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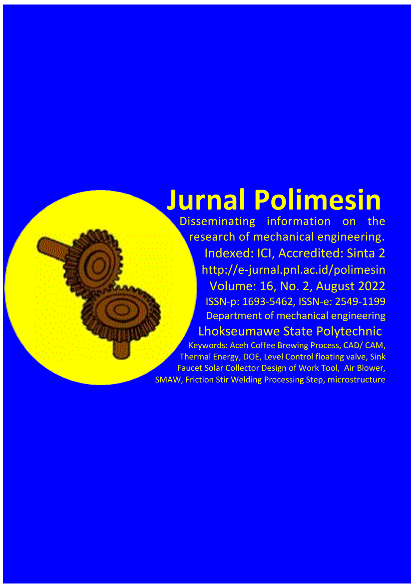

Announcements

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KEYWORDS

3D printing : Oil Treatment, Motor bensin, Viskositas, Aditif. : pure-polyester, rice-husk, sago-flour, crack-strength CAD/CAE Cooling Tower, Number of Holes, Temperature Difference, Heat Transfer Rate, Heat Transfer Coefficient. DOE Energy absorption, toughness, FSW, aluminum alloy, vehicle technology FDM FSW, rivet, FSSW, double rivet lap joint, AA 2024-T3 Gears, 3D printing, filament, tensile stress, acrylonitrile butadiene styrenee ITO poling Modeling, low alloy steel, algorithm, Artificial Neural Network (ANN), mechanical properties OPEFB composite, Finite element, ANSYS, Natural frequency, dynamic character Optimization, 3D printing, bending strength, printing time PVDF Solar Energy, System Advisor Model, Single Owner system, Grid, Local Electricity (PLN) Tobacco Leaves, refrigeration system, PLC, SCADA Turning CNC machine tools, geometric error, experimental study, ISO 13401-6. coconut fiber convergence, FEA, mesh, shaft, electric motorcycle mobility, singularity, workspace, 2(RRPaRR)-PRRR kinematic chains, and translational parallel manipulators.

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The influence of fuel type on motorcycle vehicle exhaust emission tests

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Abstract

A vehicle engine's performance can be determined through exhaust emission tests. Exhaust emissions contain air pollutants that result from incomplete fuel combustion in the vehicle's combustion chamber. This is usually due to improper oxygen and air mixture conditions. Gasoline (C_xH_y) burns and reacts with oxygen (O_2) to produce carbon dioxide (CO_2), water (H_2O), as well as non-toxic gases like nitrogen (N_2) and water vapor (H_2O (g)). However, it also generates toxic gases such as CO, HC, and Nitrogen Oxides (NO_x). Motorcycle exhaust emission tests are commonly conducted using a gas analyzer. In this study, a gas analyser was used to measure the amount of CO, CO_2, HC, O_2, and NO_x emitted from motorcycle exhausts. The tests were carried out using the Vario 160 ABS motorcycle with different types of fuel: RON 92 (S), RON 92 (P), RON 90, RON 98, and RON 92 (R). The data was collected at idle, as well as at 1600 rpm, 1800 rpm, and 2000 rpm. Three measurements were taken for each variable, and the average was calculated. The results showed that RON 98 fuel resulted in better combustion compared to RON 90 and RON 92, as indicated by the CO_2 content at idle, which was 13.95%. Additionally, when the motorcycle's engine was throttled, RON 98 fuel did not produce any NO_x. The study also revealed that RON 92 (S) fuel led to better combustion compared to both of RON 92 (P) and RON 92 (R), as evidenced by the CO content of 0.05%, CO_2 content of 13.63%, HC content of 204 ppm, O_2 content of 0.03%, and NO_x content of 4 ppm at idle.

Keywords:
Exhaust emissions, fuel, motorcycle vehicles, gas analyzer, combustion.

1 Introduction

Exhaust emission testing allows motorcyclists to gain a better understanding of their vehicle's performance. A vehicle with excellent performance is typically defined by its efficient fuel consumption and low levels of pollutant emissions. According to Hafiz Al Farisi [1], exhaust emissions are the residual particles of fuel combustion in the combustion chamber that are released through the engine's exhaust system. The incomplete fuel combustion of fuel leads to the release of exhaust emissions, which occur due to unfavorable oxygen and air mixture conditions. Gasoline (C_xH_y) combines with oxygen (O_2) to produce carbon dioxide (CO_2), water (H_2O), non-toxic gases like nitrogen (N_2), water vapor (H_2O (g)), and toxic gases such as CO, HC, and nitrogen oxides (NO_x). Several factors can contribute to incomplete combustion in motorcycle engines, including short burning durations, valve overlap, the presence of air that is not purely oxygen, impure fuel, and imperfect compression tightness.

