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ORIGINAL

Performance and Exhaust Emission of Spark Ignition Engine on Various Spark Plug Gap

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ABSTRACT – Spark plugs are components that play an important role in the ignition system of internal combustion engines. In this study, three spark plug gaps have been varied to investigate the combustion process in the combustion chamber by evaluating engine performance and exhaust emissions. The type of engine used for testing is a 1 cylinder 4 stroke engine with a capacity of 125cc using RON 90 fuel. The variations in spark plug electrode gaps applied are 0.4, 0.6 and 0.8 mm. Engine performance and emission levels were tested using a Rextro pro-dyno dynamometer and a techno test gas analyzer. Several main parameters of engine performance such as torque, power and fuel consumption were observed in three different variations and exhaust gases such as CO, CO2, HC and O2 were also observed. The results showed that engine performance increased. The highest increase in engine performance was at a spark plug gap of 0.8 mm compared to other spark plug gap variations. The resulting exhaust emissions increased in all spark plug gap parameters. Maximum power is achieved at 6.86 kW and maximum torque is 8.86 Nm at a spark plug gap of 0.8 mm. Low exhaust emissions are produced at a spark plug gap of 0.4 mm

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1.0 INTRODUCTION

This should provide an adequate background and general context for the work, explaining its significance, and indicating why it should be of interest to researchers. Avoiding a detailed literature survey or a summary of the results. State the objectives of the study at the end of this section.

Technological developments in the automotive sector are so rapid that both the quality and quantity of spark plugs are highly desirable to improve performance. Advanced technology-driven engines are increasingly being used in motor vehicles. [1]. In developed countries, many new types of vehicles have emerged, each equipped with superior and high-quality features. Spare parts manufacturers have made a breakthrough by producing necessary parts, such as spark plugs, which are generally intended for gasoline-powered vehicle engines [2]. In recent decades, internal combustion engines have been used and developed to meet demand due to their high efficiency, power and low pollutant emissions. [3]. In general, 4-stroke engines are highly sought after by people in developed countries. One example is improving the ignition system, namely by using the right spark plugs. Using the right spark plugs will also increase the engine's compression. The spark plug is the most important component affecting engine operating efficiency, resulting in high combustion output and high power output.[4].

The spark plug is a very important and vital part of a motorcycle's ignition system. A motorcycle's engine won't start if the spark plug is dead. Spark plugs function, including igniting or producing sparks as part of the combustion process within the engine. Spark plugs also act as an ignition system, storing electrical energy in a magnetic coil and releasing it through the spark plug electrode gap, located in the combustion chamber.[5][6]. The amount of power produced by a motorbike is determined by the supply of a certain amount of fuel into the cylinder due to the combustion process [7]. The combustion that occurs in the combustion chamber produces engine power in a motorcycle. The mixing of air and fuel in the cylinder, combined with the spark from the spark plug, results in combustion [8]. Combustion in the combustion chamber causes temperature to rise, followed by increased pressure in the combustion chamber cylinder. This allows the engine's pistons to move steadily, allowing the engine to operate. One of the vehicle engine parts installed in the combustion chamber is the spark plug [5]. The electrode located in the center of the spark plug is the source of the spark, which originates from the ignition coil outside the spark plug. Currently, spark plugs are divided into two types: hot and cold. Hot spark plugs are those that cool slowly through a long insulator. Cold spark plugs are those that rapidly transfer heat to the cylinder wall. Currently, almost all motorcycle users desire vehicles with high power and fuel efficiency. The automotive industry is still struggling to produce vehicles that meet these criteria.

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One factor that can improve engine performance is increasing compression pressure. The size of the compression pressure significantly affects the engine's power output. [9]. Turning the cylinder will reduce the volume of the combustion chamber, which is one way to increase engine compression. One of the simplest ways is to adjust the electrode gap on a standard spark plug. Setting the spark plug gap is certainly not arbitrary. The distance between the spark plug electrode and the spark plug ground determines the spark or spark jump. The correct spark or spark jump will impact engine performance. The ability of the spark plug to jump depends on the spark plug gap setting. A spark plug gap that is too large will impact the spark jump. A large spark plug gap is sometimes caused by wear on the spark plug. Accurately adjusting the spark plug electrode gap is crucial, as it will impact engine performance. One effect of spark plug gap on engine performance is power, torque, and fuel consumption.[10][11]. Over the past few decades, numerous studies have been conducted to investigate the effect of spark plug design on the performance of Spark-Ignition (SI) engines. Spark plug firing tip design features such as gap projection, gap size, electrode size, and tip configuration have been shown to influence engine performance.[12][13]. Other researchers also state that the most important factors affecting vehicle comfort and performance are exhaust emissions, noise, and vibrations generated by the combustion process. Failure to ignite the spark plug will result in increased emissions, noise, and vibration.[4].

