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Heat transfer of spent ion exchange resin in iron ore sintering process

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HIGHLIGHTS

- A mathematical model for heat transfer in sintering process was established.
- An effective way of spent ion exchange resin (SIER) treatment was proposed.
- Heat transfer effects of SIER in sintering process were studied.
- Effect on maximum sintering temperature of different SIER content was discussed.

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ABSTRACT

Spent ion exchange resin (SIER) is a kind of solid waste which derived from water treatment process in iron and steel industry. Utilization of SIER as a replacement of fuel in sintering process is a promising method of SIER treatment. In order to investigate the feasibility of this method, heat transfer effects of SIER in iron ore sintering process were studied in this paper via numerical simulation. A 3D unsteady numerical reference model was developed on the basis of the porous media model and local non-equilibrium thermodynamics model and verified by the data form measurement. Heat transfer effects of different SIER mass fractions (0–8%) in sintering material during the sintering process were studied on the numerical model established in this paper. The results showed that with the increasing mass fraction of SIER, the maximum combustion zone thickness and flame front speed are both increased, the heating-up point, the moment when solid temperature reached the top and the maximum temperatures were all became earlier in different location of sintering bed. When SIER content is 8%, the maximum sintering temperature exceeds the maximum limit of best sintering temperature.

1. Introduction

As a pillar of Chinese economy, iron and steel industry is in large scale and has made a significant contribution to China's rapid rate growth. However, with the booming of iron and steel industry, production of solid wastes and energy crisis are becoming serious problems [1–4]. Spent ion exchange resin (SIER) is a kind of solid wastes which origins from water treatment process in iron and steel industry. SIER has an appearance of spherical particles with the color of golden yellow and the size of 1 mm. It is the production of ion exchange resin which is widely used in different processes, such as water softening and purification, metal separation of iron and steel industry [5–7]. After service, tons of resins are unable to regenerate and discarded as waste. Its inflammability and toxicity make SIER becomes a potential concern to the environment.

Many researches are focused on the properties of ion exchange resin or spent ion exchange resin. Dubois et al. [8] studied the thermal degradation of cationic and anionic ion exchange resins in both incineration and pyrolysis, they found that hazardous products were induced from the two forms of thermal degradation. Ung et al. [9] studied the process of ion exchange resins pyrolysis with the use of a small-scale, commercial TGA. The off-gases of H_2S, SO_2, CO, and NO were observed during the pyrolysis of cationic resin. For most iron and steel plants, hundreds tons of SIER are generated during the production of iron and steel every year. Vast amounts of payment are paid for the related environmental protection companies on the storage and disposal of SIER, which has become a large burden for iron and steel plants.

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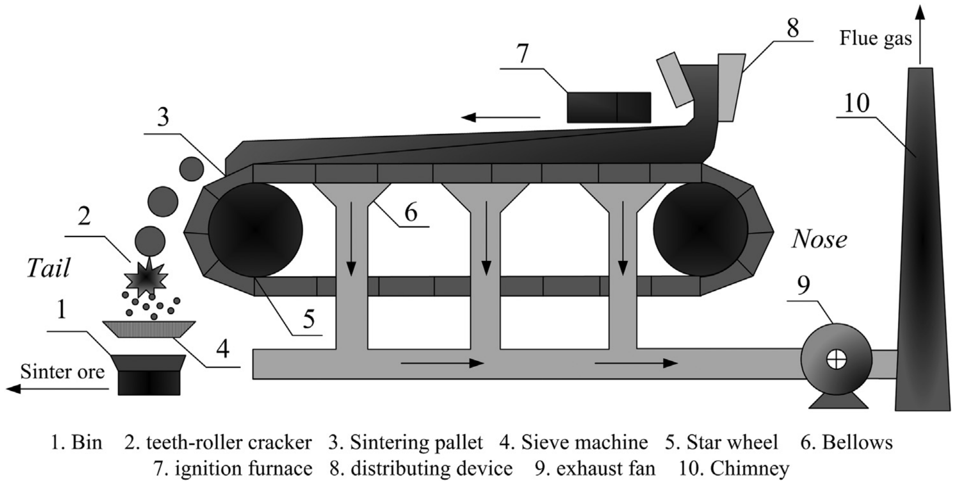

Fig. 1. Schematic diagram of sintering machine.

