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Performance of the Turbocharged Engine Toyota Raize using Pertamax 92 and Pertamax Green 95

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ABSTRACT

The automotive industry has experienced rapid technological advances in the development of more developed and efficient vehicles. An example is the Toyota Raize, which is equipped with a 3-cylinder turbocharged engine. Along with technological advances, issues have arisen regarding the use of optimal fuel to maintain engine performance. In the Indonesian market, Pertamina fuel is the main choice for consumers such as Pertamax 92 and Pertamax Green 95. The difference in octane values between the two raises questions about their impact on the performance of the Toyota Raize engine with a Turbocharger. A study was conducted on what fuel is better to use in a 3-cylinder turbocharged engine at varying engine speeds using experimental and theoretical research methods. The results showed that at engine speed 6000 RPM, the torque produced by Pertamax 92 reaches 130.8 Nm, while Pertamax Green 95 reaches 145.1 Nm. At the same speed, Engine power produced by Pertamax 92 reaches 110.2 HP, while Pertamax Green 95 records 122.2 HP. At low engine speed, Pertamax Green 95 is more efficient in fuel consumption whereas Pertamax 92 is more efficient at high speed. Pertamax Green 95 also produces a lower average CO_2 concentration compared to Pertamax 92. In conclusion, Pertamax Green 95 fuel is more consistent and efficient and provides more optimal performance compared to Pertamax 92.

1. INTRODUCTION

Technological advances in the automotive industry sector have resulted in vehicle innovations that are increasingly sophisticated and efficient in energy usage [1]–[3]. One prominent example is the Toyota Raize, a car with a 3-cylinder engine equipped with a Turbocharger, which was launched in 2021. This car has become the main choice in the Indonesian market [4], especially for families looking for a comfortable vehicle that can be used effectively in daily activities.

However, along with advances in this technology, issues have emerged related to optimal fuel use to maintain car engine performance [5], [6]. In this context, RON (Research Octane Number) is an important parameter that must be considered by users in choosing fuel that suits the needs of their car engine [7]–[9]. In the Indonesian market, Pertamina fuels are the primary choice for consumers, such as Pertamax 92 and Pertamax Green 95 [10].

The compression ratio that occurs during spontaneous combustion in the combustion chamber is determined by the RON (Research Octane Number) value [11]–[13]. Although Pertamax 92 and Pertamax Green 95 are common choices, the difference in their octane ratings raises questions regarding their impact on the performance of the Raize car equipped with a turbocharger. Varying octane levels will certainly result in different exhaust emissions and performance outcomes [6, 7]. While Pertamax 92 is generally considered safe and does not cause knocking, the use of fuel with a lower octane rating can impact the overall efficiency and performance of the engine. On the other hand, Pertamax Green 95 offers advantages in preventing knocking and enhancing engine performance, though its higher price may pose a challenge for some consumers [16].

Therefore, further research is necessary to gain a comprehensive understanding of the impact of using Pertamax 92 and Pertamax Green 95 on the performance of the Raize car equipped with a turbocharger. To ensure that Raize's engine operates optimally and efficiently, a thorough study must be conducted to analyze the effects of these two types of fuel across various engine speeds. By deeply understanding how fuels with different octane ratings influence torque, power, fuel consumption, and exhaust emissions, measures can be taken to enhance fuel efficiency, maintain engine quality, and extend the vehicle's lifespan. Additionally, a better understanding of the environmental impact of using different fuels will contribute to the development of more environmentally friendly fuels in the future.

