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Research Paper

Simulation and improvement of biogas process using monoethanolamine solvent

Hamed Salehi [1], Mirmohammad Khalilipour Langaroudi [2*], Farhad Shahraki [3]

[1] MSc student of Chemical Engineering, University of Sistan and Baluchestan, Zahedan, Iran
[2] Professor Assistant in Chemical Engineering, University of Sistan and Baluchestan, Zahedan, Iran
[3] Professor of Chemical Engineering, University of Sistan and Baluchestan, Zahedan, Iran

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1. ABSTRACT

Biogas is a sustainable energy source produced from organic waste which is mainly composed of methane and carbon dioxide. Raw biogas can be used to generate electricity, but since the energy content of biogas is directly related to methane concentration, it is necessary to improve the biogas and remove its carbon dioxide, and other impurities to inject it into the gas grid. This article represents biogas improvement process based on low-pressure steam compression, which is optimized with an expansion of the clean solvent exiting from the reboiler of the solvent recovery tower, and sending dense hot steam to the reboiler. Two common and optimal modes have been simulated by Span-Hasys software based on pure amine solvents. According to the simulation results, successful recovery of biomethane (above 99%) has been done for both processes. It was also found that the circulating solvent flow when its load is 14 times the biogas flow. The environmental analysis showed that the chemical absorption method for biogas improvement is a beneficial process for the environment, which thermodynamically is better to use its optimal structure. The obtained results showed an increase in the amount of carbon dioxide recovery, and a decrease in the heat load of the reboiler of the disposal tower to the amount of 3.62 GJ/t_CO2, which indicates a 28.74% reduction compared to the base process.

Keywords: Biogas, Simulation, Biomethane, Environment, Mono ethanolamine

2. INTRODUCTION

The release of carbon dioxide and detection of this phenomenon, which has recently led to an increase in global temperature and is still a problem worldwide, is of great importance. Therefore, a wide range of new strategies to reduce carbon dioxide emissions by absorbing and injecting carbon dioxide are promoted. Theoretically, the absorption and storage of carbon dioxide is considered as an effective method to continue using fossil fuels while reducing the emission of carbon dioxide in the air [1]. The use of fossil fuels has been dominant in the transportation sector, although renewable energy sources have been introduced into the energy market. According to the recent report of the 21st century renewable energy policy network, the share of global renewable energy increased to 20.5% in 2016. [2]. Examining the changes in the quantity and quality of air pollutants shows that pollutants resulting from human activities can aggravate this problem so much that it becomes impossible for humans and other creatures to continue living. Considering the growing trend of production and emission of these dangerous gases and the threat to the biological life of the planet, it is important to address this issue [3, 4].

3. MATERIALS AND METHODS

Optimum structure for biogas promotion is presented below in figure (1). Due to the similarities existing between biogas promotion and post-combustion of carbon dioxide, the optimal structure of weak vapor compression can be used. The low pressure of the adsorbent and the feed, the high concentration of carbon dioxide in the input feed, and the high rate of energy consumed are the similarities of both systems.

* a.khalilipour@eng.usb.ac.ir

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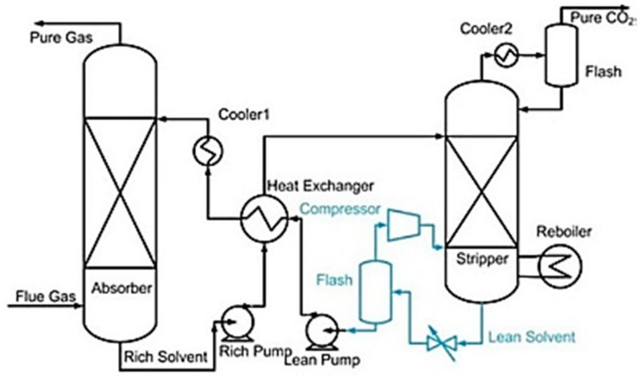

Figure 1. Schematic of the Optimal Process

The difference between the optimal structure and the conventional form of carbon dioxide absorption is in the changes that occurred in the solvent removal and recovery section. In the optimal process of Figure (1), the liquid exiting from the reboiler at high temperature is first flashed by a reducing valve and the steam and liquid resulting from the flash are separated through a vertical two-phase separator. The separation liquid in the optimal system is the weak solvent that must be compensated for the lost pressure by a pump and used again in the absorption tower, while the vapor above the separator is condensed again by a compressor to the operating pressure of the reboiler and at a higher temperature again. It is used in reboiler. The promotion of biogas process by chemical absorption method based on mono ethanolamine solvent in two common and optimal modes was simulated and analyzed using Span-Hasys software. Accordingly, in order to compare the performance of alkanolamine solvents used in the process, economic analysis was conducted to investigate functional costs and the effect of utilized solvents on the amount of energy consumption:

- Investigating the optimal structure of LVC to optimize the energy of the biogas purification process (Lean Vapor Compression)
- The design and improvement of the biogas process is aimed at determining the optimal chemical solvent for biomethane production.

4. RESULTS AND DISCUSSION

The optimization schematic of the integrated biogas improvement process is shown in Figure (2). Additionally, the simulation results are presented in Tables (1) and (2). The input biogas feed in ambient operating conditions (25 degrees Celsius and 1 atmosphere pressure) with a standard flow rate of 100 kmol/h (2761 kg/h) is from the fermentation of corn on the cob, which in all simulations is the flow rate, composition and its operating conditions are assumed to be the same in order to facilitate the comparison of conditions.

