

Experimental investigation of carbon dioxide capture

^{1,*}Medisetty Venkata Manikanta, ²Chilakala Mahendra Reddy, ³Mangalapuri Rajesh, ⁴R. Kumar

^{1,3-4}School of Mechanical Engineering, Lovely Professional University, Phagwara

²School of Mechanical Engineering, Jawaharlal Nehru Technological University, Andhra Pradesh.

Abstract

Carbon dioxide is one of the greenhouse gasses that are imperative anthropogenic due to its increased excessive accumulation on annual basis. Objecting its further growth is nevertheless necessity in these stringent climatic situations. This study is mainly focused on the effect of nanotechnology on post combustion CO₂ absorption. The role of nonmaterial and nanoparticles has been studied in the present work. This study concluded with the higher thermal stability and exceptional properties of nonmaterial and their prominent role in stabilizing the environment. However, further research is needed to explore nonmaterial in real scale applications.

1.0 Introduction

Increase in the worldwide carbon dioxide emission and their impact on the environment has created a bottle neck situation for human survival. The increase in the environmental pollution is due to the discovery of conceivable comforts to meet the worldwide outflow targets. The nations are competing with each other to fulfil the target of developed nation throughout world. On this string of development numerous large scale industries, factories and companies are going on in a continuous manner ignoring the environmental factors. Otherside, national security concern has created a competition in the field of advanced weapon discovery and nuclear weapons which are dangerous for environment. Dependency on coal, oil and electricity is causing at massive levels such that world may not meet the surplus demand in future decades. Combusting and consuming of these fossil fuels are releasing hazardous gases to the earth's atmosphere. CO₂ holds the massive contribution of 77% from the world produced Green House Gas (GHG) emissions [1][2] Over the previous century, the possibility of environmental change is due to the anthropogenic carbon dioxide (CO₂) emission increasing by 39% from 280 ppm to the record level of 416 ppm by 2020 and it is expected to reach the significant level of 600 ppm to 1550 ppm by 2030 [3]. The present work deals with the study of implementation of nanotechnology in carbon dioxide capture processes and its future scope. Thus, the largest point sources of CO₂ emission are coal and natural-gas-fired power plants. Other large-scale industries are not exceptional in polluting the environment in the similar manner. Other hand, Gasoline based vehicles are also responsible for CO₂ emission in the present situation. Coal-fired power plants are continuously emitting huge amount of CO₂ per year. Three fundamental ways are derived to tackle this situation. Firstly, switching to the natural energy resources like solar power and nuclear power are proposed. Followed by, working on energy systems to improve efficiency of the consumption and the production as well. Final approach would be, effective

handling of generated carbon via capturing and storage techniques. At present, reduction in CO₂ emission and their impact on environment is a burning issue and consist of number of challenges. Thus, CO₂ capture and storage for useful purposes is highly essential in the present scenario. The researchers are working in this direction over period of time to create a balanced and pollution free environment. The main target in this zone is not only to reduce its level but also to balance the overall carbon dioxide concentration in the environment. However, there are different approaches to control the atmospheric CO₂ level to improve energy efficiency of plants. Still, there is a lack of a suitable and cost-effective system to capture CO₂. The main concern of decarbonization approach is to maintain a balance between supply and demand sides and thereby increase in energy efficiency. It is revealed from literature that the capture of carbon dioxide using various technologies is expensive [4].

2.0 Carbon dioxide removal techniques

Three basic techniques are involved to capture carbon dioxide viz. Pre-combustion, Post-combustion and oxy-fuel combustion clearly depicted in Fig 1. Researchers have already provided an overview regarding carbon dioxide capture and storage technologies [5]–[11]. Pre-combustion technology deals with the separation of CO₂ from syngas before entering any combustion chamber at higher pressure preventing to form further bonds with other gasses after the combustion. Polymeric membrane gained the attention for the filtration of gases passing through it in industrial applications. These permeable membranes allow fine gases pass through it while CO₂ such gases are restricted [12].

