



Research on sulfur recovery from the byproducts of magnesia wet flue gas desulfurization



Liyun Yan*, Xiaofeng Lu*, Quanhai Wang, Yinhu Kang, Jie Xu, Ye Chen

Key Laboratory of Low-grade Energy Utilization Technologies and Systems, Ministry of Education, Chongqing University, Shapingba, Chongqing 400044, China

HIGHLIGHTS

- An industrial demonstration unit used to calcine MgO FGD byproduct was built.
- Existing a transition point for the SO₂ distribution along the height of furnace.
- SO₂ content cannot reach 8% under the excess air coefficient of 2.15.
- The renewable MgO-desulfurization was more economic than limestone–gypsum.

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ABSTRACT

To recycle sulfur from byproducts of magnesia wet flue gas desulfurization, the authors conducted an experimental study and computational analysis on the factors influencing the SO₂ mole fraction in the calciner gas by an industrial demonstration unit. With a sulfur content of 1.65% in coal and a generating capacity of 300 MW of power plant, the economics of the renewable magnesium oxide desulfurization technology was compared to that of limestone–gypsum desulfurization technology. The results show that the decomposition reaction of byproducts mainly occurred in the lower zone of the furnace. When the excess air coefficient was 1.05 and the magnesium sulfite content in the byproducts was 60%, the SO₂ mole fraction in the calciner gas was 10.5%. Decreasing the excess air coefficient can improve the SO₂ mole fraction in the calciner gas. When the moisture content in the byproducts was 15%, the SO₂ mole fraction reached 9.2%. The calciner exit gas temperature should be controlled at 1253.5 K or below. Adopting oxygen-enriched combustion, the oxygen content in air should be controlled to 31%. The magnesium oxide desulfurization renewable technology was found to be more economic.

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1. Introduction

According to information released by the National Energy Administration, the installed coal-fired power capacity in China reached 758 million kW by the end of 2012, accounting for 66.2% of the total installed capacity; the coal-fired electricity generating capacity is 3.68 trillion kWh, which accounts for 73.9% of the total electricity generating capacity [1]. The “Study of China Power Reduction of 2012”, jointly issued by the China Electricity Council and the United States Environmental Protection Association, showed that the desulfurization unit capacity of the entire country was 630 million kW, which accounted for 90% of the capacity of the national coal units; the sulfur dioxide emissions amounted to 913 million tons. Meanwhile, it was also noted that there was a huge

economic cost to control this single-pollutant emission. The two goals of saving energy and reducing emissions were not coordinated [2].

To eliminate the pollution of SO₂, limestone wet flue gas desulfurization (FGD) [3] was used in approximately 90% of the units. The large-scale application of limestone wet FGD causes three major issues. First, large quantities of limestone are consumed. Second, a large quantity of the desulfurization byproduct gypsum is generated. Although the utilization of desulfurization gypsum was about 71% in 2011, about 20 million tone desulfurization gypsum was piled up according to the annual report of China resources comprehensive utilization (2012) released by the national development and reform commission of the People's Republic of China [4]. The byproduct gypsum not only occupies land but also results in secondary pollution. Third, the limestone wet FGD process system has serious problems that include fouling, wear, corrosion, and so on [5], affecting the efficient and safe operation of desulfurization equipment. These factors are important because they have restricted the

* Corresponding authors. Tel./fax: +86 23 65102475.

E-mail addresses: yanziyly@sina.cn (L. Yan), xf_luke@163.com (X. Lu).

sustainable development of China's coal-fired power generation enterprises. Therefore, they must be addressed.

To solve the above problems, many studies have been conducted by domestic and foreign scholars. A number of new technologies have been proposed for replacing limestone wet FGD including the magnesia wet FGD byproducts recovery process.

In this desulfurization process, the desulfurization byproduct magnesium sulfite is thermally decomposed to recover the sulfur dioxide and produce sulfuric acid. Meanwhile, magnesium oxide is regenerated. Thus, the problems such as the consumption of desulfurizer and byproducts accumulation are completely solved. In addition, the desulfurization process is similar to the existing limestone wet FGD. The limestone is replaced by magnesium oxide, and minor modifications are made to the desulfurization system to essentially solve the scaling, corrosion, and wear in the desulfurization system [6,7]. Furthermore, because the solubility of magnesium oxide in the desulfurization slurry is much higher than that of limestone [8], its desulfurization efficiency was as high as 98%. There is no need to sacrifice additional economic benefits [9–11] to meet the stringent environmental standards.

