Research on the effect of SS316L electrode plate treatment on HHO gas production performance

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Abstract. The working principle of an internal combustion engine, in general, is to convert chemical energy from liquid fuels to mechanical energy. The type of fuel commonly used by internal combustion engines is fossil fuel, which until now has been increasing in use while its supply is running low. The present study is to conduct research in the field of new and renewable energy as an alternative fuel to replace fossil fuels. Hydrogen is a new form of energy carrier that could be obtained through the process of water electrolysis and is a promising fuel supplement in the future. Hydrogen production through the electrolysis process continues to be developed to help use environmentally friendly fuels and can have a positive impact on engine performance and exhaust emissions. However, to produce consistent and quality HHO gas output, the current HHO gas generator still needs to be improved especially for the production volume. The purpose of this research will be directed to the development of the effective electrode plate system in producing HHO gas. In order to improve the quality and volume of HHO gas production, it was found that the level of surface roughness and the contact angle of the material should be increased through grinding and polishing processes. In this research, various SS316L electrode plates with different surface roughness were made for the analysis of HHO gas production to match the expected volume of HHO gas production. Various conditions of surface roughness of the electrode plate are carrying out by grinding and polishing the surfaces of both sides of the electrode plate to a uniform roughness level.

Keywords: Electrode plate, treatment process, HHO generator, calibration, engine testing.

1. Introduction

The main problem facing the scientific community today is global warming. With the increasing use of conventional fossil fuels in the transportation sector and related environmental impacts have become a major concern worldwide. World energy consumption as per IEA 2013 in the transportation sector particularly increase by an average 1.1 % every year. Exhaust gas pollutants from internal combustion engines (ICE) also contribute greatly to total environmental pollution throughout the
world[1]. Combining all the problems of fluctuating fossil fuel prices, increasing environmental and energy security issues, plus stricter rules and regulations on engine or vehicle emissions, this has encouraged researchers to make more effort and interest in alternative fuels. One alternative fuel that is environmentally friendly is hydrogen-oxygen, one of which can be obtained through the water electrolysis process.

The process of electrolysis also called as alkaline electrolysis, because for the operation of this electrolysis process, a companion solution (catalyst) is required, namely an alkaline solution such as KOH, NaOH, etc[2]. The electrolysis process uses 2 capacitor plates, one plate is used for cathode electrode (−) and the other for anode electrode (+) in which the two capacitor plates are immersed in liquid water mixed with KOH. Both cathode and anode are given an electric voltage, by this electricity current, the cathode electrode will be compressed by H2 gas and the anode electrode will be compressed by O2[3]. This research aims to characterize the surface quality of the SS316L electrode plate as HHO cells to improve HHO gas production through the design and manufacture of integrated HHO generator. The evaluation process and the performance of HHO gas will be calibrated on the HHO generator used electrode plates before treatments and after treatments. The treatment process of stainless-steel material SS316L as the main parts of the water electrolysis process expected can increase the production volume and quality of HHO gas. By increasing the surface quality of the SS316L electrode plate and determining the appropriate distance of gap between one plate-cell to another, the amount of electrolyte solution molarity can show characteristics of HHO generators in producing HHO gas.

This research will be dedicated to the development of HHO generators through improving the quality of electrode plates. With the treatment process on the surface of SS316L electrode plates in order to produce better and better quality HHO gas production volumes and investigate the application of HHO gas in internal combustion engines to determine the impact of using HHO on performance and exhaust emissions from internal combustion engines.

A hypothesis states that, by carrying out the treatment process on the electrode plates, it will affect richer production volume output with constant voltage input and lower electric current output and HHO generator temperature[2]. At the end of this study, some evaluation, validation, and optimization should carry out testing on the internal combustion engine to determine the impact of the usage injection of HHO gas on engine performance and emissions reduction. The aim of this study is to increase the volume and quality of HHO gas produced from an HHO generator through the improvement surface quality of the SS316L electrode plates.

2. Research on HHO Generator
This research is expected to contribute to the development of science and technology and solutions in overcoming the new energy needs of HHO gas as an alternative fuel supplement through the water electrolysis process, which is a weakness of the previous HHO generator, and can provide inspiration for the environmentally friendly energy industry in Indonesia.

