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Effect of coke contraction on mean coke size

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HIGHLIGHTS

- We examined the relationship between coke size and the coke contraction ratio.
- The contraction ratio was independent of coal VM and Ro.
- The mean coke size increased with decreasing the coke contraction ratio.

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ABSTRACT

In order to develop a coal blending technology to control the size of blast furnace coke, we investigated the relationship between coke size and the contraction behavior of semi-coke after resolidification which is one of the factors determining coke size. Coke contraction after resolidification was measured successfully by heating the coal sample from room temperature to 1000 °C using a high-temperature dilatometer. The contraction coefficient of coke showed a first maximum near the resolidification temperature (contraction beginning temperature), a first minimum at around 550 °C and a second maximum at around 700 °C. The measurement of contraction characteristics of 15 coals confirmed that the first maximum of coke contraction coefficient varied according to the type of bituminous coals and was independent of coal VM (volatile matter) and Ro (vitrinite reflectance). On the other hand, the contraction coefficient of coke after the first minimum (at around 550 °C) was nearly independent of the type of bituminous coals. The coke contraction ratio between the resolidification temperature and 1000 °C increased with increasing the first maximum of coke contraction coefficient. It was confirmed both in laboratory scale and in commercial scale that mean coke size is strongly associated with coke contraction ratio after resolidification and that mean coke size increases with decreasing coke contraction ratio. In view of the information and data presented in this paper, a practical application of the technology to control coke size by coal blending based on the coke contraction percentage of each coal is expected.

1. Introduction

In blast furnace iron making process, coke acts as (1) a heat source, (2) a reducing agent, (3) a spacer for gas and liquid flow and (4) an agent to lower melting point of iron. Among them, the function of spacer is considered the most important since there is no replacement for coke to fulfill this specific role. Therefore, blast furnace coke size is required to be about 50 mm when charged in a blast furnace and to have enough strength in order to reduce the generation of fine particles caused by mechanical impact. Much emphasis is placed on strength and size of coke for stable blast furnace operation [1].

Developing a technology to control coke quality is one of the most important subjects in coke making process. Especially in Japan, which is totally dependent on metallurgical coal imports, there have been many studies on the relationship between coal blending and coke strength [2–8] and a technology to control coke quality by coal blending is now put to practical use in commercial plants. On the other hand, for coke size, which is another important quality, there have been no clear conclusions on the relationship between coal blending and coke size. Some reports show that mean coke size decreases with decreasing coal rank (increasing volatile matter content) [9,10] and other studies mention that there are no correlations between volatile matter content and mean coke size [11,12]. It is well known that coke oven flue temperature and addition of inert substance such as coke breeze are factors controlling coke size and that a decrease in coke oven flue temperature [11,13,14] and addition of coke breeze [14–16] increases mean coke size. However, since a decrease in coke oven flue temperature leads to decreasing productivity, this method is not practical to increase mean coke size. Furthermore, since addition of an inert substance such as coke breeze tends to decrease

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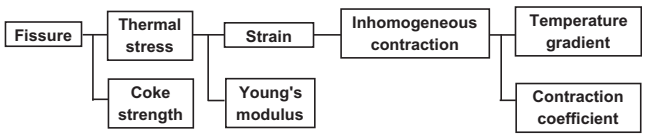

Fig. 1. Factors determining mean coke size and fissures in coke.

coke strength, expensive measures such as blending more caking coals and additives (pitch) are needed to maintain coke strength. Therefore, a technology to control coke size by coal blending is strongly required.

Coke size depends on fissures occurring in coke. As shown in Fig. 1, inhomogeneous contraction causes strain in semi-coke layer, which results in the generation of thermal stress, calculated by multiplying strain by Young's modulus. Fissures occur when the thermal stress exceeds breaking strength of coke [17–19]. Inhomogeneous contraction occurs since there is a temperature gradient in the semi-coke layer and coke layer and contraction coefficient of coke changes with temperature. There have been some studies on the dependence of contraction coefficient of coke on flue temperature and addition of coke breeze. It has been reported that an increase in coke oven flue temperature (i.e. an increase in temperature gradient) makes coke contraction more inhomogeneous, which leads to an increase in thermal stress and a decrease in coke size [20]. It has also been shown that an addition of coke breeze decreases contraction coefficient after resolidification, which leads to an increase in coke size [15,21]. The dependence of contraction coefficient of coke on types of bituminous coal was investigated [14,19,22,23] and Jenkins et al. have recently studied the mechanism of fissure formation in coke and the effect of heating rate, shrinkage and coke strength on fissure formation both from experiments and a model in great details [24–26]. However, there have been no practical studies on the dependence of coke size on the contraction coefficient.