2. METHODE

In this study, a Toyota Raize with a 1.0-liter turbocharged engine (1KR-VET, 12 Valve DOHC with VVT-i) and a G CVT variant, launched in 2021, was utilized. The vehicle had covered a distance of 32,881 kilometers at the time of testing. The specifications for the Toyota Raize's engine and performance are as follows: an engine capacity of 998 cc, 3 cylinders in-line, CVT transmission, a maximum power output of 97 HP at 6,000 RPM, a maximum torque of 140.2 Nm at 4,500 RPM, and a compression ratio of 9.5:1. The vehicle runs on gasoline with a fuel tank capacity of 36 liters. Its dimensions include a length of 4,030 mm, width of 1,710 mm, height of 1,635 mm, ground clearance of 200 mm, and a wheelbase of 2,525 mm. The chassis features electric power steering, a front MacPherson strut suspension, rear torsion beam suspension, 205/65 R17 tires, front disc brakes, and rear drum brakes, with an ABS braking system.

A chassis dynamometer was employed to measure the power and torque produced by the engine at various engine speeds during testing. Pertamax 92 and Pertamax Green 95 fuels were used as the test fuels to compare their effects on engine performance. For analysis, a computer and Global Techstream software, which is Toyota's official software, was used. A stopwatch was utilized to measure fuel consumption time. Additionally, a toolbox set was used for assembling and disassembling various vehicle components during the research process.

The data required for this study include the type of fuel used, engine speed, and engine performance metrics such as fuel consumption, torque, power, and exhaust emissions. The engine speeds to be tested are 2,500 RPM, 3,000 RPM, 3,500 RPM, 4,000 RPM, and up to 6,000 RPM. Engine performance evaluations at these specified speeds will be conducted using Pertamax 92. Subsequently, testing will be repeated with Pertamax Green 95 at the same engine speeds. Data obtained from both types of fuel will be recorded and compared to assess differences in engine performance. Data analysis will involve calculations using relevant formulas to determine the effects of Pertamax 92 and Pertamax Green 95 on engine performance at various speeds. The results are expected to provide a clear picture of the advantages or disadvantages of each type of fuel in enhancing engine efficiency and performance across different RPM levels. Consequently, this research aims to make a significant contribution to selecting optimal fuels for better and more environmentally friendly engine performance. To measure torque theoretically, equation (1) will be used.

$$T = \frac{Wb\ .\ 60{,}000}{2\pi n} \quad (1)$$

In addition to theoretical torque, theoretical power can also be expressed using equation (2).

$$Wb = \frac{2\pi nT}{60{,}000} \quad (2)$$

Equations (3) and (4) are used to calculate the theoretical specific fuel consumption (SFC). Equation (3) represents the expression for calculating the stroke volume (Vl), while Equation (4) is used to determine the clearance volume (Vc).

$$Vl = \frac{Kapasitas\ mesin}{Jumlah\ silinder} \tag{3}$$

$$R_c = \frac{Vl+Vc}{Vc} \tag{4}$$

3. RESULT AND DISCUSSION

3.1 Torque

Figure 1 presents a comprehensive comparative investigation of theoretical torque, torque with Pertamax 92, and torque with Pertamax Green 95, providing basic experiences into the performance characteristics of each fuel type. In particular, the peak torque achieved at mid-RPM with Pertamax Green 95 is in line with its superior ability to suppress knocking, supporting its suitability for turbocharged engines. For example, at 4,000 RPM, the solid torque output indicates optimization of air-fuel mixing under high compression conditions. The test information reliably illustrates that Pertamax Green 95 yields higher torque over different RPM levels when compared to Pertamax 92, though both drop brief of the theoretically predicted torque inferred from the vehicle's engine details. For instance, at an engine speed of 2,500 RPM, the theoretical torque is calculated to be 276.42 Nm, whereas the actual torque values recorded are 142.7 Nm for Pertamax 92 and 145.3 Nm for Pertamax Green 95. Additionally, at 6,000 RPM, the theoretical torque is 115.17 Nm, in differentiation to the measured torques of 130.8 Nm for Pertamax 92 and 145.1 Nm for Pertamax Green 95. The observed disparities between the theoretical and experimental torques can be ascribed to the fact that theoretical torque is determined based on the maximum power output of the engine, which serves as a preliminary estimate prior to experimental validation through testing. Thus, the theoretical torque is observed to be higher at lower RPMs, with a consequent decrease as RPM increases. However, the experimental results show a more steady trend, with Pertamax Green 95, due to its higher octane rating, illustrating prevalent torque performance in comparison to Pertamax 92, subsequently underscoring the viability of higher-octane fuels in optimizing engine output. Pertamax Green 95 consistently shows superior torque across a wide range of RPM levels due to its higher octane number, allowing for better knocking resistance and increased combustion stability. For example, at 6,000 RPM, Pertamax Green 95 reaches 145.1 Nm compared to Pertamax 92 which only reaches 130.8 Nm. This difference is due to the fuel's ability to maintain a more optimal AFR at high engine loads.

