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THERMOGRAVIMETRIC (TG) INVESTIGATION ON REDUCTION OF HEMATITE POWDER WITH CARBONIZED CORN STRAW

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Microtopography and combustion characteristics of carbonized corn straw and pine charcoal as well as anthracite were investigated to compare the property of fuel and analyze the application of corn straw in industrial activity. The reduction process of hematite with different reducing agent was studied with thermogravimetric analysis. It is indicated in the results that the initial reduction temperature was lower when carbonized corn straw was blended with hematite and an ideal reduction rate can be achieved with a C/O of 1.1, while the reduction rate of pine charcoal to hematite was lower and higher C/O is needed for anthracite to obtain the same reduction rate.

Key words: thermography, hematite, reduction, corn straw, carbonization

INTRODUCTION

A considerable amount of fossil fuels was consumed annually due to the expansion of crude steel production in the past decades, which has led to a significant increase in greenhouse gases emission and particulate pollution [1]. The annual production of crude steel in China accounts for over 50 % of total world production, accordingly a great quantity of metallurgical coke was consumed in ironmaking process [2]. Huge consumption of carbon-based fossil fuels has caused atmospheric phenomenon and become a threat for human health. The frequent fog and haze occurred in most regions of China in the past decade has bring out serious influence on human outdoor activities and significant increase in respiratory diseases rate [3, 4].

A sustainable energy source is need for the increasing energy demand and decrease the influence of industrial activity on the daily life of human [5]. Biomass, as a clean and reproducible energy source, has attracted great concern of metallurgical researchers. In consideration of the widely distribution and carbon neutral properties of biomass, its economical and environmental superiority was noticed in comparison to conventional fossil fuels [6]. Both pollution and production cost can be decreased if corn straw can be utilized as a source of fuel. The original biomass was consisted of tenacious fibrous structure and heterogeneous composition, therefore a considerable quantity of energy was consumed during the pulverization of original bioamss. The carbonization of biomass may optimize biomass properties for metallurgical application [7, 8].

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In this study, original corn straw and pine was carbonized in N_2 atmospere, by which the moisture was eliminated and their grindability and kinetic property was upgraded. Besides, the microtopography of fuels was observed with scanning electric microscope (SEM) to analyze the shape and distribution as well as granularity of fuel particles. Subsequently, the combustion behavior of carbonized corn straw (CCS) and pine charcoal (PC) as well as anthracite powder (AP) were studied, while the reduction behavior of fuels to hematite with different C/O were also tested with thermogravimetric analysis [9, 10].

EXPERIMENTAL

Samples and preparation

Corn straw were collected from fields and carbonized in N_2 atmospere under the temperature of 500 °C for 2h to eliminate volatile matters. PC was also prepared with the same procedure from pine. Beside, a widely used Yangquan anthracite in China and a hematite from Australia were also chosen for this study. The proximate analyses of fuels were shown in Table 1, while the chemical composition content of hematite is shown in Table 2. All samples were dried under 105 °C for 4h, subsequently pulverized and sieved below 0,074 mm for experiments.

Table 1 **Proximate analysis and ultimate analyses of CP sample / %**

Sample	Proximate analysis		
	FC_d	V_d	A_d
CCS	58,47	28,01	13,52
PC	83,01	15,02	1,97
AP	73,53	17,82	8,65

FC, fixed carbon; V, volatile; A, ash; d, dried;

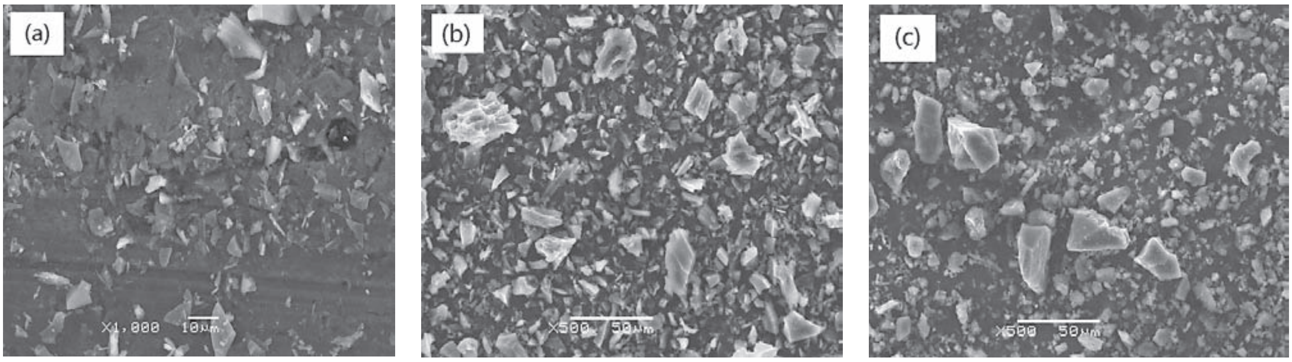

Figure 1 Microtopography of fuel pariticles: (a) CCS; (b) PC; (c) AP.

