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HYDROGEN GAS PRODUCTIVITY FROM PEAT WATER ELECTROLYSIS WITH DISTILLED WATER INJECTED INTO AN INTERNAL COMBUSTION ENGINE (ICE)

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ABSTRAK

Gas hidrogen adalah salah satu bahan bakar alternatif yang saat ini sedang banyak diteliti. Generator HHO adalah alat dengan prinsip kerja elektrolisis air dan digunakan untuk memproduksi gas hidrogen. Di beberapa kajian, air gambut dipertimbangkan untuk digunakan sebagai elektrolit. Penelitian ini menggunakan metode eksperimental guna mendapatkan hasil gas hidrogen dari elektrolisis air gambut. Dimana, pada reaktor elektrolisis yang digunakan memiliki volume air gambut sebanyak 400 mL, dengan elektroda menggunakan bahan *Stainless Steel* (SS) dengan besar luas penampang 0,01884 m^2. Adapun tenaga listrik yang digunakan sebesar 12 Volt DC dan waktu dalam proses elektrolisis selama 1 menit. Berdasarkan hasil penelitian yang telah dilakukan antara lain, dimana peningkatan HC pada gas buang di air Akuades terlihat sangat hemat pada putaran awal di 2000 rpm menghasilkan efisiensi termal, yaitu sebesar 60% Sedangkan pada air gambut peningkatan HC pada gas buang di air Akuades terlihat sangat hemat pada putaran awal di 2000 rpm dimana menghasilkan efisiensi termal yaitu sebesar 90%. Dari pengaruh rpm dan ketidakstabilan putaran rpm menyebabkan nilai CO pada gas buang kendaraan tidak stabil dimana pada saat pembacaan putaran rendah 223,24 ppm, menengah 634,94 ppm dan atas 606,89 ppm, terlihat di putaran atas nilai malah menurun dari putaran menengah. Sedangkan pada HHO air Gambut saat pembacaan putaran rendah 104,4 ppm, menengah 101,94 ppm dan atas 121,29 ppm, terlihat diputaran atas nilai makin meningkat dari putaran awal ke atas.

Kata kunci: gas hidrogen, elektrolisis, air gambut, air akuades, gas HHO, gas buang.

ABSTRACT

Hydrogen gas is one of the alternative fuels that is currently being widely researched. HHO generator is a tool with the working principle of water electrolysis and is used to produce hydrogen gas. In some studies, peat water has been considered to be used as an electrolyte. This research uses experimental methods to obtain hydrogen gas results from peat water electrolysis. The electrolysis reactor used can handle as much as 400 ml of peat water. The electrodes are stainless steel (SS) with a large cross-sectional area of 0.01884 m^2*. The electric power used was 12 Volts DC and the time in the electrolysis process was 1 minute. Based on the results of the research that has been done, among others, where the increase in HC in the exhaust gas in Aquades water looks* *very efficient at the initial rotation at 2000 rpm which produces a thermal efficiency of 60% While in peat water the increase in HC in the exhaust gas in Aquades water looks very efficient at the initial rotation at 2000 rpm which produces a thermal efficiency of 90%. The influence of rpm and the unstable rotation of rpm causes the CO value in the exhaust gas of the vehicle to be unstable where at low rotation readings 223. 24 ppm, middle 634.94 ppm and top 606.89 ppm, it can be seen that in the upper round the value even decreases from the middle round, while in HHO peat water when the low round reading is 104.4 ppm, middle 101.94 ppm and top 121.29 ppm, it can be seen that in the upper round the value increases from the initial round to the top.*

Keywords: *hydrogen gas, electrolysis, peat water, aquades water, HHO gas, exhaust gas.*

1. INTRODUCTION

Energy demand increases along with human population growth and comes from non-renewable energy sources such as oil, natural gas and coal. The increase in energy demand from non-renewable sources can be seen from data from the Ministry of Energy and Mineral Resources in 2020. Oil production in 2019 was 272 million barrels. Since 2010, oil production has decreased by an average of 2.11% each year [1]. In general, people are still very dependent on available natural resources, especially non-renewable fossil fuels while petroleum is increasingly limited. Various studies have been carried out to overcome the limited availability of natural resources, namely alternative energy sources [2].

