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The influence of electrolyzer addition to the 4-stroke modified injection system on fuel consumption and exhaust gas emissions in motorcycle engines

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Abstract

The demand for fuel is increasing along with the growth of the motor vehicle population, especially motorcycles. Currently, motorcycles rely on oil-based fuels, producing unhealthy exhaust emissions. One way to reduce fuel consumption and the resulting exhaust emissions is through the implementation of an electrolyzer. The electrolyzer is capable of saving fuel consumption and improving the engine combustion system. The objective of this research is to analyze the influence of adding an electrolyzer to the motorcycle fuel system on fuel consumption and exhaust gas. This study was conducted on a carbureted motorcycle that has been modified with injection. The results of fuel consumption and exhaust gas emission tests with electrolyzer treatment were compared with those without electrolyzer treatment. The results showed a decrease in fuel consumption at 2000 RPM by 31.36%, at 4000 RPM by 8.73%, and at 6000 RPM by 15.48%. In terms of exhaust gas emissions, CO decreased by 47.37%, CO_2 increased by 24.37%, and HC decreased by 45.11% at 2000 RPM. At 4000 RPM, CO decreased by 89.11%, CO_2 increased by 35.48%, and HC decreased by 36.98%. And at 6000 RPM, CO decreased by 41.67%, CO_2 increased by 17.26%, and HC decreased by 6.92%.

Keywords

Electrolyzer, injection system, fuel consumption, exhaust gas emissions

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Introduction

The increase in economic growth among the community has led to an increased desire for the ownership of motorcycles. According to a survey by the Central Statistics

Agency, the population of motorcycles in Indonesia continues to rise from year to year. In the West Sumatra province, in 2019, the motorcycle population was 1,979,526 units, increasing to 2,022,227 units in 2020. Similarly, in 2021, the motorcycle population continued to increase, reaching 2,188,305 units [1]. This will inevitably give rise to issues such as the increase in air pollutants due to vehicle exhaust emissions and the escalating demand for fuel. The rising use of fossil fuels in vehicles is sure to result in numerous environmental drawbacks [2]. Indeed, internal combustion engines using fossil fuels will consistently produce pollutant gases, especially CO, HC, and NOx. Additionally, this contributes to the depletion and scarcity of fossil fuels [3]. Therefore, there is a need for innovation regarding alternative fuels, one of which is the use of water as a fluid that can be applied in the vehicle combustion chamber. Currently, vehicles powered by fossil fuels can be replaced by HHO gas derived from water. Vehicles running on water-based fuel have been developed since the 19th century, with one of the most famous devices being the water fuel cell created by Stanley Meyer [4].

Vehicles fueled by water can provide a solution to fuel-related issues. However, the discovery of water as a fuel also has its drawbacks, namely, the need for a process of separating water molecules that requires a significant amount of electrical energy. By utilizing water as a supplementary fuel, it can be a solution to reduce exhaust gas emissions [5]. Discoveries in locally-made mini water fuel generators, such as the one developed by Aryanto Misel, have been researched and tested using motor vehicles, yielding positive results. This indicates the success of Aryanto Misel's mini water fuel generator [6]. Currently, HHO or brown gas has become a widely researched renewable energy alternative. The application of HHO in vehicles has the potential to reduce fuel consumption by 14% to 18%; however, obtaining it requires additional electrical energy input [7].

Continual improvements are being made to enable the widespread application of this water-based fuel in motor vehicles. Therefore, researchers actively contribute to seeking innovations for this water fuel. A study is conducted by researchers on a modified fuel-injected motorcycle using a wet cell electrolyzer treatment with a mixture of 500 ml of water and 5 grams of $NaHCO_3$ as the electrolyte. The use of an electrolyzer in fuel-injected modified motor vehicles is expected to contribute to complementing the findings previously achieved.

