Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 45 No. 3
March 2024

Motorcycle Fuel Enhancer

Raymar B. Diamante
FacultyIloilo Science and Technology University – Miagao CampusMiagao, Iloilo, Philippines

Abstract

This study aimed to design, fabricate, and evaluate a motorcycle fuel enhancer (MFE) with a functional and practical cooling design system and improved safety system. Additionally, this study focused on determining the differences in fuel consumption and particulate emission before and after using the MFE on 110-cc and 150-cc motorcycle engines. Moreover, the findings showed that using MFE can significantly reduce fuel consumption, lowering gasoline consumption and fuel expenses. It also exhibited a potential to lower the carbon emissions of 110-cc and 150-cc motors based on the results of emission tests conducted during the study.

Keywords:Motorcycle, Fuel Enhancer, Fuel Consumption, Particulate Emission, Cooling System, Hydrogen, Cathode, Anode, Hydroxy.

1. Introduction

Water and energy are indispensable to a country's social and economic development. The rising pressure on resource demands, new production, and consumption models requires a better understanding of the connections between water and energy. In a world of growing population and urbanization, cities are becoming the focus of international efforts for sustainability (Pasqual &Setegn, 2015).

Hydrogen, often in the form of Brown's gas or Hydroxy, helps technology to enhance fuel combustion of gasoline and diesel, which can range from 1 to 2%. This development can enhance ignition, and complete burning can increase power since carbon dioxide emission is not significantly reduced because engines are partially efficient. As a result, engines can be de-carbonized, become cleaner, be operated in slightly better condition, and increase fuel efficiency since less fuel is utilized to produce the same amount of power in the engine.

A car or motorcycle engine deemed ultra-simple has a very low efficiency known as “hotsabi", which produces approximately 0.40 litres of hydroxy gas per minute using ten amps of current. Another type of engine with medium efficiency, known as "Smack's Booster", produces 1.70 litres of hydroxy gas per minute using 20 amps of current. Lastly, a more recent model produced in the USA known as "Zach West Electrolyzer" was made for motorcycles. Zach's 250 cc motorcycle can run on the output of the electrolyzer, and Zach estimates the output to be 17 litres of hydroxy gas per minute (Kelly, 2004).

Issues and problems found in existing literature and designs led to the development of this MFE design. Existing designs utilize PVC pipe plastic as a material for fuel enhancers, which have low durability, i.e., are easily cracked or broken during contact with other motorcycles, and low functionality, i.e., are easily detached if placed on elevated surfaces.

2. Synthesis

Due to their non-decomposing properties, plastic pipes are not suitable for high-temperature applications because these conditions can reduce their strength. Heat can degrade the PVC pipes, reducing their lifespan and lowering their quality and resistance properties. Another limitation in the current designs for motorcycle fuel enhancers is the production of high amperes, which can reach up to twenty amperes, thus draining the motorcycle battery faster. This study was conceived because of the limitations above on the existing prior arts.

3. Research Significance

One of the main advantages of MFE compared to existing prior arts is its cooling design system, which consequently improves its safety. MFE features a design that allows the entry of cool air from the outside environment, which is made to pass through the reactor plates, thus cooling them down. This design allows the removal of hydrogen that clings to the plates and creates negative pressure inside the reactor. This enhancer also aims to raise the engine's efficiency by feeding the hydroxy gas as fuel compound into the engine's air intake and the air and gasoline mixture from the carburettor and gasoline fuel. This process can increase the engine's pulling power, making it run smoother and improving fuel consumption in all driving conditions. Moreover, the researcher is profoundly interested in utilizing readily accessible and local materials in the device's innovation and fabrication to produce a more durable yet less expensive fuel enhancer that is difficult to find in the current market.

4. Purpose of the Research

Generally, this study aimed to design, fabricate and evaluate a MFE. Specifically, it aims to:

1. Design and fabricate the MFE.

2. Determine the percentage (%) differences in motorcycle fuel consumption when tested without a MFE and with a MFE.

3. Determine the percentage (%) difference in particulate emissions in per cent (%) carbon monoxide of motorcycles when tested without a MFE and with a MFE.

5. Description of the Device

5.1 Design Criteria

The research study deals with the design and fabrication of a MFE whose design is based on improvements of the prior arts. The innovation taken from the ideas of existing prior arts and their identified advantages and problems were gathered, improved, and made into one device.