The utilization of new and renewable energy is a breakthrough in one part of the development of science and technology. The utilization of water is now increasingly developing by utilizing water as a supporting element of vehicle fuel, by converting water into Hydrogen gas [3–5].

Water covers almost 72% of the Earth's surface. The amount of water on Earth is described by a spherical model and has a volume of about 332,500,000 cubic miles (mi^3) or 1.386 million cubic kilometers (km^3). Water has the chemical formula H_2O, which means that one water molecule is composed of two hydrogen atoms covalently bonded to one oxygen atom [6][7].

The area of peatland in Kalimantan reaches 5,769,246 hectares, including West Kalimantan with an area of 1,729,980 hectares currently still not utilized as alternative energy. Organic materials in peat water have various organic substances, some of which can be dissolved in water. Fulvic acid is part of the humic fraction where this acid can dissolve in all water pH conditions. Fulvic acid has the ability to react with water where the acid can still be dissolved in water even though the humic substance has been removed [8], and has not been utilized as alternative energy. Peat water contains several compounds, namely: K, Na, Ca, Mg, Fe, and Al [9]. Seawater is a solution that contains a variety of salts. The chemical elements incorporated in seawater solution are Chlorine (Cl) 55%, Sodium (Na) 31%, then Magnesium (Mg), Calcium (Ca), Sulfur (S), and Potassium (K). In addition, in small amounts there are also Bromium (Br), Carbon (C), Strontium (Sr), Barium (Ba), Silicon (Si), and Fluorium (F). Sea water content also consists of various gases such as oxygen (O_2) and carbonic acid gas (CO_2). The production of hydrogen gas using seawater containing sodium chloride (NaCl) is the right solution because NaCl contained in seawater is a natural catalyst [10].

Electrolysis of water is the decomposition of water compounds (H_2O) into oxygen (O_2) and hydrogen gas (H_2) using an electric current through the water. At the cathode, two water molecules react by capturing two electrons, reduced to H_2 gas and hydroxide ions (OH-). Meanwhile at the anode, another two water molecules decompose into oxygen gas (O_2), releasing 4 H+ ions as well as flowing electrons to the cathode. The H+ and OH ions undergo neutralization so that several water molecules are formed again. The equivalent overall reaction of water electrolysis can be written as follows [11].

His tests led to the conclusion that the use of hydrogen can reduce harmful exhaust emissions in the form of hydrocarbons [12]. Tests were carried out by changing the compression ratio successively from 7:1 to 9:1 and with the same assumptions obtained percentage changes that resulted in a reduction in exhaust emissions in the form of CO and HC by 30.4% and 21.67% [13].

Using a single-cylinder diesel engine with a capacity of 0.667 L and a compression ratio of 20.5 : 1, they found that diesel fuel changeover with hydrogen in a diesel engine (Direct Injection) immobile dual fuel was achieved with shorter injector needles and faster injection termination [14].

In their journal, they concluded that the addition of hydrogen with air in an otto engine or diesel engine has an important effect on the thermal brake efficiency and power of the engine. plays an important role in producing a cleaner environment [15].

The researchers also found that hydrogen in the use of autos and diesel engines produces many benefits and can Catalysts function to facilitate the process of breaking down water into hydrogen and oxygen [16]. From the results of research that has been done by previous researchers obtained the results of NaOH catalyst has a flow rate of 2.203 ml/s and is the best catalyst compared to NaCl catalyst 1.24 ml/s and KOH catalyst 1.859 ml/s [17].

With various studies that have been conducted in the utilization of hydrogen as a mixture in vehicles as a supporting element. Then the availability of water is abundant, and easy to get. And in Indonesia itself has various types of water and in its use is still not maximized as an alternative energy, the Hydrogen Flow Production Rate Using Electrolyte Water, Peat Water, with NaOH Mixture is expected to be applied to various vehicles as a supporting mixture in order to reduce exhaust emissions.

2. METHOD

The electrolysis reactor used has a peat water volume of 400 mL, with electrodes using stainless steel (SS) with a cross-sectional area of 0.01884 m^2. The electric power used was 12 Volts DC and the time in the electrolysis process was 1 minute.

