Jurnal Dinamika Vokasional Teknik Mesin
Vol. 8, No. 1, April 2023, pp. 89-99
https://journal.uny.ac.id/index.php/dynamika/issue/view/57443
ISSN: 2548-7590, DOI: 10.21831/dinamika.v8i1.57443

Performance of single cylinder combustion engine with variations in fuel octane number and compression pressure

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Article Info

Article history:

Received January 01, 2023
Revised February 28, 2023
Accepted April 30, 2023
Published April 30, 2023

Keywords:

Performance
Octane number
Compression pressure

ABSTRACT

The performance of an internal combustion engine was greatly influenced by several factors, including the quality of the fuel and the compression pressure of the engine. High compression pressure, followed by the selection of the appropriate fuel octane number, would result in optimal performance. Conversely, an engine with a high compression pressure given fuel with a low octane number would produce poor performance. Unfortunately, only few users know that high compression engines require fuel with high octane numbers. The purpose of this study was to determine the difference in the power & torque output of single-cylinder combustion engine given variations in compression pressure using pertamax (RON 92) & pertamax plus (RON 95) fuel. A dynamometer test has performed to determine the difference in engine performance. The results showed that the engine with high compression pressure (11.8 Kg/cm2) with RON 95 fuel produced the highest power output of 7.5 KW with the highest torque output of 9.6 Nm. While the engine with low compression pressure (10 Kg/cm2) using RON 92 fuel produced the lowest power output of 4.2 KW with the lowest torque output of 3.8 Nm.

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INTRODUCTION

An *internal combustion engine (ICE)* is an engine that converts thermal energy into mechanical energy (Benson & Whitehouse, 1979). The performance of an internal combustion engine is greatly influenced by several factors, including the quality of the fuel (octane number) and the compression pressure of the engine. The usage of low fuel quality, in engines with high compression pressure can resulted in decrease in engine performance as well as increased the amount of fuel consumption. (Pulkrabek, 1997)

Internal combustion engine that are usually used in motorcycles and cars, there are components in the form of cylinders that contain pistons that move back and forth. The four-stroke motor requires twice the rotation of the crankshaft to produce one cycle in the cylinder (Ferguson & Kirkpatrick, 2015). In other words, four stroke engine requires two revolutions of the crankshaft to complete its cycle (Kristanto, 2015). The performance produced by an internal combustion engine depends on the combustion results of the mixture of fuel and air in the combustion chamber. This means that in an engine that has a high compression pressure and followed by the usage of the right fuel quality, it would produce optimal engine performance as well (Maurya & Agarwal, 2011).

The increase in the number of motorized vehicles as evidenced by data from the Indonesian Motorcycle Industry Association (AISI) said, throughout 2019 there were 1,100,950 units of motorcycles sold, increase 19.4% from 2018 (922,123 units) as the largest fuel consumer in the transportation sector, especially gasoline (Octa, 2019).

Currently, several fuel providers, both from the government and the private sector provided several choices of fuel types. This fuel selection is classified according to the octane number (Research Octane Number / RON). These RON values vary from RON 90, RON 92, RON 95 to even RON 98 (Decree of the Director General of Oil and Gas, 2018). A study that has been conducted by Fernandez et al entitled "Improving fuel economy and engine performance through gasoline fuel octane rating" obtained results if the power produced by the vehicle increases significantly with the usage of a better fuel octane number, besides that the time required for acceleration is also getting shorter. In addition, the increasing octane number of the fuel used, also decreases fuel consumption so, this can actively reduce vehicle exhaust emissions (Rodríguez-Fernández et al., 2020).

Another study conducted by Jiang et al obtained result that large power efficiency and low Nitrogen Oxide (NOx) emissions could be obtained by regulating exhaust gas recirculation (EGR) components as well as the selection of fuel with the appropriate octane number. The selection of fuel with the right octane number is very important to get optimal power output with low exhaust emissions in an internal combustion engine (Jiang et al., 2019).

