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THE EFFECT OF SPARK PLUG GROUND ELECTRODE ON SPARK-IGNITION ENGINE PERFORMANCE

Zain Lillahulhaq
Lecturer
Institut Teknologi Adhi Tama Surabaya
Mechanical Engineering
zain@itats.ac.id

Rizal Mahmud
Lecturer
Institut Teknologi Adhi Tama Surabaya
Mechanical Engineering
rizal@itats.ac.id

Safiullah
Ph.D
University of Hiroshima
Department of Mechanical Systems Engineering
d185183@hiroshima-u.ac.jp

Motorcycle performance is influenced by many factors, including combustion chamber dimension, fuel characteristic, type of spark plug, spray flame, ignition timing, and the combustion chamber's cooling system to avoid incomplete combustion and knocking processes. The spark plug is an essential component of SIE. Several studies, such as spark plug gap, material type, multiple-ground Electrode, roughness, etc., have been conducted to examine the effect of spark plug modifications on the combustion process. Some previous research investigates the impact of a multiple-ground electrode spark plug in biofuel combustion. However, a study about the effect of multiple-ground electrode spark plugs on the gasoline combustion process has not been conducted. This research was conducted to determine the impact of multiple-ground electrode on Supra 125 cc performance. The data displayed in this study are power, torque, BHP, and BMEP in single, double, and triple ground electrode. The results showed that the double ground electrode spark plug produced better performance than other variations.

Keywords : *Spark Plug Ground Electrode , BHP, BMEP.*

1. INTRODUCTION

The motorcycle is the mode of transportation most widely used by Indonesians. A motorcycle has several disadvantages, including limited carrying capacity and producing noise and air pollution. Several innovations have been made to overcome these disadvantages, including replacing biodiesel fuel with more environmentally friendly, such as ethanol[1, 2]. The ignition process in the combustion chamber depends on the temperature before the fuel enters the intake manifold. Ethanol has a higher RON value than gasoline has resulted in improvements in energy efficiency[3]. Ethanol can also withstand the combustion process at higher temperatures and pressures than gasoline, allowing an increase in the compression ratio of the spark-ignition engine[4]. The changing of ignition temperature in the combustion chamber must also be accompanied by adjustments to the type of spark plug, spray flame, ignition timing, and cooling of the combustion chamber to avoid incomplete combustion and knocking processes[5, 6].

The motorcycle is classified as a spark ignition engine (SIE), where the combustion process occurs due to an ignition generated by the spark plug. The spark ignition is commonly used and has higher deposit energy than laser ignition[7]. The spark plugs function to burn the fuel and air mixture in the internal combustion engine that enters the combustion chamber. Besides, spark plugs also deliver heat energy out of the combustion chamber and become an indicator of combustion in the engine[8]. Several studies have been conducted to examine the effect of spark plug modifications on the combustion process. The type of material in the spark plug has a significant impact on performance. Types of spark plugs on the market are standard, iridium, and platinum. Among the types circulating, iridium spark plugs have many advantages, including being durable to high temperature, low fuel consumption, and providing high ignition power than other types[9–11]. The tip of the iridium spark plug electrode is smaller than the standard spark plug. The smaller the electrode produced when a high voltage is applied from a high-voltage circuit, the higher the electric field strength. This condition can reduce the voltage required to flow the electric current between the spark plug electrodes. The duration of the spark will be longer due to the decrease in the necessary amount of voltage. As a result, the combustion process improves, the engine can be started quickly, and acceleration is increased[12]. Setting the spark plug gap also needs to properly control the fuel consumption, noise,

Corresponding Author: zain@itats.ac.id
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hydrocarbon emissions, and vehicle-generated vibrations[13–16]. The wide gap between the spark plugs requires a greater electrical voltage to reduce the chance of misfire. Moreover, the lean ratio air-fuel mixture may not ignite due to the narrow spark plug gap. The size of the kernel flame is affected by the gap between the cathode and the anode in spark plug. The wider the spark plug gap, the higher the ignition energy with small losses. At a narrow spark plug gap, a large amount of hot gas was captured in the spark gap and recirculated between the spark electrode tip and increased heat loss [17]. The optimum gap of the iridium spark plug is able to reduce noise optimally and produce the lowest hydrocarbon content[18]. However, in that gap, the vibration increase during the emission degradation [19].

