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

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ABSTRACT

The aim of this experiment is to investigate the effect of intake air temperature on the performance of gasoline engine fueled with 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.

Keywords: spark ignition engine; hydrogen peroxide engine; SI engine fueled with hydrogen peroxide.

INTRODUCTION

Supplies of fossil fuels are dropping each year and it is reported that it will stand only for about 50 more years [1]. Besides that, environmental pollution by exhaust gas and reckless waste of non-renewable energy sources has become another major issue in transportation [2]. Transportation has become the central attention to modern industrial society, which lead to the rapid growth of vehicle usage and increases the rate of pollution simultaneously [3,4]. Nitrogen oxides (NOx) and particulate matter are some of the harmful pollutants coming from engines, which are very tough to reduce simultaneously [5]. Diesel engines released higher levels of carbon dioxide (CO_2), NOx and other harmful air pollutants per litre of fuel compared to gasoline engines [6]. Therefore, a lot of studies have been conducted to improve the performance, fuel economy and combustion technologies for gasoline and diesel engines [7]. Researchers have focused their interest on the gaseous fuels of renewable nature that are environmentally friendly [8-12]. Besides that, researches on alternative and renewable sources of energy are being extensively carried out [13]. Primarily, reduce the dependence on petroleum oil and reduce the emissions produced by vehicles are the objectives for using alternatives fuel in the transportation sector [14].

Hydrogen is one of the famous alternative fuels among researchers lately. It is a renewable, high-efficient, clean fuel, fast burning speed, high diffusion coefficient, wide firing range and low ignition energy that can potentially secure the future of diesel-type engines [15]. Furthermore, it also has a low ignition energy, wide flammability limit and excellent combustion rate [16]. Meanwhile, hydrogen peroxide (H_2O_2) is another trending alternative fuel among researchers recently. In recent studies, field works have been conducted to develop high performance catalyst to decompose H_2O_2 with respect to active materials and catalyst supports [17]. Nagaprasad and Madhu [18] found out that the brake thermal efficiency, $\eta_{b.th}$ of diesel engine increased when hydrogen peroxide is blended with the fuel which they concluded that additional oxygen molecule released by H_2O_2 has led to a better combustion. H_2O_2 is mostly considered to be an effective combustion catalyst for different fuels [19]. Bari and Esmaeil [20] identified that with a ratio of 6% H_2O_2 mixture at 19 kW, the maximum brake thermal efficiency increased from 32.0% to 34.6% when running on diesel. Another experimental investigation focuses on performance of diesel engine by injecting a blended H_2O_2 with diesel at 2%, 5% and 10% proportions [18]. They reported that the concentration of H_2O_2 increased along with the increment of break thermal efficiency. The heat release rate in Nguyen *et al.* [5] study indicated that the 15% of jatropha hydrogen peroxide emulsions (JHE) reduced compared to the light oil. Lastly, Bari and Esmaeil [20] determined that their break specific fuel consumption (BSFC) reduced from 262.7 g/kWh to 243.4 g/kWh at 19 kW with approximately 6.1% H_2O_2 induction into diesel.

METHODOLOGY

For this experiment, specimen ratio between gasoline and hydrogen peroxide were used. In first experiment, 100% gasoline alone was used without any mixture with H_2O_2. Meanwhile in second experiment, gasoline was blended with H_2O_2 which it needs to achieve 5 vol% H_2O_2 with 95 vol% gasoline, and 10 vol% H_2O_2 with 90 vol% gasoline. 40 °C and 60 °C of temperature were controlled by hot air gun. Hot air gun is a device that release hot air flow, and the heated air is directed to the inlet of the engine. The loads for this experiment are 500 W, 1000 W, 1500 W and 2000 W. The speed of the engine is 2500 rpm, 3000 rpm and 3500 rpm. Specification of

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engine and properties of H_2O_2 are shown in Table-1 and Table-2 respectively. Results were recorded by using data acquisition (DAQ) system by DEWESOFT software.

