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Identifying major zones of an iron ore sintering bed

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ABSTRACT

An unsteady, two-dimensional axisymmetric model is applied to simulate the iron ore sintering process. The present model consists of a wide range of chemical mechanisms in conjunction with detailed and complicated kinetic models. The temperature profile and gas species distribution throughout the bed are analyzed to identify chemical reactions taking place in different parts of the sintering bed. The study shows how simulation results of temperature and gas species variations throughout the bed can be analyzed in order to identify different zones of the sintering bed, based on the chemical reactions that control the process. Simulation results indicate that the sintering bed can be divided into four distinct zones with respect to the dominant chemical reactions taking place in the vertical direction of the bed. These zones are the flame front zone, preheating zone, dry zone and evaporation zone.

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1. Introduction

The sintering process is applied to produce iron ore agglomerates with appropriate properties from iron ore powders which cannot be used in a blast furnace. In a typical sintering plant, depicted in Fig. 1, various kinds of iron ores, coke, and limestone are mixed with water in a rotating drum to form agglomerates, which are charged into a moving grate and form a sintering bed. The combustion commences at the top of the sintering bed by a hot gas jet from the ignition burners. Suction applied at the bottom of the bed draws air through the bed, which is used for coke combustion in the flame front. The flame front starts at the top of the bed and moves downward. Within the flame front the iron ores undergo partial melting, and the presence of melt causes material coalescence. As the flame front passes and cooling begins, the melts solidify around unaffected particles to form dense sinter particles.

Extensive studies have been carried out based on mathematical modeling of the sintering process [2–10]. These models differ from each other, depending on different sub-models applied to reflect effects of various parameters such as chemical reactions, kinetic mechanisms and physical properties of the sintering bed. Coke combustion is the main chemical reaction that supplies the required heat for sintering of iron ore particles in the bed. The temperature profile in the vertical direction of the sintering bed is the main characteristic of coke combustion throughout the sintering process. Most of the previous studies focused on the temperature profile predicted by various models, and the flame front propagation in the sintering bed. However, species composition in the vertical direction of the bed has not been investigated in previous works, either through mathematical modeling or by experimental studies of the sintering process. Therefore, there is still enough potential

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Nomenclature

A (m^{-1})	Specific surface of the bed
A_p(m^2)	External surface area
C_i (mol/m^3)	Molar concentration of *i*th gaseous species
C_i^e (mol/m^3)	Equilibrium molar concentration of *i*th gaseous species
C_{pg}(J/kg.K)	Specific heat of gas
C_{ps}(J/kg.K)	Specific heat of solid
$D_{eff,i}$ (m^2/s)	Effective diffusivity coefficient of *i*th gaseous species
D_i (m^2/s)	Diffusion coefficient of *i*th gaseous species in the bulk gas
d_l (m)	Diameter of limestone–calcium oxide interface
d_p (m)	Initial diameter of limestone
D_p (m)	Diameter of particle
D_t (m^2/s)	Thermal dissipation coefficient
f	Melting and solidification function
h ($W/m^2.K$)	Convective heat transfer coefficient
$K_{eff,i}$ (m/s)	Ash layer effective mass transfer coefficient of *i*th gaseous species
$K_{g,eff}$ (W/m.K)	Gas phase effective thermal conductivity
$K_{g,i}$ (m/s)	Bulk mass transfer coefficient of *i*th gaseous species through gas film
$K_{h,i}$	Equilibrium constant of hematite reaction with *i*th gaseous species
K_l(Pa)	Equilibrium constant of limestone decomposition
K_r(W/m.K)	Equivalent thermal conductivity for radiation
$K_{r,c,i}$ (m/s)	Chemical reaction rate constant of coke with *i*th gaseous species
$K_{r,h,i}$ (m/s)	Chemical reaction rate constant of hematite with *i*th gaseous species
$K_{r,l}$($mol/m^2.s$)	Chemical reaction rate constant of limestone decomposition
$K_{s,eff}$ (W/m.K)	Solid phase effective thermal conductivity
k_{wtr} (m/s)	Water mass transfer coefficient
n_c (m^{-3})	Number of coke particles per unit volume
n_h (m^{-3})	Number of hematite particles per unit volume
n_l (m^{-3})	Number of limestone particles per unit volume
P (Pa)	Static pressure
P_{H2O} (Pa)	Vapor pressure
P_{sat} (Pa)	Saturated vapor pressure
R ($mol/m^3.s$)	Reaction rate
R_i($mol/m^3.s$)	Reaction rate of *i*th gaseous agent
R_u (J/mol.K)	Universal gas constant
R_{evp}($mol/ m^{3}\cdot s$)	Evaporation rate
R_{Cond}($mol/ m^{3}\cdot s$)	Condensation rate
r_R ($mol/ m^{3}\cdot s$)	Drying rate calculated from the partial pressure difference
r (m)	Radius of hematite–magnetite interface
r_o (m)	Initial radius of hematite
Sh	Sherwood number
$SOURCE_g$ ($J/m^3.s$)	Source term of gas phase energy equation
$SOURCE_i$ ($kg/m^3.s$)	Source term of *i*th gaseous species transportation equation
$SOURCE_{mass}$ ($kg/m^3.s$)	Source term of continuity equation
$SOURCE_{momentum}$ ($kg/m^2.s^2$)	Source term of momentum equation
$SOURCE_s$ ($J/m^3.s$)	Source term of solid phase energy equation
T (K)	Temperature
T_g (K)	Gas temperature
T_m (K)	Melting temperature
T_s (K)	Solid temperature
t (s)	Time
u (m/s)	Air inlet mean velocity
V (m/s)	Superficial velocity vector
w	Mass fraction of water in the bed
w_{cr}	Critical moisture content of the solids
w_r	Reduced moisture content of the solids
X_m	Logarithmic mean molar fraction of vapor
Y_i	Mass fraction of *i*th gaseous species

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