Several other indicators on the spark plug also affect the combustion process at SIE, such as the number of the Ground Electrode (ground electrode) and electrodes and spark plug roughness[7, 20–23]. This study will discuss the effect of multiple-ground electrode on the SIE combustion process. The multiple-Ground Electrode can adjust SIE thermal efficiency in the methane fuel combustion process due to combustion stability and thus optimize the combustion phase. The multi-ground electrode spark plugs produce a bigger flame size and faster burning reaction, while the single-Ground Electrode case has a longer ignition delay time[21]. On the other hand, using a no-ground electrode spark plug has a positive effect on the combustion process of ethanol-gasoline mixes[8]. The previous research only investigates the impact of a multiple-ground electrode spark plug in the biofuel combustion process. However, a study about the effect of multiple-ground electrode spark plugs on the gasoline combustion process has not been conducted. This research was conducted to determine the impact of multiple-Ground Electrode on the SIE motorcycle Supra 125 cc performance. The data displayed in this study are power, torque, Brake horsepower (BHP), and Brake Mean Effective Pressure (BMEP).

2. EXPERIMENTAL SET UP

2.1 Experimental Apparatus and Method

This study was conducted on a supra 125 cc spark, a single-cylinder ignition engine with an NCN C8BCT spark plug having three electrode ground. The Data collecting process by testing the dynamometer chassis on a 125 cc supra fit motorbike. Initially, testing on the chassis dynamometer was carried out for spark plugs with three-electrode ground. The installation of sett up data collection in an on-wheel Chassis Dynamometer is shown in Figure 1. After the installation process, the motor spark plug is raised above the dynamometer chassis after installation.

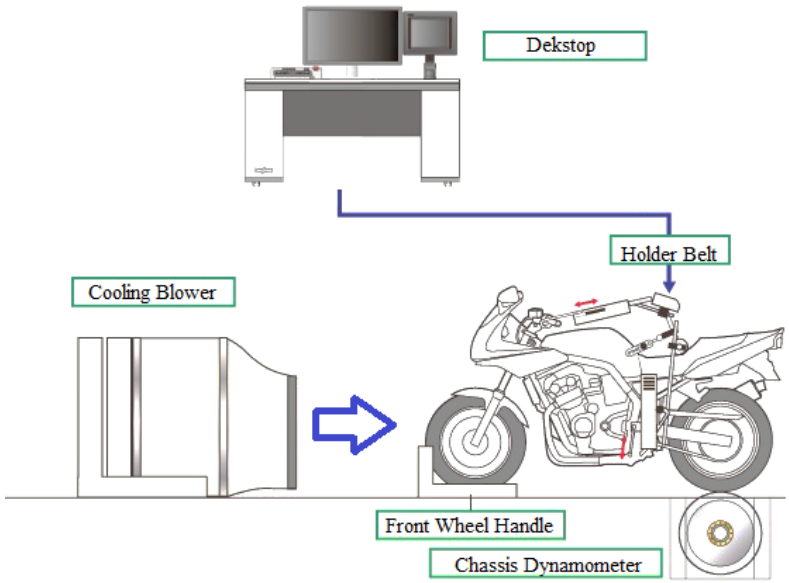

Figure 1. The data collection scheme uses a Chassis Dynamometer[24].