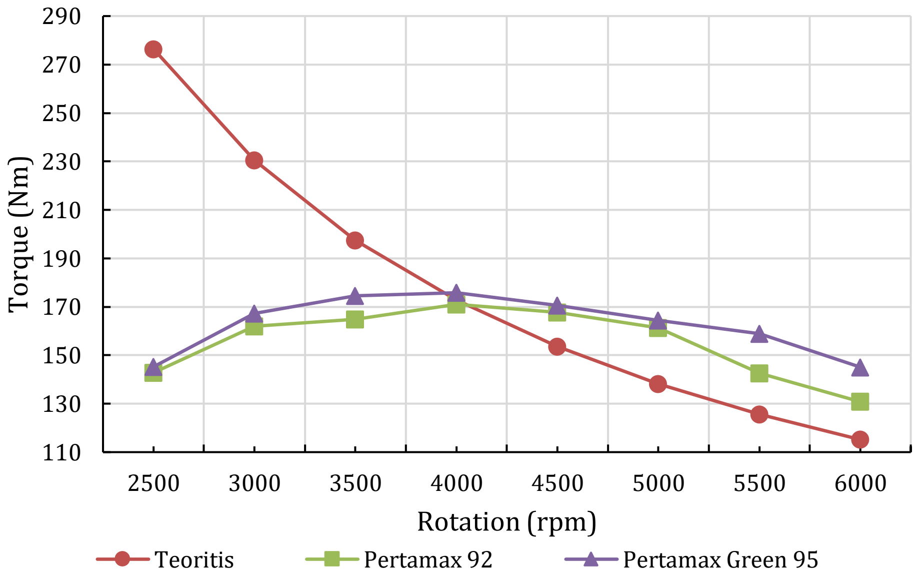

Figure 1. Comparison of Theoretical Torque (Nm) with Test Results Torque

3.2 Power

Figure 2 provides an in-depth comparative investigation of theoretical power, power with Pertamax 92, and power with Pertamax Green 95, advertising valuable experiences into the relative performance of these fuel types beneath varying engine speeds. Figure 2 reflects how Pertamax Green 95 maintains superior combustion even at maximum engine loads, emphasizing its role in maintaining engine durability and performance under stress. The experimental results clearly illustrate that Pertamax Green 95 consistently conveys predominant power output compared to Pertamax 92 and indeed outperforms the theoretical power predictions. For occasion, at 2,500 RPM, the theoretical power is calculated to be 49.18 HP, whereas Pertamax 92 and Pertamax Green 95 abdicate actual power outputs of 50.1 HP and 51 HP, respectively. This difference becomes progressively articulated at higher RPMs; eminently, at 6,000 RPM, where the theoretical power is estimated at 118.06 HP, Pertamax 92 accomplishes as it were 110.2 HP, whereas Pertamax Green 95 reaches an impressive 122.2 HP. The observed inconsistencies between the theoretical and actual power outputs can be ascribed to the fact that theoretical power calculations are based on the maximum torque specifications of the engine, serving as an initial estimate before experimental validation through thorough testing. Thus, the theoretical power tends to be lower than the measured power, particularly at higher RPMs. The noteworthy improvements observed during testing, particularly at elevated RPMs such as 5,500 and 6,000 RPM, emphasize the points of interest of Pertamax Green 95 in enhancing combustion efficiency and by and large engine performance. The higher power output related with Pertamax Green 95 highlights its potential to optimize engine operation, particularly in conditions requiring higher performance, thereby confirming the basic part of fuel quality in automotive engineering. The increase in power with Pertamax Green 95 at high RPM shows better thermal efficiency due to reduced knocking tendencies. This advantage is especially visible in turbocharged engines, where high octane fuel optimizes compression conditions.

