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EXPERIMENTAL INVESTIGATION ON DRY CELL HHO GENERATOR WITH CATALYST VARIATION FOR REDUCING THE EMISSIONS

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KEYWORDS

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HHO Generator
Catalyst
Electrolyte

ABSTRACT

Air pollution is now largely attributable to the use of vehicles that produce high pollution. The purpose of this study is to determine the contribution of HHO generator in reducing air pollution by looking at the emission level of exhaust gas. In addition, to know the type of catalyst is the best in lowering the level of these pollutants.

The research using an experimental method. The subject is Honda Supra X 125 the Year 2013 by adding a dry cell HHO generator. Emissions data collection using gas analyzer against the use of HHO generator with catalyst variation (KOH, NaOH, and NAHCO3). Data analysis was done by descriptive quantitative. The results showed (1) All types of catalysts studied (KOH, NaOH, and NAHCO3) as electrolyte solution media for HHO generators which greatly affected the reduction of CO and HC emissions in vehicles, (2) Catalyst NaOH type is the most effective catalyst in reducing CO and HC emissions. This is evidenced by the results of NaOH solution to obtain average CO gas concentration is 0.13% or a decrease of 81.74% and the use of NaOH solution to get an average concentration of HC gas is 524.33 ppm or a decrease of 69.62% when compared to standard conditions (without HHO generator).

INTRODUCTION

The problem of air pollution due to vehicle exhaust emissions is above the threshold, especially in big cities. The vehicle's exhaust gas is generated by the residue of incomplete combustion of fuel in the combustion chamber to form pollutants in the air. The pollutants contained in the exhaust gases are carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NOx), sulfur oxide (SOx), and other particulates. Exhaust emissions in certain levels can pollute the surrounding environment.

Hydrocarbons (HC) are the basic compounds of fuel oil. So HC emissions can be formed due to the incomplete combustion process. HC gas emissions smelled of gasoline and felt sore in the eyes and cause respiratory problems. Other gas emissions of carbon monoxide (CO) gas formed by Air Fuel Ratio (AFR) are not ideal or tend to be too rich. When the engine works with the right AFR the CO emissions will still form around 1% to 5% on the exhaust tip. CO gas is very dangerous because if entering into the human body can inhibit the supply of oxygen to the body. CO and HC gas content of exhaust emissions should be kept as low as possible because it is harmful to human health.

The Government has also paid close attention to this issue by stipulating Regulation of the State Minister of Environment Number 23 of 2012 on Amendment to the Regulation of the State Minister of the Environment Number 10 the Year 2012 on the Quality Standard of New Type Automotive Gas Disposal of L3. Based on the regulation, it means that the producers and owners of new motor vehicles must conduct their vehicle exhaust emissions test. Technologies that can be applied to limit motor vehicle exhaust emissions include Catalytic Converter, Positive Crankcase Ventilation Valve, Exhaust Gas Recirculation, Charcoal Canister, Air Injection System, and fuel usage engineering. The addition of certain substances into the fuel used can reduce exhaust emissions.

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The number of motorcycles that also affect the demand for fuel oil (BBM) as the basic needs of every motor vehicle. According to data from the Ministry of Energy and Mineral Resources (ESDM), domestic premium sales (RON88) in 2014 reached 29,707,002 kiloliters while in terms of production from 2008 decreased by 357,501,000 barrels to 287,902,000 barrels in 2014 This proves that more and more motor vehicles have an impact on the high demand for fuel used and fuel the scarcity of petroleum supplies. Petroleum is a source of energy from fossils and is included in non-renewable energy that can become thinner even depleted.

Indonesia is rich in the diversity of natural resources ranging from soil, water, wind, geothermal to the hot sun which has the potential to become a new renewable energy source. Quoted from the news of the Ministry of Energy and Mineral Resources, Indonesia has a large potential of renewable energy (EBT), mini/micro hydro of 450 MW, Biomass 50 GW, 4.80 kWh / m2 / day solar energy, wind energy 3-6 m/second, and 3 GW nuclear energy. Potential EBT is enough for 100 years longer or equal to 160 GW if developed into electricity. The use of this natural source of energy is expected to reduce the problem of scarcity of fossil energy sources and potentially more environmentally friendly. The potential of EBT owned by Indonesia has not been optimally utilized.