Table-1. Specification of gasoline 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

Table-2. Properties of H_2O_2.

Appearance	Colourless liquid
Concentration, %	50 %
Boiling point	114°C
Freezing point	-52 °
Specific gravity	1.20 $kg/m3$

RESULTS AND DISCUSSIONS

For this experiment, the results are divided into several parts such as volume, pressure and crank angle. Fuel consumption of oil were recorded with various engine speed at 40 °C and 60 °C by using gasoline alone (GA), 5% H_2O_2 and 10% H_2O_2 mixtures. Figure-1 and Figure-2 show the fuel consumption for GA at temperature of 40 °C and 60 °C respectively. The fuel consumption increased from zero load to 2000 W. This is because different temperature was used during the experiment.

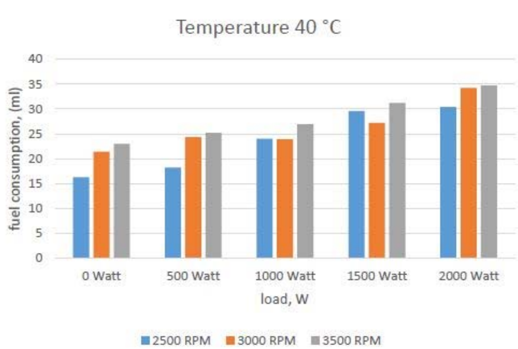

Figure-1. Gasoline alone at 40 °C.

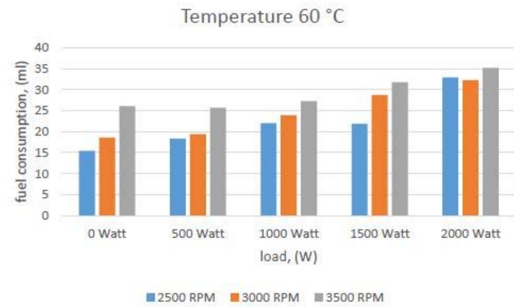

Figure-2. Gasoline alone at 60 °C.

Meanwhile, the fuel consumption for 5% H_2O_2 mixture at 40 °C and 60 °C are shown in Figure-3 and Figure-4 respectively. The graphs illustrated some increment for the fuel consumption as the engine loads increased. At 40 °C, the fuel consumption is mostly higher than the results at 60 °C, this is due to the percentage of mixture between gasoline and hydrogen peroxide. This mixture quickly vaporized and it generated more fuel consumption in engine.

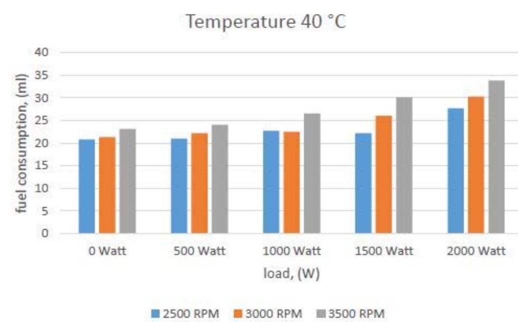

Figure-3. 5% H_2O_2 mixture at 40 °C.

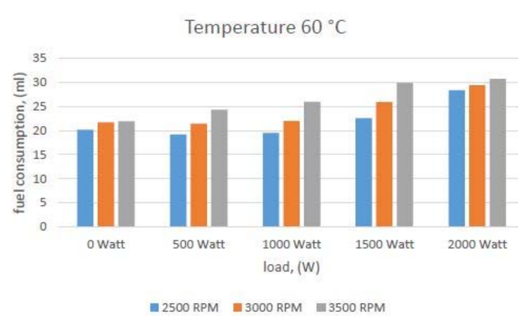

Figure-4. 5% H_2O_2 mixture at 60 °C.

