Biogas Desulfurizer Made from Waste of Aluminium Chips

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***Abstract*—Hydrogen sulfide (H_2S) is found in the biogas as an impurities. The existence of hydrogen sulfide in the biogas resulting problematic for using biogas as a fuel since it will increase the acidity of the lubricant of the engine. Hydrogen sulfide is a corrosive gas that can corrodes the steel tank of biogas container. Other serious problem concerning H_2S is, this type of gas is a harmful gas that should be avoided. This work introduces a technique to utilize aluminium chips waste that is obtained from manufacturing process. To make aluminium chips reactive to H_2S, the ion Al^{3+} should be released from the aluminium by galvanic coupling with iron in salt water. The iron uses for this purpose also come from the iron chips waste. It is found the more addition of iron chips in to the mixture of aluminium + iron the more reactive the aluminium as desulfurizer**

***Index Terms*—Aluminium, desulfurizer, galvanic coupling, hydrogen sulfide.**

I. Introduction

Hydrogen sulfide (H_2S) has to be removed before combusted to prevent environmental problem caused by emission of sulfur (S) compound, for reason of toxicity, and corrosion on equipment [1]. Foam formation was introduce in the early beginning for the removal of H_2S from the gas stream [1], but this technique was not attract the customer because the reason of simplicity, especially for the consumer from developing country.

A few years later Lee *et al.* [2] introduce method of sulfate-resistant *Acidithiobacillysthiooxidans* AZ11 for removal of H_2S. This technique also not much attract attention from the consumer because it was not easy to handle the bacteria for this process.

An interesting idea by utilizing waste was introduced by Yuan and Bandosz [3]. The waste that was used come from sewage sludge and metal sludge of various compositions. But this technique becomes not appropriate from economic point of view because the sludge should be pyrolysed at quite high temperature. Similar with work of Yuan and Bandosz [3], which is using waste for desulfurizer, Seredych [4] also using wastes i.e. fly ash for desulfurizer. But this technique become not popular since pyrolyses process is needed at higher temperature (950°C).

The idea of using natural product such as zeolite as desulfurizer was introduced by Cosoli *et al.* [5]. Zeolite is a mining product with reasonable price but not available every where. Only in certain region we can find zeolite sources from mining. Cost to delivery zeolite from mining location to the place of biogas installation could be another problem.

Recently the research on promoting metal chips waste as desulfurizer was conducted by Nindhia *et al.* [6]. By utilizing steel chips waste, the regenerative type of desulfurizer can be developed. This type of desulfurizer can be use repetitively and already successful as a component for conversion of gasoline to biogas fueled single cylinder of four stroke engine of electric generator that was invented by Nindhia *et al.* [7].

In manufacturing industry, the metal waste not only in the form of steel or iron but other type such as aluminium chips waste are much exist since many component of the engine are made from aluminium. Aluminium is not reactive to H_2S even though in the form of aluminium oxide as iron oxide in the case of iron. It is the purpose of this research to use the waste of aluminium chips as desulfurizer by using galvanic coupling method. Galvanic coupling is a potential difference that usually exists between two dissimilar metals when they are immersed in conductive solution. This potential difference produce electron flow between them [8] and metal ion will be released from one of the coupling. The metal ion is hopping will react with H_2S so that process of desulfurization to occur.

Fig. 1. Waste of aluminium (Al) chips.

II. Experimental

The waste of aluminium (Al) chips was obtained from metal manufacturing industry such as from turning or milling processes as depicted in Fig. 1. The particle size was ignored.

In order galvanic coupling to occur, the aluminium chips were mixed with iron chips. The iron chips were also obtained

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from waste of metal manufacturing industry as can be seen in Fig. 2. It was prepared 4 composition of mixtures (in wt. %) Namely: 100% Al, 75% Al+25% Fe, 50% Al+50% Fe, and 100% Fe.

The mixtures then are put inside water-salt solution (250 gram salt in 2 liters of water) for 2 days so that galvanic corrosion to occur. After 2 days in salt water the desulfurizer was taken out and installed as desulfurizer in the system of biogas pipe line. It should be noted that galvanic corrosion will not occur for the mixture of 100% Al and 100% Fe since only single metal that exist but indeed oxidation occur and will yield aluminium oxide for aluminium and iron oxide for iron.