Several studies have been conducted to determine the influence of spark plug type and gap on engine performance. One such experiment was conducted by Ogus Bas et al., which analyzed the effect of varying spark plug types and gaps on engine performance.[14]. The results of the experiment showed that the greater the gap between the spark plug electrodes, the greater the engine's power and torque. In addition to the increased power and torque, fuel consumption also increased[14][15].

With regard to spark plug technology, the spark plug gap is thought to produce a spark that will affect combustion quality. In this study, three spark plug gap settings will be investigated more thoroughly using a single-cylinder, four-stroke gasoline engine.

2.0 METHODS AND MATERIAL

A four stroke gasoline engine was selected in this test to determine the engine performance characteristics. [16]. The spark plug gap parameter was chosen by researchers to observe engine performance and emissions [17]. These parameters refer to research conducted by Ogus Bas et al. [14]. Adapun Material yang dipakai dalam penelitian ini adalah menggunakan type Busi standart dengan Merk Denso U22FS-U. As shown in Figure 1, the spark plug electrode gap will be reset according to the researcher's parameters. The parameters used in this research are 0.4 mm, 0.6 mm, and 0.8 mm. The steps taken in this research include preparing the spark plug material, such as resetting the spark plug electrode gap, as shown in Figure 2.

Figure 1. Standard Denso U22FS-U spark plug

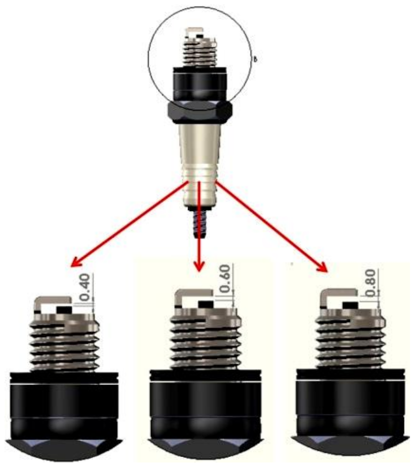


Figure 2. Schematic of spark plug electrode gap a). 0.4 mm, b). 0.6 mm, c). 0.8 mm

Figure 2 shows a schematic of the spark plug electrode gap that the researchers will use for the experiment. The spark plug specifications are shown in Table 1.

Tabel 1. Denso U22FS-U Spark Plug Specifications

Brand	DENSO
Part Number	U22FS-U
Stock Number	U22FS-U
Plug Type ID	Standart
Electrode Gap	0.7 mm
Diameter	10 mm
Reach	12.7 m
Terminal Type	Bolt
Bolt Head	16 mm
Electrode Material	Standart Nickel

Tabel. 2 Mechanical Properties RON 90[18]

Properties	Metode	Gasoline (RON 90)
Calorific Value (KJ/Kg)	Bomb Kalorimeter	45.63
Octane Number	ASTM D 613	93.0
Flash point (º C)	ASTM D 93	< 7

Setting the spark plug electrode gap is done using a filler gauge, as suggested in several literatures. [14]. The experiment used a 125 cc motorcycle engine with different spark plug gap variations. The specifications of the 125 cc motorcycle engine are as shown in Table 1. The fuel used in this study was fuel with a Research Octane Number (RON) of 90. The mechanical properties of fuel with RON 90 are shown in Table 2.

Testing of engine performance, fuel consumption and emission levels was applied to a 1 cylinder four stroke motorcycle engine with a capacity of 125cc with RON 90 fuel. The equipment used by researchers was a chassis dynamometer to test engine performance, both in terms of power and torque production[19][20]. Gas analyzer equipment with specifications Main power 110/ 220/ 240 V (± 15%) 50 to 60 Hz (± 3%) is used to test the levels of exhaust gas emissions such as CO, CO2, HC, O2, NOx produced during testing[21][22]. The injector infusion device is used to measure fuel consumption. The injector's primary function is to clean the injector holes, restoring the normal flow of fuel into the combustion chamber. Researchers used the injector infusion device to measure fuel consumption by applying the same pressure as a fuel pump.

