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__ A Computational Fluid Dynamic Comparative Study on CO_2 Adsorption Performance using Activated Carbon and Zeolite in a Fixed Bed Reactor N Sylvia1, R Mutia2, Malasari1, R Dewi1, Y Bindar3, and Yunardi4 1 Chemical Engineering Department, Malikussaleh University, Lhokseumawe, Indonesia 2 Postgraduate Program, Chemical Engineering Department, Syiah Kuala University, Banda Aceh, Indonesia 3 Department of Chemical Engineering, Faculty of Industrial Technology, Bandung Institute of Technology, Bandung, Indonesia 4 Chemical Engineering Department, Syiah Kuala University, Banda Aceh, Indonesia Email: yunardi@unsyiah.ac.id Abstract.

The increasing emission of carbon dioxide to the atmosphere from various sources has become an issue of great concern all over the world due to its significant contribution to climate change. Carbon catch and capacity are commonly recognized as the major approaches to prevent carbon dioxide from entering the atmosphere. A number of CO_2 removal innovations have been accounted for, including retention, adsorption, layer partition, and microalgal fixation.

In this investigation, a Computational Fluid Dynamics (CFD) study was performed to explore the presentation of two adsorbents, coconut fiber ordered carbon and zeolite 13X in expelling CO_2 from a ceaseless gas stream in a fixed bed adsorption fragment. A CFD code ANSYS R18.2 was used to explore the impact of stream rate and bed stature on the CO_2 evacuation productivity and adsorption limit by fluctuating the bay feed speed and bed statures.

The aftereffects of the reproduction indicated that the most noteworthy CO_2 expulsion proficiency of 63.13 percent was seen when the gas streamed at a pace of 50 cm^3/moment to the section loaded up with the initiated carbon adsorbent of 10 cm in tallness. While in the zeolite adsorbent 13X, the most noteworthy CO_2 expulsion proficiency of 57.86 percent was likewise observed when the gas streamed at a pace of 50 cm^3/minute at the bed stature of 10 cm.

Introduction Indonesia is currently facing serious energy problems due to the high dependence on fossil fuels. In fact, the country has a huge potential for renewable resources originated from agricultural wastes for energy generation. It is estimated that the country is capable of producing a potential bioenergy of 50 GW, nevertheless, only less than 2 GW has been utilized up to now.

The Indonesian Science Institute has suggested using biogas to reduce the dependence on fuel import. Such consideration was based on its availability, low capital and operational costs, renewable sources and environmentally friendly energy. It is possible that it is delivered at modern or littler scope, biogas by and large comprises of CH_4

(50-75%), CO_2 (25-50%), and another minor number of gases.

__ Its calorific value ranges from 17,900-25,000 kJ/m3; for a comparison, natural gas (LNG) has a calorific value of 37,300 kJ/m3 [1].

It is clearly seen from the biogas organization that its primary disadvantage is its high substance of CO_2 which essentially diminishes its calorific qualities. Therefore, to use biogas as the wellspring of vitality, expulsion of CO_2 before use is required. There are various philosophies accessible for expelling CO_2 from biogas.

Regular advancements for expelling CO_2 incorporate water scouring, substance and physical cleaning, layers and Pressure swing adsorption [2]. New techniques have been additionally presented for the utilization of improving the nature of biogas, for example, CO_2 liquefaction and detachment, amine assimilation [3] and cryogenic refining [4].

Although such new development technologies provide better performance, its implementation on a small scale and in the developing countries is still not beneficial at the present time. Consequently, adsorption-based advances would suit the requirement for usage in the creating nations because of its low vitality required for recovery, simple to work, low- pressure drop, and easier to scale down.

With respect to the adsorbents, permeable inorganic materials, for example, zeolite 13X, zeolite 4A, bentonite, sub-atomic strainer, and enacted carbon have been used for this purpose [5, 6, 7, 8,9,10,11,12]. Every adsorbent has its own favorable circumstances and weaknesses, in any case, actuated carbon is anything but difficult to get ready from various wellsprings of rural biomass which is bounty in all aspects of Indonesia. The same case was also applied to zeolite and bentonite which are abundant in the local region.

CFD has been used to study the flow phenomena involving momentum, heat and mass transfer with the end goal of structure and enhancement of procedure hardware. Such a strategy is a reasonable instrument to be utilized when the procedure execution is directed by liquid elements. According to the current investigation, CFD is used to consider the adsorption wonders and adsorbent execution on the expulsion of CO_2 from a blend of CH_4-CO_2 [13,14] Two sort of adsorbents, initiated carbon and zeolite 13X, were utilized in the demonstrating of fixed-bed adsorption segment by differing the stature of the adsorbent bed and the gas stream rate entering the section. Harmony qualities of the CO_2 adsorption process were assessed by test the information with different isotherm models.

