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FEASIBILITES OF USING POWER ULTRASOUND AND MICROWAVE TREATMENT IN REDUCING CO_2 CAPTURE ENERGY DEMAND

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ABSTRACT

Carbon dioxide gas is the most important Green House Gas (GHG) responsible for 64% of global warming. CO_2 capture process consumes 25-40% of total energy produced from coal-fired power plant. Hence, the energy required to operate CO_2 capture systems reduces the overall efficiency of power generation. A central concern of future research activities in the field of carbon capture is the reduction of energy demand for solvent regeneration. Present study encompasses use of alternative technology for solvent regeneration. In this study, power ultrasound and microwave energy, two different solvent like baseline MEA and low enthalpy Potassium Carbonate is used for solvent regeneration. pH is used as a good indicator of lean and rich condition of the solvent. From the experimental investigation, a promising solvent regeneration trend was observed using the above two alternate techniques. However, microwave treatment provides better performance in the form of high solvent regeneration capacity, with low nominal power input and less time consumption.

Keywords: *CO_2 Capture, Desorption, MEA, Potassium Carbonate, Power Ultrasound,*

I. INTRODUCTION

A greenhouse gas (GHG) is a gas in the atmosphere that absorbs and emits radiation within the thermal infrared range. The primary greenhouse gases in the Earth’s atmosphere are carbon dioxide, methane, nitrous oxide and ozone. The total greenhouse gases constitute 82% of CO_2. CO_2 emissions mainly comes from combustion of carbon-based fuels, principally wood, coal, oil, and natural gas. Over the last 50 years, CO_2 emission rate has been increasing at the rate of 0.25 ± 0.21%/year [1].

Carbon dioxide (“CO_2”) emissions due to combustion of fossil fuels have already resulted in a roughly 1˚C rise in global surface temperatures, and continued emissions threaten the very climate on which human livelihood depends. At the same time population and economic growth in the developed and developing worlds are expected to lead to a doubling of global energy use in the next few decades. Aggressive technological innovation, operating in concert with policy incentives, will be required to meet growing energy demand while stabilizing atmospheric concentrations of CO_2 at safe levels [2]. It has been observed that major contribution of it emission from fossil fuel combustion. Fossil fuels is used in various sector ranging from electricity and heat generation, transportation sector, Industrial sector generation to residential household with 43.9% contribution by the electricity and heat generation sector, as shown in Fig. 1.

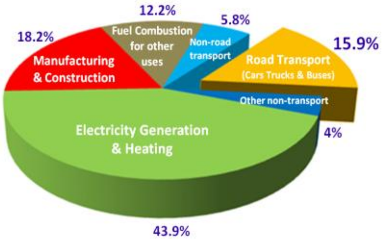

Fig. 1. CO_2 Emissions from Fossil Fuel

The capture of CO_2 plays a major role to mitigate the environmental pollution. Much research has been done on different types of sorbents that can be used in direct air capture, and many of the proposed substances carry both pros and cons. In “Pilot Plant Study of Carbon Dioxide Capture by Aqueous Mono Ethanol Amine (MEA)” Conducted at University of Texas, Austin (2006), CO_2 was captured using MEA solution [3]. Although MEA has many advantages like low cost, high solubility in water, its use is restricted due to its degradable nature in the presence of O_2 and SO_2 and high-energy demand. Further analysis by MIT’s Manya Ranjan (2010) does note a major pitfall to this resin: regions of cold temperatures and high humidity would not at all be conducive to successful operation [4]. The places where this sorbent would be the most practical are in open deserts. Lackner *et al*. (2012) suggest that other factors can include the rate at which a particular material can intake CO_2, at what thicknesses this is best achievable, in which climates the sorbents can work best (it may be that different materials will be best suited for different regions) and whether or not the optimal parameters are even structurally possible [5].

Lionel Dubois (2013) reported amine based solvents have been used for post combustion CO_2 capture [6]. A piperazine-based CO_2 capture process was for CO_2 capture as it is proved to be a good solvent [7]. The development and evaluation of a new Amine solvent was reported for Pilot Plant CO_2 capture process, a new solvent was prepared with optimisation of operating conditions and investigation of the amine degradation [8]. It was found that CO_2 dissolves into the new solvent by forming the bicarbonate anion, with subsequently high CO_2 dissolution capacity. The test results showed that the best performance of new solvent is 2.4GJ/t-CO_2 recovery energy [9].

From the literature, CO_2 is absorbed using a conventional solvent (most commonly used solvent) Mono Ethanol Amine (MEA). However, this process requires high energy, harmful degradation products and cost for solvent regeneration. Therefore, it is very important to find a new solvent for capturing the $CO_{2.}$ In this study, energy demand for solvent regeneration in CO_2 capture process will be focussed using alternative technology namely power ultrasound and microwave treatment method.

