UMEÅ UNIVERSITET

EFFECTS OF IMPURITIES ON PHASE EQUILIBRIUM IN QUICKLIME AND CEMENT CLINKER PRODUCTION

Karin Sandström

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av teknologie doktorsexamen framläggs till offentligt försvar i BIO.E.203 - Aula Biologica, biologihuset, fredagen den 31 maj, kl. 09:00.

Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Docent Pavleta Knutsson,

Avdelningen för Energi och Material, Chalmers Tekniska Högskola, Göteborg, Sverige.

Department of Applied Physics and Electronics

Organization
Umeå University
Department of Applied Physics and Electronics

Document type
Doctoral thesis

Date of publication
08 May 2024

Author
Karin Sandström

Title
Effects of impurities on phase equilibrium in quicklime and cement clinker production

Abstract
The production of quicklime and cement clinker are energy-intensive processes resulting in significant CO_2 emissions. Fuel switching, electrified heating, and carbon capture have gained attention as means of addressing this. Conventional production processes are direct-fired, meaning that the impurities, which originate from either quarries or fuels, interact with the product, influencing process performance and product quality. The suggested strategies for addressing CO_2 emissions will alter the process conditions. For example, introducing electrified heating using plasma would shift the process atmosphere to primarily CO_2, possibly affecting volatilisation and recirculation. The overall aim of this thesis was to generate new knowledge on the impact of impurities under process conditions in the context of the shift towards more sustainable quicklime and cement clinker production.

Limestone surface impurities and their effects on quicklime product quality were evaluated. Ash-quicklime interactions were studied both on a laboratory scale and using multicomponent chemical equilibrium calculations (MECs). The volatilisation of minor elements in cement clinker production was investigated on a laboratory scale, and using a counter-current MEC-model with both a conventional combustion atmosphere and high-CO_2 atmosphere.

The detailed analysis of the limestone surface layer showed enrichment of impurities. However, quicklime sampled from a parallel flow generative kiln (PFR) showed low amounts of reactants from surface impurities, which were suggested to contribute to build-ups and increased levels of lime-kiln dust instead. Laboratory-scale studies of coal ash and quicklime interactions and MECs showed that typical cement clinker phases are thermodynamically stable at the coal ash-quicklime interface. Porosity and pore-size distribution were evaluated in pure quicklime samples and quicklime samples exposed to olive pomace, pine bark, and wheat straw ash. Olive pomace ash affected quicklime microstructure severely by increasing porosity and pore size. The laboratory study on the volatilisation of minor and trace elements in cement clinker formation showed higher retention of K, Na, and S in a high-CO_2 atmosphere, likely explained by low H_2O partial pressure and high CO_2 partial pressure. Counter-current MECs showed lower enrichment of K, Na, and S in a high-CO_2 atmosphere.

Future work is suggested to investigate the fate of surface impurities entering industrial PFR kilns. Further, the effect of biomass ash on quicklime microstructure should be evaluated in a complete combustion atmosphere, as should the effects of the rolling bed and recirculation of volatile elements in the rotary kiln. The effects of an altered process atmosphere on cement clinker quality and the volatilisation of minor and trace elements are interesting topics for further studies, e.g. in a pilot-scale rotary kiln.

Keywords
Thermodynamic equilibrium calculations, thermal process chemistry, olive pomace, pine bark, wheat straw, microstructure, porosity, linear intercept method, electrification, combustion atmosphere.

Language
English

ISBN
print: 978-91-8070-395-6
PDF: 978-91-8070-396-3

Number of pages
76 + 6 papers