Water is one of the most abundant sources of EBT on earth, as it is known that two of the three parts of the earth is water. Indonesia as an archipelago country located on the equator has plenty of water and a rainy season that supports the amount of water supply. Esmail Khalife (2016) said that the water can make rising the engine performance and reducing the emissions. Water is a naturally formed compound of two elements, two hydrogen atoms, and one oxygen atom. Water compounds, when separated into their constituent elements have the form as a gas but liquid water (at room temperature). This can happen because oxygen is more electronegative to hydrogen. Such properties can be utilized to decompose water into its constituent elements (hydrogen and oxygen) ie by electrolysis method.

The results of electrolysis of water produce hydrogen gas and oxygen or hydrogen oxide hydrogen gas (HHO) or often known as Brown gas taken from the inventor name of Yull Brown. Hydrogen gas is expected to help burn the hydrocarbon chains of fuel and oxygen gas can also reduce CO emissions by helping to form green CO2 gases.

Sudirman (2009: 8) says that Brown gas is a powerful fuel, clean, able to increase mileage, and significantly reduce exhaust emissions. This is strengthening by Ammar A. Al-Rousan (2010). Based on studies that have been conducted HHO gas also proved to have a positive influence on vehicle exhaust emissions. However, until now the use of electrolyzed equipment has not been mass produced.

Some research is still done to find electrolysis that can produce HHO gas with optimal and efficient. Things that can be varied in the manufacture of electrolysis include electrode shape, electrode type, large current strength, type of solution, and so forth. Theoretically, the more wide-area electrode cross-section, the HHO gas produced is also more and more. The type of electrolyzer and the type of solution used may also affect the amount of HHO gas production. Electrolyser basically there are 2 types of wet cell and dry cell. While the type of solution there are also various kinds ranging from alkaline to acid. Therefore, to know the difference of production there is need of research based on the type of electrolyzer and type of solution.

Several types of solutions that can be used as a mixture of electrolytes in this HHO generator are potassium hydroxide (KOH), Sodium Hydroxide (NaOH) and Sodium Bicarbonate (NaHCO3).

1. Potassium Hydroxide (KOH)

KOH is a basic compound, if dissolved in water it will form a KOH solution. KOH will be a catalyst that serves to facilitate the termination of hydrogen and oxygen gas bonds in water. With the addition of KOH solution in water when electrolysed, it is thought that the greater the chance of producing large quantities of hydrogen and oxygen gas. Similarly, the influence of currents provided by the power source. The larger the current is given the more bubbles that arise from the surface of the electrode. The bubbles are the breaking process of the bond between H2 and O2 in water compound so that H2 and O2 more and more. Also Eunji Jang, et al (2017) said that KOH is very good to absorb CO2. H.H. Masjuki, et al (2016) and Mohamed M. EL-Kassaby, et al (2015) also confirmed that HHO with KOH and NaOH can recude HC, CO, Nox.

2. Sodium Hydroxide (NaOH)

Sodium hydroxide is a white dense granular compound and has hygroscopic properties, as well as its reaction with fatty acids to produce soap and glycerol. NaOH is often used in the hard soap making industry. NaOH is one type of alkali (base) strong corrosive and easy to destroy the smooth organic tissue. Sodium hydroxide pure solid white and available in the form of pellets, flakes, granules or 50% saturated solution. It is moist liquid and spontaneously absorbs carbon dioxide from the free air. It is very soluble in water and will release heat when dissolved.

3. Sodium Bicarbonate (NaHCO3)

Sodium bicarbonate is a chemical compound with the formula NaHCO3. These compounds include salt groups. These compounds are also called baking soda, sodium bicarbonate, and sodium hydrogen carbonate. Sodium bicarbonate is soluble in water. This compound is used in bread or cake because it reacts with other ingredients which will then form carbon dioxide gas, which causes the bread to "expand". NaHCO3 is generally produced through the Solvay process, which requires sodium chloride, ammonia, and carbon dioxide reactions in water. The baking soda is commercially produced from soda ash dissolved in water and then reacted with carbon dioxide. Then NaHCO3 settles. This study attempts to test the effectiveness of the use of the above solutions in producing HHO gas to the exhaust gas emissions.

