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Desulfurization performance of fly ash and $CaCO_3$ compound absorbent

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ABSTRACT

The fly ash generated from the burning of low sulfur coals is featured by high alkalinity, which alone or mixed with $CaCO_3$ can be used as the absorbent for desulfurization. The desulfurization performance of fly ash and $CaCO_3$ compound absorbent is experimentally investigated in a bubbling desulfurization reactor. Results show that the desulfurization rate of $CaCO_3$ is improved by adding fly ash at Ca/S mole ratio of 1.024. The maximum desulfurization rate of the compound absorbent could reach 94%. The optimum ratio of fly ash and $CaCO_3$ in the compound absorbent is 1:1.

1. Introduction

Coal-burning pollution is the primary form of air pollution in China. The major component of the coal-burning pollutants is SO_2. Control of SO_2 emission has been an urgent mission in China due to various deleterious effects of SO_2 on human health, plants and animals [1–3], and even the sustainable development of the economy and society [4]. The wet flue gas desulfurization is considered to be technologically, environmentally, and economically feasible [5]. To reduce the investment of wet flue gas desulfurization system as well as the expenses of operation and maintenance, good desulfurization absorbents with low price and high efficiency are needed.

In northern China, low sulfur coals have a large reserve. The fly ash generated from the burning of low sulfur coals is featured by high alkalinity, which is capable of absorbing SO_2 from flue gas. Therefore, fly ash or $CaCO_3$ mixed with fly ash can be used as the absorbent for desulfurization of power plants burning low-sulfur coals. Fly ash is formed from the enrichment of non-flammable minerals after coal burning in the furnace chamber. Aluminosilicate (clay), carbonate, sulfide, chloride and silicon dioxide mainly comes from the minerals in coal. It is believed that the most diffluent substance in fly ash is vitreous (amorphous) aluminosilicate. Fly ash is sphere or aggregation of the microsphere, with a particle diameter of 1–100 μm and density of 2.02–2.56 g/cm^3. The utilization of fly ash depends mainly on the content and reaction activity of the oxides. Fly ash as the industrial solid waste does great harm to the environment and the human body. The total utilization of fly ash is only 25–30% and most of which is used in the architectural material industry in China. High value-added utilization only accounts for a little propo-

Table 1
Composition of fly ash.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	TiO_2
S1	42.43	23.43	9.35	1.29	0.56	2.41	1.69	0.95
S2	51.52	31.81	4.47	5.82	0.49	0.98	0.96	1.06
S3	44.00	24.45	3.41	4.55	0.26	1.34	0.65	0.92

Table 2
Distribution of fly ash particle size.

	Griddle no.	Average pore size d_i (mm)	Mass fraction x_i (%)	$x_i d_i$	Average diameter d (mm)
S1	1	0.1490	1.47	0.21903	0.101
	2	0.1115	80.69	8.996935	
	3	0.0615	12.32	0.75768	
	4	0.0430	2.82	0.12126	
	5	0.0185	2.70	0.04995	
S2	1	0.1490	2.94	0.43806	0.095
	2	0.1115	65.54	7.30771	
	3	0.0615	25.99	1.598385	
	4	0.0430	3.47	0.14921	
	5	0.0185	2.06	0.03811	
S3	1	0.1490	0.05	0.00745	0.040
	2	0.1115	2.22	0.24753	
	3	0.0615	26.79	1.647585	
	4	0.0430	35.64	1.53252	
	5	0.0185	35.30	0.65305	

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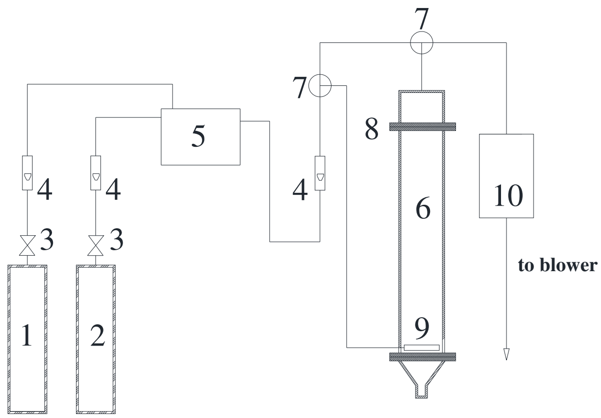

Fig. 1. Experimental setup.