The motorcycle is started at the top transmission, and the velocity is increased to 2000 RPM to withdraw the data retrieval process. The data retrieval button is pressed then the velocity is increased until it reaches the maximum condition. The desktop monitor screen will display the power and torque data generated by the vehicle. The next data collection process was carried out for double Ground Electrode spark plugs by cutting a leg of the NCN C8BCT spark plug. The spark plug is then installed on the motorcycle, and the data collection process on the chassis dynamometer is carried out. The process is repeated when data collection for spark plugs with a single Ground Electrode. The data collection process was carried out more than twice to get more precise results.

2.2 Engine Performance measurement

The data generated from the chassis dynamometer test are graphs and tables of data of angular velocity (RPM), power (HP), and torque (Nm). The regression method is applied to process the power and torque data generated in dynamometer chassis testing. This data is used to obtain vehicle performance through BHP and BMEP values with equation (1-3). The calculation results are converted into graphs to compare the performance of the spark plug Ground Electrode variations on the test vehicle.

$$BHP = T \times \omega \quad (1)$$

$$Bhp = 2 \times \pi \times n_v \times T \quad (2)$$

$$Bmep = Bhp \times z \times (A \times L \times n_v \times i)^{-1} \quad (3)$$

Where:

BHP	: Brake Horse Power	(HP)
T	: Torque	(N.m)
ω	: angular velocity	(rad/s)
A	: Piston Surface area	(m^2)
L	: stroke	(m)
i	: the number of cylinder	
z	: 1 (2 strokes motor cycle) and 2 (4 strokes cycle)	

2.3 Test Condition

The motorcycle is classified as a spark ignition engine (SIE) where the combustion process occurs due to an ignition generated by the spark plug. Spark ignition is commonly used and has higher deposit energy than laser ignition[7]. The spark plugs function to burn the fuel and air mixture in the internal combustion engine that enters the combustion chamber. Besides, spark plugs also deliver heat energy out of the combustion chamber and become an indicator of combustion in the engine [8]. In this study, three types of spark plugs of NCN C8BCT were used: one ground spark plug, double-ground spark plug, and standard spark plug, which has three ground spark plugs. This study was conducted on a supra 125 cc spark, a single-cylinder ignition. The specification of the vehicle is shown in table 1.

Tabel 1: Engine specification

PART	SPESIFICATION
Engine type	124,89 cc, 4 stroke, SOHC, Single Cylinder
Fuel Injection System	PGM-FI (Programed Fuel Injection)
Bore/Stroke	52,4 mm x 57,9 mm
Compression Ratio	9,3 : 1
Transmission Type	4 speed, Rotary
Intake Valve	1
Exhaust Valve	1
Engine cooling system	Air

3. RESULT AND DISCUSSION

3.1 Engine Performance characteristics

Vehicle performance can be described by analyzing vehicle power and torque. The variation of spark plug ground electrode affects vehicle power is shown in Figure 2. The ordinate axis (Y) shows the difference value of vehicle Power according to the increase in the angular velocity (rpm) of the vehicle expressed on the axis. The horsepower value shown in Figure 2 is the average value obtained from the chassis dynamometer test.