The dynamometer equipment used is the Rextro Pro-Dyno brand with a voltage specification of 220V 5060 Hz, a digital pick-up sensor, as seen in Figure 3.

Figure 3. Rextro Pro-Dyno Dynamometer

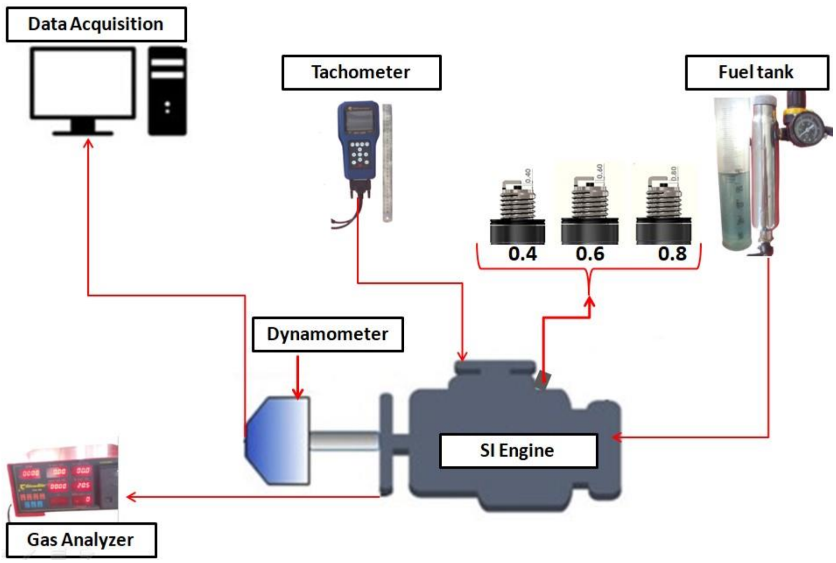


Figure 4. Testing scheme

Figures should be self-explanatory and contain a short but adequately detailed caption. Figures should be provided in one of the following formats: PNG, EPS, TIFF, JPEG, BMP. The figure(s) should have a resolution of 600 dpi for grayscale and 300 dpi for colour. All figures must be numbered sequentially in the text in the same order in which they appear (e.g. Figure 1, Figure 2). Figure 1(a) and Figure 1(b) are examples of multi-part figures in which each component should be labelled. The figure(s) caption should be written in sentence cases and placed underneath the image, centre aligned, with no period at the end of the caption.

Figure 4 shows a test scheme for engine performance using gasoline and emission levels. The test was conducted to analyze the influence of spark plug electrode gap parameters on engine performance, including power, torque, exhaust emissions, and fuel consumption. The motorcycle unit was positioned and started on a chassis dynamometer, after which spontaneous acceleration was carried out from idle speed, which was around 1250 rpm to maximum engine speed for several minutes. The test that had been carried out showed the size of the motorcycle's power and torque. The next test was to determine the emission levels using a gas analyzer. The motorcycle engine was started, then a measuring tool was inserted into the rear end of the exhaust. Measuring emission levels from engine speeds of 1250 rpm to 7000 rpm. The exhaust emission levels detected using a gas analyzer included CO, CO2, HC, O2, NOx.

3.0 RESULTS AND DISCUSSION

Experiments on engine performance and exhaust emissions have been successfully conducted with three variations of spark plug gaps. Torque, power, and SFC, as indicators of engine performance, were calculated using the following formula [23]. Simultaneously, the exhaust gas was also observed to evaluate its combustion effects. The results are presented as follows.

3.1 Power and Torque

Based on the research results presented in Figure 5, it shows an increase in power. The increase in power occurs in all types of spark plug gap variations, both at spark plug gaps of 0.4, 0.6 and 0.8 mm. From these results, it shows that the maximum engine power at a spark plug gap of 0.8 mm is 6.86 kW at an engine speed of 6486 rpm, a spark plug gap of 0.6 mm is 6.49 kW at an engine speed of 5085 rpm and at a spark plug gap of 0.4 mm is 6.34 kW at an engine speed of 4302 rpm. Based on these data, it can be concluded that the spark gap of 0.8 mm has the highest power, which is an increase of 5.39% compared to the power produced at a spark plug gap of 0.4 mm. The increase in engine power value occurs because the spark jump on the spark plug is greater, thus causing engine compression to increase.[9]. Peningkatan daya mesin tersebut sejalan dengan penelitian ogus bas dkk, bahwa dengan meningkatnya loncatan bunga api pada ruang bakar akan meningkatkan daya mesin The increase in engine power is in line with research by Ogus Bas et al., that increasing the spark jump in the combustion chamber will increase engine power. [14].

