



Comparison of oxidation behaviors of novel carbon composite brick with traditional carbon brick

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Abstract

Oxidation of carbon is one of the main problems in alumina–carbon based refractory. In this paper, the oxidation behaviors of novel carbon composite brick and traditional carbon brick were investigated by non-isothermal and isothermal experiments, and the samples after oxidation were examined by SEM and EDS analysis. The results show that the oxidation resistance of carbon composite brick is better than that of carbon brick. At 800–1200 °C, the oxidation kinetics of carbon brick follows the linear rate law, which belongs to non-protective oxidation, and the oxidation activation is 5586.76 J/mol. However, the oxidation kinetics of carbon composite brick follows the parabolic rate law, which belongs to protective oxidation. The compressive strength decreases with the increasing mass loss after oxidation due to the carbon loss, so for carbon composite brick which has less content of carbon the oxidation resistance is better than that of carbon brick. Furthermore, the existence of SiC in the surface of carbon composite brick is another reason for its good oxidation resistance.

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1. Introduction

In recent years, sidewall breakout of blast furnace hearth happened occasionally and caused great economic loss [1]. It is important to apply high quality refractories to extend the service life of blast furnace hearth [2,3]. Alumina–carbon (Al₂O₃–C) refractories are widely used in blast furnace due to their desired properties [4,5]. Carbon brick is one kind of traditional Al₂O₃–C refractories used in blast furnace hearth due to its high thermal conductivity and low wettability by molten slag [6]. However, traditional carbon brick is easy to be oxidized at high temperature condition, and after oxidation the structure of carbon brick is destroyed and the molten iron could penetrate into the brick causing further destruction [7]. In order to increase the oxidation resistance, some additives, such as Si, Al and SiC, are added into traditional carbon bricks [8,9]. However, the

effects of additives are limited due to the high percentage of carbon in traditional carbon bricks. Carbon composite brick is a new kind of refractory used in blast furnace hearth, and it is developed by Chinese engineers. For carbon composite brick, carbon is reasonably added into ceramic matrix and resin is used as binder, while by micropore processing technology, the microporous structure of carbon brick is maintained. Thus, the carbon composite brick combines the high thermal conductivity of carbon-based materials and the high corrosion resistance of ceramic materials.

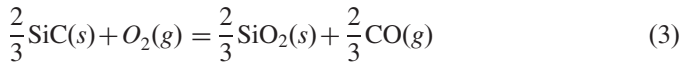
Oxidation resistance is an important index for blast furnace hearth refractory. The oxidation of carbon-based refractories is mainly caused by oxygen in the atmosphere reacting with the carbon in the materials [10]. According to the following reactions, oxidation product should be CO or CO₂:



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SiC is added into most of refractories to enhance the strength and the oxidation resistance. The oxidation behaviors of SiC can be classified into active oxidation and passive oxidation [11–16]. In the passive oxidation, the SiC interacts with the coming oxygen in surface forming SiO₂ [17,18]. Thus, the mass of the materials would be increased. It is given by the following reaction:



In the active oxidation, the mass of the materials decreases because of the formation of gaseous silicon monoxide (SiO) [19,20]. It is given by the following reaction:



There are many studies on the oxidation resistance of magnesia–carbon (MgO–C) bricks [21–23]. Hashemi et al. [21] have investigated effects of resin and graphite content on oxidation behavior of MgO–C brick. The results showed that showed that with increase in graphite content, the thickness of oxidized layer decreased even if the weight loss increased. Ali et al. [22] have studied the oxidation kinetics of MgO–C brick in the temperature range from 1000 °C to 1200 °C, and indicated that graphite in MgO–C brick is mainly consumed by gaseous oxygen in air. Cho et al. [23] have studied the improvement of oxidation resistance in graphite for MgO–C brick through surface modification, and indicated that the modified graphite shows better dispersivity than the pristine graphite. Compared with the researches on the oxidation behaviors of MgO–C bricks, there are less ones on the oxidation resistance of Al₂O₃–C bricks. This study was aimed to examine and compare the oxidation resistance of carbon brick and carbon composite brick in air at different temperatures.