II. EXPERIMENTAL SECTION

2.1 Chemicals

In the present study, a minimum purity of 99 wt% of potassium carbonate potassium bicarbonate, MEA (Rankem) were used. All these chemicals were of analytical grade and dried before use, and the water content was less than 0.1% as analysed by the Karl Fischer method.

2.2 Apparatus and Procedure

The sonicators (probe type) and microwave oven were used to study CO_2 desorption process experimentally. The pH of known concentrations of potassium carbonate and MEA in CO_2 gas was measured using a pH meter with a precision of ± 0.01. Mercury thermometer was used to measure the equilibrium temperature with an accuracy of ± 0.1 °C. In each experimental run, an initial solution of about 100 mL was prepared gravimetrically using an electronic analytical balance (Sartorius BSA 224S-CW) with a standard uncertainty of 0.0001g.

2.2.1 Sonication for MEA and K_2CO_3 solvent

A 20 kHz frequency of Ultrasound with 225 Watts of nominal power input is used for this investigation. A 100 ml 30 wt% MEA solution and 60 % conversion of 20 wt% K_2CO_3 solution is prepared. The initial temperature and pH of the solution is measured. Then the each solvent is subjected to sonication. At regular intervals, pH and temperature of the solution was measured.

2.2.2 Microwave Treatment for MEA and K_2CO_3 solvent

Microwave energy with a nominal power of 1200W is used for our investigation. . A 100 ml 30 wt% MEA solution and 60% conversion of 20 wt% K_2CO_3 solution is prepared. Each solution is subjected to microwave treatment. At regular intervals, pH and temperature of the solution was measured.

III. RESULTS AND DISCUSSION

CO_2 is an acidic gas as it gets converted to Carbonic Acid on reaction with water. pH is highly sensitive to the concentration of CO_2 present in the solution. So we are using pH as an indicator. As there is a relation between pH and temperature, these two are the basic parameter.

As CO_2 is liberated from solution, the change is found by an increase in pH. The reaction occurs as per the following reaction

$$\mathbf{2KHCO_3 \rightarrow K_2CO_3+CO_2+H_2O}$$

3.1 Effect of Sonication on Solvent pH (30 wt% MEA)

The effect of sonication on solvent pH for 30 wt% MEA solution is shown in Fig. 2. The carbon loaded 30 wt% MEA solution is used for this investigation. The initial pH of the loaded solution is 9.1. In Fig. 2, the solution pH was found to increase with increase in sonication time. This confirms the release of CO_2 from the carbon loaded 30 wt% MEA solution. At 25minutes of Sonication, the observed pH is 9.46. Hence, the difference is 0.36. This value is close to the cyclic capacity of MEA solvent.

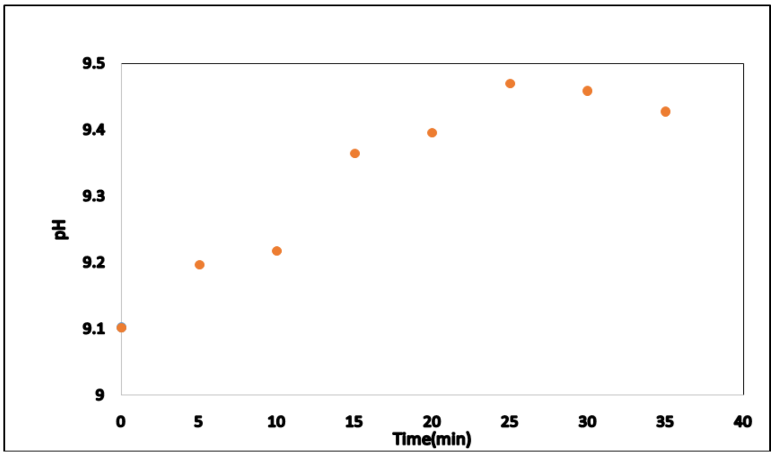

Fig. 2. Effect of Sonication on Solvent pH for 30 wt% MEA

3.2 Effect of Microwave Treatment on MEA

The effect of microwave treatment on solvent pH for 30 wt% MEA solution is shown in Fig. 3. The carbon loaded 30 wt% MEA solution is used for this investigation. The initial pH of the loaded solution is 8.81. In Fig. 3, the solution pH was found to increase with increase in sonication time. This confirms the release of CO_2 from the carbon loaded 30 wt% MEA solution. At the end of 45 seconds of microwave treatment, the observed pH is 9.24. Hence the difference is 0.43. This value is close to the cyclic capacity of MEA solvent.