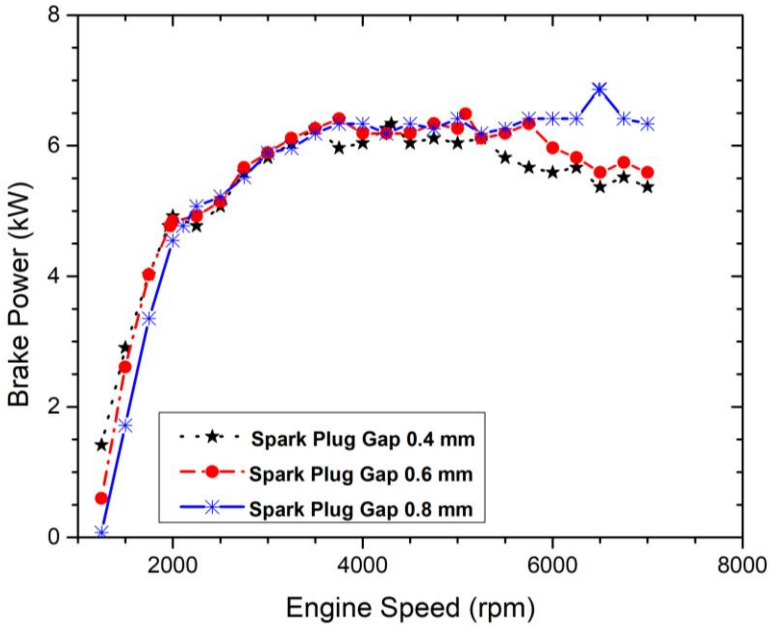


Figure 5. Engine brake power characteristics

The results of the torque test as presented in Figure 6. show that the torque value has increased. The increase in torque occurs in all variations of spark plug gap gap, both in spark plug gaps of 0.4, 0.6 and 0.8 mm. Based on these results, the maximum torque value occurs in a spark plug gap gap of 0.8 mm, which is 8.86 Nm at an engine speed of 6764 rpm, in a spark plug gap of 0.6 mm, which is 8.2 Nm at an engine speed of 6296 rpm and in a spark plug gap of 0.4 mm, which is 7.82 Nm at an engine speed of 6813 rpm. Based on these data, it can be concluded that the highest torque value is in a spark plug gap gap of 0.8 mm, which is 8.86 Nm of torque. This torque value is 11.73% higher than the torque results in a spark plug gap gap of 0.4 mm. The increase in torque is due to the larger spark jump, which causes perfect combustion in the combustion chamber. This is in line with research conducted by Yufeng et al.[9]. The differences between the various spark plug gaps are not significant. The resulting torque values for the engine are not significantly affected by the various spark plug gap parameters. Adjusting the spark plug gap is the easiest way to increase torque in a motorcycle engine. Since the torque increase is not significant, spark plug gaps of 0.4 and 0.6 mm are still acceptable.[14][9].