Manufacturers in the automotive sector, especially motorcycle manufacturers, are faced with an interesting challenge: ensuring a seamless combustion process within the combustion chamber. As a result, Fuel Injection (FI) technology has been developed, utilizing sensors in the fuel intake to ensure that the fuel entering the combustion chamber is purer, thereby reducing exhaust emissions [2]. However, there are other factors that play a crucial role in facilitating the complete combustion process within the combustion chamber. For instance, the type of fuel used during combustion is a significant factor, as higher octane fuels can lead to greater compression in the vehicle. With increased compression, the fuel and air mixture becomes more uniform, resulting in improved motor vehicle exhaust emission test results. To illustrate, tests conducted using RON 92 (P) and RON 90 fuels demonstrate superior outcomes when RON 92 (P) is utilized for all the particulates tested. This assertion is further supported by research conducted by Prasetyo et al. [3], which showed that a higher RON will reduce CO and HC but increase CO_2, indicating that the mixture is more homogeneous.

Another crucial aspect of motorcycle exhaust emissions is engine speed which is usually divided into three categories: low revs (< 1000 rpm), medium revs (1000-2500 rpm), and high revs (> 2500 rpm). As the engine speed increases, the mixture of fuel and air becomes more homogeneous, leading to complete combustion and higher CO_2 emissions. Conversely, low engine speed predominantly produces a fuel-rich mixture, leading to increased HC emissions. This statement is supported by Prasetyo et al. [3]. Similar results were also obtained by Bhikuning et al. [4], [5], [6] and Zainulsjah et al. [7].

This study investigated the influence of fuel type (RON 90–RON 98) on motorcycle exhaust emissions at idle and moving (1600-2000 rpm) conditions.

2 Materials and Methods

According to Mishra et al. [8], research methods encompass all the techniques and methods utilized in conducting research. On the other hand, research methodology refers to the approach employed to systematically address research problems. In this study, an experimental method was adopted, involving the testing of motorized vehicles with various fuels and the measurement of exhaust emissions produced by each fuel.

2.1 Time and Place of Research

This research was conducted at *Kios Uji Emisi Minyung Motor Mobil*, located at Jl. Raya Wijaya Kusuma No. 6B RT18/RW7, Duren Sawit, East Jakarta. The research process, from the literature review to data collection was conducted from September to November 2023.

2.2 Research Variables

According to Soegiyono [9], research variables are the basic units of the information studied and interpreted, from which conclusions are drawn. The three variables are used in this study:

1. Independent variable: type of fuel (RON 92 (P), RON 90, RON 98, RON 92 (S), and RON 92 (R).
2. Dependent variable: exhaust emissions like Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxygen (O_2), Nitrogen Oxide (NO_x), and HC.
3. Controlled variable: the motorcycle used was a Honda Vario 160 ABS, using a Nanhua brand gas analyzer. Testing was performed when the motorcycle was idle and moving (1600 rpm, 1800 rpm, and 2000 rpm).

2.3 Research Flowchart

This research began by conducting a literature review and preparing research tools and materials. The researchers then checked that the tools were ready for use and inserted the fuel to be tested into the motorcycle. Next, data of exhaust emissions such as CO, CO_2, HC, NO_x and O_2 were collected. After that, the researcher processed and analyzed the results obtained. Then, the researcher discussed the research findings against previous literature and stated the conclusion of this research (Fig. 1).

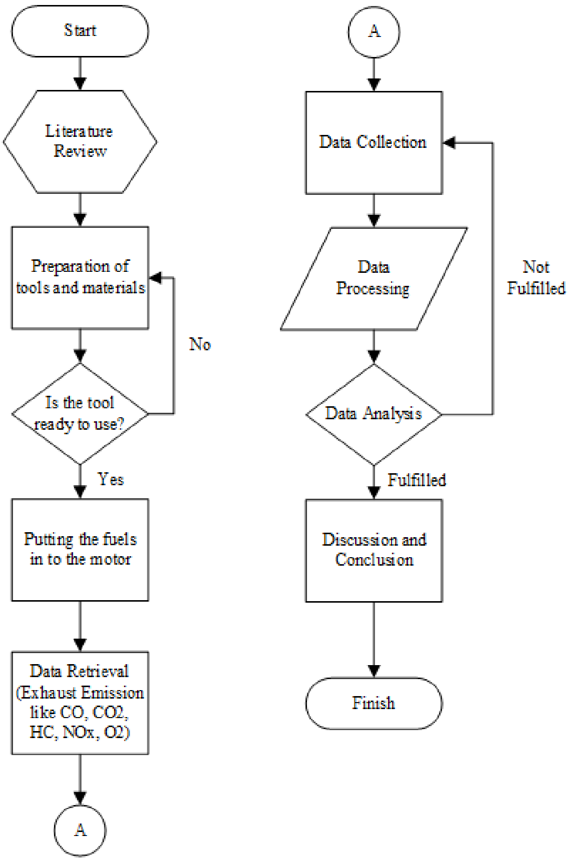

Fig. 1. Flowchart.

