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PREDICTION OF NOx CONTENT IN NATURAL GAS COMBUSTOR BASED ON SPECIES TRANSPORT MODEL

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Abstract— **Numerical study of combustion of natural gas combustion in cylindrical shaped turbulent diffusion flame furnace is presented in this paper. The objective of this study is to predict the NOx content in natural gas combustor based on species transport model. The mathematical models used for the combustion of natural gas and air includes standard k-ε model for turbulent flow and species transport model. The effect of mass flow rate of air and methane, stoichiometric ratio and mass fraction of air on the flame shape is study in this paper. The result is observed in this study of species transport model on the basis of furnace performance with different equivalence ratio. For this study of combustion process, mesh of working combustion model developed on commercial software program FLUENT was imported to simulate the data. The cylindrical shaped combustor is used to burn the methane –air using eddy dissipation/finite rate eddy dissipation model. The model used for one step combustion reaction of methane-air assuming complete combustion of the fuel to carbon dioxide and water.**

***Index Terms*—thermal, prompt, natural gas combustor,**

I. INTRODUCTION

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Combustion is one of the most important processes widely used in many industrial applications. The study of combustion has reached their advanced technology in the past few decades. For the prediction of NOx formation three different mechanism of NO formation is used, that is thermal, prompt and fuel nitrogen conversion. NO is generally formed by three chemical routes. Zeldovich or thermal mechanism that is depend on the temperature where rate formation of NO is exponentially dependent on flame temperature below 1850 K. prompt or Fenimore mechanism generally having complex chemistry and it increases with fuel rich combustion as compared to lean combustion. Our aim of this study is to analyze the mixing of chemical species in a cylindrical shaped turbulent diffusion flame furnace. Many researchers worked in this field via experimentally as well as computational way to analyze the different combustion process. One of them is cited here: K.M.Pandey, D.H.Das and B.Acharya worked on 2D model CFD analysis of combustion process. In their research, they concluded the effect of variation of specific heat on temperature in gaseous combustion with Fluent Software.

Mean flow Equation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho U_i) = 0 \quad \text{(1)}$$

$$\frac{\partial \rho U_i}{\partial t} + \frac{\partial}{\partial x_i}(\rho U_i U_j) = -\frac{\partial p}{\partial x} + \mu\left[\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) - \overline{u_i u_j}\right] \quad \text{(2)}$$

$$\frac{\partial \rho C_i}{\partial t} + \left\{\frac{\partial}{\partial x_i}(\rho U_i C_i) - \frac{\mu}{\rho_{C_i}} grad C_i\right\} = R_i \quad \text{(3)}$$

$$\frac{\partial \rho h}{\partial t} + \frac{\partial}{\partial x_j}(\rho U_i h) = \frac{\partial}{\partial x_j}\left(K grad\, T - \overline{hu_i}\right) + q_{react} + q_{rad} \quad \text{(4)}$$

Where U_i is the mean velocity in the direction x_i,ρ the fluid density,μ the viscosity,σ_{C_i} the prandtl number of the chemical species,$R_i$the rate of generation of the chemical species per unit volume ,K the thermal conductivity, q_{react} the volumetric rate of heat generation , q_{rad} the volumetric rate of heat transfer with radiation and $\overline{u_i u_j}$ and $\overline{u_i h}$ are the unknown Reynolds stresses and heat fluxes, respectively.

II. NUMERICAL MODEL

A cylindrical shaped combustor mesh is imported for the simulation of methane–air. The fluent 15.0 solves the governing equation of continuity, momentum, species and energy in the gas phase. The one step global mechanism used for methane air reaction is given as below:

$$CH_4 + 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + 7.52N_2$$

The mechanism shown above for methane –air reaction contains 5 species and 1 reaction is employed in the present study.

Based on the following governing equations, 2D simulations are performed. The finite volume method are used for the discretization of governing equations and SIMPLE algorithms are used is used for pressure and velocity coupling. The equations are solved implicitly with a 2D pressure based solver using an under relaxation method.

