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The Effect of Variations in Fuel RON 92, RON 95 and RON 98 on Engine Performance with a Compression Ratio of 12.7:1

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ABSTRACT

This study aims to analyze the effect of using fuels with different octane ratings (RON 92, RON 95, and RON 98) on the performance of a 206 cc four-stroke gasoline engine with a compression ratio of 12.7:1. The benefits of this study are to provide technical references for vehicle owners, repair shops, and automotive manufacturers in selecting fuel that matches the engine's compression ratio, as well as to raise awareness of the importance of using high-quality fuel to maintain the performance, efficiency, and durability of modern vehicle engines. Testing was conducted using a dyno test method to measure power, torque, and specific fuel consumption (SFC) at various engine speeds. The test data were analyzed using a quantitative descriptive method, comparing engine performance parameters with each type of fuel. The test results showed that high-octane fuel, such as Pertamax Turbo (RON 98), produced the best performance, characterized by maximum power, highest torque, and optimal fuel efficiency. Conversely, the use of low-octane fuel caused knocking, incomplete combustion, and increased the risk of deposit formation and corrosion due to its higher sulfur content.

Keywords*: influence, fuel, dyno test, engine performance, octane rating*

Introduction

Many new production vehicles now use high compression ratios. For example, Yamaha automatic motorcycles, which previously had an average compression ratio of under 10:1, now use a compression ratio of 11.6:1 on their latest automatic model, the Yamaha NMAX. A similar trend is observed on Honda, where the PCX 150 model uses a compression ratio of 10.6:1, which has now been increased to 12:1 on the PCX 160. This compression ratio directly correlates with engine power output. According to torque increases with an increased compression ratio. This is because increased cylinder pressure causes an increase in the temperature of the fuel-air mixture in the combustion chamber, thus improving the thermal efficiency of the Otto cycle. However, the compression ratio is limited by the material used; a higher compression ratio requires spare parts that can withstand high temperatures and pressures [1].

Vehicles with high compression ratios have both advantages and disadvantages. One advantage is increased engine torque and power, which optimizes vehicle performance. However, the drawback lies in the need to use fuel with a high RON, which is more expensive than fuel with a low RON. Fuel plays a crucial role in internal combustion engines, with RON (Research Octane Number) being the primary benchmark for determining fuel quality. Several types of fuel are available on the market, each with a different RON rating. For example, Pertamina offers four types of gasoline: Pertalite with RON 88, Pertamax with RON 92, Pertamax Green with RON 95, and Pertamax Turbo with RON 98. The RON (Research Octane Number) of a fuel indicates the maximum pressure the fuel can exert to withstand compression in an engine without detonation. The RON is directly related to the compression ratio. The higher the octane number (RON), the better the fuel can be used in engines with a higher compression ratio. Therefore, it can be concluded that the higher the RON of a fuel, the better the fuel is at resisting detonation. [2] In fact, many users of high-compression-ratio vehicles choose fuel with a low RON, such as Pertalite (RON 88). This choice is generally based on Pertalite's lower price compared to other fuels. This inappropriate fuel selection will negatively impact engine performance and durability. Using fuel that does not meet engine specifications can potentially lead to decreased efficiency, component damage, and reduced engine lifespan.

This study aims to analyze the effect of fuel octane rating on the performance of high-compression vehicle engines, while also educating the public about the importance of using the appropriate fuel to maintain engine efficiency and reliability.

Previous research conducted by [3] entitled The Effect of Use and Calculation of Premium and Pertamax Fuel Efficiency on the Performance of Gasoline Engines. This study tested the performance of the 2012 Honda Beat 108 cc engine using three types of fuel: Premium, Pertamax, and a mixture of both. Testing was carried out using a Dynotest tool to record torque, power, and specific fuel consumption (BSFC) at various engine speeds. The result, Pertamax provided the best performance with a maximum torque of 116.15 Nm at 2000 rpm and a peak power of 6.6 HP at 4000–4500 rpm. The gasoline mixture produced 99.93 Nm of torque and 6.5 HP of power, while Premium produced 67.53 Nm of torque and 6.4 HP of power. In terms of efficiency, Pertamax also excels with the lowest specific fuel consumption, namely 0.41 kg/kWh, compared to Premium (0.48) and blends (0.53).