2.4 Research Tool Scheme and Specifications

This study primarily used the materials and tools:

1. Fuels
2. Motorcycle
3. Gas analyzer
4. Tachometer

2.4.1 Fuel Specifications

One of the research tools used in this study was the fuel filled into the motorcycle and tested for motor exhaust emissions. The procedure is shown in Fig. 2.

Fig. 2. Research tool scheme.

This research used five fuels: RON 92 (P), RON 90, RON 98, RON 92 (S), and RON 92 (R). Table 1 is the specifications of the fuels used.

Table 1. Comparison of fuel specifications

Specification	RON 90	RON 92 (P)	RON 92 (S)	RON 98
Octane number	90	92	92	98
Sulfur content (%m/m)	Max. 0.05	Max. 0.05	Max 0.05	Max. 0.005
Lead (Pb) content (mg/l)	Lead (Pb) injection is not permitted	0.013	0.013	Lead (Pb) injection is not permitted
Oxygen content (%m/m)	2.7	2.7	2.7	2.7
Specific gravity (@15°C)	715-770	715-770	715-775	715-770
Color	Green	Blue	Yellow	Red

2.4.2 Vehicle Specifications

The vehicle used in this study was a Honda Vario 160 ABS (Fig. 3). Table 2 is the specifications of the motorcycle used.

Fig. 3. The motorcycle used in this study (Honda Vario 160 ABS).

Table 2. Honda Vario 160 ABS specifications

Specification	Description
Engine type	4-stroke, 4-valve, eSP+
Cooling system	Cooling liquid
Ignition system	PGM-FI (programmed fuel injection)
Stroke volume	156.9 cc
Dimension	Ø60 × 55.5 mm
Compression	12 : 1
Max. power	11.3 kW (15.4 PS)
Max. torque	13.8 Nm (1.4 kgfm)
Transmission type	Automatic, V-type
Starter type	Electric
Clutch type	Automatic, centrifugal, dry
Lubricant type	Oil
Lubricant capacity	0.8 liter

2.4.3 Gas Analyzer Specifications

The emission tests conducted in this research used a calibrated gas analyzer from the Nanhua brand (Fig. 4). The specifications of the gas analyzer used are described in Table 3.

Fig. 4. Gas analyzer.

Table 3. Gas analyzer specification

Specification	Description
Merk	Nanhua
Type/model	NHA-506 EN
Serial number	A2001968
Voltage	220–240 V AC
Frequency	50/60 Hz
Power	60 VA
Fabricator	Nanhua instruments Co., Ltd

Table 4 describes what gases can be measured in this gas analyzer. The gas analyzer has been calibrated as shown in Fig. 5.

Table 4. Measurable gases in a gas analyzer

Gas	Measuring range	Accuracy
HC	0 – 2000 ppm	± 5% rel
	2001 – 9999 ppm	± 10% rel
CO	0 – 10%	± 5% rel
CO_2	0 – 20%	
O_2	0 – 25%	
NO	0 – 5000 ppm	± 4% rel

Fig. 5. Proof that the gas analyzer has been calibrated.

2.4.4 Tachometer

A tachometer is a device used to measure engine speed. The unit measured is revolution per minute (rpm). The specifications of the tachometer used in this study is shown in Fig. 6.

Fig. 6. Tachometer.

Table 5. Tachometer specification

Specification	Description
Dimension	73.5 × 46.7 × 10 mm

2.5 Data Collection

The steps were taken in this study's data collection process:

2.5.1 Motorcycle when Idle

The steps motorcycle when idle:

1. Prepare the tools and materials.
2. Insert one of the tested fuels into the motorcycle's fuel tank, and install the tachometer on the spark plug wire.
3. Turn on the motorcycle engine.
4. Set the motorcycle to the idle condition.
5. Attach the gas analyzer probe to the exhaust channel.
6. Record the first emission test result displayed on the gas analyzer.
7. Record the second and third emission test results.
8. Record and print the average of the exhaust emission test results.
9. Repeat steps 2-7 with the other 4 fuels.

2.5.2 Motorcycle at a High-Speed Condition (Throttled)

The steps motorcycle at a high-speed condition:

1. Fill the motorcycle's fuel tank with one of the tested fuels.
2. Turn on the motorcycle and slowly throttle it to show 1600 rpm on the installed tachometer.
3. Record the data point when the vehicle is at a stable condition and 1600 rpm.
4. Record the second data point when the exhaust gas emission test results are visible when the motorcycle is at 1600 rpm.
5. Obtain the average emission test results.
6. Print the emission test results.
7. Repeat steps 1-5 at engine speeds of 1800 rpm and 2000 rpm.

