# Investigating Impact of Gasket Cylinder Addition and Octane Rating on Engine Performance

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*ABSTRACT*

*The increase in people's mobility were reflected in the growing sales of motor vehicles. This has driven automotive manufacturers to compete in creating more powerful and efficient engines. These engines were designed with high compression ratios to achieve greater efficiency. High compression ratio engine re-quired fuel with the appropriate octane number to attain opti-mal performance. It is regrettable that many users had not un-derstood that an engine with high compression had required gasoline with a high octane rating as well. This research aims to investigate the impact of different compression ratios on the output power and torque of a single-cylinder combustion en-gine using RON 92, RON 95, and RON 100 gasoline. To modify the compression ratio, various numbers of gaskets were used on the cylinder head, with 2 and 3 gaskets for each configuration. A dynamometer test was employed to measure the differences in engine performance. The research results indicate that the engine with the highest compression pressure (11 Kg/cm$^2$) using RON 100 gasoline produced the highest power of 7.90 kW, with the highest torque of 9.60 Nm. Conversely, the engine with the lowest compression pressure (10 Kg/cm$^2$) using RON 92 gasoline produced the lowest power and the lowest torque.*

***Keywords**: Gasket, Octane, Power, Torque, Performance*

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## INTRODUCTION

Currently, motor vehicle manufacturers have been developing engines with high compression ratios to enhance engine performance, both in motorcycles and cars. However, the low awareness among consumers regarding the need for high-octane fuel to achieve optimal performance in engines with high compression remains a significant challenge. Based on the latest statistical data from the Directorate General of Oil and Gas, it is evident that the sales of RON 90 gasoline were still significantly higher compared to the sales of RON 92 and 95 gasoline (Direktorat Jendral Minyak dan Gas Bumi, 2021). Based on that data, it can be concluded that a significant portion of consumers still tends to choose the use of low-octane gasoline for their vehicles, even though these vehicles generally come equipped with engines featuring high compression ratios.

According to information from the Indonesian Motorcycle Industry Association (AISI), there has been a significant increase in domestic motorcycle sales in 2021. The total sales reached 5,057,516 units, reflecting an increase of approximately 38.2% compared to the previous year, where only 3,660,616 units were recorded (AISI, 2022). The motorcycle had been the largest consumer of fuel in the transportation sector, especially gasoline. In Indonesia, various gasoline suppliers, both from government agencies and private companies, had provided various types of fuel. These types of gasoline had been classified based on the octane rating. In the Indonesian market, several variations of the RON (Research Octane Number) were available, including RON 90, RON 92, RON 95, and even RON 100 (Direktorat Jendral Minyak dan Gas Bumi, 2018).

The increase in the octane number fuel has impacts that involve simplifying the combustion process and reducing the risk of detonation (Shao and Rutland, 2015). Using fuel with higher octane rating significantly increases the power generated by the vehicle and accelerates the acceleration time. Additionally, the use of high-octane fuel is also effective in reducing vehicle exhaust emissions by decreasing fuel consumption (Rodríguez-Fernández *et al.*, 2020).

Engine with high compression ratio uses low-quality fuel, the impact is a decrease in engine performance and an increase in fuel consumption (Benson and Whitehouse, 1979). Internal combustion engines commonly used in motorcycles and cars are equipped with cylinder components containing pistons that move inside (Ferguson, 2020). The torque & power output of engine depended on how efficiently the mixture of fuel and air combusts inside the combustion chamber. In engines with large compression ratios and the use of high-quality fuel, the result is the creation of the most efficient engine performance (Maurya and Agarwal, 2011).

Detonation in an engine can reduce thermal efficiency and limit the improvement of gasoline engine performance. Detecting the signs of engine detonation is a key factor in controlling engine detonation issues. Using fuel with a higher-octane rating can mitigate the impact of detonation and enhance thermal efficiency in gasoline engines (Bi, Ma and Wang, 2019). Detonation is a term that refers to the wave that occurs when a portion of the air-fuel mixture spontaneously ignites before the ignition spark from the spark plug (Heywood, 1988). Pressure oscillations at high frequencies can be observed when detonation occurs (Qi *et al.*, 2015). Detonation has the potential to cause various types of damage, such as melting of the piston head, welding of piston rings, and leakage in the cylinder head gasket (Wang *et al.*, 2014).

