

Introduction

The main objective of this research is to develop a simple and cost effective method that captures CO₂ from power plant flue gas using calcium carbonate as the sorbent. A method was developed to deposit films of these materials on ceramic fabrics, which can be used directly in a reactor designed to use these absorbents to absorb CO₂. The developed sorbent was evaluated for CO₂ capture capacity using multi-cycle tests of cyclical carbonation-calcination experiments in the thermogravimetric analyzer (TGA). Based on the experimental data, a shrinking core model was employed to predict the behaviour of the sample.

Experimental Study

1) Sorbent preparation: The general procedure for preparation of the sorbent begins by placing strips of alumina fabric in the furnace for 15 minutes to remove any moisture, coating or binders. The alumina fabric is then removed from the furnace and weighed. Depending on the experiment, the reacting material is added to the ethyl alcohol. The mixture is placed on a vortex for 3 minutes and then sonicated with a Sonic Dismembrator for 10 minutes. Next, the mixture of sorbent and ethyl alcohol is applied to one side of the fabric and dried at 150°C for 10 minutes. After all, the other side is coated and the sorbent material is placed in a furnace at 800 °C for some hours (conditioning time) , depending to the experiment. Finally, the sample is weighed after conditioning.

2) Carbonation-Calcination Cycling Experiments: The sorbents are tested in a TGA to obtain data in the carbonation-calcinations cycles. All tests are performed using 20% CO₂ by volume in nitrogen during the carbonation cycle. Conversion is calculated based on the weight change of the sample.

Results

First, 0.5g of calcium carbonate was used as the material. The prepared sample was evaluated under isothermal condition at 750 C . The pressure of CO₂ was 80 psi. Fig. 1 shows the conversion of calcium carbonate over 21 cycles. As can be clearly seen, the maximum conversion decreases over the first few cycles and then stabilized around 53%. Then, CO₂ pressure was increased to 110 psi. According to Fig.2, changing the pressure from 80 psi to 110 psi led to a dramatic increase of maximum conversion from 0.53 to 0.71.

