International Journal of Advanced Technology and Social Sciences (IJATSS)
Vol.4, No.8, 2026: 1031-1042

Comparison of Exhaust Gas Emissions of a Carbureted Yamaha Jupiter Z Motorcycle Using Pertalite, Pertamax, and Pertamax Turbo Fuel

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A R T I C L E I N F O

Keywords: Exhaust Emissions, Yamaha Jupiter Z, Research Octane Number (RON), Gas Analyzer

Received : 5 June
Revised : 23 July
Accepted: 30 August

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A B S T R A C T

Motorcycle exhaust emissions have become an important environmental issue because they contribute to air pollution and reflect combustion efficiency. This study aimed to compare the exhaust emissions of a carbureted Yamaha Jupiter Z motorcycle using three commercially available gasoline fuels with different Research Octane Numbers, namely Pertalite RON 90, Pertamax RON 92, and Pertamax Turbo RON 98. An experimental method was employed under controlled operating conditions using engine speeds of 2,000, 4,000, and 6,000 rpm. Exhaust emissions of carbon monoxide, hydrocarbon, and carbon dioxide were measured using a calibrated gas analyzer. The results showed that emission characteristics varied with both fuel type and engine speed. Different fuels exhibited different emission patterns under the tested conditions, while carbon dioxide emissions showed relatively small variations. These findings indicate that fuel type influences exhaust emission characteristics, although the observed effects depend on engine operating conditions rather than fuel octane rating alone. Therefore, selecting gasoline that matches engine specifications can improve combustion quality and contribute to lower exhaust emissions

INTRODUCTION

The increasing number of motor vehicles, particularly motorcycles, in Indonesia has contributed significantly to higher fuel consumption and air pollution from the transportation sector. Consequently, motorcycle exhaust emissions have become an important environmental issue that requires considerable attention in the development of automotive technology (Komarulloh et al., 2024). Motorcycles are widely used because they offer high fuel efficiency, relatively low operating costs, and excellent mobility. However, the growing number of motorcycles has also led to increased exhaust emissions, which contribute to the deterioration of air quality (Pambudi et al., 2024). According to Statistics Indonesia (BPS), the number of registered motor vehicles increased significantly from 105.15 million units in 2016 to 113.03 million units in 2017, with motorcycles accounting for the largest proportion of the total vehicle population (Sanusi et al., 2019). This continuous increase in motorcycle ownership highlights the importance of evaluating exhaust emissions as part of efforts to reduce the environmental impact of the transportation sector.

Exhaust emissions are by-products of the fuel combustion process occurring inside the engine combustion chamber. These emissions generally consist of carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2), oxygen (O_2), and nitrogen oxides (NO_x) (Sunoko & Witono, 2024). Among these components, CO, HC, and CO_2 are widely used to evaluate combustion quality in gasoline engines. High concentrations of CO and HC indicate incomplete combustion, whereas CO_2 is generally associated with more complete combustion. Combustion quality is influenced by several operating parameters, including engine speed (RPM), the air-fuel ratio, and combustion system settings (Komarulloh et al., 2024). In addition, proper adjustment of the Idle Mixture Adjusting Screw (IMAS) has been reported to improve combustion efficiency, thereby reducing CO and HC emissions (Pambudi et al., 2024).

Various approaches have been developed to improve combustion quality and reduce exhaust emissions from gasoline engines. The application of a dry-cell HHO generator has been shown to enhance the combustion process, resulting in lower CO and HC emissions (Sunoko & Witono, 2024). Likewise, the implementation of an oxyhydrogen generator has been reported to improve combustion efficiency without adversely affecting engine performance (Fandikurnia et al., 2024). Another combustion enhancement method, namely the Hydrocarbon Crack System (HCS), utilizes exhaust heat to improve fuel combustion, thereby reducing fuel consumption and lowering HC, CO, and CO_2 emissions (Suryono et al., 2018). These findings demonstrate that improving combustion quality is an effective strategy for reducing exhaust emissions from gasoline engines.