2. Experimental

The samples used were cut from commercial carbon brick and carbon composite brick (Henan Winna Industrial Group Co., Ltd.). The chemical composition of the bricks is shown in Table 1 while the physical and chemical properties of the bricks are shown in Table 2.

Before experiments, the samples were cut into small cuboids with size of 25 mm × 15 mm × 15 mm. After the procedures of coarse grinding, fine grinding and drying, the final sizes of the samples were measured.

The schematic of experimental apparatus was shown in Fig. 1. The furnace is heated using Si–Mo heating elements producing a constant temperature zone. The samples were placed in a basket made by Fe–Cr–Al wires and the basket is placed in the constant temperature zone. The Fe–Cr–Al wire

Table 2

Physical and chemical properties of carbon brick and carbon composite brick.

Item	Carbon brick	Carbon composite brick
Density, (g/cm ³)	1.8	2.9
Apparent porosity, (%)	14	11
Average pore diameter, (μm)	1.0	0.2
Resistance to molten iron infiltration, (%)	20	0.6
Thermal conductivity, 300 °C	10 W/(m°C)	16
600 °C	12 W/(m°C)	14
900 °C	14 W/(m°C)	13

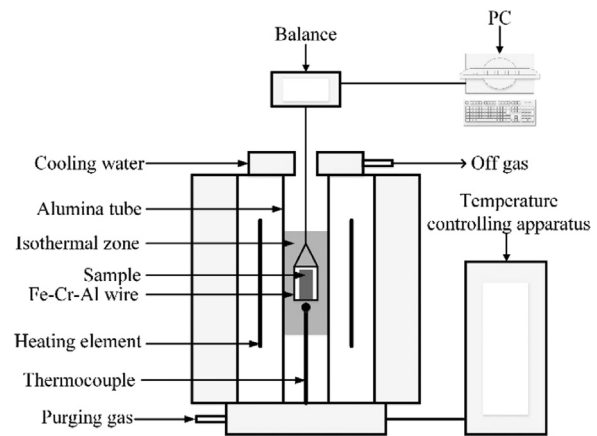


Fig. 1. Schematic of experimental apparatus.

was selected as it did not affect the reaction due to small contact area with the samples and no other reaction was found between the Fe–Cr–Al wire and the samples after experiments. When the furnace reached the required temperature for the specific experiment, the samples were placed in the basket. The weight loss data during reaction process was recorded every 30 s by computer via a digital balance. After the experiments, the samples were removed from the furnace. The weight of the samples was measured and the weight loss per unit area was determined as follows:

$$\frac{\Delta W}{A} = \frac{W_0 - W_t}{A} \quad (5)$$

where W_0 is the weight before the tests, mg; W_t is the weight after time t , mg; A is the surface area of the samples. The estimated error of the balance was ± 1 mg.

The oxidation experiments consisted of non-isothermal experiments and isothermal experiments. In the non-isothermal experiments, the temperature was controlled from 400 °C to 1200 °C with heating rate 3 K/min. In the isothermal experiments, the temperatures were maintained at 600 °C, 800 °C, 1000 °C and 1200 °C respectively, and the holding time was 300 min. During the experiments, air was supplied from the bottom of the furnace at a rate of 3 L/min making oxidizing atmosphere (oxygen partial pressure=0.21 atm).

The microstructure of the samples was investigated by SEM (FEI Quanta 250, FEI, Hillsboro, USA), EDS and

Table 1
Chemical compositions of carbon brick and carbon composite brick, wt%.

Chemical composition	Al ₂ O ₃	C	SiC	SiO ₂	Others
Carbon brick	17.5	65.0	1.8	15.4	0.3
Carbon composite brick	73.1	10.2	6.0	8.2	2.5

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