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Experiment Research on Gasification Character of Pulverized Coal at Medium Temperature

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ABSTRACT

In this paper, effect of gasification temperature and residence time on gasification characteristics of typical pulverized coals under atmosphere pressure were studied on a one-dimensional electric heating drop tube furnace system to evaluate gasification characteristics of pulverized coal at medium temperature. The results show that the gasification rate increases with the raising of the gasification temperature under the temperature among 1150℃ and 1450℃, and as the temperature is above 1350℃, the increasing rate become slower. Cold gas efficiency and carbon conversion meet the maximum value when the temperature approaches the ash fusion point of coal. With the further rise of the temperature, ash on the surface of the char starts to be melted, the gasification reaction rate decreases, due to the hindrance of the effective contact between coal char and gasification agent. The gasification efficiency would become steady when the residence time exceeds 8s.

Keywords: Gasification Characteristic; Pulverized Coal; Carbon Conversion; Cold Gas Efficiency

1. Introduction

Issues on natural resource and environment become increasingly severely in China, due to the long-term use of traditional coal combustion. Integrated gasification combined cycle (IGCC) takes advantage on high efficient and environmentally-friendly, is a new power generation technology. Gasified is one of the key devices of IGCC power generation system. Compared to the other gasification technologies, entrained flow gasification technology get rapid development for its advantages of high gasification intensity, high carbon conversion and be easily practiced on a large scale. Influencing factors on gasification efficiency of entrained flow gasified are many, effect of gasification temperature and residence time on gasification characteristics of typical pulverized coals were studied on a one-dimensional electric heating drop tube furnace system under the conditions of atmosphere pressure and medium temperature from 1150℃ to 1450℃[1-3].

2. Experimental System and Work Conditions

2.1. Experimental System

Figure 1 is the picture of experimental system, which is consisted of high temperature tube electric heating furnace, ash collected system and syngas cleaned and detected system. The furnace is made of corundum tube(2.1 m in length, 60 mm in inner diameter), the adjust temperature is up to 1550℃, the gas analysis equipment is a infrared gas analyzer produced by Wuhan Cubic Optoelectronics Technology Co., Ltd., which can proceed real time measurement on CO, CO_2, H_2, CH_4 and O_2.

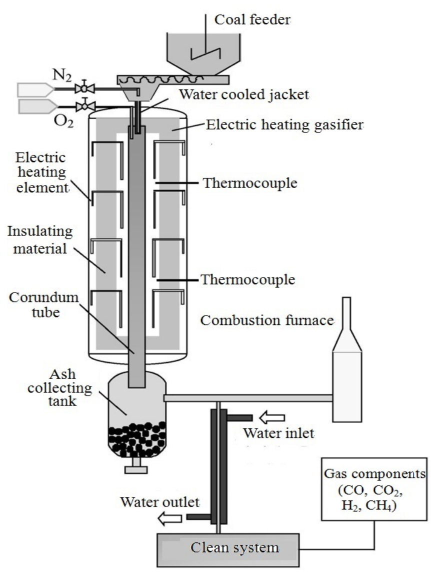


Figure 1. The schematic picture of the experimental process.

2.2. Work Conditions

Datong bituminous coal, a typical bituminous coal in China was selected for the experiment on gasification characteristic of pulverized coal at medium temperature, and effect of gasification temperature and residence time were mainly considered. The average particle size of pulverized coal is more or less than 100 μm (under 150 μm) and the feeding rate is about 0.2 kg/h. The proximate analysis and the elemental analysis of the coal is in **Table 1**, the experimental operating conditions are in **Table 2**.

2.3. Experimental Data Processing Methods

It's relatively difficult to measure the syngas directly as its high temperature. So the total amount of dry gas could be obtained by the calculation of N_2 balance, the divided relationship between the N_2 amount in the inlet and the N_2 percentage of dry gas in the outlet: $Q = \frac{Q_{in,N_2}}{\alpha_{N_2}}$, thereinto, Q is the flow of syngas, Q_{in,N_2} is the flow of N_2 amount in the inlet, α_{N_2} is the gas volume fraction of N_2 in the dry gas.

As the experiment proceeded in one-dimensional drop tube furnace, residence time of pulverized coal staying in the furnace is equal to the residence time of reactivity gas:

$$t = \frac{288 l \pi r^2}{(273+T)(Q_{in,N_2}+Q_{in,O_2})},$$

thereinto, L is the length of the furnace, r is the inner diameter of the furnace, T is the temperature of the furnace; and Q_{in,O_2} is the flow of O_2 in the inlet.