The results of the research conducted by Jiang and his team indicate that to achieve high power efficiency and reduce Nitrogen Oxide (NOx) emissions in internal combustion engines, adjustments to Exhaust Gas Recirculation (EGR) components are necessary. Additionally, selecting fuel with an appropriate octane rating plays a crucial role in achieving optimal power performance and maintaining low exhaust emissions levels (Jiang *et al.*, 2019). The increase in compression pressure also has an impact on the rise in combustion temperature inside the cylinder, and this impact varies depending on the mechanism applied at different compression ratios. This can result in a decrease in hydrocarbon (HC) emissions when the compression pressure is increased (Gong *et al.*, 2016).

Based on the explanation, we will conduct performance testing on a single-cylinder engine with two different compression pressure levels, namely 11 Kg/cm² and 10 Kg/cm². This testing will involve three different types of fuel: RON 92, RON 95, and RON 100 gasoline. The goal is to observe the differences in power and torque generated in each test.

## RESEARCH METHODOLOGY

This experimental study used a motorcycle with a single-cylinder engine with a capacity of 125 cc. The selection of this type of engine was based on the popularity of vehicles in Indonesia that use a single-cylinder engine with a capacity of 125 cc. To control the pressure inside the cylinder, a gasket was used on the cylinder head in two different variations, namely one gasket and two gaskets. The addition of a gasket to the cylinder head resulted in a change in the combustion chamber volume, which affected the compression pressure values.
Throughout the testing, the settings for the main jet, pilot jet, and the number of idle screw rotations on the carburettor remained constant. The test results data were then analyzed directly to draw conclusions. Additionally, the test results data will be presented in the shape of tables and graphs to facilitate the reader's understanding.

The principle of a dynamometer is to measure the power, torque, or force generated by an engine by measuring the forces generated by the engine. The working principle of a dynamometer involves applying a resistive load to the engine under test and then measuring the reaction or force produced by the engine or vehicle in response to that load. In the context of engine performance testing, a dynamometer records data on the torque generated by the engine at various levels of rotation, and based on this data, it is processed to calculate the power produced by the engine at a specific rotation. This fundamental principle provides a more accurate understanding of the performance and characteristics of the engine (Lourenço *et al.*, 2023).

TABLE 1. Engine specification for testing

| | |
|---|---|
| Engine type | 4-stroke, SOHC |
| Capacity (cc) | 124,8 |
| Bore x stroke (mm) | 52,4 x 57,9 |
| Compression ratio | 9,0 : 1 |
| Fuel delivery system | Carburettor |
| Ignition system | Full-transistorized |

Equation (1) can be used to measure engine performance, where torque (T) is generated, the force applied to the rotor (F), and the distance serving as the multiplication factor (r) are included as variables.

$$\boldsymbol{T = \int r\ .\ F\,\delta r} \tag{1}$$

Equation (2) can be used to calculate the power produced, with N as the rotation speed of the crankshaft (RPM).

$$\boldsymbol{P = \frac{2\,\pi\,N\,T}{60\,\times\,1000}} \tag{2}$$

Performance testing of the single-cylinder engine is conducted using a dynamometer and several additional tools such as a toolset, graduated buret, and stopwatch. Identification of the fuel specifications used in this test can be carried out through Table 2. Before conducting the dynamometer test, the first step is to position the motorcycle precisely so that the rear wheel is accurately placed on the dynamometer roller. After that, the tachometer cable needs to be connected to the high-voltage cable on the spark plug, and the fuel hose usually connected to the carburetor needs to be detached. After that, the hose from the buret will take the place of the hose that was originally connected to the carburetor. The fuels RON 92, RON 95, and RON 100 will be successively filled into the calibrated burette for testing on the dynamometer, as illustrated in Figure 1.

