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著者(和文)	THAMSIRIPRIDEEPORNChanakarn
Author(English)	Chanakarn Thamsiriprideeporn
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Thesis Outline

I. Abstract

Multicycle integrated absorption–mineralization (multicycle IAM) is a promising method for CO_2 removal by converting CO_2 into carbonates with an alkanolamine-based absorbent and industrial waste brine. Through a systematic evaluation and optimization of the blended absorbent, the optimal operation was determined to be a combination of 15 wt.% TEA and 5 wt.% MEA, which resulted in improved CO_2 conversion efficiency and reduced absorbent degradation. This technology holds significant promise for utilizing CO_2 without exerting a negative influence on the environment.

II. Chapter 1: Introduction.

A. Carbon capture, utilization, and storage (CCUS). The trade-off of CCUS technology is discussed. Additionally, the technologies involved in CO_2 capture and CO_2 utilization and storage are thoroughly described, providing a comprehensive overview of the field.

B. Problems and challenges. The issues associated with CO_2 removal through CCUS were analyzed with a focus on operation cost, application, and environmental concerns to ensure a clear understanding of the challenges faced.

C. Multicycle integrated absorption–mineralization (multicycle IAM). The multicycle IAM was designed to overcome these challenges by applying CCUS principle, which involves the reproducible process of absorption, precipitation/ regeneration, and preparation through repeated use of the recycled absorbent.

   1. Absorption. CO_2 is absorbed in the absorbent.
   2. Precipitation/ regeneration. The absorbed CO_2 is altered into solid carbonates by carbonation, and the absorbent is then desorbed or regenerated.
   3. Preparation. The by-product as acid gas is removed by nonreactive gas.

D. Objective. The research aimed to optimize the CO_2-based alkanolamine absorbent for utilization of CO_2 emissions in the multicycle IAM, under controlled conditions (20-25°C and 1 atm), with the goal of achieving conversion rate of greater than 70% and degradation efficiency of less than 60%, while minimizing operation time.

E. Scope. Monoethanolamine (MEA), diethanolamine (DEA), triethanolamine (TEA), and aminomethyl propanol (AMP) as aqueous alkanolamine absorbents, and blended absorbents composed of two amine solvents were investigated over multicycle IAM.

III. Chapter 2: Properties and performance of absorbents in multicycle IAM.

A. Alkanolamine-based absorbents. The properties, absorption mechanisms, degradation, as well as advantages and disadvantages of amines are discussed in detail with regards to their application in current commercial CO_2 scrubbers.
   1. Single absorbents. Primary, secondary, tertiary, and steric hindrance amines as MEA, DEA, TEA, and AMP absorbents.
   2. Blended absorbents. A combination of two different amine absorbents. The absorption behavior of blend can be evaluated by the individual kinetic.

B. Parameters in multicycle IAM. The definition and calculation of CO_2 absorption capacity and rate, CO_2 conversion, absorbent degradation, and energy consumption were descripted.

IV. Chapter 3: Feasibility of multicycle IAM using MEA absorbent.

A. Investigating the potential for CO_2 utilization through the production of carbonate precipitation using multiple cycles of MEA absorbent reuse.

B. The results showed that the aqueous MEA absorbent was capable of capturing additional CO_2 gases and producing a higher amount of precipitated carbonate with a recovery rate of 50% compared to traditional IAM without recycled MEA.

C. The precipitated carbonates were the primary product in multicycle IAM, composed of calcite (31.12%), aragonite (28.13%), magnesite (25.23%), and dolomite (15.52%). Furthermore, the discharge water exhibiting neutral pH levels (7.2-7.8).

D. The multicycle IAM with a 5 wt.% MEA absorbent revealed that optimal performance was not achieved because it failed to meet the criteria. Therefore, the further improvements are necessary to optimize the multicycle IAM operation.

V. Chapter 4: Comparison of amine-based absorbents in multicycle IAM

A. The multicycle IAM was improved by a double precipitation/ regeneration, resulting in a significant increase of 34% in carbonate generation. This process led to a reduction in operation time with a minimal impact on CO_2 absorption capacity.
B. The effectiveness of various alternative alkanolamine absorbents, such as DEA, TEA, and AMP absorbents, in the improved multicycle IAM was evaluated and compared with the use of MEA absorbent.
C. The results indicated that both TEA and AMP have the potential absorbents in multicycle IAM, with TEA absorbent showing consistent results and low degradation, and AMP absorbent showing an impressive high CO_2 conversion.
D. The four-cycle of 5 wt.% AMP absorbent was close to meeting the criteria for optimal multicycle IAM operation, providing a high CO_2 conversion of 90% and moderate degradation of 64%. In addition, 5 wt.% AMP absorbent consumed a low regeneration energy, 47 kilojoules per gram of CO_2, 33% less than 5 wt.% MEA.
E. The energy consumption in multicycle IAM is relatively low compared to conventional CO_2 removal using heat regeneration (over 100°C).

VI. Chapter 5: Development of amine-based absorption by blended absorbents for multicycle IAM.

A. The development of alkanolamine absorbents is crucial for optimizing multicycle IAM operation. An evaluation of blended absorbents with various blending components and proportions was conducted to improve CO_2 conversion efficiency and reduce absorbent degradation compared to single-component absorbents.
B. The results demonstrated that among the blended absorbents investigated, a select ten demonstrated the most desirable characteristics and fulfilled the criteria established for the optimal operation of multicycle IAM.
C. A blend of 15 wt.% TEA and 5 wt.% MEA absorbent showed remarkable productivity yields in terms of the amount of CO_2 absorbed and converted per overall operation time. This solvent indicated high CO_2 conversion of 80% and low degradation efficiency of 60%.

D. The energy consumption of the blended absorbents was significantly lower than the single-component absorbent. 15 wt.% TEA-5 wt.% MEA blended absorbent consumed 41 kilojoules per gram of CO_2, a reduction of 42% and 29% of the single 5 wt.% MEA and 15 wt.% TEA absorbents, respectively.

VII. Chapter 6: Conclusion

A. Conclusion. The thesis aims to conduct a comprehensive study of multicycle IAM and evaluate its feasibility by using various alkanolamine absorbents and blending approaches. The results of the study would provide insights into the optimization of multicycle IAM operation and the use of absorbents for efficient CO_2 absorption and utilization.

B. Recommendations. To improve the performance of amine-based absorbents in multicycle IAM, the inorganic compounds is added to modify the stability of chemical structure. Some inorganic compounds can enhance the reactivity of the absorbent, which can lead to faster and more efficient CO_2 absorption and conversion.