Fig. 2. Waste of iron (Fe) chips.

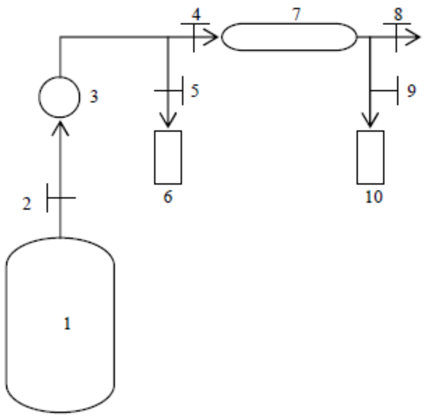

Fig. 3. Schematic of experiment for desulfurizer test performance: 1. Biogas container, 2.Valve, 3.Flow rate indicator, 4. Valve, 5. valve, 6. H_2S gas sensor, 7. Desulfurizer, 8. Valve, 9.valve, 10. H_2S gas sensor.

It was prepared about 500 gram of each mixture as desulfurizer and installed in the biogas pipe line system. The system was arranged with flow rate about 3 liters/minute. The performance of desulfurizer was evaluated by measuring the H_2S contents in the biogas before and after passing the desulfurizer as can be seen in Fig. 3. The performance of desulfurizer was measured for every 5 liters of biogas that passed the desulfurizer and was stopped until reach 50 liter.

The biogas was let flow from gas container 1 and the flow rate was controlled by using valve 2. The flow rate was checked by using flow rate indicator 3. To measure the H_2S contents in the biogas before entering desulfurizer, the valve 4 was closed and the valve 5 was opened and let the biogas flowed to the H_2S gas sensor 6. If the desulfurizer working well, then the H_2S contents in the biogas will decrease and can be measuredby closing valve 8 and open the valve 9 and let the biogas to H_2S gas sensor 10. The performance of desulfurizer then can be calculated by using Equation (1). The result will be presented in graft and analyzed.

$$\frac{H_2S\,\text{before desulfurizer} - H_2S\text{ after desulfurizer}}{H_2S\,\text{before desulfurizer}} \times 100\% \quad (1)$$

Laser-induced breakdown spectroscopy (LIBS) was utilized to proof that there is a residue of sulfur in the surface of aluminium and iron during use as desulfurizer of biogas.

III. Result and Discussion

The result is presented in the Fig. 4. It is found that by using 100% of aluminium chips the performance of desulfurizer is almost zero which is mean that the aluminium, if put in salt water will produce aluminium oxide (Al_2O_3) which is not reactive to H_2S and cannot act as desulfurizer. A Positive indication is found when small amount of iron chips is added (75% Al+25% Fe), the performance increase significantly which is above 50% in reducing amount of H_2S.

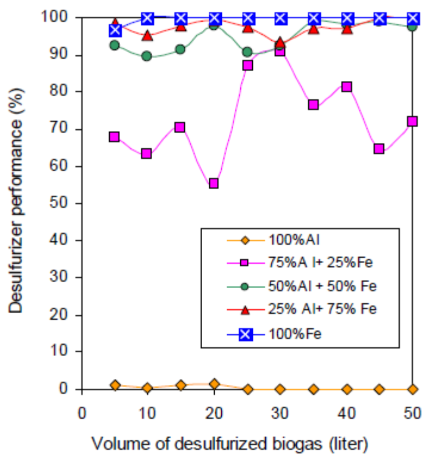

Fig. 4. Performance of aluminium as desulfurizer increase with addition of iron (Fe). Galvanic coupling occur and make aluminium more reactive to H_2S.