Why HHO generator, because HHO generator is equipment that produce hydrogen gas, which able to afford fuel reduction program. HHO generator can be made in various size from small, to the size that is well-suited requirement, from small-scale hydrogen production to large-scale use in for production facilities that always tied directly to the usage of renewable energy or non-renewable energy that may cause greenhouse gas effect emitted from electricity production process.
2.1 Electrolysis Process.

The use of hydroxyl gas (HHO gas) in gasoline engines is relatively new. This would be considered as renewable fuel that can be recycled and does not pollute because it does not contain carbon in the molecule. Hydroxyl gas also known as HHO, Brown gas, water gas, and green gas. HHO gas stands for Hydrogen-Hydrogen-Oxygen gas with a mixture of H₂ and O₂ in a ratio of 2:1 by volume. HHO gas is a water electrolysis product, which has discovered since March 1978 by Yull Brown. Therefore, electrolyte gas often referred to as "Brown's gas" or Hydrogen Rich Gas (HRG).

Water electrolysis is a technique that utilizes direct current (DC) to divide water into protons, electrons and oxygen in the form of gas at the anode (+) and hydrogen at the cathode (−) in the electrolyser. The basic idea of electrolysis in the HHO production process is to separate hydrogen and oxygen atoms in water molecules. Wet electrolysis is the electrolysis commonly used in Wet-cell, namely by inserting the two capacitor plates into distilled water or RO water (pure water), then the two electrodes are given an electric voltage, a separation process of hydrogen and oxygen will occur, then the result of the hydrogen need to be calculated and collected from the experimental process also that it is necessary to study the variable system that affects the volume of hydrogen to conclude that the use of electrolysis is the most efficient and effective. On the other hand, dry electrolysis is a new development which is usually called Dry-cell, in this process the capacitor plates are not immersed in the solution but plate is on the outside and the solution is inside the plate[4]. In the dry-cell process, the heat generated by the condenser plate can be thrown out immediately, so that it does not make the solution hotter compared to electrolysis wet-cell.

The scope of this research includes the treatment of SS316L material as electrode plates, also as well as the integration of two types of wet cells and dry cells into hybrid cells as a new concept of a hybrid type HHO generator.
2.2 Characterization of Electrode Plate

The process was started by cutting a SS316L plate with a size of 70 m/m x 100 m/m and 1 m/m thickness. Before assembled, it is necessary to pay attention to the cleanliness, and preparation of the plate surface so that the surface area becomes wider than the size of the plate itself namely by sanding the surface in a direction from left to right and from bottom to top with 36-grade size emery paper. The sharp surface is used so the gas that come out of the plate surface is immediately cut into pieces that will increase gas production about 40%. Also to be considered is that the plates that have been sanded must not touched the fingers so that there is no fat sticking to the plate, use gloves when assembling. Plates that have been assembled and ready for use must be tried out run with 2 Amp electricity conditions within 2 hours, then washed or drained with distilled water, after total of 20 hours tried out, the plate must be drained again, after the second drain the plate is ready for use, so, keep the plate clean, no traces of grease or other material from the fingers. The effects of electro polishing of work piece immersed in an electrolyte tank will also have effect on the HHO generator performance[5].

2.3 Treatment of Electrode Plates

1) Cold working processes are performed by pressed rolling on the work piece surface. In order to conduct pressed rolling, the parameter of rolling depth and rolling duration were determined. After rolling processes were conducted, then the surface roughness testing, hardness testing and micro structure testing were performed in order to determine the effect of rolling to the work piece’s surface. To observe the work piece surface, the Scanning Electron Microscope was applied and found that the surface roughness value prior to stress before cold working at Ra: 1.18 μm become Ra: 0.24 μm[6]. According to the hardness test is also obtain that the hardness of the surface of the work piece can be increase with cold working process.

2) Grinding and polishing is the final stage in the electrode plates preparation process and consists of several steps. Grinding process removed saw marks, levels and cleans the specimen surface. Polishing has removed the artefacts of grinding as well. Grinding uses fixed abrasives the abrasive...
particles bonded to the paper or platen for fast stock removal. Each step uses finer abrasive than the previous one, the ultimate goal being to produce a deformation-free, scratch-free and highly reflective sample surface. The electrode plates may need to be examined, either etched or un-etched, to reveal the microstructure of the material[7]. It was found and frequently happens that contrasts in the material will be visible after a successful etching step.

