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Original Article

The Effect of Variations in Spark Plug Electrode Tips on Power and BMEP of Motorcycle Engines

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Abstract *- The purpose of this study is to determine the largest and smallest power values and determine the maximum change in BMEP on the influence of the shape of the spark plug electrode tip on a 150 cc motorcycle engine. This study applies laboratory experiments as a research method with the open full-throttle test method. The increased power test for each spark plug with standard spark plugs yields the highest power of 6.64 kW at 6000 rpm and the lowest power at 2000 rpm of 2.04 kW. While the spherical electrode iridium spark plug produces the lowest power of 2.09 kW at 2000 rpm, the highest power at 6000 rpm of 6.68 kW, and the tapered iridium electrode spark plug produces the highest power among other spark plugs. The highest power is 7.09 kW at 6000 rpm, and the lowest power at 2000 rpm is 2.26 kW. Calculating the average effective pressure (Bmep) results in a pressure change in each spark plug from 2000 rpm to 6000 rpm, but not with a spherical electrode iridium spark plug; only 2500 rpm does not change. The calculation results in standard spark plugs with the lowest bmep value at 2500 rpm of 619 Kpa and the highest of 725.33 Kpa, while the tapered spark plug of the iridium electrode produces the lowest bmep of 606.34 Kpa at 2500 rpm and the highest of 749.78 Kpa at 6000 rpm. The tapered electrode iridium spark plug produces the highest bmep of any other spark plug, with the lowest bmep value of 670.61 Kpa at 3000 rpm and the highest of 774.23 Kpa at 6000 rpm.*

Keywords *- Bmep, Power, Round, Spark plug, Tapered.*

1. Introduction

According to data on the number of vehicles recorded per island in Indonesia published on the korlantas.polri.go.id page, the total number of vehicle ownership in Indonesia will reach more than 151 million units [1]. High market demand encourages the number of requests for motorized vehicles, which continues to increase, requiring motorized vehicle manufacturers to produce vehicles that meet consumer needs. This situation triggers motor vehicle parts manufacturers to provide the latest solutions in the form of components needed by motorcycles so that they can follow consumer desires for the quality performance of their motorized vehicle engines. Engine performance indicators can be seen from the power and brake mean effective pressure (BMEP).

The engine's combustion, which produces an explosion in the combustion chamber, causes the piston to be pushed down, and then the thrust is transmitted to the crankshaft. The force felt on the crankshaft so that the crankshaft can move is called torque [2]. Horsepower/power is how much torque can be generated in a certain period of time. Power is the ability to how fast the vehicle reaches a certain speed. Power is related to speed or top speed [4]. Many factors affect engine performance, including the ignition system and fuel quality. The ignition system on the motor functions to regulate the combustion process of the gasoline and air mixture in the cylinder according to a predetermined time, namely at the end of the compression stroke. One of the criteria the ignition system must own is that the spark must be strong. The spark plug is one component that plays an important role in producing sparks in the combustion chamber.

The varying tip of the spark plug electrode influences the combustion process; this requires the spark plug to meet requirements such as sparks must be able to reach narrow and small gaps, be able to produce combustion in areas far from sparks, and be able to produce colored sparks blue. The shape of the pointed tip of the electrode will affect the spark so that the results are more focused and stronger; therefore, the combustion process can better meet these requirements [5], so the shape of the electrode will affect the sparks produced. The results of good sparks will produce a good combustion process as well so that it has an impact on engine performance. Improving the quality of spark plugs is a new breakthrough to achieve a perfect combustion process to produce engine efficiency in terms of power and vehicle brake mean effective pressure (BMEP).

2. Theoretical Basis

2.1. 4-Step Engine Combustion Cycle

This engine type is classified as a vehicle driver by utilizing energy conversion from heat to mechanics or motion in the combustion process in the engine [6]. The internal combustion engine is divided into two types: the

external combustion engine and the internal combustion engine. The internal combustion process occurs inside the combustion engine itself, and the external combustion engine, which obtains energy from the external combustion process. The piston on a four-stroke/stroke motorcycle has to take four steps to get power through the combustion process in the engine. The steps referred to are the suction stroke, the compression stroke, the effort stroke, and finally, the exhaust stroke; this step will continue to be repeated.