In this paper, in order to develop a coal blending technology to control the size of blast furnace coke, we measured the contraction coefficient of coke for single coals and blended coals and investigated the dependence of coke size on the contraction coefficient.

2. Laboratory scale investigation

2.1. Experiment

2.1.1. Measurement of coke contraction after resolidification

Coke contraction after resolidification was measured using an apparatus (high-temperature dilatometer [14,19,22,23]) as shown in Figs. 2 and 3. The coal sample is placed in a retort and the retort is set in an electric heating furnace as shown in Fig. 2. The sample is heated at a certain heating rate and the change in length is measured by a laser displacement meter. Four retorts can be set in the furnace and three retorts are used for measurement. The last one is used for measuring temperature with a thermocouple.

As shown in Fig. 3, the sample retort consists of an outer retort and an inner retort where coal sample is charged. The inner retort is a tube (8.0 mm in inner diameter, 14.5 mm in outer diameter and 110 mm in length) closed at the bottom and made from stainless steel. The side wall is perforated to facilitate degassing with holes of 0.5 mm in diameter (16 positions along the circumference, 23 columns along the height at 4 mm intervals, 368 holes in total). The outer retort is a tube (15.5 mm in inner diameter, 24.0 mm in outer diameter and 530 mm in length) closed at the bottom and

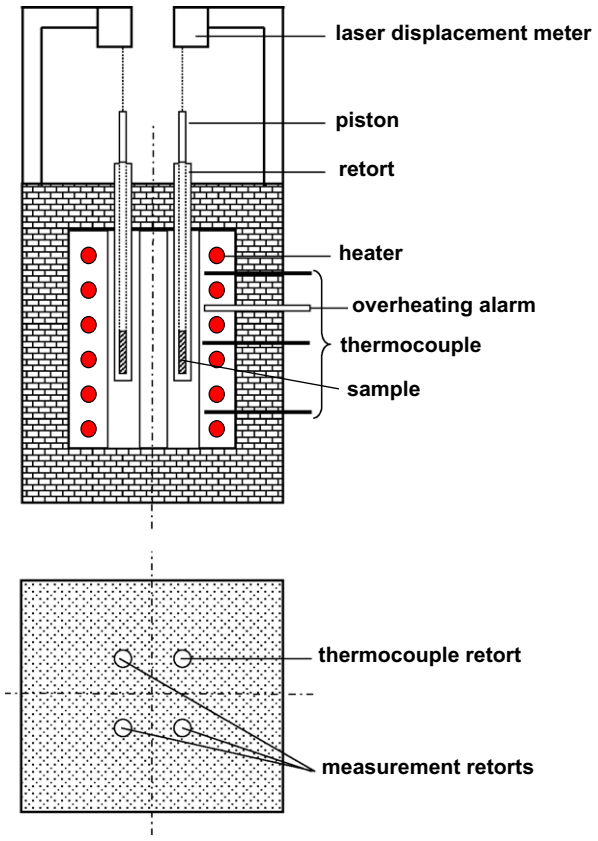

Fig. 2. Test apparatus for measuring coke contraction (high-temperature dilatometer).

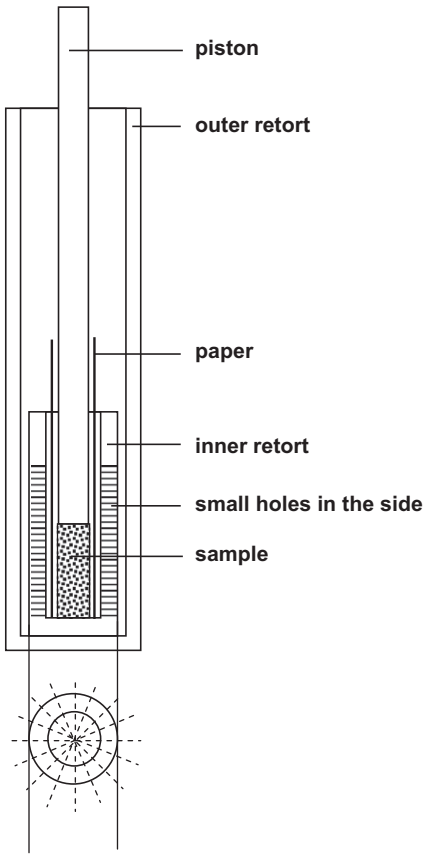

Fig. 3. Inner and outer retorts in high-temperature dilatometer.