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Dynamic Process Simulation of Limestone Calcination in Normal Shaft Kiln

Key words: shaft kiln, limestone decomposition, calcination, dynamic simulation

The lime industry is a dynamic industry, with new production methods, new products and new uses continually being developed. This industry is being profoundly affected by the general requirement to improve environmental performance. This presents a challenge, which is leading to heavy capital investments, mergers and even closures. On the other hand, it presents new opportunities to supply environmental control products.

The rapid increase of the coke price caused the necessity of substituting coke in mix-feed furnaces by cheaper fuel. The waste gas is one of the options. While the composition of the fuel varies the quality of lime has to remain constant. This is characterized by a certain reactivity (hard, medium and soft burned) and a very low rest CO_2 content. Measurements of temperature and concentration profiles are not yet possible due to the movement of feed and the high process temperatures in the reaction zone.

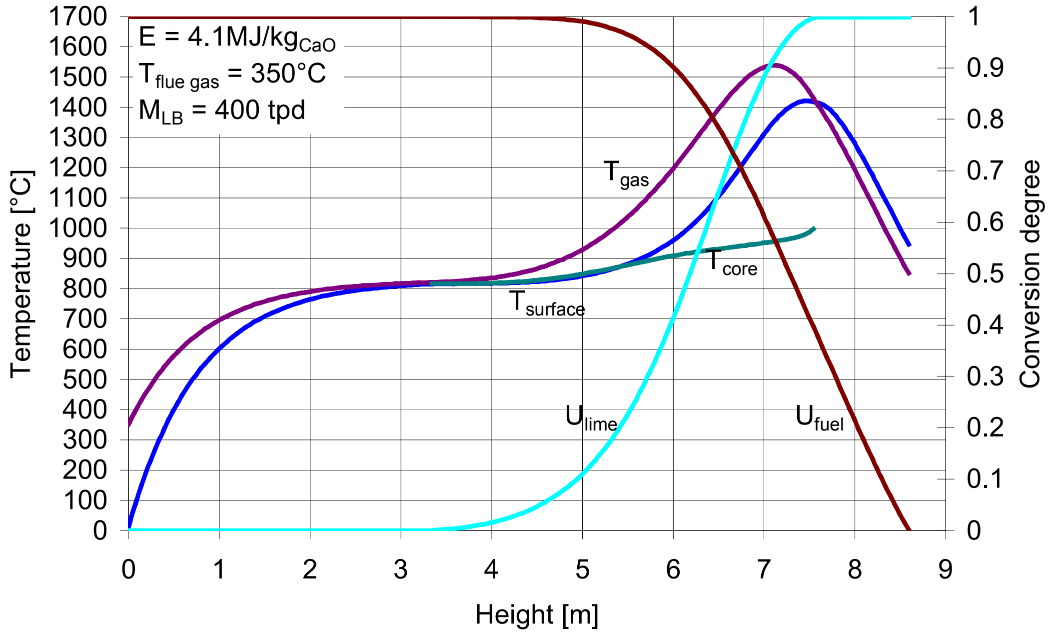
The aim of the work is to optimise the calcination process in the shaft kiln by increasing the conversion degree of limestone decomposition as well as lowering the energy usage which can be achieved by lowering carbon monoxide emission and the flue gas temperature.

The change of the preheating, reaction and cooling zone length with the change of lime particle diameter, the lime output and fuel to lime ratio is of interest. The main problem presents a counter current character of the flow of gas and solid phases in the furnace.

The numerical model is a one-dimensional finite difference solution which includes gas and solid phase motion, gas and solid phase heat conduction, gas diffusion, heat and mass transfer between the gas and particle surface and heat transfer in the gas and solid phases. Chemical reactions include fuel combustion in the gas phase and limestone thermal decomposition into quicklime and carbon dioxide, all reactions are coupled and modelled with finite rate kinetics. The bed is assumed to be one-dimensional – radial variation of temperature and composition is neglected. The differential equations are solved by finite difference method.

In its present state the model deals with limestone decomposition with the same particle size only.

The diagram shows the temperature profiles in the gas, in the core and the surface of the lime particle in a normal shaft furnace under operating condition. With the simulation it’s possible to show how the length of the reaction zone changes with the increasing throughput. At a certain point the complete decomposition is not possible.



E = 4.1MJ/kg$_{CaO}$
T$_{flue\ gas}$ = 350°C
M$_{LB}$ = 400 tpd
T$_{gas}$
T$_{core}$
T$_{surface}$
U$_{lime}$
U$_{fuel}$
Temperature [°C]
Conversion degree
Height [m]
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
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