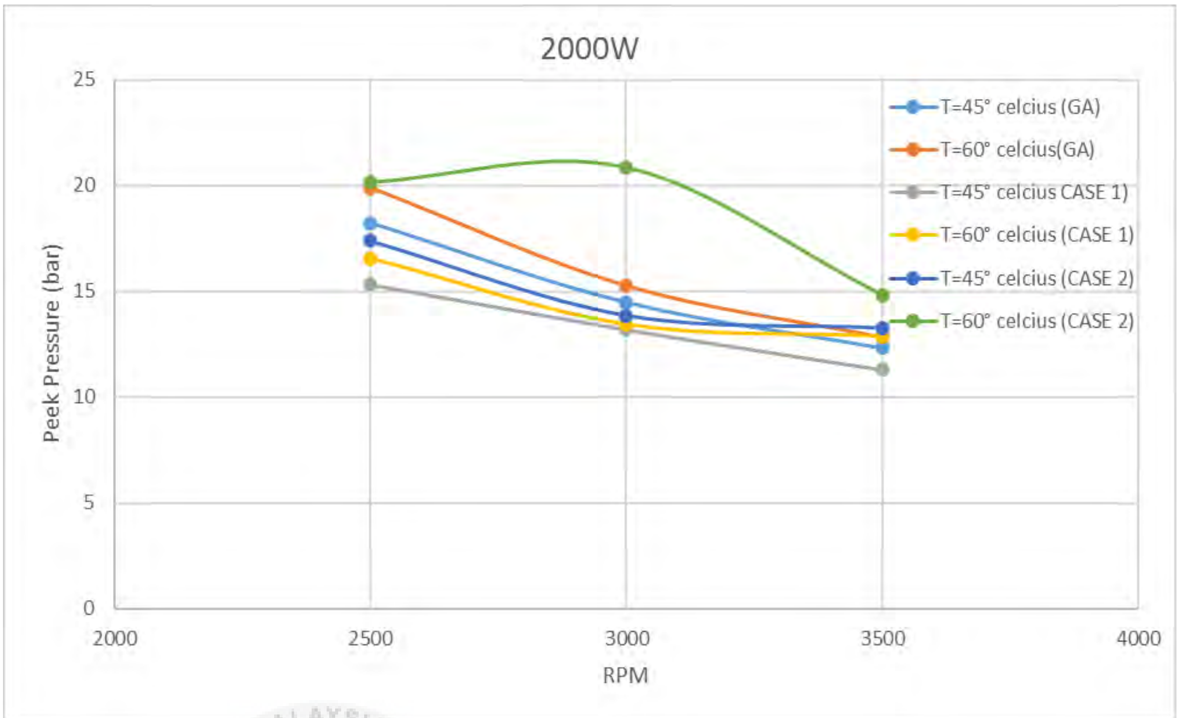




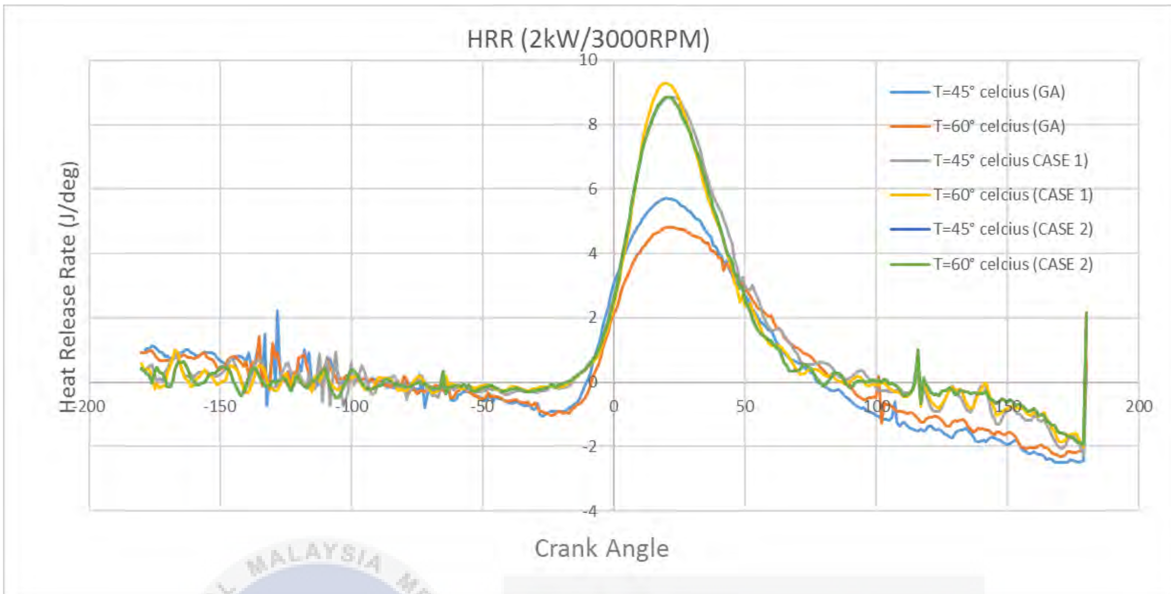
1000W
Peak Pressure (bar)
25
20
15
10
5
0
2000
2500
3000
3500
4000
RPM
T=45° celcius (GA)
T=60° celcius(GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