5.1.1 Electrical and Conveying System

The device is made up of an electrical system and a conveying system. The MFE is composed of fibreglass, rubber, stainless screw bolts with nuts, a water bubbler and water supply, a fan motor, electrolyzer cells and distilled water mixed with sodium hydroxide (NaOH) or potassium hydroxide (KOH). A safety component, including a reactor, flashback arrester and one-way valve water trap, is also created. The device's electrical system comprises a battery, a toggle switch, and an automotive electric wire. On the other hand, the device’s conveying system consists of gas outlets, PU hoses, nipple terminals and other accessories such as an air stone filter, T air control valve, I fitting and atmospheric outlet.

5.1.2 Device Construction

The MFE device was fabricated using a ½ cm thick transparent fibreglass material with 5/16 x 3 removable screw bolts and nuts for easy inspection and maintenance. The device's construction involved stacking eleven (11) 316-litre stainless plates that could cater for the standard, three of which are harmful, another three are positive, and the other five are neutral. These plates were arranged alternately, with one neutral plate placed between a negative and positive plate. A rubber gasket was also placed between the plates, which serves both as an insulator and a seal to contain the water inside the stack of plates, comprised of a dry cell. The 316-litre stainless steel plates that serve as the anode and cathode were made of a non-oxidizing and conductive metal that does not rust significantly and contaminate the solution or plates, thus affecting the temperature. These plates have 0.10 mm thickness (gauge). The rubber gasket placed between the plates as separation spacers was made of non-conductive material and was 0.30 mm thick.The modified tumbler served as a bubbler to filter and diffuse the hydrogen. The one-way valve water trap helps to filter the water that goes along with hydrogen, and the flashback arrester provides a safety mechanism in case a backfire occurs.

The hydrogen and oxygen, which are not stored separately, were made to pass through the following: (1) bubbler and water separator, (2) safety one-way valve, (3) flash arrester to avoid backfire explosion, (4) gas discharge outlet and lastly, (5) air-take area of the engine.

5.2 Limitations and Constraints

This study is limited to evaluating the MFE as adapted and tested in two types of motorcycle engine models, namely, 110-cc and 150-cc motors. The researcher used premium gasoline to compare the fuel consumption of the engines above with and without the MFE. In determining the fuel consumption, the fuel used was recorded before and after the engine had run for ten (10) minutes. The differences between the initial and final readings were recorded as the amount of fuel consumed. The observations were done in six (6) trials. Then, the motorcycle was subjected to three (3) emission particulate particle testing trials with and without the MFE to determine the percentage of carbon monoxide for both gasoline motorcycle units. All collected data, such as fuel consumption and particulate emission expressed as a percentage of carbon monoxide were recorded. The data gathered during the testing of each unit, with and without a Motorcycle Fuel Enhancer, were compared, and differences were noted to determine if MFE brought about any improvements during the said trials.

5.3 Design Preparation, Testing, and Revisions

The concept and the initial drawing of the device were first submitted to the Office of the Research Service, Division of Iloilo Science and Technology University for prior art research. Local materials available in the area were used to fabricate the device. The researcher carefully selected materials that could function continuously during the actual operation.

The device was constructed in La Paz, Iloilo City. The planning of the design for the MFE was first reviewed about the features of the latest prior art to identify and ensure that there is a possibility to develop or innovate some features in the existing one. The availability and sufficiency of the materials, tools, and equipment needed for the construction and completion of the device were ensured during the gathering, canvassing and procuring of the materials and equipment. The fabrication of the MFE was then conducted based on the design specified in the drawing plan. All units were also subjected to hydro-testing, wherein all the units were subjected to pressure to ensure no leaks in the device.

After completing the MFE, the Technical Evaluation was conducted with experts from different fields of specialization at Far East Scuba Institute, Iloilo City, in January 2019. The device's design demonstrated the usage and functions according to the proposed objectives, which the researcher explained during the technical evaluation. The proponent also conducted tests on motorcycles' fuel consumption and particulate emissions. The first test was done without an MFE, while the second one utilized the MFE. Both trials were done using gasoline fuel. The testing had six trials, and the average was obtained. Data were gathered to determine the percentage difference in fuel consumption and emission particulates to evaluate the MFE's design, fabrication, and efficiency.