Materials and Method The present study modeled the adsorption section for isolating of CO_2 from a gas blend containing CH_4 and CO_2, utilizing coconut fiber enacted carbon and zeolite type 13X as adsorbents. Every adsorbent was having a similar molecule distance across of 0.0029 m, while the bed porosity (e) was set 0.39 for enacted carbon and 0.43 for zeolite 13 X, individually.

Table 1 introduced the calculation of the adsorption segment utilized in this investigation, while the displaying structure of the adsorption segment is appeared in Figure 1 [14]. All phases in the reenactment, including pre-preparing, handling and post-preparing were performed utilizing the Fluent Ansys R18.2. The feed stream rates were differed by 50 cm3/minute, 100 cm3/minute 150 cm3/minute 200 cm3/minute and 250 cm3/minute [14] while the bed stature was shifted with 6 cm, 8 cm, and 10 cm. Perceptions were taken on the evacuation effectiveness, adsorption limit and adsorption isothermal.

Table 1 Geometry of the adsorption column __ Geometry Height Diameter __ Adsorbent 50 cm 5 cm Filter - 5 cm

__ Figure 1. Geometry for the adsorption column being studied Results and Discussion The Computational Fluid Dynamics (CFD) concentrate on the recreation adsorption procedure of CO2 expulsion was finished by shifting the stream rate and section bed tallness for every adsorbent being utilized.

Table 2 presented results on CO2 removal efficiency and adsorption limit because of a variety of flow rate and adsorbent bed heigh. The conversation of these outcomes is introduced in the following sub-areas. Table 2. Results on CO2 removal efficiency and adsorption capacity due to a variation of flow rate and adsorbent bed height __ CO2 Removal Efficiency Adsorption Capacity RUN _ __ Flow Rate Bed Height (cm) (%) (mg/gr) (cm3/min) Activated Activated _ _ _ _ _Carbon _Zeolite _Carbon _Zeolite _ _1 _ _6 _57,66 _50,21 _10898,14 _6079,64 _ _2 _50 _8 _61,01 _53,82 _6446,13 _3643,53 _ _3 _ _10 _63,13 _57,86 _3614,14 _2491,81 _ _4 _ _6 _55,60 _47,18 _21033,27 _11431,92 _ _5 _100 _8 _58,93 _50,43 _12550,55 _6880,09 _ _6 _ _10 _61,02 _55,54 _8074,48 _4767,34 _ _7 _ _6 _53,44 _45,12 _30333,87 _16408,37 _ _8 _150 _8 _57,12 _47,06 _18314,2 _9662,89 _ _9 _ _10 _58,18 _51,85 _11780,52 _6747,03 _ _10 _ _6 _51,75 _41,34 _41194,89 _19062,49 _ _11 _200 _8 _56,02 _44,13 _23136,78 _11077,18 _ _12 _ _10 _56,67 _47,25 _15814,86 _9842,38 _ _13 _ _6 _48,49 _41,21 _46573,06 _25672,01 _ _14 _250 _8 _54,97 _41,47 _27956,2 _13048,70 _ _15 _ _10 _55,5 _43,24 _19490,6 _11885,53 _ _ The Effect of Bed Height to the CO2 Removal Efficiency From Table 2, it very well may be seen that the most elevated CO2 expulsion effectiveness acquired from the utilization of enacted carbon and zeolite adsorbents were 63.13% and 57.86%, individually, which happened at a flow rate of 50 cm3/minute and with a bed height of 10 cm.

__ Meanwhile, the lowest CO_2 expulsion effectiveness for actuated carbon and zeolite adsorbents were 48.49% and 41.21%, individually, which happened at a stream pace of 250 cm3/min and with a bed stature of 6 cm.

The outcome indicated that ordered carbon was having a higher ability to hold CO_2 stood out from that of zeolite 13X. The CFD aftereffects of this examination are in accordance with test results acquired by Chue et al [15] and Das et al [16], showed that the pore surface territory of initiated carbon is a lot higher than that of zeolite 13X.

Consequently, when activated carbon is used as an adsorbent, it can purge more CO_2 from a gas blend that different adsorbents of lower pore surface area. Figure 2 outlined the connection between stream rate and CO_2 evacuation effectiveness at various bed statures for each kind of adsorbent. This figure recommended that the CO_2 adsorption is a lot higher in the initiated carbon adsorbent and the adsorption rate increments with the expansion of the bed stature. In any case, the evacuation effectiveness diminishes as the stream pace of the feed to the segment expanded [17].

At the end of the day, the impact of stream rate on the adsorption limit is the more noteworthy the feed stream rate, the littler the adsorption rate will be. At the point when the more noteworthy CO_2 stream rate entering the segment, the less contact time among CO_2 and adsorbent will be, Consequently, the level of adsorption will likewise be littler.