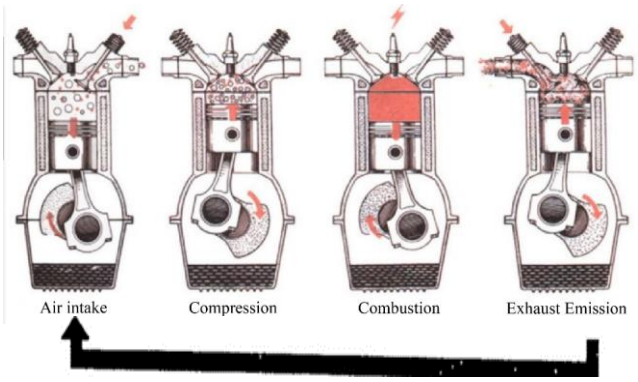


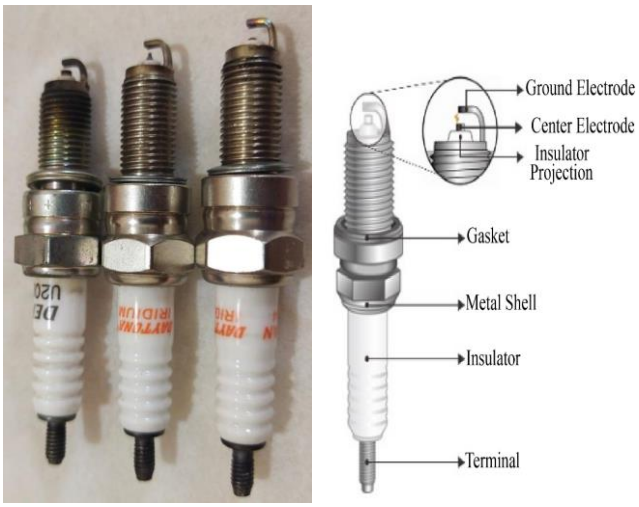
Fig. 1 4 Stroke engine principle

2.1.1. Description

- The first step is called the suction step (Intake), which is a step to create a vacuum in the combustion chamber so that fuel and air can enter. The downward movement of the piston starts from the top dead center (TMA) to the bottom dead center (BDC), simultaneously with the suction valve opening and the exhaust valve otherwise closed, the position of the crankshaft rotates 180^{o} while the camshaft rotates 90^{o}. All these conditions are called the suction step.
- The second step is the compression step (compression), which is a step to compress or compress the fuel and air mixture that is already in the cylinder chamber. The piston moves up from the bottom dead center (BDC) to the top dead point (TMA), suction valve and exhaust valve. In the same closed state, the fuel mixture is compressed. The narrowing of space that occurs in this step causes the pressure and temperature to increase. Approaching the final compression step, the spark plug sparks, and combustion occurs.
- The third step is called the Combustion Step, which is the step that is produced due to the explosion. The explosion is caused by compressed fuel and air which are then burned with sparks triggered by the spark plug, and the suction valve and exhaust valve are still closed; the fuel explosion causes the pressure and temperature in the combustion chamber to increase drastically. This is what causes the piston movement to be pushed by this pressure towards the TMB to produce a thrust to rotate the crankshaft.
- The last step is the exhaust step, which is the step to push out the combustion residue. The piston moves from the bottom up, namely from the bottom dead center (BDC) to the top dead point (TMA); condition the suction valve closes and the exhaust valve opens, the piston movement pushes exhaust gas out. After the exhaust step ends, this step will continue to repeat.

2.2. Spark Plug

The position of the spark plug engine is mounted on the inside of the internal combustion engine, to be precise, in the cylinder head with the iron electrode tip entering the combustion chamber, which functions to ignite combustion by producing an electric spark [8]. The role of the spark plug is very important in charge of sparking the sparks needed to burn the air and fuel mixture that has been compressed by the piston so that it becomes an impetus for the piston so that a business step arises. The way the spark plug works begins when the electric current is turned on by the ignition coil. When the electric current is in the spark plug, the current will jump from the middle electrode to the side electrode (negative/mass). This process produces a spark at the spark plug.