sition [6]. However, the application and research of fly ash have become a highlight in environmental science due to the increasing awareness of environmental issues. Most of the researches focus on the treatment of flue gas and wastewater [7–8], and some of them have proposed the possibility of using CaO mixed with fly ash as sorbents and developed the utilization of fly ash and CaO mixtures in flue gas desulphurization [9–12]. Fly ash is one of the most widely used supplementary materials in various high-performance cementitious systems. Higher lime content in fly ash results in improved compressive strength [13]. The addition of gypsum (product of lime after desulfurization) along with lime is more effective in reducing the hydraulic conductivity of fly ashes due to the enhanced hydration and accelerated the formation of cementitious compounds. The leachability of trace elements present in the fly ash reduces considerably with the addition of lime and gypsum [14]. For the application of gypsum, the addition of fly ash to gypsum may overcome some shortcomings of gypsum such as high brittleness and poor water resistance [15]. With the increase of fly ash, the strength of the gypsum-fly ash compounds cementitious system decreases, the fluidity increases, the setting time extends, and the hydration heat release reduces [16].

The paper carried out an experimental study on the desulfurization performance of fly ash and $CaCO_3$ compound absorbent in a small bubbling desulfurization reactor. Fly ash and $CaCO_3$ compound absorbent were prepared. Fly ash sieving and hydration, influences of fly ash and $CaCO_3$ on the desulfurization rate of compound absorbent were analyzed. The operational parameters and the optimum ratio of fly ash and $CaCO_3$ in the compound absorbent were provided for industrial application of the compound absorbent.

2. Material and methods

2.1. Fly ash preparation

Fly ash is mainly composed of SiO_2, Al_2O_3, Fe_2O_3, and CaO. Contained with a significant content of porous amorphous SiO_2 and Al_2O_3, fly ash thus could play a role in absorbing acid gas SO_2 (including physical absorption and chemical absorption). Chemical absorption ability of fly ash mainly depends on the Si—O and Al—O active group, which can combine the chemical bond or ion of the adsorbate for absorption. The essential components of the fly ash samples in this experiment are shown in Table 1. The ash samples were separated by sieving. Particles with average sizes from 100 to 40 μm were used in the study.

The purpose of analyzing the particle size of fly ash is to confirm the influence of fly ash particle size on the pH value of the hydration solution. Through the particle size analysis of fly ash, the study provides the basis for taking fly ash as absorbent. The distribution of the particle size is shown in Table 2. The surface morphologies of fly ash samples

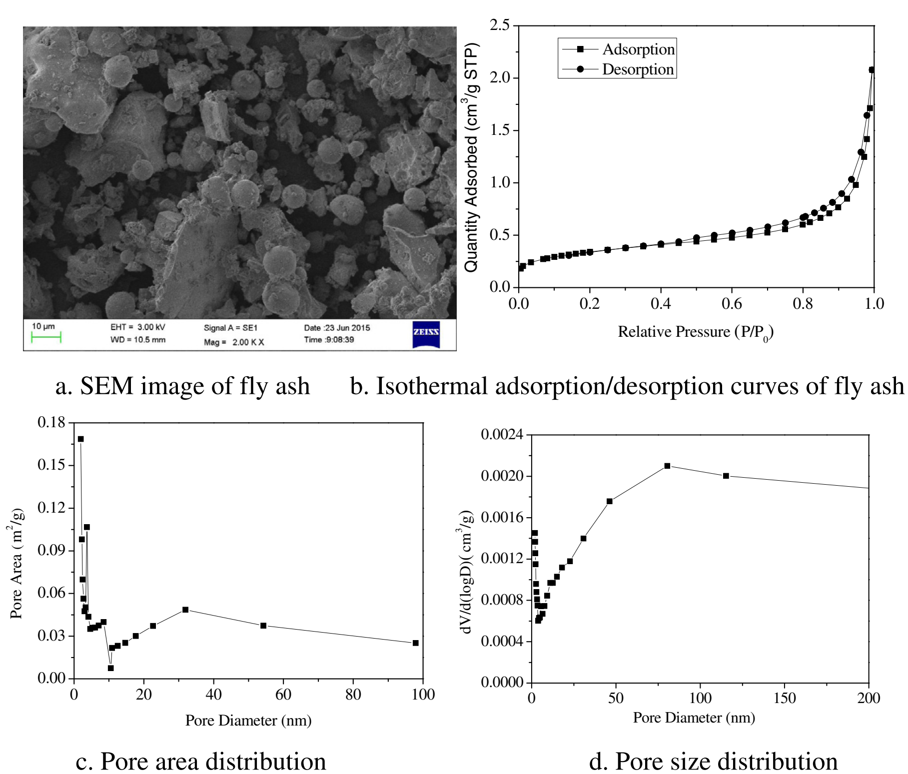

Fig. 2. Properties of fly ash.