Development of Hydrogen Gas Generator Prototype Model for Vehicle Fuel with Electrolysis Method

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Keywords: Generator, Hydrogen, Electrolysis, Emission.

Abstract: The problem of energy needs in Indonesia is a serious problem in human life. The increase in consumption of fossil fuels is not matched by the availability of natural resources, therefore alternative energy is needed to reduce dependence on fossil fuels. One alternative energy that has been found is the electrolysis of water to produce HHO gas. In this study, the model of a prototype hydrogen gas generator was developed using the electrolysis method. The HHO generator aims to reduce emissions in vehicle exhaust gases. From the results of the hydrogen gas generator development, it is found that the dimensions of the generator are length x width x height = 210 mm x 130 mm x 300 mm, using aluminium plate and polycarbonate mica as the cover. The electrolyte used is KOH with a percentage of 4%, the test results on the performance of the HHO generator show that exhaust gas emissions in vehicles will decrease compared to the use of fossil fuels with octane 90, a decrease in CO emission gas levels of 67% from 1.35% has decreased to 0.47% then the reduction in HC emission gas levels was 34% from 645.33 ppm, decreased to 422.66 ppm.

1 INTRODUCTION

The problem of energy needs in Indonesia is a serious problem in human life. Energy is an important component for human survival because almost all activities of human life are highly dependent on the availability of sufficient energy, national energy needs are still met by petroleum. Indonesia's oil reserves are predicted to remain at around 3.6 billion barrels. The reserves are estimated to be exhausted in the next 12 years (viva.co.id, September 2013). The cause of this problem is because petroleum is a non-renewable natural resource, so it takes hundreds of millions of years to get it back. In terms of controlling the sustainability of national energy, the Indonesian government also helps the use of energy composition by issuing Presidential Regulation no. 5 of 2006 concerning the Goals and Targets of the National Energy Policy states that the composition of energy types in Indonesia in 2025 is coal 33%, natural gas 30%, petroleum 20%, and renewable energy 17%. Included in this 17% are 5% biofuels, 5% geothermal, biomass, nuclear, hydro, solar and wind 5%, and 2% liquefied coal."

Hydrogen research and development continues to be developed very intensively to welcome the era of hydrogen-based energy which is predicted to be achieved in the decade of 2050. Research and development of energy in developed countries agrees that future energy must have the following characteristics (Crosbie, L. M., 2003):

1. Future energy technology must be developed, because energy demand will continue to increase
2. Future energy sources must be environmentally Friendly.
3. An effective distribution system must be able to be created, so that energy can really be widely affordable and improve people's living standards.
4. Must be safe both in terms of production, transportation, storage, and use.
5. Energy technology must be economical.

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Darmawa, I., Wiryanta, I. and Sutarna, I.
Development of Hydrogen Gas Generator Prototype Model for Vehicle Fuel with Electrolysis Method.
DOI: 10.5220/0010949400003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 581-586
ISBN: 978-989-758-615-6; ISSN: 2975-8246

6. As an energy carrier, hydrogen is quite promising and fulfills the characteristics of future energy.

Hydrogen is a chemical element on the periodic table that has the symbol H and atomic number 1. At standard temperature and pressure, Hydrogen is a colorless, odorless, non-metallic, single-valent, and a highly flammable diatomic gas. Hydrogen is the lightest element in the world. Most hydrogen exists in a compound state with other elements such as hydrocarbons and water. One way to produce Hydrogen is through the process of electrolysis with the help of electrical energy. Hydrogen gas is also known as HHO gas (Brown Gas).

Several previous studies on the development of hydrogen gas as an alternative fuel have been carried out. Study on hydrogen gas production using the PEM Water Electrolysis method has been conducted. The review discusses recent developments in PEM water electrolysis including the high performances low cost HER and OER electrocatalysts and the challenges associated with electrocatalysts and PEM cell components (Kumar, S. Shiva, 2019). Study on the effect of using a hydrogen gas mixture in internal combustion engines, both gasoline and diesel engines. Research shows that hydrogen gas mixtures can be easily used in internal combustion engines without the expense of modifying existing engine configurations (SR. Premkartikkumar, 2015). One form of innovation to improve energy efficiency in vehicles is to add or inject HHO (Brown gas) gas into the internal combustion engine. This HHO gas is produced from the electrolysis of water with the addition of a KOH catalyst. The addition of HHO gas in an internal combustion engine can improve the quality of combustion because this gas has a high calorific value and octane, hydrogen fuel is able to reduce NOx and HC gas emissions (R.F. Horng, 2008). The hydrogen-injected engine eliminates knock and backfiring. The effect of using hydrogen in a spark ignition (SI) engine can increase thermal efficiency by 14% and NOx emissions can be reduced by up to 95% (T. Suzuki, 2006). From previous research, it has been compared hydrogen injection in a spark ignition engine with a carburetor and an engine with an injection system. The result is that the fuel injection engine with the addition of hydrogen has greater power and less backfiring risk (S. Verhelst, 2005). Another research about hydrogen gas as a fuelfor combustion also done by Mujebuu, MA, 2016 and Chi, Jun, 2018. Both of them made a gas hydrogen by electrolyze water.