Electrolyzer

The electrolyte solution (0.5 liters of distilled water + 5 grams of $NaHCO_3$) in the electrolyzer tube will fill the entire electrolyzer cell space, and then an electrical voltage of 5.8 volts from the PWM controller is applied to the positive (anode) and negative (cathode) terminals on the electrolyzer tube. To prevent corrosion, an electrolyte with a catalyst content limited to 28% (by weight) is used [8]. By passing an electric current through the electrodes, the electrolysis process occurs, producing air bubbles. This is an indication of a reaction in the water, where oxygen (O_2) is generated at the anode, and hydrogen (H_2) is obtained from the cathode. These air bubbles are directed to a gas separator tube with water (water trap). In the water trap, separation occurs between water vapor and hydrogen gas using condensation techniques. Subsequently, the hydrogen gas is directed to an oxygen flowmeter, which also functions as a flashback arrestor for safety, and then continues to the intake manifold. The gas that has flowed into the intake manifold becomes homogenized with the air-fuel mixture. Figure 1 show the installation scheme of an electrolyzer on a motorcycle.

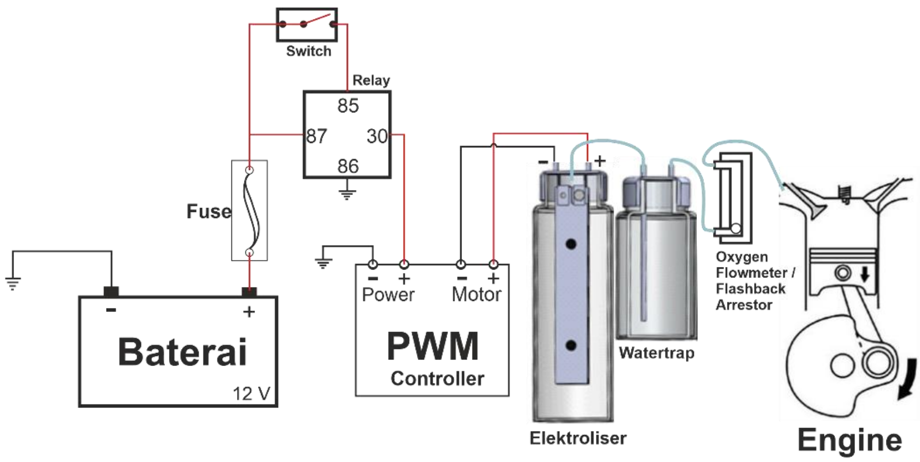


Figure 1. The installation scheme of an electrolyzer on a motorcycle

Methods

This study falls into the category of experimental research, commencing with the design and fabrication of equipment to be investigated. Subsequently, experiments were conducted with variations in engine revolutions per minute (rpm), including 2000 rpm, 4000 rpm, and 6000 rpm, and various types of experiments such as standard experiments and experiments without electrolyzer treatment. This experimental research involves testing one or two types of treatments [9]. The objective of this research is to determine the impact of adding an electrolyzer on fuel consumption and exhaust gas produced. The research design includes two groups, namely the experimental group and the control group, following the pattern outlined in Table 1.

Table 1. Research pattern

Group	Treatment	Experimental results	Description
R	X1	Y1	Without treatment (without using the electrolyzer tube)
R	X2	Y2	Treatment using the electrolyzer tube

Vehicle specification

The object of study to be investigated is a modified 4-stroke fuel-injected motorcycle, with specifications that can be seen in Table 2.

Table 2. Specifications of the Test Vehicle: Motorcycle

Item	Specification
Type	Vega 2010, 4-Stroke SOHC
Engine	113,7 cc Gasoline
Bore x Stroke	50 mm x 57,9 mm
Transmission	4-speed manual transmission
Maximum torque	8,3 Nm/4.500 rpm
Fuel system	Fuel Injection Modification

Fuel consumption testing

The fuel consumption experiment on the 4-stroke motorcycle with injection modification was conducted statically using testing equipment. This experiment began by determining the fuel consumption value without electrolyzer treatment, which served as the initial reference for comparison with the effects after the experiment with electrolyzer treatment.

Result and Discussion

After designing the electrolyzer tool, it is followed by its application on a modified fuel-injected motorcycle, as shown in Figure 2.