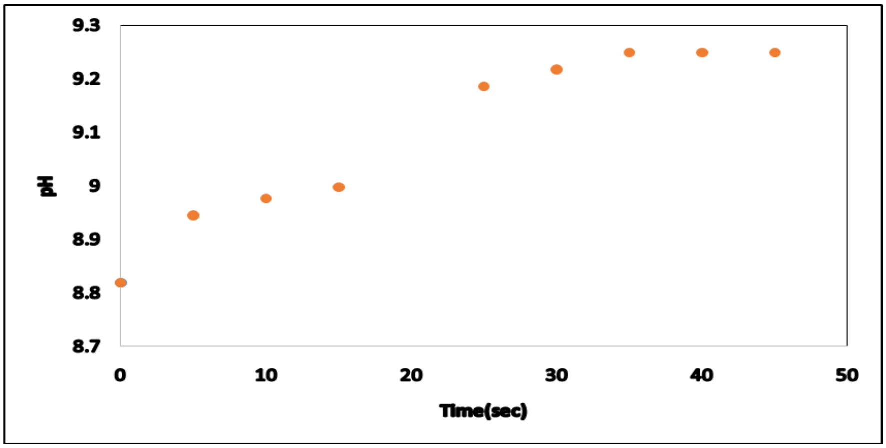

Fig. 3. Effect of Microwave Treatment on Solvent pH for 30 wt% MEA

The power applied for microwave (1200W) is almost 5.3 times the power applied for sonication process (225W). The observed cyclic capacity of MEA for sonication is 0.36 and microwave treatment is 0.43. The time taken to achieve this cyclic capacity for sonication is 35 minutes (2100 seconds) and microwave treatment is 25 seconds. This is an astonishing 84 fold increase in regeneration capacity of the solvent.

3.3 Microwave Treatment of K_2CO_3 Solvent

Potassium Carbonate, commonly called potash is a chemical compound , which is also known as K_2CO_3. It is the substance that forms strong water solution. They are odourless and known as potash or pearl ash**.** Potassium carbonate abstracts in water into potassium (K^+) and carbonateions (CO_3^{2-}). The dissolution/dissociation in water releases heat also when potassium carbonate is added to water, efficient reactions occur. When the substance decomposes at high temperature, the vapor pressure of the substance is very low and a melting point cannot be found**.**

The absorption capacity of K_2CO_3 solvent is low when compared to MEA but it can be increased by the addition of enzyme catalyst. The biggest advantage of K_2CO_3 is the ease of releasing CO_2 (Solvent regeneration) with minimum input energy. The Fig. 4 indicates that fast release of CO_2 was observed since the solvent has low cyclic capacity (low driving force).

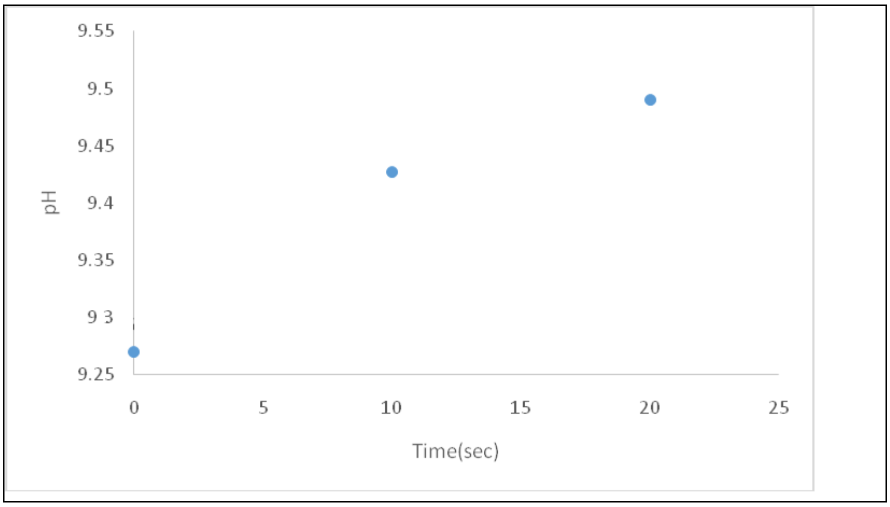

Fig. 4. Effect of Microwave Treatment on Solvent pH of K_2CO_3

IV. CONCLUSION

Present investigation encampasses alternate technique for solvent regenration has been used namely power ultrasound and microwave treatment. A promising regeneration trend was observed experimentally. Among two alternate technique, microwave works better than the sonication, since sonication process requires 84 fold increase in regeneration capacity of the solvent when compared to microwave process. The Observed Regeneration Capacity of 30 wt% MEA and K_2CO_3 is 0.375 and 0.22 respectively. Since, K_2CO_3 is low enthalpy solvent, it releases CO_2 with minimum energy requirement. This trend was confirmed by the experimental investigation. During Microwave treatment, K_2CO_3 releases very quickly even it has less driving force. Microwave treatment can be a alternative technique to minimize solvent regeneration cost of CO_2 capture process.

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