1. Research Gap and Background work

Over the last century, due to the growing trend of carbon dioxide (CO_2) emission and accumulation in the atmosphere, the earth's climate has been remarkably changed. In this regard, serious actions need to be considered for reducing the rate of CO_2 emission for years to come [1]. Carbon Capture and Storage (CCS) is one of the solutions to this matter. There are diverse ranges of developed separation technologies for reducing CO_2 emissions. Liquid Absorption is undoubtedly one of the most important and common operations of gas purification processes, and it is used in a large fraction of the systems [2,3]. However, there are some disadvantages which are associated with the mentioned method, such as corrosivity, fouling, high viscosity, high volatility, and high regeneration energy [4-6]. Solid sorbents with the high specific surface area have been developed and presented for the CO_2 capture process [7,8]. Nevertheless, they possess some drawbacks as well as benefits such as poor stability over multiple absorption-regeneration cycles and high production costs [9,10].

The abovementioned disadvantages have highlighted the necessity of applying new alternative methods.

2. Solution: Microencapsulation of Liquid Sorbent (MECS)

Microencapsulated sorbent is a novel proposed method for carbon capture. In this method, small droplets of liquid sorbent are encased in thin spherical polymer shells, which are highly permeable [11]. In this regard, this new approach benefits from the advantages of both liquid solvent (such as high absorption rate, high selectivity, etc.) and solid sorbent (such as high surface area, low volatility, etc.) methods[11]. Therefore, MECS could be applied to a wide variety of corrosive, volatile, viscous, and low absorption rate solvents since the shells have the capability of containing such solvents and presenting higher surface area [11,12]. Vericella et al.[11] manufactured spherical silicon MECS with carbonate sorbents (sodium and potassium carbonate solutions) as the core liquid, and examined CO_2 absorption rate in stationary MECS particles in comparison with stationary liquid film (having a depth of 1mm). According to their results, MECS possesses a higher level of CO_2 gas flux (more than 10-fold). Also, MECS particles were in acceptable stability and mechanical integrity through absorption and desorption cycles, which is a crucial requirement for practical applications. Stolaroff et al. [13] study the absorption performance of microencapsulated particles contain advanced solvents (including ionic liquids (ILs) and CO_2-binding Organic Liquids (CO_2BOLs)) and compared it with a liquid film of the solvent (depth of 1mm) as the liquid flow in a packed column. The result showed better absorption rates for MECS particles. Also, They investigated the proper shell material and its compatibility with each specific solvent, which is a significant challenge for efficient use in the CO_2 capture process. In results, they established and produced two new polymer formulation for encasing advanced solvents. Thomas Moore et al. [12] carefully modeled and analyzed mass transfer into MECS particles and in the packed columns for chemical (with reaction) and physical solvents. They investigated the enhancement of CO_2 absorption rate into MECS particles in comparison to the packed column. Their result revealed the increase in absorption rate of MECS in 1-2 order of magnitude, and it was not as high as suggested in previous works of Vericella et al. and Stolaroff et al. This can be attributed to the poor modeling of liquid flowing down a packed column (considering a stationary liquid film with 1mm depth) and underestimation of mass transfer surface area of structured packings [12]. Furthermore, it was shown that gas-phase resistance and core liquid motion and mixing had no significant effect on the absorption rate, especially for chemical solvents. Recently, Thomas Moore et al. [14] presented a novel gel material with a high surface area, which is an alternative method for encasing solvents inside polymers capsules. This is due to the fact that the manufacturing of capsules on a large scale is quite difficult, and proposing this new material is an effective method that is more scalable.

3. Further Research and study

According to the previous works, many challenges need to be further studied, including encapsulating of different types of solvents such as non-aqueous solvents, nanoparticle solvents, amino acid solvents, etc., since they have excellent thermodynamic properties but may suffer from highly viscous, low absorption rate or precipitate solids. Therefore, in order to apply such solvents in the separation process, microencapsulation is a practical approach that can also reduce the cost of carbon capture and storage.

Furthermore, in order to successfully produce novel capsules for the abovementioned solvents, Chemical compatibility and clear interface stability between the capsule shell materials and solvents, heat stability, mechanical integrity, high permeability, etc. should be further studied.

For additional enhancement in CO_2 absorption rates, geometry of capsules can be optimized. Also, the effect of changing the shape of microencapsulated sorbent from spherical to cylindrical can be further investigated and modeled.

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