International Journal of Marine Engineering Innovation and Research, Vol. 9(3), Sept. 2024. 512-519
(pISSN: 2541-5972, eISSN: 2548-1479)

The Effect of Number of Spark Plug Ground Electrodes and Octane Rating on Single Cylinder Engine Performance

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(Received: 04 August 2024 / Revised: 15 August 2024 /Accepted: 26 August 2024)

***Abstract*— Vehicle ignition systems, including spark plugs, are a certain way to boost a motorcycle's performance. One kind of spark plug used to ignite the combustion process in a gasoline engine is a multi electrode spark plug, which has two or more ground points built into the electrodes. This study's overarching goal is to identify the optimal combination of multi-ground spark plugs, gasoline octane value fluctuations, and power/torque/specific fuel consumption parameters. Engine performance testing relies on data collected from controlled laboratory tests. In addition, Microsoft Excel is used for data analysis, and the results are shown in graph tables. Spark plug electrode amount in feet and gasolines octane level are the independent variables. Speed the engine from 5500 to 9000. The peak power output of 6.92 Hp was achieved at 7000 rpm in the power test with RON 92 gasoline X-Line spark plugs. At 5500 rpm, the maximum torque of 8.21 Nm was produced by the torque test using RON 98 gasoline X-Line spark plugs. At 6000 rpm, the specific fuel consumption test with RON 90 fuel and standard spark plugs yields a value of 0.0800 kg/Hp.hour.**

Keywords : spark plugs, multi ground plugs, power, SFC, fuel

I. INTRODUCTION

Motorbikes are the most widely used type of vehicle in the current era. With the development of the automotive industry, many types of motorbikes are equipped with the latest technology. Many aftermarket manufacturers offer motorbike component products that can improve the performance of motorbike engines[1]. Improving the performance of motorbikes can be seen through vehicle ignition systems such as spark plugs which are spark generators to burn a mixture of fuel and air in petrol motorbikes[2].

Spark plugs are important components in the ignition system where when the high voltage function is to spark sparks, to burn the air and fuel mixture[3]. When sparks from the secondary winding coil reach the spark plug via the spark plug wire, fuel burns in all directions due to the distribution of heat. This process is known as complete combustion [4]. When a voltage between 15,000 and 30,000 volts is produced by the coil's secondary winding, this state is achieved[5].

When using spark plugs that do not match engine specifications, it causes problems in the combustion process[5]. The amount of ground points adjacent to the electrode in a multi-electrode spark plug determines the amount of spark that is created[3]. Spark plugs with multiple ground electrodes aim to make the spark plug more durable and reduce carbon build-up[5].

The choice of fuel also greatly affects the performance of the engine produced. Compression pressure in the combustion chamber, an ideal mixture of air and fuel and spark plug sparks are conditions for combustion to occur[6]. If the fuel used is in accordance with the compression ratio, the engine performance will be optimised[7]. The octane value of fuel can be used as a measure of fuel quality, if the compression pressure in the engine is high, it requires fuel with a high RON in order to get optimal engine performance[8].

Prior studies performed by Fajri et al. (2023) addressed the topic of spark plug types and their use[5] entitled "Analysis of the Use of Multi ground Electrode Spark Plug Variations on Exhaust Gas Emissions on Yamaha Nmax 155 cc Motorbikes". At 1500 rpm, the 4-foot multi-ground spark plug decreased CO emissions by 26.22%, whereas the multi-ground spark plug without legs lowered them by 26.76%. In 2020, Ibrahim et al[9] "A Comparative Study Of The Performance And Exhaust Emissions For Standard And Multi Electrode Spark In SI Engine" was the title of his study. We found that four-leg electrode spark plugs, which employ several ground electrodes, can boost power, torque, and BSFC, which in turn reduces BTE. The rise in cylinder temperature and size of the spark led to better fuel combustion, which in turn reduced emissions of CO and HC while increasing emissions of CO2[10] "Performance of 4-Stroke Motorcycle Engines with the Use of Spark Plug Variations" was the subject of his research. Results showed that 13.9 horsepower was achieved at 8000 revolutions per minute using octane 90 fuel 3-foot spark plugs. As an added bonus, the maximum torque of 13.14 Nm may be achieved at 7000 rpm when using 90 spark plugs with octane gasoline. Sriyanto published in 2018[11] "The Effect of Spark Plug Type on Motorcycle Exhaust Emissions" is the title of his research. Results