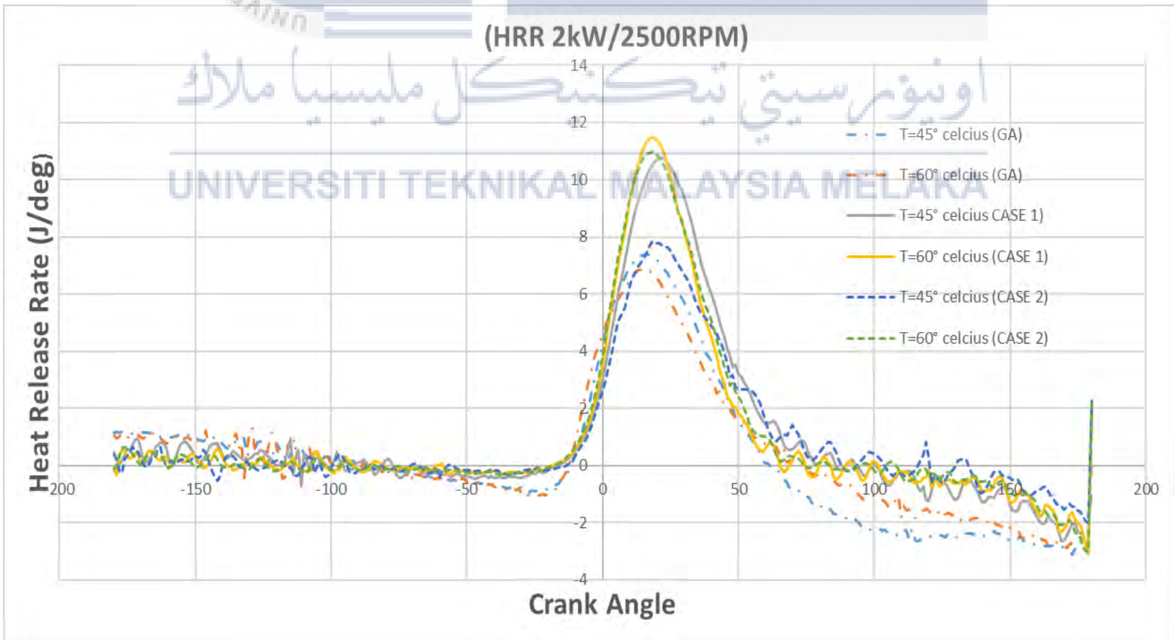


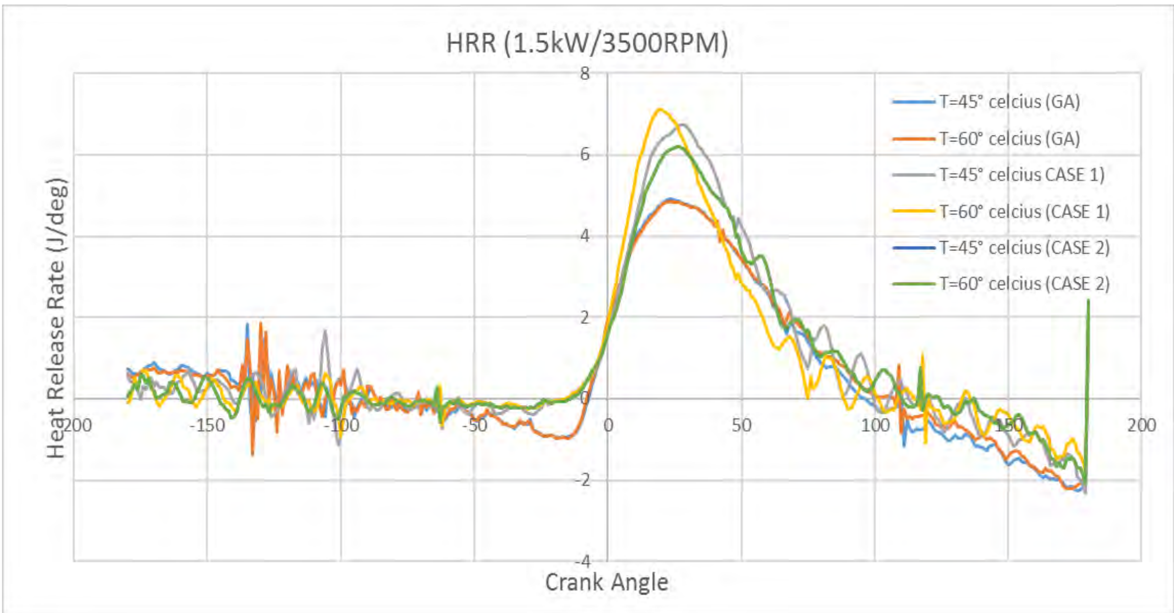
1500W
Peek Pressure (bar)
25
20
15
10
5
0
2000
2500
3000
3500
4000
RPM
T=45° celcius (GA)
T=60° celcius(GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

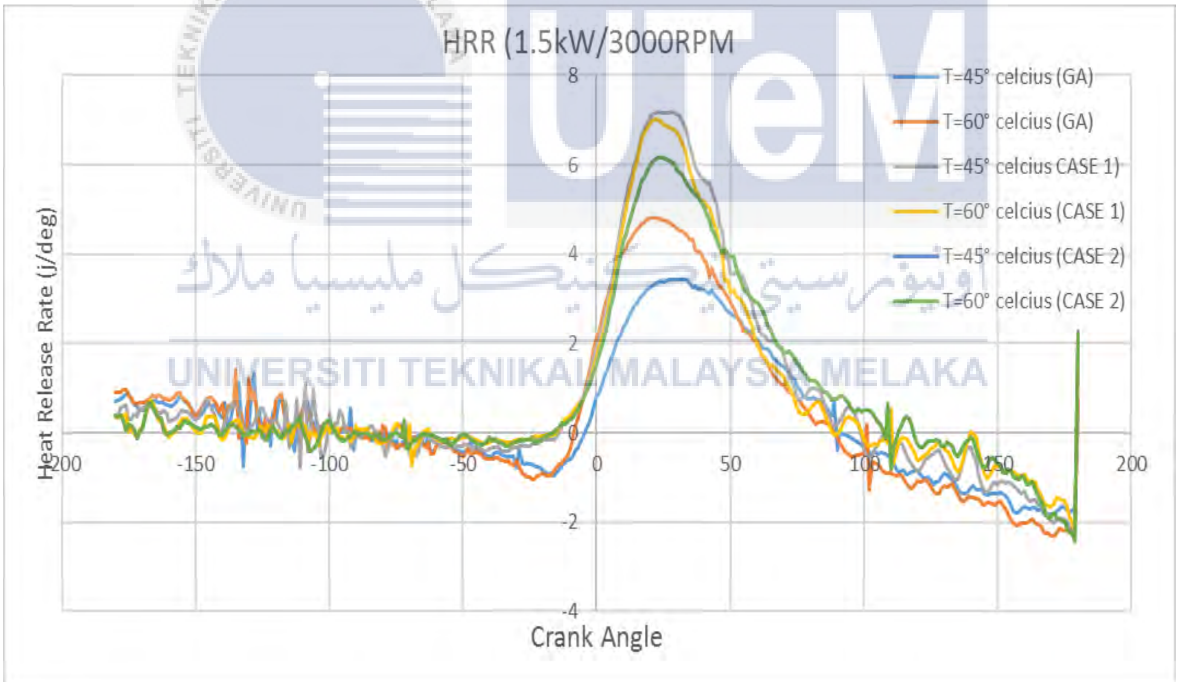

2000W
Peek Pressure (bar)
RPM
25
20
15
10
5
0
2000
2500
3000
3500
4000
T=45° celcius (GA)
T=60° celcius(GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

(C) Heat Release Rate Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature






HRR (1.5kW/3500RPM)
Heat Release Rate (J/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)
8
6
4
2
0
-2
-4
-200
-150
-100
-50
0
50
100
150
200