Thermogravimetric tests of blends

Thermogravimetric characteristics of fuels and hematite powder (HP) were investigated by utilizing a HCT-4 thermogravimetric analyzer. About 17,5 ± 0,1mg sample was loaded and heated from ambient temperature to 1 440 °C at heating rate of 20 °C/min in N_2 atmosphere with a flow rate of 100 ml/min. Besides, blends of hematitie with different fuels and different C/O were also tested to study the effect of fuel quantity on reduction behavior of hematite.

RESULTS AND DISCUSSION

Microtopography of fuel particle

The distribution and morphology of different fuel particles were observed with SEM, while the microtopography of different samples is shown in Figure 1. As can be seen from the photos that carbonized corn straw mainly exists in slice shapes, which indicates the advantage of CCS in specific area per unit comparing to other fuels. The particles of PC sample are observed to be granular while the edges and corners of its particles are very sharp. Simultaneously, the internal structure of PC particles was also noticed to be porous. However, the particles of pulverized AP sample are more regular in sharp in comparison to other two samples and the internal of its granule is relatively solid.

Table 2 **Chemical composition content of hematite samples / %**

Fe	FeO	SiO_2	CaO	MgO	Al_2O_3
65,24	0,45	3,12	0,21	0,22	1,13

Thermogravimetric behavior of samples

The thermogravimetric behaviors of different samples were exhibited in Figure 2. It can be seen that the initial reaction temperature of CCS is as low as about 250 °C and its maximum reaction rate can be obtained at about 350 °C, while the initial reaction temperatures of PC and AP are above 300 °C and their maximum reaction rates were respectively achieved at the temperature of 500 °C and 600 °C. Simultaneously, the thermogravimetric characteristic of HP showed that the de-

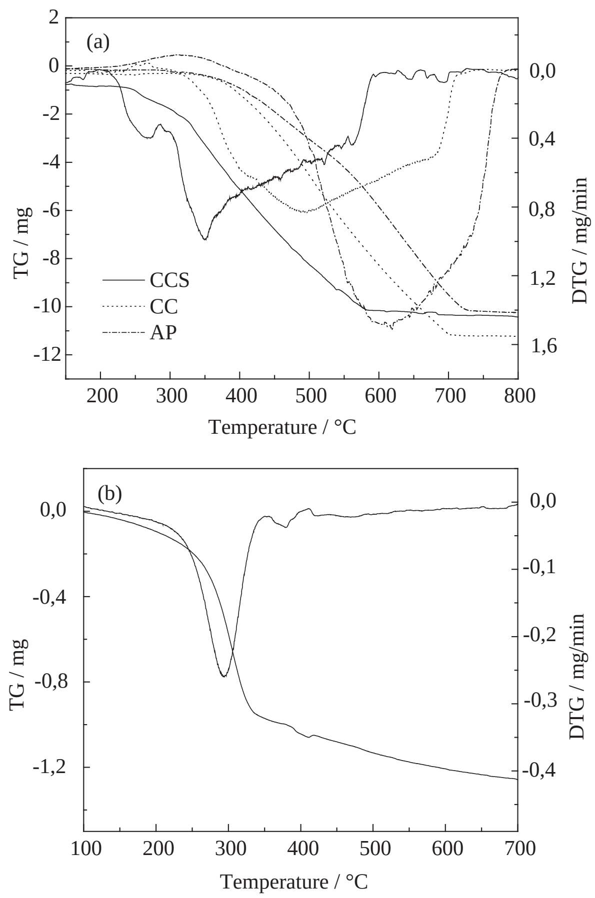

Figure 2 Thermogravimetric analysis of samples: (a) Fuels in air atmosphere; (b) Hematite powder in N_2.

composition of crystal water occurred at the temperature zone between 250 °C and 350 °C, while it seemed to be very stable at other temperatures.

Reduction behavior of samples

The reduction behaviors of different blend samples were shown in Figure 3. A sharp decrease on TG curve of all samples was noticed around 300 °C, which was identified as the decomposition of crystal water in hematite. Meanwhile, a relatively stable stage of sample was observed in the temperature zone between 300 °C and 800 °C, which was possibly attributed to the pyrolysis of volatile in fuels. Subsequently, the reaction temperature between CCS and hematite initiated at about

850 °C due to the superior activity of CCS, while the initial reduction temperatures of other fuels are both over 900 °C. Tough the maximum reaction rate of CCS blends was much lower than that of PC and AP, the reduction of CCS was completed at lower temperature due to its constant reduction reaction rate under lower temperatures.

The proportion of fuel has a great influence on the reduction rate of samples with CCS and PC when value of C/O was below 1,1, while the further increase in proportion of above two fuels was not seemed to effective on their reduction reaction. However, an obvious relationship between reduction rate and C/O was noticed in AP blends, which was possibly related to the activity of carbon in AP fuel. To CCS and PC fuels, an ideal reduction rate can be achieved with the C/O of 1,1, while that of AP was supposed to be 1,2 at least.