3 Results and Discussion

The types of data measurements recorded in this study as shown in Table 6.

Table. 6. Results

Gas	Results
Carbon Monoxide (CO)	Gas test results when the motorcycle is idle, 1600 rpm, 1800 rpm and 2000 rpm on 5 fuels.
Carbon Dioxide (CO_2)	Gas test results when the motorcycle is idle, 1600 rpm, 1800 rpm and 2000 rpm on 5 fuels.
HC Hydrocarbon (HC)	Gas test results when the motorcycle is idle, 1600 rpm, 1800 rpm and 2000 rpm on 5 fuels.
Oxygen (O_2)	Gas test results when the motorcycle is idle, 1600 rpm, 1800 rpm and 2000 rpm on 5 fuels.
Nitrogen Oxide (NO_x)	Gas test results when the motorcycle is idle, 1600 rpm, 1800 rpm and 2000 rpm on 5 fuels.

3.1 Carbon Monoxide (CO) Gas Test Results

3.1.1 Motorcycle when Idle

Data from CO gas emission test from when the motorcycle was idle are as shown in Table 7.

Table 7. CO gas emission test results

Fuels	Amount of CO gas
RON 92 (P)	0.76%
RON 92 (S)	0.05%
RON 92 (R)	0.83%
RON 98	0.29%
RON 90	0.17%

Fig. 7 is the results of the CO gas emission test when the motorcycle was idle.

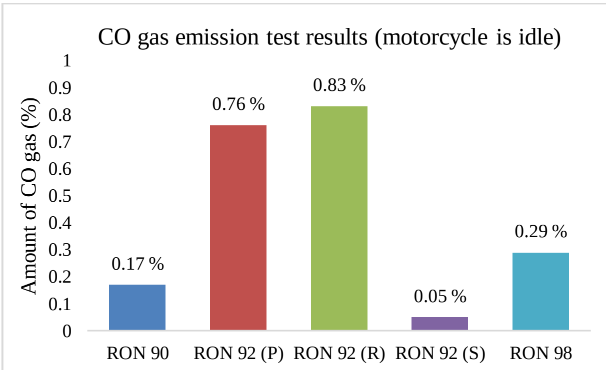

Fig. 7. CO gas emission test results.

Fig. 7 shows that the highest level of CO gas was observed when RON 92 (R) fuel was used at 0.83%, followed by RON 92 (P) at 0.76%, RON 98 at 0.29%, RON 90 at 0.17%, and RON 92 (S) at 0.05%.

The results show that RON 92 (S) fuel has the lowest CO content, suggesting that it is easier for the RON 92 (S) fuel to achieve a homogeneous mixture and achieve complete combustion.

Previous studies have found that the higher the octane number, the faster the mixture can be homogeneous. According to Prasetyo et al. [3] and Suryati et al. [10], complete combustion will result in a lower CO value. However, in this study, RON 92 (P) and RON 92 (R) fuel with octane number 92 and RON 98 with octane number 98 have a higher CO gas content value than RON 90 fuel with octane number 90. This result may be caused by the fuel being injected just before the combustion process, resulting in a fuel-rich mixture and incomplete combustion, thereby making CO.

3.1.2 Motorcycle at a High-Speed Condition (Throttled)

Data from the CO gas emission test from when the motorcycle was throttled are as shown in Table 8.

Table 8. CO gas emission test results

Fuels/engine speed	1600 rpm	1800 rpm	2000 rpm
RON 92 (P)	0.05%	10%	10%
RON 92 (S)	10%	10%	0.12%
RON 92 (R)	9.38%	10%	0.12%
RON 98	0.17%	10%	10%
RON 90	9.76%	10%	10%

Fig. 8 is the results of the CO gas emission test when the motorcycle was throttled.

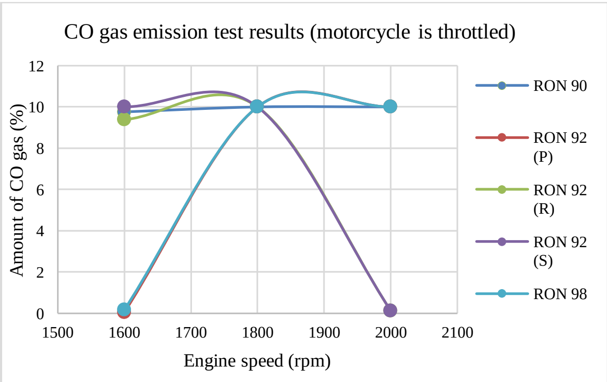

Fig. 8. CO gas emission test results from when the motorcycle was throttled.