(a) **(b)**

Fig. 2 (a) Spark plugs, (b) Spark plug construction

Spark plugs have a center electrode model, generally a large electrode model and a small electrode model. This large size is usually round in shape and is widely installed in spark plugs with electrode types from nickel alloy [9]. While small or tapered sizes are usually used for spark plugs whose category is in the category of maximizing vehicle or engine performance. The important thing about a spark plug that provides good performance is that it can reduce the resistance of the spark plug (quenching action), which means the resistance to the flame explosion process. It can be interpreted that the larger the shape of the electrode, the greater the resistance. Meanwhile, the smaller the electrode, the smaller the resistance. With a stronger flame explosion power, it is certain that, in the end, it can make combustion efficiency and fuel use better.

2.3. Power

Power is the magnitude of the motor's work for a certain time. In the combustion engine, power is produced from the combustion process of the air and fuel mixture that occurs in the combustion chamber, which is usually called indicator power. The indicator power is the energy source

per unit working time of the engine to deal with all engine loads. The power generated by a motorcycle can be measured using a dynamometer, so to calculate the shaft power value can be calculated using the formula [10]:

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

Information:

Ne : Effective shaft power(Kw)
N : Engine speed (Rpm)
T : Torque (Nm)

2.4. Bmep (Brake Mean Effective Pressure)

The process of burning a mixture of air and fuel which is triggered by a spark from a spark plug in the combustion chamber, will produce explosive power so that there will be a push or pressure acting on the piston so that the piston is pushed to the bottom dead center (BDC) and performs the work step.

The magnitude of this pressure varies along the stroke of the piston. If a constant pressure is taken that acts on the piston and produces the same work, then the pressure is referred to as work per cycle per volume of the piston stroke. To find the value of Bmep (Break Mean Effective Pressure) can be calculated using the following formula:

$$Bhp = \frac{2 .\pi .n .T}{1000} \text{ (kW)}$$

$$Bmep = \frac{Bhp \, . \, z}{A .L .n.i} \text{ (KPa)}$$

Information:

Bhp : Power (kW)
A : piston cross-sectional area (m2)
L : piston stroke length(m)
i : number of cylinders
n : engine speed (rpm)
z : 1 (two-stroke motor) or 2 (four-stroke motor)

3. Materials and Methods

3.1. Tools and Materials Research

The testing process required tools and materials, there are tools and materials prepared for testing are as follows:

Table 1. Tools and materials

No	Information	
1.	Materials	Iridium spark plugs
		150 cc motorcycle
		92 Octane Fuel
2.	Tools	Spark Plug Wrench
		Dynamometers
		Blowers

3.2. Preparation and Setup of Equipment

Fig. 3 Dynamometer

The gas analyzer setting procedure is explained as follows:

1. Turn on the computer, then enter the data input of the vehicle to be tested and the data of the dyno tool used. As well as setting the received folder as a place to save the dyno test results.
2. Raise the motor onto the dyno test machine, insert the front wheel into the wheel slot and then adjust the length of the motor to the roller of the dyno test tool.
3. The scan tool cable is attached to the scan socket on the motor for RPM readings, then attach the strap to the rear seat of the motorbike and the other side is locked to the body of the dyno test tool after being installed, then tightened and the process of tightening the left and right must be straight in balance so that the motor completely upright.
4. The engine is turned on, and it waits a moment until the engine reaches working temperature because, in this condition, the engine can work optimally.
5. The program is in run mode, where the program is ready in this method.
6. Then press the start button to start; when pressed, the motor tester must open the throttle valve to the maximum by turning the gas on the handlebar until the engine shows its maximum capability (maximum Rpm). The start button is pressed, indicating that the program on the PC run is carrying out the graphic recording process so that the start button pressing must coincide with the driver opening the throttle.

7. After the monitor and the motor indicator shows that it has reached the maximum Rpm, immediately press the start button again. Then on the PC monitor, it can show the test results in the form of graphs and test data tables.

4. Results and Discussion

This research focuses on engine performance which includes power testing and calculating the average effective pressure (bmep) of a 150 CC vehicle with the treatment of replacing spark plugs using standard spark plugs, round electrode iridium spark plugs, and tapered iridium electrode spark plugs with 92 octane fuel. The research will be continued with performing data processing on the Power test data, which will later be processed into Bmep data through the calculation formula above. The test data and calculations that have been obtained are then arranged in tables and plotted into graphs, and processed so that conclusions can be obtained from the use of variations in the tip of the spark plug electrode.