Previous studies in Indonesia generally confirm that fuels with higher octane numbers improve motorcycle engine performance in terms of torque, power, fuel efficiency, and emissions. [1] showed that Pertamax outperforms Pertalite in power, torque, specific fuel consumption, and exhaust emissions on a 208 cc engine. Similar findings were reported by [4], who demonstrated that blending higher-octane fuel (Premium–Pertamax mixtures) improved combustion quality, resulting in optimal torque, power, fuel efficiency, and effective pressure on a Honda [3] also found that higher-octane fuels such as Pertamax Turbo produced the highest torque and power, while lower-octane fuels showed poorer fuel economy, confirming that octane rating directly affects combustion quality and engine output.

Further experimental work examined the interaction between octane rating, ignition systems, and operating conditions. [4] reported that higher octane fuel combined with racing ignition coils yielded the highest power and torque, although statistical analysis showed limited significance at mid-range engine speeds. Emphasized the importance of matching high-octane fuels with increased compression ratios, demonstrating that a compression ratio of 11.5:1 with optimized ethanol vapor delivery significantly improved power and torque. [3] similarly showed that increasing compression ratio and optimizing injection duration improved torque, power, and thermal efficiency when using ethanol-blended fuels, despite a slight increase in BSFC due to ethanol’s lower heating value.

Several studies focused on engine design and mechanical modifications to enhance combustion efficiency. Azhar [1] found that converting fuel delivery from carburetor to injection and increasing compression ratio significantly increased torque and power. Demonstrated that increasing the squish head tilt angle improved torque output by enhancing mixture motion and combustion efficiency. Showed that increasing compression ratio when using E85 fuel could mitigate torque losses and slightly improve performance, reinforcing the principle that high-octane or ethanol-based fuels require higher compression ratios for optimal operation.

International studies further strengthen these findings by highlighting the broader efficiency and sustainability implications of high-octane fuels. Confirmed that higher octane ratings improve thermal efficiency, allow more aggressive ignition timing or boost, reduce fuel consumption, and lower emissions, particularly under real-world driving conditions, [5], [6], [7] collectively demonstrated that high-octane fuels—especially when combined with ethanol content, EGR optimization, or appropriate engine calibration—extend knock limits, improve efficiency, and reduce greenhouse gas emissions. These studies underline that the full benefits of high-octane fuels are maximized when engine design and calibration are aligned with fuel characteristics, supporting the development of cleaner and more energy-efficient combustion systems.

This study highlights the mismatch between fuel usage and the characteristics of high-compression engines, where many users of modern vehicles continue to use low-octane fuel such as Pertalite RON 88 due to its lower cost. This practice leads to engine knocking or premature detonation, which reduces combustion efficiency, promotes deposit formation and corrosion in the combustion chamber, and decreases thermal efficiency as well as engine performance in terms of power and torque. In the long term, these effects shorten engine lifespan and reflect a gap between user behavior and engine technical specifications, ultimately impacting vehicle performance and national energy consumption efficiency.

The urgency of this research stems from several key aspects: technically, high-compression engines require high-octane fuel to achieve optimal combustion and prevent knocking, yet public awareness of this requirement remains limited; in terms of energy efficiency, using the appropriate fuel improves combustion efficiency, leading to more effective fuel consumption and reduced energy waste; from a sustainability perspective, proper fuel selection enhances engine durability and can help lower exhaust emissions, supporting green energy principles; and educationally, this study provides empirical insight for both the public and the automotive industry on the importance of matching fuel RON with engine compression ratios to maintain performance and extend engine life. Therefore, this research is significant not only for academics and industry stakeholders but also for the general public as everyday motor vehicle users.

The novelty of this research can be viewed from several perspectives. First, the study employed a 206 cc four-stroke gasoline engine with a high compression ratio of 12.7:1, which is rarely used in similar studies in Indonesia, where most previous research focused on engines with compression ratios below 11:1. Second, it provides a direct comparison of three commercially available Pertamina fuels—RON 92 (Pertamax), RON 95 (Pertamax Green), and RON 98 (Pertamax Turbo)—tested under controlled conditions using a dynamometer, generating empirical data that are highly relevant to modern engines. Third, the research applied an actual thermal efficiency analysis based on output power and specific fuel consumption (SBF), offering a more detailed understanding of how fuel energy is converted into mechanical power. Finally, beyond its experimental contribution, this study emphasizes an educational perspective by delivering practical recommendations for modern vehicle users, highlighting the performance and durability implications of selecting inappropriate fuels for high-compression engines.

