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RESEARCH PAPER

Release and transformation of sodium in an opposed multi-burner coal-water slurry gasifier

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Abstract: Based on the bench-scale opposed multi-burner (OMB) coal-water slurry gasification experimental platform, the transformation and release characteristics of sodium during the reaction of coal in the gasifier were studied. Particles sampled at different axial distances from burner plane to top and bottom along the gasifier chamber were analyzed. After the microwave digestion and chemical fractionation analysis, the content of sodium was tested by flame atomic absorption spectrometer (FASS). The morpholo。丁gy and elements of particles were analyzed by scanning electron microscopy and energy spectrum application system (SEM-EDS). The FASS results showed that the release rate of sodium increased first then decreased with increasing distance to the burner plane. The area near the burner plane was the major release area of sodium. With the reaction in progress in the gasifier the occurrence form of sodium was transformed from water-soluble sodium and ion-exchangeable sodium into the acid-soluble sodium and residual sodium. Combining the SEM-EDS and FASS results, the spherical particles which were formed through melt minerals reacted with sodium in the gas phase to form silicate and sialic acid salt in gasifier. The increasing number of spherical particles led to an increase in the sodium content in the particles.

Key words: opposed multi-burner (OMB) gasifier; particles; sodium; release; occurrence form

Large-scale entrained-flow coal gasification technology with the advantages of high conversion efficiency, large capacity and strong adaptability to coal is the leading and key technology for developing coal-based industries, such as valuable chemical products, combined cycle power generation, hydrogen, etc.[1]. East China University of Science and Technology (ECUST) and Yankuang Group developed the coal water slurry (CWS) gasification technology with opposed multi-burner (OMB), which has achieved a wide industrial applications because of enormous social and economic benefits[2,3].

Pyrolysis, combustion and gasification of coal exist simultaneously in the gasifier, which cause the transformation and release of sodium. The release and transformation of sodium play an important role in the formation of ash. Alkali metal chlorides react with Cr_2O_3 at high temperatures[4–6]. The entrained high chrome refractory bricks of the entrained-flow gasifier is mainly composed of Cr_2O_3, so the presence of alkali metal can easily lead to the corrosion of refractory bricks.

A great deal of research has been done on the release characteristics of sodium during the process of coal conversion. Song et al[7,8] studied the release and transformation of sodium in pyrolysis and gasification of the high-sodium Zhundong coal and found that sodium was mainly released in the form of NaCl, and NaCl reacts with ash to form aluminosilicates. Wei et al[9] investigated the volatility and morphological transformation of Na in semicoke obtained by washing and pyrolysis of coal in a fixed bed. The study showed that at higher than 600°C a part of the residue sodium was transformed into acid soluble sodium. Dai et al[10–12] studied the release migration of sodium in the combustion process of a 30 MW pulverized coal-fired industrial boiler and investigated the effect of sodium on the bond behavior of ash. Wang et al[13] studied the release migration of sodium in Zhundong coal during pyrolysis and found that the sodium was transformed from water-soluble state, ion-exchange state and acid-soluble state to residual state with increasing temperature during pyrolysis.

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Table 1 Proximate and ultimate analyses of coal

Proximate analysis w_{ad}/%				Ultimate analysis w_{ad}/%				
M	*A*	*V*	FC	C	H	O	N	S
1.38	10.59	32.19	55.84	71.8	4.61	11.07	1.17	0.75

Table 2 Chemical composition of coal ash

Composition *w*/%										
SiO_2	Al_2O_3	Fe_2O_3	Na_2O	CaO	SO_3	TiO_2	MgO	K_2O	P_2O_5	others
49.01	32.48	5.31	3.97	3.64	2.03	1.23	0.73	0.72	0.63	0.25

Li et al[14] studied the release migration of sodium in high-sodium coal during combustion and found that sodium was converted from water-soluble state and ion-exchange state to acid-soluble state and residual state with increasing temperature during combustion. At present, there was a lot of research on the release and transformation of sodium in coal during the process of pyrolysis and combustion. But the research mostly concentrated in the small-scale experimental device and there were few reports on the release and transformation of sodium in the entrained-flow coal-water slurry gasifier.

This paper studied the release and transformation of sodium in OMB CWS gasifier based on the bench-scale OMB CWS gasification experimental platform. The particles were sampled at different axial distances from burner plane to top and bottom along the gasifier chamber. After the microwave digestion and chemical fractionation analysis, the content of sodium was tested by flame atomic absorption spectrometer (FASS), and the morphology and elements of particles were analyzed by scanning electron microscopy and energy spectrum application system (SEM-EDS). The results would provide the theoretical basis for stable operation of the entrained-flow gasifier.

1 Experimental

1.1 Raw material

In the gasification experiments, industrial CWS was used as gasification raw materials. The CWS was purchased from Zhejiang Coal Science and Technology Of Clean Energy Co., LTD. The proximate and ultimate analyses of raw coal are shown in Table 1, and the chemical composition of coal ash is listed in Table 2.

1.2 Experimental

The schematic diagram of bench-scale OMB entrained-flow gasifier is shown in Figure 1. The gasification chamber is 2200 mm in height with an inner diameter of refractory wall of 300 mm and an external diameter of stainless-steel casing of 800 mm.

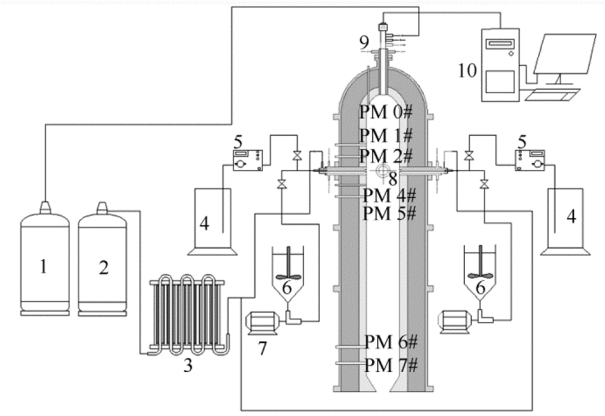

Fig. 1 Schematic diagram of bench-scale OMB entrained-flow gasifier

1: Ar tank; 2: O_2 tank; 3: evaporator; 4: diesel tank; 5: gear pump; 6: CWS-water slurry tank; 7: screw pump; 8: burner 3# and burner 4#; 9: camera; 10: computer

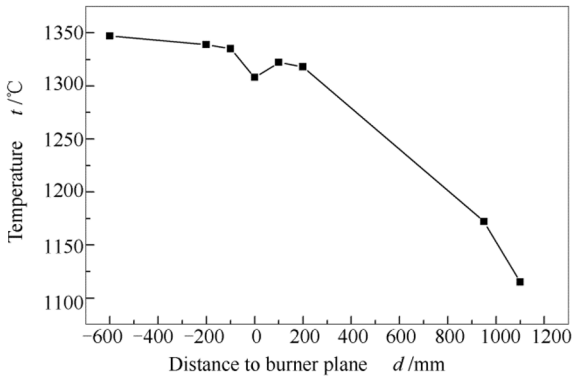

Fig. 2 Temperature in different distance from burner plane

The fiber blanket is filled between the stainless-steel casing and refractory wall to reduce the heat loss. Four burners are oppositely installed with 90° in the same plane which is 600 mm distance to the top of gasifier. There are several sampling ports along the axial gasifier, which are used for collecting solid particles and testing temperature. The high temperature endoscopy is applied for observing the flames in the top of gasifier. The hot syngas and slag are quenched by water in the quench chamber, then flow to the downstream processes.

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