In addition to engine operating parameters and combustion enhancement technologies, fuel type is another important factor influencing combustion characteristics. Differences in fuel properties affect combustion quality and consequently alter exhaust emission characteristics (Agus Winoko et al., 2025). Previous studies have shown that different gasoline fuels produce variations in CO, HC, and CO_2 emissions from gasoline engines (Dani et al., 2024). Sanusi et al. (2019) also reported that fuel type significantly affected CO and HC emissions in a Yamaha Vixion motorcycle equipped with an electronic fuel injection (EFI) system. These findings indicate that fuel properties contribute to combustion behavior and exhaust emission characteristics.

Fuel combustion characteristics are strongly associated with the fuel's Research Octane Number (RON). A higher RON provides greater resistance to knocking, allowing combustion to occur more smoothly and in a more controlled manner (Agus Winoko et al., 2025). In Indonesia, the gasoline fuels most commonly available for motorcycles are Pertalite (RON 90), Pertamax (RON 92), and Pertamax Turbo (RON 98). The differences in octane ratings among these fuels are expected to produce different combustion characteristics and exhaust emission profiles in spark-ignition engines (Dani et al., 2024).

Although previous studies have demonstrated that fuel characteristics influence exhaust emissions, most investigations have focused on fuel-injected motorcycles, alternative fuel blends, or combustion enhancement technologies. Comparative studies evaluating the effects of commercially available gasoline fuels, namely Pertalite, Pertamax, and Pertamax Turbo, on a carbureted motorcycle under identical operating conditions remain limited. The Yamaha Jupiter Z was selected as the experimental object because it employs a carburetor fuel system according to the manufacturer's specifications, making it suitable for evaluating combustion characteristics using fuels with different Research Octane Number (RON) values (Yamaha Motor Co., 2003). Using a single motorcycle model throughout the experiment also minimizes variations caused by differences in engine specifications, allowing the observed emission characteristics to be attributed primarily to fuel type.

Therefore, this study aims to analyze and compare the effects of Pertalite, Pertamax, and Pertamax Turbo on the carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) emissions of a Yamaha Jupiter Z motorcycle at different engine speeds under identical testing conditions. The novelty of this study lies in the direct comparison of three commercially available gasoline fuels with different octane ratings using the same carbureted motorcycle under controlled experimental conditions, providing a more objective evaluation of the influence of fuel type on exhaust emission characteristics.

LITERATURE REVIEW

Exhaust emissions are gaseous by-products generated during the combustion process in spark-ignition engines. These emissions mainly consist of carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2), oxygen (O_2), and nitrogen oxides (NOx), which are commonly used to evaluate combustion quality and engine performance. High concentrations of CO and HC generally indicate incomplete combustion caused by an improper air–fuel mixture, whereas CO_2 and O_2 serve as indicators of combustion efficiency (Sunoko & Witono, 2024). Several engine operating parameters, including engine speed (RPM), air–fuel ratio, ignition timing, and fuel characteristics, influence the formation of exhaust emissions (Komarulloh et al., 2024; Pambudi et al., 2024).

Among these factors, fuel characteristics play an important role in determining combustion quality and exhaust emission formation. One of the most important fuel properties is the Research Octane Number (RON), which represents a fuel's resistance to knocking during combustion. Fuels with higher octane ratings generally produce more stable combustion and are better suited to engines with higher compression ratios, thereby reducing the formation of harmful emissions (Agus Winoko et al., 2025). In Indonesia, the gasoline fuels commonly used in motorcycles are Pertalite (RON 90), Pertamax (RON 92), and Pertamax Turbo (RON 98), each having different combustion characteristics that may influence exhaust emission levels (Dani et al., 2024).

