CHEMICAL ENGINEERING TRANSACTIONS
VOL. 82, 2020
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Bruno Fabiano, Valerio Cozzani, Genserik Reniers

ISBN 978-88-95608-80-8; **ISSN** 2283-9216
DOI: 10.3303/CET2082075

Generation of Oxyhydrogen Gas for Internal Combustion of a Minor Vehicle

Shaibert Abrahan Veramendi Caico[a], Carlos Alberto Castañeda Olivera[a], Jhonny Wilfredo Valverde Flores[a,b], Jorge Jave Nakayo[a], Verónica Tello Mendivil[a], Elmer Benites-Alfaro[a,*]

[a]Universidad César Vallejo, C.P. 15314, Lima 39, Perú
[b]Universidad Nacional Agraria La Molina, C.P. 15026, Lima 39, Perú
ebenitesa@ucv.edu.pe

In the research, an oxyhydrogen gas generating system was built and installed for use in a smaller vehicle. The aim was to check the ability to use oxyhydrogen gas as ecological technology in a 0.2 L internal combustion engine. A linear motorcycle was used for the study and the experimental tests were carried out in parallel with both gasoline and oxyhydrogen gas to compare its efficiency. The results showed yields of 10 km / sol and 92 km / sol for gasoline and oxyhydrogen gas, respectively. Furthermore, with oxyhydrogen gas a favorable reduction in the emission of polluting gases into the environment was found. Finally, the research shows that there are strong reasons to opt for the use of oxyhydrogen gas as an alternative fuel, and it could easily be adapted in vehicle engines.

1. Introduction

Air pollution and concern for the care of the environment encourage looking for new alternatives to find the best use of natural resources such as their use of energy for various human activities. There is an exponential growth in the use of energy and this has led to the use of fossil resources that have caused serious pollution problems that have been detrimental to human health, and climatic changes as a result of greenhouse gases. In this context, renewable energies arise as a good alternative because they are clean energies, they can be recycled, they make it easier to take care of the environment, they are obtained from inexhaustible natural sources (sun, biomass, water, air, etc.) that do not produce pollutants and are essential to face global warming and climate change.Motorized transport is a service widely used by the population and is an important source of contamination in the country and the world, making the use of renewable energy an economic and environmental advantage. Various technological and ecological studies reveal that hydrogen can be used in a dual way with gasoline in combustion engines, both are combustible agents, thus reducing the amount of carbon for combustion with excess air in the piston chamber and thus achieve a lower emission of polluting gases (Shin et al, 2019; Mehrjerdi, 2019; Turoń, 2020; Ugurlu and Oztuna, 2020).
Hydrogen is found in natural sources such as water and has a high probability of generating it with some feasibility. One of the methods is based on the electrolysis of water, so in the present research, hydrogen and oxygen were obtained separately and both were used for combustion in an Otto engine. This method of combustion generated fewer gaseous pollutant emissions compared to combustion by conventional fuels. Therefore, hydrogen is presented as an efficient alternative that implicitly includes the use of renewable energy, which is a scientific aspect still to be resolved and which offers many advantages in the face of the energy demand for transport fuels, which continues to be an indispensable means for the population. Hydrogen is an ideal energy carrier and is used as a fuel in electric vehicles, in heating or as an industrial raw material, and is identified as the best alternative for the transport sector and a high-grade heat source in industrial processes (Magyar A., 2014; IRENA , 2018; Jackson et al., 2020; Liemberger et al., 2018).
The on-board generation system of HHO gas to a vehicle reduced the consumption of fuel and polluting gases resulting from combustion (Cando and Quelal, 2012; Familiar, 2011; Göllei A., Görbe P., Juma et al., 2015;

Paper Received: 30 November 2019; Revised: 28 March 2020; Accepted: 30 July 2020
Please cite this article as: Veramendi Caico S.A., Castaneda Olivera C.A., Valverde Flores J.W., Jave Nakayo J., Tello Mendivil V., Benites-Alfaro E.G., 2020, Generation Of Oxyhydrogen Gas For Internal Combustion Of A Minor Vehicle, Chemical Engineering Transactions, 82, 445-450 DOI:10.3303/CET2082075

Quezada and Torres, 2014; Rogel, 2013; Sáinz, 2016). The weight of the material used for the hydrogen system as well as its autonomy are two characteristics that make it difficult to compete with a vehicle that runs on hydrogen with diesel (Casado, 2016).