In this study, the variables used are testing peat water and distilled water (H_2O), which acts as an electrolyte for the electrolysis process. The data generated on HHO will flow into the vehicle's air suction system. The scheme is more detailed in Figure 1.

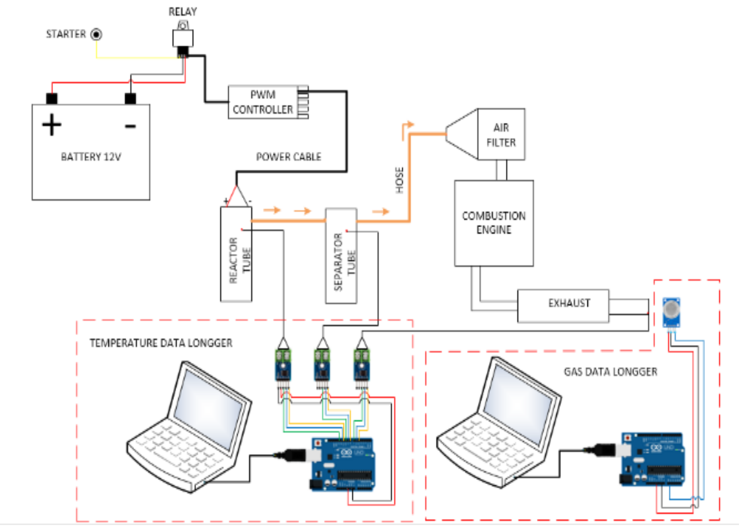

Figure 1. Schematic of Peat Water Hydrogen Research

The following are the results of the composition tests that have been carried out on peat water-electrolyte presented in Table 1:

Table 1: Composition of Peat Water in ppm

Fulvat	K	Na	Ca	Mg	Fe	Al
60	3.59	30.9	19.3	52.31	36.86	7.06

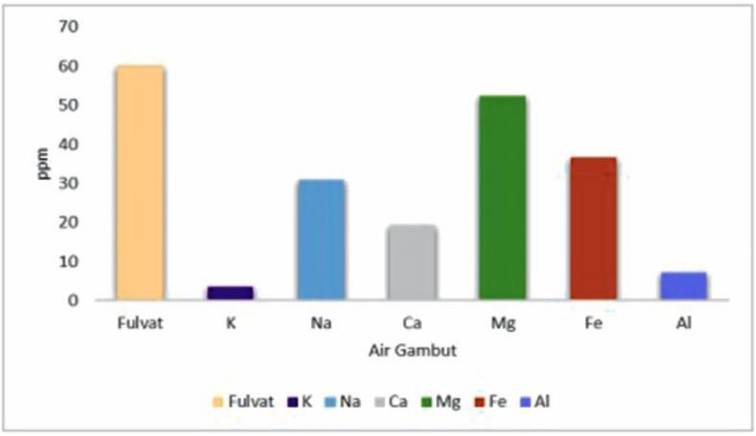

Figure 2. Peat Water Composition Chart [9]

In the graph presented in Figure 2, it can be seen that the composition of fulvic acid is more than the composition of other compounds, which is 60 ppm, thus fulvic acid is very instrumental in the process of weakening hydrogen bonds in H_2O in peat water to produce hydrogen gas by electrolysis method. Other compounds that help in the process of producing hydrogen gas are K, Na, Ca, Mg, Fe, and Al compounds. These compounds can react with water and produce H_2 products, in other words these compounds can help to maximize hydrogen gas productivity.

HC is the worst problem for vehicle engines. The concentration of HC in the exhaust is inversely proportional to the engine speed. This is due to the increase in turbulence intensity of the combustion and unburned gas process thus increasing the oxidation rate of HC. There is a decrease in HC concentration in the exhaust with the addition of HHO gas.