Research Methods

The data collection method used comparative test results between Pertamax, Pertamax Green, and Pertamax Turbo using a 206 cc engine. Vehicle performance test data was collected twice [8], [9], [10], [11].

The tests were conducted to determine the significant differences in performance between vehicles using Pertamax, Pertamax Green, and Pertamax Turbo. The vehicle performance tests measured torque, power, and kbbs at specific rpm. The data collection method used comparative test results between Pertamax, Pertamax Green, and Pertamax Turbo using a 206cc engine. Vehicle performance test data was collected twice.
The tests were conducted to determine the significant differences in vehicle performance between those using Pertamax, Pertamax Green, and Pertamax Turbo. In the vehicle performance tests, torque, power, and kbbs were measured at specific rpm [4], [5][7], [12].

Research Method: The data obtained from the engine performance tests for power, torque, and exhaust emissions were then presented for analysis in a graph. The data obtained were used to determine the effect of fuel variations on engine performance and fuel consumption. The independent variables in this study were Pertamax, Pertamax Green, and Pertamax Turbo.

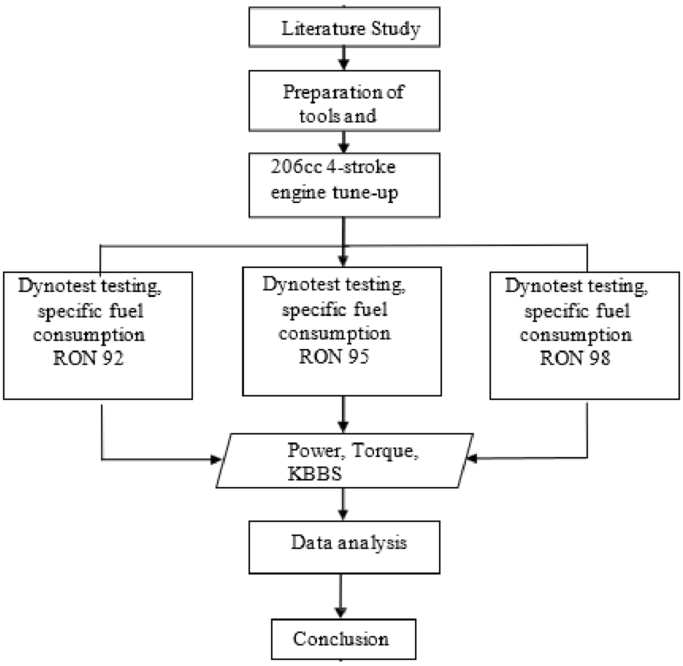

Figure1. Research Flowchart

Research Variables

1. Independent Variable
   This variable is called the influencing variable because it influences other variables. The independent variables in this study are Pertamax, Pertamax Green, and Pertamax Turbo [13], [14], [15], [16], [17].
2. Dependent Variable
   This variable is influenced by other variables, therefore it is also called the influenced variable or the affected variable. The dependent variables are power, torque, and fuel consumption [18], [19], [20], [21].
3. Control Variable
   a. Using a four-stroke gasoline engine.

b. The compression ratio of the engine is 12.7:1.
c. The engine speed is between 5,500 rpm and 10,000 rpm.

Research Time and Location

This research will be conducted on March 10, 2025. The power, torque, and KBBS testing will be conducted in the Thermodynamics Lab of Mechanical Engineering, Muhammadiyah University of Surakarta.

Results and Discussion

Power Test Results

Power testing on an engine with a compression ratio of 12.7:1 using several types of fuel: RON 92, RON 95, and RON 98. The test used a dyno test method and yielded the following results.