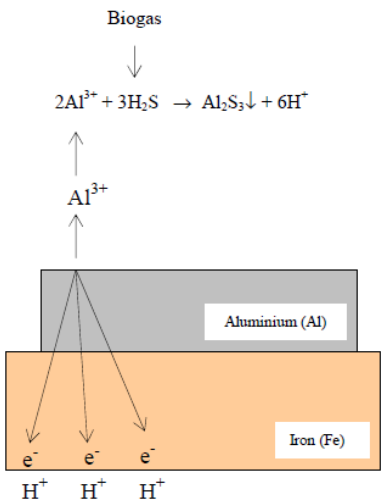

Fig. 5. Schematic reaction of ion Al^{3+} with H_2S from biogas.The ion of Al^{3+} release from surface of aluminium due to galvanic coupling with iron.

With addition of iron, so that a mixture of Al+Fe is obtained and if this mixture is put in electrolyte of salt water, this condition will make galvanic coupling to occur and aluminium will release the ion Al^{3+} as can be explained in Fig. 5. The ion Al^{3+} is reactive to H_2S as can be explain in the reaction in the Fig. 5. This reaction will eliminate the H_2S impurity in the biogas.

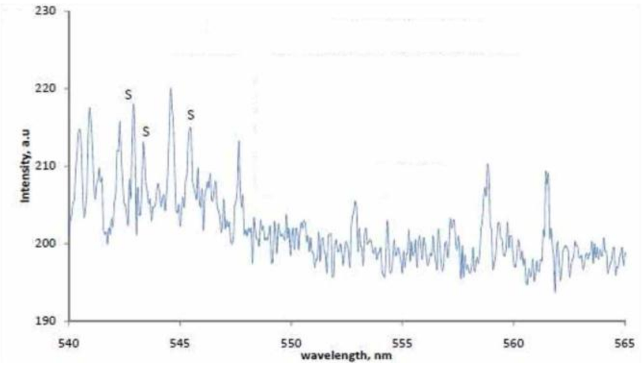

Fig. 6. The surface of aluminium in the micture of 75% Fe+25% Al. It was found containing sulfur which proof the ability of the aluminium to react with H_2S due to galvanic couplig to occur with iron (Fe).

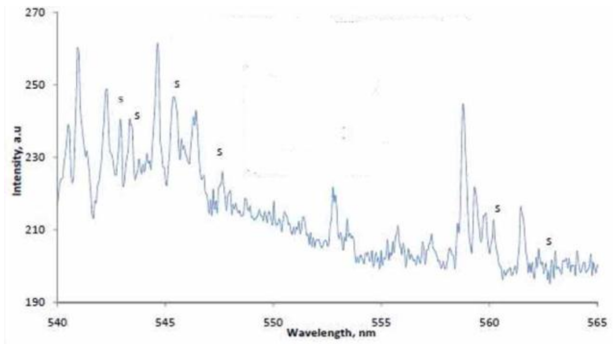

Fig. 7. The surface of iron in the micture of 75% Fe+25% Al. It was also found containing sulfur which proof that the reaction of $Fe(OH)_3$ with H_2S was also occurred.

It is interesting to discuses here that if the iron contents are increase to become 50% Fe and similarly happen with 75% Fe, the reactivity of desulfurizer increase very much and approaching value of 100% Fe. This condition is achieved because there are two reaction of desulfurization to occur *i.e.* reaction from Al^{3+}(proofed in Fig. 6 from LIBS result) and reaction from iron oxide ($Fe(OH)_3$). As mixture of Al+Fe is put in the salt water in order galvanic coupling to occur. There will be other reaction occur *i.e.* reaction of iron and salt water to form iron oxide $Fe(OH)_3$ (proofed in Fig. 7 from LIBS result). This iron Oxide is very reactive to H_2S [6], [7] as reaction in the (2) bellow:

$$2Fe(OH)_3 + 3H_2S \rightarrow Fe_2S_3 + 6\,H_2O \qquad (2)$$

IV. Conclusion

It can be concluded that the waste of aluminium chips is suitable to be used as desulfurizer. The aluminium chips should be mixed with iron in order the galvanic coupling to occur and release ion Al^{3+}. The ion Al^{3+} is reactive to H_2S. The galvanic coupling between Aluminium and iron can be done by mixing the aluminium and iron continued by put in the salt water as electrolyte.

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