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Original Research Paper

Flue Gas Desulfurization Experimental Research on Activated Carbon Fibre

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ABSTRACT

As a new type of high performance adsorbents and catalysts, activated carbon fibre (ACF) shows broad application prospects in flue gas desulfurization because of its unique physical and chemical properties. We designed a set of experiments to study the factors affecting desulfurization performance of ACF, namely determining desulfurization performance of ACF before and after its regeneration, ACF soaked with 100g lime and ACF soaked with the fly ash and lime whose ratio was 1:1. The results show that after ACF regeneration, desulfurization performance of ACF declines, and the duration is also reduced; after being soaked with 100g lime, desulfurization performance of ACF has been improved significantly, and the duration also increases; after being soaked with the fly ash and lime in the ratio of 1:1, desulfurization performance of ACF is higher than that soaked with 100g lime, and the duration is longer.

INTRODUCTION

There are many ways for flue gas desulfurization (Chunhua Liu 2013, Zhiguang & Yanhong 2013, Jianhong 2013, Renyuan 2013, Ting et al. 2013, Li et al. 2003) and all have significant advantages, but they also face some difficult problems to solve. The activated carbon materials get the popularization and utilization because of its characteristics of wide variety of sources, recycling and recovery of sulphur resources (Haojie et al. 2005, ACF shows its huge advantage in carbon flue gas desulfurization. ACF is a new type of carbon material developed after the ordinary granular and powdered activated carbon (Haiyan & Wuzhong 2003), with features of a large external surface area, abundant micropores and uniform distribution (Yi et al. 2002), which is a high performance adsorbent and catalyst.

At present, there are many research results on factors affecting desulfurization performance of ACF in the world, which are related to precursor materials of preparing ACF, specific preparation conditions and physical and chemical properties of its surface. Therefore, the former had a higher desulfurization performance; Kaixi et al. (2002) believed that the oxygen-containing functional groups on the surface of ACF were adverse to desulfurization, and the oxygen-containing functional groups converted into CO and released by heat treatment methods. Experimental results show that the desulfurization performance of activated carbon materials is improved (Kaixi et al. 2002). The relationship between the surface physical properties and desulfurization performance of ACF has not been a definitive conclusion, and researches in this area are relatively few (Yansong et al. 2011) . At this stage, whether for surface physical properties of ACF or for its surface chemical properties, the research efforts need to be further improved. Under such conditions, we designed four sets of experiments to study and analyse factors affecting desulfurization performance of ACF from two aspects of physical and chemical properties and strive to draw reliable conclusions.

MATERIALS AND METHODS

Experimental process: The experimental process is shown in Fig. 1. After being compressed by the air compressor, the air flow into the buffer tank 2 (the pressure gauge 3 indicates the pressure of the air), and its pressure becomes relatively stable. Then the air flow into the mixed gas buffer tank 8 through the glass rotor flowmeter 7 (which indicates the flow of air). Meanwhile, SO_2 flow from the gas tank into the mixed gas buffer tank (pressure gauge 4 indicates the pressure of mixed gas) through the glass rotor flowmeter 6 (which indicates the flow of SO_2) to mix with air. After the pressure of mixed gas become stable, the mixed gas flow into packed tower 9. The experiment adopts dry desulfurization, therefore, the mixed gas can flow into the absorber directly from its lower part, and the purified gas is discharged from the upper portion of the absorber. Before and after entering the absorber, the concentration of SO_2 is measured by the flue gas sampling analyser, and these two monitorings are carried out at the same time. This experiment adjusts the flow of SO_2 to 40mL/min and the flow of air to $3m^3/h$ and strives to simulate the actual composition of flue gas.

Experimental program: We designed a sets of experiments to analyze factors affecting the desulfurization performance of ACF from the chemical properties. Determining desulfurization performance of the two types of ACF (whose width was 1cm) - viscose felt with the thickness of 2mm, viscose felt with the thickness of 3mm before and after regeneration. Determining desulfurization performance of the three types of ACF (whose width was 1cm) - viscose felt with the thickness of 2mm, viscose felt with the thickness of 3mm and PAN-based ACF before and after being soaked with 100g lime. Determining desulfurization performance of the two types of ACF (whose width was 1cm) - viscose felt with the thickness of 2mm, viscose felt with the thickness of 3mm after being soaked by fly ash and lime (50 g of fly ash and 50 g of lime) whose ratio was 1:1.