Table 2. Power Data Per Engine Revolution of The Three Fuels

RPM	RON 92	RON 95	RON 98
5500	10.55	11.85	11.55
6000	14.7	14.65	15.7
6500	16.25	16.9	17.55
7000	17.35	18.25	18.75
7500	18.45	19.1	19.85
8000	19.4	19.95	20.6
8500	20.3	21.1	21.7
9000	21.55	22.45	23.1
9500	22.1	23.45	24.2
10000	22.35	23.95	24.45

Based on Table 2, the engine power increases consistently with rising engine speed (RPM) for all three fuel types—RON 92, RON 95, and RON 98—indicating a strong positive relationship between RPM and power per engine revolution. Across the entire RPM range, RON 98 produces the highest power output, followed by RON 95 and RON 92, suggesting that higher-octane fuels enable more efficient and stable combustion, especially as engine load and speed increase. The power gap between the fuels becomes more pronounced at higher RPMs, particularly above 8500 RPM, highlighting that the performance advantage of higher RON fuels is more significant under high-speed operating conditions. This implies that RON 98 is the most suitable choice for achieving maximum engine performance, while RON 92 remains adequate at low to mid RPMs but is less optimal at higher RPMs.

Torque Test Results

In addition to power testing, torque testing was also conducted using a dyno test method, yielding the following results:

Table 3. Torque Data Against Engine Speed of The Three Fuels

RPM	RON 92	RON 95	RON 98
5500	13.42	15.045	14.635
6000	17.165	17.765	18.415
6500	17.52	18.23	18.905
7000	17.425	18.28	18.76
7500	17.305	17.85	18.58
8000	17.01	17.52	18.085
8500	16.71	17.44	17.91
9000	16.72	17.485	17.995
9500	16.315	17.32	17.855
10000	15.695	16.83	17.18

The torque output for all three fuels initially increases with engine speed, reaching peak values in the mid-range RPM (around 6500–7000 RPM), and then gradually decreases as RPM continues to rise. Throughout the entire speed range, RON 98 consistently delivers the highest torque, followed by RON 95 and RON 92, indicating superior combustion quality and resistance to knock at higher octane levels. The differences in torque among the fuels are more noticeable at higher RPMs, where RON 98 maintains relatively higher torque while RON 92 experiences a more pronounced decline. This trend suggests that higher-octane fuels are more effective in sustaining torque at elevated engine speeds, contributing to better overall engine performance and drivability, especially under high-speed operating conditions.

Specific Fuel Consumption Calculation

Specific fuel consumption (SFC) is the amount of fuel used to produce power in an engine. From the KBBS test that I have conducted, the results data are as in the following table.

Table 4. Specific Fuel Consumption Data

Fuel Type	Time (s)	Fuel Consumption (ml)	Power (HP)
RON 92	5.3	14.5	22
RON 95	5.08	12	24.3
RON 98	5.16	11	24.9

RON 98 demonstrates the best overall fuel efficiency and performance, as it produces the highest power output (24.9 HP) while consuming the least amount of fuel (11 ml), indicating the lowest specific fuel consumption among the three fuels. RON 95 shows moderate performance with a balanced combination of lower fuel consumption (12 ml) and relatively high power (24.3 HP), while RON 92 records the highest fuel consumption (14.5 ml) and the lowest power output (22 HP), reflecting less efficient combustion. Although the operating time differences are relatively small, the results clearly indicate that increasing the fuel octane rating improves combustion efficiency, reduces fuel consumption, and enhances engine power, making RON 98 the most efficient and effective fuel in this comparison.

And after carrying out calculations based on the formula above, the results were as follows:

Table 5. Data of Specific Fuel Consumption Calculation Results

RPM	KBS RON 92	KBS RON 95	KBS RON 98
5500	0.6393247	0.495505	0.4543256
6000	0.5026415	0.4310215	0.344186
6500	0.4526896	0.3595951	0.3086451
7000	0.4262165	0.3329584	0.2853804
7500	0.3982679	0.3194372	0.2717258
8000	0.3718521	0.3084761	0.262919
8500	0.3590297	0.2926936	0.2512863
9000	0.3374214	0.2747997	0.2386164
9500	0.3343258	0.2644081	

The specific fuel consumption of the three types used obtained different values, the higher the engine speed, the lower the specific fuel consumption value obtained.

Power Analysis Test Result Data

From the test results using 3 types of fuel with different RON, the following power graph results were obtained.

