

Numerical Methods of Calculations of Limestone Calcination in Cement Industry

Jacek Wydrych^{1, a)} and Bolesław Dobrowolski^{1, b)}

¹Department of Thermal Engineering and Industrial Facilities, Opole University of Technology, Opole, Poland.

^{a)}Corresponding author: j.wydrych@po.opole.pl

^{b)}b.dobrowolski@po.opole.pl

Abstract. Clinker burning is the most complex process in cement production from limestone. This is especially visible for the two-stage combustion of fuel in a rotary kiln without the typical reactor-decarbonizator. This work presents results of numerical studies on thermal-flow phenomena in the riser chamber, which will be designed to burn fuel in the system AS (combustion air supplied separately from the clinker cooler). The mathematical model is based on a combination of two methods of motion description - Euler method for the gas phase and Lagrange method for particles. The most important part of the calculation methodology is modeling of the calcination process, which depends on the gas temperature, CO₂ partial pressure and material roasting time. The obtained results of calculations can be the basis for further optimization the design and operating conditions in the riser chamber with the implementation of the system AS.

INTRODUCTION

Industrial installations for clinker production have a very complex structure and they are difficult to analyses by theoretical methods. One of the most important elements of this installation is precalciner, where is the initial stage of the raw material calcination. This work presents modelling the phenomena flow in the chamber with atypical construction shown on fig. 1.

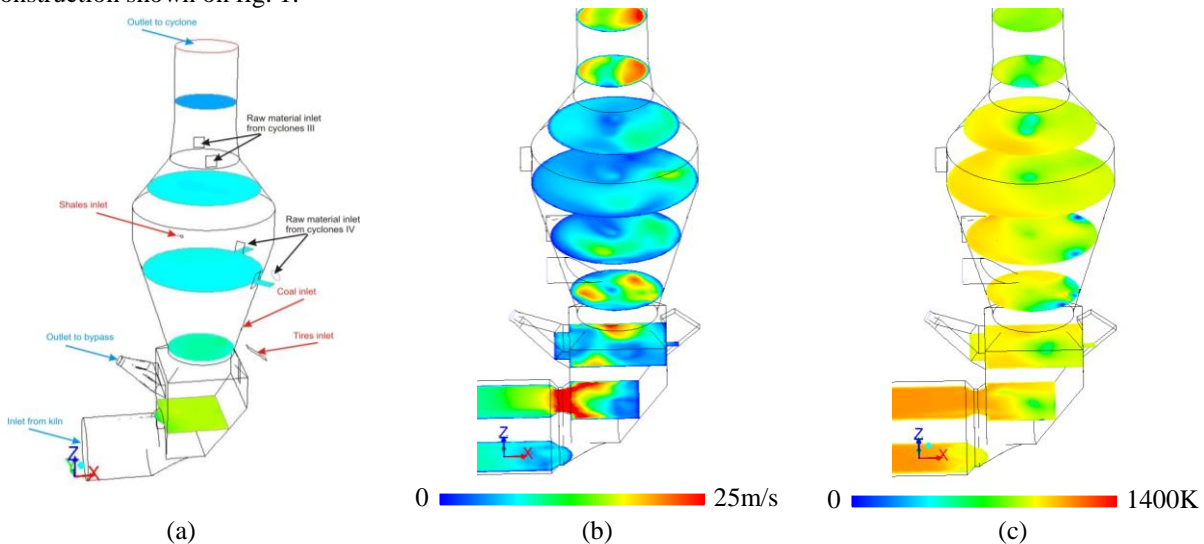


FIGURE 1. For precalciner chamber a) Calculation domain with control cross-sections b) Distribution of velocity magnitude c) Temperature distribution

Outlet from kiln is the source of gas produced during the combustion of fuel and chemical transformation of raw material in the high temperature. The same cross-section is treated as a outlet for calcined material. Raw material is supplied from two inlets. In the following descriptions raw material inlets from cyclones III and VI are called upper and lower inlets, respectively, regarding outlets inlet from kiln and outlet to cyclones are called lower and upper outlets.

