

Effect of Coal Combustion on the Reactivity of a CaO-Based Sorbent for CO₂ Capture

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ABSTRACT: CaO is usually decomposed from limestone to capture CO₂. CaO regeneration (limestone decomposition) is an endothermic reaction and needs a lot of heat, which could be from coal combustion through mixing the coal particles and limestone particles. However, the effect of coal combustion on the CaO sorbent reactivity for CO₂ capture needs to be clarified. In this study, the reactivity of the sorbent decomposed from the limestone/coal mixture under various conditions was investigated using thermogravimetric analysis. The results show that the sorbent reactivity decreases with carbonation–calcination cycles because of sorbent sintering under a high temperature. Although coal combustion could supply heat for limestone decomposition, it is also found that sorbent reactivity decreases after adding the coal particles to the limestone particles. Evidently, coal ash remains in the CaO sorbent after coal combustion, but the results show that coal ash does not react with CaO or CaCO₃ in a fixed-bed reactor. Coal ash has little influence on the sorbent reactivity. Also, most coal sulfur released out, and little reacted with the CaO sorbent. The main explanation for the reactivity decrease after adding the coal particles to limestone particles may be the combustion of fixed carbon and volatile matter in the coal particle, which results in a high local particle temperature. Therefore, the CaO sorbent sintering occurs during coal combustion. CO₂ capture capacities decrease in both the chemical- and diffusion-controlled stages in the carbonation reaction after coal addition. Fortunately, steam activation could enhance the sorbent reactivity, even in the presence of coal combustion.

1. INTRODUCTION

The increasing emission of greenhouse gas CO₂ from fossil fuel combustion intensifies global warming.^{1,2} One method to reduce CO₂ emission is the calcium looping process via post-combustion CO₂ capture.^{3,4} Calcined limestone or dolomite can be used in this calcium looping process because of its low price, easy attainment from natural minerals, and high CO₂ absorption capacity.^{5,6}

The calcium looping process includes two reactors: a carbonation reactor and a calcination reactor. In the carbonation reactor, CaO reacts with CO₂ from the flue gas to form CaCO₃. In the calcination reactor, CaCO₃ decomposed to CaO. Calcium looping had been investigated by many researchers since it was first proposed in 1999.⁷ Hughes et al.⁸ investigated the long-term conversion of limestone-derived sorbent for CO₂ capture. Wang et al.⁶ investigated the properties of dolomite in calcium looping. Besides, the properties of reactivity,^{9–12} mechanical strength,^{13–16} and steam activation^{17–20} of the sorbents were also widely investigated. In addition to the Ca-based sorbent, some other methods for preparing sorbent, such as the sol–gel method²¹ and synthesis of a Ca-based sorbent,²² had also been developed for CO₂ capture.

However, another issue of the calcium looping is the heat supply for the calciner, which is rarely investigated. The calcination reaction is an endothermic reaction. Therefore, the heat must be continuously supplied for the calcination reactor. The external heat can be supplied through fuel combustion in the calciner. Lu et al.^{23,24} considered that the heat supply for

limestone decomposition could be from petroleum coke combustion in an atmospheric dual-fluidized-bed combustion system. Some calcium looping process projects had also been industrially demonstrated in Germany, China, and Canada.^{25–29} The heat supply of these projects was from electrical heating, oxy-fuel biomass combustion, oxy-fuel petroleum coke combustion, or oxy-fuel diesel oil combustion. The heat supply for the calciner could also be from oxy-coal combustion because of the abundance and low cost of the coal material. As we all know, it is very convenient to supply heat for limestone decomposition from coal combustion in a real power plant. Besides, the cost of the calcium looping process project would be reduced a lot through oxy-coal combustion to supply heat. However, when coal combustion heat is supplied for the limestone decomposition, it is better to mix the coal particles with the limestone particles before decomposition/combustion. However, the effect of coal combustion on the reactivity of the CaO-based sorbent is still unclear.

In previous investigations, limestone decomposed in a CO₂ atmosphere individually, which is an unrealistic calcination condition. In practical application, the coal particles and limestone particles decompose together in an O₂/CO₂ atmosphere or even an O₂/CO₂/steam atmosphere. Many factors may influence the sorbent reactivity, including coal sulfur, coal ash, and high temperature. Ridha et al.³⁰ found that

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