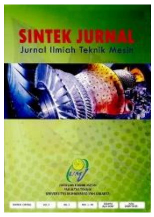
SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin
ISSN: 2088-9038, e-ISSN: 2549-9645
Homepage: http://jurnal.umj.ac.id/index.php/sintek




# PERFORMANCE COMPARISON OF ONE CYLINDER COMBUSTION ENGINE WITH VARIATIONS OF COMPRESSION PRESSURE & OCTANE NUMBER GASOLINE

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Accepted: 22-12-2022 Revised: 30-05-2023 Approved: 01-06-2023

**ABSTRACT**

Nowadays, automobiles and motorcycles manufacturer produced more powerful and efficient engines. This engine usually has high compression pressure to achieve high performance and economic gasoline consumption. Unfortunately, only few people known that high compression engine requires high octane number gasoline. The aim of this research were to find out the differences of power & torsion output of one cylinder combustion engine which given several compression pressure variances using Pertamax & Pertamax racing gasoline. Dynamometer test has been carried out to find the performance difference of one cylinder combustion engine. The results shown that the highest compression pressure engine (11,8 Kg/cm$^2$) using Pertamax racing gasoline (RON 100) produced highest power output at 7,8 KW with torsion output at 10 Nm. Meanwhile, the lowest compression pressure engine (10 Kg/cm$^2$) using Pertamax gasoline (RON 92) produced lowest power output at 4,2 KW with torsion output at 3,8 Nm.

**Keywords**: performance; compression pressure; octane number

## 1. INTRODUCTION

Internal combustion engine is an engine that converts thermal energy into mechanical energy [1]. The performance of an internal combustion engine was influenced by several factors, including: gasoline quality and compression pressure. The usage of poor quality gasoline can result in a decrease of engine performance and also higher gasoline consumption [2].

The internal combustion engine that usually applied for cars and motorcycles uses a cylinder in which there is a piston that can move back and forth [3]. The performance produced by an engine depends on the combustion results of the gasoline and air mixture in the combustion chamber, this means that the higher the compression pressure followed by the usage of good quality gasoline, will be produced the optimal engine performance [4].

Currently, several gasoline fuel providers, both government and private, provide several choices of gasoline fuel types, ranging from octane 90, octane 92, octane 95, octane 98 even octane 100. A study conducted by Watson entitled Octane number and knock in the highspeed internal combustion engine got the results that vehicle power significantly increased with the octane rating of the fuel, thus decreasing the time needed for acceleration. Moreover, the specific fuel consumption decreased as the octane rating increased, proving that the fuel can take an active part in reducing greenhouse gas emissions. The boost pressure, which increased with the octane number, was identified as the main factor, whereas the ignition advance was the second relevant factor. [5].

Another study conducted by Fletcher et. al. found that the increase in compression ratio and fuel cetane number improves combustion and improves the performance of engine. Further there is a significant decrease in hydrocarbon (HC), Carbon monoxide (CO) and smoke emissions however there is an increase in Nitrogen oxides (NOx). [6].

Automotive manufacturers, both motorcycles and cars, are producing engines with high compression pressure to produce better performance. But unfortunately, there are still many consumers who do not understand, if an engine that has a high compression pressure requires fuel with a high octane number in order to produce optimal engine performance. This can be seen from the latest statistical data published by the Directorate General of Oil and Gas that sales of RON 90 gasoline are still much higher than sales of RON 92 and RON 100 gasoline. This data reflects that there are still many consumers who choose gasoline with a low octane number for use in today's vehicle engines which tend to have high compression pressures.

Based on the above discussion, we would conduct the dynamometer test of one-cylinder combustion engine with 11,8 Kg/cm$^2$, 11 Kg/cm$^2$, 10 Kg/cm$^2$ compression pressure respectively which using Pertamax (RON 92) & Pertamax Racing (RON 100) gasoline to see differences of power and torque output. It is hoped the results of this study can provide information for motorized vehicle users to use fuel with an octane number that appropriate to the compression pressure of their vehicle in order to produced optimal engine performance.

