



## Numerical study of Air Preheating Effect on NO<sub>x</sub> Emissions in a Heating Furnace<sup>#</sup>

Mohamed CHAOUR<sup>1,2,\*</sup>, Sofiane BOULKROUNE<sup>1,2</sup>, Mounira BOUREBIA<sup>1</sup>

<sup>1</sup> Research Center in Industrial Technologies CRTI, P.O. Box 64, Cheraga 16014 Algiers, Algeria.

<sup>2</sup> University of Brothers Mentouri Constantine, Department of Mechanical Engineering, Campus Chaab Ersas Constantine, Algeria.

\* Corresponding Author : [chaourmed@yahoo.fr](mailto:chaourmed@yahoo.fr)

(First received 2 November 2016 and in final form 15 December 2016)

<sup>#</sup> Presented in "3<sup>rd</sup> International Conference on Computational and Experimental Science and Engineering (ICCESEN-2016)"

### Keywords

pollutant emission  
industrials burners  
turbulent combustion

**Abstract:** This work aims to evaluate the reduce pollutant emission by steel reheating furnaces and operating process of the diffusion flame industrials burners. The example developed here is particularly interested in the influence of the air preheating temperature on NO<sub>x</sub> emissions as well as the dynamic characteristics and heat flow. The study was conducted on an industrial gas burners 250 kilowatt. Numerical simulations are per formed using the computer code FLUENT, using the turbulence standard k-ε model coupled to turbulent combustion ED (Eddy Dissipation). The probability density function PDF model (6 species and reactions 3) with a chemical equilibrium model. The results obtained for different air preheat temperatures show that NO<sub>x</sub> emissions depend on the air preheat temperature.

## 1. Introduction

Turbulent combustion occurs in the industry mostly in gas burners, jet engines and rocket motors. The turbulence plays an indispensable role to mix as quickly as possible the gas present, it is mainly due to strong velocity gradients between air and gas [1]. In the industrial sector, the burners are the most alternative adopted for converting fossil fuels into thermal energy. This prompted several authors [2] and [3] to optimize the operation of these burners to increase their yields and reduce their emissions. The use of burners in a furnace of reduces fuel consumption, in fact, the preheating of the combustion air allows a significant energy saving. Modeling the turbulent combustion generally requires consideration of complex kinetics; otherwise, the simulation of the formation of pollutants requires a clearance calculation of satisfactory heat [4].

In this work, we focus on numerical simulation of turbulent flow with methane-air combustion, we are interested in the combustion air preheating effect on the reaction zone, flame temperature and concentrations in flue gases.

## 2. Mathematical formulation of the problem

The aerothermochemistry the balance equations used in a combustion study for a compressible flow are [5] and [6].

Continuity equations

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = 0 \quad (1)$$

Momentum equations

$$\frac{\partial \rho u_i}{\partial t} + \frac{\partial}{\partial x_j} (\rho u_j u_i) = -\nabla p + \nabla \tau + \rho \sum_{\alpha} \gamma_{\alpha} f_{\alpha} \quad (2)$$

Energy equation

$$\frac{\partial (\rho e)}{\partial t} + \frac{\partial}{\partial x_j} (\rho u_j e) = -\nabla (\rho u) + \nabla (\tau u) + \rho \sum_{\alpha} V_{\alpha} \gamma_{\alpha} h_{\alpha} - k \nabla T \quad (3)$$

Species equation

$$\frac{\partial \rho y_i}{\partial t} + \frac{\partial}{\partial x_j} (\rho u_j y_i) = -\nabla (\rho V_i y_i) + \nabla \tau + \rho w_i \quad (4)$$

Thermodynamic state

$$p = \rho \sum_{\alpha} \frac{\gamma_{\alpha}}{M_{\alpha}} RT \quad (5)$$

With:  $i=1, 2, 3$  and  $j=1, 2, 3$ .

### 3. Geometry

The studied burner is a diffusion flame burner [7] with a power of 250 KW. The methane is injected with a flow rate of 0.105 kg / s through a diameter of 20 mm, and the oxidant at a rate of 0.82 kg / s and a diameter of 70 mm for the same particular data considered.

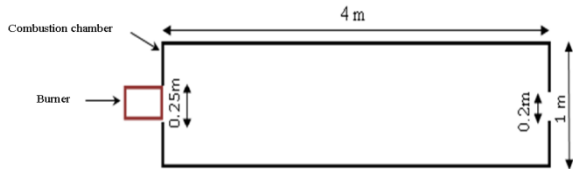


Figure 1. Geometric configuration of the oven.

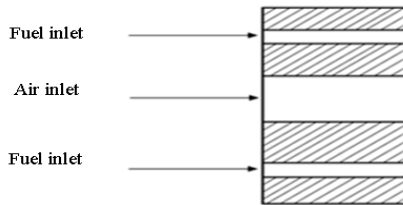


Figure 2. Geometric configuration of the burner.

### 4. Injection and boundary conditions

The injection conditions characterizing the oxidizing inputs are obtained by setting an excess air rate equal to 10%. Thus, the flows and temperatures considered are given by the following table1:

Table 1. Conditions of injection.

Flow of methane (Kg/s)	0.105
Temperature of injection (K°)	300
Air flow of combustion (Kg/s)	0.82

The boundary conditions of the configuration studied are given in Figure 3.

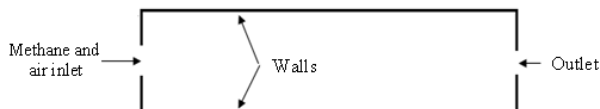


Figure 3. Boundary conditions.