The post-combustion is the concept of separating carbon from the flue gas after the combustion of the fuel and the total process is depicted in Fig 1. The major advantage of this particular technology is its installation without interrupting the production process of any plant. However, it induces a penalty to the concerned plant by reducing its overall productivity. Any coal-fired power plant uses oxygen to perform the combustion process in which nitrogen also has some composition. This presence of nitrogen content in the oxygen dilutes the carbon dioxide concentration in the generated flue gas. In this context, sequestration of carbon dioxide is comparatively expensive [13]. Oxy-fuel combustion technology encourages the fuel gas to be recycled to perform the combustion process. This process of recycling generates composition of CO₂ and water. Condensation of water content helps us to capture and store the CO₂ directly without making any further process involved. However, there are more effective methods under development.

3.0 Experimental setup

The experimental setup on its whole works on regenerative principle. CO₂ cylinder at regulated flow is connected to the stripper column of 1000 mm height made up of stainless steel which was preinstalled with air filter at the top and two stages of ceramic rings consecutively to eradicate the gas from any impurities. All the components of experimental set-up are represented in Fig. 1.

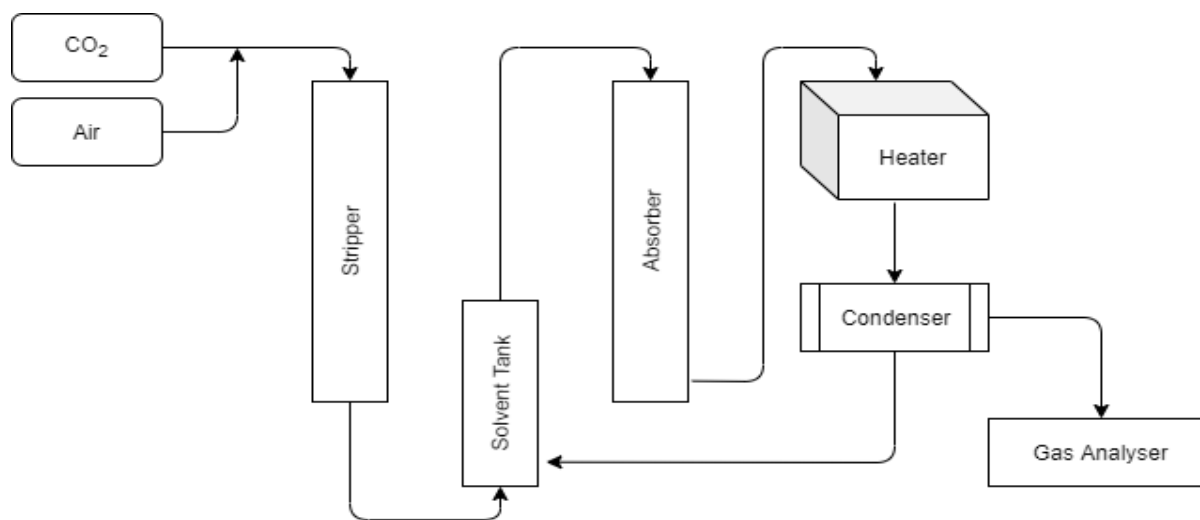


Fig. 1 Experimental arrangement

4.0 Results and discussion

Test-1 Observation

In this, the test rig was used for MEA solution. Table 1 represents the maintained flow rate of the solvent, air and carbon dioxide subsequently. The motive of this observation is to analyze the effect of flow rates on the captured CO₂ captured at the outlet. In this context, flow rate of the solvent and carbon dioxide is increased gradually from 10 litres per hour (LPH) to 18 LPH and 5 litres per minute (LPM) to 25 LPM respectively.

Table 1 Observation to capture CO₂ gas using MEA solution

Flow rate (LPM)			CO ₂ %		
Solvent (59.99 LPH)	Air	Carbon dioxide	In gas mixture	Captured through solvent	Total captured at outlet
10	15	5	65.0	30	35
12	15	10	66.70	42	24.7
14	15	15	67.70	43	24.7
16	15	20	68.0	43.5	24.5
18	15	25	68.5	44	24.5

Test-2 Observation

In the second test, the test rig was used for colloidal nano solution. Various compositions of aqueous MEA solution and colloidal silver nano (CSN) particles are used as shown in the Table 2 to stimulate the reaction properties of the resultant solvent. Whereas, flow rates of air and carbon dioxide is kept constant as 15 LPM and 5 LPM respectively. The main interest in this observation is to assess the effect incurred to the total captured CO₂ at outlet for changing the composition of the solvent.