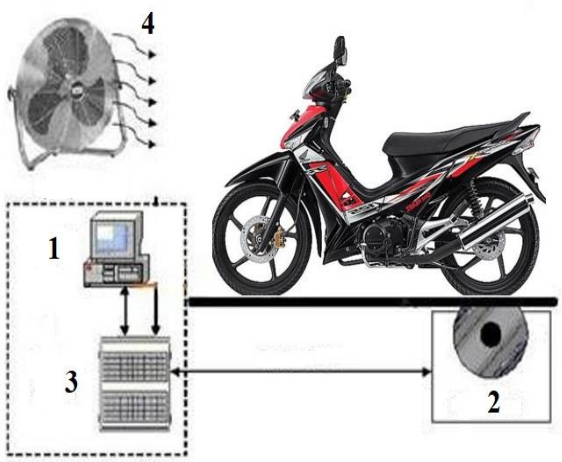


FIGURE 1. Dynamometer testing scheme (1) monitor, (2) roller dynamometer, (3) GPU (graphic processing unit), (4) blower.

Upon completion of preparations, performance testing can be carried out by two individuals. One person will operate the dynamometer software, while the other will assume responsibility for operating the engine.

TABLE 2. Fuel specification for testing

| **Unit** | **RON 92** | **RON 95** | **RON 100** |
|---|---|---|---|
| RON | 92 | 95 | 100 |
| Caloric value (kj/kg) | 43848 | 43920 | 47336 |
| Distilation (Evap. volume at) | | | |
| 10% (°C) | 70 | 68 | 62 |
| 50% (°C) | 110 | 103 | 105 |
| 90% (°C) | 180 | 165 | 151 |
| FBP (°C) | 215 | 205 | 203 |
| Density (Kg/m3) | 770 | 760 | 721 |

## RESULT AND DISCUSSION

### Torque Output Comparison

The torque testing was carried out at varying levels of compression pressure utilizing RON 92, RON 95, and RON 100 fuels. Table 3 presents the results of the torque testing on the engine utilizing RON 92 fuel. Each value of torque was obtained through three repeated tests, and the figures displayed in Table 3 represent the average values. In general, the 11 Kg/cm² compression engine produced larger torque at all engine speeds.

TABLE 3. Torque output with RON 92 fuel

| **Torque output (Nm) at various comp. pressure** | | |
|---|---|---|
| **Rpm** | **10 Kg/cm²** | **11 Kg/cm²** |
| 5000 | 9,26 | 9,52 |
| 5500 | 8,85 | 9,61 |
| 6000 | 8,25 | 9,07 |
| 6500 | 7,32 | 8,52 |
| 7000 | 6,05 | 7,34 |
| 7500 | 5,27 | 6,48 |
| 8000 | 3,75 | 5,40 |

The 11 Kg/cm² compression engine yields a peak torque of 9,61 Nm at speed of 5500 Rpm. In general, the 11 Kg/cm² compression engine is capable of generating 14.8% more torque compared to the 10 Kg/cm² compression engine. The comparison of torque output from the engines with compression pressures of 11 and 10 Kg/cm² utilizing RON 92 fuel can be observed in Figure 2.

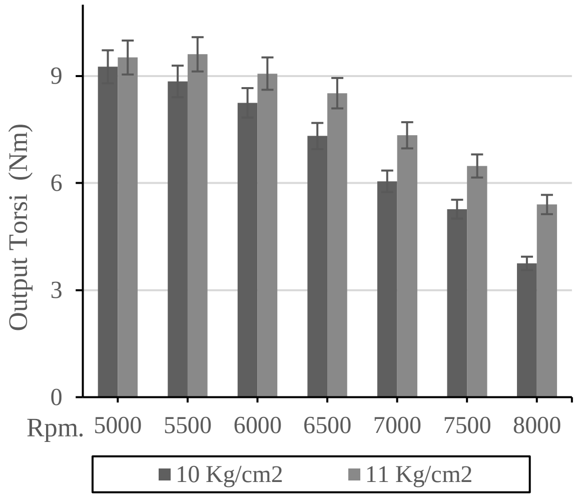


FIGURE 2. Torque output with RON 92 fuel with various compression pressure

The peak torque output obtained from the engine utilizing RON 95 fuel is presented in Table 4. The 11 Kg/cm² compression engine produces a peak torque of 9,61 Nm at speed of 5000 Rpm. In contrast, the 10 Kg/cm² compression engine generates a lower peak torque output of 9,26 Nm (Rodríguez-Fernández *et al.*, 2020).