From this description, on this research will design and apply an electrolyser to produce sufficient HHO (Brown Gas) gas for motorcycles engines by making a prototype hydrogen gas generator which will later be used for environmentally friendly vehicle fuel.

2 RESEARCH METHODOLOGY

The development of hydrogen gas generator prototype model for vehicle fuel were divided into two sections. The first was creates a design of the HHO generator. The flowchart of the research are shown in Figure 1.

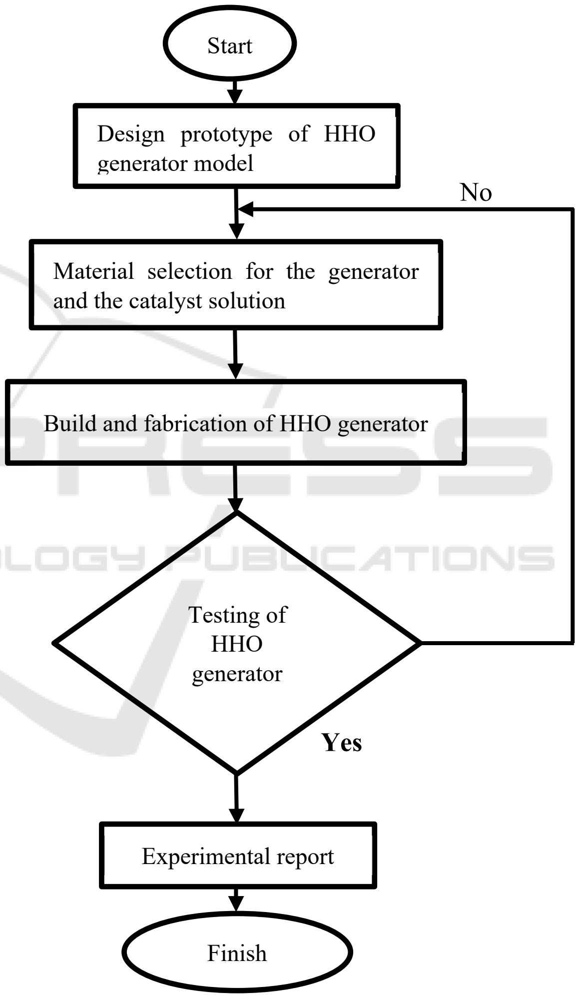

Figure 1: Flowchart of the research.

By using CAD the design of the micro hydro power screw Archimedes turbines were shown in Figure 2.

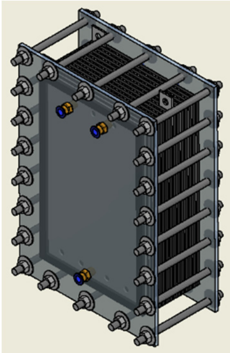

Figure 2: Design of HHO generator.

3 RESULT AND DISCUSSION

From the geometry design using CAD in Fig.2, then the prototype of HHO generator were built and developed. The hydrogen generator made has the following sizes, length x width x height = 210 mm x 130 mm x 300 mm, number of plates = 13 sheets, number of cells = 12 cells, plate material = aluminium. The prototype of HHO generator were shown in Figure 3 below:

Figure 3: Prototype HHO generator engine.

In this HHO generator engine, there are several types of components, including:

1. Aluminium plate with a thickness of 2 mm. The generator made is divided into 3 plates, namely:
   a. Positive plate, positive plate is a plate that carries positive current. The positive plate has the following sizes, the negative plate size is 270 mm high, 160 mm wide and 2 mm thick, 2 pieces.
   b. Negative plate, negative plate is a plate that carries negative current. The negative plate size is 270 mm high, 160 mm wide, and 2mm thick, 1 piece.
   c. Neutral plate, neutral plate is a plate that limits the negative plate and positive plate. The neutral plate has the following dimensions, 250 mm high, 160 mm wide and 2 mm thick with a total of 10 plates.
2. Polycarbonate mica, using polycarbonate mica with a length of 210 mm x a width of 297 mm with a thickness of 5 mm.
3. The rubber gasket used has a height of 270 mm, a width of 160 mm and a thickness of 5mm.