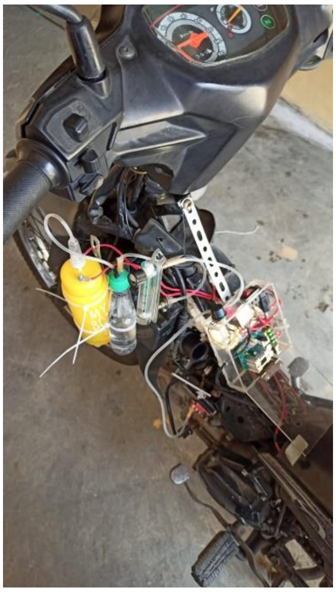


Figure 2. The application of the electrolyzer on a motorcycle

Research data results with and without electrolyzer treatment at various engine speeds, namely 2000 rpm, 4000 rpm, and 6000 rpm, are presented in Table 3. Based on the information in the table, the investigated electrolyzer was able to produce an average of 1.91 ml per second with a voltage of 5.80 volts.

Table 3. Results of measuring the production of HHO gas per second

Experiment	Voltage	Time (second)	Output Volume (ml)	Production (ml/s)
1	5.80	10	20	2
2	5.79	10	19	1.9
3	5.81	10	18.4	1.84
Average Flow Rate				1.91

Fuel consumption testing

The fuel consumption experiment on the 4-stroke motorcycle with injection modification begins by determining the fuel consumption value without the use of the electrolyzer, serving as the initial reference for comparison against the effects after experimenting with the electrolyzer treatment. This information is documented in Table 4, where variations in engine revolutions are conducted within a specified time of 60 seconds. The experiment is repeated twice, and the average values are calculated for comparison.

Table 4. Results of fuel consumption experiments without treatment

Without Electrolyzer Treatment						
No.	**Engine Revolutions (RPM)**	**Time (second)**	**Experiment**			**Average fuel consumption (ml/s)**
			I	**II**	**Average**	
1	2000	60	7.4	6.8	7.1	0.118
2	4000	60	7.2	8	7.6	0.126
3	6000	60	9.6	9	9.3	0.155

After applying the electrolyzer to the modified fuel-injected 4-stroke motorcycle fuel system, fuel consumption experiments were conducted with two trials. Subsequently, the average value of these two results was calculated, as shown in Table 5.

Table 5. Results of fuel consumption experiments with treatment

With Electrolyzer Treatment						
No.	**Engine Revolutions (RPM)**	**Time (second)**	**Experiment**			**Average fuel consumption (ml/s)**
			I	**II**	**Average**	
1	2000	60	4.2	5.6	4.9	0.081
2	4000	60	7.2	6.6	6.9	0.115
3	6000	60	8.6	7.2	7.9	0.131

Based on the experiment data in Table 4 and Table 5, there is a change in fuel consumption with the addition of an electrolyzer to the fuel system of the modified fuel-injected 4-stroke motorcycle, as seen in Table 6.

Table 6. Calculation of the average change in fuel consumption

No.	**Engine Revolutions (RPM)**	**Fuel Consumption (ml/s)**		**Fuel consumption difference (ml/s)**
		Withouth Electrolyzer	**With Electrolyzer**	
1	2000	0.118	0.081	0.037
2	4000	0.126	0.115	0.011
3	6000	0.155	0.131	0.024

According to the data calculation of the average fuel consumption change in Table 6, it can be explained in the form of a graph. The fuel consumption experiment can be seen in Figure 3.