Oxygen element of the gas products is mainly from pulverized coal and the injected O_2 in the inlet, such as CO, CO_2 and H_2O. Therefore, the amount of vapor in the syngas can be calculated by the balance of O_2 element, the amount of vapor in the syngas(mol) = oxygen amount of the injected O_2 + oxygen amount of coal – the amount of the oxygen element from carbon dioxide and carbon monoxide in the gas, the calculation formula is

$$\alpha_{H_2O} = \frac{2Q_{in,O_2}/22.4 + M\gamma_C/16 - 2Q\alpha_{CO_2}/22.4 - Q\alpha_{CO}/22.4}{Q + 2Q_{in,O_2}/22.4 + M\gamma_C/16 - 2Q\alpha_{CO_2}/22.4 - Q\alpha_{CO}/22.4} \times 100\%$$

Thereinto, α is the gas volume fraction of in the dry gas.

Carbon conversion η is the index to calculate how much carbon is transferred to the content in gas during the gasification process:

$$\eta = \frac{(V_{CO2} + V_{CO} + V_{CH_4})/22.4}{M\gamma_C/12} \times 100\%,$$

thereinto, V is gas volume, M is the amount of coal; and γ_C is the amount of carbon in the coal.

Cold gas efficiency η_d is the heat value proportion of fuel and gas products, the calculation formula are:

$$\eta_d = \frac{h_{H_2} + h_{CO} + h_{CH_4}}{h_{f,coal}} \times 100\%,$$

thereinto, h is the gas heat value, $h_{f,coal}$ is the heat value of coal.

Table 1. Proximate analysis and the elemental analysis of the datong coal.

Coal		Datong
Proximate analysis（%）	Mad	1.61
	Aad	26.89
	Vad	28.26
	FCad	42.34
Ultimate analysis（%）	Cad	77.78
	Had	5.39
	Oad	12.79
	Nad	1.09
	Sad	2.69
Ash fusion temperature（℃）	DT	1350
	ST	1370
	FT	1400

Table 2. The Experimental operating conditions.

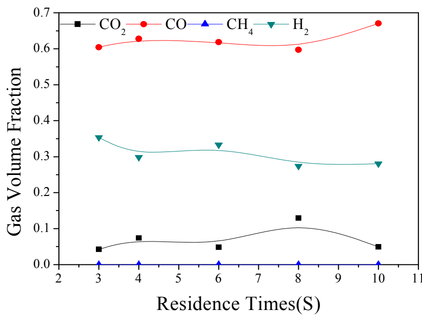
Pressure	Temperature（℃）	Residence time（S）	Ratio of O/C
1atm	1150 1250 1350 1450	10 8 6 4 3	1:1

3. Experimental Results and Discussions

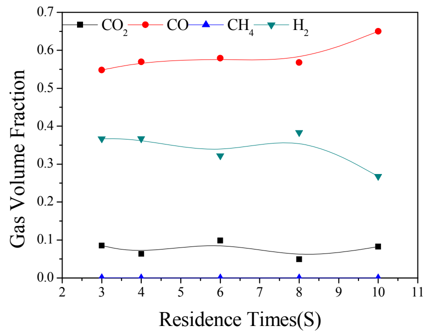
In an actually running entrained flow gasified, the controllable parameter is the feeding rate of coal and O_2, residence time and the amount of steam. Commonly, gasification temperature and the atmosphere inside the furnace can be adjusted by changing the rate of O/C. This adjustment would change the processes of gasification reactivity and the content of syngas, which would definitely change the residence time of gasification agent in the furnace. Therefore, research of gasification temperature and residence time on the gasification characteristic of coal has a significant meaning for the design and following operation of the gasified [4].

3.1. Effect of Temperature and Residence Time on the Composition of Syngas

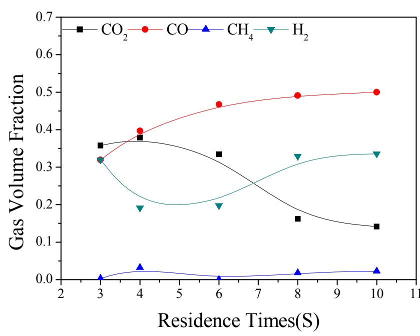
The method of changing injecting rate of N_2 to change the residence time of pulverized coal staying in the furnace was selected in this paper, the range is from 3s to 10s. **Figure 2** shows the effect of gasification temperature and residence time on the composition of syngas [5].



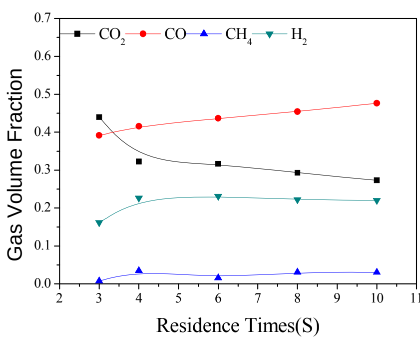
(a) Temperature:1450℃



(b) Temperature:1350℃



(c) Temperature:1250℃



(d) Temperature:1150℃

Figure 2.The effect of temperature and residence time on the components of synthesis gas of Datong Coal