Table 2 CO₂ capture v/s Aqueous MEA- Colloidal silver nano particles concentration

Aqueous MEA- Colloidal silver nanoparticles concentration	Flow rate (LPM)		CO ₂ %		
	Air	Carbon dioxide	In gas mixture	Captured through solvent	Total captured at outlet
Aqueous MEA (90%)+ Colloidal silver nanoparticles (10%)	15	5	66	32	34
MEA(85%)+ Colloidal silver nanoparticles (15%)	15	5	67	35	32
MEA(80%)+ Colloidal silver nanoparticles (20%)	15	5	67.5	37	30.5
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	5	67	37	30.

Table 3 CO₂ capture v/s flue gas flow rate

Aqueous MEA- Colloidal silver nanoparticles concentration	Flow rate (LPM)		CO ₂ %		
	Air	Carbon dioxide	In gas mixture	Captured through solvent	Total captured at outlet
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	5	63.5	35	28.5
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	10	64	36	28
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	15	66	36	30
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	20	67	37	30

Table 4 CO₂ capture v/s CO₂ loading on system performance

Aqueous MEA- Colloidal silver nanoparticles concentration	Flow rate (LPM)		CO ₂ %		
	Carbon dioxide	In gas mixture	Captured through solvent	Total captured at outlet	
MEA(75%)+ Colloidal silver nanoparticles (25%)	5	66.5	32	34	
MEA(75%)+ Colloidal silver nanoparticles (25%)	10	67	32.2	34.8	
MEA(75%)+ Colloidal silver nanoparticles (25%)	15	67.70	33	34.7	
MEA(75%)+ Colloidal silver nanoparticles (25%)	20	68	33.1	34.9	

In first observation, the test rig was used solely for MEA solution. The effect of air flow rate, solvent flow rate and gas flow rate on CO₂ gas capture was analyzed. As stated in the Table 2, flow rate of the solvent and

the carbon dioxide is increased gradually there by increasing the CO₂ percentage in the air mixture. We found 30% to 44% of carbon capture occurred relevant with the CO₂ percentage in the air mixture.

Similarly, second observation was made combining the MEA solvent with the varying compositions of colloidal silver nano particles. In this, CO₂ and air flow rates are kept at constant and the compositions of the MEA and Colloidal Silver Nano particles (CSN) are varied regularly. CO₂ capturing rate is increased gradually from 90%-10% (MEA-CSN) to 80%-20%, but the graph was plateaued from 80%-20% to 75%-25%. Again same test was continued by increasing the CO₂ flow rate from 5 Litres per minute (LPM) to 20 LPM where air passage is constant keeping the MEA-CSN composition at 75%-25% resulting the gradual CO₂ capture rate (Table 3). We tried by passing the similar test with the absence of air flow (Table 4). With slight difference, test conducted with air flow shown higher capture rate. The rate of CO₂ capture is shown with various conditions have been shown in figs. 2-5.