The difference between the initial and final readings of the gasoline consumed by the engine motor in ten (10) minutes for every trial was recorded, and their mean differences (mL/10 minutes) were computed. The results were converted into litres per hour and multiplied by 12 to determine the daily gasoline saved. To determine the gasoline consumed per month, it was multiplied by 30. Finally, the approximate monthly savings using the MFE was also calculated by multiplying the monthly gasoline saved by the approximate price per litre (PhP 50.00/litre).

Figures 1, 2, 3, and 4 show the proposed design of a Motorcycle Fuel Enhancer in various views and with proper labels, while Figure 5 shows its electrical circuit system.

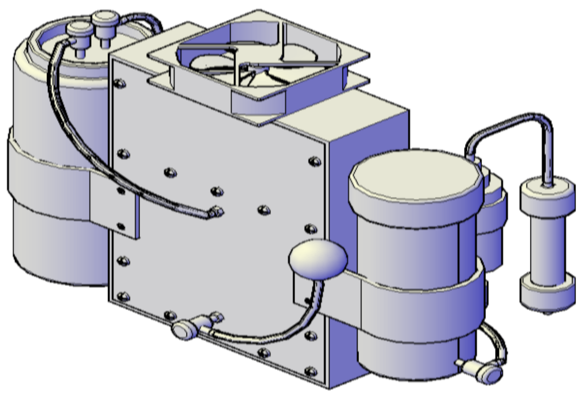

Figure 1.The Proposed Design of a Motorcycle Fuel Enhancer in Pictorial View.

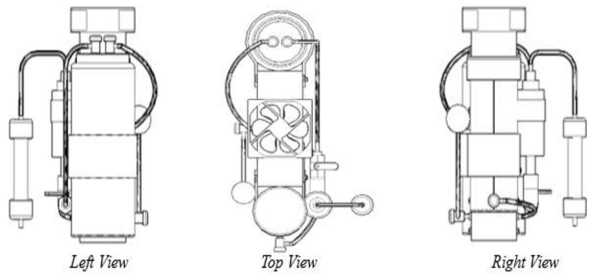

Figure 2. Orthographic Drawing of the Motorcycle Fuel Enhancer.

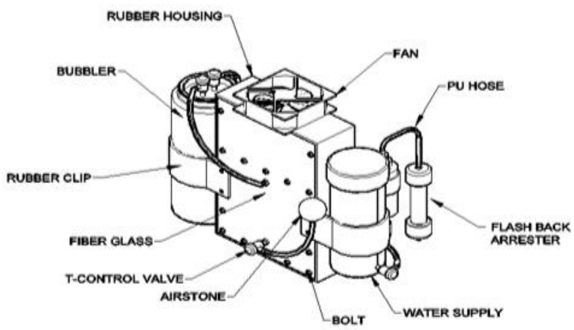

Figure 3.Front perspective view of Motorcycle Fuel Enhancer.

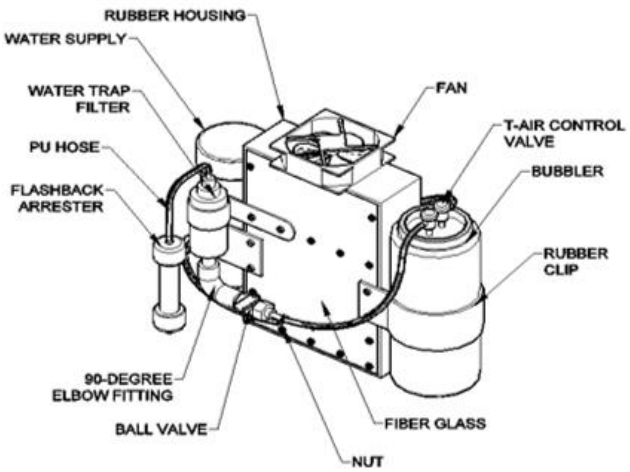

Figure 4.Back perspective view of Motorcycle Fuel Enhancer.