2. Materials and Methods

The construction of the vehicle prototype called ShaibertOxi was carried out in a small vehicle workshop that is located in the district San Martin de Porres, Lima - Peru. For this, an oxyhydrogen gas generating system was needed.

2.1. Construction of the oxyhydrogen gas generating system

The oxyhydrogen gas generating system by means of electrolysis was built with acrylic material with dimensions of 10 cm wide, 32 cm long and a height of 18 cm. It contained electrodes for electrolysis, a cooling system, an electrical system, an electrical power source (battery) and switches (Figure 1).

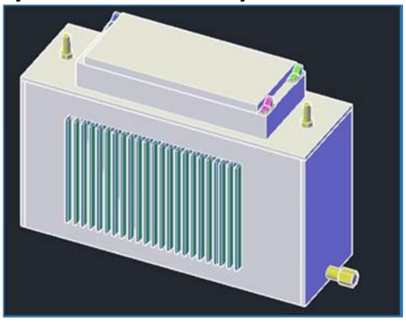

Figure 1. Oxyhydrogen gas generating device

a. Electrodes and installation of the oxyhydrogen gas generating system
The electrodes were made of 316L stainless steel, with dimensions 9.8 cm long, 15 cm high and 0.05 cm thick. The total of electrodes was 60 and were fixed in 4 groups of 15 with the distance necessary to generate the electrolysis within the oxyhydrogen gas generating device, as shown in Figure 2.

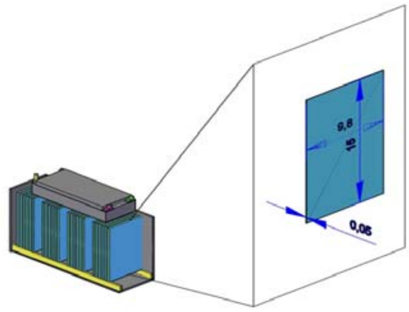

Figure 2. Fixing the electrodes inside the oxyhydrogen gas generating device

b. Cooling system
The cooling system of 22 cm x 14 cm was composed of aluminum, as shown in Figure 3. The purpose of this system is to cool the internal heat of the oxyhydrogen gas generating device, which is produced by the electrochemical reaction of water.

Figure 3. Heat sink

c. Device electrical assembly

The consumption of the device electrical system is 96 watts. It was located at the top and was covered by acrylic material in the shape of a box (Figure 4). Inside the box were 4 electric transformers from 5V / 3A and 6 electric transformers from 5V / 1.2A connected in series that allowed the electric current necessary to produce the oxyhydrogen gas to enter.

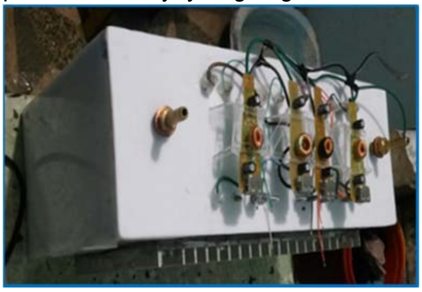

Figure 4. Device electrical system

d. Electric power source

The electrical power source consisted of an automotive battery 14 plate, 12 V, 80 A, and 960 watts of total delivery of stored energy (Figure 5).

Figure 5. Battery as an electrical power source

e. Installation of the light switches

Three light switches were installed for the device turning on procedure. The green color switch corresponded for the 4 transformers of 5V / 3A and the blue color switch for the other 6 transformers of 5V / 1.2A. Finally, the third switch is a direct connection auxiliary to certain electrolyzers, in order to meet the demand for the necessary oxyhydrogen fuel (see Figure 6)

Figure 6. Device light switch system

f. Route of the oxyhydrogen gas for the supply to the vehicle

In Figure 7, the path of the oxyhydrogen gas for supply to the vehicle is observed. The oxyhydrogen gas is sent through hoses to a 40 cm high, 7.6 cm diameter PVC pre-accumulator (highlighted in red), to subsequently supply the oxyhydrogen gas to the piston chamber, there is a security control (arrests flame) in the highlighted yellow color, that prevents the possible return of the flame, and in the box highlighted in green the connection of the hose to the modified carburettor is evident.

Figure 7. Route of the oxyhydrogen gas to supply the vehicle

2.2 Installation and adaptation of the oxyhydrogen gas generator system adapted to the vehicle

Figure 8 shows the oxyhydrogen gas generator system adapted to the vehicle with a 0.2 L engine. The pilot tests were carried out in order to demonstrate that the ShaibertOxi prototype is an economical and eco-friendly vehicle for consumption.