2.1. *Wet Type HHO Generator Design 45mm x 45 mm*

The preparation of the main materials for a wet-type HHO generator involves selecting high-quality stainless steel plates, acrylic sheets, and durable seals to ensure efficient operation and longevity. The cathode, anode, and neutral plates are precisely cut to dimensions of 45 mm x 45 mm to maintain uniformity in the electrolysis process. To facilitate proper gas flow and electrical insulation, each plate is perforated at the top and bottom with Ø 10 mm holes, where Ø 10 mm seals are inserted to prevent leaks and unintended short circuits. For electrical connections, modifications are made by cutting the upper left side of the anode plate and drilling a Ø 6 mm hole on the uncut right side to accommodate a bolt, allowing the positive current from the battery to flow effectively. Similarly, the cathode plate has its upper right side cut, with a Ø 6 mm hole drilled on the uncut left side for the bolt that connects to the battery's negative terminal. These carefully structured modifications ensure a stable and efficient flow of electricity across the plates, maximizing hydrogen gas production. Once the plates are prepared, they are assembled within an acrylic casing in a cathode-neutral-anode sequence, ensuring adequate spacing and insulation to prevent electrical shorts. Properly securing the components and testing electrical continuity before adding the electrolyte is essential to ensure the optimal performance of the HHO generator, as shown in Figure 3. Meanwhile, the type of wet generator specification in Table 2 is as follows:

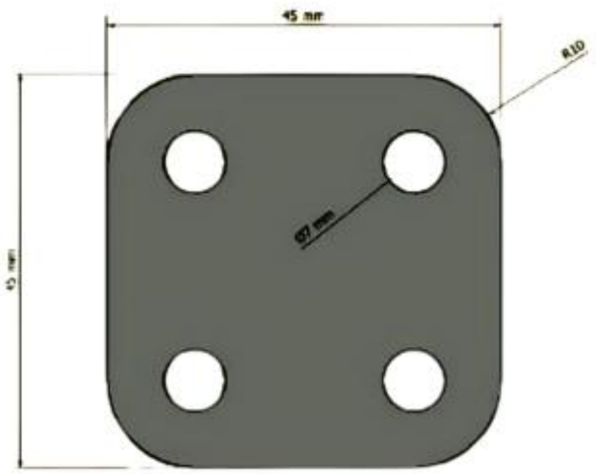

Figure 3. Size of Anode and Cathode Plate

Table 2. Wet type HHO Generator Tools and Materials

The Tools		Materials	
Type	**Size (mm)**	**Type**	**Size (mm)**
• Ring pass key • Minus screwdriver • Rubber Hammer • Steel Mistar	• 8,10,12 and 14	• Stainless Steel Anode, Cathode and Neutral Plate • Acrylic • Sheel • Stake • Bolt and Nut	• 45 x 45 x 2 • 45 x 45 x 2 • Ø 95 inside • Ø 100 outside • Ø 10 • 6

According to Swisscontact (2001), motor vehicle exhaust gases consist of non-toxic substances, such as: nitrogen (N_2), carbon dioxide (CO_2), and water vapor (H_2O) and toxic substances such as: carbon monoxide

(CO), hydrocarbons (HC), oxides of nitrogen (NOx), sulfur oxides (SOx), lead dust (Pb), and particulates. In motor vehicles, pollution comes from four sources, namely:

a. Exhaust pipes are the most important source (65-85 percent) and emit both burned and unburned hydrocarbons (HC), various nitrogen oxides (NOX), carbon monoxide (CO), and a mixture of alcohols, aldehydes, ketones, penic acids, esters, ethers, eoxides, peroxides, and other oxygenates.
b. The oil sump is the second source (20 percent), and emits hydrocarbons which are burnt or unburnt due to blowby.

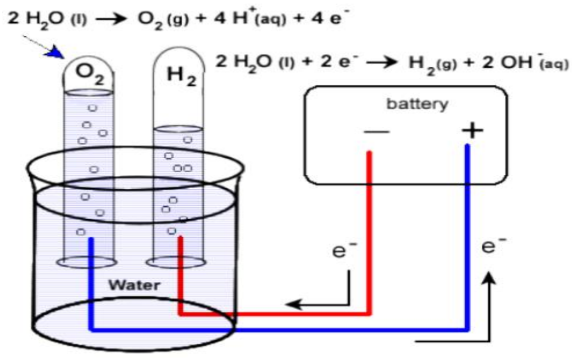

Figure 4. Process Electrolysis Water [11]

Figure 4 shows that electrolysis requires only four main components: batteries, electrodes, electrolytes, and water vessels.

a. The fuel tank is a hot weather-induced factor with a raw hydrocarbon vaporization loss (5 percent).
b. The carburetor is another factor, especially driving in stop and go positions in hot weather, with vaporization losses and raw fuel (5-10 percent) .