It can be seen in the reaction rate cures of CCS blends that a stable reaction rate was noticed between 900 °C and 1 100 °C, while the maximum reaction rate

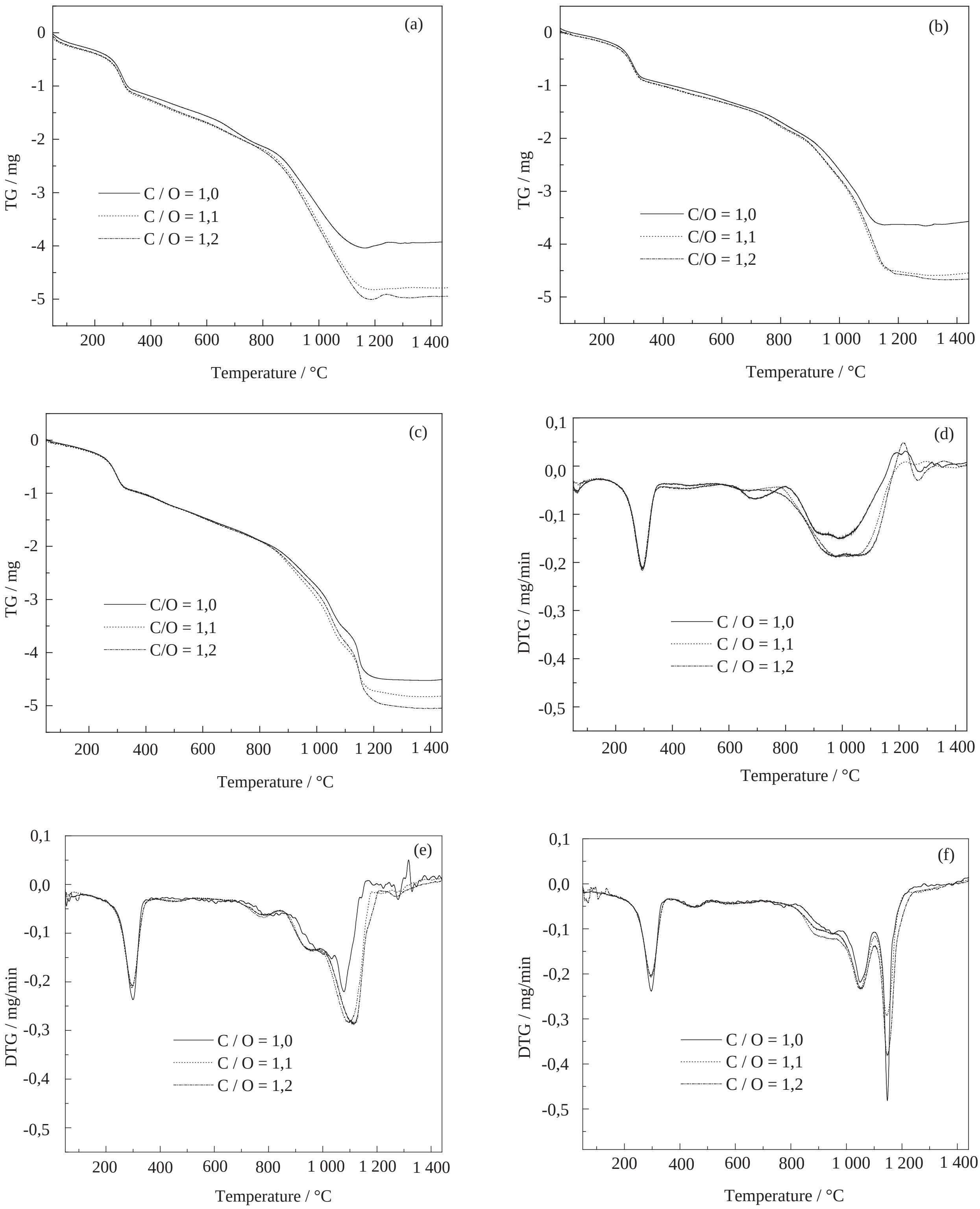

Figure 3 Thermal reduction of samples: TG curves of CCS (a), PC (b), AP (c) and DTG curves of CCS (d), PC (e), AP (f).

of samples with PC and AP were respectively achieved at the temperature of 1 100 °C and 1 150 °C. Moreover, though maximum reaction rate of PC and AP blends were higher than that of CCS blends, their reaction time under those rates were unabiding. Namely, the reduction of hematite powders can be carried out below the temperature of 1 000 °C with a superior and constant reaction rate.

CONSLUSIONS

CCS is likely to exist in slice shape after pulverization, consequently its specific area is relatively higher than other carbon-based fuels. As a result, a superior activity of CCS was noticed comparing to charcoal and anthracite, consequently it is feasible to be utilized as a new energy source for metallurgy.

The maximum reduction reaction rate of CCS can be achieved at a low temperature of 350 °C, while that of PC and AP samples are over 500 °C and 600 °C respectively. Hence, the superb activity of carbon in CCS manifests its application possibility in both combustion and reduction utilization.

An ideal reduction rate can be achieved when CCS was applied as a reducing agent in hematite powders with the C/O of 1,1, while the reduction rates of PC blends was lower under the same C/O and higher C/O value was indispensable for AP blends to achieve the same reduction rate.

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