## 2. METHODS

The performance parameters of an internal combustion engine were determined by several factors, including thermal efficiency, power and torque, specific fuel consumption and exhaust emissions. Thermal efficiency is defined as the ratio of the useful output energy or work produced by a system to the input energy in the form of heat. It is usually expressed as a percentage. The higher the thermal efficiency, the more effectively the system converts heat into useful work.

Power and torque are two important engine performance parameters which particularly in relation to engines and rotational systems. Power is the rate at which work is done or energy is transferred. It measures how quickly work is being performed or energy is being consumed or produced, while Torque defined as twisting force, is a measure of the rotational force applied to an object. Torque is commonly measured in units of newton-meters (Nm).

Another engine performance parameters were Specific fuel consumption (SFC) and exhaust gas emissions. SFC interpreted as measure of the fuel efficiency of an engine. It represents the amount of fuel consumed per unit of output power generated. SFC is typically expressed in units of mass per unit of power, such as grams per kilowatt-hour (g/kWh). Exhaust gas emissions refer to the gases and particles that are discharged from various combustion processes, primarily from engines and industrial processes. The major exhaust gas emissions of concern include: Nitrogen Oxides (NOx), Carbon Monoxide (CO), Carbon Dioxide (CO2) & Particulate Matter (PM).

The research method is experimental method, carried out with oned cylinder combustion engine motorcycle with 125 cc cylinder capacity. To modify the compression pressure on the engine, usage of a gasket on the cylinder head with a total of one, two and three gaskets. By adding a several numbers of cylinder head gasket, a change in the volume of the combustion chamber will be obtained, resulting in a different value of compression pressure. The research data were analyzed by observing directly the experimental results and then concluding and determining the results of the research that had been carried out in the form of graphs and tables. The tool used to measure power and torque is a dynamometer.

Before conducted the dynamometer test, the motorcycle should be tied-up correctly with the position of rear tire exactly on the dynamometer roller. The tachometer cable should connect with the high-voltage cables on the motorcycle, and the gasoline hose from the gasoline tank should be disconnected and closed securely. As a replacement, the gasoline inlet connected with the burette hose which the using Pertamax (RON 92) & Pertamax Racing (RON 100) gasoline filled after the hose connected correct and safely. The performance test scheme with dynamometer are shown in figure 1.

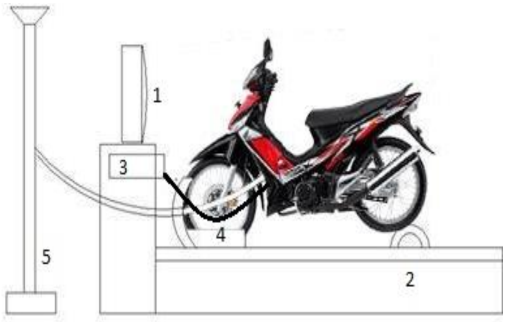


**Figure 1.** Dynamometer testing scheme; (1) Screen Monitor, (2) Roller Dynamometer, (3) Processing Unit/Computer, (4) Tachometer cable, (5) measuring burette.

After all the preparation completed, the test can be carried out by two persons, one person to operate the motorcycle and the another one operates the dynamometer test software. This process shown at figure 2.

**Figure 2.** Performance test using dynamometer

## 3. RESULTS AND DISCUSSION

### 3.1 Power Output Comparison

Based on Table 1 are seen the differences of power produced from several compression pressure using Pertamax Racing (RON 100) gasoline. Each values of power obtained from three times testing, then those values that shown at Table 1 below are averaged value. The highest compression pressure (11.8 Kg/cm$^2$) generally produced higher power output almost at all engine revolutions (Rpm). Table 1 shown the power output at various compression pressure in kilo Watt (kW).