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showed a 29% decrease in CO emissions and a 61% decrease in HC emissions at 3000 rpm when multi-electrode spark plugs made of platinum and iridium were used[12]
"Performance Of Using Spark Plugs And Fuels Variations On 4-Stroke Motorcycle Engines" is the title of his study. Based on our testing, we know that using iridium spark plugs maximizes horsepower (14.3 HP) and torque (13.4 Nm) at 8000 and 7000 rpm, respectively. The maximum fuel usage of 0.059 kg/kWh was recorded at 6000 rpm when running on 95 octane fuel with iridium spark plugs.

The research aims to find out, while utilizing multi ground spark plugs and varying gasoline octane values, what the biggest difference in power and torque is, as well as the minimum change in specific fuel consumption.

1.1 Literatur Review

1. Fuel

Fuel is a substance that comes from petroleum and can be converted into energy. Fuel works if it mixes well with oxygen[13]. An essential component of engine combustion, fuel's calorific value shows the maximum heat that fuel may emit during a full combustion event. The fuel used should be in accordance with the needs and configuration of the engine in the combustion chamber. Each fuel has a different octane value depending on the compression value of the engine[14]. Fuels that are often used are petrol, diesel, fuel gas, and bensol. Octane number is a number that indicates the quality of the fuel and how much pressure can be applied before the fuel ignites spontaneously[15].

2. Electronic Fuel Injection System

The fuel injection system is a fuel spraying process that is controlled using sensor output signals processed by the ECO (Electronic Control Unit). The EFI system determines the optimum air and fuel ratio for the engine during injection depending on the operating conditions of the engine. In addition to increasing engine power, improving the performance of internal combustion engines and reducing exhaust emissions are the goals of developing and using EFI[16].

3. Spark Plug

In motor vehicles the spark plug is one of the most important components. The spark plug construction consists of a spark plug terminal, spark plug insulator, spark plug thread and spark plug electrode. On a motorbike, it functions to forward the electric current from the coil to the combustion chamber and burn the fuel and air mixture. Spark plugs have several types, namely standard, iridium and platinum spark plugs[17]. A spark plugs with two or more ground points next to the electrode is called a multi-electrode spark plug. The spark that is generated is proportional to the number of ground points[3]. Spark plugs with multi-ground electrodes aim to make the spark plug more durable and reduce carbon build up[5].

II. Method

The research used laboratory experimental methods to obtain data. The research variables consisted of

1. The independent variables are standard spark plugs, grounded 2-foot spark plugs, grounded 3-foot spark plugs and X-line spark plugs as well as fuel types Ron 90, 92, 98.

2. The dependent variables include the largest power and torque and specific fuel consumption.

3. The engine speed and compression ratio are the control variables. The possible values are 5500, 6000, 6500, 7000, 7500, 8000, 8500, and 9000 rpm. Both on and off campus areas of Malang State Polytechnic were active in the execution of this study.

2.1 Power and Torque Testing

Putting the car through its paces on a dyno to gauge its horsepower and torque. The first step is to raise the vehicle on the dyno test tool, install the dynotest probe on the spark plug coil cable, pull the gas with full throttle opening and then take data according to the test variations carried out at engine speeds of 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000 rpm, the test results will appear on the dyno test monitor screen.