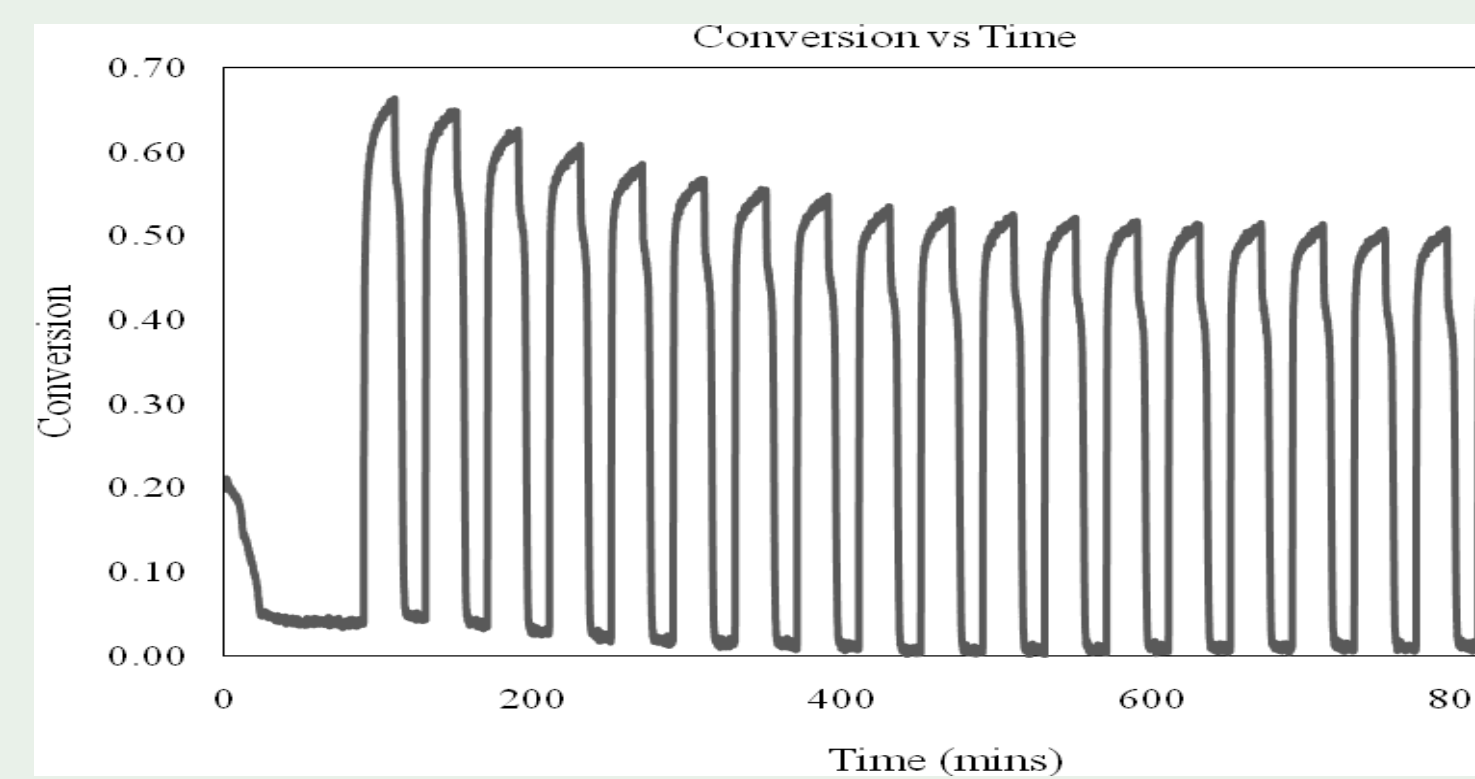


Fig. 1 Conversion of Calcium carbonate over 21 cycles

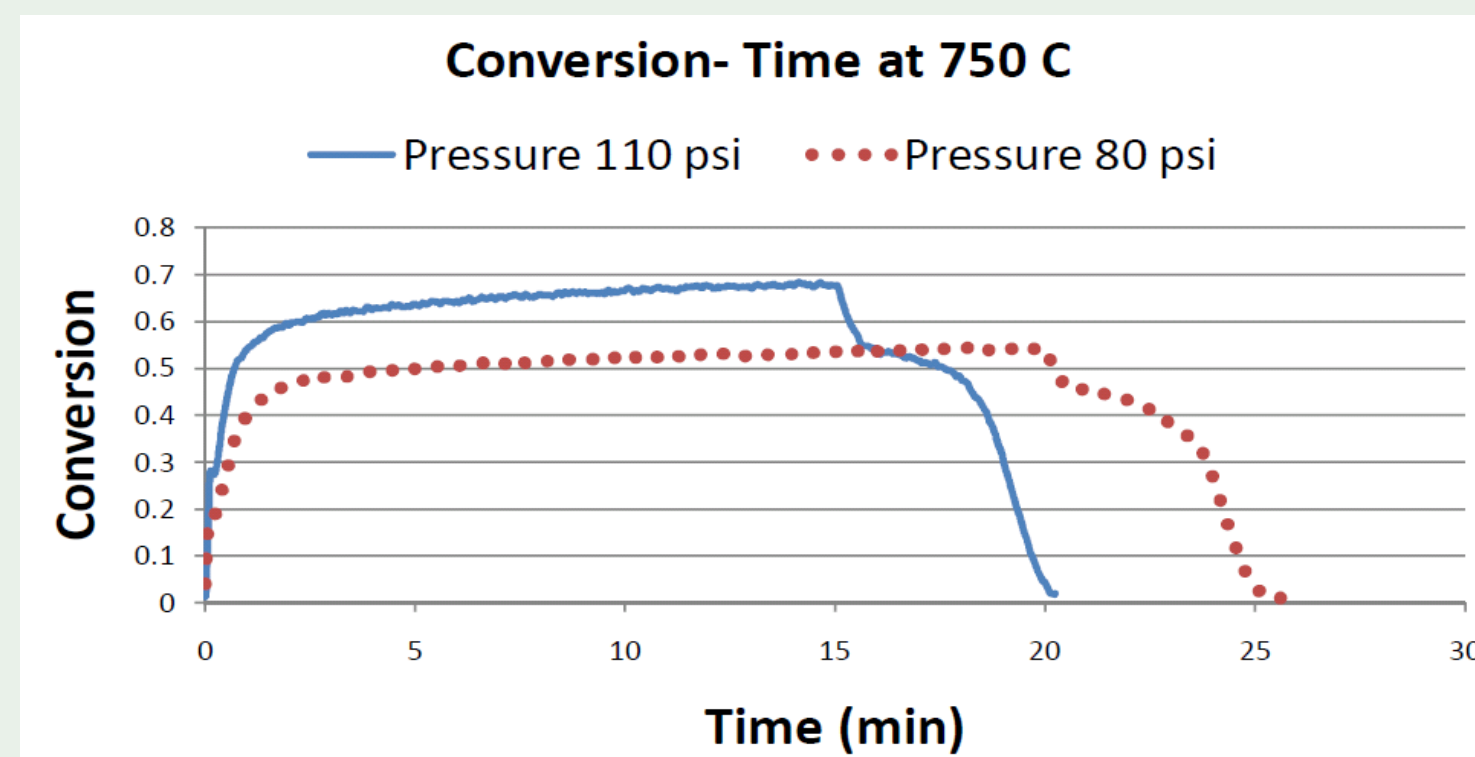


Fig. 2 Variations of conversion in two different pressures

Effect of operating temperature in conversion is shown in Fig. 3. As can be seen, decreasing the temperature from 750C to 700C leads to a dramatic increase in maximum conversion from 0.53 to 0.72 while the time required for calcination increases from 5.5 to 11.7 min. Further decrease in temperature does not effect the maximum conversion so much while it has an undesirable effect on calcination time.

