Biogas Desulfurization Using Iron Gram Waste Machining Practicum Process at The Department of Mechanical Engineering, Politeknik Negeri Semarang

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***Abstract*— The important matter about biogas as an alternative energy source was the presence of hydrogen sulfide (H_2S) which is very corrosive. The biogas desulfurization process was absolutely necessary to reduce the risk of damage to the equipment. For small-scale applications, the selection of the type of adsorbent became important to reduce additional costs. One alternative material that can be used was iron gram waste. The aim of this study was to investigate the use of iron gram waste resulting from the machining practicum process at the Department of Mechanical Engineering, Politeknik Negeri Semarang as an alternative material for making adsorbents. Iron gram waste was processed into Iron (III) Oxide (Fe_2O_3) and Iron (III) Hydroxide ($Fe(OH)_3$), formed into billets with an average billet mass of 250 gr. The performance test of the adsorbent in the biogas desulfurization process was carried out under conditions of variation in the flow rate of biogas feed 1, 2, and 3 liters per minute, and the volume of biogas purified in one process was 50 liters. As a result, the most optimum performance was obtained in the test with a feed biogas flow rate of 1 liter/minute, with a percentage reduction in H_2S levels contained in the biogas by an average of 82,56%.**

Keywords*— adsorption, biogas, desulfurization, hydrogen sulfide (H_2S), iron gram waste.

I. INTRODUCTION

Most of biogas ingredient were methane gas (CH_4) which ranges from 50-70%, carbon dioxide gas (CO_2) (25-45%), and hydrogen sulfide gas (H_2S), water vapor (H_2O), nitrogen (N_2) and hydrogen (H_2) as the rest [1]. From this composition, the gas ingredient in biogas can be used as a substitute for fuel was methane gas (CH_4). This means that the presence of other gases besides CH_4 in the biogas has the potential to reduce the efficiency of using biogas as a substitute for fuel. Moreover, the presence of highly corrosive H_2S in biogas can cause damage to the equipment used.

Biogas purification classified as a technology that refers to efforts to improve the quality of biogas, namely increasing the percentage of CH_4 ingredient by reduced or eliminated the ingredient of other impurity gases, such as CO_2, H_2S, and H_2O, in order to optimize the calorific value of biogas, and reduce the risk of damage (corrosion) on equipment [2].

The use of biogas as a substitute for fuel in everyday life, reducing (even eliminating) the H_2S ingredient in biogas was an absolute thing to do. In addition to reduce the potential damage to equipment due to corrosion, the H_2S ingredient in the biogas, if mixed, will cause smell and potential poisoning to users [3].

The technology for absorbing H_2S in biogas has been widely developed, be it physical, chemical, or physico-chemical. The materials used as sorbents also vary, which generally tend to use solid-type sorbents, both those that work with a physisorption mechanism or those that work with a chemisorption mechanism [4].

In the H_2S absorption process with a chemisorption mechanism, the solid sorbents used were generally made of various composite materials, for example the use of iron hydroxide [5], the use of zeolites [6], the use of laterite [7], the use of kaolin [8], the use of silica [9], and the use of carbon and other solid phases [10].

In recent years, the trend of biogas purification has led to the use of waste as a purification medium [11][12][13][14][15][16]. It aims to obtain a cheap sorbent material so that it can be applied on a small scale, namely the household scale. Nindhia, et.al. [12] investigated the use of waste Zinc (Zn) from batteries as H_2S absorption media. As a result, the use of 100% Zn can reduce the H_2S ingredient in the biogas significantly increase to 100%. In another study, Nindhia et.al. [3] investigated the use of iron waste from the turning process as an H_2S absorbent, where the results were also optimal, namely being able to eliminate H_2S levels in biogas increase to 100%.

Nindhia, et.al. [13] also reported the impact of using carbon rods from battery waste to purify biogas from H_2S ingredient. In his research, the carbon rods from the battery waste were activated using $KMnO_4$. As a result, H_2S is absorbed increase to 100%. Meanwhile, Pelaez-Samaniego et.al. [16] investigated the use of gasified tar waste as a medium for H_2S absorption and reported that tar waste from the gasification process has the potential to be used as an absorbent for biogas purification from H_2S.

Based on prior research, the use of waste as a medium for biogas purification is interesting to study further. Currently, the machining practice at the Mechanical Engineering Workshop Politeknik Negeri Semarang left waste in the form of iron gram as a result of the turning process, where the waste has the potential to be used as a biogas purification medium. Therefore, in this study, an investigation will be carried out regarding the use of iron gram waste as a medium for biogas

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purification in order to obtain a low-cost adsorbent so that later it is feasible to be applied on a small scale.