Power is defined as the output in relation to the input of time. The quantity of energy that is used up in a certain length of time is called power[18] Formula for measuring power:

$$Ne = \frac{2\pi \times n \times T}{60} \quad (1)$$

Description:
Ne : Power (Hp)
n : Engine speed (rpm)
T : Torque (Nm)

The thrust action that happens on the crankshaft and piston is called torque[19]. The following is the formula for torque:

$$T = \frac{2\times\pi\times n}{60\times Ne} \quad (2)$$

Description:
T :Torque (Nm)
Ne : Power (Kw)
n : Engine speed (rpm)

Figure 1. Power and Torque Testing

2.2 Specific Fuel Consumption Testing

Installing a pressure bar on the fuel line from the fuel pump and dividing the fuel lines into two injectors—one for the vehicle's material supply and one for measuring the fuel that comes out—to calculate specific fuel consumption data. put a tachometer in the car so you can monitor the controlled engine speed while you drive. use a timer to determine how long it takes for the burette to produce fuel.

Figure 2. Specific Fuel Consumption Testing

The quantity of gasoline used per unit of time is known as specific fuel consumption[20] Fuel flow formula:

$$mf = \frac{V}{t} \times \frac{3600}{1000} \times \rho bb \qquad (3)$$

Description:
mf: Fuel flow rate (kg/hour)
V : Volume of measuring cup (cc)
t : Time (s)
ρbb : Specific gravity of fuel (kg/l)

Formula SFC :

$$Sfc = \frac{mf}{Ne} \qquad (4)$$

Description:
mf: Fuel flow rate (kg/hour)
V : Volume of measuring cup (cc)
t : Time (s)
ρbb : Specific gravity of fuel (kg/l)

III. Results and Discussion

A. Power

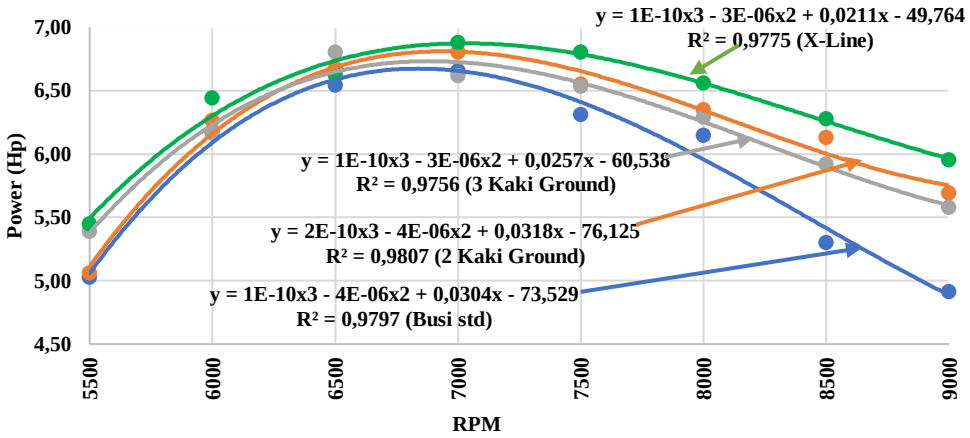

Figure 3. Power testing using RON 90 Fuel

Rotational speeds between 5500 and 9000 rpm, with 500 rpm increments between each adjustment.See Figure 3 for details: a regular spark plug puts out 4.91 Hp at the lowest and 6.65 Hp at the highest; a 2 ground legs spark plug puts out 5.06 Hp at the lowest and 6.80 Hp at the highest; a 3 ground legs spark plug puts out 5.39 Hp at the lowest and 6.80 Hp at the highest; and an X-Line spark plug puts out 5.45 Hp at the lowest and 6.88 Hp at the highest. At 7000 rpm, the X-Line spark plug produced a maximum power of 6.88 Hp.

With X-Line spark plugs, the peak output is 6.88 horsepower at 7000 revolutions per minute. Maximizing power from lower to higher revolutions, denser torque, and increased acceleration are all benefits of using X-Line spark plugs, which have four times the electrical conductivity of regular spark plugs and employ headless spark plug head technology.