Figure 3 illustrates the variation in torque output from a single-cylinder engine with varying compression pressures. Generally, the 11 Kg/cm² compression engine utilizing RON 95 fuel generates a higher torque output compared to the 10 Kg/cm² compression engine. The lowest torque output, measuring 4,07 Nm, is produced by the 10 Kg/cm² compression engine at speed of 8000 Rpm. At the same engine speed, the 11 Kg/cm² compression engine is capable of generating a torque output that is 1,26 Nm greater.

TABLE 4. Torque output with RON 95 fuel

| **Torque output (Nm) at various comp. pressure** | | |
|---|---|---|
| **Rpm** | **10 Kg/cm²** | **11 Kg/cm²** |
| 5000 | 9,26 | 9,61 |
| 5500 | 8,81 | 9,28 |
| 6000 | 8,12 | 9,02 |
| 6500 | 7,60 | 8,47 |
| 7000 | 7,46 | 7,22 |
| 7500 | 5,79 | 6,44 |
| 8000 | 4,07 | 5,33 |

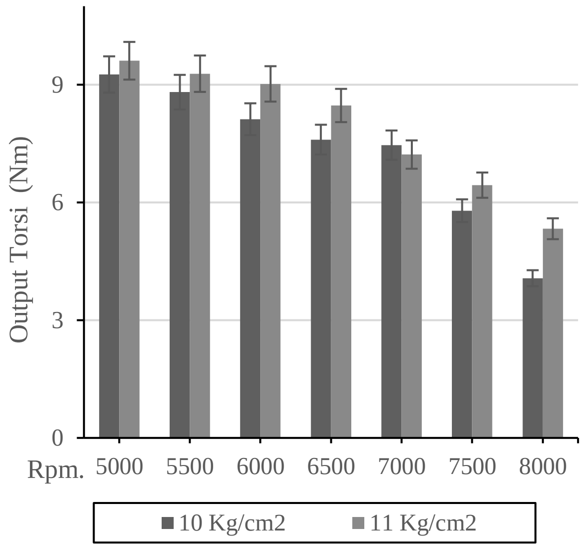


FIGURE 3. Torque output with RON 95 fuel with various compression pressure

A 11.1% greater torque output is observed on the 11 Kg/cm² compression engine at an engine speed of 6000 Rpm, measuring 9,02 Nm compared to the engine with a compression pressure of 10 Kg/cm². Similarly, incremental increases in torque output of 0.65 Nm and 1.26 Nm are observed at engine speeds of 7500 Rpm and 8000 Rpm, respectively, on the 11 Kg/cm² compression engine compared to the 10 Kg/cm² compression engine. As the compression pressure of the engine increases, so too does the resulting torque output (Kalghatgi, 2017).

The torque measurements presented in Table 5 were obtained through testing of engines with varying compression pressures, utilizing RON 100 fuel. Each value listed in Table 5 represents the average of three trials. Generally, the engine with the highest compression pressure, 11 Kg/cm², tends to produce greater torque output across all engine speed ranges (Rahmat and Wijaya, 2023).

TABLE 5. Torque output with RON 100 fuel

| Torque output (Nm) at various compression | | |
|---|---|---|
| **Rpm** | **10 Kg/cm²** | **11 Kg/cm²** |
| 5000 | 8,97 | 9,60 |
| 5500 | 8,57 | 9,56 |
| 6000 | 8,05 | 9,28 |
| 6500 | 7,44 | 8,23 |
| 7000 | 6,47 | 7,53 |
| 7500 | 5,50 | 6,65 |
| 8000 | 4,18 | 5,22 |

At an engine speed of 5000 Rpm, the 11 Kg/cm² compression engine reaches a maximum torque output of approximately 9.60 Nm. At the same engine speed, the 10 Kg/cm² compression engine produces a lower torque output, with a difference of approximately 0.66 Nm. The comparison of torque output from engines with varying compression pressures utilizing RON 100 fuel can be clearly observed in Figure 4. The engine operating at a compression pressure of 10 Kg/cm² produces the lowest torque output of approximately 4.18 Nm at an engine speed of 8000 Rpm. At an engine speed of 8000 Rpm, which is consistent, the 11 Kg/cm² compression engine is capable of generating a higher torque output of 5.22 Nm. Overall, the torque output at the compression pressure of 11 Kg/cm² exhibits a 14% increase compared to the 10 Kg/cm² compression engine. These test results once again confirm that engines with higher compression pressures require higher octane rating fuels to achieve optimal torque output. These findings corroborate previous findings in studies conducted by Purnomo and Munahar (Purnomo and Munahar, 2019).