Fig. 8 shows the CO gas emission test results from when the motorcycle was throttled at 1600 rpm, 1800 rpm and 2000 rpm using 5 fuels (RON 92 (P), RON 92 (S), RON 92 (R), RON 98 and RON 90).

The CO gas emissions from RON 92 (R) and RON 92 (S) indicate that as the engine speed increases, the CO gas emissions will decrease. This finding aligns with the theory and research conducted by Prasetyo et al. [3] and Suryati et al. [10], which found that as engine speed increases in an engine filled with RON 92 (P), CO gas levels will decrease. Conversely, based on Prasetiyo's research [11], the combustion of RON 92 (P) fuel mixture in engines at 1600-2000 rpm is still rich in fuel, resulting in incomplete combustion.

This study observed variations in the outcomes of emission tests for RON 92 (P), RON 98, and RON 90 fuels. This discrepancy may be attributed to the fuel-oxygen mixture remaining rich in fuel during the 1600-2000 rpm conditions, leading to incomplete combustion.

3.2 Carbon Dioxide (CO_2) Gas Test Results

3.2.1 Motorcycle when Idle

Carbon dioxide is a product of complete combustion. Table 9 are the CO_2 gas emission test results from when the motorcycle was idle.

Fig. 9 exhibits the CO_2 emission test results from 5 fuels. The highest CO_2 emission observed was from RON 98 (13.95%), followed by RON 90 (13.88%), RON 92 (S) (13.63%), RON 92 (P) (12.76%), and RON 92 (R) (11.94%).

Table 9. CO_2 gas emission test results

Fuels	Amount of CO_2 gas
RON 92 (P)	12.76%
RON 92 (S)	13.63%
RON 92 (R)	11.94%
RON 98	13.95%
RON 90	13.88%

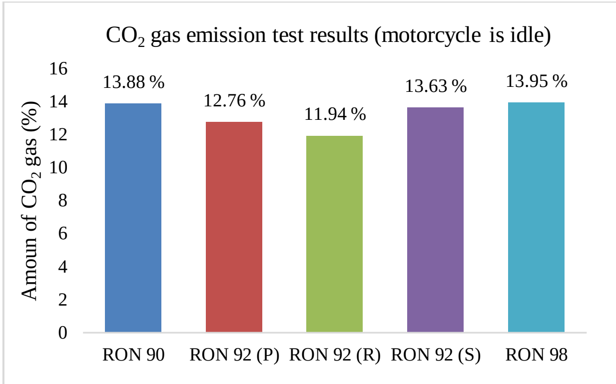

Fig. 9. CO_2 gas emission test results.

RON 98 fuel produced more CO_2 than RON 92 and RON 90 indicates that the RON 98 fuel achieves better combustion than the other tested fuels. Between the RON 92 fuels tested, RON 92 (S) had the highest CO_2 emission, followed by RON 92 (P) and RON 92 (R). This result may be because when the motorcycle is idle, RON 92 (S) fuel was able to produce a more homogeneous mixture than RON 92 (P) and RON 92 (R), resulting in complete combustion.

According to Prasetyo et al. [3] and Suryati et al. [6], a higher-octane number results in a more uniform mixture, leading to complete combustion and, consequently, higher CO_2 emissions. In this study, fuels with octane number 92 (RON 92 (S), RON 92 (P) and RON 92 (R)) had a lower CO_2 content than fuel with octane number 90 (RON 90). This result may be due to the octane number 92 fuel's inability to reach a homogeneous stage or fuel-rich mixture when the motorcycle was idle.

3.2.2 Motorcycle at a High-Speed Condition (Throttled)

Data from the CO_2 gas emission test from when the motorcycle was throttled are as shown in Table 10.

Table 10. CO_2 gas emission test results

Fuels/engine speed	1600 rpm	1800 rpm	2000 rpm
RON 92 (P)	14.72%	6.88%	6.81%
RON 92 (S)	6.34%	6.46%	13.79%
RON 92 (R)	5.94%	5.43%	5.97%
RON 98	14.35%	6.91%	6.37%
RON 90	5.89%	6.48%	6.69%

Fig. 10 is the results of the CO_2 gas emission test when the motorcycle was throttled.

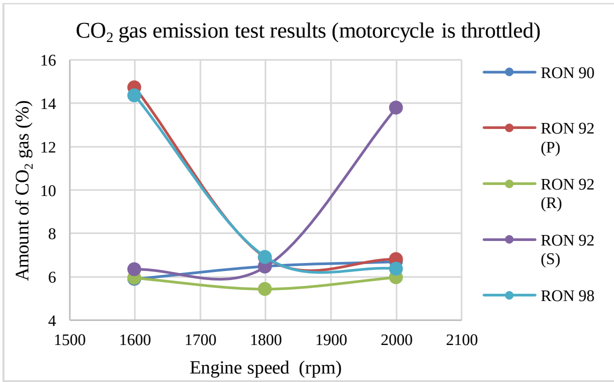

Fig. 10. CO_2 gas emission test results when the motorcycle was throttled.