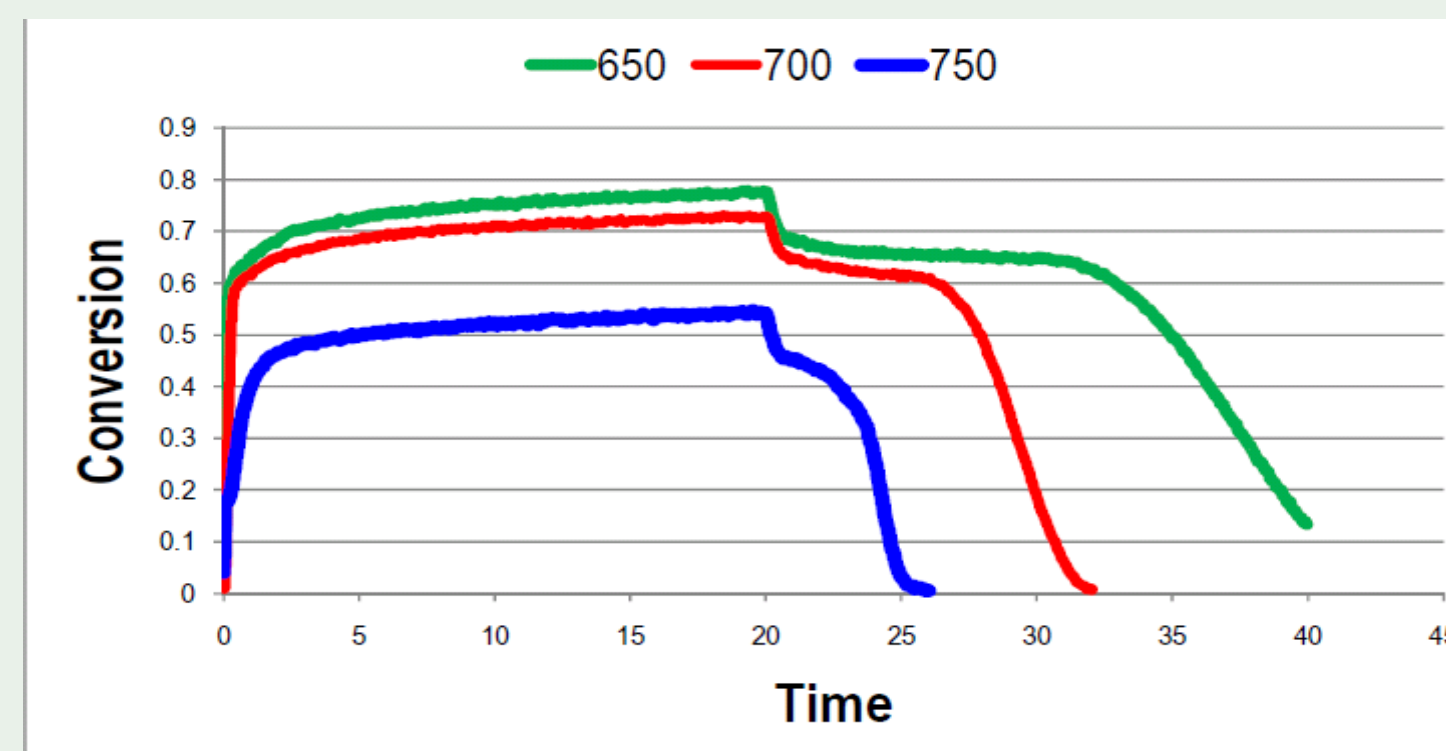


Fig. 3 Variations of conversion in different temperatures

The gas-solid CO₂-CaO reaction proceeds through two rate controlling regimes. At the very initial stage of reaction, the reaction occurs rapidly by heterogeneous surface chemical reaction kinetics. Following this initial stage, as compact layer of product CaCO₃ is developed on the outer region of a CaO particle, the rate of reaction decreases due to the diffusion limitation of reacting species through the layer. Based on these facts, a shrinking model is obtained. Fig.4 shows how well the model fits the experimental data.