HRR (1.5kW/3000RPM)
Heat Release Rate (j/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)
8
6
4
2
0
-2
-4
-200
-150
-100
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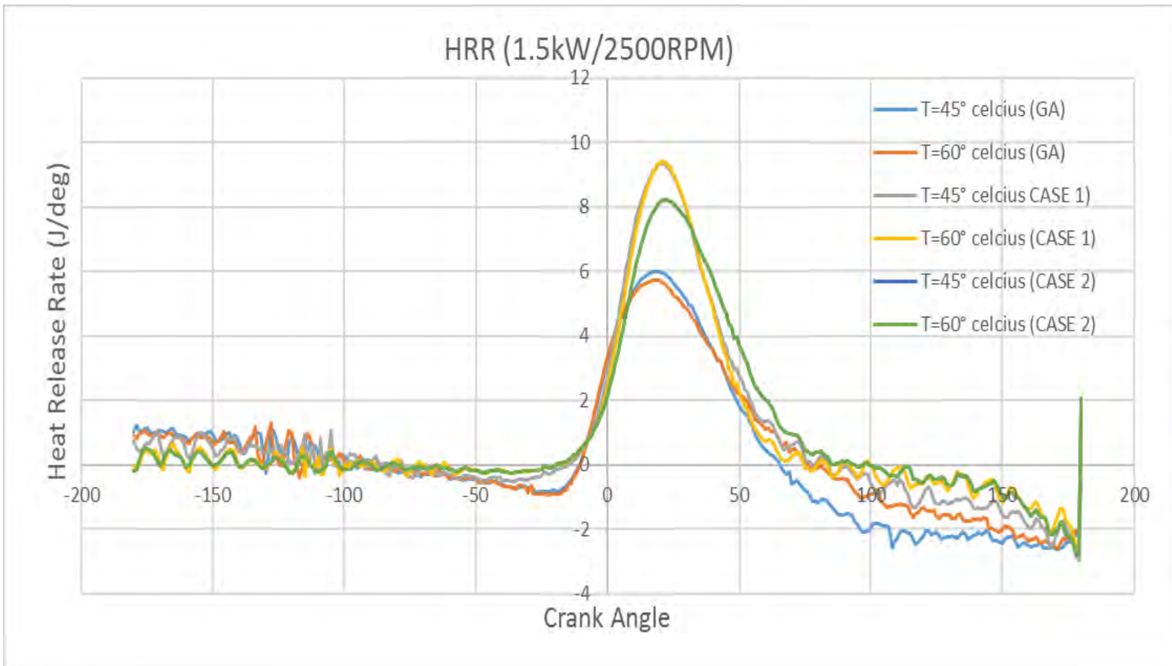
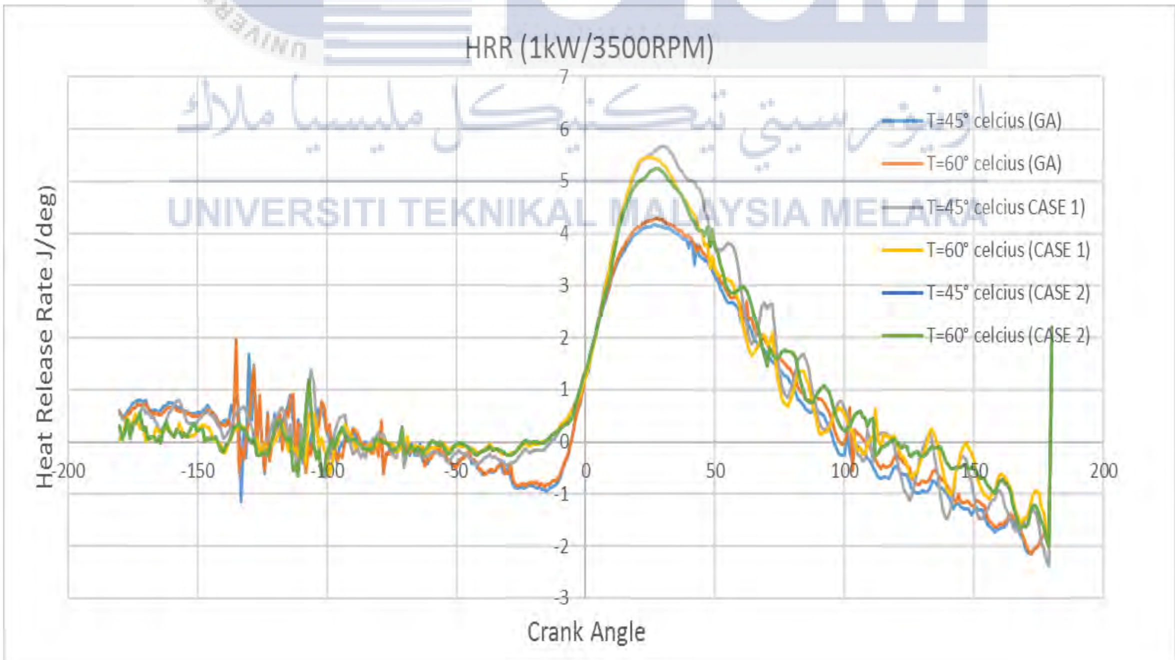
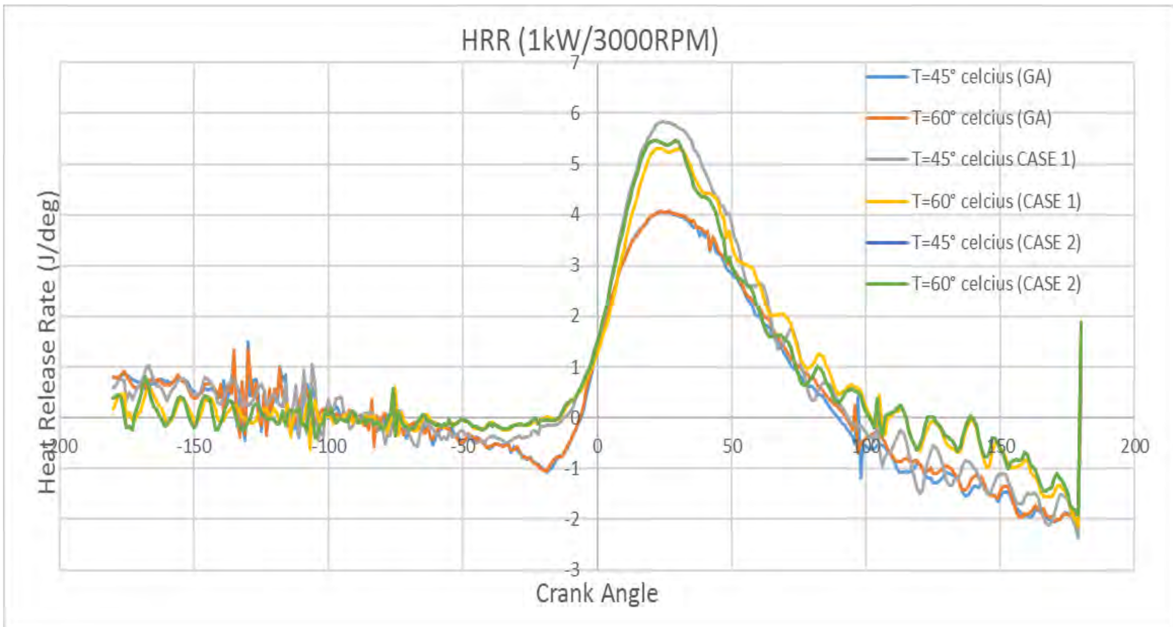
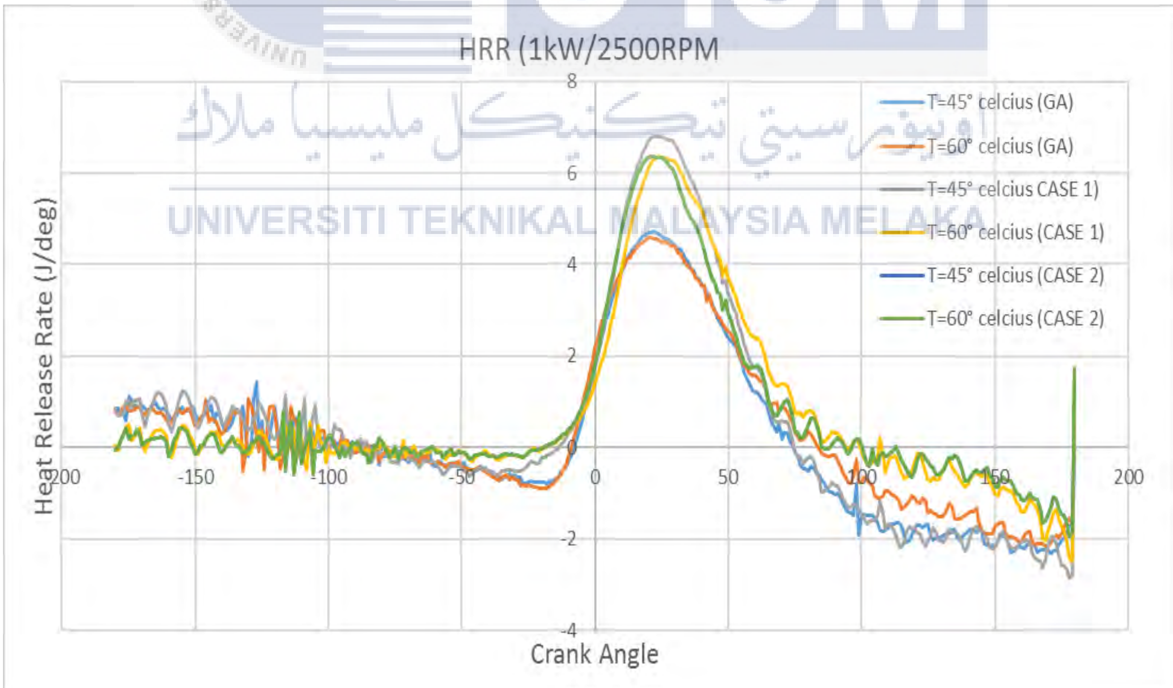
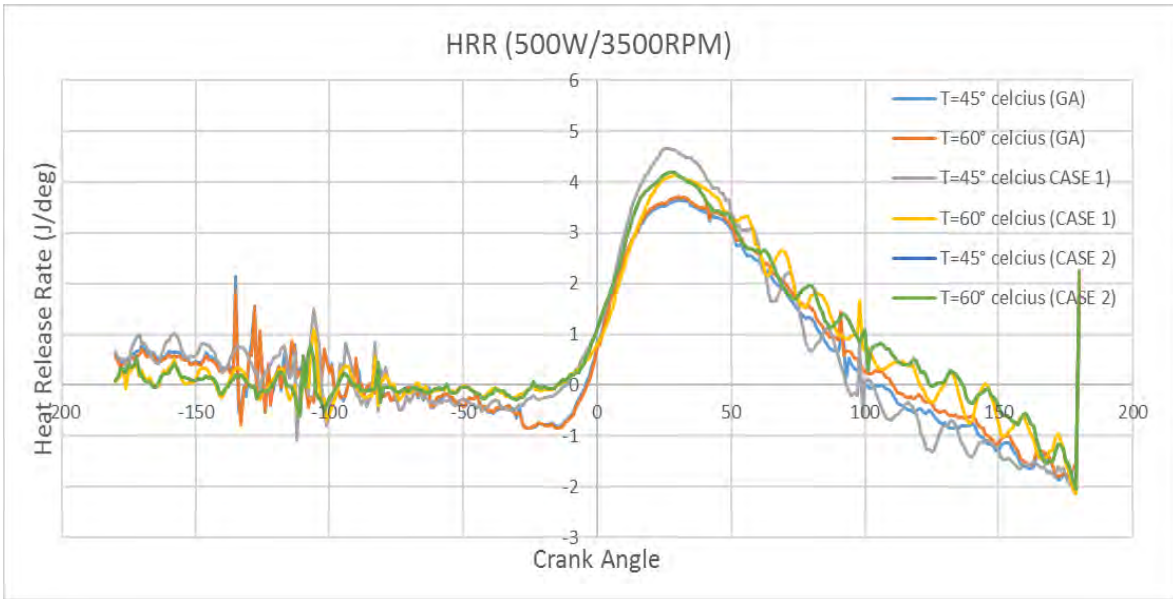
0
50
100
150
200