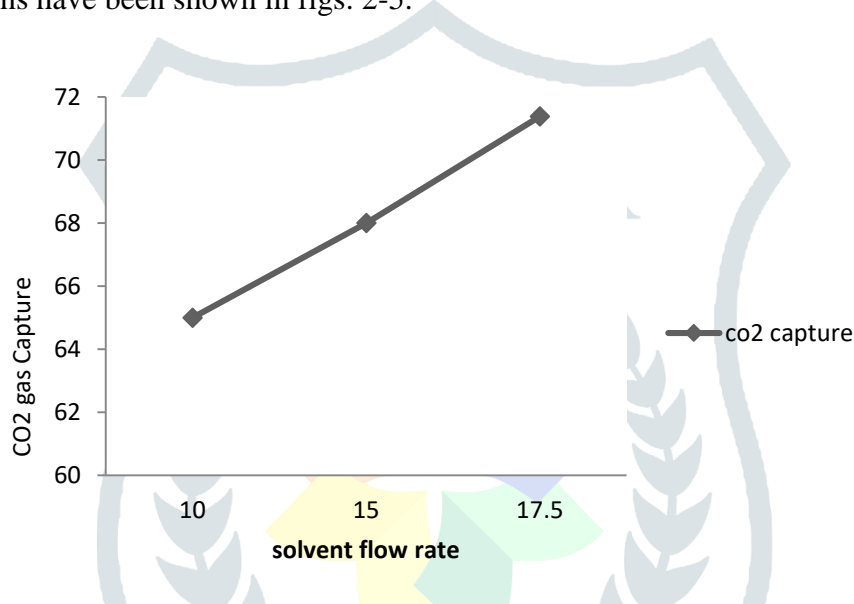


Fig. 2 CO₂ capture rate with MEA solvent

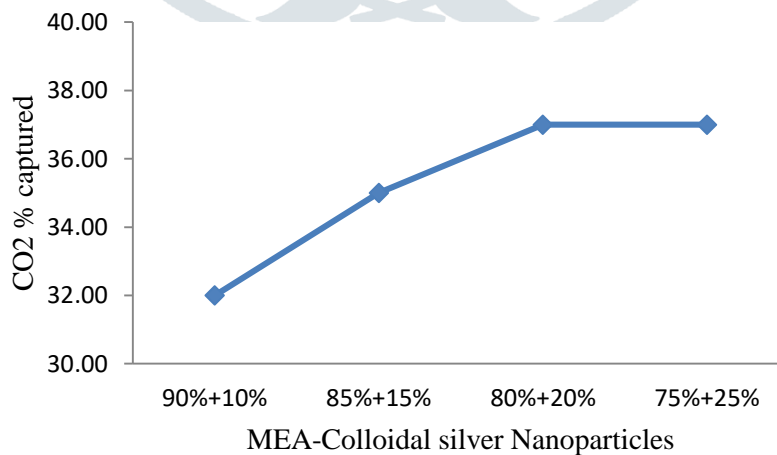


Fig. 3 CO₂ capture rate with MEA-CSN particles

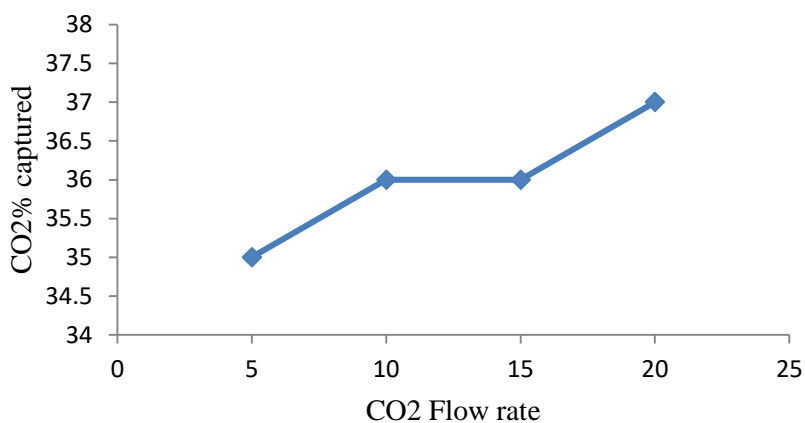


Fig. 4 CO₂ capture rate with MEA- CSN particles at constant air flow

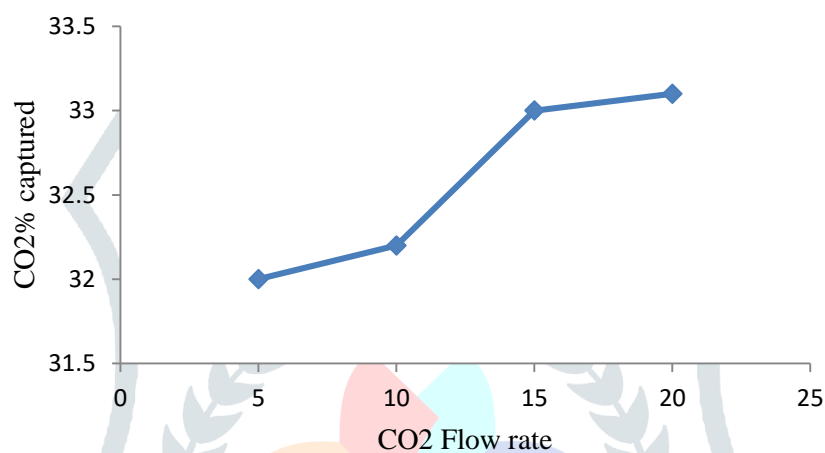


Fig. 5 CO₂ capture rate with MEA- CSN particles without air flow

5.0 Conclusion

Capturing carbon dioxide is broadly categorized as three segments namely, pre-combustion, post-combustion and oxy-fuel combustion. We dealt with post combustion technology using MEA solvent and CSN particles assessing the rate of CO₂ capture at different levels. Although MEA solvent alone gave the satisfied result, confining it with CSN particles has increased its reaction rate with the carbon dioxide more generating the tremendous results in the limited span. Also, it was notices that increasing in the solvent flow rate might increase the capturing rate but it was limited to some extent. In other words, exceeding the limit of the ideal solvent flow rate would not give sufficient time to make the reaction with the CO₂ gas. This may again cut down the raising graph.

References

- [1] F. Abdul *et al.*, "Pollution to solution : Capture and sequestration of carbon dioxide (CO 2) and its utilization as a renewable energy source for a sustainable future," *Renew. Sustain. Energy Rev.*, vol. 71, no. January, pp. 112–126, 2017.

- [2] N. Nakicenovic, "Special Report on Emission Scenarios," 2000.
- [3] E. S. Rubin, J. E. Davison, and H. J. Herzog, "The cost of CO₂ capture and storage," *Int. J. Greenh. Gas Control*, vol. 40, no. 2015, pp. 378–400, 2015.