RESEARCH METHODS

This research is a quantitative type that used experiment method. Exhaust emission test refers to SNI 09-7118.3-2005 from National Standardization Body (BSN) on How to Test Motor Vehicles Category L Under Idle Condition. This research was conducted at the Automotive Laboratory of Mechanical Engineering Education Study Program of FKIP UNS Surakarta by using Gas Analyzer Technotest STARGAS 898.

The subject of research is a Honda Supra X 125 motorcycle in 2013.

Table 1. The Specifications of a Honda Supra X 125

Engine Type	4 SOHC Steps
Cooling System	Cooling air
Diameter x stroke	52.4 x 57.9 mm
Volume	124.8 cc
Compression Ratio	9.0: 1
Maximum power	9.3 PS / 7.500 rpm
Maximum torque:	1.03 kgf.m / 4000 rpm
Clutch	Double,automatic, centrifugal, wet type
Starter	Pedal and electric

Experimental set up can be described as follows:

The HHO Generator mounting design in this study is described in Figure 1 below. The electrical system of the HHO Generator is supplied from the motor battery with a switch from the ignition. HHO gas from the HHO generator is fed into the combustion chamber through the intake manifold so as to mix with the fuel mixture with air from the carburetor. Contains the type of research, time and place of research, targets, subjects, procedures, instruments and techniques of data analysis and other matters related to the way research. targets, research subjects, procedures, data and instruments, and data collection techniques, as well as data analysis techniques and other matters related to the way research.

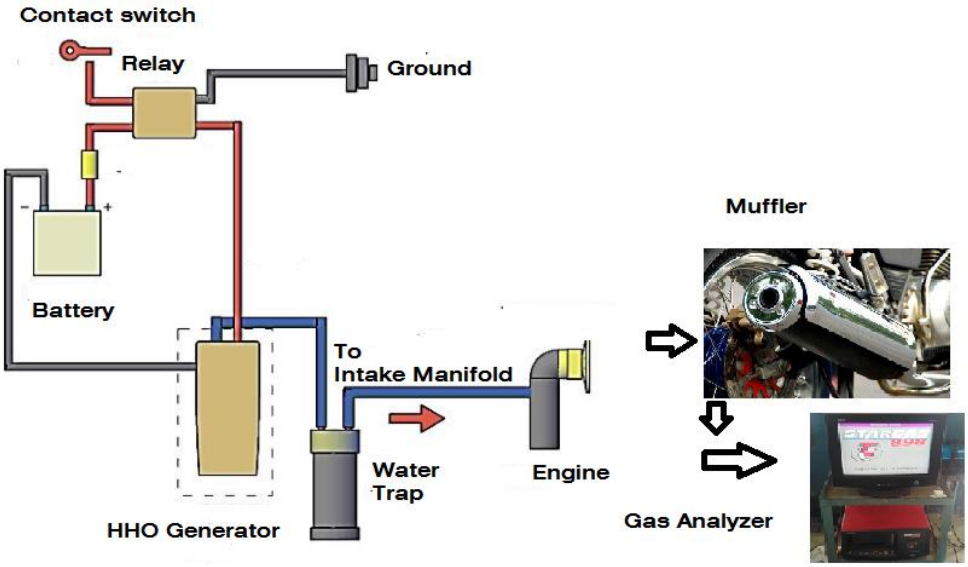

Figure 1. Experimental set up

The experimental procedures that applied in this study can be illustrated in the following figure.

