Development of a Carbon Capture Device for Mobile Emissions Sources

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Extended Abstract

Vehicles, trucks and other motors continue to play a leading role in increasing the air pollution rates in the world today. Recently, the Environmental Protection Agency (EPA) in US has started to consider carbon dioxide, a product of "perfect" combustion, as a pollution source [1]. Carbon dioxide does not directly harm human health, but it is a "greenhouse gas" that traps the earth's heat and contributes in global warming phenomena. Carbon capture and sequestration (or carbon capture and storage, CCS) is considered to be a critical strategy worldwide to limit carbon dioxide (CO_2) emissions; the main greenhouse gases responsible for global warming. Nearly all current research on CCS focuses on capturing CO_2 from large, stationary sources such as power plants. Such plans usually entail separating CO_2 from flue gas, compressing it, and transporting it via pipeline to be sequestered underground. In contrast, the system described in this paper captures CO_2 directly from mobile sources such as automobiles. Therefore, the objectives of this work is to:
• Design a simple device to capture CO_2 emissions from mobile sources such as internal combustion engines (ICEs).
• Find the optimum operation conditions in terms of concentration of the absorption material and CO_2 flow rate in order maximum efficiency of solution (absorption limit).

The device is mainly consists of a compact cylinder filled with an absorbent solution for the CO_2 emissions. The actual exhaust emissions have been simulated by a mixture of CO_2 and N_2, as the major components in the engine exhaust, keeping the same volumetric ratio as the actual exhaust. A distributor with a special design is used to increase the area of contact between CO_2 gas and the solution in order to increase the absorbent efficiency. Figure 1 shows a schematic diagram of the test rig. Different materials that have high absorption characteristics of CO_2 such as NaOH and CaOH [2] will be used to evaluate the device performance. A number of parameters including absorbent material concentration and a mixture (CO_2/N_2) flow rate are tested in order to reach the maximum absorption efficiency. CO_2 percentage is measured at the entrance and exit of the device by using a gas analyzer to calculate the absorbent ratio with the time. Moreover, the temperature of the mixture was recorded during the absorption process by using a thermocouple type K attached to a DAQ system. It should be mentioned that the dimensions of the developed device were chosen to be close to that of a catalytic converter in modern vehicles. This can ensure that the proposed device will easily fit to the design of the actual exhaust systems of the modern vehicles.

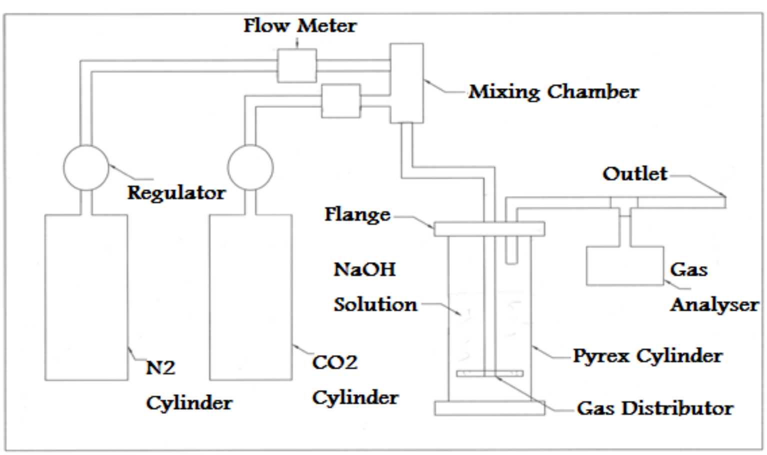
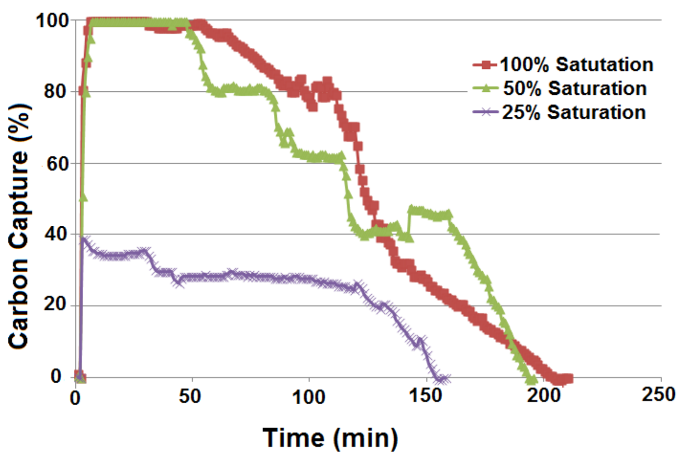


Fig. 1 Schematic diagram of the test rig.

The initial results show that

- The reaction that results from dissolving NaOH in water is exothermic and produces lots of heat and thus care must be taken while preparing the solution with different concentrations.
- The higher concentration of NaOH solution, the higher the absorption of carbon dioxide, Fig. 2, but will result in more blockage since more Na_2CO3 crystals will be formed due to this higher concentration.
- The fully saturated solution has the longest ability to fully capture the CO_2 gas unlike lower concentrations.
- Time taken until a solution is consumed varies with the concentration; where the highest the concentration gives the longest time to be consumed.
- Cooling process is needed especially for the fully saturated solution because a high temperature has been observed during the absorption process, Fig. 3. This temperature might affect the reaction, and as a result affecting the ability of absorbing or capturing carbon dioxide.



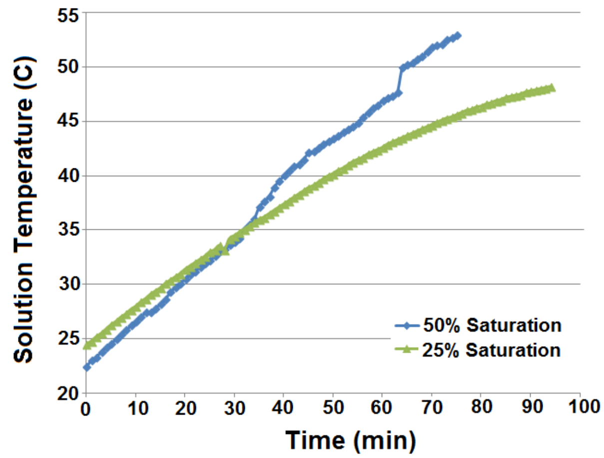


Fig (2) CO_2 absorption versus time for different saturations Fig (3) Solution temperature during absorption versus time for different saturations.

Future work:

More work will be done to fully evaluate the propose device. the distributor shape or design. The shape plays a great role since it directly affects the absorption process inside the cylinder by changing the area of contact between the CO_2 gas and the solution. One way to improve mixing is by adding a propeller inside the cylinder. Another parameter which can be varied is the flow rate of carbon dioxide and nitrogen. Varying the temperature of carbon dioxide and nitrogen will definitely result in having different data and thus acquire more knowledge about the capturing process. The second stage of this work will include testing the device with actual internal combustion engine in order to evaluate the device at actual conditions.

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