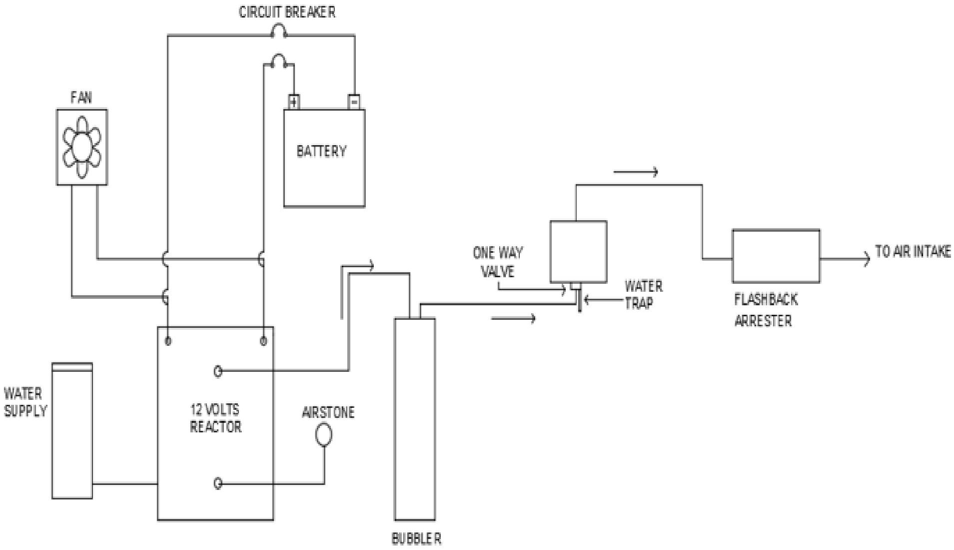

Figure 5. The electrical circuit system of the Motorcycle Fuel Enhancer.

6. Results and Discussions

6.1 Technology

The MFE is a motorcycle device that will raise the engine's efficiency by feeding hydroxy gas as fuel compound into the engine's air intake, along with the air and gasoline mixture from the carburettor and gasoline fuel. This efficiency will improve fuel-burning quality, increase engine pulling power, smoother operation, and fuel consumption in all driving conditions.

6.2 Brief Description of the Drawing

The following illustration shows a brief description of the parts of the Motorcycle Fuel Enhancer in order to give users a clear view.

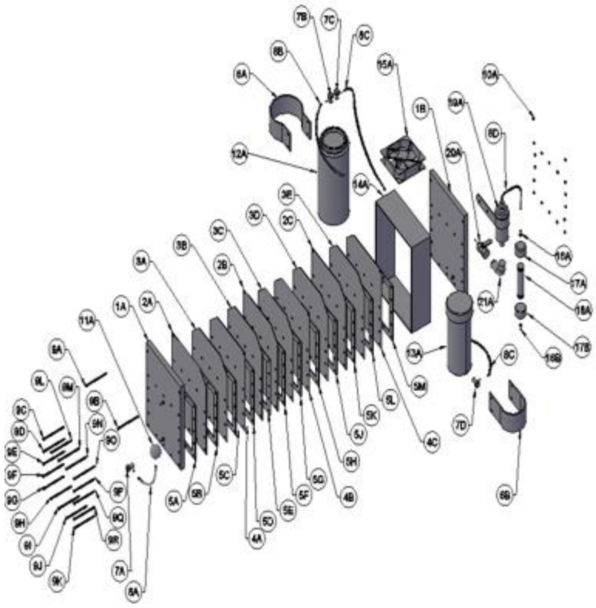

Figure 6.The exploded view of the Motorcycle Fuel Enhancer.

6.3 Detailed Description of the Technology

The function and usage of the MFE are further described and exemplified concerning the specific embodiments in the drawing.