Figure-5 and Figure-6 show the fuel consumption for 10% H_2O_2 mixture at 40 °C and 60 °C respectively. The fuel consumptions increased as the engine loads increased at both temperatures. The fuel consumption at 60 °C is higher compared to 40 °C which differed from the results of 5% H_2O_2 mixture. This is because the amount H_2O_2 percentage is higher. Therefore, the mixture is faster

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to vaporize and it generates more fuel consumption in the engine.

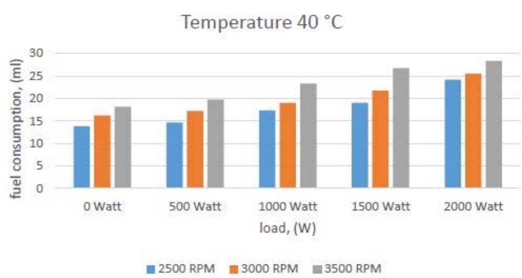

Figure-5. 10% H_2O_2 mixture at 40 °C.

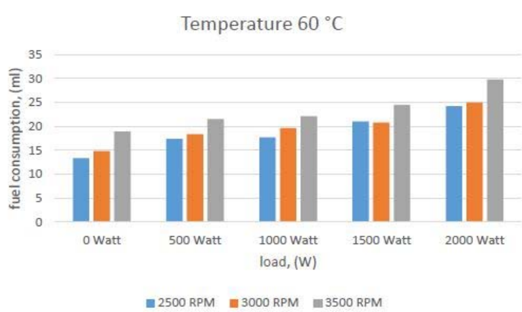

Figure-6. 10% H_2O_2 mixture at 60 °C.

P-θ DIAGRAM

The results from Figure-7 verified that all curves moved upward with the same pattern before top dead center (TDC) which occurred with normal combustion without pre-ignition. The pressure of for 10% H_2O_2 mixture is the highest compared to GA and 5% H_2O_2 mixture. The pressure curves for 10% H_2O_2 mixture shifted to the right and the pressure for GA and 5% H_2O_2 mixture ranged from 20° to 45°. There is an effect to promote the auto ignition in the engine and H_2O_2 has significant effect on promoting the auto ignition of hydrogen. The thermal decomposition reaction of H_2O_2 is the most important reaction for the production of hydroxide radicals which promotes hydrogen auto-ignition [21].

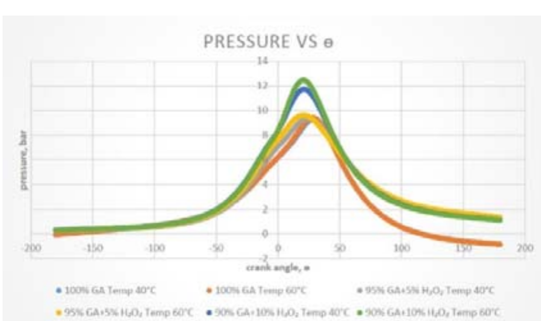

Figure-7. P-θ diagram with various temperatures at 3500 rpm.

P-V DIAGRAM

For the P-v diagram, the data recorded from BDC to TDC where it ranges from -180° to 180°. 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. Figure-8 shows the P-v diagram of GA. 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 $0.07 kPa.m3$. Meanwhile, for temperature 60 °C is $0.06 kPa.m3$.

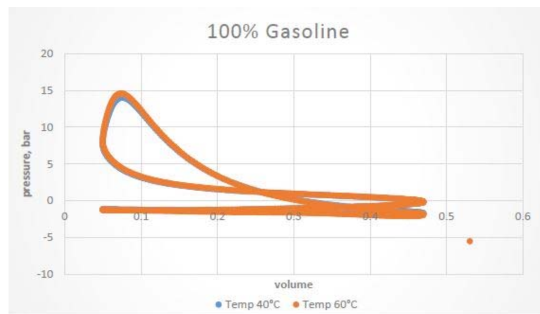

Figure-8. P-V diagram of GA.