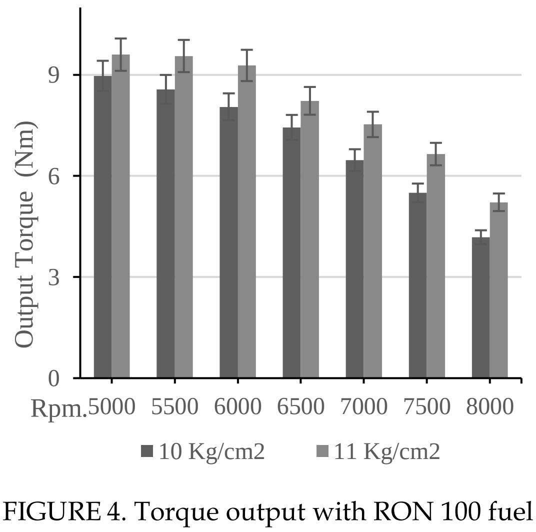


FIGURE 4. Torque output with RON 100 fuel with various compression pressure

Figure 5 illustrates the comparison of torque outputs generated by the engine operating at 11 Kg/cm² compression pressure with three types of fuels, namely RON 92, RON 95, and RON 100. From an engine speed range of 5000 Rpm to 8000 Rpm, it is evident that the engines using RON 100, RON 92, and RON 95 fuels display fluctuating torque values. However, overall, the engine using RON 100 fuel is capable of generating a torque output that is 1.3% higher than the engine using RON 95 fuel. This further reinforces the notion that utilizing high octane rating fuels in engines with high compression pressure results in optimal torque outputs (Rahmat *et al.*, 2023).

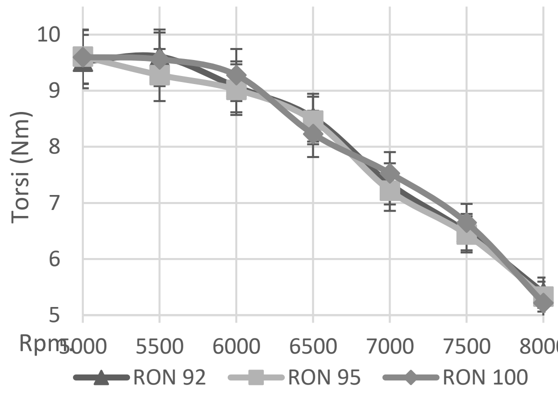


FIGURE 5. Torque output at 11 Kg/cm² compression with RON 92, 95 & 100 fuel

*Power Output Comparison*

According to the data presented in Table 6, we can observe the power output correlation at varying compression pressure while using RON 92 fuel during testing. Each power output reading was obtained through three distinct trials, and the values presented in Table 6 represent the average of these three tests. In general, the 11 kg/cm² compression engine, produced higher power outputs across various engine speeds (RPM). Table 6 records power output in kilowatts (kW) for various compression pressure as depicted.

TABLE 6. Power output with RON 92 fuel

| Power output (kW) at various comp. pressure | | |
|---|---|---|
| **Rpm** | **10 Kg/cm²** | **11 Kg/cm²** |
| 5000 | 6,53 | 6,70 |
| 5500 | 6,87 | 7,43 |
| 6000 | 7,00 | 7,67 |
| 6500 | 6,77 | 7,83 |
| 7000 | 6,00 | 7,27 |
| 7500 | 5,60 | 6,90 |
| 8000 | 4,23 | 6,13 |

An engine with a compression ratio of 10 kg/cm² generates lower power output compared to the 11 kg/cm² compression engine as demonstrated in Table 6. At a compression ratio of 10 kg/cm², the maximum power output of 7.0 kW is achieved at 6000 RPM. On the contrary, an engine with a compression ratio of 11 kg/cm² is capable of producing a power output of 7.67 kW at the same engine speed, as shown in Table 6. This is due to the fact that a higher compression ratio results in more optimal power output.

