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The Effects of Using Porosity Profiles on Performance and Emission of Pollutants in the Porous Media Burners

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ABSTRACT

In this paper, a two-dimensional axisymmetric model for premixed methane/air combustion in porous media has been developed. For this aim, a numerical model with chemkinII library is used along with its database. This code solves the continuity, navier stokes, the solid and gas energy and the chemical species transport equations using the finite volume method. The pressure and velocity have been coupled with the simple algorithm. In this paper, an attempt is made to apply the profile of porosity instead of constant porosity for two zones of the burner. The results showed that by applying the varying porosity along the burner, the peak temperature can be decreased by about 4.5%, and subsequently, the amount of exhaust pollutants such as NO_x can also be decreased while increase in pressure loss along the burner is negligible. The effects of increasing the inlet velocity and the wall temperature are also investigated. The results showed that by increasing the inlet velocity, the peak temperature and the emission of NO_x will be decreased and also by increasing wall temperature, the peak temperature and the emission of NO_x will be increased.

KEYWORDS

Porous Media, Axisymmetric Combustion, Finite Volume, Heat transfer, Chemical Kinetic

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1- INTRODUCTION

The history of using porous media began in 1982, when the Japanese researcher Echigo [1] considered recycling energy from exhaust gases of a high temperature apparatus. He found out that in this manner, it would be possible to transfer a major part of heat energy to the porous media via convection. Furthermore, the efficiency of the porous layer in recycling is increased by increasing the temperature of the intake gas.

Wang and Tien (1984)[2] carried out studies in this field by using the two-heat flux model for the equations of heat radiation and considering the distribution of radiation energy by the porous media. They found that the distribution of radiation energy by the porous layer resulted in reduction of the amount of absorbed energy by the porous media and reduction of the efficiency of the porous layer.

J.C.F. Pereira and X.Y. Zhou (1998)[3] investigated the combustion of methane fuel by using four models of combustion such as the Full mechanism (49 species and 227 chemical reactions), Skeletal mechanism (27 species and 77 chemical reactions), 4-Step reduced mechanism (9 species and 4 chemical reactions) and one global mechanism (1GM, include 4species and 1 chemical reaction). They found that the 4-Step reduced mechanism has the most agreement with the Full mechanism.

In 1999, Malico [4] performed a two-dimensional numerical study for combustion and emission of pollutants in porous media and investigated the effects of excess air ratio, thermal conductivity and convective heat transfer coefficient and radiation properties.

In 2002, Chung [5] studied the effects of hydrogen addition on methane combustion inside a porous media burner in the one-dimensional system. He showed that by increasing hydrogen in the fuel, the speed of the flame and the emission of CO will increase.

Lari et al. (2007)[6] performed a thermal analysis of the porous media burners. They found that the burners with higher optical thickness have a lower peak temperature. Finally, Hossainpour and Haddadi (2008)[7] surveyed the effects of several parameters on the combustion and formation of pollutants in the one-dimensional state with multi step kinetics.

In the present work, the effects of variable porosity, inlet velocity and wall temperature on the gas temperature and pollutant emissions are investigated.

2- METHODOLOGY

First, the interpreter of chemkin read the entrance information and then early assumptions were determined for all relative variables. The momentum equations midcorresponding boundary conditions for axial and radialdirections are computed by using the Tri Diagonal Matrix Algorithm method.

In this stage, the equation of pressure correction is calculated by using the Tri-Diagonal Matrix Algorithm method and the values of velocity and pressure have been corrected. The gas phase energy and chemical species transport equations are computed as follows:

Since the algebraic equations system is stiff from using a multi step kinetic model and conventional iterative solution methods like Tri-Diagonal Matrix Algorithm lead to divergence, the source terms in gas phase energy and chemical species transport equations which are defined as follows, are solved by the DVODE subroutine.

$$\frac{\partial}{\partial t}(\rho Y_k) = \dot{\omega}_k . W_k \quad (1)$$

$$\frac{\partial}{\partial t}(\rho C_p T_f) = -\sum_{K=1}^{N_s} \dot{\omega}_k h_k W_k \quad (2)$$