Figure-9 shows the P-V diagram of 5% H_2O_2 mixture. 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 $0.1731 kPa.m3$. Meanwhile for temperature 60 °C is $0.1735\ kPa.m3$. Temperature at 40 °C is lower compared to temperature 60 °C due to lower pressure supplied to the engine.

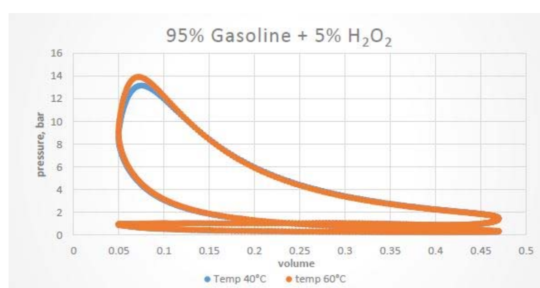

Figure-9. P-V diagram of 5% H_2O_2 mixture.

P-V diagram of 10% H_2O_2 mixture is shown in Figure-10. 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 $0.1636\ kPa.m3$. Meanwhile, for temperature 60 °C is $0.1735\ kPa.m3$. The temperature 60 °C is lower than temperature 40 °C

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because the specimen 10% hydrogen peroxide is higher than 5% hydrogen peroxide.

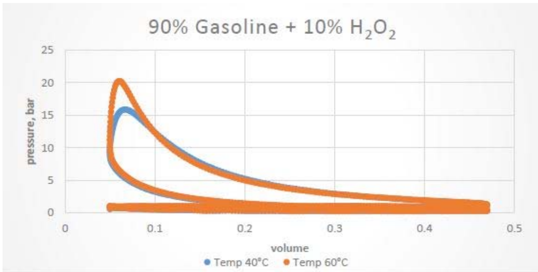

Figure-10. P-V diagram of 10% H_2O_2 mixture.

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. Figure-11 shows the peak pressure against engine speed. The graph illustrated that the peak pressure the peak pressure for GA, 5% H_2O_2 and 10% H_2O_2 mixtures reduced during increment of engine speed from 2500 rpm to 3500 rpm. Various pressures affected the pressure. Furthermore, the ratio is the main factor which causes increase of the different 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 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 remains 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 [20].

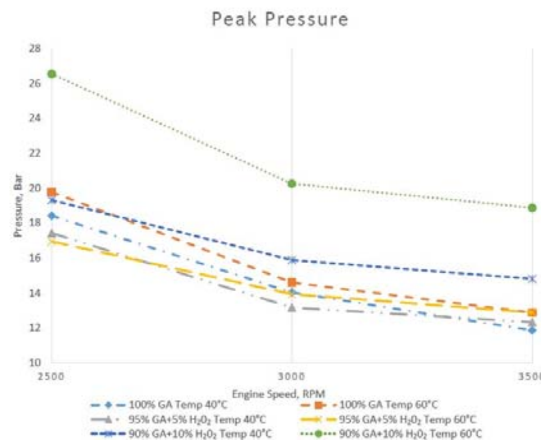

Figure-11. Peak pressure against engine speed.

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. Indicated work against engine speed is shown in Figure-12. 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 J. Meanwhile, with same properties for 5% H_2O_2 and 10% H_2O_2 is 168.1739 J and 155.69 J.

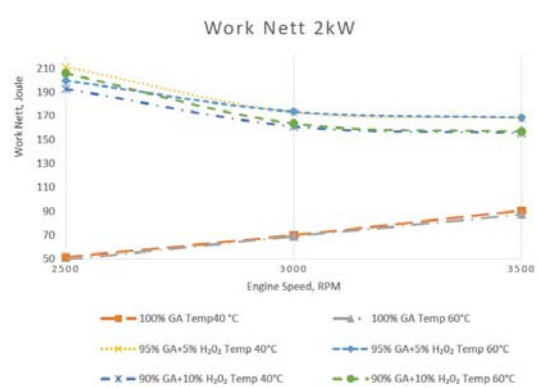

Figure-12. Indicated work against engine speed.

