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Numerical Study on the Influence of Operational Settings on Refuse Derived Fuel Co-firing in Cement Rotary Kilns

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Abstract

Cement production in rotary kilns requires large amounts of thermal energy, which is provided by combustion of different fuels. Substitution of fossil fuels by refuse derived fuels (RDF) can minimize production costs and reduce CO_2 emissions, but often causes displacement of the sintering zone, impacts flame stability and cement quality. The current paper briefly introduces our numerical approach which describes particle motion and combustion characteristics of typical non-spherical RDF particles. By using these models in CFD simulations, a case study is presented. Fuel properties, primary- and secondary air settings and fuel feed location for a generic rotary kiln of industrial scale are varied to show the effects of operational settings on co-firing of RDF. Shift of flame shape and location as well as particle burnout are analyzed. Based on the information generated, optimized operational settings are identified and discussed.

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Keywords: rotary kiln; cement clinker; CFD; combustion; refuse derived fuels (RDF); burner settings

1. Introduction

Rotary kilns are widely used for the production of cement clinker. The clinker formation process demands large amounts of thermal energy to heat up the material to sintering temperatures above 1700 K. To provide the energy required, different types of fossil and alternative fuels are commonly fired through the main burner at the material outlet of the kiln (see Fig. 1). Modern kiln burners are often so called multi-channel burners which consist of a number

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of different primary air and fuel conveyance ducts, allowing the combustion of different types of solid, liquid and gaseous fuels.

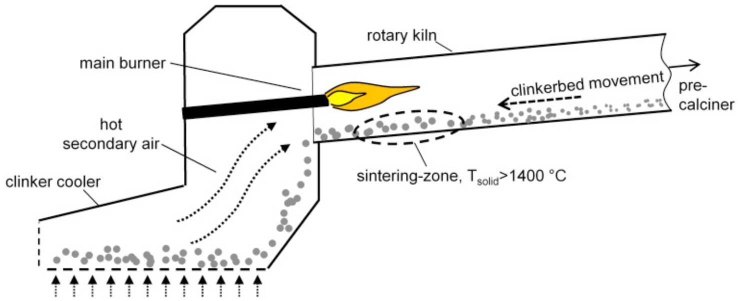

Fig. 1: Clinker formation process in a modern plant rotary kiln.

Additional energy is provided by secondary air, which recuperates heat in the clinker cooler and enters the kiln as a parallel stream around the burner.

Fossil fuels, typically pulverized coal, are increasingly replaced by refuse derived fuels (RDF) [1] which offer the potential to minimize production costs and to reduce CO_2-emissions. In contrast to fossil fuels, RDF consists of irregular shaped, mostly flat particles with edge lengths exceeding 1 cm. Large particle sizes and strong chemical and physical inhomogeneities hinder easy substitution of fossil fuels in rotary kilns [2] and limit their share at a low level [1]. The local heat release which is critical for flame geometry and temperature distribution is not just strongly dependent on the fuel properties but can also be influenced by primary- and secondary air settings [3]. According to this, a proper selection of these parameters offers potential to actively adjust the flame characteristics for RDF co-firing and gives the opportunity to obtain an appropriate RDF burnout. As general guidelines are rare and not profound, further research is needed to identify the effects of different operational points on heat distribution and fuel burnout in rotary kilns.

In this paper we present a case study of RDF co-firing in an industrial scale rotary kiln under different operational settings, regarding primary and secondary air variations as well as different RDF feed locations. For this study our in-house RDF flight and combustion models [4,5] were used in combination with Ansys FLUENT following the Euler/Lagrange approach.

2. Overview of the RDF Simulation Methodology

Our modelling approach is based on comprehensive fuel characterisation and numerical models, which were developed to calculate particle trajectories [4] and characteristic combustion behaviour [5] of the different RDF components.

2.1. Fuel characterisation

As a first step, a sorting analysis of an RDF sample is carried out, which groups the numerous fuel components into the major fractions (which shares are usually > 5 mass-%). For the case study in this paper, we assume a “model RDF” with typical components as shown in Figure 2. Major components usually are 3D plastics, 2D foil sheets, paper and cardboard (P&C) snippets, textiles and the fines representing the leftovers which cannot be assigned clearly to a particular fraction. Each of these fractions is extensively characterized by determining their thermophysical and calorific properties as well as geometrical parameters like particle shape and particle size distribution. Further experimental characterization is carried out to analyse individual particle trajectories in an automated drop-shaft [4] to obtain drag and lift coefficients and their time-dependent fluctuations. Characteristics of the thermal conversion process are investigated using a single particle reactor [6]. A single particle is suddenly introduced into a hot gas flow with temperatures up to 1200 °C and with varying oxygen concentration. Optical access through two ports allows