Currently, automotive vehicle manufacturers created engines with high compression pressure to produce optimal power output, but unfortunately there are still many consumers who do not realized that engine which have a high compression pressure required a high octane number of fuel in order to produce optimal power output. Based on the description above, we will conduct performance testing using a dynamometer on a single cylinder engine with compression pressure values of 11.8 Kg/cm2 and 10 Kg/cm2 where each test uses pertamax fuel (RON 92) and pertamax plus (RON 95) to see the difference in power and torque output.

METHOD

The method used in this study is experimental method, which was carried out on a motorcycle with a single-cylinder engine with a capacity of 125 cc. To regulate the compression pressure of the engine, the use of gaskets on the cylinder head in the amount of one gasket and three gaskets. The addition of a gasket to the cylinder head resulted in a change in the volume of the combustion chamber, resulting in the change in the value of the compression pressure.

The performance parameters of the machine can be calculated using equation (1), where (T) is Torque, (F) is the force exerted against the rotor multiplied by the distance (r).

$$T = F \times r \quad (1)$$

The power generated can be calculated using equation (2), where N is the speed of rotation of the crankshaft (Rpm).

$$P = 2\pi NT / (60 \times 1000) \quad (2)$$

The test result data then analyzed directly and then concluded. The test result data changed in the form of tables and graphs to make it easier to read. The equipment used to perform the performance test is a dynamometer with some additional equipment such as; toolset and burette measure. The experimental design in this study is shown by Figure 1.

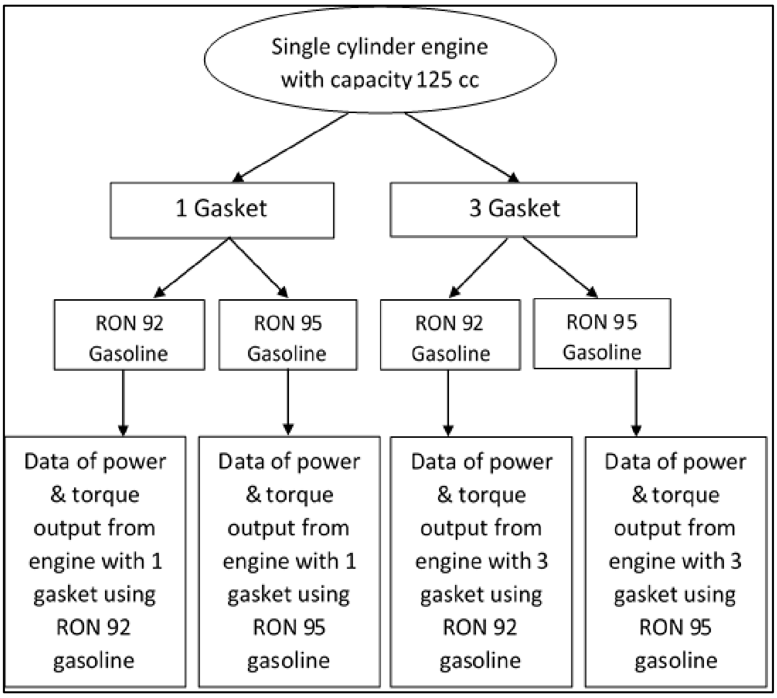

Figure 1. Study experiment design

Before testing with a dynamometer, the motorcycle must be positioned correctly, where the position of the rear wheels must be directly above the dynamometer roller. The tachometer cable must relate to a high voltage cable to the spark plug, then the hose to the carburetor removed and instead, the hose leading to the carburetor connected with a hose from the measuring burette where inside this burette will be filled with RON 92 and RON 95 fuel alternately. The test scheme using a dynamometer shown in Figure 2.