Figures 3 to 5 show the shapes of the impact of the stream rate on adsorption rate utilizing zeolite 13X adsorbent, while Figure 6 to 8 shows the forms of the impact of the stream rate on the adsorption rate utilizing enacted carbon of coconut fiber adsorbent. activated carbon-zeolite Figure 2. The effect of adsorbent bed height on CO_2 removal efficiency.

From Figure 3 to 8, it very well may be seen that there is a shading contrast regarding speed in the adsorption section. The redder in shading delineated the higher the stream rate, while the bluer in shading showed the lower the stream rate entering the adsorption segment. The outcomes plainly demonstrated that at the higher bed the speed of the gas in the section diminishes, because of the expansion of the protection from the stream permitting more CO_2 to be held on the outside of the adsorbent.

__ / _ _(a) _(b) _(c) _ _Figure 3.

A contour of fluid flow rate at 50 cm3/minute (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm _ _/ _ _(a) _(b) _(c) _ _Figure 4. A contour of fluid flow rate of 100 cm3/min (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm. _ _/ _ _(a) _(b) _(c) _ _Figure 5. A contour of fluid flow rate of 150 cm3/min (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm _ _

__ / _ _(a) _(b) _(c) _ _Figure 6.

A contour of fluid flow rate of 50 cm3/minute (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm _ _/ _ _(a) _(b) _(c) _ _Figure 7. A contour of fluid flow rate of 100 cm3/min (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm. _ _/ _ _(a) _(b) _(c) _ _Figure 8. A contour of fluid flow rate of 150 cm3/min (a) bed height of 6 cm, (b) bed height of 8 cm, and (c) bed height of 10 cm _ _

__ From Figure 3 to 8, it very well may be seen that there is a shading distinction as far as speed in the adsorption segment.

The redder in shading delineated the higher the stream rate, while the bluer in shading demonstrated the lower the stream rate entering the adsorption section. The outcomes unmistakably indicated that at the higher bed the speed of the gas in the segment diminishes, because of the expansion of the protection from the stream permitting more CO2 to be held on the outside of the adsorbent.

The Effect of Flow Rate on Adsorption Capacity Figure 9 portrayed the connection between stream rate and adsorption limit in the two sections. It is seen that the most noteworthy adsorption limit of 46,573.06 mg/g happened in the section loaded up with actuated carbon adsorbent made of coconut fiber at a stream pace of 250 cm3/min and bed tallness of 6 cm.

Then, the most minimal adsorption limit of 2491.81 mg/g happened at the section loaded up with the adsorbent of zeolite 13X at a stream pace of 50 cm3/moment and bed tallness of 10 cm. It shows that the enacted carbon adsorbent is better when it is utilized for CO2 refinement process contrasted with that of zeolite 13X.

For this circumstance, it will in general be seen that the more significant the stream rate, the higher as far as possible, indicating that the higher the stream rate, the more CO2 particles will come into contact with the pore surface of the adsorbent so the adsorption limit increments [18, 19] as set apart by the red shading in the lighter piece of the permeable zone. activated carbon-zeolite Figure 9.

The correlation between flow rate and adsorption capacity in both columns Isothermal Adsorption Figures 10 and 11 showed the adsorption isotherm of carbon dioxide with different adsorbents, respectively. The adsorption data were fitted with standard isotherm models, including those of Langmuir and Freundlich. As to adsorption isotherm of carbon dioxide in initiated carbon, the Langmuir model appears to give a superior fit contrasted with that of Freundlich.

the condition and linearization results are likewise appeared in table 3. The linearity of Freundlich isotherm adsorption is higher than Langmuir isotherm. It shows the technique of CO2 adsorption with a started carbon of coconut fiber and zeolite 13X adsorbents is in a multilayer method. The adsorption strategy in activated carbon of coconut fiber happens on the grounds that it has CO2 adsorbing properties through N2 [20, 21, 22].

Plus, authorized carbon has a physical structure with a particularly hard granular shape causing it to can adsorb gas, while the adsorption method in zeolite 13X occurs considering the way that the zeolite 13X has an incredibly little and uniform pore size, high Si/Al substance, and Na content as a minor segment of the zeolite.

__ Figure 10. Adsorption isotherm of carbon dioxide in activated carbon adsorbent
Figure 1.

Adsorption isotherm of carbon dioxide in activated carbon-zeolite 13X Table 3. Parameter isotherm model via linearized technique for pressure 1atm and temperature 25°C

__ Conclusion The higher CO_2 removal efficiency and CO_2 adsorption capacity were produced by the adsorbent of activated carbon made of coconut fiber than that of zeolite 13X.

It shows that the relationship between adsorption rate and capacity are inversely proportional. The procedure of CO_2 adsorption using activated carbon and zeolite 13X is in multilayer one. Further research is still required to investigate the optimization of operating parameters with the aim at obtaining higher removal efficiency.

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