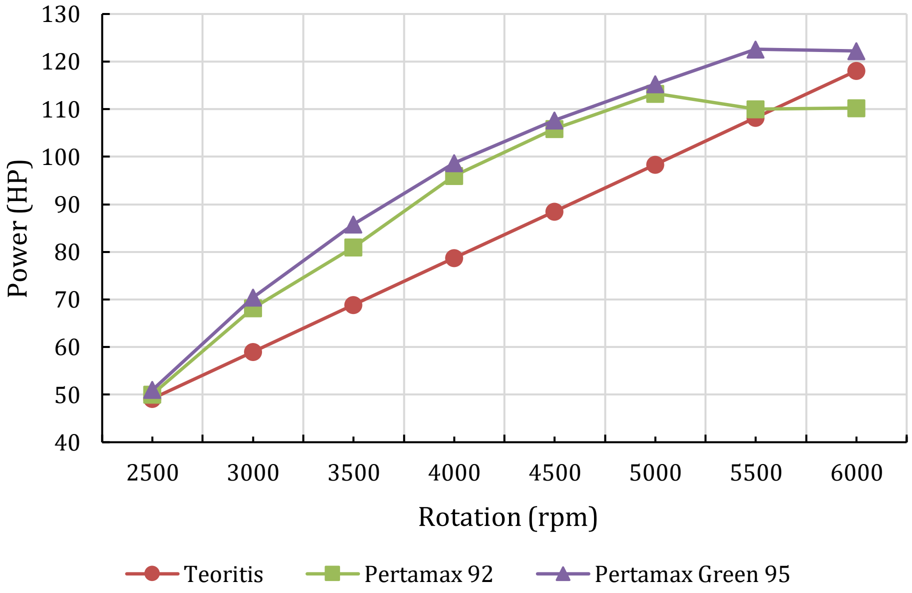

Figure 2. Comparison of Theoretical Power (Watts) with Test Results Power

3.3 Specific Fuel Consumption (SFC)

Figure 3 illustrates the comparative analysis of specific fuel consumption (SFC) with Pertamax 92 and Pertamax Green 95. Figure 3 shows the contrasting efficiencies between the two fuels at various RPM ranges. At low RPM, Pertamax Green 95 benefits from perfect combustion facilitated by its high octane number, while at high RPM, Pertamax 92's efficiency highlights its ability to adapt to faster combustion cycles. At RPM levels from 2,500 to 3,500, Pertamax Green 95 exhibits a lower theoretical specific fuel consumption compared to Pertamax 92. At 3,000 RPM, Pertamax Green 95 records the lowest value at 37.93 kg/HP·hr, whereas Pertamax 92 has a value of 39.33 kg/HP·hr. However, at RPM levels from 5,500 to 6,000, Pertamax 92 shows a lower specific fuel consumption, with values of 45.91 kg/HP·hr and 47.11 kg/HP·hr, compared to 51.23 kg/HP·hr and 50.61 kg/HP·hr for Pertamax Green 95. This difference is influenced by factors such as air temperature, air pressure, and air-fuel ratio (AFR), which vary with engine speed. For instance, at lower RPMs, Pertamax Green 95 might demonstrate better efficiency due to lower air pressure and AFR, leading to more efficient combustion compared to Pertamax 92. The specific fuel consumption (SFC) trend shows the balance between fuel efficiency and combustion characteristics. At low RPM, Pertamax Green 95 shows better efficiency, possibly due to stable AFR and lower heat loss. However, at high RPM, Pertamax 92 efficiency increases, possibly due to faster flame propagation, suitable for higher engine speeds despite its lower knock resistance.