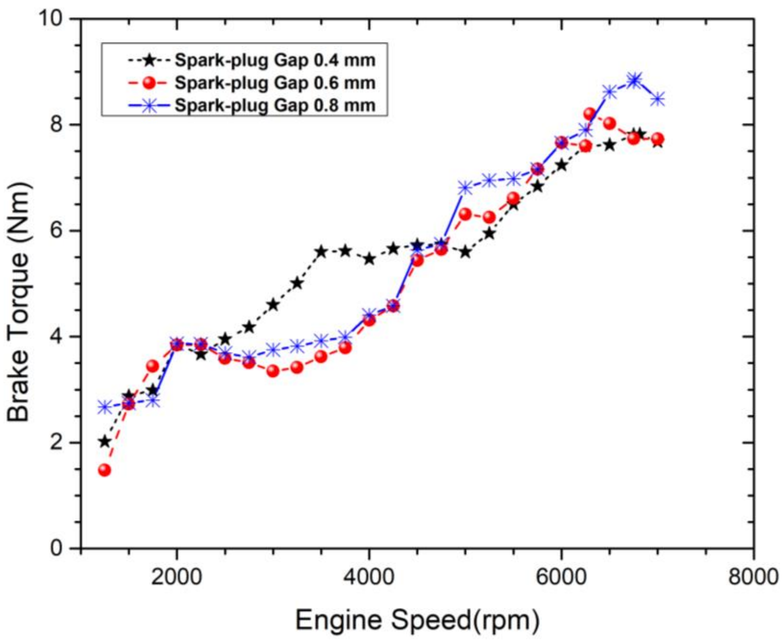


Figure 6. Engine brake torque characteristics

3.2 Specific Fuels Consumsion (SFc)

The ratio of the mass of fuel consumed by an engine to the power produced over a given period of time is also known as Specific Fuel Consumption (SFc). The SFc value is highly dependent on the power produced by the engine. Specific fuel consumption is shown in Figure 7.

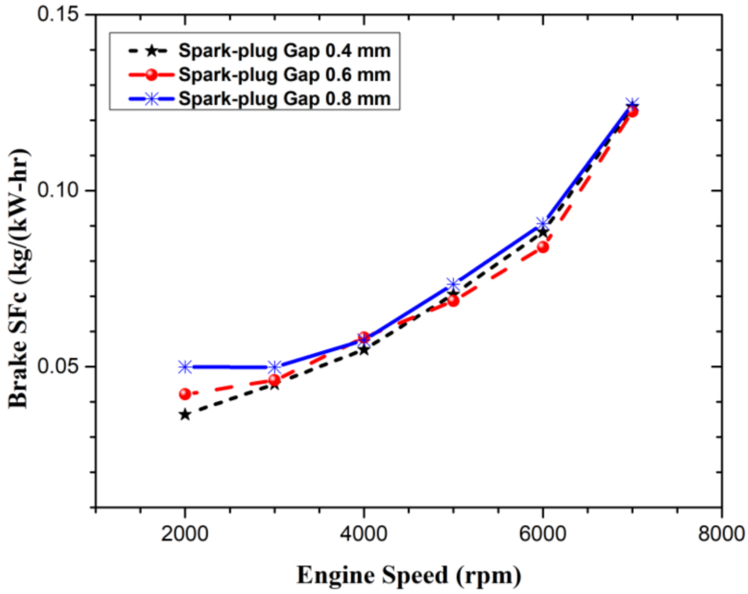
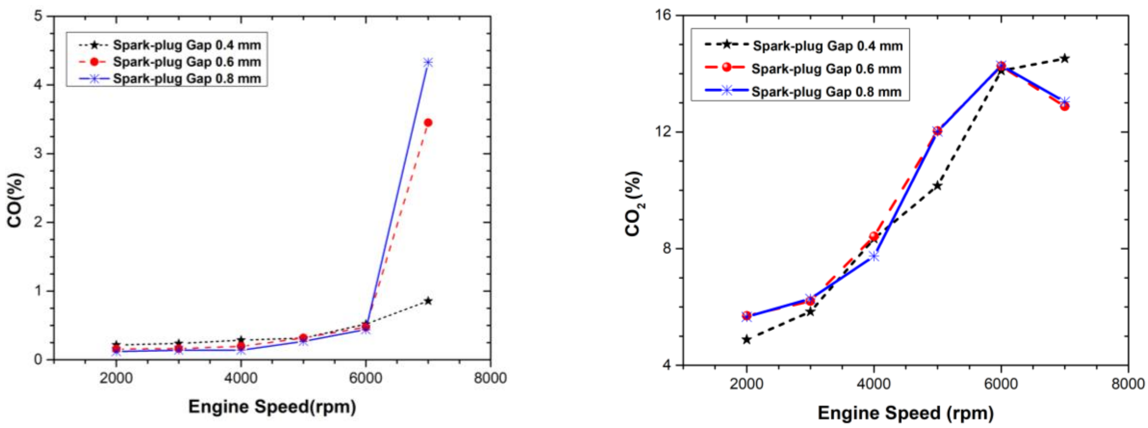