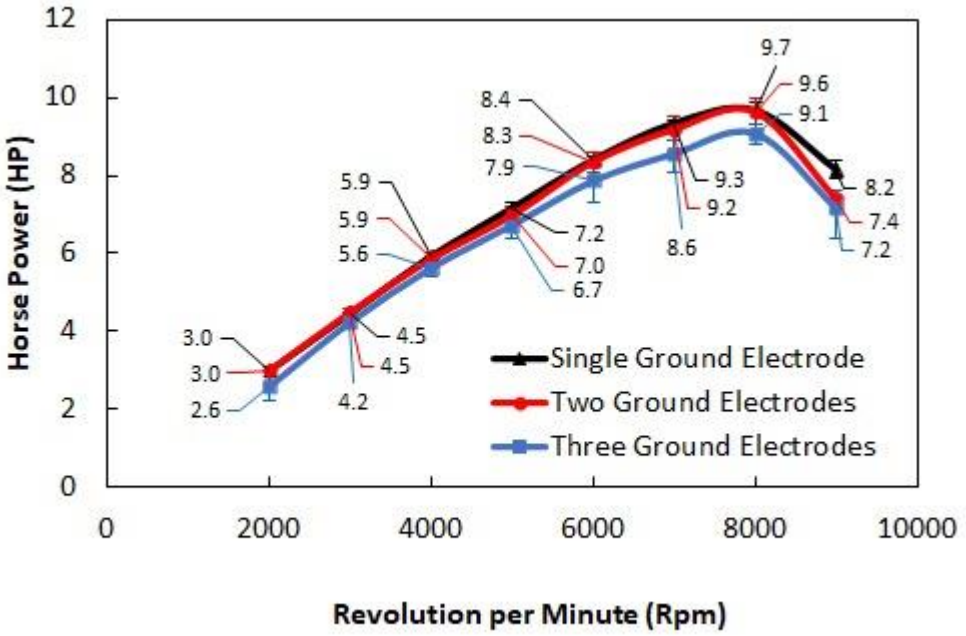

Figure 2. Graph of vehicle power as the function of angular velocity on the chassis dynamometer test.

The results showed that the value of the vehicle's horsepower increased from 2000 - 8000 rpm. The vehicle shows the optimum performance at an angular velocity of 8000 rpm with a power value of 10 HP. After that, the vehicle's power decreased to 8 HP when it reached 10000 rpm. This increment of trend line power along with angular velocity occurs in all variations of the spark plug. Vehicles that use standard spark plugs with three electrode spark plugs produce lower performance than single and double spark plugs. The optimum value of power generated by a standard spark plug is 8 HP. This value tends to be lower compared to other variations that generate Power up to 10 HP. The power transmitted from the shaft to the vehicle wheels decreases due to friction losses during the transmission process, friction between the wheels and the chassis dynamometer's surface, and the weight of the vehicle wheels.

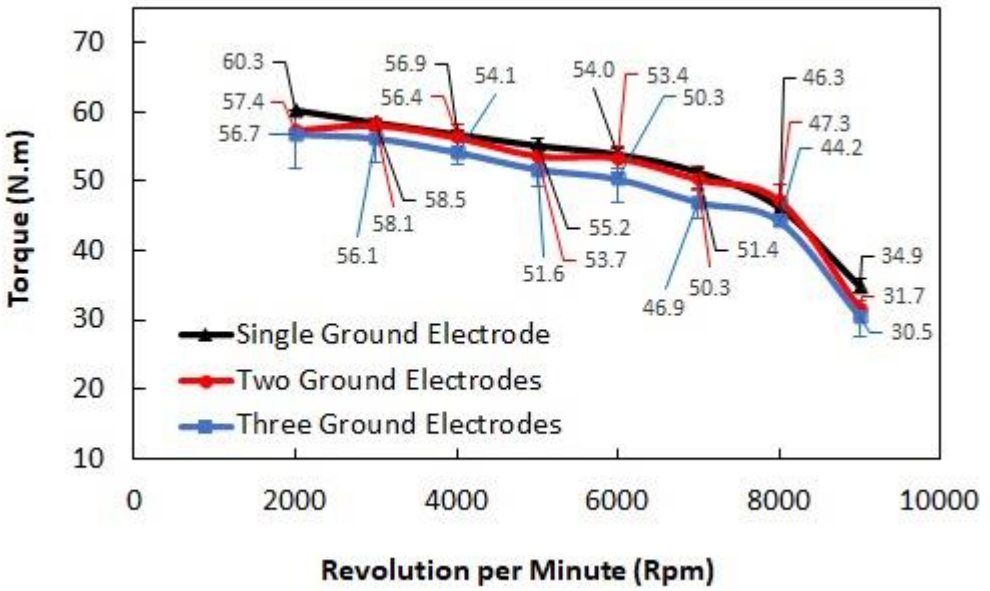

Figure 3. Graph of vehicle Torque as the function of angular velocity on the chassis dynamometer test.

