Models for Turbulence and Thermodynamics in Simulating Non-Premixed Combustion in a Cement Kiln

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Abstract

In previous work, we addressed the need to revisit the choice of turbulence models in simulating non-premixed turbulent combustion in a cement kiln. The role of models for thermodynamics requires a re-assessment as well. In this work, we compare results using two-equation and Reynolds stress tensor turbulence models. We evaluate the modeling of the transonic flow using thermodynamical properties formulated in terms of either the density or the compressibilty. Both the non-reactive and the reactive simulation will be considered. It is expected that this work will lead to a better understanding of how to simulate the pollutant formation caused by combustion of gaseous fuels in cement kilns.

Keywords: *non-premixed combustion, turbulence, thermodynamics, pollutant formation, rotary kiln*

1 Introduction

Rotary kilns are horizontally placed cylindrical ovens. They are widely used in the material processing industry as described in [1]. Our aim is to accurately simulate the non-premixed turbulent combustion and the resulting pollutant formation in such ovens. Various models for the flow, chemistry and heat transfer by radiations ought to be made. In this paper we focus of the aerodynamics of this challenging problem.

2 Models for Turbulence

The turbulent non-premixed combustion is the kiln occurs at high Damkohler number and is thus dominated by mixing of the gaseous fuel and the primary and secondary combustion air streams.

In previous work [4, 2], we used a Reynolds-Averaged Navier-Stokes models with two-equation turbulence closures to model the flow (and thus the mixing) in the kiln. Literature however shows that two-equation models might fail to be sufficiently accurate in regions of high shear. Such regions occur for instance at the interaction of jets. We are therefore interested in using a more accurate combustion model. The Reynolds stress model solves for the six (in 2D four) components of the symmetric stress tensor R and the turbulent dissipation epsilon. The magnitude of the tensor R is equal to the turbulent dissipation ϵ. The Launders, Reece and Rodi variant of this model is implemented as the LRR model in OpenFoam.

In the full paper, we intend to compare results for the non-reactive and reactive flow using the realizable k-ϵ and the LRR turbulence models.

3 Models for Thermodynamics

The flow through the burner nozzles occurs at high mass flow rates through nozzles with a small cross-sectional area. Near the burner the flow is transonic. A suitable compressible flow formulation is thus requires [3].

A choice of to express the thermodynamical properties in either density (rhoThermo) or compressibility (psiThermo) ought to be considered. Suitable inlet (mass flow rate) and outlet (wave transmissive) boundary conditions need to be adopted. And the choice to perform either stationary or transient simulations needs to be made.

In the full paper, these choices will be discussed in detail.

4 Numerical Results

Figure 1 shows preliminary results for the computed velocity. More results will be shown in the full paper.

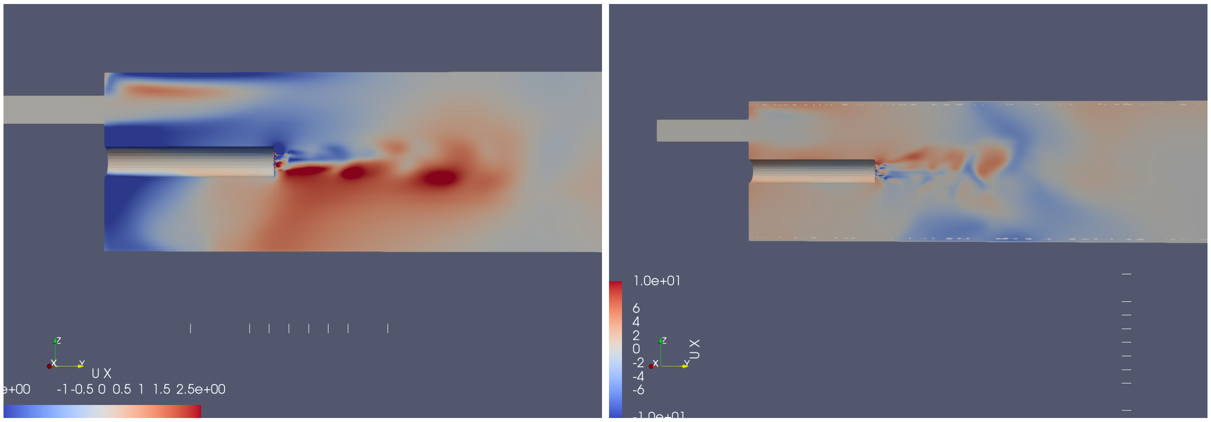

Figure 1: Computed x-component (out of plane component) of the velocity in the non-reactive (top) and reactive (bottom) showing the swirl around the burner pipe.

5 Conclusions

In this contribution, we intend to discuss models for turbulence and thermodynamics is the simulation of the combustion in a cement kiln.

References

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