Figure 8. Adaptation of the oxyhydrogen gas generating system on board the vehicle

2.3. Evaluation of gases generated by combustion of gasoline

For the evaluation of the gases generated by combustion of gasoline and oxyhydric gas (66.6% H_2 and 33.4% O_2), 100 g of each fuel were used. In gasoline combustion, the gases evaluated were CO_2, H_2O and NO_2, while, for combustion with oxyhydrogen gas, the gases evaluated were H_2O and NO_2.
The chemical reactions of air and the combustion of gasoline and oxyhydrogen gas are shown in Equation 1, Equation 2 and Equation 3, respectively.

$$N2 \ + \ 2\,O2 \rightarrow 2\,NO2 \qquad (1)$$

$$C9H20 \ + \ 14\,O2 \rightarrow 9\,CO2 \ + \ 10\,H2O \qquad (2)$$

$$2\,H2 \ + \ O2 \rightarrow 2\,H2O \qquad (3)$$

To determine the excess oxygen, 200% of excess air was considered, as shown in equation 4.

$$200\%\,(\text{excess}\,O_2) = \frac{[O_2\ \text{incoming} - O_2\text{required}]}{[O_2\text{required}]} \qquad (4)$$

3. Results

3.1 Fuel consume per vehicle trip

Fuel consumption, either with oxyhydrogen gas or gasoline, is shown in Table 1. For this, an urban section of the city of Lima - Peru was considered, which included a distance of 121.9 km (round trip) located in the districts of San Martín de Porres (SMP) and Huaros.

Table 1. Fuel consumption per vehicle trip

Fuel type	start time	Origin	End time	Destination	Travel time	Fuel consumption
Gasoline	7:00	SMP	9:25	Huaros	2h y 25 min	3,78 L
	9:50	Huaros	12:20	SMP	2h y 30 min	3,12 L
oxyhydrogen gas	13:25	SMP	15:30	Huaros	2h y 5 min	0,250 L Water
	15:50	Huaros	18:00	SMP	2h y 10 min	0,242 L Water

From Table 1, a notable difference in gasoline consumption compared to oxyhydrogen gas was observed. Both outbound and return gasoline consumption was 3.78 L and 3.12 L, respectively. Meanwhile, water consumption was 0.250 L and 0.242 L, respectively. For the return sections (Huaros to SMP) the fuel consumptions (oxyhydrogen gas and gasoline) were lower than the fuel consumptions one way due to the fact that the route of the vehicle was downhill, and consequently less fuel consumption.

3.2. Vehicle speed performance

Table 2 shows the speeds reached by the vehicle with both gasoline and oxyhydrogen gas, considering different accelerations as evidence.

Table 2. Speed reached by the vehicle with gasoline and oxyhydrogen gas

Fuel	Acelerations	Revolutions per minute (rpm)	Mileage (km/h)
Gasoline	1	4000	80
	2	6000	100
oxyhydrogen gas	1	4000	70
	2	6000	80

According to the results shown in Table 2, the mileage achieved by the vehicle using oxyhydrogen gas as fuel (70 and 80 km / h) was less than that achieved with gasoline (80 and 100 km / h). This was due to difficulties in the production of oxyhydrogen gas and complications from the distance from the carburetor to the piston chamber. It was also observed that, with an acceleration of 6000 rpm, the vehicle with gasoline reaches 100 km/h, while with oxyhydrogen gas it reached 80 km/h due to certain problems in the installation system that were mentioned above.

3.3. Evaluation of gases generated by internal combustion

The mass balance of the combustion process for both gasoline and oxyhydrogen gas is shown in Table 3.
From Table 3, it was observed that from the gasoline burning of 100 g, there were concentrations of CO2 and NO2 with percentages of 6.1 and 19.7%, respectively. Meanwhile, the combustion of 100 g of oxyhydric gas had NO2 as the only contaminant with a percentage of 10.7%. Consequently, the values obtained indicated that the use of oxyhydrogen gas as fuel is very favorable due to its lower generation of polluting gases into the environment. The fuel used (oxyhydrogen gas) has water as its source and its price per liter is one tenth of the cost of conventional fuels obtained from fossil sources.

