Utilization of Welding Electrode Waste To Purify Biogas From Hydrogen Sulfide Impurities

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***Abstract*— The biogas desulphurization process has a crucial role in the widespread use of biogas due to the toxic and corrosive nature of the element hydrogen sulfide on equipment. This study investigated the potential use of waste welding electrodes as a biogas purification medium. Variables in the form of feed biogas flow rates of 1, 2, and 3 liters/minute were studied for their effects. As a result, the most optimum performance was obtained in the test with a feed biogas flow rate of 1 liter/minute, with an average reduction percentage of hydrogen sulfide content in the biogas of 27.12%.**

Keywords*— *adsorption, biogas, desulfurization, hydrogen sulfide (H_2S), welding electrode.

I. Introduction

The decomposition process of organic waste in an anaerobic digester, apart from producing dominant gases such as methane (CH_4) and carbon dioxide (CO_2), also produces hydrogen sulfide gas (H_2S) [1-2]. Although in relatively small amounts, the presence of H_2S in biogas needs more attention. This is because H_2S is a toxic compound with a pungent odor that can harm human health [3]. As an illustration, exposure to H_2S concentrations in humans starting from 2 ppm will cause headaches and eye irritation. In comparison, exposure to H_2S concentrations of 1000 to 2000 ppm will result in loss of consciousness and even death [4-5]. In addition, H_2S also causes corrosion in equipment [6-7]. Therefore, desulfurized technology plays a crucial role in increasing the efficiency of using biogas and ensuring user safety and equipment safety.

To minimize the potential dangers of biogas in general, European commissions have set standards regarding the maximum threshold for H_2S content in biogas of 20 mg/m^3 [3]. But in fact, the concentration of H_2S content in biogas resulting from the anaerobic decomposition process generally has a much higher value than the established quality standards, which range from 200 – 18000 mg/m^3 [8]. In response, many researchers have reported the results of investigations of various desulphurization techniques by considering the impact on the environment, such as the use of chemicals, energy consumption, and the resulting emissions [9], as well as costs incurred and accommodating local wisdom [10].

As the desulphurization process reported in most studies found, laboratory-scale investigations predominate. This indicates that selecting the most effective and efficient biogas desulfurization technique is still challenging for researchers. Several desulfurization techniques that have been proposed include: adsorption and absorption (chemical scrubbing) [11], aerobic and anaerobic bio trickling filters (BTFs) [12], anoxic desulfurization [13], biological bubble column [14], membrane bioscrubble [15], and photocatalytic desulfurizer [16]

Using waste as a medium for biogas purification is getting more attention from researchers [17-22]. In addition to considering the environmental impact, this is also aimed at obtaining an inexpensive purification medium that can be applied in small-scale desulphurization processes. For example, Apriandi et al., in a previous study [6], reported using grams of iron left over from the turning process as an H_2S adsorption medium in biogas with up to 82.56% adsorption effectiveness. Obis et al. investigated the use of bottom ash waste from the incineration process as an adsorbent [23], with a maximum H_2S removal of 72%. Meanwhile, Nindhia et al. reported the results of the adsorption of H_2S with adsorbents from battery waste carbon rods [19]. The carbon rod was activated using $KMnO_4$ with the result that the effectiveness of H_2S adsorption was up to 100%.

From the research reports above, optimizing waste as a biogas desulphurization medium is interesting for further study. The nature of H_2S, which is reactive towards metals (especially iron), provides a great opportunity for the application of waste containing iron as a purification medium, one of which is welding electrode waste which contains a film containing iron powder (Fe) with a concentration of 25% - 40% [24]. Therefore, in this study, an investigation and evaluation will be carried out regarding the use of waste welding electrodes as a medium for purifying biogas from H_2S elements as a base for the development of low-cost and environmentally friendly adsorbents so that later it is feasible to applied on a small scale.