The chassis dynamometer test also produces torque to measure the force which rotates an object in axis data. The torque produced by the dynamometer chassis test is shown in Figure 3. The ordinate axis (Y) shows the change in the vehicle's torque to the increase in the angular velocity (rpm) of the vehicle expressed on the axis. The test results show that the various ground electrode produce similar trend line torque. Chassis dynamometer test results increasing the angular speed of the vehicle causes a decrease in the vehicle torque value. The highest torque value of the vehicle is achieved at the vehicle's initial speed of 2000 rpm. The number of Ground Electrode spark plugs on the 125 cc supra fit affects the combustion process result in different torque where the standard spark plug produces the lowest torque value than the other variations. The torque generated by the single spark plug and the double ground electrode spark plug has similar torque. The highest torque value is produced by applying a single ground electrode spark plug of 60 Nm.

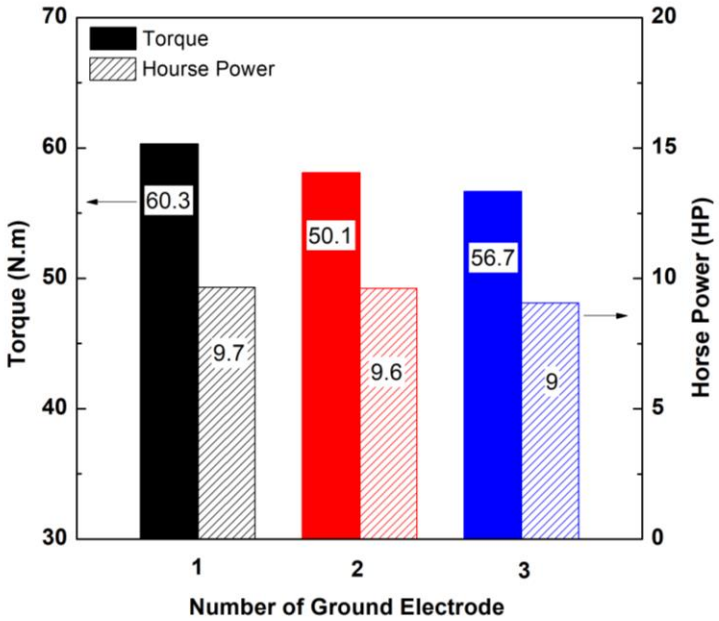

Figure 4. Graph of vehicle Torque as the function of angular velocity on the chassis dynamometer test.

The maximum value produced by testing the chassis dynamometer on various spark plug ground electrodes is shown in graph 4. The graph shows the vehicle's performance in the form of torque and power values shown on the ordinate axis (Y) to the (x) axis of variations in the number of ground spark plug

electrodes. The maximum value of torque generated by the vehicle is shown by a black bar chart (single electrodes ground), red (double ground electrodes), and blue (three electrodes ground). Figure 4 shows that the highest torque value with a single ground spark plug reaches > 60 Nm. The use of variations of double and three electrodes ground spark plugs in vehicles produces a lower torque of < 60 Nm. The power value generated by the vehicle from the dynamometer test is depicted through a lined bar chart. The results showed that vehicles using a single-type spark plug and double ground electrodes had similar power values of around 50 HP. In comparison, the three ground electrodes generate the lowest power spark plug of approximately 48 HP.

3.2 Effect of Spark Plug Ground Electrode

In this study, power measurements were carried out using an on-wheel chassis dynamometer to measure the vehicle wheels' power. This condition shows that the power generated from the on-wheel chassis dynamometer test is useful energy. An axle dynamometer is a vehicle performance test to measure the vehicle shaft's transmission power. Besides using an axle dynamometer, the value of brake horsepower can be represented as the power shaft.

