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Combustion Behavior of Coke in Shaft Kilns with Hypostoichiometric Air Flow

Bassem Hallak[a], Nyein Linn[a], Eckehard Specht[a], Fabian Herz[a,b]*

[a] *Otto von Guericke University Magdeburg, Universitaetsplatz 2, 39106 Magdeburg, Germany*
[b] *Anhalt University of Applied Sciences, Bernburger Strasse 55, 06366 Koethen, Germany*

Abstract

The mixed feed shaft kiln is used in the lime industry in order to manufacture so-called medium to hard-burnt lime. This type of kiln is fired with lumpy coke particles. A mathematical model has been developed for the combustion under shaft kiln conditions which includes a counter current flow and an excess air number lower than one. The reaction with oxygen is dominated by mass transfer. The reaction with carbon dioxide (Boudouard reaction) is dominated by the chemical kinetics. To determine this, spherical coke particles with 30-40mm diameter were gasified with carbon dioxide and nitrogen mixtures in a tube furnace. The influence of the Boudouard reaction on the combustion time and the length of combustion zone in mixed feed shaft kilns are discussed as a function of excess air number, temperature and size. It is shown how the combustion zone is shifted to the bottom of kiln with decreasing excess air number.

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* Corresponding author. Tel.: +49-391-675-1806; fax: +49-391-671-2762.
E-mail address: fabian.herz@ovgu.de

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1. Introduction

Coke has been widely used over the centuries as a key source of energy and as a reducing agent in special industries such as lime, steel, mineral wool, soda, and sugar industries. The mixed feed lime shaft kiln process is described in Figure 1, which shows the principal temperature curves of gas, coke and stone, as well as the reaction zones. The process of the shaft kiln is based on the counter current principle between the air and the fuel. The coke and limestone particles are charged from the top of the kiln and moves slowly downwards by gravitational force through three zones: the preheating, reaction and cooling zone. The coke particles size decreases during the combustion process. The combustion air fed into the kiln from below cools the stones. As soon as the air makes contact with the coke, oxidation begins and the gas temperature rises steeply. Heat for the calcination is generated by oxidation of coke particles in combustion zone in which the coke reacts with oxygen to form carbon monoxide. It reacts in the gas phase with the oxygen to produce carbon dioxide. Towards the top of the kiln, the concentration of carbon dioxide in gas rises and oxygen concentration decreases. The carbon dioxide reacts with the coke and in turn produces carbon monoxide, which further reacts with oxygen in the gas as long as it is available. With an excess air number less than one, a Boudouard-zone is formed between the preheating zone and the combustion zone, where almost no oxygen is available and the coke reacts only with carbon dioxide to form carbon monoxide.

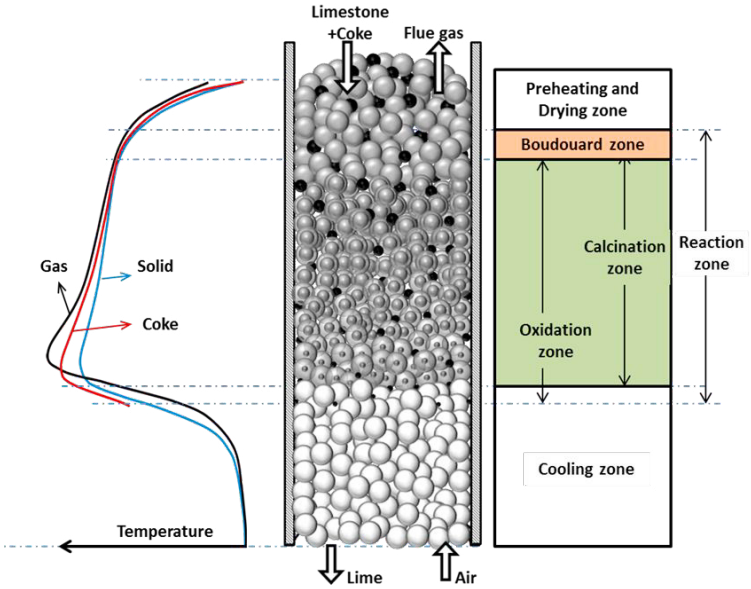

Fig. 1. Schematic diagram of coke burning in mixed feed shaft kiln.

Nomenclature

A	Surface	T	Temperature in °C	Bou	Boudouard
d	Particle size	t	Time	C	Coke
D	diffusivity	w	velocity	CO_2	Carbon dioxide
E_A	Activation energy	β	Mass transfer coefficient	g	Gas
k	Reaction coefficient	λ	Air excess number	O_2	Oxygen
M	Mass flow	ρ	Density	OX	Oxidation
p	Partial pressure	ψ	Porosity	s	Solid
R	Gas constant	δ	Diameter of particle		
Sc	Schmidt number	ν	kinematic viscosity		