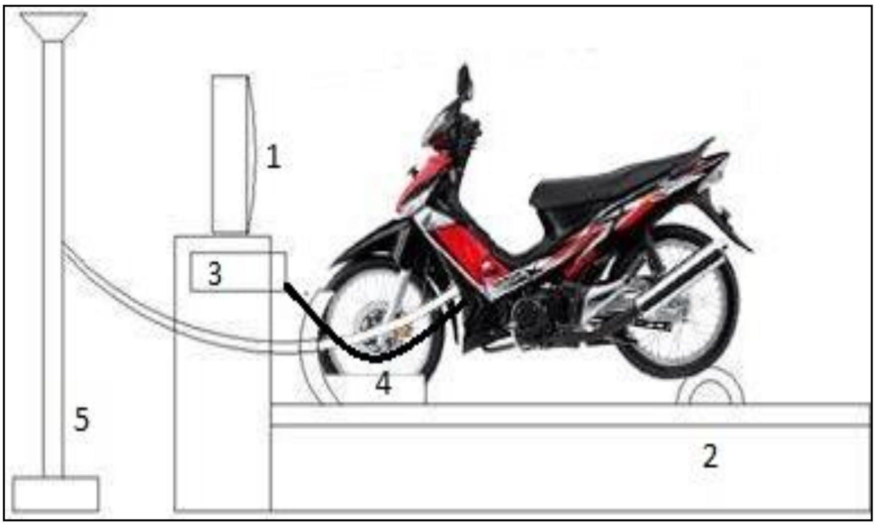

Figure 2. Performance test scheme

After all the preparations completed, performance test can be done by two people, where one person will operate the motorcycle, and the other person will operate the computer /software. The testing process shown by Figure 3.

Figure 3. Performance testing process

RESULTS AND DISCUSSION

Power Output Comparison

Based on Table 1 is seen a comparison of power output from several variations in compression pressure using RON 95 fuel. Each value of the power output is obtained from three times testing and then the value shown in Table 1 is the average value. Engine with high compression pressure (11.8 Kg/cm^2) generally produce higher power output at almost all engine revolutions (Rpm).

Table 1. Power output with gasoline RON 95

Power output (KW) at some variations of compression pressure		
Rpm	10 Kg/cm^2	11.8 kg/cm^2
4000	4,7	5,4
5000	6,6	6,8
6000	6,9	7,5
7000	6,4	7,2
8000	4,6	5,8

Meanwhile, lower compression pressure engine (10 Kg/cm2) generally produce lower power output in almost all engine revolution ranges (Rpm) when compared to engines with higher compression pressure (11.8 Kg/cm^2). The power output of several variations in compression pressure using RON 95 fuel can be seen clearly in Figure 4.

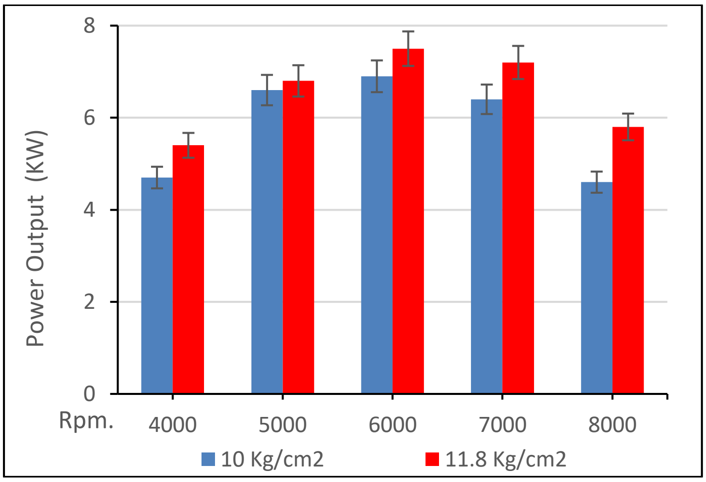

Figure 4. Power output using RON 95 gasoline with compression pressure variations

The comparison of power output at 8000 Rpm, on the same engine with a compression pressure of 10 Kg/cm2 only produces a power output of 4.6 KW, while engine with a compression pressure of 11.8 Kg/cm^2 is able to produce 26% higher power output.