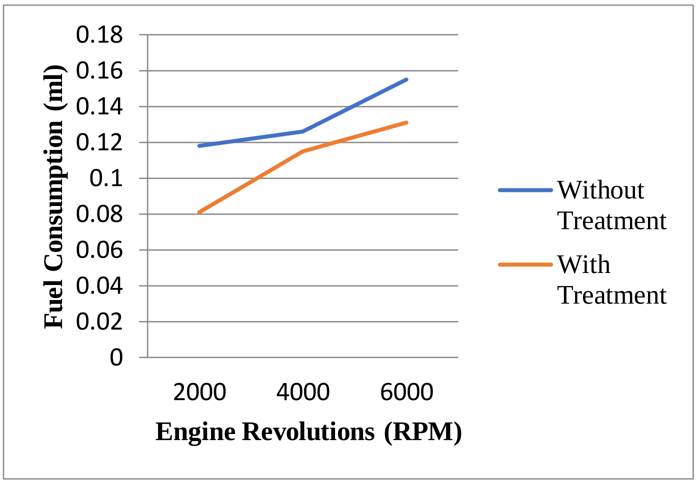


Figure 3. Graph of fuel consumption

From the graph in Figure 3, the experimental results and comparison between the addition of an electrolyzer and without an electrolyzer can be observed, showing better results with the addition of an electrolyzer. The best reduction in fuel consumption occurs at 2000 RPM, with a decrease in fuel usage of 0.037 ml/second. This is because the addition of HHO gas during combustion increases the octane value of the air-fuel mixture, leading to more efficient combustion. Hydrogen has a higher octane value compared to pertalite, with the octane value of hydrogen gas exceeding 130 [10].

Exhaust gas emission testing

This experiment was conducted with variations in engine revolutions and two trials to obtain average values that would serve as a reference for exhaust gas emission values with electrolyzer treatment. The values for CO, CO2, and HC were obtained as shown in Table 7 and Table 8.

Table 7. Results of exhaust gas emission experiments without treatment.

Without Electrolyzer Treatment										
No.	Engine Revolutions (RPM)	CO (%)			CO2 (%)			HC (ppm)		
		I	II	Average	I	II	Average	I	II	Average
1.	2000	6.14	6.78	6.46	8.1	7.9	8	176	243	209.5
2.	4000	5.01	5.09	5.05	9.4	9.2	9.3	115	116	115.5
3.	6000	4.44	4.45	4.44	9.9	9.8	9.85	208	240	224

Table 8. Results of exhaust gas emission experiments without treatment.

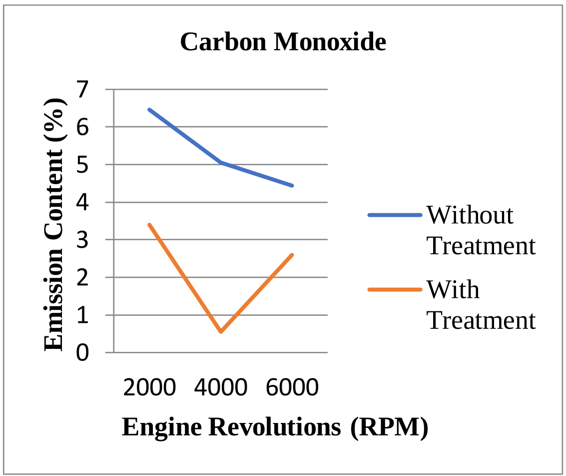
With Electrolyzer Treatment										
No.	Engine Revolutions (RPM)	CO (%)			CO2 (%)			HC (ppm)		
		I	II	Average	I	II	Average	I	II	Average
1.	2000	2.76	4.04	3.4	10.2	9.7	9.95	92	138	115
2.	4000	0.25	0.86	0.55	12.7	12.5	12.6	151	45	98
3.	6000	2.32	2.87	2.59	11.6	11.5	11.55	165	252	208.5

Based on the experimental data in Table 7 and Table 8, changes in the exhaust gas emission values can be observed in Table 9. The values of CO and HC show a decrease, but the CO2 value experiences an increase, indicating improved combustion.