The front cover fibreglass (1A) and back fibreglass (1B), covered and secured by the rubber and stainless plate, serve as the body of positive plates (2A), (2B), and (2C), which serve as the anode and negative plates (4A), (4B) and (4C) which serve as a cathode. Neutral plates (3A) to (3E) are found between an anode and cathode. The plate was insulated in between by a rubber gasket (5A) to (5M), which is sealed to contain the water inside the plates comprising a dry cell. The bolts and nuts (9C) to (9R) lock or bind both sides of the fibreglass (1A) and (1B), including both the rubber and stainless plates inside. The bolts and nuts (9A) bind all the positive/anode plates, and (9B) bind all the negative/cathode plates. The rubber housing (14A) covers all sides of the reactor to protect it against any contact from other materials, serves as a duct to the fan (15A), and pulls all the heat in the heat sink inside the reactor. When the air enters, the air stone (11A) filters the air intake by the hose (8A) connected to the T-control valve (7A), which controls the air flows going to the air cold intake by the reactor, thus helping the plates to cool down and the hydrogen that clings to the plates to be pushed out. The discharge output of the reactor is located in the hose (8B), which is attached and connected to the T-control valve (7B) and the bubbler (12A). The gas flow to the bubbler water separates the hydrogen from oxygen. After separation, the hydrogen goes out from the bubbler and flows to the T-control valve (7C). The rubber clip (6A) holds the bubbler (12A), which is attached to the reactor and locked by the bolts and nuts (9D) and (9E). The discharge of the T-control valve (7C), which is the hydrogen flow out in the hose (8C), is connected to the intake of ball valve control (20A), which is also connected to the elbow fitting (21A) and the intake of one-way valve water trap filter (19A), thus serving as one of the safety devices because of its one-way flow. It also traps and filters the exceeding water flow together with the hydrogen. The one-way valve water trap (19A) is attached to the reactor and locked by the bolts and nuts (9N) and (9O). The hose (8D) that comes from the discharge line of the one-way valve water trap (19A) is connected to intake I-fitting (16A) and to the threaded cup (17A) that is attached to a safety component of the device, which is the flashback arrester (18A), that can stop the fire explosion in the case of a backfire explosion accident. The second threaded cup (17B) is connected to the discharge outlet of the flashback arrester (18A). After the second threaded cup (17B), the I-Fitting (16B) is also connected, which serves as a discharge outlet of the flashback arrester going to the hose in which the hydrogen flows towards the motorcycle's air intake. The water supply reservoir (13A) supplies the water in the reactor when needed. The water supply reservoir (13A) is connected to a T-control valve (7D), which controls the water supply flow to the reactor. Water flows to the hose (8C), connected to the T-control valve (7D) outlet, which goes towards the reactor's intake.

Figure 6 reveals the description of the Motorcycle Fuel Enhancer. This device is dissimilar from the other prior arts, especially the need for cooling design systems in the existing prior arts. The device's claims include (1) cooling device system design and (2) improved device safety. Furthermore, the device can cool down the reactor plates by using incoming cool air from the outside area, which is then made to pass through all the plates. This technology removes hydrogen that clings to the plates and creates negative pressure inside the reactor. Moreover, the researcher is profoundly interested in utilizing readily accessible and local materials in the device's innovation and fabrication to produce a more durable yet less expensive fuel enhancer that is difficult to find in the current market.

6.4 Interpretation of the Data

To test the device's effectiveness, the researcher utilized a 110-cc and a 150-cc motor, both tested under the same conditions: (1) without load and (2) with load, for 10 minutes. In the experiment, the motor was supplied with gasoline fuel from a graduated cylinder through a hose connected to the engine. The amount of gasoline consumed by the motor within 10 minutes was computed as the difference between the initial Reading and final readings indicated in the graduated cylinder. For each trial, the researcher filled the graduated cylinder with 100 mL of gasoline, allowed the engine to run for 10 minutes, and recorded the final volume reading. The graduated cylinder was refilled to 100 mL before every trial. A total of 6 trials were done for each of the following set-ups: (a) 110 cc motor idling without device, (b) 110 cc motor idling with device, (c) 110 cc motor with load without device, (d) 110 cc motor with load with device, (e) 150 cc motor idling without device, (f) 150 cc motor idling with device, (g) 150 cc motor with load without device, (h) 150 cc motor with load with device. After gathering the needed data, the researcher determined the percentage of decrease in gasoline consumption of the motors without the gadget and with the gadget using the formula:

$$percentage\ of\ decrease = \frac{Initial\ reading - final\ reading}{initial\ reading} \text{x } 100\%$$

The results of the observation, as well as the percentage of decrease, are reflected in the following tables below.

Tables 1 and 2 show the fuel consumption in terms of the percentage of the 110-cc motorcycle without and with load, respectively.

Table 1. Fuel Consumption of the 110-cc Motorcycle (without load) in 10 minutes.

Trials	Without Gadget			With Gadget			% Diff in Consumption (savings)
	Initial Reading (ml)	Final Reading (ml)	% Consumed	Initial Reading (ml)	Final Reading (ml)	% Consumed	
1	100	75.00	25.00	100	78.00	22.00	3.00
2	100	76.00	24.00	100	81.00	19.00	5.00
3	100	75.00	25.00	100	82.00	18.00	7.00
4	100	77.00	23.00	100	80.00	20.00	3.00
5	100	78.00	22.00	100	79.00	21.00	1.00
6	100	74.00	26.00	100	79.00	21.00	5.00
Mean	100	75.83	24.17	100	79.83	20.17	4.00
SD	0.00	1.47	1.47	0.00	1.47	1.47	2.10

Table 2. Fuel Consumption of the 110-cc Motorcycle (with load) in 10 minutes.