The HHO generator that has been developed then tested in a 100cc four stroke gasoline engine. The test was conducted to determine the flow rate and efficiency of the dry cell type HHO generator, with the main ingredient in the form of water and additional KOH catalyst with a mass percentage of 4% of the water volume of 2000 ml.

Figure 4: Performance test of HHO generator.

The result from the test shown in table 1 below:

Table 1: Test Result.

No	Catalyst	Voltage (V)	Curren t (A)	Time (s)	$x_0 \pm \Delta x$
1	KOH	14.8	20	3.56 5.30 4.58 2.05 3.36	3.77$\pm$2.72

3.1 P HHO Generator

From the result above it can be seen that the KOH catalyst requires a voltage of 14.8 volts with a current of 20 amperes, which has an average time of 3.77±2.72 seconds to produce 10 ml of HHO gas.

The power used in HHO generator then can be known:

P = V.I
P = 14.8 V. 20 A
P = 296 watt

3.2 HHO Gas Flow Rate

From the result in table 1, the flow rate of HHO gas can be known:

$$V_{HHO} = \frac{volume}{t}$$

$$\mathrm{V_{HHO}} = \frac{10\ \mathrm{ml}}{3.77\ \mathrm{s}} = 2.56\ \mathrm{ml/s}$$

3.3 HHO Gas Flow Rate

Based on the results of the calculation of the HHO generator power consumption and HHO gas flow rate, it can be calculated to find the efficiency of the HHO generator tool that uses a KOH catalyst with a percentage of 4%, with an additional value of the density of HHO gas of 0.491167 gr/l and a value of 0.491167 gr/l. from the LHV of HHO gas of 13.25 kJ/gr.

$$\eta_{HHOgen} = \frac{V_{HHO} \times \rho_{HHO} \times LHV_{HHO}}{P_{HHOgen}} \times 100\%$$

$$\eta_{HHOgen} = \frac{2.56 \times 0.491167 \times 13.25}{296} \times 100\%$$

$$\eta_{generator\ HHO} = 5.6\ \%$$

The ratio of hydrogen gas and oxygen gas in Brown's gas is the same, so the density of HHO and LHV HHO does not affect the cause of the increase or decrease in the efficiency of the generator. While the amount of power greatly affects the increase and decrease in efficiency in this study. The higher the power used, the lower the efficiency, it can be seen that the greater the current, the higher the productivity, but not proportional to the greater the energy used so that the efficiency will decrease. A lot of the energy used is turned into heat and not used to break the bonds of water, so a lot of energy is wasted and the efficiency will decrease.

3.4 Exhaust Emission Testing

The exhaust testing was conducted in a single cylinder 4 stroke engine, 110 cc. The experimental set up was shown in Figure 5 below:

Figure 5: Engine set-up.

The results from the emission test (CO and HC) without using a hydrogen generator shown in table 2 below. The results from the CO emission test are in percentage (%) and the results from the HC test are parts per million (ppm)

Table 2: Emission test without hydrogen generator.

No	CO (%)	HC (ppm)
1	0.93	677
2	1.44	629
3	1.79	630
Average	1.35	645.33

The results from the emission test (CO and HC) using dry cell type hydrogen generator, and water – KOH as the catalyst shown in table 3 below. The results from the CO emission test are in percentage (%) and the results from the HC test are parts per million (ppm).

Table 3: Emission test with hydrogen generator (water-KOH catalyst).

No	CO (%)	HC (ppm)
1	0.46	433
2	0.50	403
3	0.45	432
Average	0.47	422.66

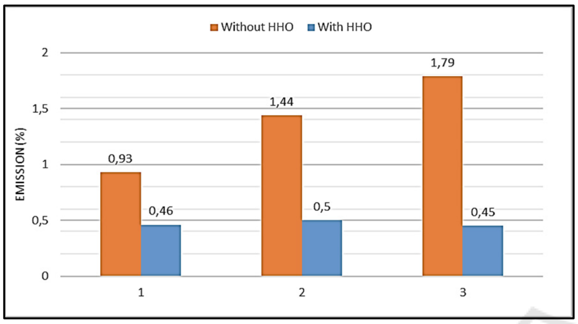

Figure 6: Emission test of CO (%).