The DVODE subroutine solves the first order ordinary differential equations by the Hindermarsh-Gear algorithm in which the updated mass fraction and temperature $[Y_i]^{new}$, $[T_g]^{new}$ are calculated by:

$$[Y_i]^{new} = [Y_i]^{old} + [\Delta Y_i]^{transport} + [\Delta Y_i]^{source} \quad (3)$$

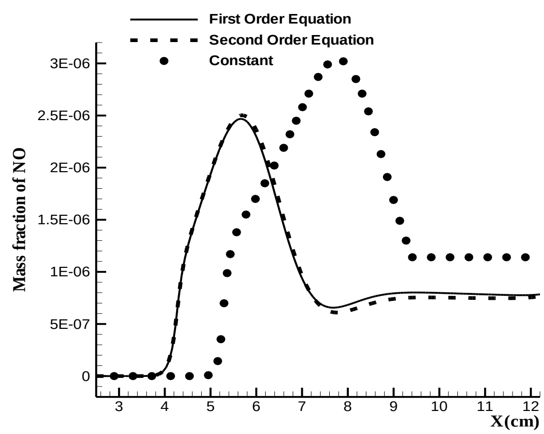
$$[T_g]^{new} = [T_g]^{old} + [\Delta T_g]^{transport} + [\Delta T_g]^{source} \quad (4)$$

The update properties are calculated by subroutines of chemkin and the new values of each parameter.

Finally, the above steps are repeated until convergence is achieved.

3- SIMULATION RESULTS

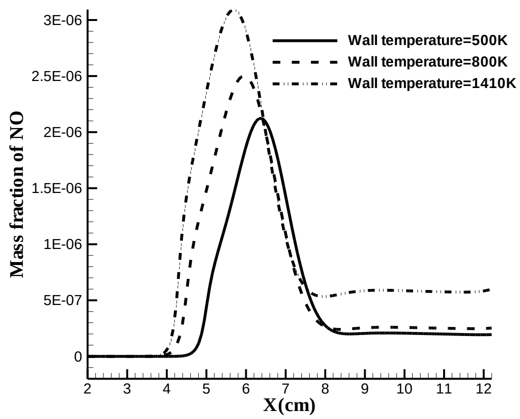
By using porosity variation, the peak temperature will decrease about 4.5% and consequently NO_x emission will be decreased.



Fig(1) Mass fraction of NOx

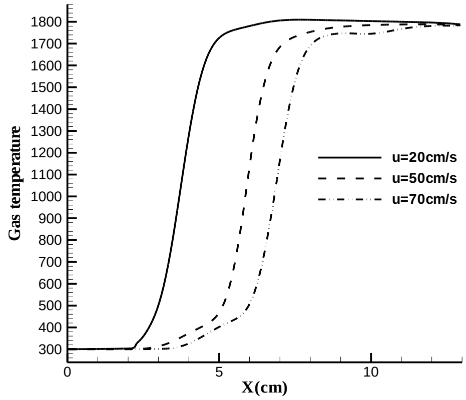
The optimal porosity profile will decrease the significance of the pressure losses.

By increasing the wall temperature, the peak temperature and the amount of NO emission at the outlet of the burner increased.



Fig(2) The effects of wall temperature on the NOx emission

By increasing inlet velocity, the flame front moves downstream, the flame thickness increases, and the peak temperature decreases.



Fig(3) The effects of wall temperature on the gas temperature

4-CONCLUSIONS

Premixed methane/air fuel combustion is studied in the porosity vitiating porous burner using five multi-step combustion mechanisms that are: GRI-3.0, GRI-2.11, GRI-1.2, Skeletal and 17Species mechanisms. The results are :

a) By using porosity variation, the peak temperature will decreases about 4.5% and consequently NOx emission will be decreased.

b) By increasing the inlet velocity, the flame front moves to the downstream and the peak temperature and pollutants emission will decrease.

5- REFERENCES

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