Fig. 1. Waste welding electrode

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ISSN 0216-8685 (print); 2528-6889 (online)

II. METHODS

The material in welding electrode waste is cut to a size of 1-2 cm (Fig. 1). The piece of the waste electrode is then activated using a solution of $KMnO_4$ and water. The activation process was carried out by immersing the sample in a $KMnO_4$-water solution for 6 hours. 250 grams of activated electrode pieces were then put into an adsorption column made of PVC pipe with a diameter of 4 inches as a medium for H2S absorption. System schematic details of the biogas desulphurization equipment used are shown in Fig. 2.

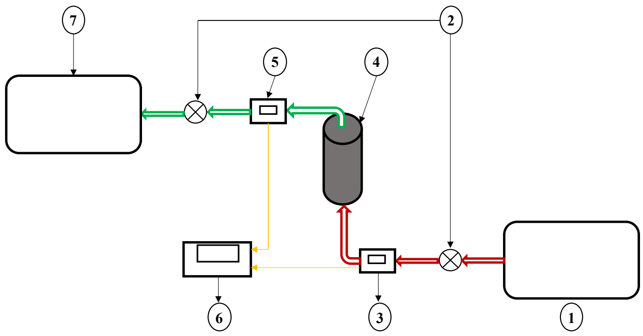

Fig. 2. Desulfurizer performance testing schematic : (1) biogas container before purification, (2) valve, (3) flow rate sensor, (4) desulfurizer, (5) H_2S gas sensor, (6) display of sensor readings, and (7) biogas container after purification

Biogas as much as 50 liters flowed at varied speeds (1, 2, and 3 liters/minute). The H_2S content in the biogas feed was first measured using an Arduino-based H_2S gas sensor 3 (three) measurements to get the average value of the H_2S content contained in the biogas to be purified. The composition of the H_2S content in the biogas after purification is measured and recorded. The performance of the biogas desulfurization system is calculated using Equation (1).

$$\frac{H_2S\ before\ purification - H_2S\ after\ purification}{H_2S\ before\ purification}\ x\ 100\% \qquad (1)$$

III. RESULTS AND DISCUSSION

Electrodes are materials used to do electric welding work, where these electrodes function as a burner that causes an arc to light up. In principle, electrodes can be divided into three groups, namely: (1) non-coated electrodes; (2) electrodes with a thin coating; and (3) thick-coated electrodes [24]. Generally, thick-coated electrodes are the type most widely used in the field. When the welding arc is lit, this coating will turn into a gas that will neutralize or reduce carbon monoxide (CO) or hydrogen (H_2) gas. The general properties of this electrode are moderate welding penetration, can be used on AC and DC currents, and film content in the form of iron powder (Fe) 25% - 40% [24].

Fig. 3 provides a visualization regarding the performance of a desulphurization tool made from welding electrode waste. Operating conditions during the test: carried out at ambient temperature (± 30°C), the initial H_2S content contained in the feed biogas was 89.1 ppm, and the feed biogas flow rates were 1, 2, and 3 liters/minute. The results of the analysis show that there is a trend of decreasing H_2S content after the purification process using an adsorbent in the form of pieces of welding electrodes that have been activated using a $KMnO_4$-water solution and put into the adsorption column for each variation of feed biogas flow rate.