Figure 7. Brake Sfc characteristics

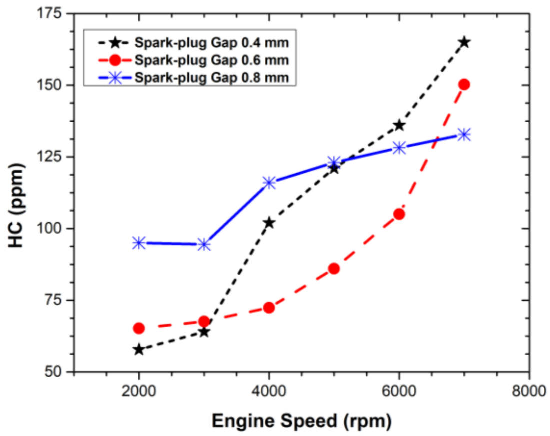
Figure 7 shows that specific fuel consumption at all types of spark plug electrode gaps increases. The increase occurs from 2000 rpm to 7000 rpm. The increase in specific fuel consumption at all types of spark plug electrode gaps and at all engine speeds is due to the increasing spark jump produced by the spark plug. The results of the graph can be concluded that the lowest specific fuel consumption value is in the 0.4 mm spark plug electrode gap test, namely 0.036 kg/kW-hr. The highest specific material consumption value is in the 0.8 mm spark plug electrode gap test, namely 0.125 kg/kW-hr. This shows that the lower the specific fuel consumption, the more efficient the fuel consumption can be.

3.3 Exhaust Gas Emissions

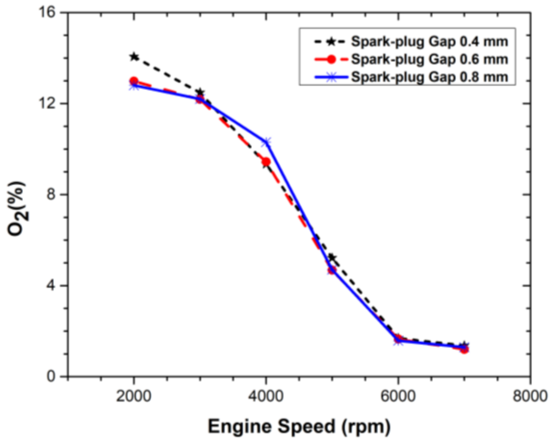
This exhaust emission test was conducted to analyze the effect of spark plug electrode gaps on exhaust emissions in motorcycle engines. The study was conducted at engine speeds of 2,000 to 7,000 rpm. The emission levels studied included carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HC), oxygen (O2), and nitrogen oxides (NOx).



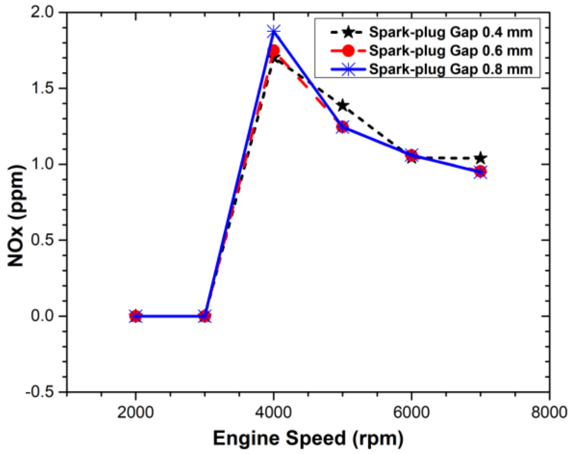
(a) (b)



(c)



(d)



(e)

Figure 8. Exhaust gas emissions, (a). CO, (b). CO2, (c). HC, (d). O2, (e). Nox

Figure 8. shows the results of the exhaust emission test of Carbon Monoxide (CO) type on a 125 cc motorcycle in all types of spark plug electrode gaps. Figure 8. (a) The results show an increase in CO in all types of spark plug electrode gaps. The results can be concluded by researchers that the average results of carbon monoxide (CO) at various engine speeds are spark plug electrode gaps of 0.4 mm 0.405%, spark plug electrode gaps of 0.6 mm 0.793%, spark plug electrode gaps of 0.8 mm 0.907%. The level of carbon monoxide (CO) exhaust emissions on motorcycles is controlled by the air and fuel ratio. Carbon monoxide (CO) is obtained when the motorcycle operates with a rich air and fuel ratio. The oxygen content is not sufficient to convert all carbon content into carbon dioxide (CO2), therefore some gasoline fuel cannot burn and some carbon ends up as CO.