**Table 1.** Power output with RON 100 gasoline

| Rpm | Power at Compression pressure (KW) using Pertamax Racing (RON 100) | | |
|---|---|---|---|
| | 10 Kg/cm$^2$ | 11 Kg/cm$^2$ | 11.8 Kg/cm$^2$ |
| 4000 | 4.9 | 5.5 | 5.6 |
| 5000 | 6.3 | 6.8 | 7.0 |
| 6000 | 6.8 | 7.9 | 7.8 |
| 7000 | 6.4 | 7.5 | 7.6 |
| 8000 | 4.7 | 5.9 | 6.5 |

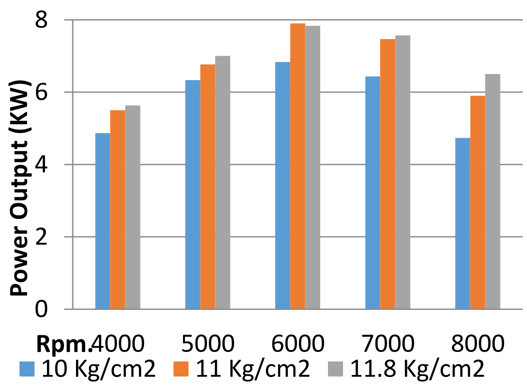


**Figure 3.** Various power output at various compression pressure using RON 100 gasoline.

Meanwhile, the lowest compression pressure (10 Kg/cm$^2$) generally produced lower power output almost at all engine revolutions (Rpm). For example, power output comparison at 5.000 Rpm, the same engine with 10 Kg/cm$^2$ compression pressure only produced 6,3 KW power output, while 11 Kg/cm$^2$ compression pressure engine produced 6,8 KW power output, and the engine with highest compression pressure at 11,8 Kg/cm$^2$ produced 7,0 KW power output and can be seen in Figure 3.

Based on Figure 3 we can see the power output comparison at all range engine revolutions (Rpm). At middle compression pressure (11 Kg/cm$^2$) also produced middle range of power output, which means at this point, the engine can produced output power that higher than the lowest compression pressure (10 Kg/cm$^2$), but generally cannot produce power output higher than the highest compression pressure (11,8 Kg/cm$^2$) [2]. Another example at 8000 Rpm engine rotation range, power output of 4.7 KW, 5,9 KW and 6,5 KW is generated by the engine with a compression pressure of 10 Kg/cm$^2$, 11 Kg/cm$^2$ and 11,8 Kg/cm$^2$ respectively.

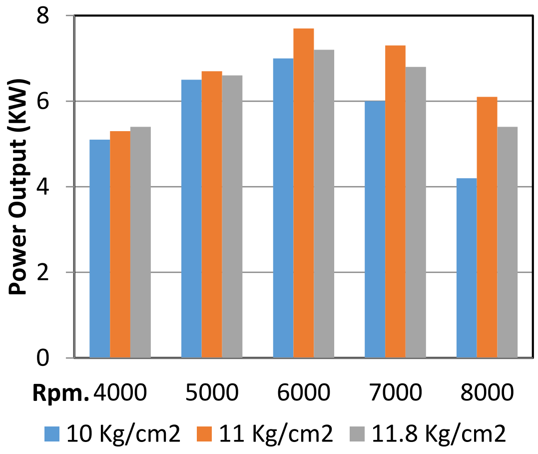


**Figure 4.** Various power output at various compression pressure using RON 92 gasoline.

Based on Table 2 are seen the differences of power produced from several compression pressure using Pertamax (RON 92) gasoline. Overall, at 10 Kg/cm$^2$ compression pressure, the engine is producing lower power compared to a compression pressure of 11 Kg/cm$^2$ or 11.8 Kg/cm$^2$. The highest value of power produced at compression pressure of 10 Kg/cm$^2$ is only 7 KW in the rotation range of 6000 Rpm.