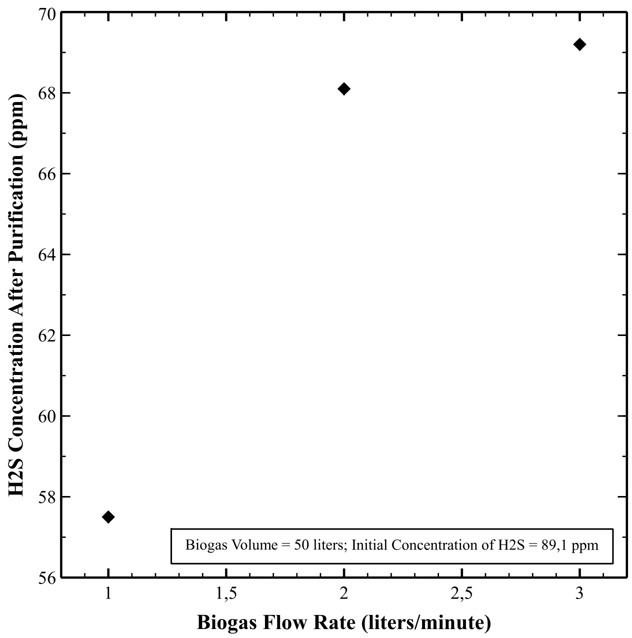

Fig. 3. H_2S content after desulfurization process

For each feed biogas flow rate, the amount of H_2S concentration that can be removed also has a different value. The biogas flow rate of 1 liter/minute performed best with the concentration of H_2S in the final biogas after the purification process of 57.5 ppm (from the previous 89.1 ppm before the purification process) or decreased by 31.6 ppm. The smaller the feed biogas flow rate will provide the higher the contact time between the biogas and the adsorbent [25], providing sufficient reaction time between H_2S-Fe and impacting the better the adsorption process [6].

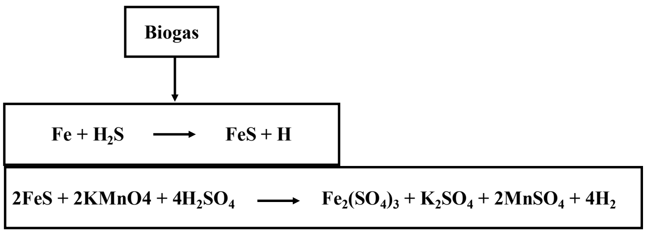

Fig. 4. Schematic of the reaction between Fe-H_2S-$KMnO_4$-H_2O

The activation process of waste electrodes with $KMnO_4$-H_2O solution significantly affects the adsorbent's ability to adsorb H_2S. Coupled with the very reactive nature of H_2S towards Fe, it also facilitates the reaction process, as shown in Fig. 4. Overall, the investigated welding electrode waste-based biogas desulphurization system has a fairly good performance with an average H_2S adsorption efficiency of 27. 12%. The system performance efficiency for each feed biogas flow rate variation is visualized in detail in Fig. 5, where the highest work efficiency of the system at 1 liter/minute feed biogas flow rate variation is 35.47%.

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ISSN 0216-8685 (print); 2528-6889 (online)

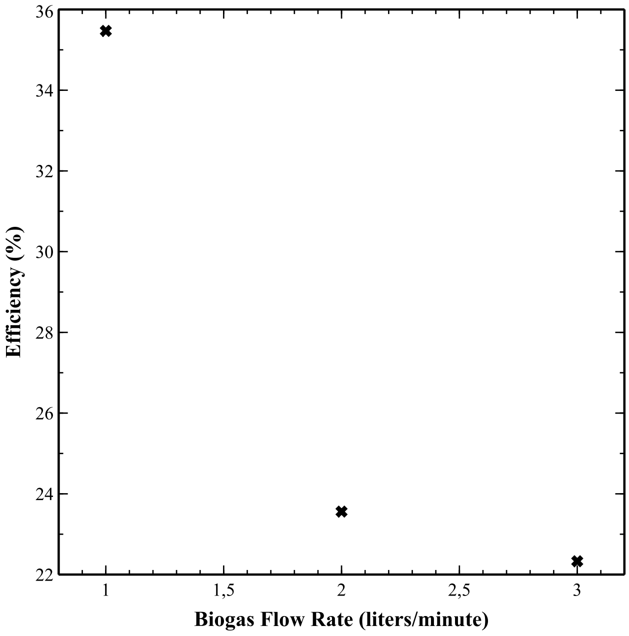

Fig. 5. Efficiency of the desulfurization system

IV. Conclusion

Waste welding electrodes can be used to make low-cost alternative sorbents in the biogas desulphurization process. Variations in the feed biogas flow rate in the biogas desulfurization process have a significant effect on the performance of the adsorbent in binding H_2S. The lower the feed biogas flow rate, the better the adsorbent's performance in the H_2S adsorption process.

Acknowledgment

The Applied Thermofluids Laboratory, Rowosari, Semarang, is gratefully acknowledged by the authors for providing measuring equipment support.

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ISSN 0216-8685 (print); 2528-6889 (online)