Figure 8.(b) shows that the percentage of carbon dioxide levels in exhaust emissions at all types of spark plug electrode gaps actually experienced a decrease in CO2 emission levels. The average carbon dioxide levels at various engine speeds were 9.64% for a spark plug electrode gap of 0.4 mm, 9.917% for a spark plug electrode gap of 0.6 mm, and 9.837% for a spark plug electrode gap of 0.8 mm. Carbon dioxide levels are the expected result of combustion in the combustion process, because the higher the CO2 obtained, the more efficient the motorcycle operation will be. In Figure 8.(c), the hydrocarbon levels produced at all types of spark plug electrode gaps increased, along with the increase in engine speed.[4]. The average value of hydrocarbon levels for various types of spark plug electrode gaps is 107.6 ppm at a spark plug electrode gap of 0.4 mm, 91.07 ppm at a spark plug electrode gap of 0.6 mm, 114.9 ppm at a spark plug electrode gap of 0.8 mm. Hydrocarbon levels are the result of the fuel process that cannot be burned in the combustion chamber. Several studies of hydrocarbon emissions are that the air-fuel ratio is not stoichiometric so that combustion is not perfect.[4][10]. Increasing levels of hydrocarbon emissions indicate that engine power is decreasing and fuel consumption is also increasing. [24].

The percentage value of oxygen content as seen in Figure 8.(d) decreased in all types of spark plug electrode gaps of 0.4, 0.6 and 0.8 mm. The average O2 value at various engine speeds is 7.358% for spark plug electrode gaps of 0.4 mm, 7.022% for spark plug electrode gaps of 0.6 mm, and 7.145% for spark plug electrode gaps of 0.8 mm. The combustion process that occurs is not perfect in the engine leaving oxygen to the air. The remaining oxygen content becomes smaller when combustion occurs more perfectly. Nitrogen Oxide (NOx) levels in all types of spark plug electrode gaps increased at an engine speed of 4000 rpm, the values are 1,703 ppm for spark plug electrode gaps of 0.4 mm, 1,749 ppm for spark plug electrode gaps of 0.6 mm, and 1,875 ppm for spark plug electrode gaps of 0.8 mm. At engine speeds above 4,000 rpm, NOx emissions decrease. Nitrogen oxide (NOx) levels are emissions that occur due to the high operating temperature of the engine. The air used for combustion actually contains 80% nitrogen. At high temperatures (>1370°C), nitrogen mixes with the fuel and forms NOx compounds. Combustion engines with poor combustion tend to operate at higher temperatures, thus producing NOx.

Regarding exhaust emission testing, differences in spark plug electrode gaps tend to increase CO, CO2, and HC emission levels. The greater the gap, the higher the CO, CO2, and HC levels at various engine speeds. However, O2 decreases at all engine speeds. NOx emission levels are highest at certain engine speeds, namely at 4000 rpm. The highest NOx values occur at spark plug electrode gaps of 0.8 mm compared to spark plug electrode gaps of 0.4 and 0.6 mm. These data demonstrate that larger spark gaps consistently have higher peak pressures, and consequently, higher temperatures in the cylinder produce higher NOx emissions.[10][25].

4.0 CONCLUSIONS

Engine performance and exhaust emissions at 3 spark plug gaps have been comprehensively studied. From the experiments that have been conducted, power and torque increase along with increasing spark plug gap. The highest power and torque occurred at a spark plug gap of 0.8 mm. Power increased by 5.39% compared to the power produced at a spark plug gap of 0.4 mm and torque increased by 11.73% compared to the torque results at a spark plug gap of 0.4 mm. Regarding specific fuel consumption, it actually increased at a spark plug gap of 0.8 mm. From this indicator, it shows that fuel is increasingly wasteful. Exhaust emissions increased at 3 variations of spark plug gap, but oxygen intake actually decreased. At 4000 rpm, NOx has the highest value. The intense combustion process is what causes the high NOx value.

5.0 CONFLICT OF INTEREST

The authors declare that there are no financial or non-financial conflicts of interest that could have influenced the research, authorship, and publication of this article. The research was conducted independently and objectively.

6.0 AUTHORS CONTRIBUTION

Feri Hidayatulloh: Conceptualisation; Methodology; Investigation; Formal analysis; Data curation; Validation; Resources; Writing – original draft.

Ata Syifa Nugraha: Investigation; Formal analysis; Validation; Visualisation; Writing – review & editing.

The corresponding author confirms that all authors have reviewed and agreed to the accuracy of the author contribution statements and approved the final manuscript.

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