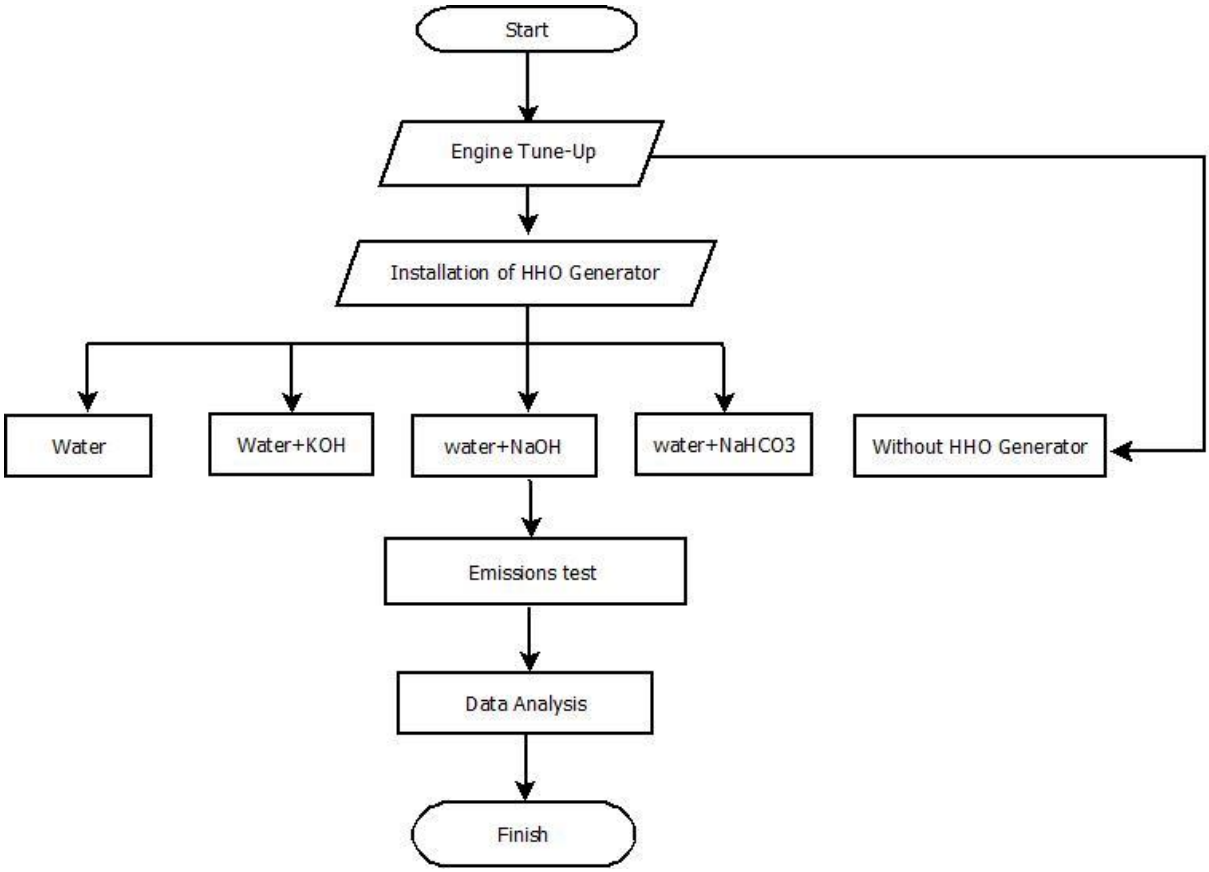

Figure 2. experimental procedures

The steps:

a. Preparation Step

1) Designing HHO Generator tool.

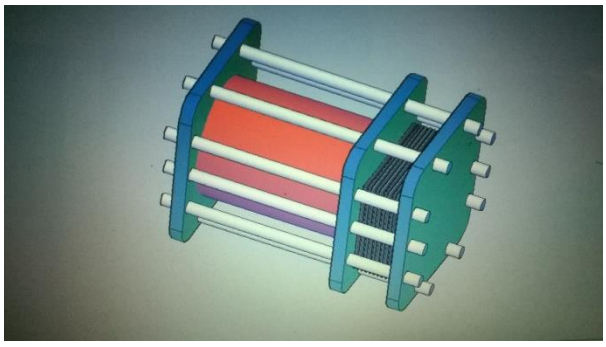

Figure 3. The design of dry cell HHO Generator

Figure 4. Dry cell HHO Generator

2) Conducting tune up on research material that will be used is Honda Supra X 125 motorcycle in 2013.
3) Preparing research tools and materials.
4) Keep the vehicle in a flat position and 600C engine temperature.
5) Checking the exhaust gas pipe (exhaust) does not leak and turn off the vehicle accessories system.
6) Ensure the Gas Analyzer Technotest test type STARGAS 898 is in ready condition.