Previous studies have consistently demonstrated that fuel type significantly affects motorcycle exhaust emissions. Dani et al. (2024) reported that motorcycles fueled with higher-octane gasoline produced lower CO and HC emissions than those using lower-octane fuels. Similar findings were reported by Sanusi et al. (2019), who found that Pertamax Turbo generated the lowest CO and HC emissions among the tested fuels on a Yamaha Vixion motorcycle equipped with an electronic fuel injection (EFI) system. These findings suggest that increasing the octane rating improves combustion quality, thereby reducing incomplete combustion products.

Besides fuel characteristics, several studies have investigated combustion enhancement technologies as an approach to reducing exhaust emissions. Sunoko & Witono, (2024) demonstrated that a dry-cell HHO generator improved combustion efficiency and reduced CO and HC emissions. Likewise, Fandikurnia et al. (2024) reported that an oxyhydrogen generator enhanced combustion performance without negatively affecting engine operation. Suryono et al. (2018) also found that the Hydrocarbon Crack System (HCS), which utilizes exhaust heat, reduced fuel consumption and lowered HC, CO, and CO_2 emissions. Furthermore, Komarulloh et al. (2024) reported that engine speed significantly influences CO, HC, and CO_2 emissions, while Pambudi et al. (2024) found that proper adjustment of the Idle Mixture Adjusting Screw (IMAS) improved combustion efficiency by optimizing the air–fuel mixture, resulting in lower CO and HC emissions.

Although previous studies have demonstrated the influence of fuel characteristics, combustion technologies, and engine operating parameters on exhaust emissions, most investigations have focused on motorcycles equipped with electronic fuel injection systems, modified combustion technologies, or fuel blends. Comparative studies evaluating the effects of commercially available gasoline fuels, namely Pertalite, Pertamax, and Pertamax Turbo, on the exhaust emissions of the Yamaha Jupiter Z under identical operating conditions remain limited. Therefore, this study addresses this research gap by providing empirical evidence regarding the influence of different gasoline fuels on exhaust emission characteristics using the same motorcycle under controlled experimental conditions.

METHODOLOGY

This research employed an experimental approach to investigate the effect of different gasoline fuels on the exhaust emissions of a Yamaha Jupiter Z motorcycle. The research workflow is presented in Figure 1, illustrating the sequence of experimental procedures from preparation to statistical analysis.

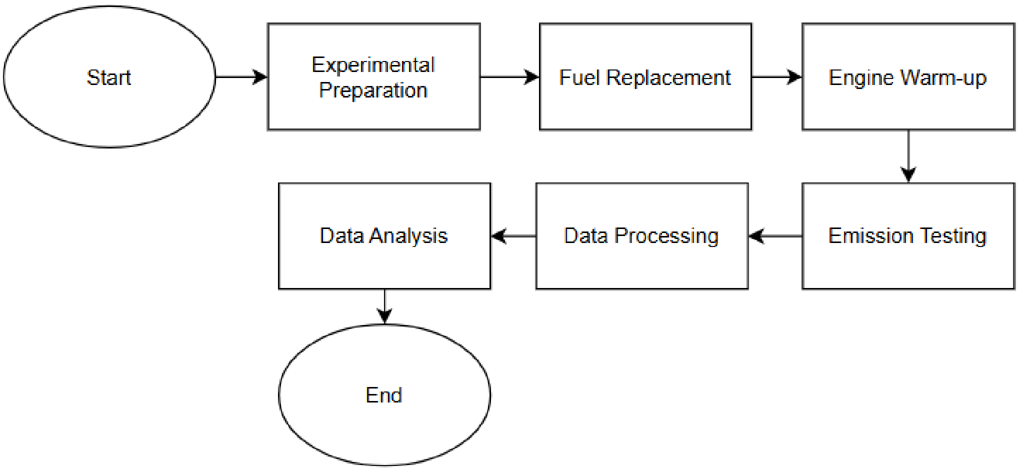

Figure 1. Research Workflow

Figure 1 presents the research workflow adopted in this study. The experimental procedure consisted of experimental preparation, fuel replacement, engine warm-up, emission testing, data collection, and data presentation. During the preparation stage, the motorcycle, measuring instruments, and test fuels were prepared prior to testing. The motorcycle was inspected to ensure that the combustion system, fuel system, and exhaust system were in proper operating condition, while engine adjustments were performed according to the manufacturer's specifications. A gas analyzer was calibrated before each measurement to ensure data accuracy. The independent variable in this study was the fuel type, consisting of Pertalite (RON 90), Pertamax (RON 92), and Pertamax Turbo (RON 98), whereas the dependent variables were carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2).