HRR (1.5kW/2500RPM)
Heat Release Rate (J/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

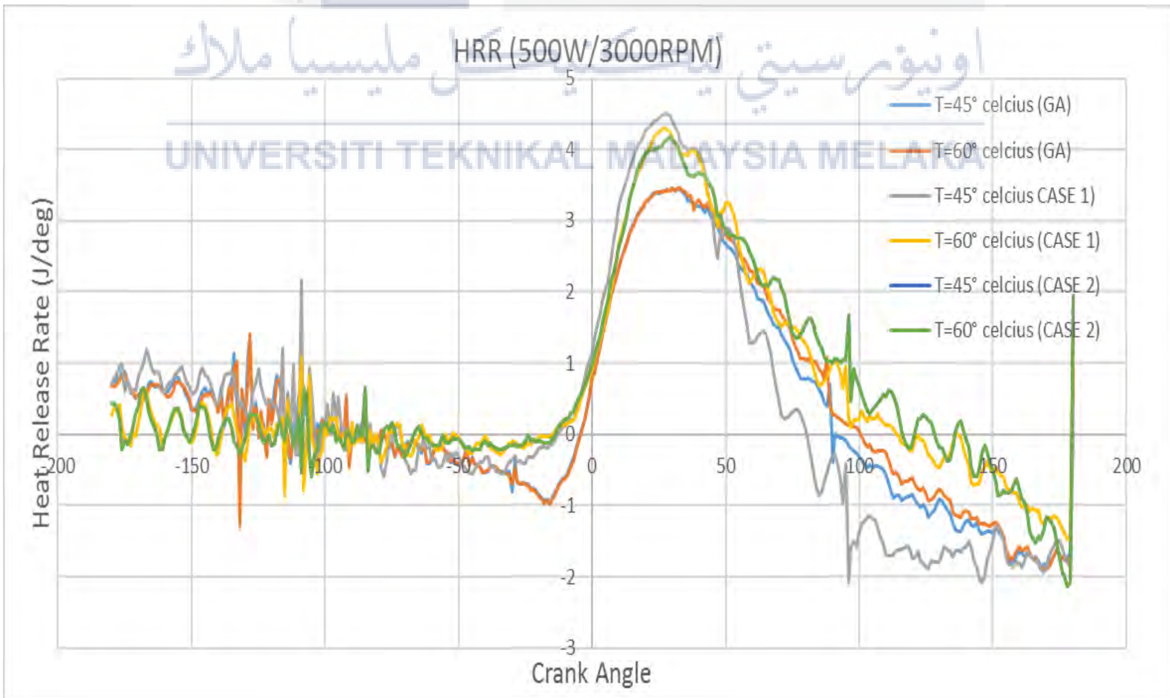

HRR (1kW/3500RPM)
Heat Release Rate J/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)


HRR (1kW/3000RPM)
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)
Heat Release Rate (J/deg)
Crank Angle

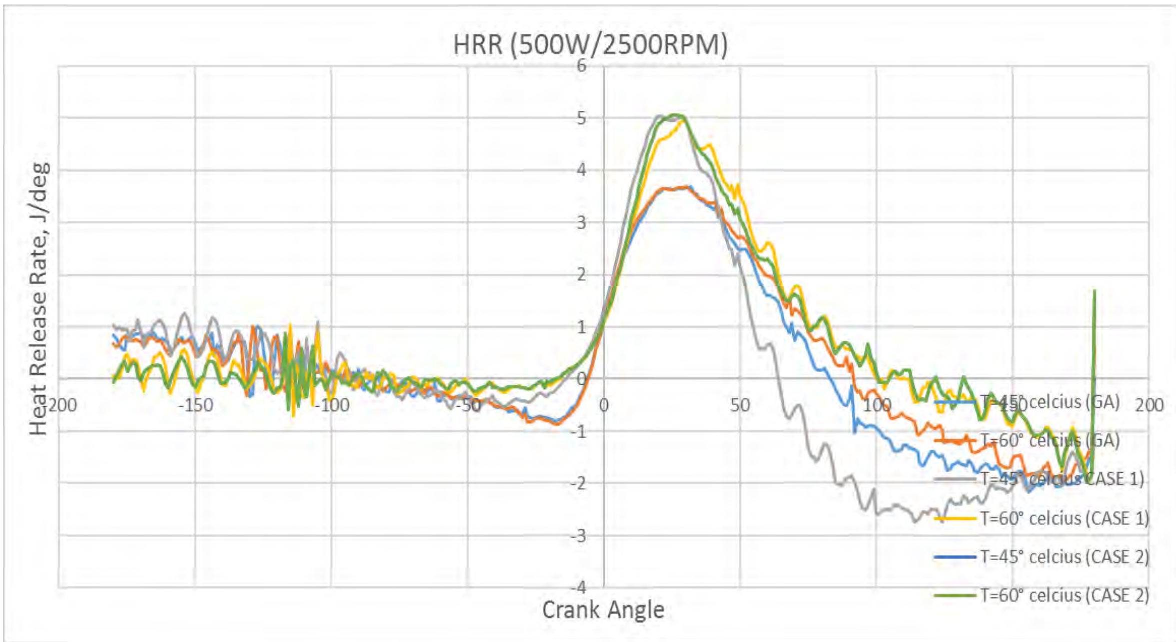

HRR (1kW/2500RPM
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)
Heat Release Rate (J/deg)
Crank Angle