**Table 2.** Power output with RON 92 gasoline

| Power at Compression pressure (KW) using Pertamax (RON 92) | | | |
|---|---|---|---|
| Rpm | 10 Kg/cm$^2$ | 11 Kg/cm$^2$ | 11.8 Kg/cm$^2$ |
| 4000 | 5.1 | 5.3 | 5.4 |
| 5000 | 6.5 | 6.7 | 6.6 |
| 6000 | 7.0 | 7.7 | 7.2 |
| 7000 | 6.0 | 7.3 | 6.8 |
| 8000 | 4.2 | 6.1 | 5.4 |

Compared to the previous results, in general the power produced by an engine with a compression pressure of 11 Kg/cm$^2$ is higher than of an engine with a compression pressure of 11.8 Kg/cm$^2$. The highest power output of 7.7 KW is produced by an engine with a compression pressure of 11 Kg/cm$^2$ at 6000 Rpm, while an engine with a compression pressure of 11.8 Kg/cm$^2$ only produces power of 7.2 KW at the same range of engine Rpm. This proves that the higher the compression pressure of an engine, it requires high octane number of gasoline so the engine is able to produce optimal power [7].

**Table 3.** Power output comparison with RON 92 & RON 100 gasoline

| | Power Output at 11.8 Kg/cm$^2$ (KW) | |
|---|---|---|
| Rpm | Pertamax | Pertamax Racing |
| 4000 | 5.4 | 5.6 |
| 5000 | 6.6 | 7.0 |
| 6000 | 7.2 | 7.8 |
| 7000 | 6.8 | 7.6 |
| 8000 | 5.4 | 6.5 |

Table 3 shown the comparison of power output between the usage of Pertamax and Pertamax racing on engine with a compression pressure of 11.8 Kg/cm$^2$. From the Rpm range of 4000 to 8000, engine that use Pertamax racing gasoline are able to produce a higher power output compared to engine that use Pertamax gasoline. In general, the engine that using Pertamax racing gasoline produces average power output 10% higher compared to engine that using Pertamax gasoline.

Figure 5 clearly shown, the comparison of engine power output at 11.8 Kg/cm$^2$ compression pressure using RON 92 and RON 100 gasoline. For example, at 6000 Rpm, engine that uses Pertamax gasoline produces power output of 7.2 KW, while engine that uses Pertamax racing gasoline is able producing power output of 7.8 KW. This again proves, that the usage of high-octane gasoline which has higher resistance to knocking in engine with high compression pressure will produce optimal power output. Because the high-octane number gasoline also able to avoid pre-ignition phenomenon [8].

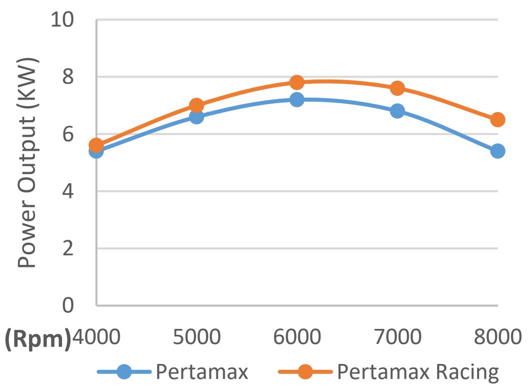


**Figure 5.** Power output comparison at 11.8 Kg/cm$^2$ compression pressure using RON 92 and RON 100 gasoline.

## 3.2 Torque Output Comparison

The results of torque testing on several engine compression pressure variants using Pertamax racing gasoline have been carried out and the results can be seen in Table 4. Each value of torque obtained from three times testing, then those values shown in Table 4 below are averaged value. The highest compression pressure (11.8 Kg/cm$^2$) generally produced higher torque output almost at all engine revolutions (Rpm) [7].

**Table 4.** Torque output with RON 100 gasoline

| | Torque at Compression pressure (Nm) | | |
|---|---|---|---|
| Rpm | 10 Kg/cm$^2$ | 11 Kg/cm$^2$ | 11.8 Kg/cm$^2$ |
| 4000 | 9.1 | 9.7 | 10.0 |
| 5000 | 9.0 | 9.6 | 9.9 |
| 6000 | 8.0 | 9.3 | 9.2 |
| 7000 | 6.5 | 7.5 | 7.6 |
| 8000 | 4.2 | 5.2 | 5.8 |

The highest torque output of 10 Nm is produced by the engine with a compression pressure of 11.8 Kg/cm$^2$ obtained at engine rotation range of 4000 Rpm. At the same engine rotation range, torque output of 9.1 Nm and 9.7 Nm is generated by the engine with a compression pressure of 10 Kg/cm$^2$ and 11 Kg/cm$^2$ respectively.