Following the preparation stage, the remaining fuel in the fuel tank and carburetor was completely drained before introducing the selected test fuel to prevent cross-contamination among fuel types. The engine was then operated until it reached its normal operating temperature before exhaust emission measurements were conducted using a calibrated gas analyzer at engine speeds of 2,000 rpm, 4,000 rpm, and 6,000 rpm. The concentrations of carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) were recorded for each fuel type. Each fuel was tested three times at each engine speed, and all measurement results were documented to ensure the consistency and reliability of the experimental data.

The research results were organized according to fuel type and engine speed, and the data from the three repetitions were presented in tabular form. The emission characteristics of each fuel were subsequently compared using line charts to illustrate the trends of CO, HC, and CO_2 emissions under different engine operating conditions. The graphical and tabulated data were then interpreted to evaluate the effect of fuel type on the exhaust emission characteristics of the Yamaha Jupiter Z motorcycle.

RESULTS

This section presents the experimental results obtained from the exhaust emission measurements of the Yamaha Jupiter Z motorcycle using three different gasoline fuels, namely Pertalite, Pertamax, and Pertamax Turbo. The measured emission parameters include carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2). The results are summarized in tables and figures to facilitate comparison among the tested fuel types under the selected engine operating conditions.

Carbon Monoxide (CO) Emissions

Carbon monoxide (CO) is one of the primary indicators of combustion quality in spark-ignition engines. Lower CO emissions generally indicate a more complete combustion process due to a more efficient oxidation of carbon during fuel combustion.

Table 1. Measurement Results of Carbon Monoxide for Various Fuel Types and Engine Speeds

Fuel Types	2000 RPM	4000 RPM	6000 RPM
Pertalite	2,13%	2,13%	1,99%
Pertamax	2,45%	2,09%	1,60%
Pertamax Turbo	1,90%	1,70%	1,96%

Table 1 shows that CO emissions varied with fuel type and engine speed. At 2,000 rpm and 4,000 rpm, Pertamax Turbo produced the lowest CO emissions, while Pertamax recorded the highest values. At 6,000 rpm, Pertamax exhibited the lowest CO emission, followed by Pertamax Turbo and Pertalite.