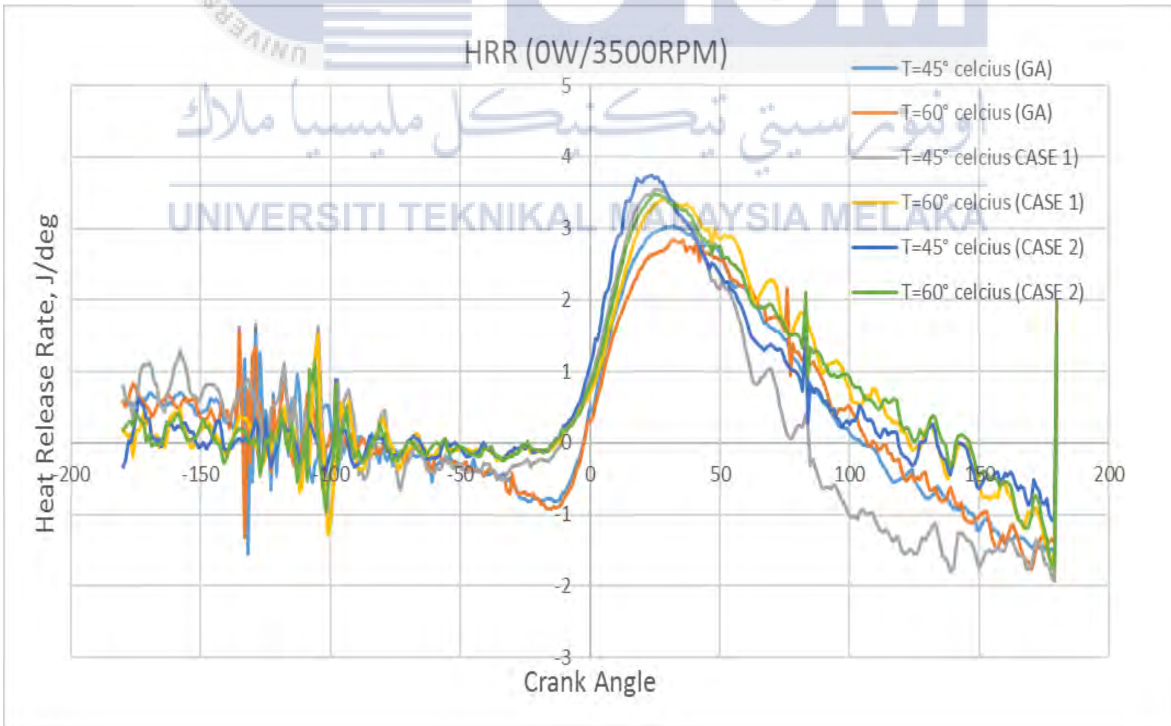


HRR (500W/3500RPM)
Heat Release Rate (J/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

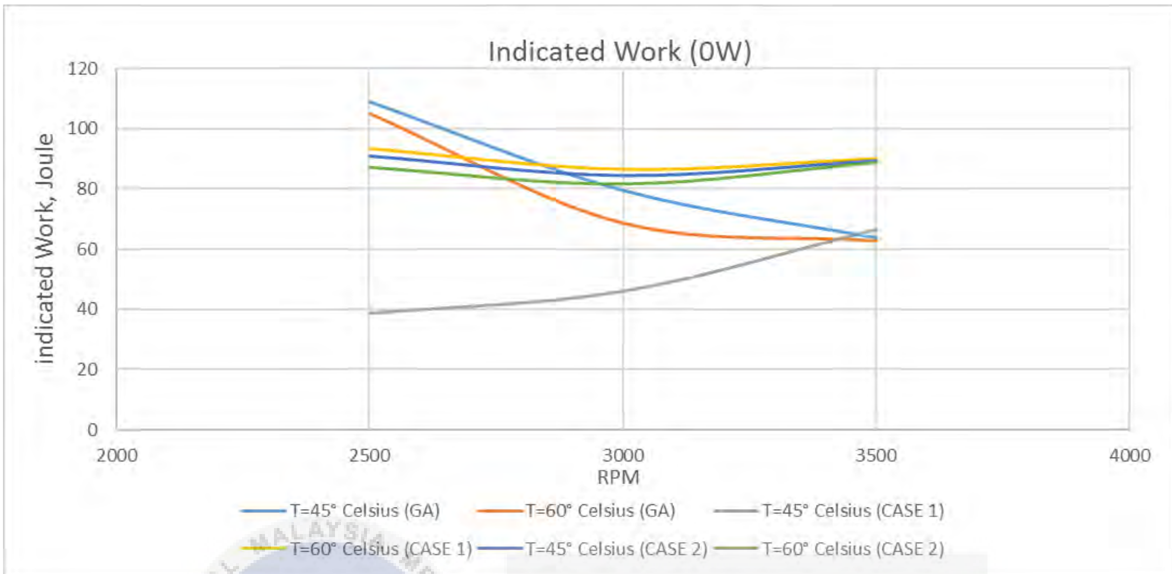


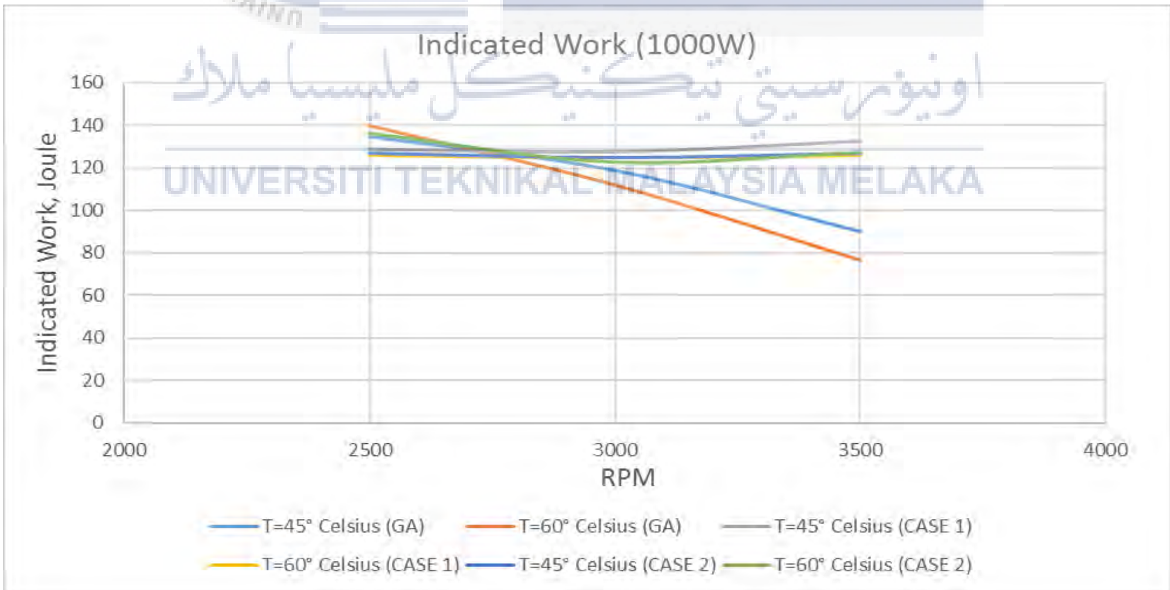
HRR (500W/3000RPM)
Heat Release Rate (J/deg)
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

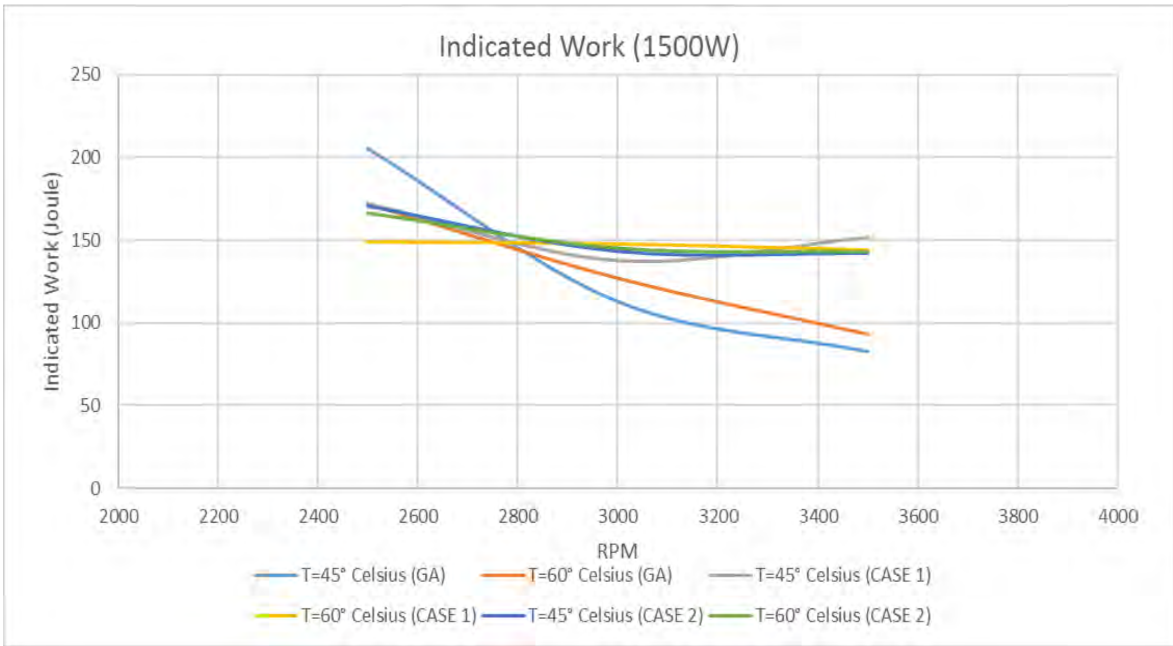

HRR (500W/2500RPM)
Heat Release Rate, J/deg
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