- [4] D. Y. C. Leung, G. Caramanna, and M. M. Maroto-valer, "An overview of current status of carbon dioxide capture and storage technologies," *Renew. Sustain. Energy Rev.*, vol. 39, pp. 426–443, 2014.
- [5] A. Azapagic and R. M. Cue, "Carbon capture , storage and utilisation technologies : A critical analysis and comparison of their life cycle environmental impacts," vol. 9, pp. 82–102, 2015.
- [6] M. Wang, A. S. Joel, C. Ramshaw, D. Eimer, and N. M. Musa, "Process intensification for post-combustion CO₂capture with chemical absorption: A critical review," *Appl. Energy*, vol. 158, pp. 275–291, 2015.
- [7] M. A. Habib *et al.*, "Carbon capture by physical adsorption : Materials , experimental investigations and numerical modeling and simulations – A review," vol. 161, pp. 225–255, 2016.
- [8] T. Wang, J. Hovland, and K. J. Jens, "Amine reclaiming technologies in post-combustion carbon dioxide capture," *JES*, pp. 1–14, 2014.
- [9] A. Goli, A. Shamiri, A. Talaiekhosani, N. Eshtiaghi, N. Aghamohammadi, and M. Kheireddine, "An overview of biological processes and their potential for CO₂ capture," *J. Environ. Manage.*, 2016.
- [10] Z. Zhang and D. Huisingh, "Carbon dioxide storage schemes: Technology, assessment and deployment," *J. Clean. Prod.*, pp. 1–25, 2016.
- [11] R. W. Baker, *Gas Separation*. 2004.
- [12] B. J. P. Buhre, L. K. Elliott, C. D. Sheng, R. P. Gupta, and T. F. Wall, "Oxy-fuel combustion technology for coal-fired power generation," *Prog. Energy Combust. Sci.*, vol. 31, no. 4, pp. 283–307, 2005.