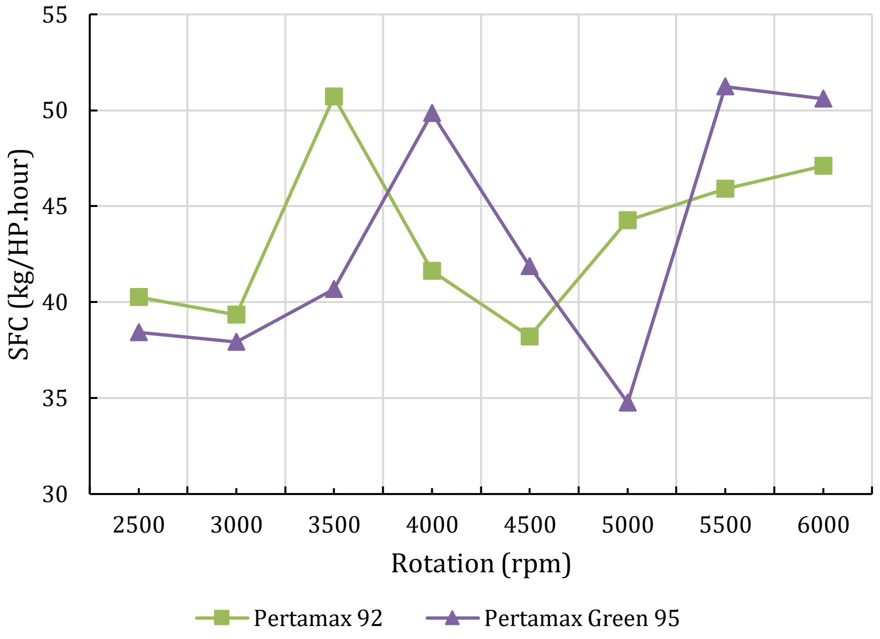

Figure 3. Comparison of Specific Fuel Consumption (SFC)

3.4 Exhaust Emission (CO_2)

Figure 4 illustrates the comparative investigation of CO_2 emissions when utilizing Pertamax 92 and Pertamax Green 95, highlighting the variations in emission patterns at different engine speeds (RPM). The investigation uncovers that Pertamax 92 shows CO_2 emission values extending from 7.9% to 14.5%, whereas Pertamax Green 95 shows emissions varying between 9.9% and 14.8%. Eminently, at particular engine speeds such as 4,000 RPM and 5,000 RPM, Pertamax Green 95 produces higher CO_2 emissions compared to Pertamax 92. Alternately, at 4,500 RPM and 5,500 RPM, Pertamax Green 95 illustrates lower CO_2 emissions than Pertamax 92. These discoveries emphasize the fact that CO_2 emission performance is not uniform across different fuel types and is essentially affected by the engine speed at which the combustion occurs. The variations in exhaust gas emissions can be ascribed to the particular combustion characteristics of each fuel type at different RPM levels, reflecting the complicated relationship between fuel composition, combustion efficiency, and engine operation. This complex interaction proposes that whereas Pertamax Green 95 generally supports more effective combustion, driving to higher power output as illustrated in prior investigations, it moreover produces varied outflow results depending on the particular operating conditions. This highlights the requirement for a nuanced understanding of fuel performance, where both power output and environmental affect are carefully considered in evaluating the overall adequacy of different fuels. The CO_2 emission results show a fairly complex evaluation. Although Pertamax Green 95 produces slightly higher emissions at certain RPM ranges, its overall performance shows an average reduction in CO_2 concentration, in line with Indonesia's sustainability goals. This reduction contributes to efforts to achieve national commitments in the Paris Agreement to reduce greenhouse gas emissions. In addition, the use of Pertamax Green 95 in vehicles such as the Toyota Raize supports the practical application of cleaner fuels, while improving engine performance. Comparison with applicable local emission standards, such as compliance with EURO IV, shows that Pertamax Green 95 is a viable alternative to reduce urban pollution.