As the figure shows that the composition of the syngas changes with residence time under different gasification temperature conditions, the content of CO increases with the increasing of residence time. When the temperature is higher than 1300℃, the increasing rate becomes smaller and the content of H_2 slightly decreases with the increasing of the residence time, while the content of CO_2 generally remains steady. When the gasification temperature is lower than 1300℃, the increasing rate of CO is relatively bigger, and the fluctuation of H_2 and CO_2 is quite drastic as well. The content of CO_2 falls down with the increase of residence time. With the increase of residence time, the content of H_2 would increase first and then decrease while the temperature is 1250℃. This is mainly caused by the reactivity of H_2O-C is higher than CO_2-C. As the residence time decreases to a certain extent, combustion reactions are mainly happened in the furnace and most of coal char would escape from the furnace directly without reacting with H_2O and CO_2. So, most of H_2 are mainly produced by the paralysis of coal at this condition. With the increase of residence time, the reacting time between H_2O-C and CO_2-C would be extended correspondingly. Followed by the large products of CO_2 and CO, the volume proportion of H_2 in the syngas would be decreased. Due to the reactivity of H_2O-C is bigger than CO_2-C, the volume proportion of H_2 in the syngas increases again with the further increasing of residence time. It can also be seen from the Figure that the volume proportion of CH_4 gets down gradually with the rise of the temperature. When the temperature is above than 1350℃, the volume proportion of CH_4 drops to 0, which indicates that CH_4 is mainly from the volatile components, and the higher temperature of gasification reaction is, the easier CH_4 be decomposed [6,7].

3.2. The Effect of Temperature and Residence Time on the Carbon Conversion and Cold Gas Efficiency

Figure 3 shows the effect of temperature and residence time on carbon conversion and cold gas efficiency of Datong coal. It can be seen from Figure that the carbon conversion and cold gas efficiency increases with the increase of residence time. When it is lower than 1350℃, carbon conversion and cold gas efficiency increases with the increasing of gasification temperature. When it is higher than 1450℃, carbon conversion and cold gas efficiency almost remains the same as that at 1350℃, even slightly lower. The main reason is that the ash would be appeared and accumulated on the surface of coal char particles with the proceeding of gasification reactions, when the gasification temperature is higher than the ash fusion temperature, it would be transferred to liquid phase. It tends to shrink as globular material on the surface

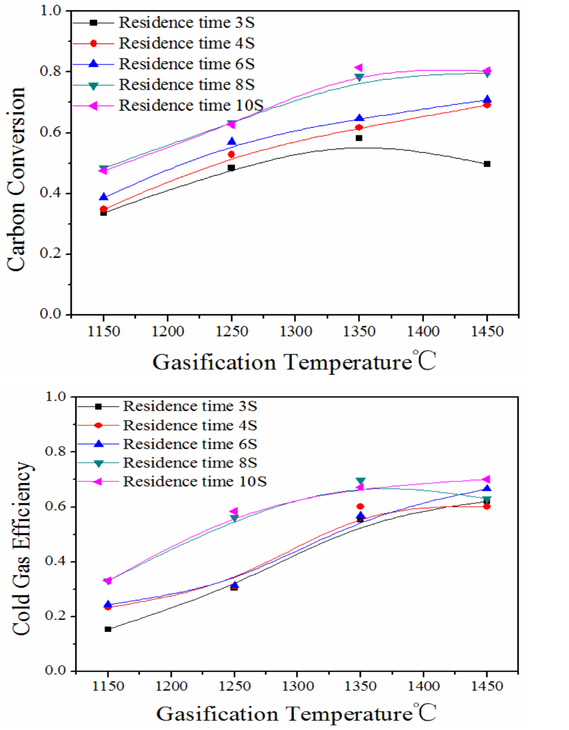


Figure 3. Effect of Temperature and Residence Time on the Carbon Conversion and Cold Gas Efficiency of Datong Coal.

lead to the decrease of effective surface area or separated the char particles from the reacting gases by wrapped the char particles. So the gasification reactivity and gasification reaction rate would be greatly reduced, caused carbon conversion and cold gas efficiency decrease at temperature higher than the ash fusion temperature, which is consistent with the research result of Lu Cheng, Jae Goo Lee and so on [8-11].

4. Conclusions

1) The temperature is one of the most important factors affecting the gasification characteristic of pulverized coal. Under the experimental condition of temperature from 1150℃ to 1450℃, the higher the gasification temperature is, the faster gasification rate of pulverized coal is, and when the temperature is higher than 1350℃, the increasing rate becomes slow down. The maximum carbon conversion is more or less than 80% under experimental conditions.

2) The residence time also has a great influence on gasification of pulverized coal. The carbon conversion and cold gas efficiency goes up with the increase of the residence time under the same temperature conditions. And carbon conversion and cold gas efficiency remains steady after 8 seconds.

3) When the temperature approaches to the coal ash fusion temperature, the carbon conversion and cold gas efficiency reaches the maximum value. With the further increase of temperature, the ash content on the surface of char begins to fuse, which would hinder the effective contact between char and gasification agent and lead to a decline for the gasification reaction rate.

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