Torque output of the engine with several compression pressure variants that uses Pertamax racing gasoline as a whole can be seen more clearly in Figure 6. The torque output with the lowest value is produced by an engine with a compression pressure of 10 Kg/cm$^2$ at a rotation range of 8000 Rpm, which is only 4.2 Nm. In the same engine rotation range, an engine with a compression pressure of 11 Kg/cm$^2$ is able producing a better torque output of 5.2 Nm and greater torque output value is produced by an engine with a compression pressure of 11.8 Kg/cm$^2$ in value of 5.8 N.m.

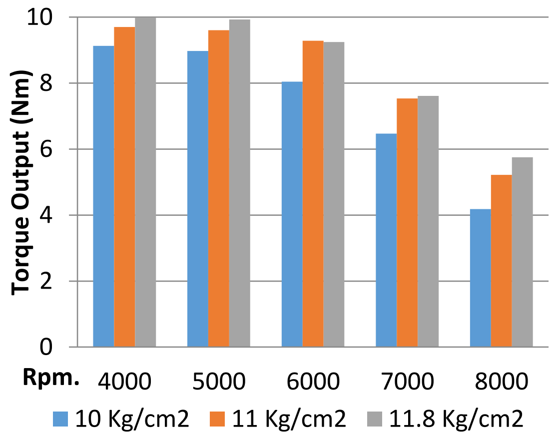


**Figure 6.** Various torque output at various compression pressure using RON 100 gasoline.

The results of this test indicate that the higher the compression pressure of an engine, the higher the octane number of fuel is required so the engine is able to produce optimal torque output. The torque output test on the engine with several compression pressure variants using Pertamax gasoline where the results can be seen in Table 5.

**Table 5.** Torque output with RON 92 gasoline

| | Torque at Compression pressure (Nm) | | |
|---|---|---|---|
| Rpm | 10 Kg/cm$^2$ | 11 Kg/cm$^2$ | 11.8 Kg/cm$^2$ |
| 4000 | 9.1 | 9.4 | 9.5 |
| 5000 | 9.3 | 9.5 | 9.3 |
| 6000 | 8.3 | 9.1 | 8.5 |
| 7000 | 6.1 | 7.3 | 6.9 |
| 8000 | 3.8 | 5.4 | 4.8 |

The highest torque output with a value of 9.5 Nm is obtained at a compression pressure of 11 $Kg/cm^2$ at an engine speed of 5000 Rpm. In addition, torque output with the same value is also obtained at a compression pressure of 11.8 $Kg/cm^2$ at an engine speed range of 4000 Rpm. However, in general, a higher torque output value is obtained on an engine with a compression pressure of 11 $Kg/cm^2$ [9].

Torque output on the engine with several compression pressure variants that use Pertamax (RON 92) gasoline as a whole can be seen more clearly in Figure 7. The torque output with the lowest value is produced by an engine with a compression pressure of 10 $Kg/cm^2$ at an engine rotation range of 8000 Rpm, which is only 3.8 Nm. In the same engine rotation range, an engine with a compression pressure of 11.8 $Kg/cm^2$ is able to producing a better torque output of 4.8 Nm and the highest torque output value in the engine rotation range of 8000 Rpm is produced by an engine with a compression pressure of 11 $Kg/cm^2$ which is in value of 5.4 Nm.