This paper proposed an environment-friendly and resource-saving method of SIER treatment. SIER mixed with iron ore was sintered in sintering process. Sintering, as physical-chemical process of iron ores preparation and obtaining of a controlled situation, is a large energy consumption process in iron and steel production [10–12]. During the sintering process, SIER can completely combusted in a high temperature environment (over 1200 °C) while the pollutant gases are absorbed by the tailing gas treatment unit in sintering machine. Moreover, combustion heat of SIER can be a part of energy which supplies the sintering process. In order to investigate the feasibility of this method, the heat transfer effects of SIER in iron ore sintering process were studied in this paper via numerical simulation. In this paper, a 3D unsteady numerical reference model was developed on the basis of the porous media model and local non-equilibrium thermodynamics model and verified by the measurement data. The heat transfer effects of different mass fractions (0–8%) of SIER in sintering material during the sintering process were studied on the numerical model established in this paper.

2. Establishment of model

2.1. Model simplification

Fig. 1 schematically shows the diagram of sintering machine. As illustrated in Fig. 1, with the effect of two star wheels located at the nose and tail of sintering machine, respectively, sintering pallets move along the pathway slowly. During this process, air is supplied to the sintering bed by the draft suction fan. The combustion commences at the top of sintering bed and propagates into the bed with sintering near the flame front. In this paper, we only focus on the sintering process in a single sintering pallet. Therefore, the computational domain can be simplified to a cuboid with the size of 4000 × 1500 × 650 mm which illustrated in Fig. 2.

2.2. Model assumptions

Sintering process involves a series of physico-chemical reactions over a large temperature range. As shown in Table 1, sintering process contains coke combustion, limestone calcination, magnetite oxidation and water evaporation, etc., coupling with sintering bed shrinking, which is difficult to describe accurately. This paper only focus on heat transfer effects of SIER in iron ore sintering process. Based on this way, the assumptions made in this model are as follows:

(1) There is no temperature gradient within the sinter particles.
(2) The radiation between/in solids and gases is ignored.
(3) The shrinkage of sintering bed and condensation of liquid are ignored.
(4) The sintering bed is treated as porous media with the porosity of 0.4.
(5) Coke combustion, SIER combustion, water evaporation and limestone calcination are in consideration and treated as inner heat source.

2.3. Mathematical description

(1) Porous media model

A homogeneous porous media model is used to describe the gas flow in sintering bed. For this model, a source term added to the momentum conservation equations is described as follow [13]

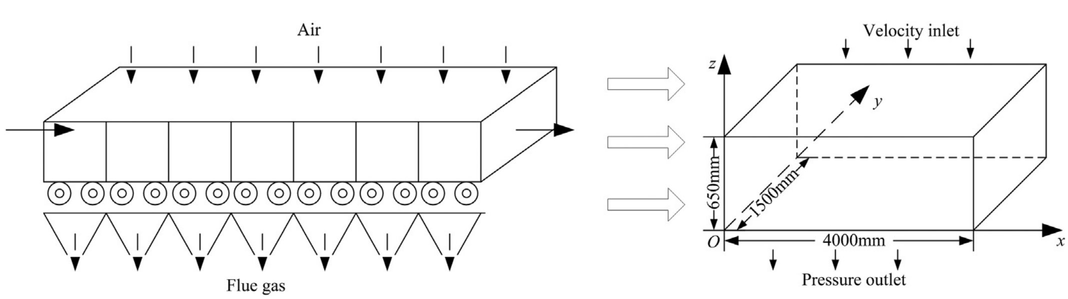

Fig. 2. Simplification of computational domain.