4.1. Power Test Data

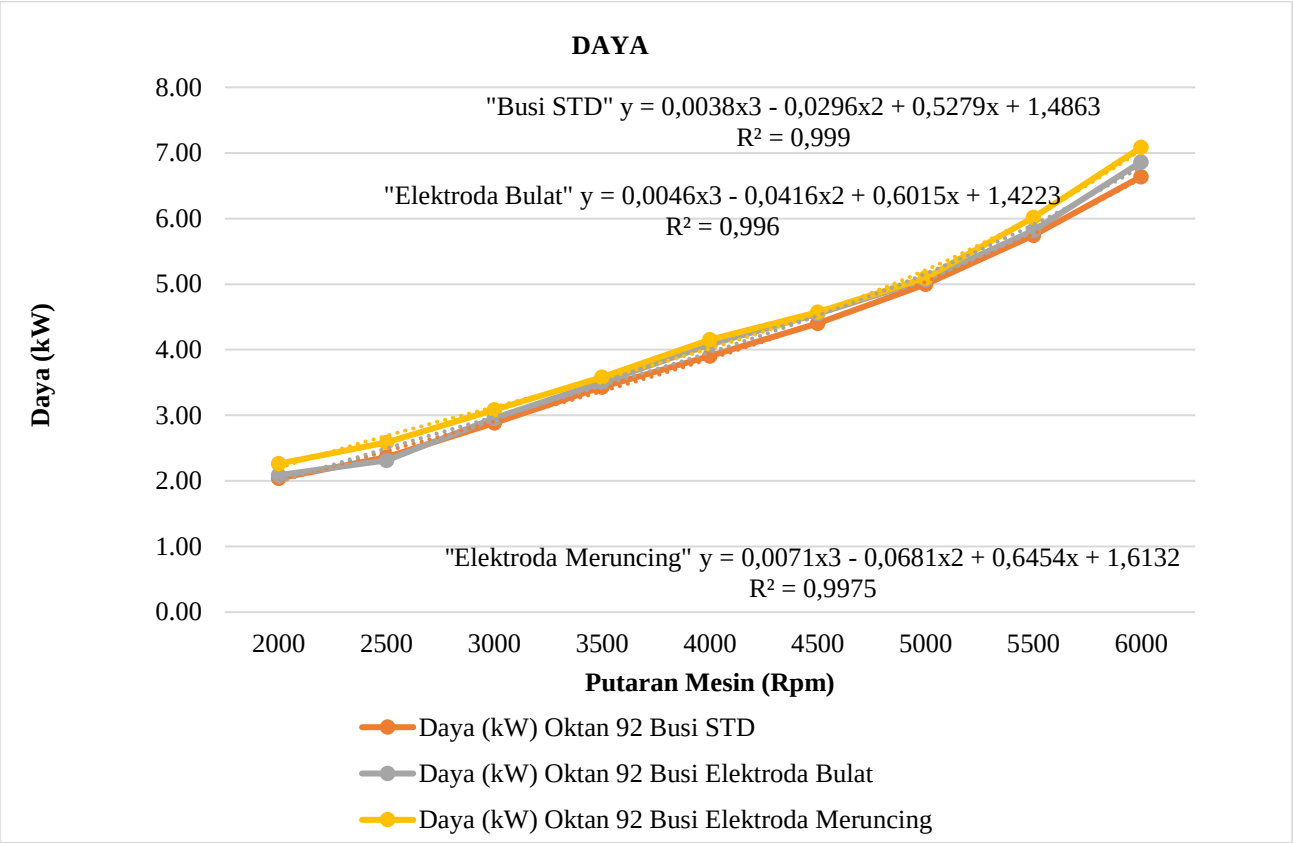


Fig. 4 Power graph

Table 2. Power data

Putaran Mesin (Rpm)	Daya (kW) Oktan 92		
	Busi STD	Busi Elektroda Bulat	Busi Elektroda Meruncing
2000	2,04	2,09	2,26
2500	2,36	2,31	2,59
3000	2,88	2,96	3,08
3500	3,43	3,51	3,58
4000	3,90	4,08	4,15
4500	4,40	4,55	4,58
5000	5,00	5,07	5,10
5500	5,74	5,82	6,02
6000	6,64	6,86	7,09

The results of data processing included in the graph, as shown in Figure 4, can explain that all tests from the application of iridium spark plugs with round and tapered electrode shapes are capable of producing tests with an increase in maximum power at 6000 rpm rotation compared to using standard spark plugs. This shows that using iridium spark plugs with rounded and tapered electrode shapes on vehicles can increase the engine's maximum power.