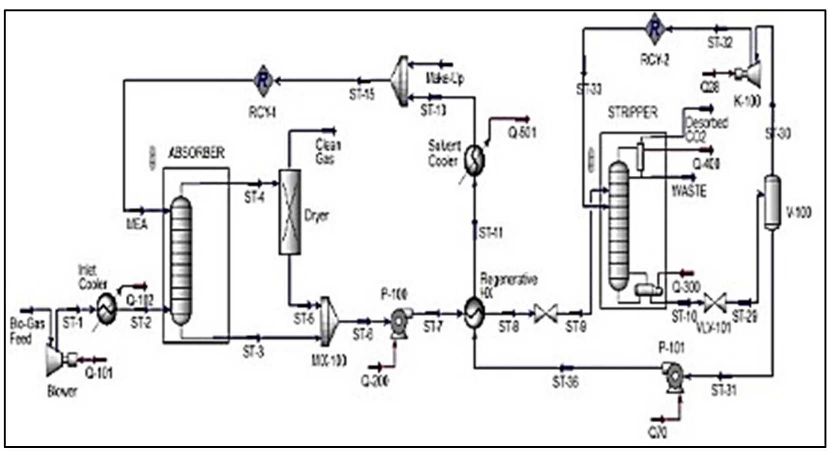

Figure 2. Schematic simulation of biogas improvement process based on mono ethanol amine solvent

Table 1. Biogas feed compositions based on mono ethanol amine solvent

Compounds	Molar Component
Methane	0.5
Hydrogen	0.05
Carbon dioxide	0.43
Nitrogen	0.02

Table 2. Energy balance results based on optimal mono ethanol amine solvent

Parameter	Value
Heat transfer rate in amine-amine heat exchanger ($\frac{kj}{h}$)	3647000
Solvent cooling duty cooler ($\frac{kj}{h}$)	4308000
Duty Compressor ($\frac{kj}{h}$)	183600
Reboiler Energy Consumption ($\frac{GJ}{h}$)	6.186
Energy consumption of the rich solvent pump ($\frac{kj}{h}$)	5842
Clean solvent pump energy consumption ($\frac{kj}{h}$)	3889

Table 3. Technical results (optimal mono ethanol amine)

Issue	Value
Ratio of flow rate of solvent to biogas $\left(\frac{L}{G}\right)_{Ratio}$	14
Clean amine loading	0.099
Dirty amine loading	0.5047
Carbon dioxide recovery percentage ($\frac{CO_{2,capt}}{CO_{2,in}}$)	90
Biomethane recovery percentage ($\frac{CH_{4,out}}{CH_{4\ in\ biogas}}$)	99.97
Intensity of solvent recovery energy ($\frac{GJ}{t_{CO2}}$)	3.62

The results obtained for simulating the process in two normal and optimal modes and based on the solvent of 30% by weight of mono ethanolamine indicate a high recovery of 99% of biomethane for both processes. Also, the circulating solvent flow rate was 14 times the biogas flow rate with a load of 0.099. The obtained results indicated a major difference in the amount of solvent recovery energy; In the optimal method by sending condensed steam in operating conditions of 190.4 C and 200 kPa pressure, the energy consumption of the reboiler of the disposal tower reached 3.62 GJ/t_CO2, which has decreased by 28.74% compared to the base process. The results presented in Table (3) indicate that the value of the Eregen parameter (solvent recovery energy intensity) for the optimal process is equal to 3.62, which shows a 28.74 percent reduction compared to the conventional process with MEA solvent. Therefore, when the LVC structure is used, the energy consumption decreases significantly. But due to the use of additional equipment such as compressor, pump and separator, firstly the price of the equipment, secondly the cost of utility and lastly the operating cost of the system has increased and finally the total production cost of biomethane has shown an increase of 13.38% compared to the conventional MEA process.

5. CONCLUSION

In this article, the promotion of biogas based on mono ethanolamine solvent in two common and optimal conditions by chemical absorption method with alkanolamine solvents has been simulated and investigated. From the tests conducted for pure amine solvents with amine activated by piperazine, the results indicated an increase in carbon dioxide recovery percentage from 90 to 94.58% when using activated diethanolamine solvent, which shows the high affinity of this solvent. It is used to absorb carbon dioxide gas and improve the selective absorption property of the base solvent. Investigations showed that the piperazine activator in combination with other solvents has a great effect in reducing the energy intensity of solvent recovery and also reducing the heat load of reboiler up to 6.3 and 1.7 GJ/h, respectively for the first type amine and the second one was activated, which directly affected the steam consumption and pump duty. According to the investigation, the LVC method has been able to greatly reduce the energy consumption for the recovery of the MEA solvent and put this solvent in a very favorable position in terms of energy.

6. REFERENCES

[1] IEA. IEABioenergy Task 37, Country Reports Summary, 2015.
[2] Network-REN21 REP, “Renewables Global Status Report,” REN21 Secretariat, Paris, 2018.
[3] Tybirk K., Solberg FE., Wennerberg P., Wiese F., Danielsen CG. Biogas Liquefaction and use of Liquid Biomethane, Status on the market and technologies available for LNG/LBG/LBM of relevance for biogas actors, BioGas, 2017.
[4] Angelidaki I., et al. Biogas upgrading and utilization: current status and perspectives, Bio technol Adv, 36 (2), pp. 452–466, 2018.