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Development and demonstration of pilot scale 50 liters H_2 production from swine farm in Thailand

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ABSTRACT

Hydrogen production using steam reformation from biogas as feedstock was designed, constructed and demonstrated. Biogas was gained from swine wastewater pond in Ratchaburi province, Thailand. This biogas was firstly cleaned by removing Hydrogen sulfide; H_2S, using Lo-Cat. Iron complex compound (Fe (III) EDTA) solution was reacted with hydrogensulfide ion. Then the complex compound was regenerated oxygen from the air. Carbondioxide was separated from biogas using molecular sieve as an adsorbent. The result showed that the outlet gas from cleaning system was comprised of methane 46.53% while H_2S was less than 100 ppm. Next step, hydrogen gas was produced by steam reformation reaction with Ruthenium 5% on Alumina as catalyst which operated at 700-800°C. The gas product is H_2 37.73%, CO 20.38% and CH_4 1.08% at the production rate of 50 liters per day.

KEYWORDS

Biogas;
Steam reforming;
Hydrogen;
Lo-Cat process.

INTRODUCTION

Hydrogen is fuel for future which be used in car engine and releases non-carbondioxide gas. Hydrogen can be changed to be electric energy through high-efficiency fuel cell for transportation. At the present time, Thailand has developed many kind of alternative energy include producing gases for substitute pure hydrogen in fuel cell. Steam reformation technique was used in changing those gases to be more proper gas and increasing efficiency for using in fuel cell or even in direct combustion. This will be another choice for alternative energy relating to Thailand developing energy road map.

The energy resource which was used for producing hydrogen gas by steam reformation in this case is methane. Methane is biogas produced by fermentation of biomaterials and bio-waste, including wastewater from swine farm and cassava plant. Since Thailand is agricultural country, the large amount of methane was produced in each day. Hydrogen producing from methane by steam reformation will be another way utilizing this kind of biogas.

Horikawa studied about the variables that affected the H_2S eliminating process from biogas by using Ferric Chloride solution reacted with EDTA at concentration of 0.2 molar[1]. The reaction could change reactant to be Ferric Chelate (Fe^{3+}-EDTA) which could react with H_2S absorbed by water from feeding biogas at the rate of 1000 ml per minute. The result found that the H_2S-eliminating efficiency was above 90%, at the ab-

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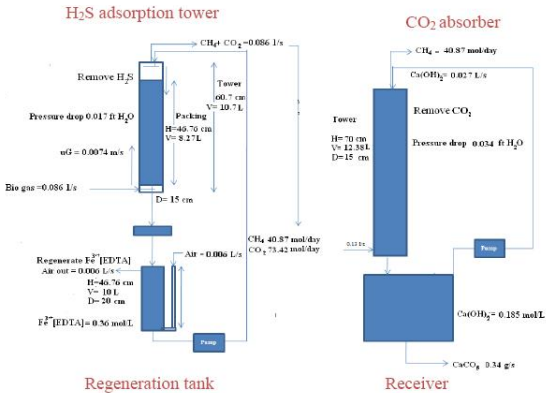

Figure 1 : The cleaning gas system for preparation of methane

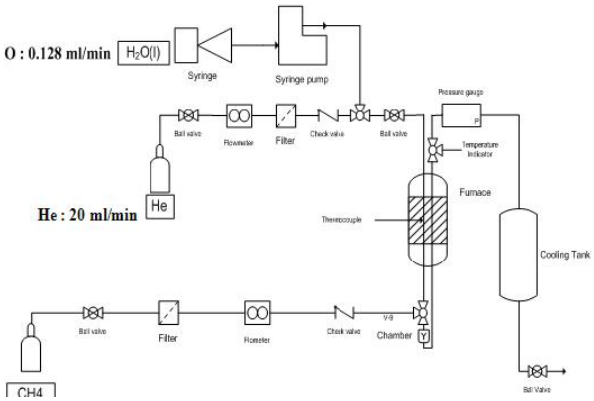

Figure 2 : The hydrogen production by steam reformation process

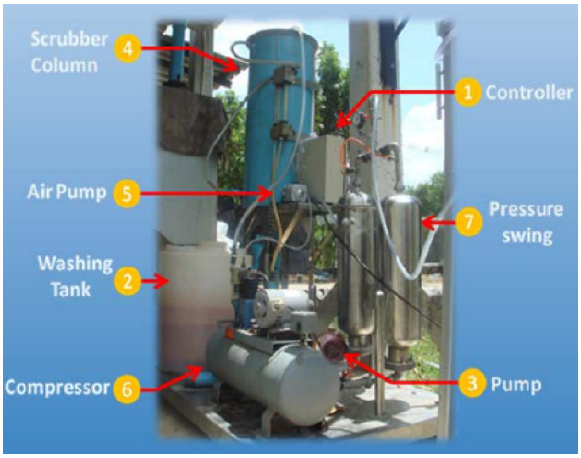

Figure 3 : The gas cleaning unit

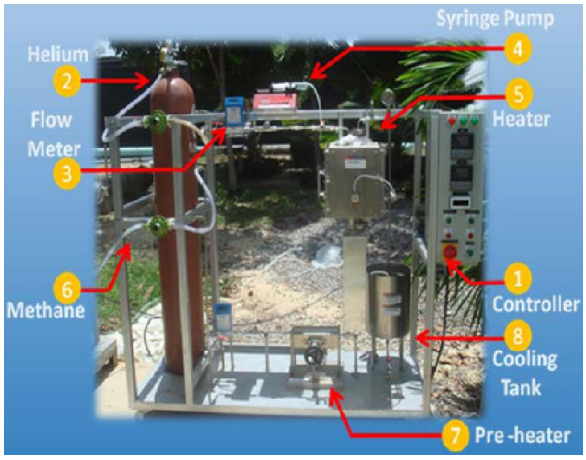

Figure 4 : The hydrogen producing unit

sorb rate of 83 ml per minute. This reaction had advantage that the Chelate solution would react with only H_2S, so there was no loss when regenerated.