II. Methods

The preparation of adsorbents from iron gram waste followed the method carried out by Negara, et. al. [17] with several modifications. Spiral-shaped iron gram waste was used as the basic material for the manufacture of adsorbents. The iron gram waste was heated at a temperature of 900°C with the aim of eliminating residual stresses to facilitate the formation process, and cooled slowly afterwards. A total of 500 grams (with 250 grams each) of iron gram waste that has gone through the heating and cooling process naturally was molded and pressed to form billets. The billet that has been formed was put into a container filled with water and circulated with air to form air bubbles for 1 (one) hour. This series of processes will produce Iron (III) Oxide, Fe_2O_3, and Iron (III) Hydroxide, $Fe(OH)_3$, both of which are highly reactive to H_2S gas.

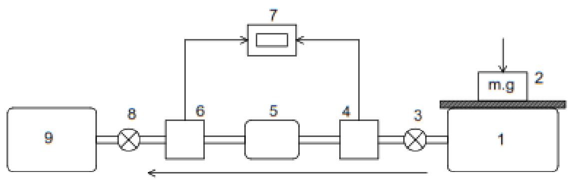

Fig. 1. Desulfurizer performance testing schematic : (1) biogas container, (2) loading system, (3) valve, (4) flow rate sensor, (5) desulfurizer, (6) H_2S gas sensor, (7) display of sensor readings, (8) valve, and (9) biogas container

The adsorbent in the form of billet made from iron gram waste was inserted into the pipe and 50 liters of biogas is flowed for each test process (Fig.1). The H_2S ingredient in the biogas feed was first measured using an Arduino-based H_2S gas sensor for 3 (three) measurements to get the average value of the H_2S ingredient contained in the biogas to be purified. The feed biogas flow rate was varied 1 liter per minute, 2 liter per minute, and 3 liter per minute. The H_2S ingredient after going through the purification process was measured, and the performance of the biogas purification system was calculated using Eq. (1)

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

III. Results and Discussion

The results of testing the initial H_2S ingredient contained in the biogas feed gave an average H_2S ingredient value of 71.2 ppm. Fig.2 showed that there is a trend of decreasing H_2S ingredient after the purification process using an adsorbent in the form of billets made from iron gram waste for each variation of the feed biogas flow rate. This result was also in agreement with those obtained by Negara [17] and Nindhia [3] who confirmed that grams of iron that have been processed into Iron (III) Oxide (Fe_2O_3) and Iron (III) Hydroxide ($Fe(OH)_3$) were reactive to gases H_2S ingridient contained in the biogas follows the schematic of the reaction as shown in Fig.3.

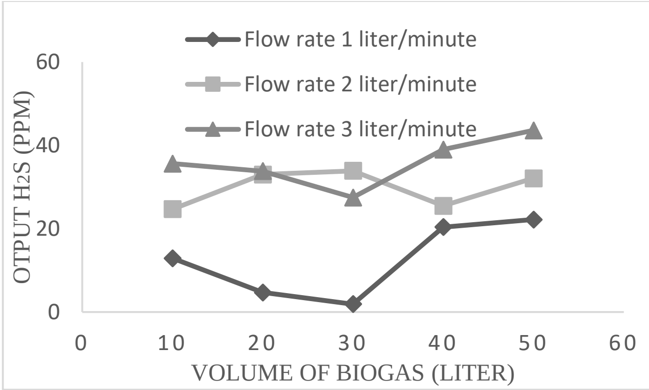

Fig. 2. Ingredient of H_2S after desulfurization process

Fig.2 also showed that, from tested with three variations of the feed biogas flow rate, the most optimum reduction in the H_2S ingredient contained in the biogas, respectively, was at the feed biogas flow rate of 1 liter per minute, 2 liters per minute, and 3 liters per minute, with the best H_2S ingredient output of 1.9 ppm at the condition that the volume of biogas fed is 30 liters. The low flow rate of biogas feed causes the contact time between the adsorbent and biogas to be longer, so that the adsorption process becomes more leverage [2].

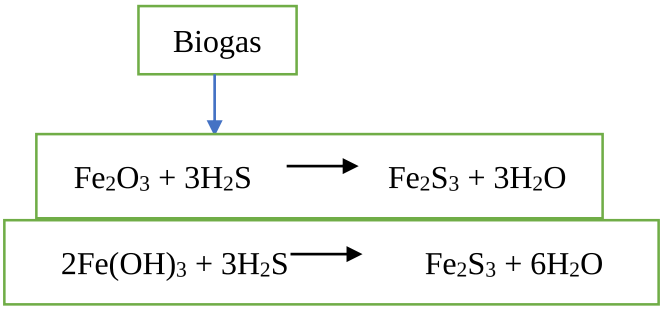

Fig. 3. Reaction schematic of iron (III) oxide (Fe_2O_3) and iron (III) hydroxide ($Fe(OH)_3$) with hydrogen sulfide gas (H_2S) contained in biogas

The performance of the biogas desulfurization process was depicted in Fig.4, where it can be explained that from testing with three variations of the feed biogas flow rate (1 liter per minute, 2 liters per minute, and 3 liters per minute) it affects the performance or affects the H_2S binding ability of the desulfurizer. The most optimum performance was obtained in the test with a feed biogas flow rate of 1 liter per minute, with the percentage reduction in the H_2S ingredient contained in the biogas by an average of 82,56% when compared to the average reduction in H_2S levels in the biogas in the test with The flow rates of biogas feed 2 liters per minute and 3 liters per minute are 71,29% and 49,58%, respectively.