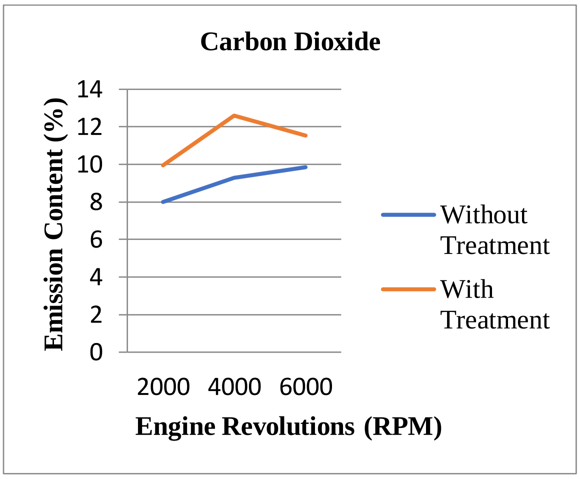
Table 9. Calculation of the average change in exhaust gas emission.

No	Engine Revolutions (RPM)	Exhaust Gas Emission								
		CO (%)			CO_2 (%)			HC (ppm)		
		Without Treatment	With Treatment	Difference	Without Treatment	With Treatment	Difference	Without Treatment	With Treatment	Difference
1	2000	6.46	3.4	3.06	8	9.95	-1.95	209.5	115	94.5
2	4000	5.05	0.55	4.5	9.3	12.6	-3.3	115.5	98	17.5
3	6000	4.44	2.59	1.85	9.85	11.55	-1.7	224	208.5	15.5

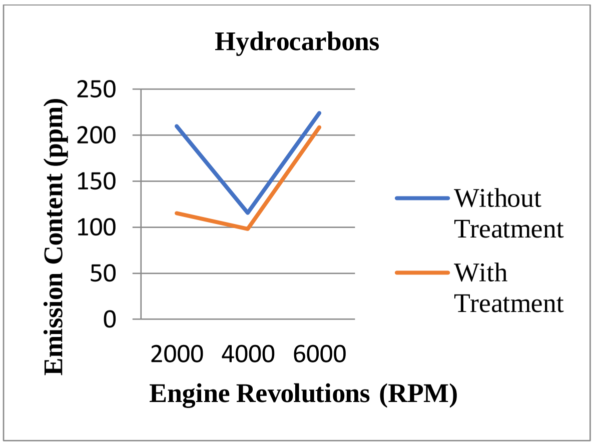
According to the data calculation of the average change in exhaust gas emissions in Table 9, it can be explained in the form of graphs in Figure 4.



(A)



(B)



(C)

Figure 4. Graph of exhaust gas emissions

From the graph, changes in exhaust gas emissions from the experiment and the comparison between the addition of an electrolyzer and no electrolyzer can be observed. For CO emissions (A), there is a decrease with the highest value occurring at 4000 RPM, amounting to 4.5%. Meanwhile, for CO_2 emissions (B), there is an increase with the highest value at 4000 RPM, reaching 3.3%. In the case of HC emissions (C), a decrease is observed with the highest value at 2000 RPM, amounting to 94.5 ppm. The concentration of CO_2 can be used as a reference to determine the combustion status in the combustion chamber. If the CO_2 value is higher, it can be concluded that the combustion is approaching perfection or improving. Ideally, CO_2 emissions should be in the range of 12% to 15%. If the CO_2 value is below 12%, attention should be paid to other emissions produced. It is important to note that the source of CO_2 is only from the combustion chamber. If the CO_2 produced is too low but CO and HC values are normal, it can be concluded that there is a leak in the exhaust pipe [11].

Conclusion

Based on fuel consumption, there is a decrease. At 2000 RPM, there is a decrease in fuel consumption by 31.36%, at 4000 RPM there is a decrease of 8.73%, and at 6000 RPM there is a decrease of 15.48%. Based on the exhaust gas emission experiment, there are changes in the produced exhaust gas. At 2000 RPM, there is a decrease in CO by 47.37%, an increase in CO_2 by 24.37%, and a decrease in HC by 45.11%. At 4000 RPM, there is a decrease in CO by 89.11%, an increase in CO_2 by 35.48%, and a decrease in HC by 15.15%. At 6000 RPM, there is a decrease in CO by 41.67%, an increase in CO_2 by 17.26%, and a decrease in HC by 6.92%.

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