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Flow Mixing in the Gap between the Cars in Tunnel Kilns

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Abstract

The effect of side injection on mixing of the two axial flows i.e flow through the ware and flow through the gap between ware and walls in the preheating nzone of tunnel kiln is investigated.
The 3D temperature field in the cross section between two cars is calculated using the CFD tool (ANSYS Fluent). The mixing quality is evaluated using the contours of temperature, the frequency of temperature distribution and the maximum temperature difference. The influence of injection flow rate, injection velocity, position of nozzels and nozzle number on the mixing behaviour are analyzed.
The results show that use of two side injection nozzles is more effective than one side injection nozzle to achieve mixing. Moreover, a relatively better mixing is achieved when the nozzles are installed at the opposite side walls at higher vertical distance (larger distance apart).
The mixing quality increases strongly until an impulse flow rate of about 4 N. For higher values of impulse, the influence becomes relatively low.

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Keywords: Tunnel kiln, CFD, Flow Mixing, Injection Velocity, Nozzle Position

1. Introduction

Tunnel kilns Tunnel kilns are used to produce the ceramic materials such as bricks, tiles, vitrified clay, porcelain ware, etc. The processes carried out in tunnel kilns require a homogeneous temperature distribution in the cross section of the kilns. The axial flow through the ware, placed on the kiln car offer more resistance in the flow than that offered

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by the axial flow between the ware and the side walls, or between the ware and the roof [1]. This difference in the resistances in axial flows causes these flows to have different temperatures upon leaving a particular kiln car. These flows have to be mixed before they enter the ware on the next car. In some cases, blowers are installed in the preheating zone which suck the gases off and blow them in at different locations. However, this has a weak effect [2]. In other cases, air is injected from outside in the gaps between the cars.

The present work aims to study the influence of the side wall injection on gas circulation using Computational Fluid Dynamics (CFD). The space between two kiln cars is imaged as a simplified geometry. The different temperature regions for the ware and the gas are represented by two separate flow streams. One and two side injections are considered in this study.

Nomenclature

B_K	Kiln width
G	Geometry
H_K	Kiln hight
H_R	Height ratio
IFR	Impuls flow rate
$\dot{M}$	Mass flow rate
M_R	Mixing ratio
T	Temperature
X,Y,Z	Cartesian coordinates
H	Vertical nozzle position
h_w	Ware height
W	Velocity
ΔT_o	Initial temperature difference
θ	Dimensionless temperature difference

2. Problem setup

Figure 1 shows schematically the longitudinal section of a tunnel kiln with two cars. Both axial flows i.e. gas flow through the ware and the gas flow through the gap between the ware and the side walls, flow in a direction opposite to the direction of movement of kiln car.

Figure 2 shows schematically the cross section between the two kiln cars. The ambient air at 20 ˚C is injected through the side walls to affect the mixing. The mixing of the two axial flows is calculated for the domain shown in Figure 1. The ware could have different shapes and sizes in different kilns. Thus, the width of gap between the ware and the side walls as well as the gap between ware and the roof differ from kiln to kiln. Thus, to study the mixing behavior, few assumptions have been made in this work.The ware is assumed to have rectangular shape with an even interface to the gap. The gas flow in the gap has a temperature of 400 ˚C while the flow coming out of the ware has a temperature of 300 ˚C. Thus, an initial temperature difference of 100K is considered to evaluate the temperature field during the mixing. The kiln with height of 3.3 m and a width of 4m is considered, which are typical dimensions of most of the kilns. Both axial flows have equal volumetric flow rate with a velocity of 0.126 m/s. The cross sectional area of the ware and the gap are taken as equal. The flow through the gap is represented as gas zone and the flow through the ware is represented by the ware zone. The gas zone and ware zone are shown in Figure 2. The mixing behavior could be affected by number of factors like number of nozzles, position of side injection, mass flow rate of side injection, and velocity of the injected flow. Table 1 enlists the considered values of these parameters. A single nozzle is used in arrangement I. Two side injections are used to obtain other arrangements(II-V). Two side injection nozzles are located opposite at the same level (h=0.5 Hk) in the second arrangement (II). The other three arrangements (III-V) are obtained by increasing h.