Trials	Without Gadget			With Gadget			% Diff in Consumption (savings)
	Initial Reading (ml)	Final Reading (ml)	% Consumed	Initial Reading (ml)	Final Reading (ml)	% Consumed	
1	100	61.00	39.00	100	61.00	39.00	0.00
2	100	59.00	41.00	100	64.00	36.00	5.00
3	100	60.00	40.00	100	66.00	34.00	6.00
4	100	58.00	42.00	100	61.00	39.00	3.00
5	100	58.00	42.00	100	63.00	37.00	5.00
6	100	60.00	40.00	100	66.00	34.00	6.00
Mean	100	59.33	40.67	100	63.50	36.50	4.17
SD	0.00	1.21	1.21	0.00	2.26	2.26	2.32

Both tables show that 4% of fuel was saved during "without load" conditions when using the device, while 4.17% of fuel was saved during "with load" conditions. Table 1 shows that fuel consumption reached 24.17 mL without the device and decreased to 20.17 mL upon using MFE. The same trend was observed in Table 2, wherein the fuel consumption reached 40.67 mL without the device and decreased to 36.50 mL when using MFE. Both findings implied that the MFE could help consumers save fuel based on the reduced gasoline consumption within 10 minutes before and after the device was used.

Tables 3 and 4 show the fuel consumption of 150-cc motorcycles without and with load, respectively.

Table 3. Fuel Consumption of the 150-cc Motorcycle (without load) in 10 minutes.

Trials	Without Gadget			With Gadget			% Diff in Consumption (savings)
	Initial Reading (ml)	Final Reading (ml)	% Consumed	Initial Reading (ml)	Final Reading (ml)	% Consumed	
1	100	59.00	41.00	100	61.00	39.00	2.00
2	100	60.00	40.00	100	60.00	40.00	0.00
3	100	61.00	39.00	100	62.00	38.00	1.00
4	100	58.00	42.00	100	61.00	39.00	3.00
5	100	60.00	40.00	100	61.00	39.00	1.00
6	100	59.00	41.00	100	60.00	40.00	1.00
Mean	100	59.50	40.50	100	60.83	39.17	1.33
SD	0.00	1.05	1.05	0.00	0.75	0.75	1.03

Table 4. Fuel Consumption of the 150-cc Motorcycle (with load) in 10 minutes.

Trials	Without Gadget			With Gadget			% Diff in Consumption (savings)
	Initial Reading (ml)	Final Reading (ml)	% Consumed	Initial Reading (ml)	Final Reading (ml)	% Consumed	
1	100	37.00	63.00	100	40.00	60.00	3.00
2	100	38.00	62.00	100	38.00	62.00	0.00
3	100	36.00	64.00	100	38.00	62.00	2.00
4	100	37.00	63.00	100	39.00	61.00	2.00
5	100	39.00	61.00	100	40.00	60.00	1.00
6	100	36.00	64.00	100	38.00	62.00	2.00
Mean	100	37.17	62.83	100	38.83	61.17	1.67
SD	0.00	1.17	1.17	0.00	0.98	0.98	1.03

Both tables show that 1.33% of fuel was saved during "without load" conditions when using the device, while 1.67% of fuel was saved during "with load" conditions. Table 3 shows that without the device, fuel consumption reached 40.50 mL, decreasing to 39.17 mL upon using MFE. The same trend was observed in Table 4, wherein the fuel consumption reached 62.83 mL without the device and decreased to 61.17 mL upon using MFE. Both findings implied that the MFE could help consumers save fuel based on the reduced gasoline consumption within 10 minutes before and after the device was used.

The per cent (%) savings per hour for each set-up were then calculated and shown in Table 5. Based on the results, usage of MFE can help a motorist save about 25% and 9.96% of fuel in an hour when using a 110-cc and 150-cc motor, respectively, with load. This usage shows that MFE was able to reduce fuel consumption significantly.

Table 5. Fuel Consumption and Fuel Savings of the Motors (without and with load).