Fig. 10 shows the CO_2 gas emission test results at 1600 rpm, 1800 rpm, and 2000 rpm with 5 fuels (RON 92 (P), RON 92 (S), RON 92 (R), RON 98 and RON 90).

There was a noticeable rise in the CO_2 emitted from RON 92 (S) and RON 92 (R) fuels as the engine speed rose. These findings align with research conducted by Prasetyo et al. [3] and Suryati et al. [10]. Conversely, when RON 92 (P) fuel was used, the CO_2 gas released decreased as the engine speed increased. This result is supported by Suhaldin et al. [12]. Such results may be caused by more fuel being pumped into the combustion chamber or less air entering the chamber when the engine increases speed, resulting in a fuel-rich mixture and incomplete combustion.

The test results regarding CO_2 content from 5 fuels with engine speeds of 1600-2000 rpm showed that 2 fuel types, RON 92 (P) and RON 98, emitted less CO_2 as the engine speed increased. These results are caused by more fuel being pumped to the combustion chamber at the time of higher rotation, but because the air valve moves faster, it was difficult to achieve a homogeneous mixture.

3.3 Hydrocarbon (HC) Gas Test Results

3.3.1 Motorcycle when Idle

Table 11 is the HC gas emission test results from when the motorcycle was idle.

Table 11. HC gas emission test results

Fuels	Amount of HC gas (ppm)
RON 92 (P)	1054
RON 92 (S)	204
RON 92 (R)	655
RON 98	376
RON 90	335

HC or hydrocarbon is a residual gas from incomplete combustion due to the fuel's failure to mix with air. Fig. 11 shows the results of the HC emission tests with 5 fuels. The highest result HC emission was from RON 92 (P) (1054 ppm), followed by RON 92 (R) (655 ppm), RON 98 (376 ppm), RON 90 (335 ppm), and RON 92 (S) (204 ppm).

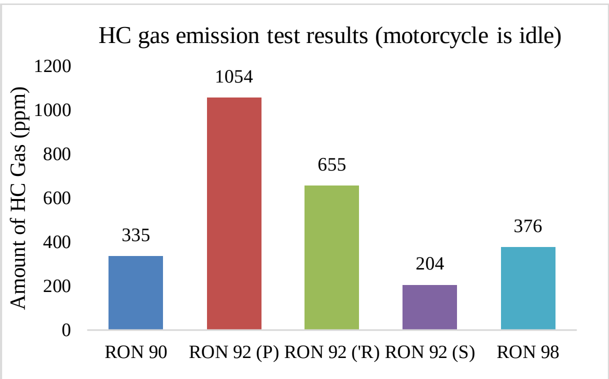

Fig. 11. HC gas emission test results.

This study found that RON 92 (P) and RON 92 (R) released more HC than the other tested fuels. This result may be caused by the fuel-rich mixture in the combustion chamber, resulting in incomplete combustion.

The results also showed that the HC value of RON 98 fuel surpasses that of RON 92 (S). This finding is unusual, as fuel with a higher octane number would typically obtain a uniform mixture. Nevertheless, this result may be caused by more fuel being pumped into the combustion chamber, resulting in a fuel-rich mixture and producing HC.

3.3.2 Motorcycle at a High-Speed Condition (Throttled)

Data from the HC gas emission test when the motorcycle was throttled are as shown in Table 12.

Table 12. HC gas emission test results (in ppm)

Fuels/engine speed	1600 rpm	1800 rpm	2000 rpm
RON 92 (P)	95	1791	1289
RON 92 (S)	2558	1644	59
RON 92 (R)	1895	1660	1638
RON 98	172	1530	1625
RON 90	1768	1576	1422

Fig. 12 is the results of the HC gas emission test when the motorcycle was throttled.

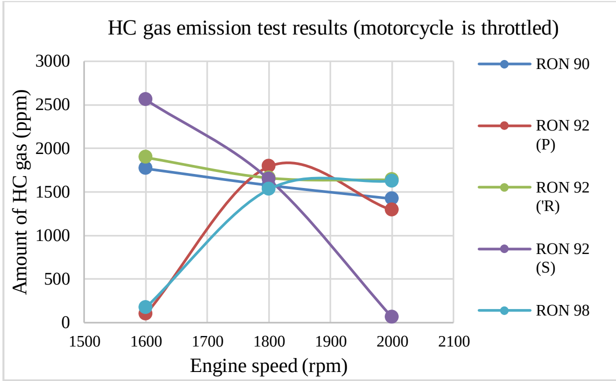

Fig. 12. HC gas emission test results when the motorcycle was throttled.