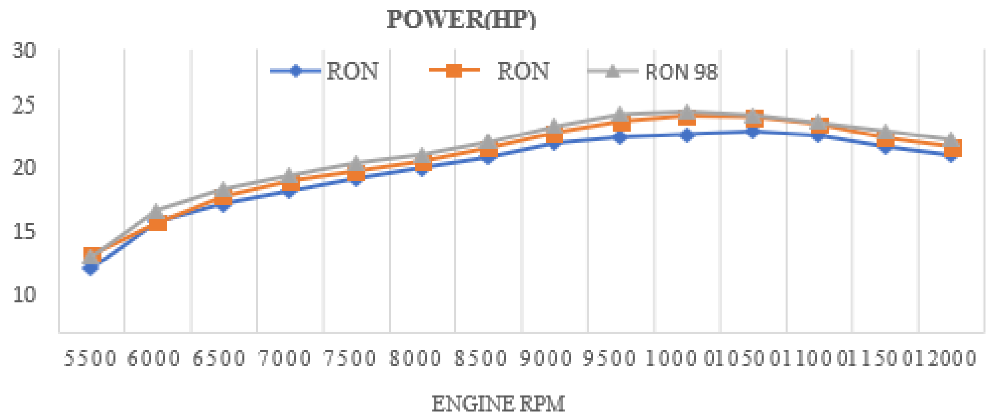

Figure 2. Power Graph Against Engine Speed of The Three Fuels

From the graph of the dyno test results on an engine with a compression ratio of 12.7: 1, it shows that RON 98 produces the highest power of 24.45 HP, followed by RON 95 with 23.95 HP, and RON 92 with the lowest power of 22.35 HP, all of these peak powers are obtained at an engine speed of 10,000 rpm. This difference is greatly influenced by the octane value (RON) of each fuel. Thermodynamically, engine efficiency can be explained through thermal efficiency, especially in the ideal Otto cycle which represents the characteristics of a gasoline engine. However, in reality, the actual thermal efficiency of an engine is always lower than ideal efficiency due to mechanical losses (such as friction between the piston and other moving components), thermal losses (heat lost to the cylinder walls and cooling system), and incomplete combustion. To minimize these losses and approach ideal efficiency, the engine requires optimal ignition timing, namely near the MBT (Minimum Advance for Best Torque) point, where peak combustion pressure occurs just as the piston begins its downward movement. However, in engines with high compression ratios, the pressure and temperature in the combustion chamber are very high, so low-RON fuels tend to experience premature combustion (knocking), which forces the ignition system to operate suboptimally (retarded timing). Under these conditions, the use of high-octane fuel is crucial because it is resistant to auto-ignition, allowing combustion to occur at ideal timing. With proper ignition timing and more stable combustion, the heat energy from combustion can be maximally converted into mechanical work. This is what allows high-compression engines, such as those with a 12.7:1 ratio, to operate more thermally efficiently when using high-octane fuel.

Fuel with a high RON rating, such as RON 98, has the ability to withstand high pressures and temperatures in the combustion chamber during the compression process without experiencing premature combustion (autoignition) or knocking. This characteristic is especially important in engines with high compression ratios, such as 12.7:1, where the air-fuel mixture is compressed to much greater pressure than in engines with low compression ratios. This compression process causes the temperature in the combustion chamber to increase significantly even before the spark plug ignites. The use of 98 octane fuel allows combustion to occur at the right time, according to the ignition system settings. In addition to its high octane rating, this fuel is equipped with Ignition Boost Formula (IBF), an additive developed by Pertamina, which functions to increase the speed and stability of combustion, so that peak pressure is achieved more efficiently and timely. With more stable combustion, the pressure of the combustion gas is more optimal, pushing the piston to the maximum and increasing engine power. Thermodynamically, the power produced by an engine is related to the pressure and temperature of the combustion products that push the piston. RON 95 is capable of producing quite high power because it has an octane number that is still relatively high, although slightly lower than RON 98. The high octane number allows this fuel to be used in engines with a high compression ratio (12.7: 1) without experiencing knocking symptoms. One of the advantages of RON 95 fuel is the bioethanol content, which naturally has a high octane number, faster ethanol combustion because it has a simple chemical structure (C2H5OH) and contains oxygen in its molecules. This additional oxygen content increases combustion efficiency, accelerates the combustion reaction, and supports more complete combustion. RON 92 has the lowest octane rating and a higher sulfur content than RON 95 and RON 98, making it less suitable for high-compression engines such as 12.7:1. The low octane rating increases the risk of premature combustion (knocking), while burning sulfur produces SO_2 and SO_3, which form sulfuric acid (H_2SO_4) when reacting with water vapor. At high temperatures and pressures, this acid accelerates corrosion of valves, piston rings, and cylinder walls, and triggers the buildup of deposits in the combustion chamber. This combination of damage and deposits causes compression leaks, incomplete combustion, and reduced thermal efficiency, which directly impacts engine power.