Motor	Fuel Consumption in %		Fuel Savings in % (with the gadget)	
	Without gadget	With gadget	In 10 minutes	In 1 hour
110 cc Motor (Idling)	24.17	20.17	4.00	24.00
110 cc Motor w/load	40.67	36.50	4.17	25.00
150 cc Motor (Idling)	40.50	39.17	1.33	7.98
150 cc Motor w/load	62.83	61.17	1.66	9.96

Tables 6 and 7 show the emission test results regarding the percentage of carbon monoxide of the 110-cc and 150-cc motorcycles, respectively, without and with the load.

Table 6. Emission Test Results of 110-cc Motorcycle in terms of % carbon monoxide.

110-cc Motor	% Carbon monoxide (CO)	
Trial	Without Gadget	With Gadget
1	0.15	0.20
2	0.04	0.04
3	0.13	0.04
Mean	0.11	0.09
SD	0.06	0.09

Table 7. Emission Test Results of 150-cc Motorcycle in terms of % carbon monoxide.

150-cc Motor	% Carbon monoxide (CO)	
Trial	Without Gadget	With Gadget
1	2.02	1.29
2	2.41	1.61
3	1.64	0.21
Mean	2.02	1.04
SD	0.39	0.73

Tables 6 and 7 show a decrease in carbon emission exhibited by a reduction of % carbon monoxide released by both the 110-cc and 150-cc motors using MFE. A difference of 0.02% and 0.98% in the 110-cc and 150-cc motors, respectively, were observed. These findings imply that the emission test results were significantly reduced using MFE.

7. Findings

The findings of the study are as follows:

- Based on the statistical analysis using the Mann-Whitney U Test at $\alpha = 0.05$, there is a significant difference in the fuel consumption of 110-cc and 150-cc motors before and after using the MFE. The same findings were observed throughout all the set-ups, namely, 110-cc motor without load ($p = 0.005$), 110-cc motor with load ($p = 0.015$), 150-cc motor without load (0.038), and 150-cc motor with load (0.033). These results show that fuel consumption was significantly reduced by using MFE.
- Based on the statistical analysis using One-sample T-Test at $\alpha = 0.05$, there is a significant difference between the carbon emitted by a 110-cc motor, both without and with MFE, compared to the standard value of 2.20%. A p-value of 0.00 and 0.001 were obtained, respectively. This result implies that

the carbon monoxide (CO) emitted by a 110-cc motor is significantly lower than the standard value.

- Based on the statistical analysis using One-sample T-Test at α = 0.05, there is no significant difference between the carbon emitted by a 150-cc motor, both without and with MFE, compared to the standard value of 2.20%. A p-value of 0.510 and 0.111 were obtained, respectively. This finding implies that the carbon monoxide (CO) emitted by a 150-cc motor is comparable to the standard value.

8. Conclusions

Based on the findings, the following conclusions were drawn:

- The design of the MFE exhibited a functional cooling design system and improved safety by allowing the entry of cool air from the outside environment, which is made to pass through the reactor plates, thus cooling them down and removing the hydrogen that clings to the plates.

- The MFE significantly raised engine efficiency. It helped increase the engine's pulling power, making it run smoother and improving its fuel consumption in all driving conditions.

- The usage of MFE can significantly reduce fuel consumption, thereby lowering gasoline consumption and expenses by up to 7.56 litres and PhP 378.00/month for a 110-cc motorcycle and up to 3.86 litres and PhP 179.28/month for a 150-cc motorcycle, based on a 12 hours per day usage with load and an average price of gasoline at P50/litre.

- Based on the results of the final evaluation of MFE by experts, the device is highly practicable. It could lower the carbon emissions of 110-cc and 150-cc motors based on the results of emission tests conducted during the study.

9. Recommendations

Given the findings and conclusions, the following are recommended:

- Process application for Product Certification from the Department of Science and Technology (DOST) and the Department of Trade and Industry (DTI).

- Process application for Product Patenting at the Philippines Patent Office for security and patent rights.

- Monitor the conditions of MFE and the engine through the monitoring gauges daily. Furthermore, observations must be recorded as monitoring sheets and personal interviews to make corrections and improvements in the design, if needed.

- Establish the standard amount of hydrogen added to the gasoline-air mixture according to motorcycle conditions.

- Continue conducting further research by referring to drivers, automotive mechanics and engineers, mechanical engineers and other experts in the field.

10. Acknowledgment

This study was conducted through the generous support and contributions of the following persons to whom the researcher gratefully acknowledges:

I sincerely thank Dr. Karlo S. Sira for his unwavering support and guidance throughout the publication. His expertise, insights, mentoring, coaching, and encouragement were invaluable in completing this work.