Table 3. Mass balance in the combustion process

Combustibles	Components	Input		Output	
		grams	Percentage	grams	Percentage
Gasoline	C_9H_20	100	2.0 %	---	---
	N_2	3950	77.4 %	3643.7	71.4 %
	O_2	1050	20.6 %	---	---
	CO_2	---	---	309.4	6.1 %
	H_2O	---	---	140.6	2.8 %
	NO_2	---	---	1006.3	19.7 %
	Total	5100	100%	5100	100%
oxyhydrogen gas	H_2	66.6	0.9 %	---	---
	N_2	5636.1	78.3 %	5417.6	80.4 %
	O_2	1498.2	20.8 %	---	---
	H_2O	---	---	599.4	8.9 %
	NO_2	---	---	717.9	10.7 %
	Total	7200.9	100%	6734.9	100%

4. Conclusions

The research showed that the use of oxyhydrogen gas in the internal combustion of a 0.2L engine is economical and eco-friendly with the environment. It was compared that for 100 grams of combusted oxyhydrogen gas, 10.7% of NO2 was produced as the only pollutant, while burning gasoline with the same amount revealed 19.7% of NO2 and 6.1% of CO2 as characteristic pollutants of the hydrocarbon combustion.

References

Cando, H., Quelal, H., 2012, Construcción y adaptación de un sistema generador de gas hidrógeno para suministrarlo a un motor de combustión interna. Universidad técnica del norte. Ibarra.

Casado Cerezal, D., 2016, Dimensionado y evaluación de un vehículo automóvil basado en una pila de combustible con almacenamiento a bordo de hidrógeno. Universidad de Valladolid, España.

Familiar Xaudaró, C., 2011, Inyección de hidrógeno como potencial mejora de los motores actuales. Universidad Politecnica de Cataluña, España.

Göllei A., Görbe P., Magyar A., 2014, Examination, Modelling and Simulation of Hydrogen Generation Cell for Complex Renewable Energy System, Chemical Engineering Transactions, 39, 409-414

IRENA (2018). Hydrogen from renewable power: Technology outlook for the energy transition, International Renewable Energy Agency, Abu Dhabi.

Jackson, C., Raymakers, L. F. J. M., Mulder, M. J. J., & Kucernak, A. R. J. ,2020, Assessing electrocatalyst hydrogen activity and CO tolerance: Comparison of performance obtained using the high mass transport ‘floating electrode’ technique and in electrochemical hydrogen pumps. Applied Catalysis B: Environmental, 268(November 2019), 118734.

Juma, D., Martínez, H. W., Erazo, G., & Castro, J., 2015, Diseño e instalación de un sistema de alimentación gasolina–hho en el motor de combustión interna del vehículo monoplaza tipo buggy del laboratorio de mecánica de patio de la ESPE extensión Latacunga. Universidad de las Fuerzas Armadas, Ecuador.

Liemberger W., Miltner M., Harasek M., 2018, Efficient Extraction of Helium from Natural Gas by Using Hydrogen Extraction Technology, Chemical Engineering Transactions, 70, 865-870.

Mehrjerdi, H. (2019). Off-grid solar powered charging station for electric and hydrogen vehicles including fuel cell and hydrogen storage. International Journal of Hydrogen Energy, 44(23), 11574–11583.

Quezada Romero, E. M., Torres Gualan, D. F. (2014). Implementación de un generador de hidrógeno de celda seca en un vehículo Chevrolet Steem 1.6 L (Bachelor's thesis).

Rogel Rivera, D. F. (2013). Análisis del funcionamiento del generador de Hho como optimizador de la combustión de un motor Otto. Bachelor's thesis, Universidad del Azuay, Ecuador.

Sáinz Casas, D. (2016). Adaptación de un motor de combustión interna alternativo de gasolina para su funcionamiento con hidrógeno como combustible. Aplicaciones energéticas y de automoción. Universidad Pública de Navarra, España

Shin, J., Hwang, W. S., Choi, H. (2019). Can hydrogen fuel vehicles be a sustainable alternative on vehicle market?: Comparison of electric and hydrogen fuel cell vehicles. Technological Forecasting and Social Change, 143(January), 239–248. https://doi.org/10.1016/j.techfore.2019.02.001

Turoń, K. (2020). Hydrogen-powered vehicles in urban transport systems-current state and development. Transportation Research Procedia, 45(2019), 835–841. https://doi.org/10.1016/j.trpro.2020.02.086

Ugurlu, A., Oztuna, S. (2020). How liquid hydrogen production methods affect emissions in liquid hydrogen powered vehicles? International Journal of Hydrogen Energy, In Press.