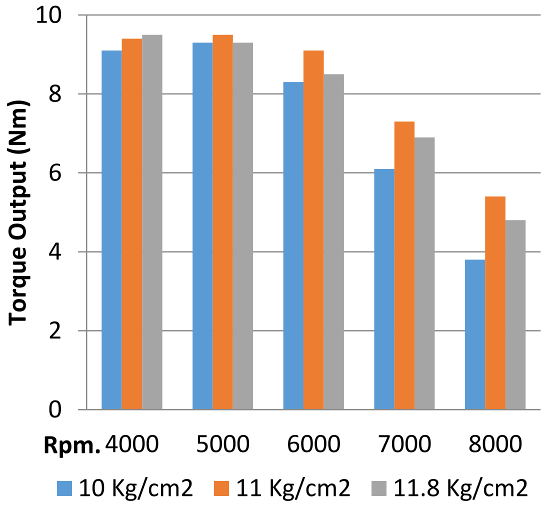


**Figure 7.** Various torque output at various compression pressure using RON 92 gasoline.

This experiment proves that usage of fuel with the appropriate octane number in an engine with the appropriate compression pressure will produce optimal torque output. The combustion chamber in an engine with high compression pressure very risk of preignition, so it is required fuel that can prevent this phenomenon happened [7]. Meanwhile, the usage of fuel with a low octane number in an engine with a high compression pressure results in a less optimal of torque output. This is due to the phenomenon of detonation, which is the combustion of the fuel mixture is too early which is caused by the high temperature in the combustion chamber. Another term for this phenomenon is knocking [6].

**Table 6**. Torque output comparison with RON 92 & RON 100 gasoline

| | Torque Output at 11.8 $Kg/cm^2$ (KW) | |
|---|---|---|
| Rpm | Pertamax | Pertamax Racing |
| 4000 | 9.5 | 10.0 |
| 5000 | 9.3 | 9.9 |
| 6000 | 8.5 | 9.2 |
| 7000 | 6.9 | 7.6 |
| 8000 | 4.8 | 5.8 |

Table 6 are shown the torque output comparison between the usage of Pertamax and Pertamax racing gasoline on engine with a compression pressure of 11.8 $Kg/cm^2$. From the range of 4000 Rpm to 8000 Rpm, engine that use Pertamax racing fuel are able to produce a higher torque output compared to engine that use Pertamax fuel. In general, the engine that using Pertamax racing gasoline also produces average torque output 10% higher compared to engine that using Pertamax gasoline.

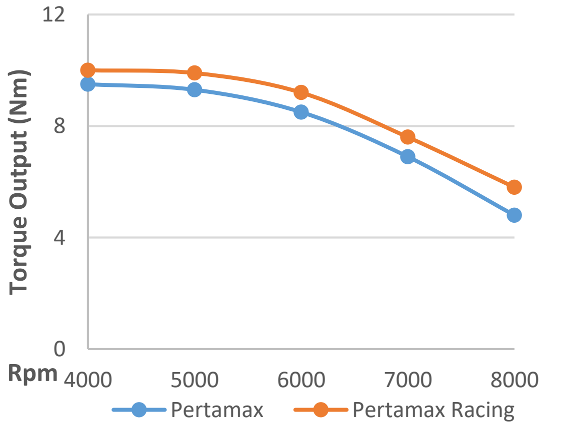


**Figure 8.** Torque output comparison at 11.8 $Kg/cm^2$ compression pressure using RON 92 and RON 100 gasoline.

For example, at 6000 Rpm, engine that uses Pertamax gasoline produces a torque output of 8.5 Nm, while engine that uses Pertamax racing gasoline is able to producing a torque output of 9.2 Nm. Another comparison in the rotation range of 8000 Rpm, engine that uses Pertamax racing gasoline is able to producing a torque output of 5.8 Nm, whereas an engine that uses Pertamax gasoline only able to produce a torque output of 4.8 Nm. This again proves, that the usage of high-octane fuel in an engine with high compression pressure will produce optimal torque output [10].

## 4. CONCLUSION

The power and torque produced by an internal combustion engine are greatly influenced by the compression pressure and the octane number of the fuel used. The use of Pertamax racing gasoline on an engine with a compression pressure of 11.8 $Kg/cm^2$ produces the highest power and torque output. However, the torque output produced on an engine with a compression pressure of 11 $Kg/cm^2$ using Pertamax gasoline is greater when compared to an engine with a compression pressure of 11.8 $Kg/cm^2$. From this, it can be concluded that the selection of the gasoline octane number should be adjusted to the compression pressure of the engine used, in order to obtain optimal power and torque output.

## ACKNOWLEDGEMENTS

The author give thanks to the Hyperspeed workshop, Semarang for providing facilities for testing.

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