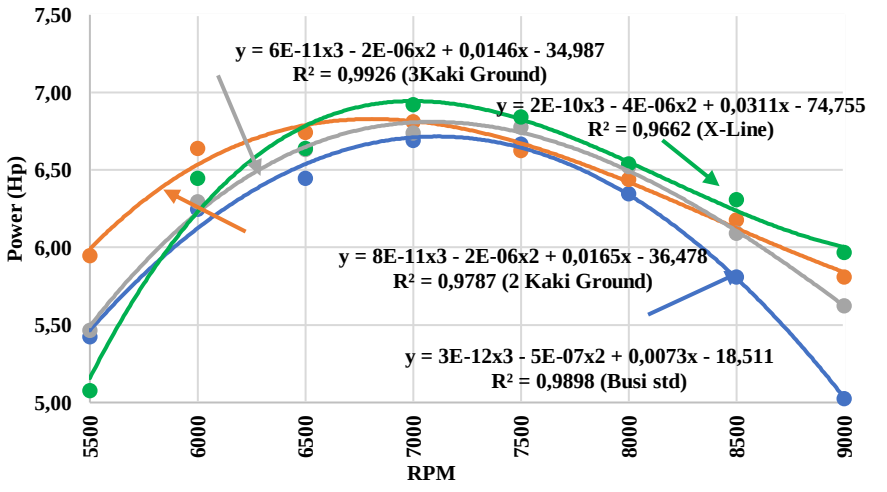

Figure 4. Power testing using RON 92 Fuel

Displays, with a variation of 500 rpm, the connection between power output and variations in rotational speed from 5500 rpm to 9000 rpm. Figure 4 shows that the following power ratings are given by different types of spark plugs: standard, 2 ground legs, 3 ground legs, X-Line, and minimum, 2 ground legs. For the standard spark plug, the minimum power is 5.02 Hp and maximum is 6.69 Hp, for the 2 ground legs, the minimum power is 5.81 Hp and maximum is 6.81 Hp, for the 3 ground legs, the minimum power is 5.46 Hp and maximum is 6.78 Hp, and finally, the X-Line spark plug has a minimum power of 5.08 Hp and a maximum of 6.92 Hp. When employing the X-Line spark plug, the maximum power output is 6.92 Hp at 7000 rpm.

X-Line spark plugs provide 6.92 Hp at 7000 rpm, which is the maximum power. Maximizing power from lower to higher revolutions, denser torque, and increased acceleration are all benefits of using X-Line spark plugs, which have four times the electrical conductivity of regular spark plugs and employ headless spark plug head technology.