By collaborating with Department of Alternative Energy Development and Efficiency, The developing and demonstrating of hydrogen production by steam reformation system from methane for using in fuel cell has been done. The pilot scale system which can produce hydrogen at the rate of 50 liters per day was developed, including hydrogen storage system with high pressure and cleaning system. Main compounds of the system will follow the concept of Hydrogen production from waste[2].

MATERIAL AND METHODS

Hydrogen production by steam reformation from methane consists of 2 vital parts; biogas cleaning and H_2 production, as follow:

Biogas cleaning process

This process had objective to eliminate hydrogen sulfide and carbon dioxide from biogas by using LoCat method. This method depended on redox reaction between sulfide-ion in water solution reacted with ferric-ion in water solution. The reaction can be shown as equations (1) and (2)

$$H_2S_{(g)} \rightarrow H_2S_{(aq)} \quad (1)$$

$$H_2S_{(aq)} + 2Fe^{3+}[EDTA]_{(aq)} \rightarrow S_{(s)} + 2Fe^{2+}[EDTA]_{(aq)} + 2H^+_{(aq)} \quad (2)$$

These reactions can reduce the chemical usage by redox reaction of Ferrous ion with oxygen (air) to Ferric ion back to reactor again[3]. The design for gas cleaning system consists of 2 processes. The first is hydrogen sulfide eliminating process and the second is carbon dioxide eliminating process. Conceptual design was done by commercial simulation named ASPEN Plus V. 7. The details of the system are shown in figure 1. All

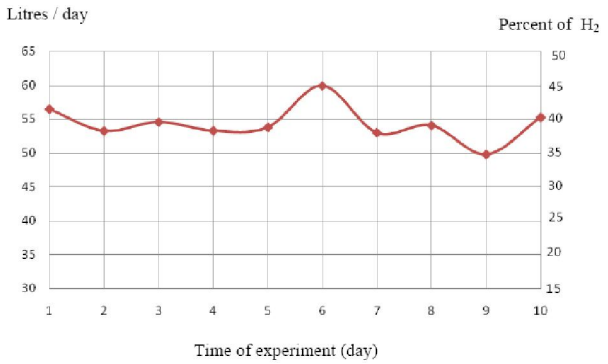

Figure 5 : The H_2 producing rate per day from 10 experiments, with the average of 54.33 liters

sizing equipments are re-calculated with common market supplies in order to suit for rural community.

Steam reformation process

After cleaning gas process, methane will be sent to steam reformation process. This process is the reaction between methane and steam at the temperature around 700-800°C by using Ruthenium as catalyst. The reaction can be shown as equation (3).

$$CH_{4(g)} + H_2O_{(g)} + (Heat) \rightarrow CO_{(g)} + 3H_{2(g)} \quad (3)$$

The design for this process, simulated from ASPEN, can be shown in figure 2.

The next step, the gas cleaning unit and hydrogen producing unit have been built up, as shown in figure 3.

Then, the hydrogen producing unit was constructed, as shown in figure 4.

RESULT AND DISCUSSION

The result of the cleaning gas process and reformation process testing can be shown as follow:

The result of the cleaning gas process

Since H_2 produced from biogas by steam reformation process needed to be cleaned before processing, according to large proportion of CO_2 and H_2S composed in gas, causing damage of apparatus. The result, the feeding biogas composed of methane 42.35%, CO_2 52.35%, air 5.3% and H_2S 100 ppm. After cleaning process by the method of LO-CAT and molecular sieve (Type A), the cleaned gas comprised of methane 46.53%, CO_2 44.87%, air 8.6% and H_2S less than 100 ppm. The gas feeding rate was 50 ml per minute, which was methane input at the rate of 33.5 liters per day.

The result of steam reformation process

The steam reformation process from swine-farming biogas by using Ruthenium 5% on Alumina as catalyst in atmospheric pressure and temperature of 700°C, operating time 100 hours, divided into 10 times (10 hours per each time). After the process, gas was analyzed by Gas Chromatography (GC) for H_2 composed in produced gas. The result is shown in figure 5, which could be calculated to H_2 producing rate.

The proportion of H_2 in product gas was about 37.73%, CO 20.38%, methane 1.08% and Helium (He) along with CO_2 was 40.81%. The H_2 production rate equaled to 54.33 liters per day on average, and gas flow rate was 0.1 liters per minute.

CONCLUSION

This article demonstrated the prototype of 50 liters hydrogen production. We used swine farm at Rachaburi that normal produced biogas as a testing site. The prototype comprised of biogas for power generator purification and hydrogen reformation by stream reforming. This prototype was designed as a mobile rig in order to connect to biogas producer directly. Purity and quality of hydrogen is sufficient for future use as fuel gas for combustion.

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