In internal combustion motors, the characteristics of the exhaust products from combustion in the combustion chamber are that if carbon monoxide (CO) decreases, oxides of nitrogen (NOx) will rise high while burnt hydrocarbons (HC) also increase although not as high as NOx.

Conventionally required energy of 286 kJ to produce 1 mole of hydrogen (H_2) or 2 gr H_2 equal to 24.287 liters of H_2, so to make 1 kg of H_2 required 39.72 kWh (Archer Energy System, Inc.) 1 kg of H_2 is equivalent to the energy of 1 gallon/3.78541 liters of gasoline. In the Global Hydrogen Inc. experiment report, it is stated that 4 kg of hydrogen can drive a vehicle for 270 miles.

2.2. *Power on HHO Generator*

To produce HHO gas using the water electrolysis process requires electrical energy. The source of the generator's electrical energy can be taken from a motorcycle battery. For this reason, it is necessary to know how much power is needed by the HHO generator. The formulation to find the required power is:

$$P = V \, x \, I \tag{1}$$

The potential difference is obtained using a voltmeter installed in parallel with the circuit and the electric current can be measured using an ammeter installed in series with the circuit during the test.

2.3. *Rate of HHO Gas Production (Mass Flow Rate)*

The main product of the water electrolysis process using an HHO generator is HHO gas. So to find out how well the HHO generator is performing, it is necessary to know how much HHO gas is produced by the HHO generator. To calculate the mass flow rate of HHO gas can be found with the following equation:

$$M = Q \, X \, \rho \tag{2}$$

$$Q = V/T \tag{3}$$

The measured gas volume is obtained from the gas measuring equipment that the researcher made with a plastic sheet made into a closed cylinder on one side without any leaks with a measuring volume and the gas production time is obtained from measuring time using a stopwatch starting from the 0 cc line until the gas fills the cylinder volume.

2.4 *Efficiency of the HHO generator (%)*

Efficiency is the ratio between useful energy and energy given to a system. The use of calculating the efficiency of an energy conversion device is to find out how optimal the device can work.

$$\eta = \frac{\Delta hf \times \dot{n}}{(V \times I)} \times 100\% \tag{4}$$

2.5 *Exhaust gas emissions*

Motor vehicle exhaust gases consist of non-toxic substances, such as: nitrogen (N_2), carbon dioxide (CO_2), and water vapor (H_2O) and toxic substances such as: carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), sulfur oxides (SOx), lead dust (Pb), and particulates.

When the mixture is poor, the HC concentration increases. This is due to the lack of fuel supply, causing the propagation of sparks to be slow and the fuel will soon escape before burning completely, and also in rich mixture conditions the HC concentration will increase due to the presence of fuel that has not reacted with air due to insufficient air supply to react completely, so there are some hydrocarbons that come out during the exhaust process.

3. RESULTS AND DISCUSSION

In this sub will be shown graphs and analysis of the data that has been taken on the neutral plate wet cell type HHO generator in the laboratory to select 10 grams of NAOH before being tested on a 4-stroke engine. What will be analyzed are the performance parameters of the HHO gas generator such as electric current, power, temperature, discharge, production rate and efficiency against the test time for 1 minute 60 seconds interval of 15 minutes with the same amount of NAOH 10 grams. From the analysis of the performance of the Wet cell type HHO generator and 8 neutral plates of 10 gram NAOH per 400 ml distilled water, the best will be tested on a 4-stroke engine. Tested on a 4-stroke 110 cc engine, data collection starts with a time of 1 minute / 60 seconds with a HHO gas production rate of 0.268-4 m^3/s and HHO Peat Water 0.1014 m^3/s.

3.1 *Fuel Pertalite + HHO water Aquades at efficiency*

Analysis of the HHO gas production rate and its efficiency from low to peak rotation is 158%, 162% and 170%, for the results of HHO gas efficiency after being calculated, namely; 0.268-4, 0.1176-2, 0.1219-2 m^3/s assuming the volume of the HHO flow rate is in the range of 40 m^3 / s, 42 m^3/s, and 43 m^3/s.