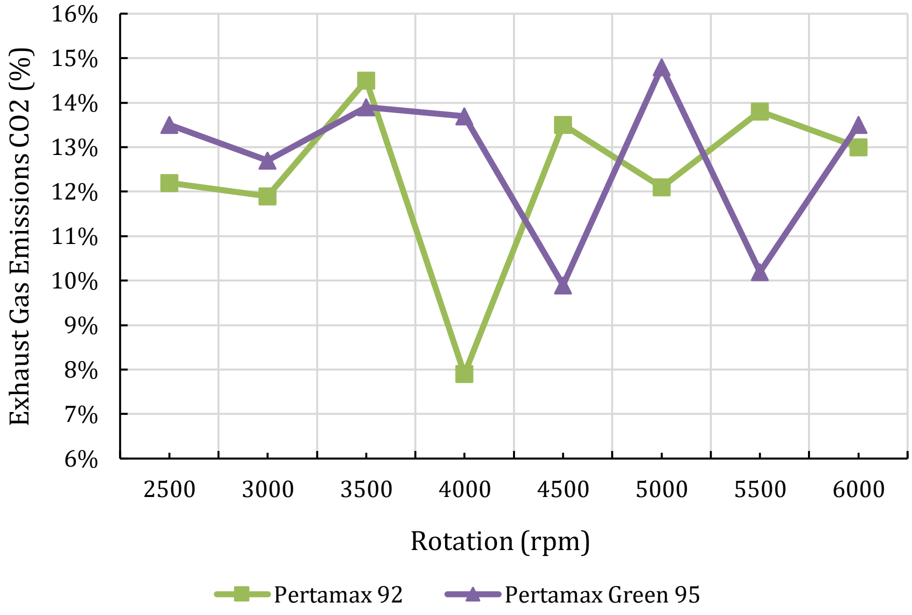

Figure 4. Comparison of CO2 Exhaust Emissions

4. CONCLUSION

The utilization of Pertamax Green 95 fuel shows particularly predominant engine performance in comparison to Pertamax 92, particularly within the context of the Raize Turbocharged engine. Pertamax Green 95 accomplishes a top torque of 175.8 Nm at 4,000 RPM and accomplishes a maximum power output of 122.2 HP at 6,000 RPM, outperforming the performance measurements observed with Pertamax 92. Additionally, Pertamax Green 95 illustrates more efficient average fuel consumption and produces lower exhaust emissions over a range of engine speeds. These characteristics collectively show that Pertamax Green 95 not as it were improves engine performance in terms of torque and power but moreover contributes to more effective fuel utilization and diminished environmental affect. Thus, Pertamax Green 95 is recommended as the preferred fuel for the Raize Turbocharged engine, advertising a more efficient and effective alternative to Pertamax 92. The advantages observed with Pertamax Green 95 highlight its capability to optimize engine performance whereas minimizing fuel consumption and emissions, subsequently supporting its suggestion for drivers looking for improved efficiency and environmental stewardship in their vehicle operation. Although the experimental setup is controlled, variables such as ambient temperature, humidity, and atmospheric pressure can have subtle effects on the results. In tropical areas such as Indonesia, where these factors fluctuate significantly, their impact on AFR, combustion efficiency, and engine heat release cannot be ignored. For example, higher humidity levels can reduce oxygen availability, slightly changing combustion efficiency. Recognizing these conditions emphasizes the need for further research under various environmental settings to increase the generalizability of these findings.

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