RESULTS AND DISCUSSION

Chemical Properties

The influence of regeneration treatment on desulfurization performance of two types of ACF

a. Desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm after regeneration is given in Table 1, and the comparison of desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm before and after regeneration is shown in Fig. 2.
b. Desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm after regeneration is given in Table 2, and the comparison of desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm before and after regeneration is shown in Fig. 3.

Analysis of experimental results: The experiment for regeneration of ACF was made by use of washing recycling method,

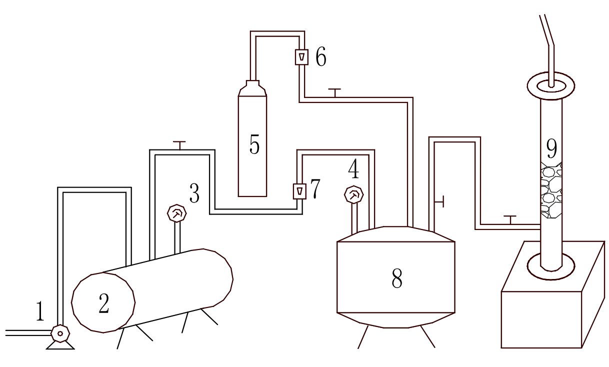

Fig. 1: The experimental process diagram.
(1. Air compressor; 2. Buffer tank; 3, 4. Pressure gauge; 5. SO_2 gas tank; 6. LZB-3F glass rotor flowmeter (mL/min); 7. LZJ-25F glass rotor flowmeter (m^3/h); 8. Mixed gas buffer tank; 9. Packed tower)

Table 1: Desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1 cm after regeneration.

Sampling time (min)	The concentration of SO_2 (mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	221	24	89.1
11	221	153	30.8
16	221	354	0

Notes: The weight:34.7g; The height of filler:37cm; The resistance:4650Pa

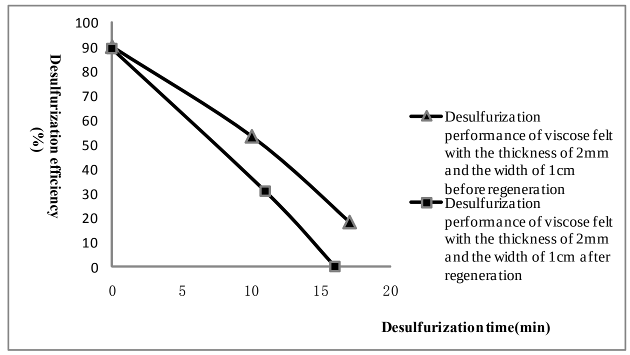

Fig. 2: Desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1 cm before and after regeneration.

Table 2: Desulfurization performance of viscose felt with the thickness of 3 mm and the width of 1 cm after regeneration.

Sampling time (min)	The concentration of SO_2 (mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	245	37	84.9
7	612	432	29.4
10	1015	690	32.0
14	977	768	21.4

Notes: The weight:38.7g; The height of filler:29cm; The resistance:2800Pa

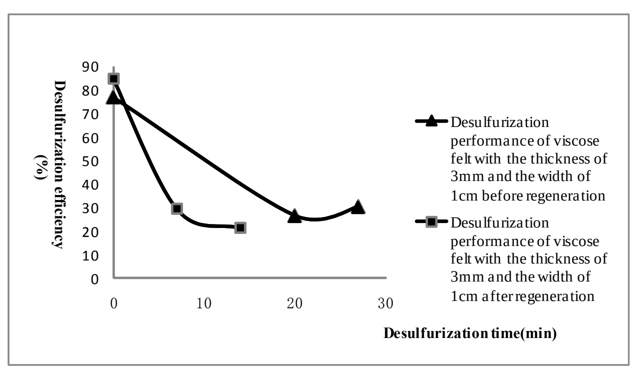

Fig. 3: Desulfurization performance of viscose felt with the thickness of 3 mm and the width of 1 cm before and after regeneration.