Fuel Inlet Velocity	0.4 m/s
Air Inlet Velocity	100m/s
Equivalence Ratio	0.80
Excess air percent	25%
Inlet temperature	300 K

III. RESULT AND CONCLUSION:

TABLE.1: VALUES OBSERVED AFTER SIMULATION OF THE DATA

Exit temperature	602.75 K
Exit velocity	0.814m/s
Mass fraction of pollutant NO assuming only thermal NOx	0.002
Mass fraction of pollutant NO assuming only prompt NOx	0.00016
Mass fraction of pollutant NOx assuming thermal and prompt NOx	0.0023

As per literature the NOx concentration is increases with increasing equivalence ratio at first and then decreases. In the fig .1 the contour of mass fraction of NO ppm is shown, which is calculated by assuming thermal and prompt NOx together. Similarly, the contour of the mass fraction of NO ppm assuming thermal and prompt NOx separately are shown in fig.2 and fig.3. NO concentration is very high where temperature is very high and having nitrogen and oxygen concentration are available there. Mass weighted average exit NO mass fraction is lower without prompt NOx as compared to thermal and prompt NOx together. So we have also examined that in this case flame is lean and prompt NO production is low.

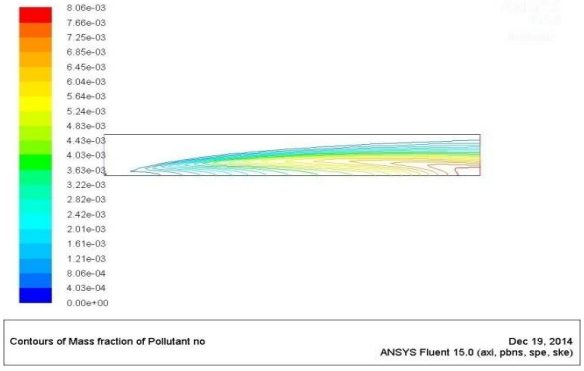

Fig.1 Mass fraction of NO ppm assuming thermal and prompt NOx together

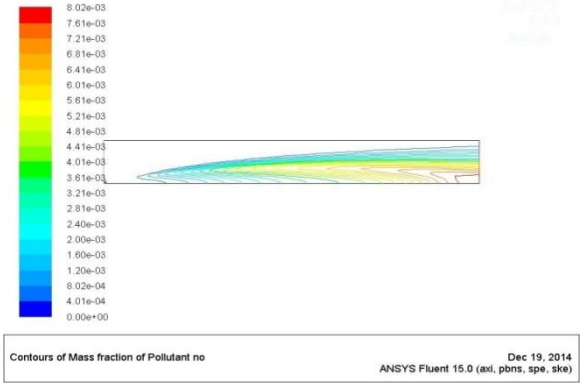

Fig.2 Mass fraction of NO ppm assuming thermal NOx

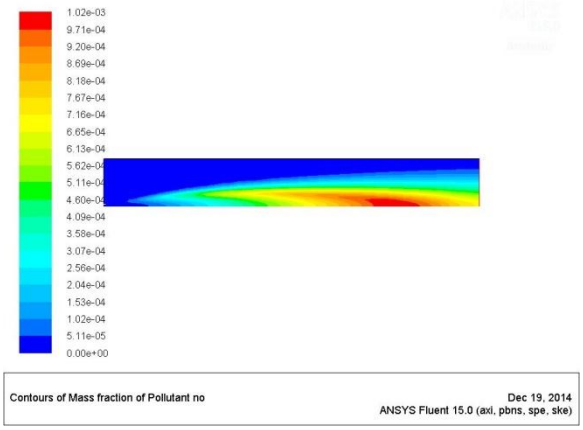

Fig.3 Mass fraction of NO ppm assuming prompt NOx

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