Figure 6 provides a more detailed depiction of the power output pattern of the engine at varying compression pressure while utilizing 92 RON fuel. For instance, at an engine speed of approximately 8000 RPM, the 11 kg/cm² compression engine is capable of producing a power output of 6.13 kW. Meanwhile, an engine with a 10 kg/cm² compression pressure produces a power output that is 31% lower, approximately 4.23 kW, at the same engine speed. Apart from the octane number of the fuel, compression ratio is also proven to be a crucial factor that affects power output (Qi *et al.*, 2015).

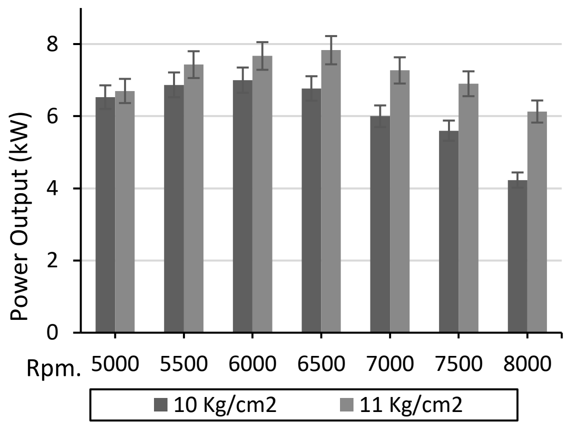


FIGURE 6. Power output with RON 92 fuel with various compression pressure

As depicted in Table 7, there is a noticeable difference in power output generated by the engine with varying compression ratios while utilizing 95 RON fuel. Generally, the 10 kg/cm² compression engine produces a lower power output compared to the 11 kg/cm² compression engine. At a compression presure of 10 kg/cm², the maximum power output only reaches 7.0 kW at 6500 RPM.

Figure 7 demonstrates that the peak power output, approximately 7.77 kW, is attained on the 11 kg/cm² compression engine when the engine operates at an engine speed of around 6500 RPM. This finding also confirms that engines with higher compression pressure require higher octane rating fuel to achieve optimal performance (Zhou *et al.*, 2021).

TABLE 7. Power output with RON 95 fuel

| **Power output (kW) at various comp. pressure** | | |
|---|---|---|
| **Rpm** | **10 Kg/cm$^2$** | **11 Kg/cm$^2$** |
| 5000 | 6,57 | 6,80 |
| 5500 | 6,87 | 7,23 |
| 6000 | 6,90 | 7,63 |
| 6500 | 7,00 | 7,77 |
| 7000 | 6,40 | 7,13 |
| 7500 | 6,03 | 6,83 |
| 8000 | 4,63 | 6,03 |

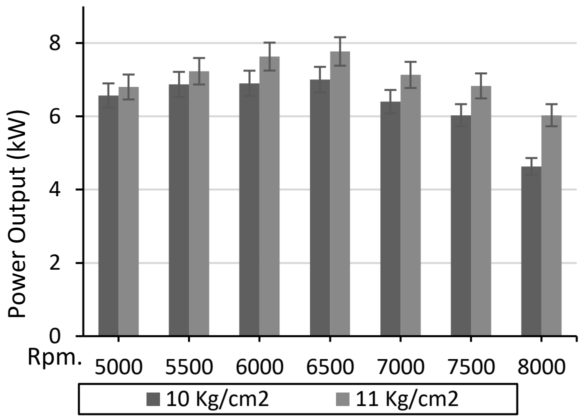


FIGURE 7. Power output with RON 95 fuel with various compression pressure

In Table 8, the power output results for various compression ratios while utilizing 100 RON fuel are presented. Generally, the 11 kg/cm² compression engine, also generates higher power output at varying engine speeds (RPM) (Zhou *et al.*, 2023). Conversely, the engine with a lower compression pressure, specifically 10 kg/cm², tends to produce lower power output at varying engine speeds (RPM).

As an example, at an engine speed of 6500 RPM, the 10 kg/cm² compression engine generates power output that is 10.2% lower compared to the engine with a compression ratio of 11 kg/cm². At an engine speed of 6000 RPM, the 11 kg/cm² compression engine can produce peak power output of 7.90 kW, which is 1.07 kW higher than the engine with a compression pressure of 10 kg/cm². Detailed information about the power output tests using 100 RON fuel can be found in Figure 8. Figure 8, it is evident that there is a correlation between engine speed (RPM) and power output. The engine utilizing 100 RON fuel and a compression pressure of 11 Kg/cm² consistently generates higher power output compared to the 10 Kg/cm² compression engine at all engine speeds. This finding clearly confirms that engines with higher compression ratios require higher octane number fuels to achieve optimal power output (Mogi *et al.*, 2022).