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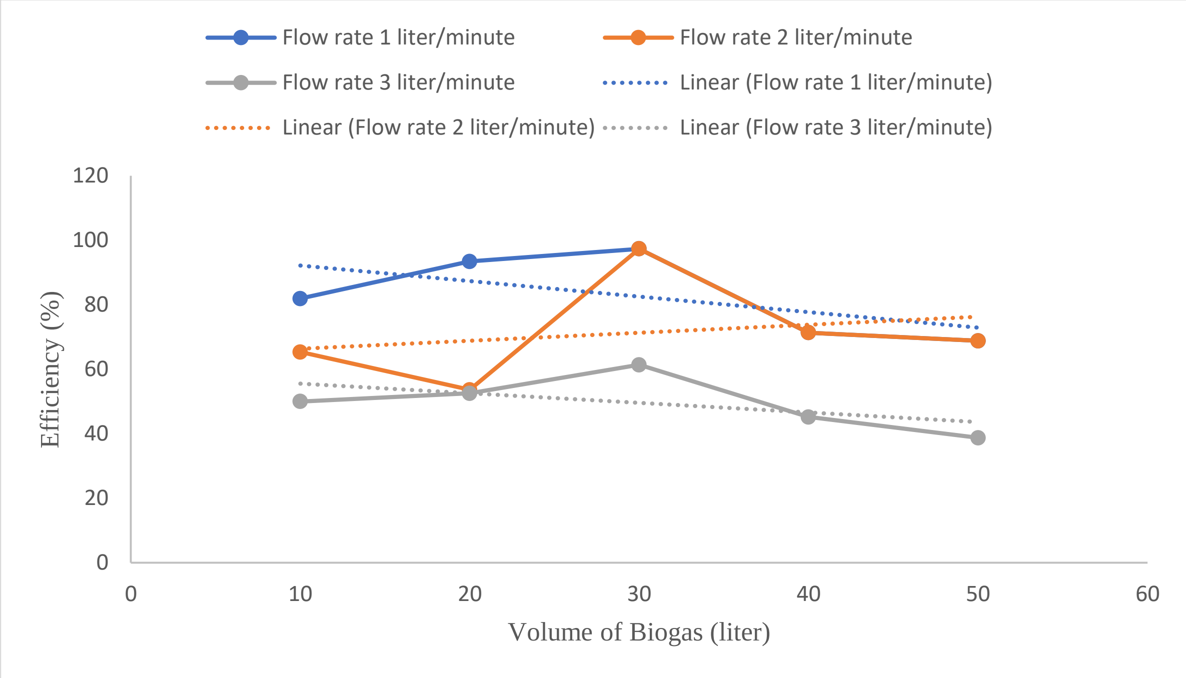

Fig. 4. The effect of variations in the feed biogas flow rate on the performance of a biogas desulfurizer made from irin gram waste

IV. Conclusion

The iron gram waste from the machining practicum at the Mechanical Engineering Department of the Politeknik Negeri Semarang can be used as a low-cost alternative sorbent making material in the biogas desulfurization process. The iron gram waste is processed into Iron (III) Oxide (Fe_2O_3) and Iron (III) Hydroxide ($Fe(OH)_3$) which were very reactive to the element H_2S. The variation of feed biogas flow rate in the biogas desulfurization process has implications for the performance of the adsorbent in binding H_2S. The lower the feed biogas flow rate, the better the performance of the adsorbent in the H_2S adsorption process.

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References

[1] N. Apriandi, “Analisa Biodigester Polyethilene Skala Rumah Tangga Dengan Memanfaatkan Limbah Organik Sebagai Sumber Penghasil Biogas,” *Orbith*, vol. 17, no. 1, pp. 23–29, 2021.

[2] N. Apriandi, I. G. B. W. Kusuma, and I. M. Widiyarta, “Pemurnian Biogas Terhadap Gas Pengotor Karbondioksida (CO2) Dengan Teknik Absorbsi Kolom Manometer (Manometry Column),” *Logic*, vol. 13, no. 1, pp. 55–60, 2013.