This study's results for the HC gas emitted from using RON 92 (P), RON 92 (S), and RON 92 (R) align with established theories and research as all three fuels demonstrated a decrease in HC gas levels as the engine speed increased. Additionally, Ningrat et al. [13] state increasing engine speed will reduce HC exhaust gas levels.

However, Fig. 12 shows that RON 98 fuel resulted in higher HC exhaust gas levels as the engine speed increased. This result may be due to the higher combustion chamber temperature as the engine speed increases, which results in the faster mixing of fuel with air and incomplete combustion.

3.4 Oxygen (O_2) Gas Test Results

3.4.1 Motorcycle when Idle

Data from the O_2 gas emission test when the motorcycle was idle are as shown in Table 13.

Table 13. O_2 gas emission test results

Fuels	Amount of O_2 gas
RON 92 (P)	4.72%
RON 92 (S)	0.03%
RON 92 (R)	0.03%
RON 98	0.02%
RON 90	0.02%

Oxygen or O_2 is a reactant in the combustion process. If O_2 can produce a homogeneous mixture with fuels, then the level of O_2 exhaust gas produced would be smaller [3], [12], [13]. Fig. 13 shows O_2 exhaust gas levels when using RON 92 (P) (4.72%), RON 92 (S) (0.03%), RON 92 (R) (0.03%), RON 98 (0.02%), and RON 90 (0.02%).

This study found that RON 92 (S), RON 92 (R), RON 98, and RON 90 obtained low O_2 gas content. Meanwhile, the O_2 exhaust gas level from using RON 92 (P) fuel was high, indicating that the mixture of this fuel with air failed to mix to produce a homogeneous mixture.

3.4.2 Motorcycle at a High-Speed Condition (Throttled)

Data from the O_2 gas emission test when the motorcycle was throttled are as shown in Table 14. Several previous studies [2], [3], [12] have shown that as the engine speed increases, the O_2 exhaust gas content will decreases. This phenomenon happens because O_2, as a reactant of the combustion process, mixes with fuel homogeneously and produces a fire in the combustion chamber.

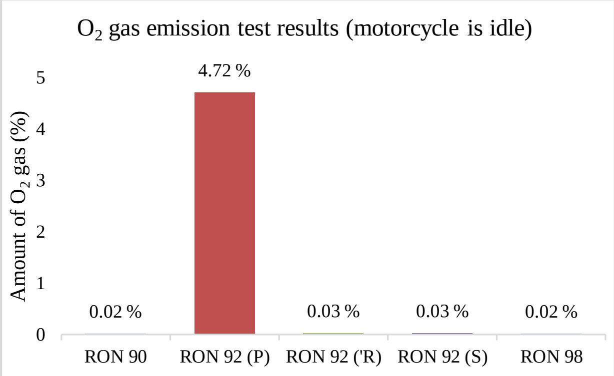

Fig. 13. O_2 gas emission test results.

Table 14. O_2 gas emission test results

Fuels/engine speed	1600 rpm	1800 rpm	2000 rpm
RON 92 (P)	0.59%	0%	12.67%
RON 92 (S)	0.03%	0.03%	0.04%
RON 92 (R)	0.03%	0.03%	0.03%
RON 98	0.03%	0.03%	0.02%
RON 90	0.02%	0.02%	0.02%

Fig. 14 shows that the O_2 exhaust gas content aligns with theoretical expectations when using RON 92 (S), RON 92 (R), RON 98, and RON 90 fuels. However, the use of RON 92 (P) fuel resulted in an unusual increase in O_2 exhaust gas levels with engine speed. This anomaly can be attributed to inadequate fuel and air mixing in the combustion chamber, leading to incomplete combustion and the presence of residual O_2.

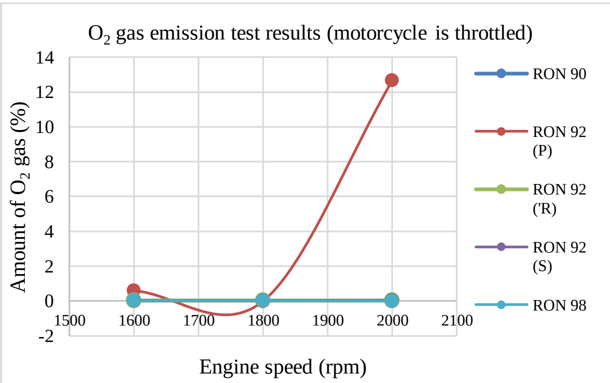

Fig. 14. O_2 gas emission test results when the motorcycle was throttled.

