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CO_2 Dissociation in the Pressurized, Low-temperature CO_2 Capture and Compression Process of Oxy-fuel Combustion Systems

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1. Introduction

CO_2 capture and storage (CCS) is becoming increasingly important for the sustainable development of fossil fuel energy infrastructure in a carbon-constrained economy, and reducing the emissions of CO_2 to slow down global warming. It is estimated that roughly one third of all CO_2 emissions due to human activity come from fossil fuels used for generating electricity. Electricity generation from fossil fuels, especially from coal, also produces other pollutants such as NO_x, SO_x and mercury. Apart from these power plants, other industry sectors that use fossil fuels as their primary energy source, such as oil refineries, fertilizer and cement plants, also emit large amounts of CO_2 to the atmosphere. Currently, there are three main pathways for capturing CO_2 from fossil fuel energy conversion systems, namely, pre-combustion, post-combustion, and oxy-fuel combustion. Among these approaches, pre-combustion and oxy-fuel combustion take advantage of the fact that CO_2 capture is facilitated by increasing the concentration of CO_2 in the flue gas stream, or by increasing the flue gas pressure or both. There are several different processes available for CO_2 capture such as absorption, adsorption, membrane separation, low-temperature separation, etc. Among these, the low-temperature gas separation is the preferred capture route for flue gas streams that are rich in CO_2, specifically the flue gas that are generated from an oxy-fuel combustion plant.

The Zero Emission Technologies Group (ZET) of CanmetENERGY in Ottawa is currently pursuing a leading research and development program in the field of near-zero emission fossil fuel technologies for power generation. As a part of this program, the ZET Group has developed an efficient CO_2 capture and compression process that can be integrated with oxy-fuel and other combustion systems to effectively remove CO_2 from their stack gas streams. The development of a proof-of-concept CO_2 Capture and the Compression Unit (CO_2CCU) is one of the major outcomes of this research program [1, 2]. The CO_2CCU was commissioned in 2008 and since then different CO_2

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capture and multi-pollutant emissions control tests have been successfully completed in this unit. The multi-pollutant capture through lead chamber reactions is being investigated in this unit [3]. In this context, several multi-pollutant capture issues have already been investigated, but the work is ongoing to the better understand these reactions. One of the issues that was observed during the experimental campaign and requires further investigation, is the presence of CO in the process stream coming out of the CO_2CCU, when the partial pressure of the CO in the inlet flue gas stream to the unit is zero. This has been observed in few cases when testing to capture CO_2 in the CO_2CCU was done with synthetic flue gas that, from the outset, was free of CO.

In this paper, we present and discuss our latest observation about the unexpected CO appearance in the process streams of the pilot-scale CO_2 capture and compression unit (i.e., CO_2CCU) at CanmetENERGY in Ottawa. While, we are still investigating this matter further, this paper explores any linkage to CO_2CCU process and possible mechanism that might have contributed to the CO_2 dissociation. Hence, the relationships among CO_2 dissociation factors with respect to the CO_2CCU will be discussed with respect to possibility of dissociation of CO_2 and formation of CO in the CO_2CCU during the pressurized, low-temperature CO_2 separation and compression process.

2. CO_2 Dissociation Parameters

CO_2 is a very stable molecule. It has been a big challenge for a lot of scientists around the world to break the stable CO_2 bond and reuse it again. The dissociation of CO_2 bond, if successful, will cause the formation of CO, which is a good source of energy and also can reduce the concentration of CO_2 in the atmosphere. If thermodynamically favorable, this would be considered as an effective solution for dealing with CO2 emissions from fossil fuel fired industrial plants. In general, the technologies available to break the CO_2 bond require large amount of energy and hence they are considered to be very costly. Researchers have been working on this topic in recent years with the hope to come up with processes that are economical and can be easily executed.

The following technologies are considered to be plausible pathways for breaking the CO_2 bond:

- Exposure of CO_2 to ultraviolet light can break the CO_2 bond to form CO and O_2;
- Exposure of CO_2 to Gama radiation dissociates CO_2 into CO and O_2;
- From thermodynamics data, it is known that CO_2 can be dissociated at 2000ºC;
- Ultrasound vibration dissociates CO_2 molecules to CO and O_2 [4]
- Ferrites are used as catalyst to activate CO_2 in order to form CO and O_2 [5]

Out of these five pathways only the last two (others are not readily applicable), are investigated here to find out if any CO_2 dissociation can occur in the low-temperature, pressurized environment of the CO_2 capture and compression unit. Moreover, the existence and extent of vibration in the gas compressor of the CO_2CCU, as a source of ultrasound, is measured and investigated to single out the cause of CO appearance (that usually happens in an intermittent form) in the overall process.

3. Effect of Ultrasound and Ferrite Materials on CO Formation in the CO_2CCU

The effect of the ultrasound and the presence of Ferrite materials in the CO_2CCU are investigated to find out if the presence of CO in the process streams is due to presence of any one of these two foregoing parameters, or it is due to some other parameters and hence requires further investigation. Detailed research is in progress and the final findings will be presented later on in this paper.

4. References

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