Table 3: Desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1 cm after being soaked with 100g lime.

Sampling time (min)	The concentration of SO_2(mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	406	26	93.6
12	592	81	86.3
16	924	428	53.7
19	1011	564	44.2

Notes: The original weight of viscose felt with the thickness of 2mm:40g; The total weight of viscose felt soaked by lime:79.6g; The filling weight after being soaked by lime: 59.2g; The height of filler:37cm; The resistance:2500 Pa; The ash rate:32.4%

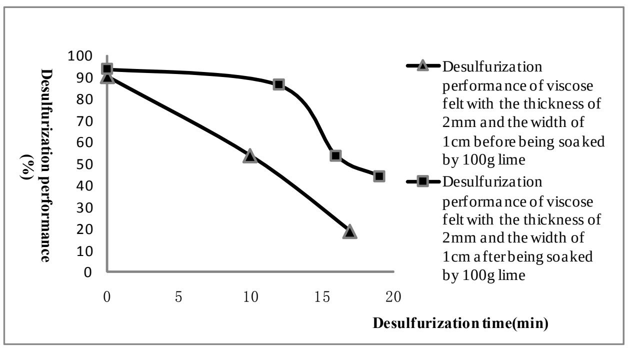

Fig. 4: Desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1 cm before and after being soaked by 100g lime.

Table 4: Desulfurization performance of viscose felt with the thickness of 3 mm and the width of 1 cm after being soaked by 100g lime.

Sampling time (min)	The concentration of SO_2(mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	373	16	95.7
16	941	161	82.9
20	717	388	45.9
23	1292	623	51.8
26	1261	533	57.7
28	1075	513	52.3

Notes: The original weight of viscose felt with the thickness of 3mm:40g and ACF was repeatedly washed with water about five times and dried at 100°C. As can be seen from Figs. 2 and 3, compared with viscose felt before regeneration, desulfurization performance of viscose felt after regeneration decreases, and the duration is also reduced. May be because washing affect the organizational structure of ACF, the number of pores decreases, and the active site of SO_2 decreases, which make the adsorption and desorption decreasing. Desulfurization performance of ACF is also reduced.

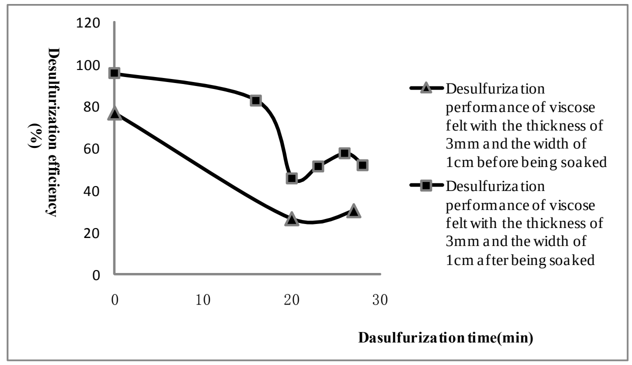

Fig. 5: Desulfurization performance of viscose felt with the thickness of 3 mm and the width of 1 cm before and after being soaked by 100g lime.

Table 5: Desulfurization performance of PAN-based ACF with the width of 1 cm after being soaked by 100g lime.