Figure 3. Combustion Chamber Before and After Testing

Torque analysis of testing using 3 types of fuel with different RON results in the following torque graph:

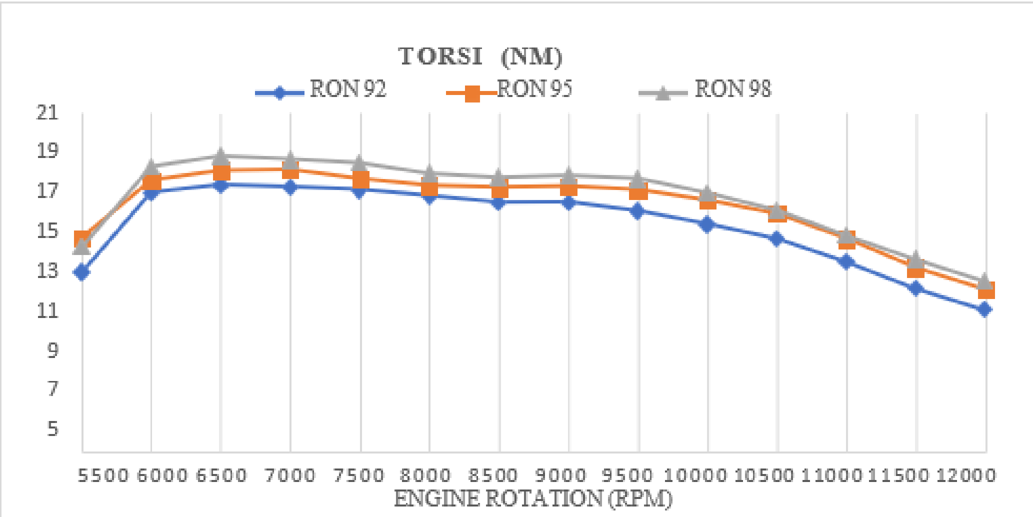

Figure 4. Engine Speed From Three Fuels

Dyno testing results showed that RON 98 fuel produced the highest torque, reaching approximately 18,905 Nm at 6,500 rpm, followed by RON 95 and RON 92 fuels. This higher torque is in line with the octane rating and combustion quality of each fuel. RON 98 fuel is supported by Ignition Boost Formula (IBF) technology, which helps accelerate and stabilize combustion, and its high octane rating allows the combustion gas pressure to push the piston more effectively and produce greater torque, reaching 18,905 Nm at 6,500 rpm. RON 95 fuel remains competitive with 18.28 Nm of torque at 7,000 rpm thanks to the bioethanol content that enriches the oxygen in the mixture, but torque is slightly lower due to the lower calorific value of bioethanol. Meanwhile, RON 92 fuel produces the lowest torque, namely 17.52 Nm at 6500 rpm engine speed, this is due to the low octane value and higher sulfur content, which reduces combustion efficiency and effective pressure on the piston which causes the twisting force (torque) to be low.

From the results of tests that have been carried out using fuel with different RON and calculations, the following specific fuel consumption graph was obtained.