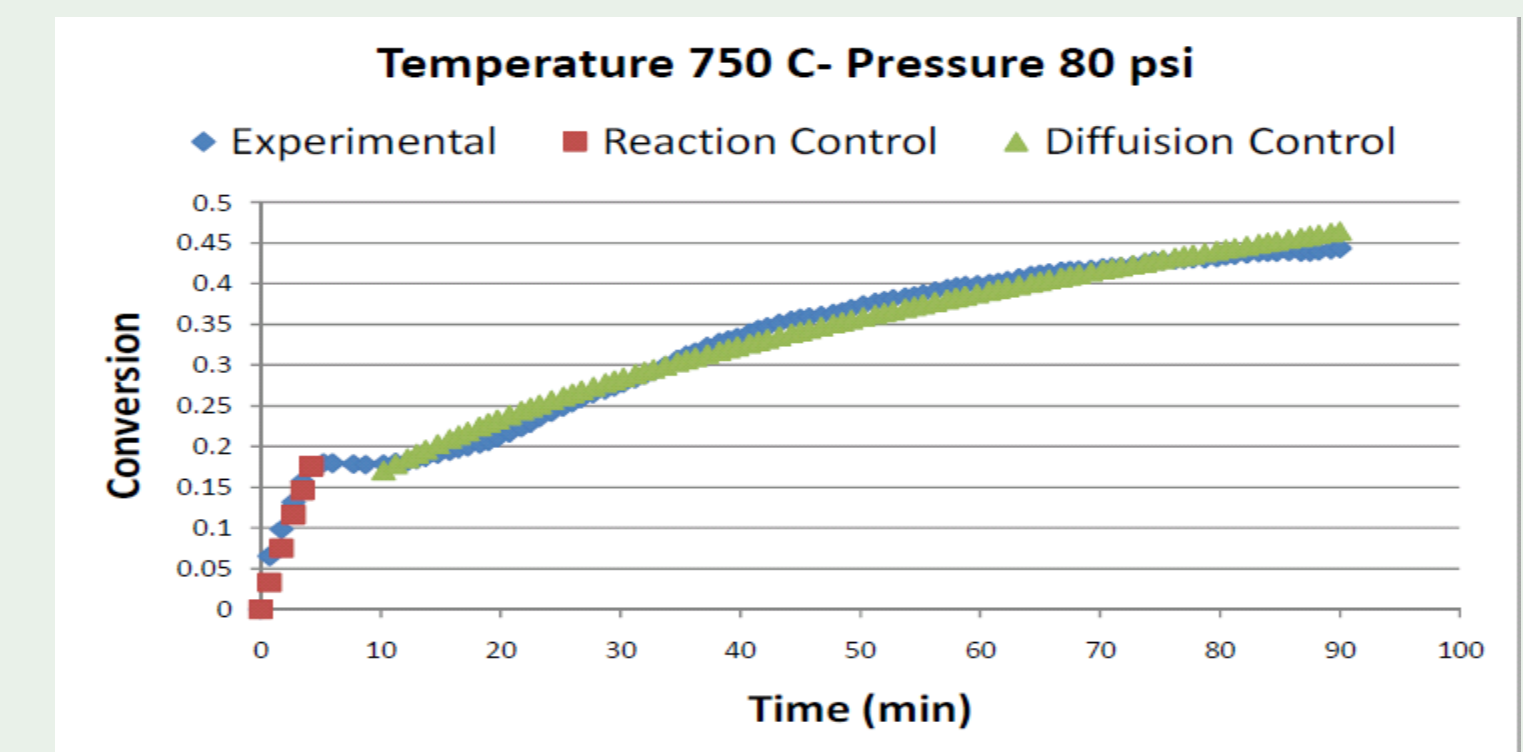


Fig. 4 Prediction of conversion using two rate control regimes

The equations for reaction control regime is:

$$X = 1 - \left(1 - \frac{kt}{3}\right)^3$$

where $k = 0.043988$ and X is the conversion. Similarly, the equation for diffusion control regime is:

$$-3(1 - X)^{\frac{2}{3}} + 2(1 - X) = 2kt - 1$$

where $k = 0.000514$.

Conclusions

- It was shown that with the new preparation method calcium carbonate can maintain its ability to absorb CO₂ over the long time.
- It was found that there are optimal values for pressure and temperature.
- A shrinking core model was obtained that is able to predict the behavior of the sorbent.

References

- ¹ Lee, M. S., Goswami, Y., Hettinger, B., Vijayaraghavan, S., 2006. Preparation and characteristics of calcium oxide pellets for UT-3 thermochemical cycle. Proceedings in 2006 ASME International Mechanical Engineering Congress and Exposition.
- ² Lee, M. S., Goswami, Y., Kothurkar, N., Stefanakos, E. K., 2007. Fabrication of porous calcium oxide film for UT-3 thermochemical hydrogen production cycle. Proceedings in Energy Sustainability 2007, ASME.