3) Polishing is a final process for the electrode plates that follows with lapping them to give the final surface characteristics of size, surface roughness, and required flatness of the plates. Polishing surface roughness of the material have been carried out by electro chemical method, by grinding work and by abrasive polishing to improve the quality of the surface plates after machining process, as well as cold working process. Polishing also can be used in many materials from steels to composite ceramics[8]. It does not create a good planarization of the plates which should be done in lapping prior to polishing, since it in corrects flatness with low discrepancies not in a big scale. Polishing has primarily considered to have mostly three-body abrasive mechanisms.

3. Result and Discussion
The following considerations will have influence for HHO generator production process:
First, the process of making a HHO generator, will be starting from design the HHO generator, choose the material to be use, preparing the process of materials or parts including the main material of SS316L as electrode plate, then the process treatment by grinding and polishing the surface of electrode plates until can reaches 0.25 μm roughness using grinding and polishing machine, then test the surface plate roughness by scanning electron microscopy.
Second, the process of decided cell generators spacers, design the dimension of HHO frame generators, and then the assembling process of dry cell generators into designed HHO frame generators. Next is a functional test performance to find out possibility leaks in the generator gasket, and measured the HHO generator by checking the volume of HHO gas production in liters per minute.
Third, apply the implementation test of HHO gas, for internal combustion engine. This test subject to: determine the engine performances, calculate CO₂ emissions, and calculate fuel consumption as the effect of injecting HHO gas to the engine. The data obtained from this implementation running test should be evaluated, analyzed, and validated for the next improvement of HHO generator.

3.1 The treatment process results of electrode plates
The treatment process results of electrode plate shown in Table 1 and Table 2 below.

| Table 1. Average of Roughness Value of Electrode Plate |
|--------------------------------------------------------|
| Treatment (μm)                                         |
| Before                        | 2.025 | 1.299 | 1.558 | 1.109 | 1.086 | 1.258 | 0.974 | 1.015 |
| After Treatment (μm)          | 1.547 | 1.665 | 1.668 | 1.459 | 1.688 | 0.945 | 0.985 | 1.109 |

Figure 4. Pace Technologies NANO 2000TGrinder-Polisher Machine
Figure 5. Samples of 400 Grits Sandpapers
Table 2. Surface roughness measurement result.

| Plate No. | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-----------|----|----|----|----|----|----|----|----|----|----|
| 1         | 0.331 | 0.286 | 0.289 | 0.347 | 0.429 | 0.282 | 0.405 | 0.125 | 0.164 | 0.225 |
| 2         | 0.427 | 0.490 | 0.585 | 0.372 | 0.651 | 0.680 | 0.623 | 0.687 | 0.555 | 0.552 |
| 3         | 0.486 | 0.381 | 0.356 | 0.328 | 0.418 | 0.562 | 0.476 | 0.344 | 0.529 | 0.261 |
| 4         | 0.332 | 0.182 | 0.252 | 0.302 | 0.258 | 0.337 | 0.332 | 0.279 | 0.213 | 0.150 |
| 5         | 0.211 | 0.222 | 0.183 | 0.214 | 0.365 | 0.274 | 0.189 | 0.284 | 0.161 | 0.174 |
| 6         | 0.483 | 0.581 | 0.257 | 0.440 | 0.032 | 0.184 | 0.409 | 0.226 | 0.165 | 0.392 |
| 7         | 0.584 | 0.493 | 0.609 | 0.576 | 0.417 | 0.478 | 0.540 | 0.423 | 0.671 | 0.519 |
| 8         | 0.575 | 0.521 | 0.570 | 0.492 | 0.388 | 0.553 | 0.347 | 0.399 | 0.403 | 0.372 |
| 9         | 0.154 | 0.163 | 0.168 | 0.149 | 0.214 | 0.206 | 0.161 | 0.252 | 0.154 | 0.137 |
| 10        | 0.146 | 0.131 | 0.178 | 0.087 | 0.147 | 0.139 | 0.103 | 0.213 | 0.179 | 0.183 |

3.2 Calibration data of Hybrid HHO Generator.

Calibration was done after assembling the electrode plates to HHO generator with different voltage input and also examined in electrolysis process with different quantity of catalyst to be used, in this research the catalyst is KOH. By this method then the real estimation of production HHO volume in HHO generator can be calculated and determine the effectiveness of electrode plates.