b. Measurement

1) Without using HHO Generator
   a) Preparing materials to be tested is Honda Supra X 125 motorcycle 2013 in 2013.

b) Preparing the gas emission test equipment is Gas Analyzer Technotest STARGAS 898 type.
c) Raise the engine speed to reach 1,900 rpm to 2,100 rpm, then hold for 60 seconds.
d) Returns motorcycle conditions on idle rotation.
e) Insert the Gas Analyzer's probe into the exhaust pipe of the motorcycle as deep as 30 cm for 20 seconds.
f) Carry out the data of CO gas concentration in percent (%) and HC gas in measured ppm units in the Technotest Gas Analyzer type STARGAS 898.
g) Turns off the engine after the first measurement is finished and waits up to 600C engine temperature before the second and third measurements.

2) Using HHO Generator
a) Preparing materials to be tested is Honda Supra X 125 motorcycle 2013 in 2013.
b) Installing a Wet Cell HHO Generator with the first solution of pure water.
c) Preparing the gas emission test equipment is Gas Analyzer Technotest STARGAS 898 type.
d) Raise the engine speed to reach 1,900 rpm to 2,100 rpm, then hold for 60 seconds.
e) Restore motorcycle condition on idle rotation.
f) Insert the Gas Analyzer's probe into the exhaust pipe of the motorcycle as deep as 30 cm for 20 seconds.
g) Conducting data of CO gas concentration in percent (%) and HC gas in measured ppm units in the Technotest Gas Analyzer type STARGAS 898.
h) Turns off the engine after the first measurement is finished and waits up to 600C engine temperature before the second and third measurements.
i) Repeat the second step by substituting the solution with the next solution ie with KOH, NaOH, and NaHCO3 solutions then proceed by installing a Dry Cell HHO Generator and a solution of the same variation as above.

RESULTS AND DISCUSSION

The result of this research is the exhaust gas emission test (CO and HC) on Honda Supra X 125 the Year 2013 motorcycle with the use of HHO type dry cell generator which is varied with 3 types of solution (catalyst). Exhaust emissions testing data will be classified as follows:

Results of Exhaust Emissions Testing (CO and HC) Without Using HHO Generator

The following are data on exhaust emissions test results (CO and HC) without using HHO Generator (standard state). The results of the CO gas emissions test in% volume and HC in parts per million (ppm) can be seen in Table 2.

Table 2. Results of Exhaust Emission Test (CO And HC) Without Using HHO Generator

Replication	CO (%)	HC (ppm)
1	0.722	1859
2	0.657	1507
3	0.758	1812
Average	0.712	1726

Based on the results of the three-times exhaust emissions test, it can be seen the average CO gas emissions of 0.712% and HC gas of 1.726 ppm.

Result of Exhaust Emission Test (CO and HC) Using HHO Dry Cell Generator

The following data is the data of exhaust emission test result (CO and HC) using Wet Cell HHO type and Dry Cell type with a variation of electrolyte solution ie pure air, pure air with KOH catalyst, pure air with NaOH catalyst, and pure air with NaHCO3 catalyst. The result of the CO emission exhaust emissions test in% volume can be seen in Table 3.

Table 3. Exhaust Emission Test Results CO (%) Using HHO Generator in pure air solution

Replication	Water	Water+KOH	Water+NAOH	Water+NAHCO3
1	0.253	0.168	0.140	0.206
2	0.179	0.192	0.154	0.272
3	0.128	0.174	0.096	0.112
Average	0.187	0.178	0.130	0.197

To facilitate the delineation of data, a comparison graph is made between the average CO emission rate (without using HHO Generator) and using HHO Generator with a variation of electrolyte solution type. The CO emission ratio comparison can be seen in Figure 5 below.