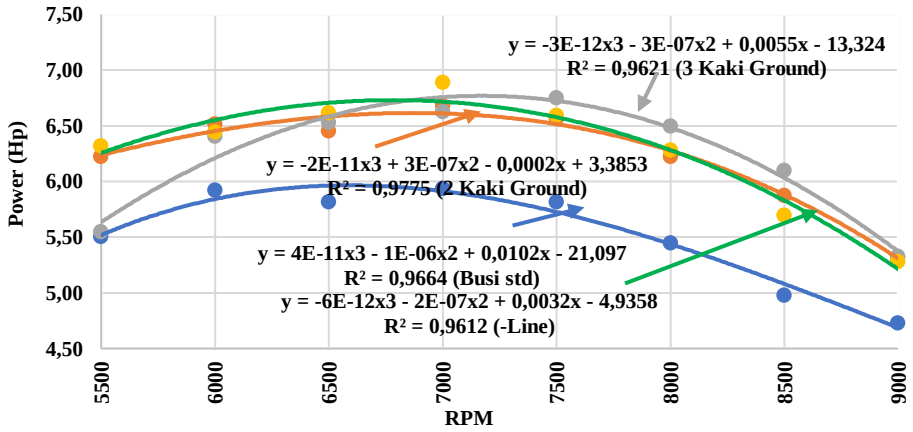

Figure 5. Power testing using RON 98 Fuel

The relationship between the input power and the range of rotational speeds (from 5500 to 9000 rpm) with a repeatability of 500 rpm. Figure 5 shows that typical spark plug specifications include a minimum power output of 4.73 Hp and a maximum power output of 5.94 Hp, a minimum power output of 5.32 Hp and a maximum power output of 6.68 Hp for 2 ground legs spark plugs, a minimum power output of 5.33 Hp and a maximum power output of 6.75 Hp for 3 ground legs spark plugs, and a minimum power output of 5.28 Hp and a maximum output of 6.89 Hp for X-Line plugs.

With X-Line spark plugs, the peak output is 6.89 horsepower at 7000 revolutions per minute. Maximizing power from lower to higher revolutions, denser torque, and increased acceleration are all benefits of using X-Line spark plugs, which have four times the electrical conductivity of regular spark plugs and employ headless spark plug head technology.

B. Torque

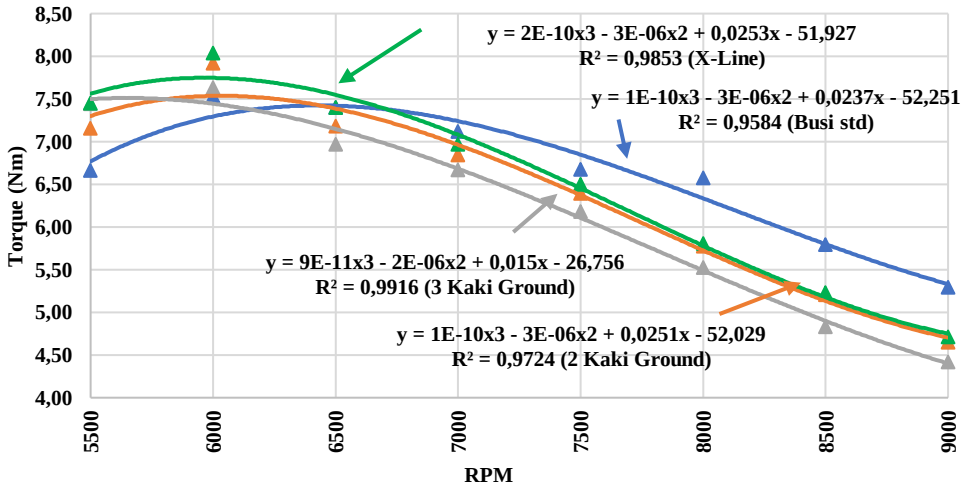

Figure 6. Torque testing using RON 90 fuel

The connection between torque and rotational speed, where the former falls between 5500 and 9000 rpm and the latter changes by 500 rpm. Figure 6 shows that different types of spark plugs have different minimum and maximum torque values. The standard spark plug has a minimum of 5.29 Nm and a maximum of 7.53 Nm, the 2 ground legs spark plug has a minimum of 4.65 Nm and a maximum of 7.92 Nm, the 3 ground legs spark plug has a minimum of 4.42 Nm and a maximum of 7.63 Nm, and the X_Line spark plug has a minimum of 4.71 Nm and a maximum of 8.04 Nm.

With X-Line spark plugs, the maximum torque reached 8.04 Nm at 6000 rpm. Thanks to their four times higher electrical conductivity compared to regular spark plugs, X-Line spark plugs are able to produce more maximum torque. Additionally, their headless spark plug head technology allows them to sprinkle spark plug fire 1x360 degrees, increasing acceleration and producing maximum power from lower to upper revolutions.