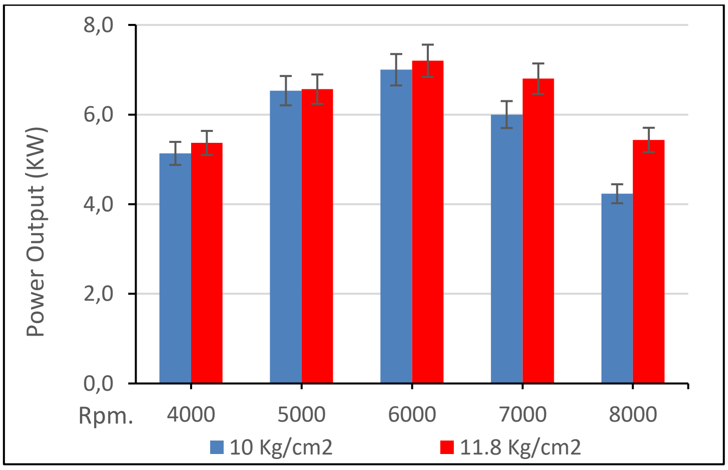

Figure 5. Power output using RON 92 gasoline with compression pressure variations

Based on Figure 5 is seen the difference in the power output produced by the engine with several variations in compression pressure using RON 92 fuel. Overall, engine with compression pressure of 10 Kg/cm2 also produces lower power output compared to an engine with a compression pressure of 11.8 Kg/cm^2. The highest power output of an engine with compression pressure of 10 Kg/cm^2 is only 7.0 KW at an engine speed of 6000 Rpm.

Table 2. Power output with gasoline RON 92

Power output (KW) at some variations of compression pressure		
Rpm	10 Kg/cm^2	11.8 kg/cm^2
4000	5,1	5,4
5000	6,5	6,6
6000	7,0	7,2
7000	6,0	6,8
8000	4,2	5,4

The power output produced by an engine with a compression pressure of 11.8 Kg/cm2 produces greater power output compared to an engine with a compression pressure of 10 Kg/cm^2. As comparison, power output with a value of 5.4 KW is produced by an engine with a compression pressure of 11.8 Kg/cm2 at engine revolution range of 8000 Rpm, while in the same engine revolution range, engine with a compression pressure of 10 Kg/cm2 only produces power output in amount of 4.2 KW. This proves that engines with higher compression pressures require a higher fuel octane number in order to produce optimal power output (Muku & Sukadana, 2009).

Table 3. Comparison of engine power output using two types of fuel

Power output at compression pressure 11.8 Kg/cm^2 (KW)		
Rpm	Pertamax	Pertamax Plus
4000	5,4	5,4
5000	6,6	6,8
6000	7,2	7,5
7000	6,8	7,2
8000	5,4	5,8

The comparison of power output between RON 95 and RON 92 fuel usage in engine with a compression pressure of 11.8 Kg/cm^2 is shown by Table 3. From engine revolution range of 5000 to 8000 Rpm, engine that use pertamax plus fuel are able to produce higher power output compared to engines that use pertamax. In general, engine that use pertamax plus fuel are able to produce 4% higher power output compared to engine that use pertamax.

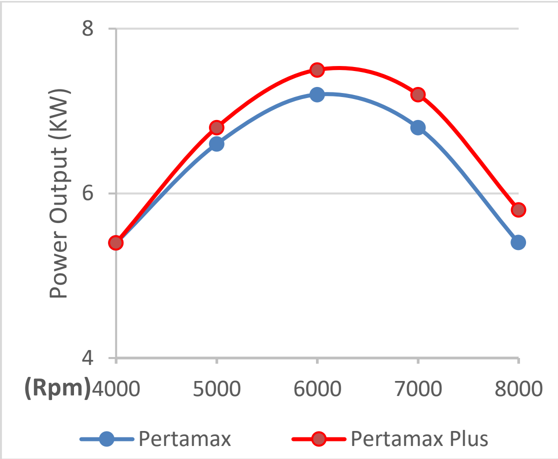

Figure 6. Comparison of power output at a compression pressure of 11.8 Kg/cm^2 using gasoline RON 92 & RON 95

Figure 6 clearly shown the comparison of engine power output at a compression pressure of 11.8 Kg/cm^2 using RON 92 & RON 95 fuel. At an engine revolution range of 8000 Rpm, an engine using RON 92 fuel produces a power output of 5.4 KW. In addition, engine that uses RON 95 fuel produces 7% higher power output at the same engine revolution. This again proves, that the usage of fuel with a high octane number in engine with high compression pressure will produce optimal power output (Saifudin & Susila, 2018).