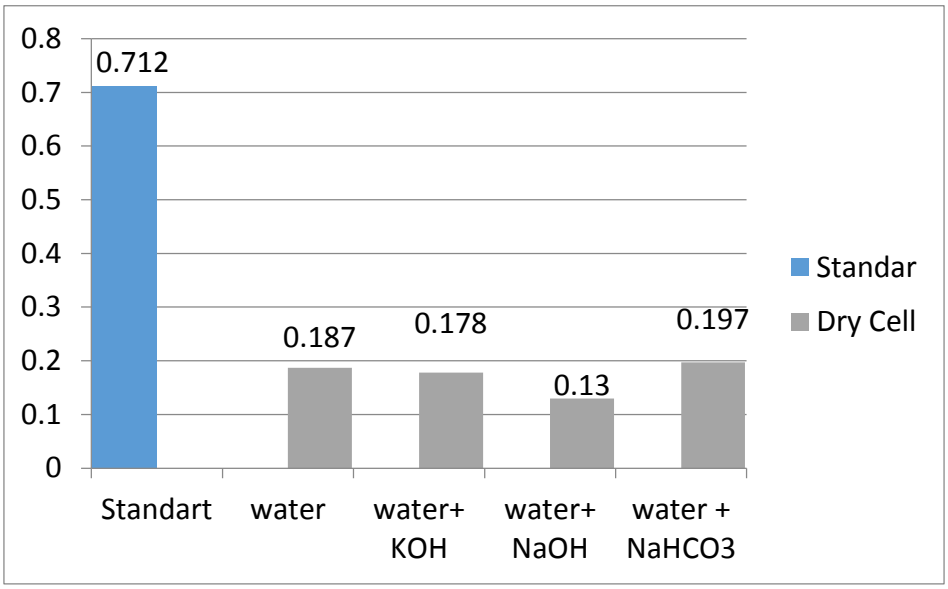

Figure 5. Comparison Graph of the CO Emissions on standard engine Using HHO Generator

Based on figure 5 above can be known the average CO emissions under standard conditions or without using HHO Generator is higher when compared with using the HHO Generator. In other words, the use of HHO Generator causes CO emissions of CO. The exhaust gas emissions vary according to the variation of the type of electrolyzer and the type of solution used in the HHO Generator.

The use of HHO Generator Dry cell with pure water solution obtained average CO gas concentration is 0.187% or a decrease of 73.74% compared to standard conditions. While the content of KOH obtained average CO gas concentration is 0.178% or a decrease of 75% compared to standard conditions. Usage with NaOH solution obtained average CO gas concentration was 0.13% or decreased by 81,74% compared with the standard condition. This CO gas emission shows the smallest concentration compared to other types of Dry Cell types. While the content of NaHCO3 obtained average CO gas concentration is 0.197% or decreased by 72.33% compared with standard conditions. The results of the HC exhaust emissions experiments measured in ppm (parts per million) can be seen in Table 4 below.

Table 4. Results of HC (ppm) Exhaust Emission Testing Using HHO Generator

Replication	Water	Water+KOH	Water+NAOH	Water+NAHCO3
1	1710	1168	535	1578
2	1631	1195	613	1290
3	1443	964	425	1185
Average	1594.67	1109	524.33	1351

To facilitate the depiction of data, a comparison chart is made between the average HC emission emissions of standard conditions (without using HHO Generator) and using HHO Generator with various types of the electrolyte solution. The comparison graph of HC exhaust emission can be seen in Figure 6 below.