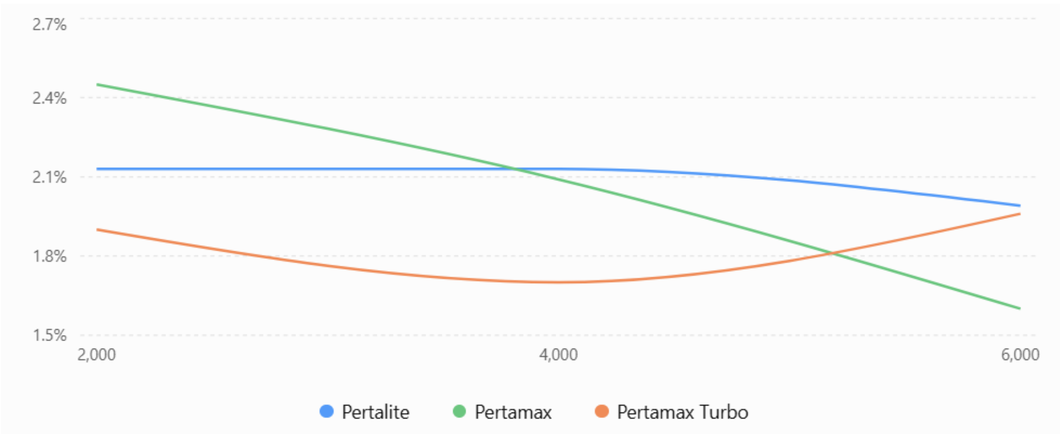

Figure 2. Comparison of CO emissions for different fuel types

Figure 2 illustrates the CO emission trends across the tested engine speeds. Pertalite showed relatively stable emissions before slightly decreasing at 6,000 rpm. Pertamax exhibited a continuous decrease as engine speed increased, whereas Pertamax Turbo decreased from 2,000 rpm to 4,000 rpm before increasing slightly at 6,000 rpm.

Hydrocarbon (HC) Emissions

Hydrocarbon (HC) emissions measured during the experiment are summarized in Table 2 for each fuel type at engine speeds of 2,000 rpm 4,000 rpm, and 6000 rpm.

Table 2. Measurement Results of Hydrocarbon for Various Fuel Types and Engine Speeds

Fuel Types	2000 RPM	4000 RPM	6000 RPM
Pertalite	1060 PPM	477 PPM	1480 PPM
Pertamax	1479 PPM	563 PPM	418 PPM
Pertamax Turbo	1012 PPM	1619 PPM	1398 PPM

Table 2 shows that HC emissions varied with fuel type and engine speed. At 2,000 rpm, Pertamax Turbo produced the lowest HC emission of 1012 ppm, while Pertamax recorded the highest value of 1479 ppm. At 4,000 rpm, the lowest HC emission was observed for Pertalite at 477 ppm, whereas Pertamax Turbo produced the highest emission of 1619 ppm. At 6,000 rpm, Pertamax generated the lowest HC emission at 418 ppm, followed by Pertamax Turbo at 1398 ppm and Pertalite at 1480 ppm.

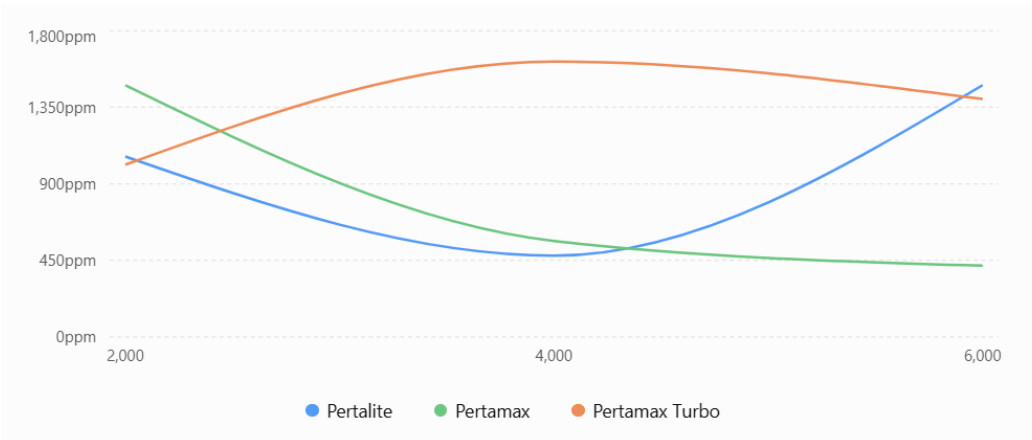

Figure 3. Comparison of HC emissions for different fuel types

Figure 3 illustrates the HC emission trends for the tested fuels at different engine speeds. Pertamax showed a continuous decrease in HC emissions, while Pertalite and Pertamax Turbo exhibited fluctuating emission trends as engine speed increased.

Carbon Dioxide (CO_2) Emissions

Table 3 presents the average carbon dioxide (CO_2) emissions produced by the Yamaha Jupiter Z motorcycle using Pertalite, Pertamax, and Pertamax Turbo at engine speeds of 2,000 rpm, 4,000 rpm, and 6,000 rpm.