Torque Output Comparison

The result of torque testing on several variations of compression pressure using RON 95 & RON 92 fuel have been carried out and the result can be seen in Table 4. Each value of the torque output is obtained from three times testing and then the value shown in Table 4 are average value. Engine with high compression pressure (11.8 Kg/cm^2) generally produced higher torque output at all engine revolutions (Rpm).

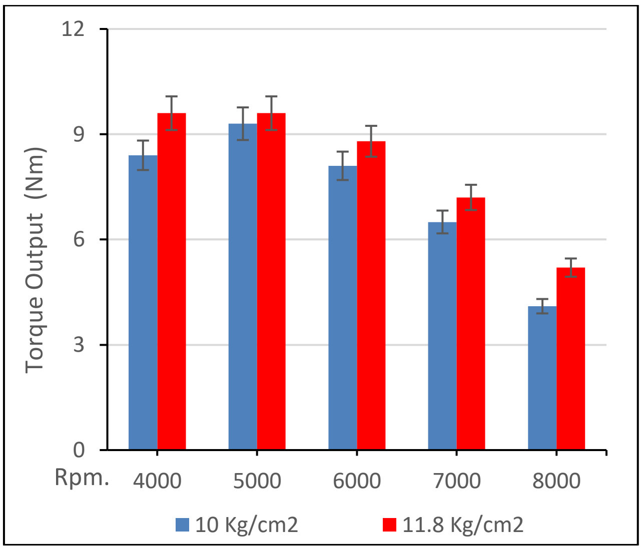

Figure 7. Torque output using RON 95 gasoline with compression pressure variations

The highest torque output of 9.6 Nm produced by an engine with a compression pressure of 11.8 Kg/cm2 over an engine revolution range from 4000 to 5000 Rpm. At the same engine revolution range, lower torque output difference of 1.2 Nm and 0.3 Nm produced by engine with compression pressure of 10 Kg/cm^2 in the engine revolution range from 4000 to 5000 Rpm respectively. The torque output of engine with some variations in compression pressure using RON 95 fuel can be seen clearly in Figure 7.

Table 4. Torque output with gasoline RON 95

	Torque output (Nm) at some compression pressure variations	
Rpm	10 Kg/cm^2	11.8 kg/cm^2
4000	8,4	9,6
5000	9,3	9,6
6000	8,1	8,8
7000	6,5	7,2
8000	4,1	5,2

The lowest torque output with value of 4.1 Nm produced by engine with a compression pressure of 10 Kg/cm2 at engine revolution of 8000 Rpm. At the same engine revolution range, engine with a compression pressure of 11.8 Kg/cm^2 produced larger torque output in amount of 1.1 Nm. The results of this test indicate that the higher compression pressure of engine, the higher octane number of the fuel is needed so the engine is able to produce optimal torque output. (Wardhana et al., 2018)

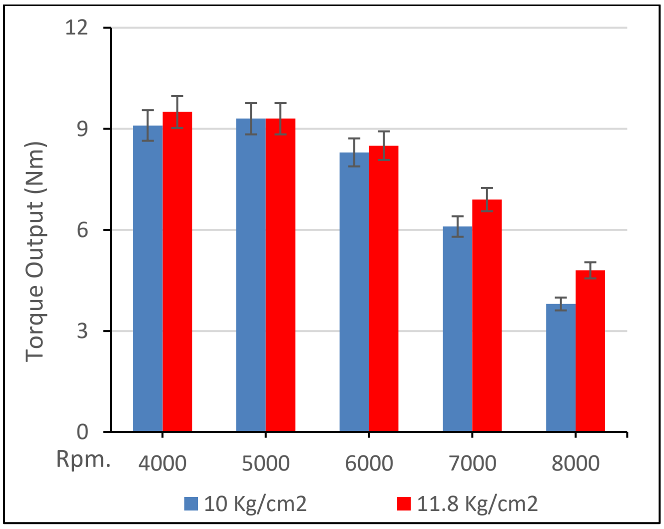

Figure 8. Torque output using RON 92 gasoline with compression pressure variations