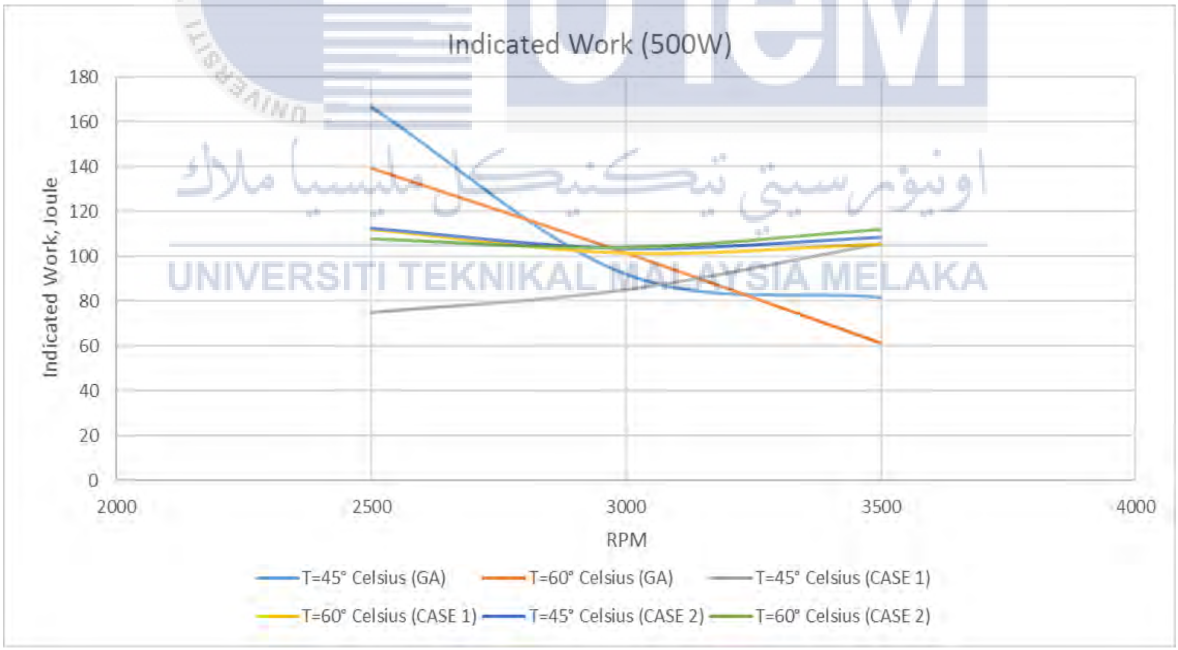

HRR (0W/3500RPM)
Heat Release Rate, J/deg
Crank Angle
T=45° celcius (GA)
T=60° celcius (GA)
T=45° celcius CASE 1)
T=60° celcius (CASE 1)
T=45° celcius (CASE 2)
T=60° celcius (CASE 2)