Sampling time (min)	The concentration of SO_2(mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	771	568	26.3
2	817	403	50.7
5	727	286	60.7
8	806	611	24.2
9	735	494	32.8
20	760	410	46.1

Notes: The original weight of PAN-based ACF:64.6g; The filling weight after being soaked by lime:79.1g; The height of filler:43cm; The resistance:1100Pa; The ash rate:18.3%

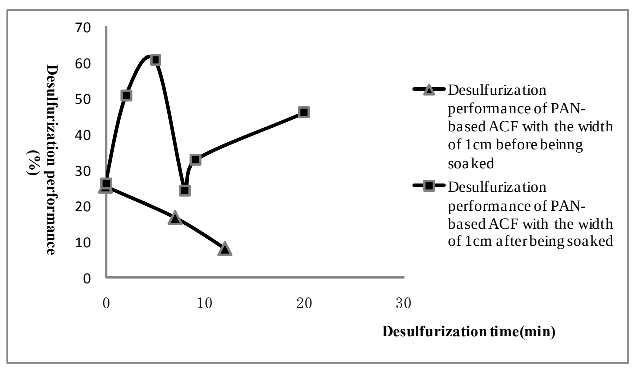

Fig. 6: Desulfurization performance of PAN-based ACF with the width of 1 cm before and after being soaked by 100g lime.

The influence on desulfurization performance of three types of ACF after treatment of being soaked by 100g lime

a. Desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm after being soaked by 100g lime is given in Table 3, and the comparison of desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm before and after being soaked with 100g lime is shown in Fig. 4.

Table 6: Desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1cm after being soaked by fly ash and lime whose ratio was 1:1.

Sampling time (min)	The concentration of SO_2(mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	618	303	95.1
4	1015	32	96.8
13	1383	25	98.2
23	898	385	57.1

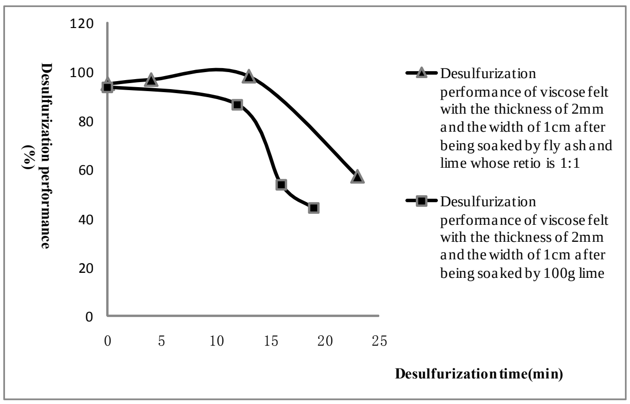

Fig. 7: The comparison between desulfurization performance of viscose felt with the thickness of 2 mm and the width of 1 cm after being soaked by fly ash and lime whose ratio was 1:1 and that after being soaked by 100g lime.

b. Desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm after being soaked by 100g lime is given in Table 4, and the comparison of desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm before and after being soaked by 100g lime is shown in Fig. 5.
c. Desulfurization performance of PAN-based ACF with the width of 1cm after being soaked by 100g lime is given in Table 5, and the comparison of desulfurization performance of PAN-based ACF with the width of 1cm before and after being soaked with 100g lime is shown in Fig. 6.

***Analysis of experimental results*:** As can be seen from Figs. 10,11 and 12, desulfurization performance of ACF has been significantly improved after being soaked with 100g lime, and the duration is also increased. The reason is that ACF is mixed with $Ca(OH)_2$ thoroughly, and Ca^{2+} diffuse to the surface of ACF, which increases ACF's adsorption capacity of SO_2 and improves desulfurization efficiency. At the same time, it can be found that desulfurization efficiency of ACF soaked has a downward trend with the growth of desulfurization time. It indicates that ACF is affected by $Ca(OH)_2$ after being soaked at the initial time, improving the adsorption capacity. But with the increasing of time, the adsorption capacity is easy to reach a saturation, resulting in the decrease of desulfurization efficiency. That is, Ca^{2+} are introduced to the surface of ACF by the way of ion exchange or complexing, which greatly promotes the removal capacity of ACF for SO_2.

Table 7: Desulfurization performance of viscose felt with the thickness of 3 mm and the width of 1 cm after being soaked by fly ash and lime whose ratio was 1:1.