Break Mean Effective Power (BMEP) is the pressure that can be used to move the crankshaft. Hot air pressure, which contains high energy resulting from the combustion process, is called indicative mean sufficient power (IMEP). After the combustion process occurs, the piston will be pushed back and blocked by friction. The remaining pressure used to move the piston is called BMEP. The BMEP value analysis is crucial because BMEP results from combustion, which is then converted into a torque and displacement value. The change in BMEP value due to the increase in angular velocity is shown in Figure 6.

Figure 5 shows that the BMEP graph is similar to the torque generated by vehicles, where the BMEP decreases during the angular velocity increment. An increase in angular velocity occurs as the fuel intake manifold is opened wide to create a rich Air-fuel mixture. The combustion timing is shorter, in this condition, and the piston moves faster. Increasing the fuel ratio when the combustion process is carried out rapidly can cause the combustion process to be incomplete. The energy possessed by the fuel cannot be fully converted into an explosion during combustion and thrown into the exhaust manifold. The pressure generated during the combustion process decreases as the angular velocity increases.

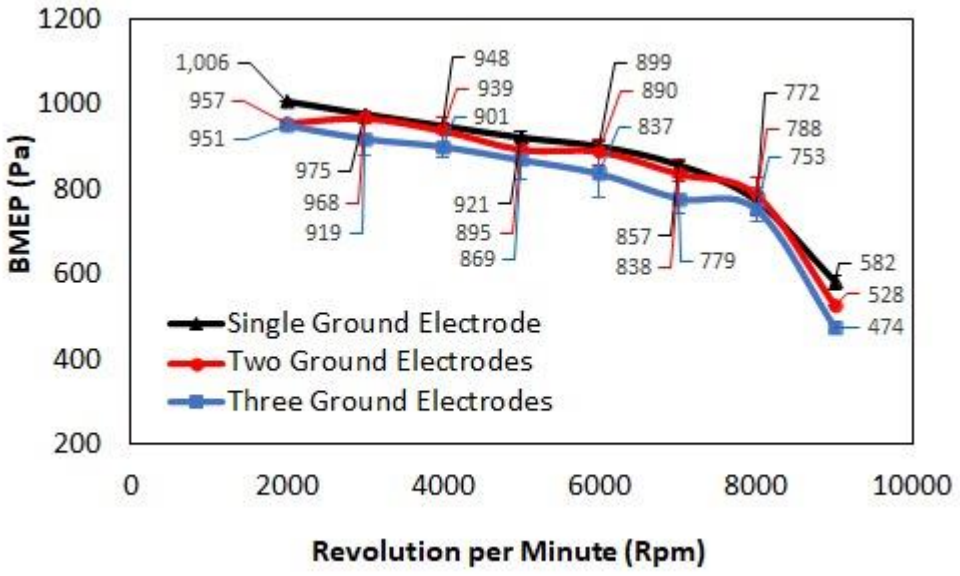

Figure 5. Graph of vehicle BMEP as the function of angular velocity on the chassis dynamometer test.

This research shown in the previous graph shows that a double ground electrode spark plug shows the best performance. This condition is illustrated by the vehicle's high power, torque, BHP, and BMEP, indicating that using a double ground electrode spark plug triggers a better combustion process. Further research can be verified by reviewing other parameters such as combustion and flame kernel emissions.

4. CONCLUSION

The spark plug has a crucial influence on the combustion process at SIE. In this study, a chassis dynamometer test was carried out to determine vehicle performance against variations in the number of ground electrode spark plugs. The fluctuation value of power, torque, BHP, and BMEP is observed along with the vehicle's angular velocity increment. The results showed that the double ground electrode spark plug produced better performance than other variations. This condition indicates that using the double ground electrode spark plug results in an ideal combustion process.

5. ACKNOWLEDGEMENT

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