TABLE 8. Power output with RON 100 fuel

| Power output (kW) at various comp. pressure | | |
|---|---|---|
| **Rpm** | **10 Kg/cm²** | **11 Kg/cm²** |
| 5000 | 6,33 | 6,77 |
| 5500 | 6,67 | 7,43 |
| 6000 | 6,83 | 7,90 |
| 6500 | 6,87 | 7,57 |
| 7000 | 6,43 | 7,47 |
| 7500 | 5,87 | 7,07 |
| 8000 | 4,73 | 5,90 |

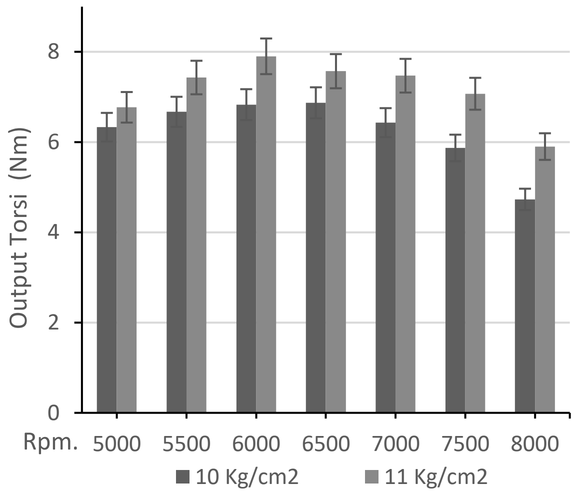


FIGURE 8. Output torque with RON 100 fuel with various compression pressure

Figure 9 clearly illustrates the relationship between power output and three types of fuels, namely RON 92, RON 95, and RON 100, in an engine with a compression pressure of 11 Kg/cm² within a range of engine speeds from 5000 RPM to 8000 RPM. A similar trend can also be observed in Figure 9 regarding torque output, as the power output in the 11 Kg/cm² compression engine also exhibits fluctuations. Although fluctuating, overall, the engine utilizing RON 100 fuel is capable of generating 1.5% higher power output compared to the engine using RON 95 fuel. This further reinforces the notion that the utilization of high octane rating fuel in engines with high compression ratios leads to optimal power output (Rodríguez-Fernández *et al.*, 2020).

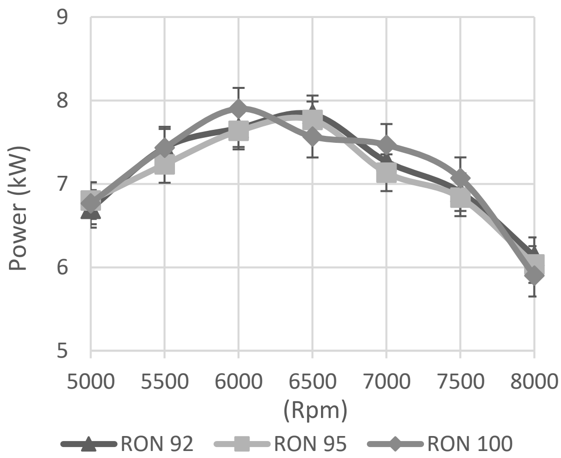


FIGURE 9. Power output at 11 Kg/cm² compression with RON 92, 95 & 100 fuel

## CONCLUSION

The performance of an internal combustion engine is heavily influenced by two critical factors: compression ratio and octane rating of the fuel being used. Test results indicate that when a compression pressure of 11 Kg/cm² is combined with RON 100 fuel, optimal power output and torque are achieved. Therefore, selecting the appropriate fuel with the correct octane rating in accordance with the compression ratio of the engine is crucial for achieving optimal power output and torque. Further research is required to investigate the effects of compression ratio and fuel octane rating on exhaust gas emissions. This is crucial in light of growing environmental concerns and climate change, as governments are increasingly focused on creating sustainable practices.

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