Sampling time (min)	The concentration of SO_2(mg/m^3)		Desulfurization efficiency (%)
	The inlet	The outlet	
0	973	79	91.9
8	944	18	98.1
13	1570	57	96.4
24	1174	243	79.3

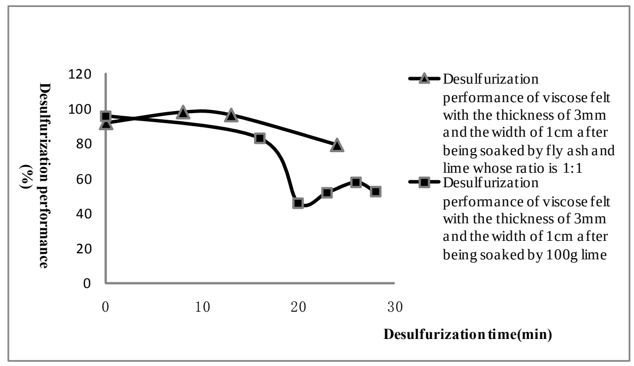

Fig. 8: The comparison between desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm after being soaked by fly ash and lime whose ratio was 1:1 and that after being soaked by 100g lime.

The influence on desulfurization performance of two types of ACF after treatment of being soaked by fly ash and lime (50 g of fly ash and 50 g of lime) with ratio of 1:1

a. Desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm after being soaked by fly ash and lime whose ratio was 1:1 is given in Table 6, and the comparison between desulfurization performance of viscose felt with the thickness of 2mm and the width of 1cm after being soaked by fly ash and lime whose ratio was 1:1 and that after being soaked by 100g lime is shown in Fig. 7.
b. Desulfurization performance of viscose felt with the thickness of 3mm and the width of 1cm after being soaked by fly ash and lime whose ratio was 1:1 is given in Table 7, and the comparison between desulfurization performance of viscose felt with the thickness of 3mm and the

width of 1cm after being soaked by fly ash and lime whose ratio was 1:1 and that after being soaked by 100g lime is shown in Fig. 8.

***Analysis of experimental results*:** Compared with ACF being soaked with 100g lime, desulfurization performance of ACF soaked with fly ash and lime (50g of fly ash and 50g of lime) whose ratio was 1:1 is more efficient, and the duration is longer. The reason is that fly ash and $Ca(OH)_2$ are mixed and have a reaction, which will generate calcium silicate and hydrated calcium silicate. This can further enhance the adsorption activity of calcium for SO_2 and thereby improve the utilization of calcium and the absorption efficiency of SO_2.

CONCLUSIONS

From desulfurization reaction mechanism of ACF, we can draw the conclusions that chemical properties affecting desulfurization performance of ACF include oxygen-containing functional groups and nitrogen-containing functional groups, in essence, is to study the influence of specific surface area on desulfurization performance of ACF; the regeneration of ACF, the treatment of ACF being soaked by 100g lime and the treatment of ACF being soaked by fly ash and lime whose ratio was 1:1, in essence, is to act on the functional groups on the surface of ACF by means of chemical treatment, thereby affecting the active site of SO_2 on its surface, and ultimately affecting desulfurization performance. The specific experimental conclusions are as follows:

1. Regeneration treatment: Desulfurization performance of viscose felt after regeneration decreases, and the duration is also reduced.
2. Treatment of being soaked by 100g lime: Desulfurization performance of ACF has been significantly improved after being soaked by 100g lime, and the duration also increases.
3. Treatment of being soaked with fly ash and lime whose ratio was 1:1: Compared with being soaked by 100g lime, desulfurization performance of this way is more efficient, and the duration is longer.
4. For different types of ACF materials, changing the width has different influences on the specific surface area of the material, therefore, there is no unified conclusions for the influence on desulfurization performance and we need to do some deeper researches; although the regeneration treatment of viscose felt reduces the active site of SO_2, desulfurization performance, and the duration, the recycling use can be achieved, which is the value; the treatment of being soaked by 100g lime increases ACF's adsorption capacity for SO_2, therefore, it can be used to enhance desulfurization performance of ACF. After being soaked by fly ash and lime whose ratio was 1:1, desulfurization performance of ACF is better, so, we need to further explore the best way of soaking treatment.

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