Table 3. Measurement Results of Carbon Dioxide for Various Fuel Types and Engine Speeds

Fuel Types	**2000 RPM**	**4000 RPM**	**6000 RPM**
Pertalite	2,5%	2,5%	2,3%
Pertamax	2,6%	2,5%	2,8%
Pertamax Turbo	2,3%	1,8%	2,1%

As presented in Table 3, CO_2 emissions varied with fuel type and engine speed. At 2,000 rpm, Pertamax produced the highest CO_2 emission of 2.6%, while Pertamax Turbo recorded the lowest value of 2.3%. At 4,000 rpm, Pertalite and Pertamax produced the same CO_2 emission of 2.5%, whereas Pertamax Turbo remained the lowest at 1.8%. At 6,000 rpm, Pertamax recorded the highest CO_2 emission of 2.8%, followed by Pertalite at 2.3% and Pertamax Turbo at 2.1%.

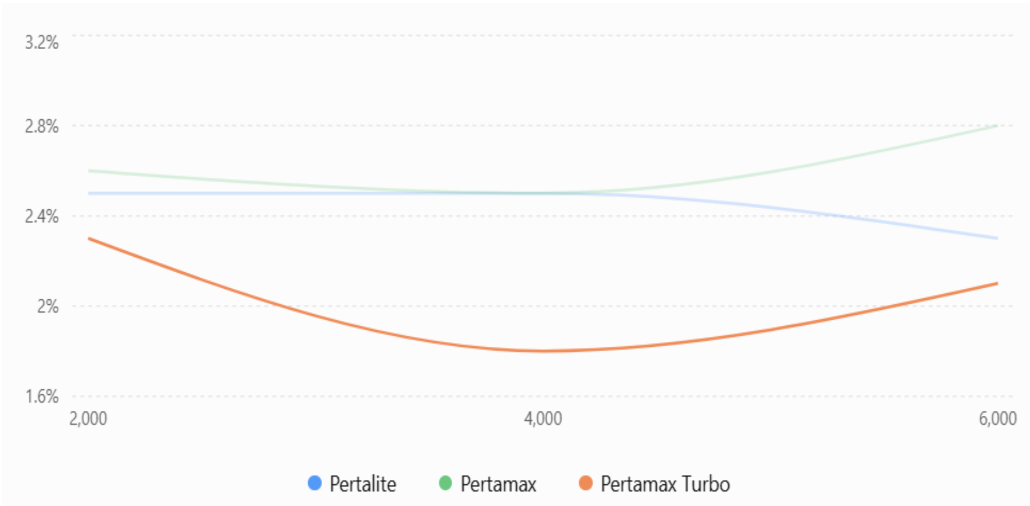

Figure 4. Comparison of CO_2 emissions for different fuel types

Figure 4 shows the CO_2 emission trends across the tested engine speeds. Pertamax exhibited a slight decrease followed by an increase, while Pertalite remained relatively stable before decreasing at 6,000 rpm. In contrast, Pertamax Turbo decreased at 4,000 rpm and increased slightly at 6,000 rpm.

DISCUSSION

The experimental results demonstrate that fuel type influenced the exhaust emission characteristics of the Yamaha Jupiter Z motorcycle, although the magnitude of its effect varied among the measured emission parameters. The differences observed in carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) emissions indicate that combustion characteristics were affected by fuel properties, particularly the Research Octane Number (RON). Fuels with higher octane ratings generally provide greater resistance to knocking, allowing combustion to occur more smoothly and efficiently.

However, the influence of octane rating also depends on engine operating conditions, especially engine speed and combustion characteristics. Winoko and Firmansyah (2021) reported that variations in fuel octane number and engine speed significantly affected HC and CO_2 emissions, indicating that the effect of fuel properties is closely related to engine operating conditions. Likewise, Wibowo et al. (2020) explained that fuel characteristics influence combustion efficiency and consequently affect the formation of CO, HC, and CO_2 emissions in spark-ignition engines.