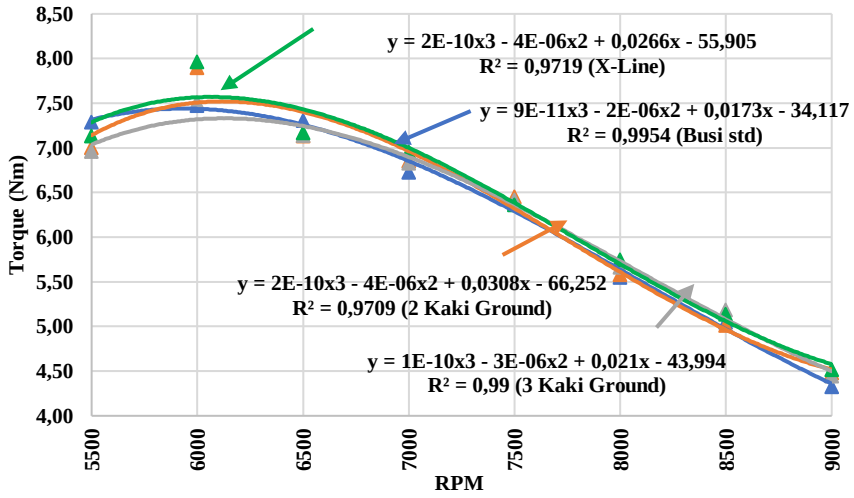

Figure 7. Torque testing using RON 92 fuel

A 500-rpm range of rotational shifts produces a torque relationship with an output of 5500–9000 rpm. Figure 7 shows that different types of spark plugs have different minimum and maximum torque values. The standard spark plug has a minimum of 4.33 Nm and a maximum of 7.48 Nm, the 2 ground legs spark plug has a minimum of 4.48 Nm and a maximum of 7.90 Nm, the 3ground legs spakr plug has a minimum of 4.45 Nm and a maximum of 7.51 Nm, and the X-Line spark plug has a minimum of 4.52 Nm and a maximum of 7.97 Nm.

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With X-Line spark plugs, the maximum torque reached 7.97 Nm at 6000 rpm. The X-Line spark plugs are four times more electrically conductive than regular spark plugs, which allows them to generate more maximum torque. Additionally, their headless spark plug head technology allows them to splash the spark plug fire one full revolution, increasing acceleration and power from lower to higher revolutions.

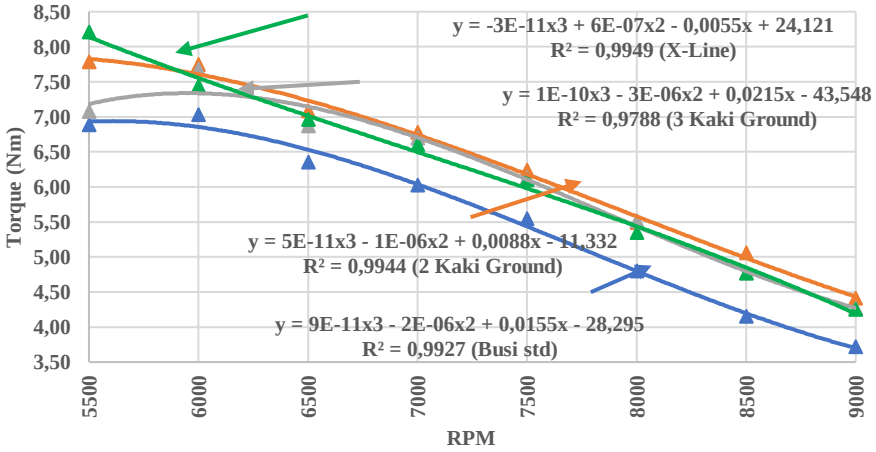

Figure 8. Torque testing using RON 98 fuel

The torque-response relationship generated by a 500-rpm swing in the range of 5500 to 9000 revolutions per minute. Figure 8 shows that different types of spark plugs have different minimum and maximum torque values. The standard spark plug has a minimum of 3.72 Nm and a maximum of 7.03 Nm, the 2 ground legs spark plug has a minimum of 4.41 Nm and a maximum of 7.78 Nm, the 3 ground legs spark plug has a minimum of 4.26 Nm and a maximum of 7.67 Nm, and the X-Line spark plug has a minimum of 4.25 Nm and a maximum of 8.21 Nm.