[3] T. G. T. Nindhia, K. M. T. Negara, I. M. Sucipta, I. W. Surata, I. K. A. Atmika, and D. N. K. P. Negara, “Performance of Repetitive Type of Biogas Desulfurizer Made from Steel Chips Waste,” in *Proceedings of the 2nd International Converence on Sustainable Technology Development*, 2012, pp. 63–69.

[4] A. G. Georgiadis, N. D. Charisiou, and M. A. Goula, “Removal of hydrogen sulfide from various industrial gases: A review of the most promising adsorbing materials,” *Catalysts*, vol. 10, no. 5. MDPI, May 01, 2020. doi: 10.3390/catal10050521.

[5] M. Lincke, U. Petasch, U. Gaitzsch, A. Tillmann, M. Tietze, and F. Niebling, “Chemoadsorption for Separation of Hydrogen Sulfide from Biogas with Iron Hydroxide and Sulfur Recovery,” *Chemical Engineering and Technology*, vol. 43, no. 8, pp. 1564–1570, Aug. 2020, doi: 10.1002/ceat.202000032.

[6] L. H. de Oliveira *et al.*, “H2S adsorption on NaY zeolite,” *Microporous and Mesoporous Materials*, vol. 284, pp. 247–257, Aug. 2019, doi: 10.1016/j.micromeso.2019.04.014.

[7] N. Thanakunpaisit, N. Jantarachat, and U. Onthong, “Removal of Hydrogen Sulfide from Biogas using Laterite Materials as an Adsorbent,” in *Energy Procedia*, 2017, vol. 138, pp. 1134–1139. doi: 10.1016/j.egypro.2017.10.215.

[8] A. H. Abdullah, R. Mat, A. S. A. Aziz, and F. Roslan, “Use of kaolin as adsorbent for removal of hydrogen sulphide from biogas,” *Chemical Engineering Transactions*, vol. 56, pp. 763–768, 2017, doi: 10.3303/CET1756128.

[9] Fahriansyah, Sriharti, and M. Andrianto, “Peningkatan Gas Metana dan Nilai Kalori Bahan Bakar Biogas Melalui Proses Pemurnian Dengan

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

Metode Tiga Lapis Adsorpsi Bahan Padat," *Jurnal Riset Teknologi Industri*, vol. 13, no. 2, pp. 182–191, 2019.

[10] Y. Suprianti, "Pemurnian Biogas untuk meningkatkan Nilai Kalor melalui Adsorpsi Dua Tahap Susunan Seri dengan Media Karbon Aktif," *Jurnal Elkomika*, vol. 4, no. 2, pp. 185–196, 2016.

[11] A. Widyastuti, B. Sitorus, and A. Jayuska, "Karbon Aktif Dari Limbah Cangkang Sawit Sebagai Adsorben Gas Dalam Biogas Hasil Fermentasi Anaerobik Sampah Organik," *JKK*, vol. 2, no. 1, pp. 30–33, 2013.

[12] T. G. T. Nindhia, I. W. Surata, I. D. G. P. Swastika, and P. Widiana, "Processing zinc from waste of used zinc-carbon battery with natrium chloride (NaCl) for biogas desulfurizer," in *Key Engineering Materials*, 2016, vol. 705, pp. 368–373. doi: 10.4028/www.scientific.net/KEM.705.368.

[13] T. G. T. Nindhia, I. W. Surata, I. K. A. Atmika, D. N. K. P. Negara, and I. P. G. Artana, "Processing Carbon Rod from Waste of Zing-Carbon Battery for Biogas Desulfurizer," *Journal of Clean Energy Technologies*, vol. 3, no. 2, pp. 119–122, 2015, doi: 10.7763/jocet.2015.v3.179.

[14] T. G. T. Nindhia, I. W. Surata, and R. Antara, "Pemanfaatan Limbah Cangkang Tiram Untuk Memurnikan Biogas Dari Pengotor Karbondioksida," *Buletin Udayana Mengabdi*, vol. 16, no. 1, pp. 128–132, 2017.

[15] S. M. Rambe and E. H. Sipahutar, "Rekayasa Adsorben Dari Limbah Serbuk Besi Untuk Penyerapan H2S Dalam Biogas," *Jurnal Teknik dan Teknologi*, vol. 11, no. 22, pp. 13–19, 2016.

[16] M. R. Pelaez-Samaniego, J. F. Perez, M. Ayiania, and T. Garcia-Perez, "Chars from wood gasification for removing H2S from biogas," *Biomass and Bioenergy*, vol. 142, Nov. 2020, doi: 10.1016/j.biombioe.2020.105754.

[17] K. M. T. Negara *et al.*, "Pemurnian Biogas Dari Gas Pengotor Hidrogen Sulfida (H2S) Dengan Memanfaatkan Limbah Geram Besi Proses Pembubutan," *Jurnal Energi dan Manufaktur*, vol. 5, no. 1, pp. 33–41, 2012.

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