Applied Thermal Engineering 48 (2012) 414–425

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Numerical and experimental thermal analysis of an industrial kiln used for frit production

T.S. Possamai*, R. Oba, V.P. Nicolau

Department of Mechanical Engineering, Federal University of Santa Catarina, Campus Universitário, Trindade, Florianópolis 88.040 900, SC, Brazil

HIGHLIGHTS

► Numerical simulation applied to a ceramic frits melting kiln.
► Method of finite volumes.
► Numerical results compared with experimental data.
► Model estimates the global thermal behavior of the kiln.

ARTICLE INFO

Article history:
Received 29 March 2011
Accepted 13 May 2012
Available online 24 May 2012

Keywords:
Ceramic frits
Numerical simulation
Ceramic kiln

ABSTRACT

This paper describes a methodology for the study and modeling of the thermal energy in ceramic frit melting kilns with an oxy-fired combustion process through the development of a numerical simulation in CFD software. Ceramic frits are vitreous compounds that provide glazes with specific properties for use in the coating of other ceramics, especially those of the ceramic tile industry. The aim of this study is to generate technical subsidies in order to support economically viable proposals for the ceramic industry. The CFD modeling is performed using the commercial software Ansys CFX 11.0, which is based on the method of finite volumes. The geometric domain of resolution consists of the internal cavity of the kiln. The CFD resolution is coupled to a three-dimensional heat conduction code along the kiln walls to determine the external temperature distribution. The thermal problem is composed of the combustion of natural gas with oxygen, the internal turbulent flow of exhaust gases, the energy loss by convection and radiation to the environment through the walls and the radiation within the kiln cavity with participating media. Data collected in an operating kiln are used to verify the numerical solution, achieving a good agreement in the general analysis of the kiln. The numerical solution provides physically consistent results, making it possible to predict the behavior of the kiln as a whole in similar cases with changes in the parameters of the manufacturing process or in the geometry. Other specific results, such as heat flux inside the kiln, are presented and discussed.

1. Introduction

Ceramic frits are a product of a ceramic sub-sector that uses melting kilns to melt a compound of oxides at temperatures in the order of 1700 K to create a melted product. The melted product then undergoes an abrupt cooling to 300 K producing the final product – a ceramic frit – which is later used in the preparation of ceramic glazes, providing them with several properties and allowing the safe employment of toxic chemical components such as PbO. The compound is comprised of oxides and varies according to the ceramic frit properties required, however, it is mainly composed of SiO_2 (generally 50 to 70 wt.%). Al_2O_3, CaO, ZnO and B_2O_3 are also usually present although many formulations with other components have been studied [1–4]. The melting kilns differ greatly from the kilns commonly applied for ceramics characterized by a tunnel format and large size reaching up to 200 m [5]. This type of kiln is similar to gas-fired industrial kilns used to melt aluminum in a continuous process.

The demand for energy saving requires the application of numerical analysis to this type of equipment. The optimization of kilns involves a large number of variables and complex physical phenomena. An accurate model provides detailed information in an inexpensive manner in addition to allowing the analysis of several cases. Nicolau and Dadam [6] evaluated through a numerical model a complete thermal energy balance including all energy fluxes related to the process of brick production in a tunnel kiln and indicated that the optimization of parameters such as the

* Corresponding author. Tel.: +55 48 3721 9390; fax: +55 48 3721 7615.
E-mail addresses: talita@labcet.ufsc.br, talitapossa@gmail.com (T.S. Possamai).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.05.025