METHOD OF CALCULATIONS

In order to realize numerical calculations, the mathematical model containing equations of motion for the gaseous phase and particles was formulated. Gas motion was described with the Euler method, and the particle motion – by the Lagrange method. To analyze motion of the gas-particle polydispersive mixture, in this paper the PSI-Cell method was applied (Particle Source in Cell). Numerical calculations are based on the following assumptions: considered flow is stationary, without phase changes, and both phases are incompressible. Heat transfer between particles of raw material and gas was added to the numerical calculations. During the movement of limestone particles through the calciner chamber, five stages of the calcination process can be identified, which accompanies this movement. The shrink core model was adopted to study the distribution of spherical limestone particles in the calcination process. At a given time step there is a centrally located core of undecomposed carbonate surrounded by a coating of calcium oxide with the face of reaction occurring on the surface between the core and the coating. The presence of CO₂ in ambient gases has an inhibiting effect on the calcination process, however, it is difficult to determine the effect of the partial pressure exerted by CO₂ on this process. The paper presents the theoretical basis of calcination calculation method and its application in the ANSYS Fluent program. The application of the model in the Fluent is possible using the user defined procedures UDF, which was thoroughly presented at the work

RESULTS AND ANALYSIS

Completed numerical calculations have shown that the construction of the lift chamber and its operating conditions (the presence of the tertiary air, the combusted fuel flow rate) affect the heat-flow and thermochemical processes in the chamber. Temperature of particle, which is a function of ambient temperature and the residence time of the particles in the zones of sufficiently high temperature influence on the limestone calcination effectiveness. This paper presents possibilities of numerical calculations to recognize resident time of particle in precalciner chamber and particle temperature as an effect of radiative hest exchange between gas and limestone particles.

CONCLUSIONS

Obtained results presents possibilities of numerical calculations to recognize resident time of particle in precalciner chamber and particle temperature as an effect of radiative hest exchange between gas and limestone particles. Presented results are good base to further works on the formation and emission of pollutants especially NO_x and CO₂ to atmosphere. Additional aim of the future works ought to be investigation the heat and mass transfer during thermal decomposition of a single solid particle of raw lime material. In order to implement appropriate conditions it is required to incorporate appropriate procedures in the form of so-called user-defined functions (UDF) in Fluent.

REFERENCES

1. G. Borsuk, J. Wydrych, B. Dobrowolski, *Modification of the Inlet to the Tertiary Air Duct in the Cement Kiln Installation* (Chemical and Process Engineering-Inżynieria Chemiczna i Procesowa, Volume: 37 Issue: 4 Pages: 517-527 Published: DEC 2016).
2. G. Borsuk, B. Dobrowolski, G. Nowosielski, J. Wydrych, J. Duda, *Numerical simulation of thermal-hydraulic processes in the riser chamber of installation for clinker production* (Archives of Thermodynamics Volume: 37 Issue: 1 Pages: 127-142 Published: MAR 2016).
3. J. Wydrych, B. Dobrowolski, G. Borsuk, S.Pochwała, *Influence of calcination process on the formation of selected air pollutants* (Conference: International Conference on Energy, Environment and Material Systems

(EEMS) Location: Polanica Zdroj, POLAND Date: SEP 13-15, 2017 Sponsor(s): Opole Univ Technol, Fac Mech Engr; Ctr Educ, Competence, Innovat & Technol; Republ Poland, Minist Sci & Higher Educ; Oddzial Elektrownia Opole, GiEK S A; Oil Opole; Energetyka Cieplna Opolszczyzny SA Jelenia Gora; Warta Cementownia INTERNATIONAL CONFERENCE ENERGY, ENVIRONMENT AND MATERIAL SYSTEMS (EEMS 2017) Book Series: E3S Web of Conferences Volume: 19 Article Number: UNSP 02002 Published: 2017).