The average data result from calibration test of HHO generator with different voltage input are shown as Table 3 and Table 4 and its corresponding figure of Figure 6 and Figure 7 below:

Table 3. Average of test result for calibration of HHO generator

| Input Voltage (V) | Output Current (A) | Time Duration (Sec) | HHO Gas Produced (ml/min) | Power (Watt) |
|------------------|-------------------|---------------------|--------------------------|-------------|
| 12               | 0.888             | 2.363               | 14,106                   | 10,656      |
|                  | 1.188             | 1.280               | 26,041                   | 14,256      |
|                  | 1.520             | 1.193               | 27,940                   | 18,240      |
|                  | 1.884             | 1.044               | 31,928                   | 22,608      |
|                  | 2.276             | 0.536               | 62,188                   | 27,312      |

Table 4. Average of test result for calibration of HHO generator

| Input Voltage (V) | Output Current (A) | Time Duration (Sec) | HHO Gas Produced (ml/min) | Power (Watt) |
|------------------|-------------------|---------------------|--------------------------|-------------|
| 14               | 1.236             | 1.200               | 27,778                   | 17,304      |
|                  | 1.634             | 0.582               | 57,273                   | 22,876      |
|                  | 2.024             | 0.561               | 59,417                   | 28,336      |
|                  | 2.510             | 0.316               | 105,48                   | 35,140      |
|                  | 2.934             | 0.334               | 99,799                   | 41,076      |
3.3 The calculation of HHO Generator performance by electrolyze catalyst (KOH).

The HHO generator produced (ml/min) = (33.333) ml/(time duration second) * 60 (minute). This constant number 33.333 (ml) for calculation formula based on the volume of bottle sample used in this research calculation, bottle volume used 500 ml with 15th scale, so, every scale represents 500 ml divided by 15 = 33.333 ml. To predict the performance of HHO generator in different catalyst volume to be use, the test also applied with different volume of catalyst during the process of electrolyzing. The result of testing can be seen as follow in Table 5 and Figure 8 below.

| Catalyst KOH Weight (gram) | Time Duration (sec) | HHO Gas Produced (ml/min) |
|---------------------------|--------------------|--------------------------|
| 5                         | 2,363              | 14,106                   |
| 10                        | 1,280              | 26,041                   |
| 15                        | 1,193              | 27,940                   |
| 20                        | 1,044              | 31,928                   |
| 25                        | 0,536              | 62,188                   |
4. Conclusion

The developing of HHO generator were successful which has very promising, good possibility and bright prospect in the near future to increase the performance of internal combustion engine with high octane renewable fuel, can be recycled and does not pollute because it does not contain carbon in the molecule. The HHO generator advances in hydrogen technology and new renewable energy applications show rapid progress and promised of an increasingly hydrogen-based economy. Because the use of hydrogen for the electric and transport utility sector stretches across virtually every country, electric utilities need to understand the potential benefits and impacts.

Through this result we can conclude that HHO generator processing may provide an environmentally friendly treatment due to its potential of utilizing no hydrocarbon during the processes and also have a potential application in especially internal combustion engine, which able to afford fuel reduction program.

- Hydrogen has a very high-octane number, which is more than 130, when hydrogen flow into intake manifold through air filter engine, higher octane will make a very high quality of fuel that will be burn inside the combustion engine.
- Increasing fuel quality will makes power gain then the engine falls lighter, more stable temperature, lower noise and vibration, engine more responsive, and caused fuel reduction.
- With combination of traditional hydrocarbon fuel and water (hydrocarbon crack system + HHO) engine efficiency will be increase.
- The collaboration of hydrogen from two different sources (from water and traditional fuel) will be reinforces until maximum of engine efficiency.

5. Acknowledgement

The authors would like to acknowledge Bina Nusantara University for the financial support, through Binus Applied Research Grant, No. 079/VR.RTT/VIII/2020.

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