I also want to thank our colleagues at Iloilo Science and Technology University (ISAT U)-Intellectual Property Management Office and ISAT U Miagao Campus Research office for their helpful feedback and support. I am grateful for their contributions, which have enriched our research and made it more meaningful.

Finally, I would like to thank my family and friends for their love and support throughout the research process. Their encouragement and support have been a constant source of motivation for me, and I am grateful for their unwavering belief in me.

References

[1] Articulo, R. (2015). Hydraulic Swaging and Flaring Hand Tool. Unpublish MIT Thesis, Iloilo Science and Technology University, La Paz, City.

[2] Calderon, M.S.T. (2018). Multi-function Drafting Device. Unpublish DIT Dissertation, Iloilo Science and Technology University, La Paz, City.

[3] Castillano, M. (2017). Concrete Hollow Block Mixing Pan with Counter Flow Paddle. Unpublish DIT Dissertation, Iloilo Science and Technology University, La Paz, City.

[4] Chambers, S. B. (2002). Apparatus for producing orthohydrogen and parahydrogen (Xogen et al.).

[5] Confessor, J.A. (2016). Portable Manual Rebar Bender. Unpublish DIT Dissertation, Iloilo Science and Technology University, La Paz, City.

[6] Cubar, J. (2017). Hydraulic Break System Bleeding Apparatus. Unpublish DIT Dissertation, Iloilo Science and Technology University, La Paz, City.

[7] Gallego, C.D. (2018). Plasma Cutting Tracer JIG. Unpublish MIT Thesis, Iloilo Science and Technology University, La Paz, City.

[8] Gibilisco, S. (2013). Alternative energy demystified. Mcgraw-Hill.

[9] Haefner, R., & Leathers, P. (2008). Automotive technology for general service technicians (pp. 627–669). Thomson/ Delmar Learning.

[10] Hicks, T. G. (2006). Handbook of Mechanical Engineering Calculations, Second Edition (2nd ed.). McGraw Hill Professional.

[11] Hollembeak, B. (2006). Classroom Manual for Automotive Fuels and Emissions. Delmar Thomson Learning.

[12] Hosford, W. F. (2008). Materials for engineers (pp. 110–124). Cambridge University Pres.

[13] Kelly, P. J. (2004). A Practical Guide to Free-Energy Devices (pp. 101–135). Elsevier, Inc.

[14] Lindsay, A. H. (2007). Gas/liquid separator for hydrogen generating apparatus (BLUTIP POWER TECHNOLOGIES Ltd Patent).

[15] Meyer, S. A. (1990). Method for the production of a fuel gas (MEYER MARILYN Patent).

[16] Munshi, S., McTaggart-Cowan, G. P., Rogak, S. N., & Bushe, W. K. (2008). Method and apparatus of fuelling an internal combustion engine with hydrogen and methane (University of British Columbia Patent).

[17] Myer Kutz. (2015). Mechanical engineers' handbook (2nd ed.). John Wiley & Sons Inc.

[18] Parker, S. P. (2001). Grolier Concise Encyclopedia of Science and Technology (6th ed.). McGraw-Hill Book Company.

[19] Pasqual, J. C., &Setegn, S. G. (2015). The Importance of Water-Energy Nexus for Sustainable Development: A South America Perspective. Springer EBooks, 431–443. https://doi.org/10.1007/978-3-319-12194-9_23

[20] Pickerill, K. (2006). Automotive engine performance (4th ed., pp. 1–620). Delmar Cengage Learning.

[21] Serway, R. A., & Jewett, J. W. (2004). Physics for scientists and engineers with modern physics (pp. 971–973). Cengage.

[22] Sherman, A., & Sherman, S. (1989). Chemistry and Our Changing World (2nd ed.).

[23] Shimizu , M., Horii , Y., Morimoto , J., & Imao, R. (2006). Intake structure in fuel cell powered vehicles and motorcycles with fuel cell mounted thereon (Honda et al.).

[24] Speight, J. (2008). Synthetic Fuels Handbook. McGraw Hill Professional.

[25] Standard Educational Corporation. (2006). New standard encyclopedia. (Vol. 6). Standard Educational Corp.

[26] Yang, J. Y., & Hsu, Y.-S. (2003). Rapid coupling device for hydrogen storage canister (Asia Pacific Fuel Cell Technologies Ltd Patent).