3.2 *Thermal efficiency and exhaust gas emission removal results CO, CO_2 and HC HHO Water Aquades*

At the time of testing at the initial rotation at 3000 to the end of 4000 rpm, the increase in thermal efficiency greatly affects the HHO flow rate and especially the final fuel disposal results, namely HC, where the increase in HC in the exhaust gas in Aquades water looks very efficient at the initial rotation at 2000 rpm where it produces thermal efficiency which is 60% then at 3000 rpm 35% and finally at 4000 rpm which is 15%.

From the influence of rpm and the unstable rotation of rpm causes the CO value in the exhaust gas of the vehicle to be unstable where at the time of reading the low rotation of 223.24 ppm, the middle 634.94 ppm and the top 606.89 ppm, it can be seen at the top of the value even decreases from the middle rotation. Therefore, it is calculated again as CO_2, namely 126.74 ppm, 249.24 ppm, and 841.33 ppm. Table 3 shows that the stability of the CO_2 sensor increases from beginning to end at 4000 rpm.

3.3 Pertalite Fuel + Peat water HHO at efficiency

Analysis of the HHO gas production rate and its efficiency from low to peak rotation is 156%, 158% and 162%, for the results of HHO gas efficiency after calculation, namely; 0.1014 m^3/s, 0.268-4 m^3/s and 0.1176-2 m^3/s. assuming the volume of the HHO flow rate is in the range of 39 m^3/s, 40 m^3/s, and 42 m^3/s.

In order for the research to successfully create hydrogen fuel, the next step is to calculate the specific fuel consumption, namely SFC (specific fuel consumption) where at 2000 rpm engine speed consumes 1.83 kg/kw.h fuel, at 3000 rpm consumes 2.1 kg/kw.h fuel and at 4000 rpm which is 2.44 kg / kw.h. testing is carried out equally in the range of 60 seconds or 1 minute with an initial amount of 3.5 liters of pertalite fuel.

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3.4. *Thermal efficiency and exhaust gas emission removal results of CO, CO_2 and HC HHO Peat Water*

At the time of testing at the initial rotation at 3000 to the end of 4000 rpm, the increase in thermal efficiency greatly affects the HHO liquefaction rate and especially the final fuel disposal results, namely HC, where the increase in HC in the exhaust gas in Aquades water looks very efficient at the initial rotation at 2000 rpm where it produces thermal efficiency which is 90% then at 3000 rpm 70% and finally at 4000 rpm which is 70%.

From the influence of rpm and the stability of the rpm rotation causes the CO value in the exhaust gas of the vehicle to be unstable where at the time of reading the low speed of 104.4 ppm, the middle 101.94 ppm and the top 121.29 ppm, seen at the top of the value is increasing from the initial round to the top. Therefore, it is calculated again in the form of CO_2, namely 126.74 ppm, 249.24 ppm, and 841.33 ppm. Table 3 shows that the stability of the CO_2 sensor increases from beginning to end at 4000 rpm for the Aquades Water electrolyte, while Peat Water in Table 4 is as follows.

Table 3. The Measurement and Calculation of Temperature Aquades Water

Aquades Water PH	**Test parameters**	**Engine rotation**		
		Idling	**Middle**	**Top**
	Time (60 second)	2000	3000	4000
of water in HHO (14)	HHO inlet water temperature (°C)	31.05	29.75	31.25
	Separator water temperature(°C)	26.25	26.25	25.25
	HHO gas efficiency (m^3/s)	0.268-4	0.1176-2	0.1219-2
	gas production rate HHO (%)	158%	162%	170%
NAOH (10 Gram)	HHO volume of water after 1 minute	5 ml	7 ml	8 ml
Separator (1.6 liter)	volume of the flow rate H_2	40 m^3/s	42 m^3/s	43 m^3/s
Aquades water (6)	Exhaust gas temperature(°C)	46.25	53.75	62.50
Peat Water + NaOH (14)	fuel flow rate	1.5 ml	4.5 ml	7.5 ml
2300 rpm after H_2 inlet	starting fuel	3.5 liter	3.5 liter	3.5 liter
	SFC + HHO kg/ kW.hour	0.108	1.22	3.99
	Exhaust gas emission test			
	CO (ppm)	223.24	634.94	606.89
	CO_2 (ppm)	198.62	1065.16	1211.46
	HC	40%	70%	80%
	Efisiensi Thermal	60%	35%	15%
	Volt HHO	9.5 Volt	2.40 Volt	2.35 Volt
	Current HHO	5 Ampere	5 Ampere	5 Ampere
	HHO power	48.5 Watt	39 Watt	34.5 Watt
	Starting Battery Power	9.8 Volt	7.69 Volt	6.96 Volt
	Final Battery Power	9.7 Volt	7.8 Volt	6.92 Volt