With X-Line spark plugs, the maximum torque reached 8.21 Nm at 5500 rpm. Thanks to their four times higher electrical conductivity compared to regular spark plugs, X-Line spark plugs are able to produce more maximum torque. Additionally, their headless spark plug head technology allows them to sprinkle spark plug fire 1x360 degrees, increasing acceleration and producing maximum power from lower to upper revolutions.

C. Specific Fuel Consumption

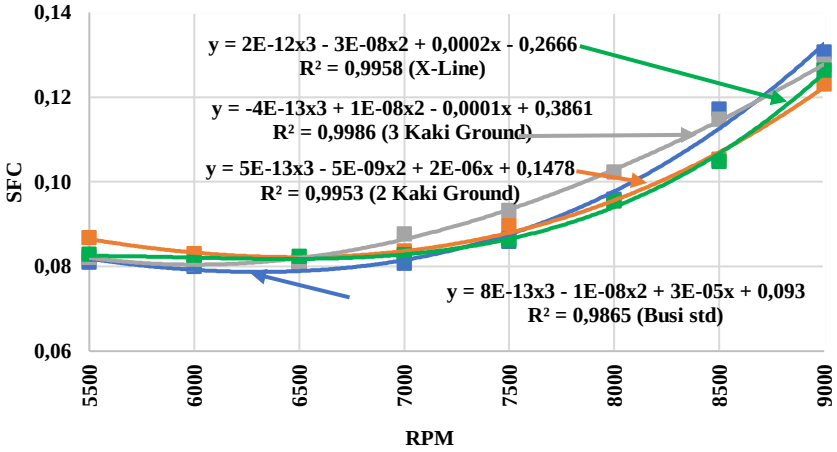

Figure 9. Specific fuel consumption testing using RON 90 fuel

A 500 rpm range of changes in rotation yields a link between specific fuel consumption and frequency of rotation (5500 rpm to 9000 rpm). Figure 9 shows that different types of spark plugs have different minimum and maximum SFC values. The standard spark plug has a minimum of 0.0800 kg/Hp.hour and a maximum of 0.1307 kg/Hp.hour. The 2 ground legs spark plug has a minimum of 0.0814 kg/Hp.hour and a maximum of 0.1231 kg/Hp.hour, 1231 kg/Hp.h. The 3 ground legs spark plug has a minimum of 0.0805 kg/Hp.h and a maximum of 0.1277 kg/Hp.h. Finally, the X-Line spark plug has a minimum of 0.0811 kg/Hp.h and a maximum of 0.1264 kg/Hp.h.

Using conventional spark plugs, the minimum specific fuel consumption at 6000 rpm was 0.0800 kg/Hp.h.

