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Visualization study on the methane segregation injection technology in iron ore sintering process

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Abstract

It is widely reported that sinter strength would be weakened due to the damaged heat condition adopting low grade solid fuels, such as biomass. Moreover, the unevenly distributed heat in sintering bed is considered to be problematic on the quality of sintered ores. Aiming at solving these problems, the gaseous fuel (methane) injection method is experimentally investigated. Furthermore, the methane segregation injection method is firstly proposed. In this paper, the heat pattern in melting zone is recorded by the thermal infrared imager.The premixed air and methane is injected to the melting zone from the top surface of sintering pot and burned near the solid fuels combustion zone. Methane concentrations of 0.0% and 0.5% are tested, keeping the total calorific heat input unchanged. The non-segregation (0.5%-0.5%) and segregation (0.8%-0.2%) injection cases are also compared. The results indicate that methane injection method could extend the melting zone from the upstream without increasing the energy consumption, which is helpful to the improvement of sinter strength. From the infrared images, it is observed the melting zone becomes much more uniform after employing the segregation injection method. The present study provides an effective way to maintain the sinter quality when using low grade fuels in sinter plant, and minimize the imbalance of heat distribution in sintering bed.

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Key words: iron-ore sintering, gaseous fuel injection, methane concentration, fuel segregation, heat pattern

1. Introduction

Iron ore sintering is a pre-treatment technology to convert iron ore fines into porous and permeable sinters which are the most important burden materials for blast furnace. The main process is described in detail in our previous published paper [1]. Conventionally, coke breeze is employed to provide heat

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needed for the formation of melting phase. However, the increasing cost and environmental issue of coke breeze necessitate the efforts to seek for alternative fuels with low cost and emission. From a longer-term view, fossil energy should be partially replaced by renewable energy gradually. In the last decade, the co-firing of coke breeze and biomass in iron ore sintering has drawn wide attention. Ooi et al. examined the combustion characteristics of sunflower seed husk [2] and charcoal [3] in sintering process. It was found that, the proper substitution of coke breeze were 10% for sunflower seed husk, and 20% for charcoal, respectively. The sintering performance was badly weakened at high biomass proportion. Kawaguchi et al. [4] performed sintering experiments using raw biomass and carbonized char. Sintering yield and combustion efficiency were low when raw biomass was used directly. Generally, most biomass belongs to the low grade fuel compared to coke breeze. The excessively high flame front speed at high biomass proportion narrows the thickness of melting zone, leading to the deteriorated sinter strength. Therefore, it is necessary to broaden the melting zone directly for high sinter strength when applying the low grade fuels in sinter plant.

The unevenly distributed heat is considered to be problematic on the sintered ores quality [5]. For example, under-melting of iron ores in the upper bed results in the weakened sinter strength. While the over-melting of iron ores in the lower bed causes a waste of energy. To solve this problem, researchers [6] proposed the multi-layer (solid fuel content) method using newly developed charging device, by which the coke content in raw materials realized cascaded distribution (decreasing from upper bed to lower bed). However, it is difficult to control the coke content in different layers flexibly and preciously. What's more, the specialized charging device brings low universalness.

In this paper, gaseous fuel injection method [7] is employed to maintain the high sinter strength for the utilization of low grade fuels, as well as minimize the imbalance of heat distribution in sintering bed. The method enables to create a secondary combustion zone to broaden the high temperature zone through a flexible way. Meanwhile, the new method can easily and preciously achieve the fuel segregation for optimizing energy distribution in sintering bed. The research is carried out at the laboratory scale to observe the melting zone evolutions at different conditions using the infrared thermography.

2. Experimental method and materials

The experimental setup shown in Fig. 1 consists of gases supply and methane injection systems, fixed sintering reactor, ignition system and infrared temperature measurement system (FLIR, SC2500). Methane flows through the pressure reducing valve (PRV), filter, ball valve, mass flow controller (MFC) (Bronkhorst) and check valve, respectively. Finally, the methane is injected into the main pipe, and premixed with the air. To achieve fully mixing of methane and air, two measures are taken in the present study. The double side inlet of methane is adopted. And the metal foam (thickness of 10 mm, pore size of 0.8 mm) is arranged in the pipe to enhance the mixing, as shown in Fig. 1. A K-type thermocouple is inserted in the wind box to monitor the exhaust gas temperature. Four S-type thermocouples are arranged to record the bed temperature at the wall for correcting the parameters in infrared thermography.

In the base case, raw materials contain iron ore fines, return fine, hydrated lime and solid fuels, as shown in Table 1. For the other cases, the fuels mass is converted based on equivalent calorific heat. Iron ore particles bigger than 5 mm are crushed into finer particles to improve the air flow uniformity. According to the preliminary tests, the optimum moisture content is 10.25%. For each test, about 400 g hearth ores and 10 kg raw materials after granulation are fed into the sintering reactor. The available gaseous fuels in iron and steel production process are natural gas, coke oven gas and blast furnace gas. The main compositions of these gases are carbon monoxide or methane. As an elementary research, we select methane (99.9%) as the injection fuel considering the toxicity of carbon monoxide.