Table 4. The Measurement and Calculation of Temperature Peat Water

Peat Water PH	**Test parameters**	**Engine rotation**		
		Idling	**Middle**	**Top**
	Time (60 second)	2000	3000	4000
of water in HHO (14)	HHO inlet water temperature (°C)	32.5	32.75	33.25
	Separator water temperature(°C)	29.5	29.75	30.25
	HHO gas efficiency (m^3/s)	0.1014	0.268-4	0.1176-2
	gas production rate HHO (%)	156%	158%	162%
NAOH (10 gram)	HHO volume of water after 1 minute	4 ml	5 ml	7 ml
Separator (1.6 liter)	volume of the flow rate H_2	39 m^3/s	40 m^3/s	42 m^3/s
Peat Water (5)	Exhaust gas temperature(°C)	59.25	66.75	86
Peat water + NAOH (14)	fuel flow rate	3 ml	4 ml	5 ml
2500 rpm	starting fuel	3.5 liter	3.5 liter	3.5 liter
	SFC + HHO kg/kW.hour	1.83	2.1	2.44
	Exhaust gas emission test			
	CO (ppm)	104.4	101.94	121.29
	CO_2 (ppm)	126.74	249.28	841.33

Table 4. The Measurement and Calculation of Temperature Peat Water, continued

Peat Water PH	Test parameters	Engine rotation		
		Idling	Middle	Top
	HC	90%	70%	70%
	Thermal Efficiency	3%	24%	28%
	Volt HHO	2.45 Volt	2.5 Volt	2.25 Volt
	Current HHO	5 Ampere	5 Ampere	5 Ampere
	HHO power	38 Watt	38.2 Watt	34.7 Watt
	Starting Battery Power	7.6 Volt	7.64 Volt	6.95 Volt
	Final Battery Power	10.7 Volt	7.97 Volt	8.02 Volt

4. CONCLUSION

Based on the results of the research that has been done, conclusions can be drawn, among others, where the increase in HC in exhaust gas in Aquades water looks very efficient at the initial rotation at 2000 rpm where it produces thermal efficiency which is 60% next at 3000 rpm 35% and finally at 4000 rpm which is 15%. While in peat water, the increase in HC in the exhaust gas in distilled water looks very efficient at the initial rotation at 2000 rpm where it produces a thermal efficiency of 90%, then at 3000 rpm 70% and finally at 4000 rpm which is 70%.

From the effect of rpm and the unstable rotation of rpm, it causes the CO value in the exhaust gas of the vehicle to be unstable where at the time of reading the low speed of 223.24 ppm, the middle 634.94 ppm and the top 606.89 ppm, it can be seen that in the upper round the value even decreases from the middle round. While in HHO peat water when reading the low speed of 104.4 ppm, the middle 101.94 ppm and the top 121.29 ppm, it can be seen that in the upper round the value increases from the initial round to the top.

This can be explained where the pertalite + HHO Peat Water is smaller than the pertalite + HHO AQuades fuel as a result of these combustion conditions can produce greater energy and the flame speed that occurs faster resulting in the combustion of premium + peat fuel is more perfect than pertalite + HHO Aquades fuel and pure pertalite.

At 3000 rpm 35% and finally at 4000 rpm which is 15%. While in peat water the increase in HC in the exhaust gas in Aquades water looks very efficient at the initial rotation at 2000 rpm where it produces thermal efficiency which is 90% then at 3000 rpm 70% and finally at 4000 rpm which is 70%.

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