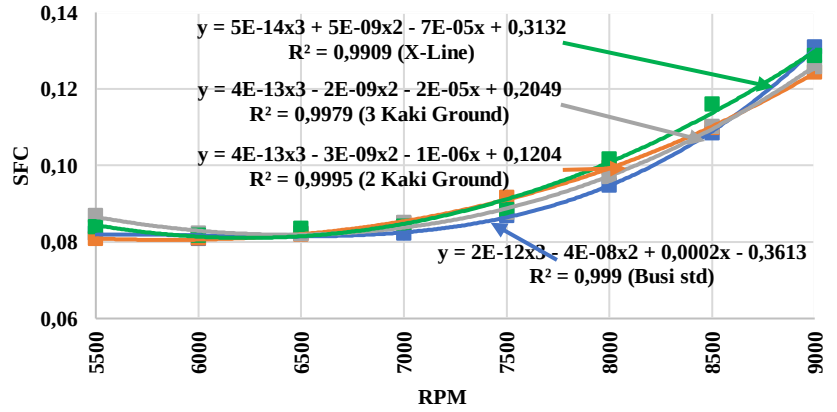

Figure 10. Specific fuel consumption testing using RON 92 fuel

The correlation between the particular fuel consumption produced and the range of 500 rpm changes in rotation, from 5500 rpm to 9000 rpm. Based on Figure 10, it can be seen that the standard spark plug produces a minimum SFC of 0.0808 kg/Hp.hour and a maximum SFC of 0.1308 kg/Hp.hour for the 2 ground legs spark plug produces a minimum SFC of 0.0808 kg/Hp.hour and a maximum SFC of 0.1243 kg/Hp.hour while the 3 ground legs spark plug produces a minimum SFC of 0.0821 kg/Hp.hour, 1243 kg/Hp.h while the 3 ground legs spark plug produces a minimum SFC of 0.0821 kg/Hp.h and a maximum SFC of 0.1258 kg/Hp and the X-Line spark plug produces a minimum SFC of 0.0816a kg/Hp.h and a maximum SFC of 0.1287 kg/Hp.h.

At 6000 rpm with regular spark plugs, the most economical specific fuel consumption was 0.0808 kg/Hp.h.

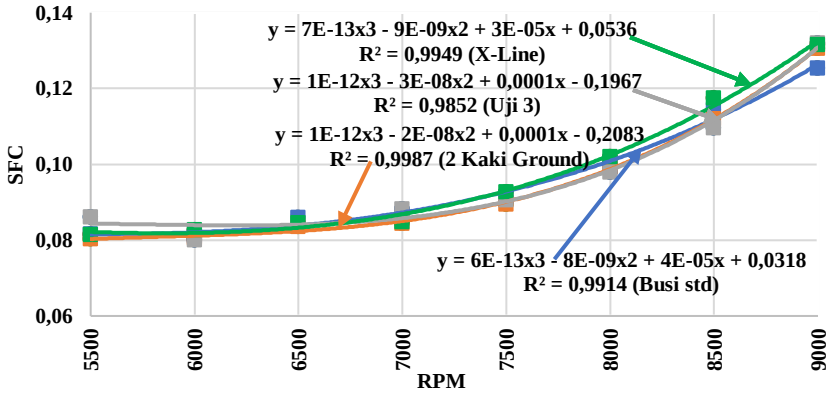

Figure 11. Specific fuel consumption testing using RON 98 fuel

The correlation between the particular fuel consumption produced and the range of 500 rpm changes in rotation, from 5500 rpm to 9000 rpm and beyond. Figure 11 shows that different types of spark plugs have different surface area fraction coefficients (SFCs). The standard spark plug has a minimum SFC of 0.0823 kg/Hp.hour and a maximum of 0.1287 kg/Hp.hour. The 2 ground legs spark plug has a minimum SFC of 0.0803 kg/Hp.hour and a maximum of 0.1306 kg/Hp.hour, 1306 kg/Hp.h. The ground legs spark plug has a minimum SFC of 0.0801 kg/Hp.h and a maximum SFC of 0.1320 kg/Hp.h. Finally, the X-Line spark plug has a minimum of 0.0815 kg/Hp.h and a maximum of 0.1316 kg/Hp.h.

With 3 ground legs spark plugs, the most efficient specific fuel consumption was 0.0801 kg/Hp.h at 6000 rpm.

IV. Conclusion

It is possible to deduce the following from the conducted tests:

1. Running on RON 92 gasoline with 6.92 Hp X-Line spark plugs at 7000 rpm produces the most power.
2. 82.1 Nm of torque, measured at 5500 rpm, was produced by utilizing RON 98 spark plug X-Line gasoline.
3. At 6000 rpm with regular spark plugs, the most economical specific fuel consumption was 0.0800 kg/Hp.hour.

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