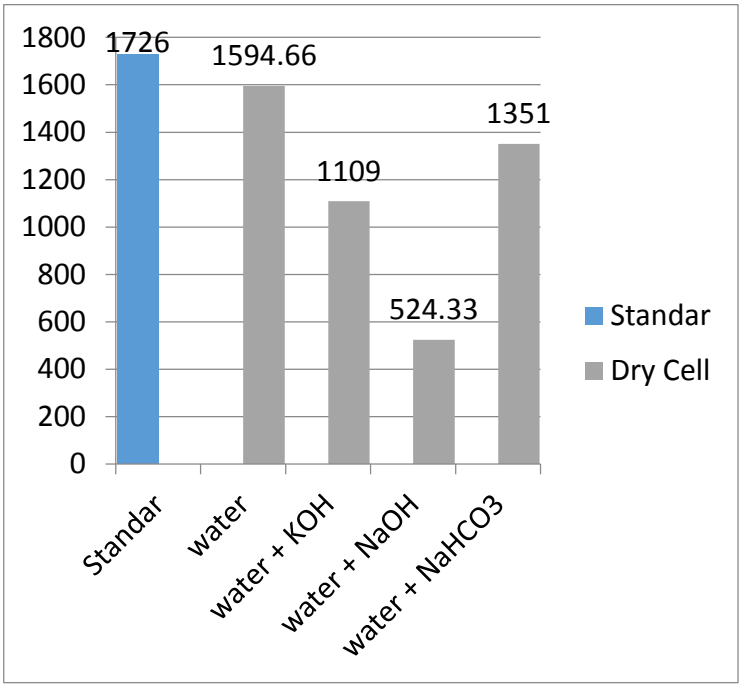

Figure 6. Comparison Graph of the HC Emissions on HHO Generator

Based on figure 6, it can be known that using HHO Generator is higher when compared with using HHO Generator. In other words, the use of HHO Generator causes HC exhaust emissions. The exhaust gas emission reduction varies according to the variation of the type of electrolyzer and the type of solution used in the HHO Generator.

The use of Dry Cell HHO Generator with average pure air aqueous concentration of HC gas is 1,594,66 ppm or decrease that is equal to 7,6% compared to standard condition. While the KOH content obtained average HC gas concentration is 1,109 ppm or decreased by 35.75% compared to standard conditions. Usage with NaOH solution obtained mean the concentration of HC gas is 524,33 ppm or decrease 69,62% compared to standard condition. And, the use of the NaHCO3 solution obtained average HC gas exhaust concentration is 1.351 ppm or a decrease of 21.72% compared to standard conditions.

The research that has been done shows the influence of the use of Dry cell HHO Generator to the exhaust emission. The use of NaOH solution is a strong base capable of reacting quickly so it fits with the construction of Dry Cell which can release heat well. In other words, the addition of HHO gas makes the increase in burning efficiency, the partial combustion of carbon fuel get reduced, resulting in lowered CO emission. Ali Can Yilmaz, Erinc¸ Uludamar, Kadir Aydin (2010) said that NaOH was specified as the most appropriate catalyst. And corroborated by Tamer M. Ismaila , et al (2018) said HHO gas by adding NaOHcan reduce HC and CO emissions.

CONCLUSION

Based on the results of the above research, it can be concluded as follows:

1. All types of catalysts studied (KOH, NaOH, and NAHCO3) are electrolyte solution media for HHO generators which greatly affect the reduction of CO and HC gas emissions in vehicles
2. Catalyst NaOH type is the most effective catalyst in reducing CO and HC emissions. This is evidenced by the results of NaOH solution to obtain average CO gas concentration is 0.13% or a decrease of 81.74% and the use of NaOH solution to get an average concentration of HC gas is 524.33 ppm or a decrease of 69. 62% if compared to standard conditions (without HHO generator) Conclusions can be generalized findings according to research problems, can also be a recommendation for the next step.

REFERENCES

Ammar A. Al-Rousan (2010). Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold. International journal of hydrogen energy 35, 12930-12935

Asosiasi Industri Sepeda Motor Indonesia (AISI). (2014). *Motorcycle Production Wholesales Domestic and Exports*. Diperoleh pada 13 Januari 2016, dari http://www.aisi.or.id/statistic/

Badan Standardisasi Nasional. (2005). *Emisi Gas Buang – Sumber Bergerak – Bagian 3: Cara Uji Kendaraan Bermotor Kategori L Pada Kondisi Idle (SNI 09-7118.3-2005)*. Jakarta: BSN.