From all the tests carried out, it was found that the best spark plug test data results and capable of producing the highest power test were the Tapered Iridium Electrode Spark Plugs. As seen from the table and graph above, the tapered iridium electrode spark plugs experience a steady increase in power from 2000 to 6000 rpm and produce the highest power among the other spark plugs. The highest power is 7.09 kW at 6000 rpm, and the lowest power at 2000 rpm is 2.26 kW. In testing using round electrode iridium spark plugs, the test results showed an increase in power at each engine speed but not as high as testing using iridium spark plugs with tapered electrodes, with the highest power

test results of 6.86 kW and the lowest test results of 2.09 kW at 2000 engine speed rpm.

4.2. Brake Mean Effective Pressure Data Test

Table 3. Bmep data

Putaran Mesin (Rpm)	Bmep (Kpa)		
	Oktan 92		
	Busi STD	Busi Elektroda Bulat	Busi Elektroda Meruncing
2000	668,28	684,58	741,63
2500	619,38	606,34	678,06
3000	630,25	646,55	673,71
3500	642,67	656,64	670,61
4000	639,76	668,28	680,50
4500	641,11	662,85	666,47
5000	655,24	665,02	668,28
5500	684,58	693,47	717,18
6000	725,33	749,78	774,23

Table 3. Bmep change data

Putaran Mesin (Rpm)	Bmep (Kpa)	
	Oktan 92	
	Busi STD	Busi Elektroda Bulat
2000	16,30	73,35
2500	- 13,04	58,68
3000	16,30	43,47
3500	13,97	27,94
4000	28,52	40,75
4500	21,73	25,35
5000	9,78	13,04
5500	8,89	32,60
6000	24,45	48,90