### 5. Methodology

Numerical simulation is performed using the industrial code "FLUENT" that uses a digital method finite volume coupled to a multi grid resolution scheme. The problem is stationary, two dimensional and axisymmetric.

Solving the governing flow equations is performed using the SIMPLE algorithm and using the turbulence model k-ε standard [4]. The coupling between turbulence and responsiveness of the system imposed by the combustion reactions were treated by the ED method (Eddy Dissipation). [8]

The mesh geometry (Figure 4) is achieved by means of triangles. It is ended at the inlet and the outlet of the combustion chamber. Further, it the rest of the combustion chamber becomes increasingly loose, the number of node and 14623.

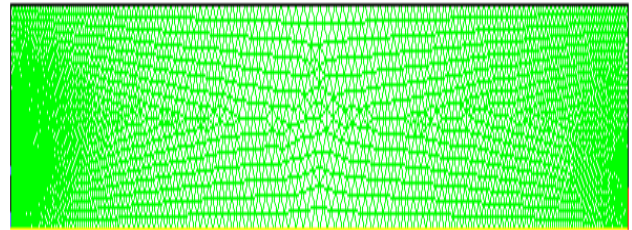


Figure 4. Mesh of the combustion chamber.

### 6. Results

The figure 5 evolution of mass fractions of CO<sub>2</sub> and NO<sub>x</sub> at the outlet of the combustion chamber. It is noted that the mass fraction of CO<sub>2</sub> in the flue gases decreases when augment the air preheat temperature, so the fuel contains less carbon atom. In the same figure, we see that the mass fraction of NO<sub>x</sub> is lower for a reaction without air preheating. However, the air preheating causes a very significant increase in nitrogen oxide emissions.

In Figure 6, we see that the flame temperature increases to increase the air preheat temperature. This result agrees well with Figure 5, logically, that the increase in the subsequent flame temperature preheating leads to a higher level of nitrogen oxide emissions.

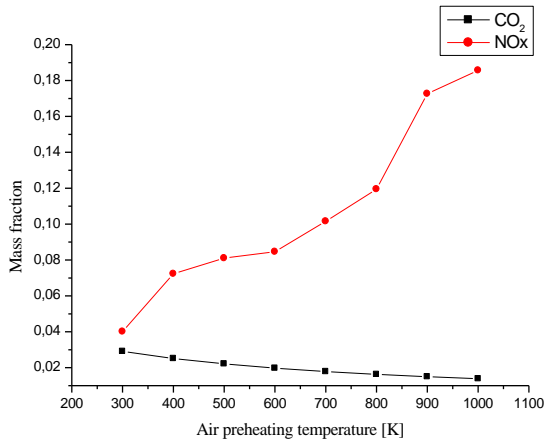


Figure 5. Profiles mass fractions of NO<sub>x</sub> and CO<sub>2</sub>.

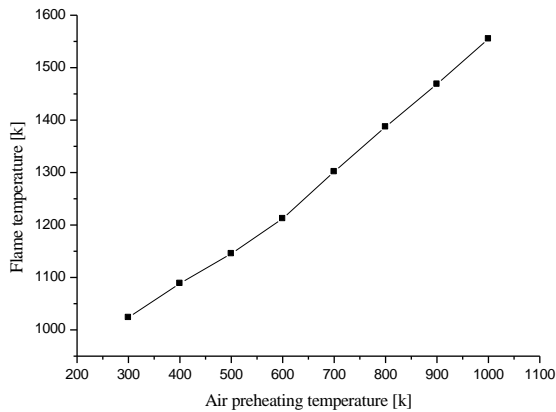


Figure 6. Profiles of flame temperature.

## 7. Conclusion

In this study, we numerically simulated the air preheating influence on harmful emissions. It was considered as a preheated oxidant air and it was shown that the increase of the injected air temperature increases the flame temperature and hence NO<sub>x</sub> emissions. So we must try to reduce the local temperature to minimize the formation of nitrogen oxide thermally.

## References

- [1] F. Bouras, A. Soudani et M. Si-Ameur "Simulation aux grands échelles de la combustion turbulente couplée à des fonctions densités de probabilité" Proceeding of International Conference on Energetics and Pollution, Organized by LEAP. 45-50 (2007)
- [2] L. Bebar, V. Kermes, P. Stehlik, J. Canek and J. Oral "Low NO<sub>x</sub> burners prediction of emissions

- concentration based on design" Measurements and modelling" Waste management. 22-4 (2002) 443-451
- [3] E.Perthuis "Revue des techniques de réduction des émissions d'oxydes d'azote au niveau des brûleurs" Revue Générale de Thermique. 330 (1989) 374-377
- [4] R. Mouangue, M. Obounou "Numerical simulation of turbulent diffusion flames of H<sub>2</sub>/Air" Phys. Chem. News. 50(2009) 69-78
- [5] C. David Pierce "Progress-variable approach for large-eddy simulation of turbulent combustion" PhD. Stanford University. 2001
- [6] S. Cheolko and H. Jin Sung "Large-scale turbulent vertical structures inside a sudden expansion cylinder chamber Flow. Turbulence and Combustion" Kluwer Academic Publishers. 68 (2002) 269-287
- [7] A. Soudid, W. Kriaa, H. Mhiri, G. Le Palec & P. Bournot "Simulation d'un brûleur industriel. Etude de l'effet des ventelles sur les caractéristiques de l'écoulement" 18ème Congrès Français de Mécanique, Grenoble. France. 2007
- [8] S. Nechad, A. Khelil, L. Loukarfi et M. Brakia "Simulation numérique à trois dimensions d'une flamme de diffusion en utilisant un schéma réactionnel quasi-global et détaillé" 20ème Congrès Français de Mécanique. Besançon. France. 2011