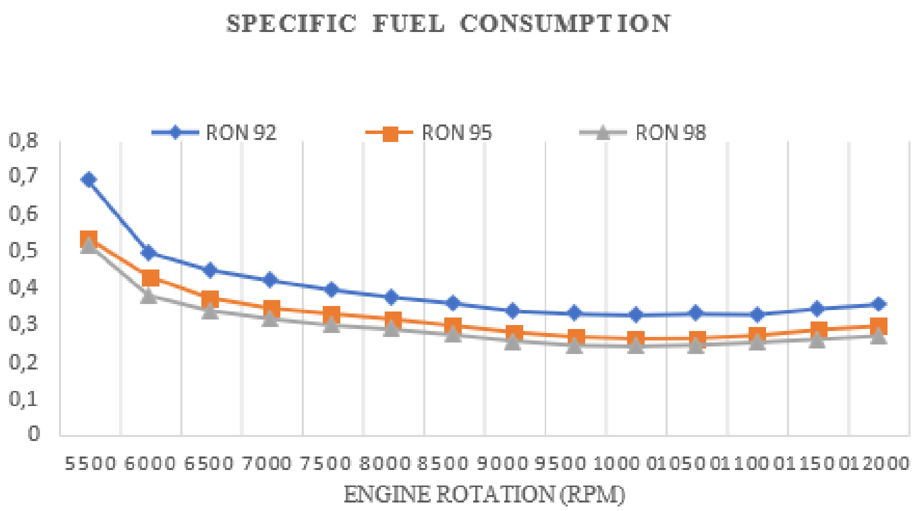

Figure 5. Specific Fuel Consumption Per Rpm of The Three Fuels

Test results showed that RON 98 fuel had the lowest specific fuel consumption (SFC) across the entire engine speed range, followed by RON 95 and RON 92. The SFC reflects the efficiency of fuel utilization relative to power output [22], [23], [24], [25], [26]. The lower the SFC, the higher the engine's thermal efficiency, as more combustion energy is converted into mechanical power. Pertamax Turbo recorded the lowest SFC of 0.228075091 kg/hp.h at 10,000 rpm, supported by its high octane rating and Ignition Boost Formula (IBF) technology, which increases combustion speed and stability.

RON 95 fuel also demonstrated good efficiency with a SFC of 0.258967629 kg/hp.h, thanks to its bioethanol content, which enriches the oxygen mixture and accelerates combustion. Conversely, RON 92 had the highest SFC of 0.331286449 kg/hp.h due to incomplete combustion, potential knocking, and high sulfur content, which accelerates deposit formation and corrosion. Deposits and corrosion reduce thermal efficiency by disrupting the shape of the combustion chamber, increasing compression leaks, and increasing friction, resulting in wasted energy and increased fuel consumption [27], [28], [29].

Fuel Consumption and Power

Table 5. Fuel Consumption and Power

Fuel Type	Time (s)	Fuel Consumption (ml)	Power (HP)	Power (W)
RON 92	5.3	14.5	22.35	16,666.39
RON 95	5.08	12	23.95	17,859.51
RON 98	5.16	11.5	24.45	18,232.36

The actual thermal efficiency calculations show that engine efficiency is significantly influenced by high output power and low specific fuel consumption. The higher the power and the lower the specific fuel consumption, the more optimal the conversion of fuel energy into mechanical power, resulting in higher engine thermal efficiency.

Conclusion

In high-compression engines, higher fuel octane ratings lead to better engine performance. This is evident from the use of RON 98, which produces the highest power output of 24.45 hp and a peak torque of 18.905 Nm in an engine with a compression ratio of 12.7:1. In contrast, RON 92 shows the lowest performance because it is less capable of withstanding the high pressure and temperature in the combustion chamber, increasing the risk of knocking and incomplete combustion. Engine power and torque are strongly influenced by fuel quality, with RON 98 delivering the most optimal results due to its high resistance to pressure, which prevents knocking, as well as the presence of an Ignition Boost Formula (IBF) that promotes faster and more stable combustion. RON 95 also demonstrates relatively good performance, supported by its bioethanol content, which enhances oxygen availability and accelerates the combustion process. Meanwhile, RON 92 exhibits inferior performance as it is more prone to knocking and contains higher sulfur levels, which can cause deposits and damage engine components. The use of low-RON fuel with high sulfur content in high-compression engines can trigger knocking, accelerate deposit formation and corrosion in the combustion chamber, and lead to compression leakage. These conditions disrupt the combustion process, reduce effective cylinder pressure, increase friction losses, and ultimately result in significant energy losses and decreased engine performance.

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