De Silva, TS., Senevirathne, L., Warnasooriya, TD. (2015). HHO Generator – An Approach to Increase Fuel Efficiency in Spark Ignition Engines. *European Journal of Advances in Engineering and Technology*, 2 (4): 1-7. Diperoleh pada 15 Februari 2016, dari http://www.ejaet.com/PDF/2-4/EJAET-2-4-1-7.pdf.

Electrolyzer in a CI Engine working on Dual Fuel Mode. Energy Procedia 90, 209–216. http:// dx.doi.org/10.1016/j.egypro.2016.11.187

Esmail Khalife, et al. (2016). Impacts of additives on performance and emission characteristics of diesel engines during steady state operation. *Progress in Energy and Combustion Science*, 59, 32-78. http://dx.doi.org/10.1016/j.pecs.2016.10.001

Eunji Jang, Seung Wan Choi, Seok-Min Hong, Sangcheol Shin, Ki Bong Lee (2017). Development of a cost-effective CO2 adsorbent from petroleum coke via KOH activation. Applied Surface Science 429, 62–71. http:// dx.doi.org/10.1016/j.apsusc.2017.08.075

H.H. Masjuki, A.M. Ruhul , Nirendra N. Mustafi , M.A. Kalam , M.I. Arbab, I.M. Rizwanul Fattah. (2016). Study of production optimization and effect of hydroxyl gas on a CI engine performance and emission fueled with biodiesel blends. international journal of hydrogen energy 41, 14519-14528. http://dx.doi.org/10.1016/j.ijhydene.2016.05.273

Kementerian Energi dan Sumber Daya Mineral. (2008, 25 Agustus). Potensi Energi Baru Terbarukan (EBT) Indonesia. Diperoleh 23 Januari 2016, dari http://esdm.go.id/berita/umum/37-umum/1962-potensi-energi-baru-terbarukan-ebt-indonesia.html.

Kementerian Energi dan Sumber Daya Mineral. (2015). *Handbook of Energy & Economic Statistics of Indonesia*. Diperoleh pada 14 Februari 2016, dari http://esdm.go.id/publikasi/statistik/handbook.html.

Melfiana, E., Harto, A.W., & Agung, A. (2007). Pengaruh Variasi Temperatur Keluaran Molten Salt Reactor Terhadap Efisiensi Produksi Hidrogen dengan Sistem High Temperatur Electrolysis (HTE). *Prosiding Seminar Nasional ke-13 Teknologi dan Keselamatan PLTN serta Fasilitas Nuklir*, hlm. 107 – 112. Universitas Gajah Mada, Jakarta. Diperoleh 12 Januari 2016, dari https://www.academia.edu/1480827/Pengaruh_Variasi_ Temperatur_Keluaran_Molten_Salt_Reactor_TerhadapEfisiensiProduksi_Hidrogen_dengan_Sistem_High_T emperature_Electrolysis_HTE_.

Mohamed M. EL-Kassaby, Yehia A. Eldrainy , Mohamed E. Khidr, Kareem I. Khidr (2015). Effect of hydroxy (HHO) gas addition on gasoline engine performance and emissions. Alexandria Engineering Journal, 55, 243–251. http://dx.doi.org/10.1016/j.aej.2015.10.016

P. V. Manua, Anoop Sunilb, S. Jayarajc. (2016). Experimental Investigation using an On-Board Dry Cell

Sudirman, Urip. (2008). *Hemat BBM dengan Air*. Jakarta: Kawan Pustaka.

Sugiyono. (2013). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, dan R&D)*. Bandung: Alfabeta.

Tamer M. Ismaila, Khaled Ramzya, M.N. Abelwhabb, Basem E. Elnaghib, M. Abd El-Salamc, M.I. Ismaild. (2018). Performance of hybrid compression ignition engine using hydroxy (HHO) from dry cell. Energy Conversion and Management 155, 287–300. http://dx.doi.org/10.1016/j.enconman.2017.10.076

Yilmaz, A. C., & Aydin, K. (2010). Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines, *international journal of hydrogen energy* 35, 11366-11372 https://doi.org/10.1016/j.ijhydene.2010.07.040