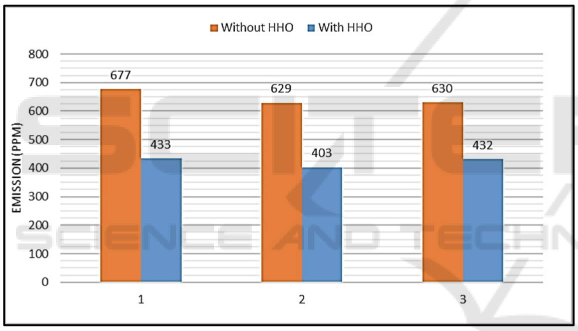

Figure 7: Emission test of HC (ppm).

From Figure 6 it can be seen that the ratio of CO gas when not using an HHO generator is much greater than using an HHO generator. The use of a hydrogen generator causes differences in exhaust gas emissions in CO gas (carbon monoxide) which is quite far, compared to the standard which uses RON 90 fuel, the average concentration of CO gas without HHO generator was 1.35% then in using HHO generator, the average concentration decreasing into 0.47%.

The emission test of HC gas with and without using HHO generator were shown in Figure 7. The result showed that the use of HHO generator also can decreasing the emission of HC gas compared to the standard which uses RON 90 fuel. The average emission of HC gas were 645.33 ppm and the average emission of HC using HHO generator were 422.6 ppm, which the decreasing was about 34.5%.

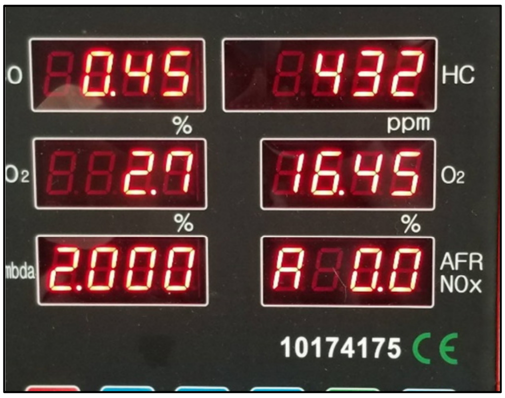

Figure 8: Emission test using gas analyser.

4 CONCLUSIONS

From the discussion above, it can be concluded that the HHO generator that has been made can work properly. The generator can produce enough HHO gas that can be use in motorcycle engine. The test result of uses HHO gas to the engine showed that the use of HHO generator can reduce the emission of exhaust gas (CO and HC) compared to the standard which uses RON 90 fuel. The average concentration of CO gas decreasing about 0.47%, and the average emission of HC decreasing about 34.5%.

ACKNOWLEDGEMENTS

The authors would like to thank the Director and the Head of P3M Politeknik Negeri Bali for funding this research. Authors also like to thanks to all the staff of mechanical engineering department of PNB for all their hands.

REFERENCES

Chi, Jun, Hongmei Yu, (2018). Water electrolysis based on renewable energy for hydrogen production. *Chinese Journal of Catalysis.* 39, p. 390–394.

Crosbie, L. M., Chapin, Douglas, (2003). Hydrogen Production by Nuclear Heat. *GENES4/ANP2003.* Sep. 15-19, 2003, Kyoto, JAPAN.

Kumar, S. Shiva, V. Himabindu, (2019). Hydrogen production by PEM water electrolysis – A review. *Materials Science for Energy Technologies.* Vol. 2, p 442–454.

Mujebuu, MA., (2016). Hydrogen and syngas production by superadiabatic combustion – A review. *Applied Energy.* 273, p. 210-224.

R.F. Horng, et al, (2008). Driving characteristics of a motorcycle fuelled with hydrogen-rich gas produced by an onboard plasma reformer. *Int. Journal of hydrogen energy*. 33, p. 7619 – 7629.

SR. Premkartikkumar, AR. Pradeepkumar, (2015). Effect of using hydrogen mixed gases as a fuel in internal Combustion engines – A Review. *International Journal of Innovative Research in Advanced Engineering (IJIRAE).* Vol. 2, p. 29 – 31.

T. Suzuki, Yoshihito Sakurai, (2006). Effect of Hydrogen Rich Gas and Gasoline Mixed Combustion on Spark Ignition Engine. *Powertrain & Fluid Systems Conference & Exhibition,* Toronto, Canada, October 16-19.

Verhelst, S., R. Sierens, (2001), Aspects concerning the optimisation of a hydrogen fueled engine. *Int. Journal of hydrogen energy*. 26, p. 981 – 985.

viva.co.id, September 2013.