Capture CO_2 using Steel Slag combined with high salt effluent

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Abstract

The global warming and greenhouse effect are increasingly severe. China is the world's largest CO_2 emitter and is facing tremendous pressure to reduce CO_2 emission. Analyses of CO_2 emission sources in China show that coal-fired power plants, cement plants and steel mills make up the vast majority of CO_2 emissions. Therefore, it is important to reduce CO_2 emissions in the three industries.

In order to reduce the capture cost we propose high salt effluent from the enterprise to absorb CO_2. CO_2 can be fixed in carbonates with Ca^{2+} and Mg^{2+} in high salt effluent. CO_2 capture by high salt effluent can reach the combination of CO_2 capture and storage. There are many steel industries in China. A large amount of slag waste is produced every year and heavy accumulation causes environmental pollution and waste of land resources. The slag with rich alkaline substances can be reinforce CO_2 capture by high salt effluent. and carbonate product can be used as raw material for other industries. It achieve resource utilization of steel slag and the combination of CO_2 capture and storage, and use waste to treat waste.

On-line chromatography method is applied to determine the CO_2 solubility in high salt effluent (simulated system) without and with steel slag (simulated system). It

is studied on the influence of temperature and salinity on CO_2 capture by high salt effluent and found the increase of temperature and salinity adverse to CO_2 capture by high salt effluent. It is also studied on the influence of temperature, steel slag concentration, steel slag composition and their synergy on CO_2 capture by high salt effluent with steel slag and found the decrease of temperature and the increase of slag concentration favor to CO_2 capture, and CaO, MgO and their synergy all promote CO_2 capture. Relative to temperature and salinity, the increasing concentration of steel slag has greatly promoted CO_2 capture by high salt effluent, and CO_2 solubility increases by 1115.56% per 1% increase in steel slag concentration.

The thermodynamic model is built to study on CO_2 capture by high salt effluent without and with steel slag and the average errors between calculation values and experimental values are less than 5% and explain the experimental results. The influence of temperature and salinity on CO_2 capture are achieved by Henry's constant and ionization constant. The increase of steel slag enhances the alkalinity of the solution and increases the concentration of H_2CO_3, HCO_3^-, CO_3^{2-} and improves the formation of carbonate, which promotes CO_2 capture. CaO and MgO can promote CO_2 capture because of high solubility in seawater and MgO is better than CaO in CO_2 capture and Fe_2O_3 and Al_2O_3 have little effect on CO_2 capture because of low solubility in high salt effluent.

The kinetics of CO_2 absorption in high salt effluent without and with steel slag was studied. The mass transfer coefficient decreases with decrease of pressure and pH. The increase of temperature, decrease of salinity and increase of slag concentration can increase mass transfer coefficient and promote CO_2 absorption rate. In composition of steel slag, Fe_2O_3 can increase CO_2 absorption rate.

Finally, the process of CO_2 capture by high salt effluent without and with steel slag were built by Aspen Plus. The effluence of temperature, pressure, liquid-gas ratio, seawater salinity, solid-gas ratio (i.e. the added quantity of steel slag) on CO_2 absorptivity were studied. Optimal conditions were determined to consist of a liquid–gas ratio of 250-280, an absorber temperature of 27–32 ℃, an absorber pressure of 1–1.5 atm and a steel slag to gas ratio of 0.09-0.10 for ensuring CO_2 absorption capacity above 90%. Two-third of CO_2 was captured and stored in calcium carbonate form. Then the energy consumption and cost in the process were analyzed to be 1.017GJ/tCO_2 and 76.29RMB/tCO_2, respectively. Compare to other absorption processes, this process has lowest system cost.

Key words: CO_2 capture; high salt effluent; steel slag; thermodynamics; kinetics