(D) Indicated Work Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature

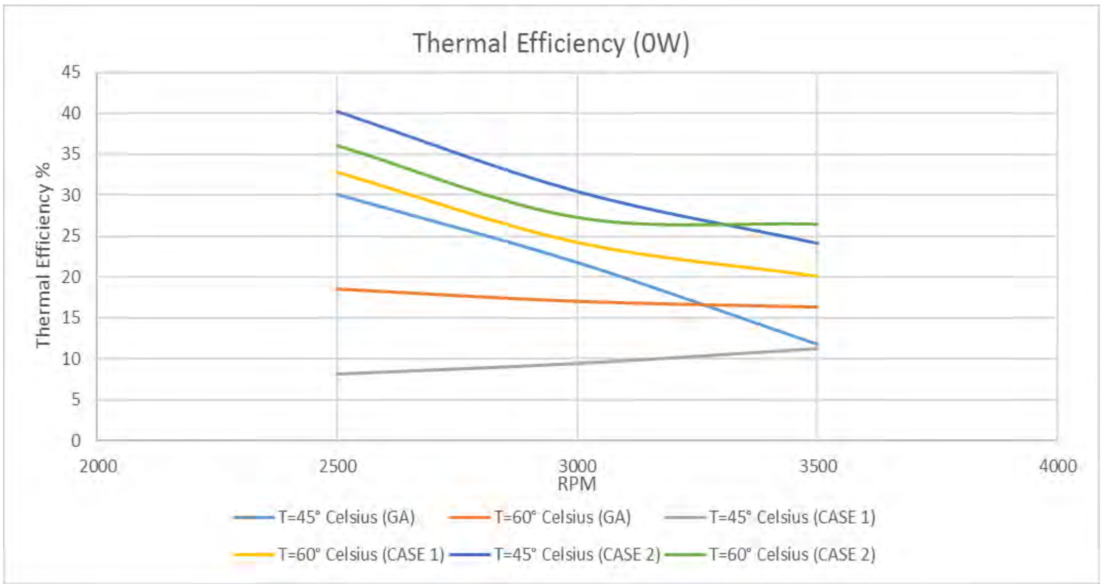


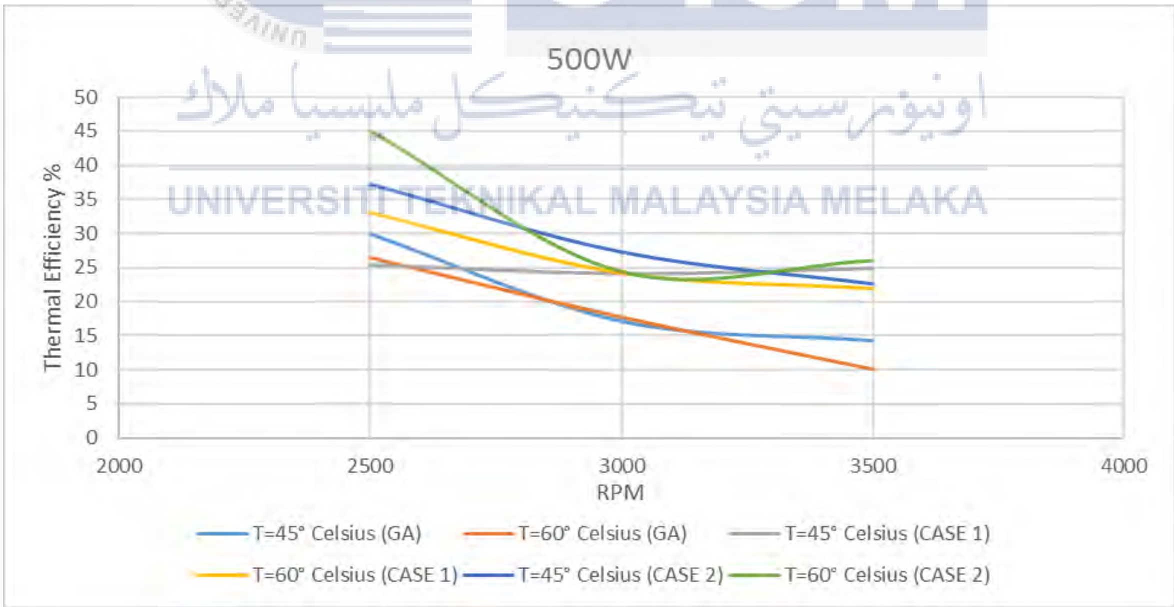


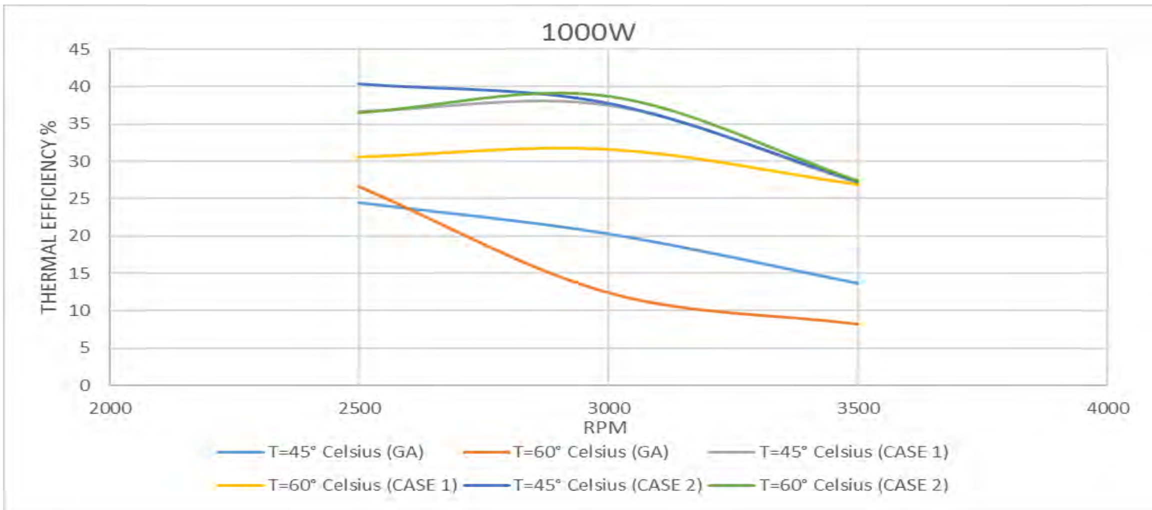

Indicated Work (1500W)
Indicated Work (Joule)
250
200
150
100
50
0
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)

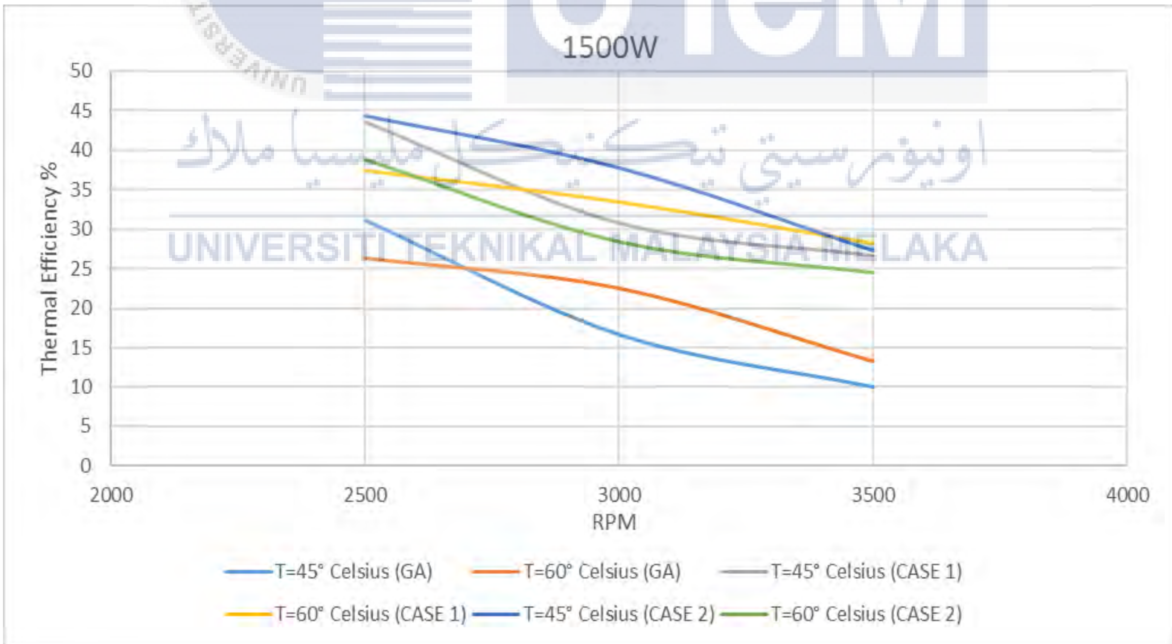

Indicated Work (500W)
Indicated Work, Joule
180
160
140
120
100
80
60
40
20
0
2000
2500
3000
3500
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)

(E) Indicated Thermal Efficiency Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature

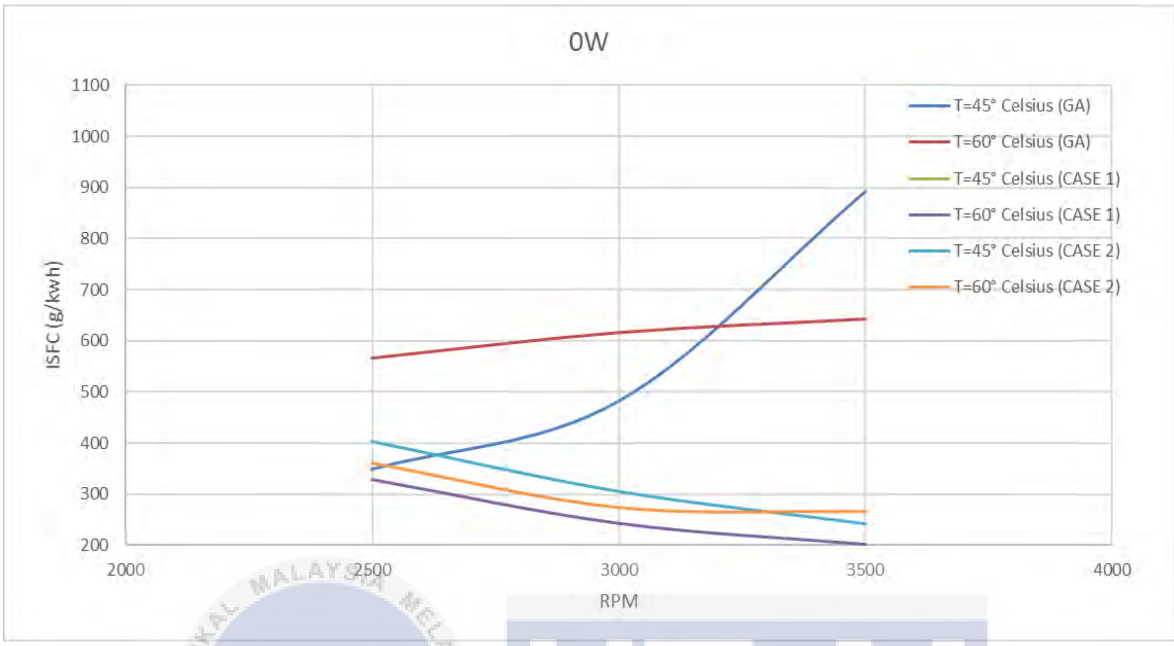


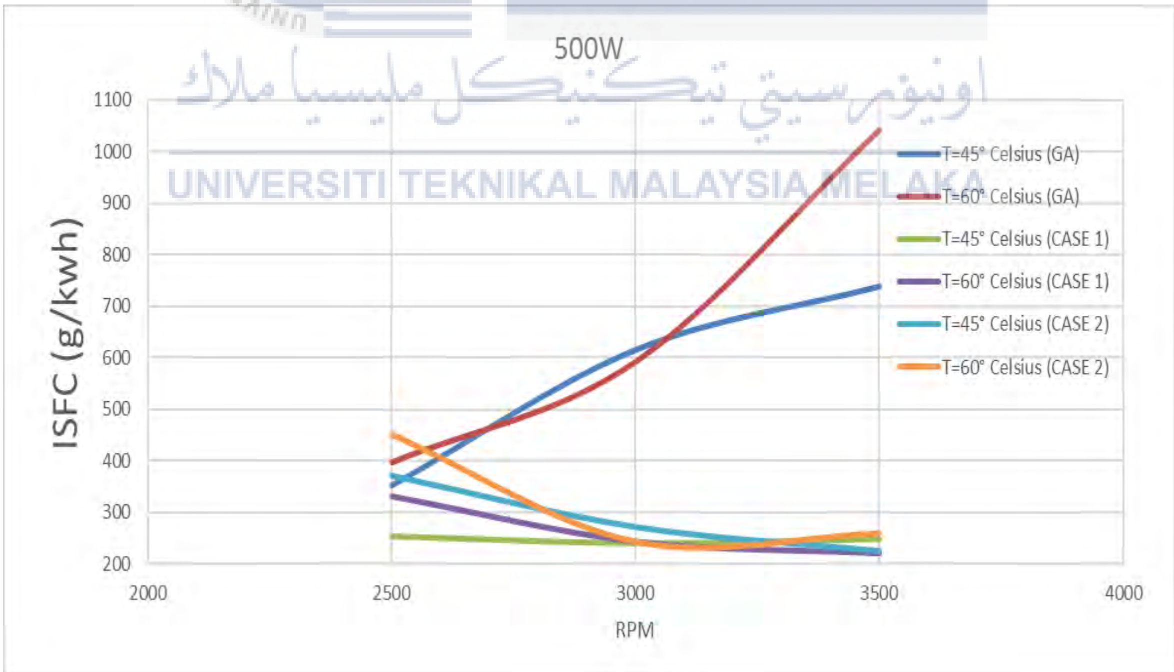


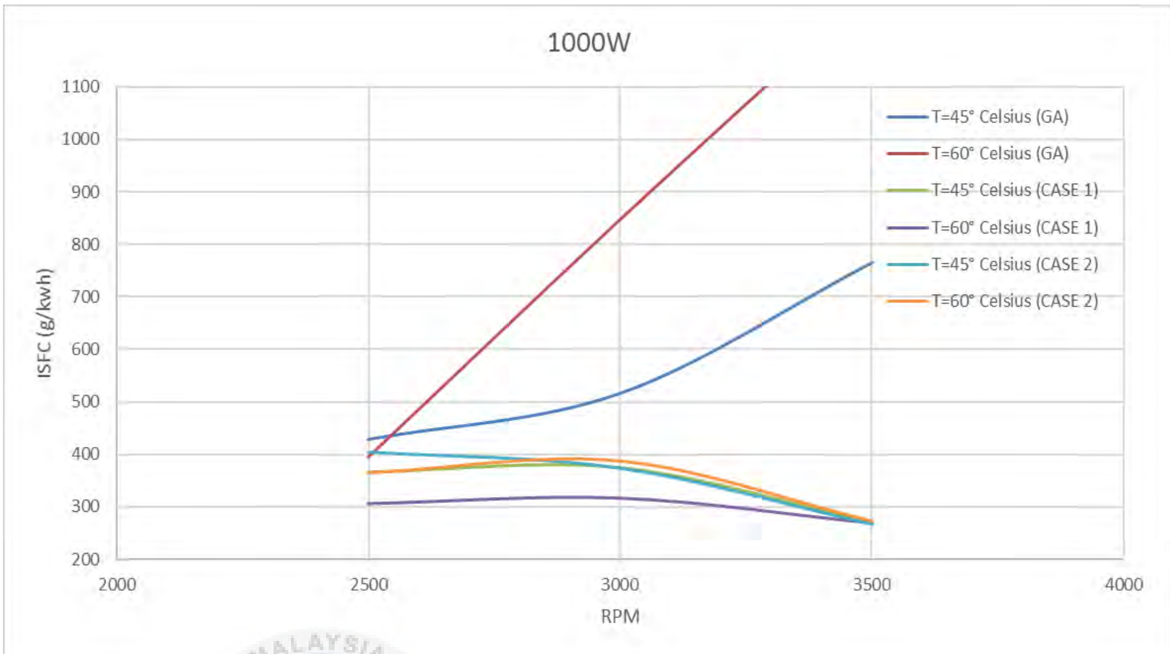

1000W
THERMAL EFFICIENCY %
45
40
35
30
25
20
15
10
5
0
2000
2500
3000
3500
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)

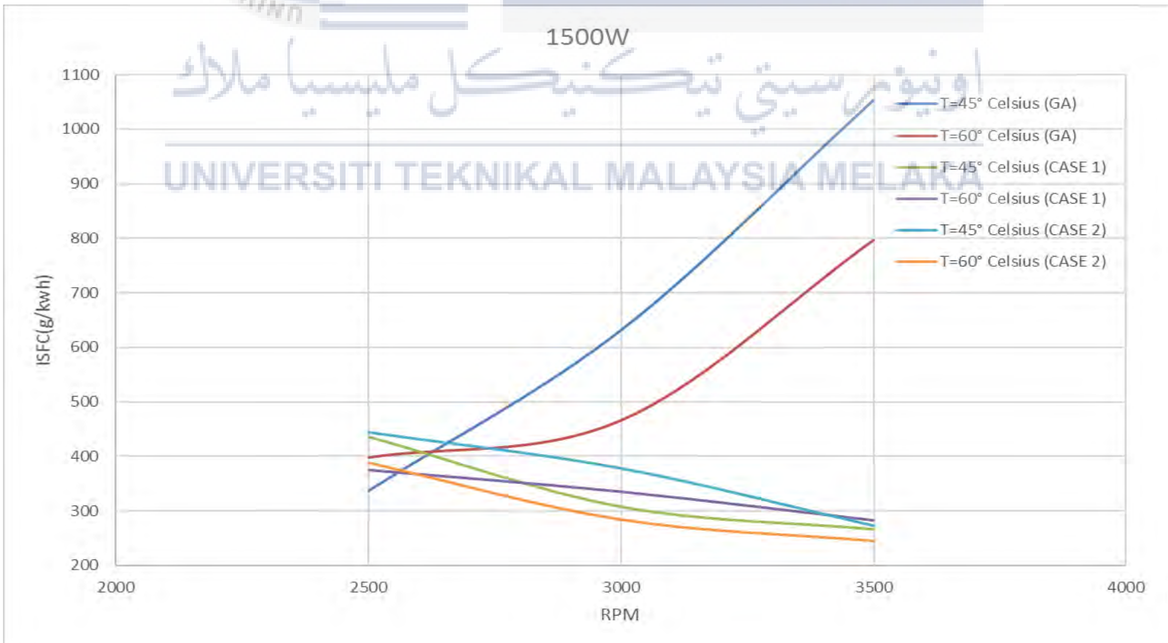

1500W
Thermal Efficiency %
50
45
40
35
30
25
20
15
10
5
0
2000
2500
3000
3500
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)

(F) Indicated Specific Fuel Consumption Graph for GA, CASE 1 and CASE 2 with Various Load and Fuel Temperature






1000W
1100
1000
900
800
700
600
500
400
300
200
ISFC (g/kwh)
2000
2500
3000
3500
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)


1500W
1100
1000
900
800
700
600
500
400
300
200
ISFC(g/kwh)
2000
2500
3000
3500
4000
RPM
T=45° Celsius (GA)
T=60° Celsius (GA)
T=45° Celsius (CASE 1)
T=60° Celsius (CASE 1)
T=45° Celsius (CASE 2)
T=60° Celsius (CASE 2)