Industrialized application and economic evaluation of this process had been done in United States [12–14]. However, this process has not been widely used for the lack of magnesium resources and higher-priced MgO in Europeans and Americans and the detailed data about the influencing factors of SO₂ mole fraction have not been reported. When manufacturing sulfuric acid, there is a minimum SO₂ mole fraction (usually above 8%) required in the raw material.

In China, a lot of research has been carried out [15] and a series of patents has been published [16–19] without industrialization demonstration or application recycling MgO and SO₂ from MgO FGD byproducts.

Thus, the author experimentally studied the factors that influence the SO₂ mole fraction in the calciner gas on an industrial demonstration unit. Using the calciner as a physical model, the feasibility of recycling SO₂ in the calciner gas by byproducts calcined was computationally analyzed. The economics of the renewable magnesium oxide desulfurization technology was compared with that of limestone–gypsum technology.

2. Experimental

2.1. Experimental apparatus

The main body of the industrial demonstration unit (Fig. 1) was a fluidized bed calciner, including a furnace (500 mm in diameter

and 7000 mm in height), a feed port, and an air distribution plate. The auxiliary systems included a feeding system, flue gas system, and water system, as well as a data measurement and acquisition system. The workflow process was as follows:

Flue gas system: the high-pressure airflow from the air preheater entered the furnace from the air chamber, fluidizing the bed material. Above the material layer, the introduced natural gas was burned. The bed material was heated until the furnace temperature reached approximately 1000 °C. After the calciner gas was exhausted from the furnace, the stream passed through the air preheater that acted as a heat exchanger and then entered the cyclone segregator. In the cyclone segregator, the solid particles remaining after the gas–solid separation were cooled down by an ash cooler and collected in a dust collector; the gas entered an alkali absorption tower via two draft fans, and then discharged.

The material system: the MgO desulfurization byproducts were stored in a feed bin after being pulverized. A metering screw conveyor was used to convey the byproducts to a Venturi feeder driven by high-pressure air that was used to feed the materials into the fluidized bed calciner.

2.2. Experimental conditions

Natural gas was used in the experiments as the heat source. The MgSO₃ content in the byproducts was 35.32% (dry basis). The cases in Table 1 were used to study the SO₂ mole fraction in the calciner gas exiting the furnace. The gas composition was determined with a flue gas sampling and analysis system. The measured point located 5295 mm above the air distribution plate. The system consisted of a stainless steel sampling tube, a cyclone separator, the particle collection device, filters, a vacuum pump, and a gas analyzer (Testo-MGA5), as shown in Fig. 2. The measurement accuracies for gas analyzer are O₂:±2%Vol; SO₂:±2% F.S.

3. Calculations

3.1. Computational model

The calciner shown in Fig. 1 was used as a geometric model for computational analysis. A small chamber model was built along the flow direction of gas–solid in the furnace, as shown in Fig. 3. The inlet of the first small chamber (the small chamber I) was in a horizontal line with the feed port of byproducts. The small chambers were divided symmetrically because the experiment in the furnace was operated under the dilute phase pneumatic conveying and the

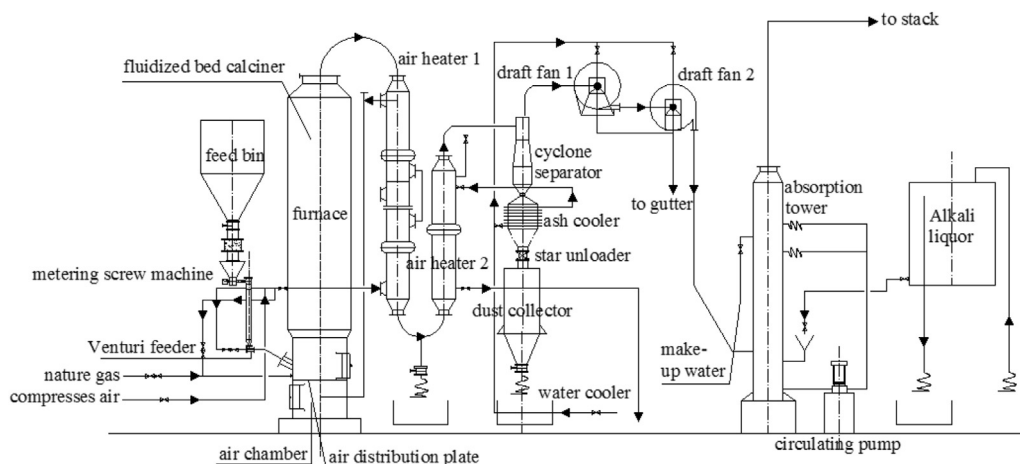


Fig. 1. Industrial demonstration unit.

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