The present findings are generally consistent with previous studies reporting that fuels with higher octane ratings tend to improve combustion quality and reduce incomplete combustion products. Dani et al. (2024) reported that Pertamax Turbo generally produced lower CO and HC emissions than lower-octane gasoline under several engine operating conditions. Similarly, Sanusi et al. (2019) found that Pertamax Turbo generated lower CO and HC emissions than conventional gasoline when tested on a Yamaha Vixion motorcycle. Susanto et al. (2019) also reported that using fuel according to engine specifications reduced CO and HC emissions, whereas lower-octane fuels tended to increase incomplete combustion products. These findings support the present study, where differences in fuel type produced different exhaust emission characteristics under the same experimental conditions.

Although higher-octane fuels generally exhibited lower CO emissions, the HC results did not show a consistent trend across all engine speeds. This finding suggests that hydrocarbon emissions are influenced not only by fuel octane rating but also by combustion stability, air-fuel mixture formation, flame propagation, and engine operating conditions. Pambudi et al. (2024) reported that an improper air-fuel mixture increases HC emissions due to incomplete combustion, while Komarulloh et al. (2024) demonstrated that engine speed strongly influences combustion quality and exhaust emission characteristics. Winoko and Firmansyah, (2021) likewise observed that changes in engine speed altered HC and CO_2 emissions even when higher-octane fuel mixtures were used, confirming that engine operating conditions play an important role alongside fuel properties.

The CO_2 emission results showed relatively small differences among the tested fuels. Carbon dioxide is the primary product of complete combustion; therefore, relatively stable CO_2 emissions indicate that combustion occurred under similar operating conditions. Wibowo et al. (2020) explained that combustion efficiency is influenced by fuel characteristics and engine operating conditions, resulting in different CO_2 emission levels depending on combustion completeness. Likewise, Winoko and Firmansyah, (2021) reported that CO_2 emissions varied with both fuel octane value and engine speed, supporting the observation that CO_2 formation is associated with combustion efficiency rather than fuel type alone.

Overall, this study confirms that fuel selection contributes to the exhaust emission characteristics of carbureted motorcycles. However, the findings also indicate that fuel octane rating alone does not determine exhaust emission characteristics, as combustion behavior is also influenced by engine operating conditions and fuel system characteristics. Since the Yamaha Jupiter Z used in this study employs a carburetor, differences in fuel atomization and air-fuel mixture formation may have contributed to the observed emission characteristics. Therefore, selecting fuel that matches the engine specifications, together with proper engine maintenance, can help improve combustion quality and reduce exhaust emissions. This conclusion is consistent with the findings of Susanto et al. (2019), who emphasized that fuel should be selected according to engine specifications to achieve optimal combustion performance and lower exhaust emissions.

CONCLUSIONS AND RECOMMENDATIONS

This research demonstrated that fuel type influences the exhaust emission characteristics of a Yamaha Jupiter Z motorcycle, particularly carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2). The results showed that exhaust emissions varied with fuel type and engine speed, indicating that combustion characteristics are influenced by both fuel properties and engine operating conditions. Therefore, selecting gasoline that matches engine specifications, together with proper engine maintenance, can help improve combustion quality and reduce exhaust emissions. These findings provide useful information for motorcycle users and serve as a reference for future studies on fuel characteristics and engine performance.

FURTHER STUDY

This study was limited to a single Yamaha Jupiter Z motorcycle equipped with a carburetor fuel system and evaluated only three commercially available gasoline fuels under engine speeds of 2,000 rpm, 4,000 rpm, and 6,000 rpm. In addition, the investigation focused only on carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) emissions. Therefore, future studies are recommended to include a wider range of engine operating conditions, different motorcycle models, electronic fuel injection (EFI) systems, and additional exhaust emission parameters such as nitrogen oxides (NO_x). Further investigations may also evaluate fuel consumption and engine performance to provide a more comprehensive understanding of the relationship between fuel characteristics, combustion efficiency, and exhaust emissions.

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