Torque output testing of the engine with several variations in compression pressure using RON 92 fuel can be seen in Figure 8. The highest torque output of 9.5 Nm produced by an engine with a compression pressure of 11.8 Kg/cm^2 at engine revolution range of 4000 Rpm. In general, the torque output produced by engine with a compression pressure of 11.8 Kg/cm^2 is higher compared with engine with a compression pressure of 10 Kg/cm^2. The test results of the torque output produced by the engine with some variations in compression pressure can be seen clearly in Table 5.

Table 5. Torque output with gasoline RON 92

	Torque output (Nm) at some compression pressure variations	
Rpm	10 Kg/cm^2	11.8 kg/cm^2
4000	9,1	9,5
5000	9,3	9,3
6000	8,3	8,5
7000	6,1	6,9
8000	3,8	4,8

The lowest value of torque output produced by an engine with a compression pressure of 10 Kg/cm2 at the engine rotation range of 8000 Rpm is only 3.8 Nm. In the same engine revolution range, the higher torque output in amount of 1 Nm produced by an engine with a compression pressure of 11.8 Kg/cm^2. This test proved that the usage of a low octane number of fuel in engine with low compression pressure only results in less optimal torque output (Ariawan et al., 2016).

Table 6. Comparison of engine torque output using two types of fuel

	Torque output at compression pressure 11.8 Kg/cm^2 (Nm)	
Rpm	Pertamax	Pertamax Plus
4000	9,5	9,6
5000	9,3	9,6
6000	8,5	8,8
7000	6,9	7,2
8000	4,8	5,2

Table 6 shown a comparison of the torque output produced by the engine with a compression pressure of 11.8 Kg/cm^2 using RON 92 and RON 95 fuel. From an engine revolution range of 4000 Rpm to 8000 Rpm, engines that use RON 95 fuel are able to produce higher torque output compared to engine that use RON 92 fuel. In general, engine that uses RON 95 fuel are able to produce 4% higher torque output compared to engine that use RON 92 fuel.

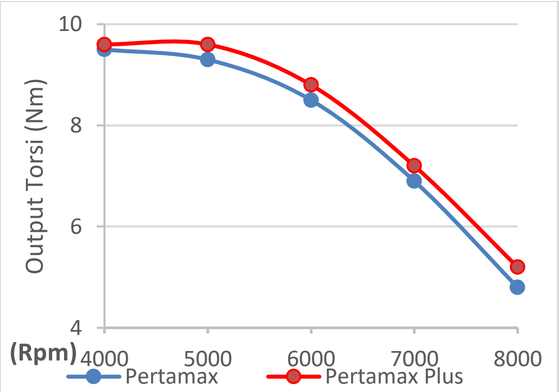

Figure 9. Comparison of torque output at a compression pressure of 11.8 Kg/cm^2 using RON 92 & RON 95 gasoline

Based on Figure 9 clearly shown the comparison of engine torque output at a compression pressure of 11.8 Kg/cm^2 using RON 95 & RON 92 fuel. At engine revolution range of 8000 Rpm, engine that uses RON 92 fuel produced a torque output of 4.8 Nm, meanwhile, engine that uses RON 95 fuel able to produced 8% higher torque output in amount of 5.2 Nm. This again proves, that the usage of fuel with a high octane number in engine with high compression pressure will produced optimal torque output (Laduni, 2022).

CONCLUSION

Power and torque produced by an internal combustion engine are strongly influenced by the compression pressure and octane number of the fuel used. The usage of RON 95 fuel in engines with a compression pressure of 11.8 Kg/cm^2 produces the highest power and torque output. From this, it can be concluded, that the selection of the octane number of the fuel must be adjusted to the compression pressure of the engine in order to produce optimal power and torque output.

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