3.5 Nitrogen Oxides (NO_x) Gas Test Results

3.5.1 Motorcycle when Idle

Data from the NO_x gas emission test when the motorcycle was idle are as shown in Table 15.

Table 15. NO_x gas emission test results

Fuels	Amount of HC gas (ppm)
RON 92 (P)	24
RON 92 (S)	4
RON 92 (R)	42
RON 98	56
RON 90	72

NO_x gas consists of Nitrogen Monoxide (NO) and Nitrogen Dioxide (NO_2). NO_x gas is formed during fuel combustion with air because air contains 79% Nitrogen and 21% Oxygen. Fig. 15 shows the NO_x exhaust gas levels from using RON 90 (72 ppm), RON 98 (56 ppm), RON 92 (R) (42 ppm), RON 92 (P) (24 ppm), and RON 92 (S) (4 ppm).

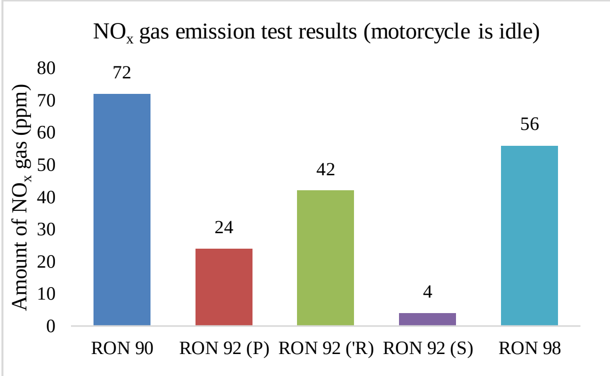

Fig. 15. NO_x gas emission test results.

The results show that fuels with an octane rating of 92 could produce a uniform mixture, which leads to complete combustion. On the contrary, fuels with octane ratings of 98 and 90 tend to produce higher levels of NO_x gas because they are unable to create a homogeneous blend of fuel and air.

3.5.2 Motorcycle at a High-Speed Condition (Throttled)

Data from the NO_x gas emission test when the motorcycle was throttled are as shown in Table 16.

Table 16. NO_x gas emission test results (in ppm)

Fuels/engine speed	1600 rpm	1800 rpm	2000 rpm
RON 92 (P)	42	61	31
RON 92 (S)	49	28	37
RON 92 (R)	12	11	17
RON 98	0	0	0
RON 90	39	0	0

Fig. 16 is the NO_x gas emission test results when the motorcycle was throttled.

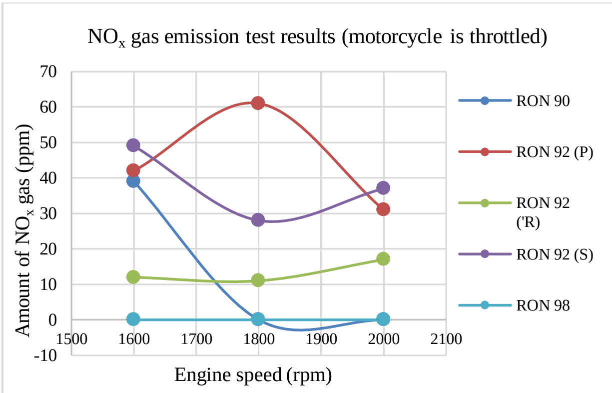

Fig. 16. NO_x gas emission test results when motorcycle is throttled.

Fig. 16 shows the results of NO_x gas emission tests at 1600 rpm, 1800 rpm and 2000 rpm with 5 fuels (RON 92 (P), RON 92 (S), RON 92 (R), RON 98, and RON 90). The results indicate that RON 92 (R) fuel has the highest NO_x exhaust gas content compared to other fuels with an octane number of 92. This finding suggests that using RON 92 (R) fuel in motorcycles can result in a uniform fuel-air mixture. Furthermore, RON 98 fuel emerges as the preferred choice due to its complete lack of NO_x exhaust emissions in this study.

4 Conclusion

The conclusions can be made from this research's results:

1. Based on the octane numbers (RON 90, RON 92, and RON 98), RON 98 was more likely to achieve complete combustion than RON 90 and RON 92. This is evidenced by the CO_2 content when the motorcycle was idle at 13.95%. Moreover, when the motorcycle was throttled, the engine filled with RON 98 did not produce NO_x at all.

2. Next, when comparing fuels with an octane number of 92, RON 92 (S) was found to be more likely to achieve complete combustion than RON 92 (P) and RON 92 (R). This is evidenced by the CO content being 0.05%, the CO_2 content being 13.63%, the HC content being 204 ppm, the O_2 content being 0.03% and the NO_x content being 4 ppm when the motorcycle was idle.

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