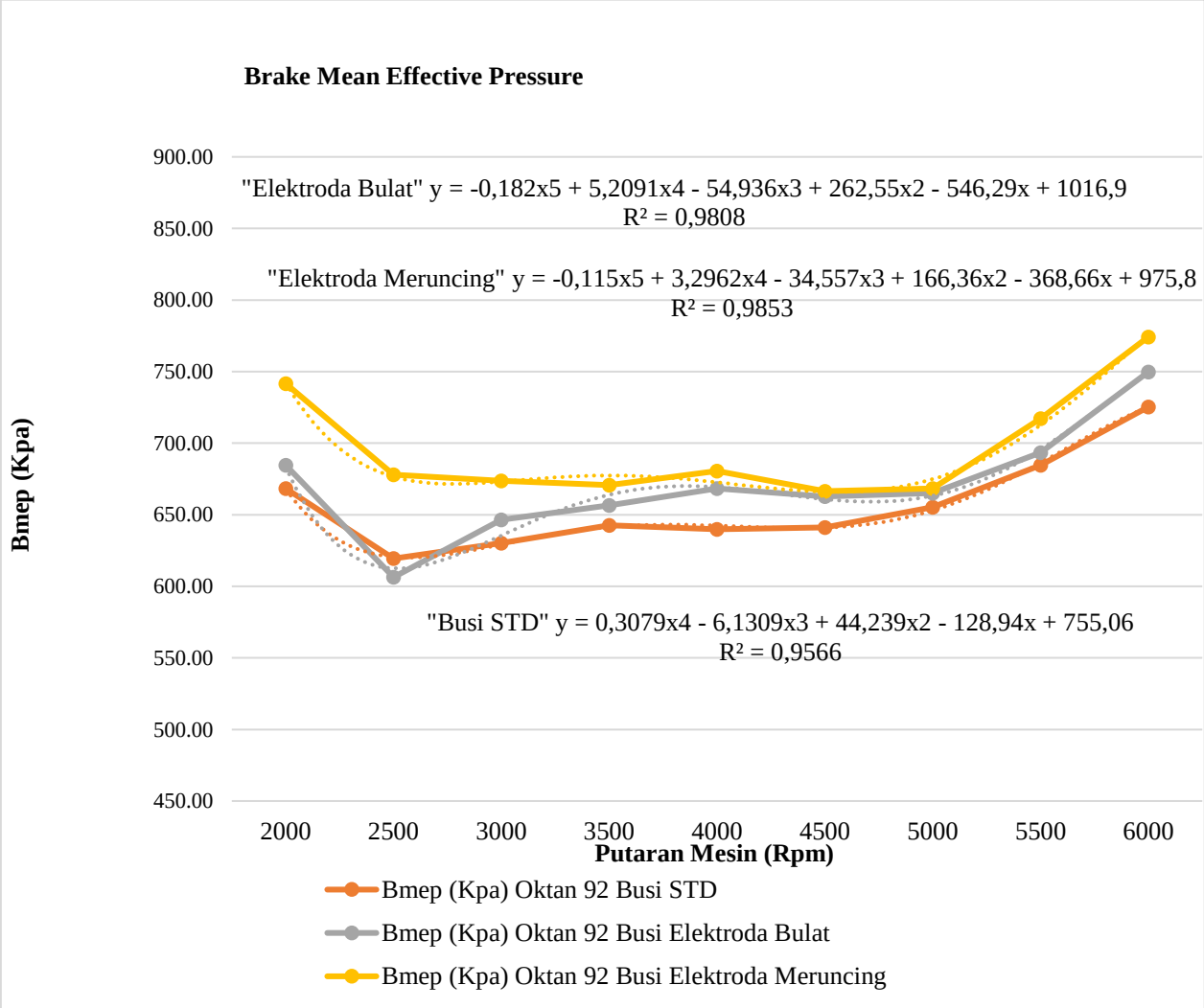


Fig. 5 Bmep graph

Based on the results of data processing and calculations, it can be displayed in a graph like Figure 4. It can be noted that all calculations using iridium spark plugs with round and tapered electrodes can produce an increase in the average effective pressure value (bmep) at each engine speed test from 2000 rpm to 7000 rpm compared to testing using standard spark plugs.

Of all the calculated data, the best spark plugs and the highest power output are iridium spark plugs with tapered electrodes. This can be seen from the table and graph above; iridium spark plugs with tapered electrodes have a significant increase in bmep value from 2000 rpm to 6000 rpm, and the highest bmep value among other spark plugs is with the highest bmep value of 774.23 Kpa at 6000 rpm rotation and lowest at 3500 rpm of 670.61 Kpa.

When using round electrode iridium spark plugs, there was an increase in the bmep value at 2000 rpm to 6000 rpm, except that at 2500 rpm, there was no increase. The highest bmep value was 749.78 Kpa at 6000 rpm, and the lowest bmep value was 606.34 Kpa.

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From the graph and table above, it can be concluded that the change in the bmep value or the average effective pressure on the vehicle engine increases significantly with the increase in the power generated by the vehicle engine. The bmep value or average effective pressure is generated from the power calculation, meaning that the greater the power produced by the engine, the greater the resulting bmep value and vice versa.

5. Conclusion

Based on the results of tests and calculations, as well as data processing that has been carried out on power and average effective pressure (bmep) from tests using iridium spark plugs and 92 octane fuel with several variations in the shape of the tip of the electrode on the spark plug, the following conclusions can be drawn:

- Power testing has increased for each spark plug, with standard spark plugs producing the highest power of 6.64 kW at 6000 rpm and the lowest power at 2000 rpm of 2.04 kW. While iridium spark plugs with round electrodes produce the lowest power of 2.09 kW at 2000 rpm and the highest power at 6000 rpm of 6.68 kW, and the tapered iridium electrode spark plugs produce the highest power among the other spark plugs. The highest power is 7.09 kW at 6000 rpm, and the lowest power at 2000 rpm is 2.26 kW.
- The calculation results of the average effective pressure (Bmep) produce a change in pressure at each spark plug from 2000 rpm to 6000 rpm, but not with round electrode iridium spark plugs; only at 2500 rpm does it not change. The results of the calculations produce a standard spark plug with the lowest bmep value at 2500 rpm of 619 Kpa and the highest bmep of 725.33 Kpa, while round electrode iridium spark plugs produce the lowest bmep of 606.34 Kpa at 2500 rpm and the highest is 749.78 Kpa at 6000 rpm. Tapered electrode iridium spark plugs produced the highest bmep compared to other spark plugs, with the lowest bmep value of 670.61 Kpa at 3000 rpm and the highest of 774.23 Kpa at 6000 rpm.

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