INDICATED POWER

Figure-13 shows the results of indicated power against engine speed. For gasoline alone, the result of the power increase from 2500 rpm until 3500 rpm 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

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differed. This is because, at temperature 60 °C, the result is higher than temperature 40 °C.

Figure-13. Indicated power against engine speed.

THERMAL EFFICIENCY

The outcomes for thermal efficiency at 2 kW is shown in Figure-14. For GA, the temperature is 40 °C which is higher than temperature of 60 °C where the value is 12.96% than 12.30% at 3500 rpm. However, for engine speed 3000 rpm, 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 3500 rpm as the value is 27.67% than 24.67%. Meanwhile, at engine speed 2500 rpm 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. 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%.

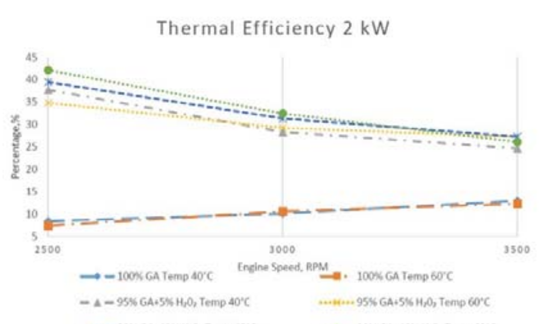

Figure-14. Thermal efficiency against engine speed at 2 kW.

INDICATED SPECIFIC FUEL CONSUMPTION

Figure-15 illustrates about the indicated specific fuel consumption (ISFC) against engine speed at 2 kW. For GA, the result showed that for temperature 60 °C is higher than temperature 40 °C with using engine speed 2500 rpm. The result is the same with using engine speed 3500 rpm. However, during using engine speed 3000 rpm the result of temperature 40 °C is higher than using temperature 60 °C. For 5% H_2O_2 mixture, the result for using temperature 40°C is higher than temperature 60 °C. This result is same between engine speed 3000 rpm and 3500 rpm. Meanwhile, for temperature 40 °C is lower than temperature 60 °C when using engine speed 2500 rpm.

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

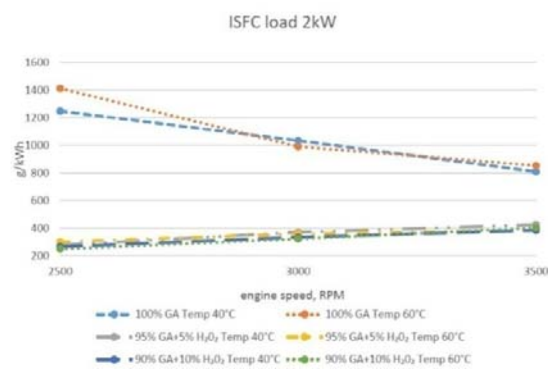

Figure-15. ISFC against engine speed at 2 kW.

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. These results can be seen in Figure-16 which illustrates about the heat release rate with engine loads of 2 kW at 3500 rpm. GA 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. Meanwhile, 5% H_2O_2 mixture shows the value before the maximum power is at positive point, until it reaches TDC. After reach to TDC, it continues consistent at positive point and until reach at 150^{o} of crank, it values goes to negative point until end of the crank angle.

Lastly, 10% H_2O_2 mixture indicated that 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.

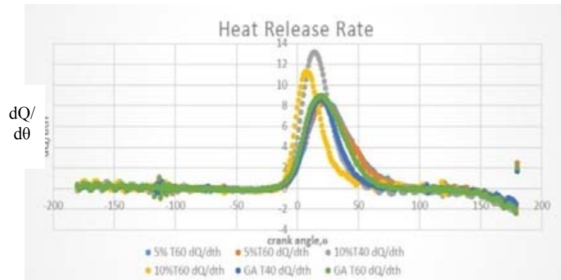

Figure-16. Heat release rate against engine speed at 2 kW.

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.

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