Furnace Burner Design for Power Plant Industry using CFD and its Optimization

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Abstract - This work presents selected results of numerical simulations of processes in utility boiler pulverized coal tangentially fired dry-bottom furnace. The simulations have been performed by specially developed comprehensive mathematical model. The main features of themodel are a tangential fired geometry where four burners are kept at the corner of the burner for generating central vortex in the boiler which provides the flame propagation effectiveness and time to sustain flame for longer time and efficient combustion. The turbulence is captured using k–e gas turbulence model, Eulerian–Lagrangian approach, particles-to-turbulence interaction, diffusion model of particle dispersion is used to understand the particle of pulverized coals on the vortex generation. The parametric study is performed to understand the effect of diameter and velocity on the central vortex for the on and off switching of burners.

Keywords - Tangentially fired furnace; Burner Tripping, Coal-fired Power Plant, Temperature Characteristics.

I. INTRODUCTION

In our day to day life electricity is required to reduce the human efforts. This electricity is generated from power producing plants. There are number of power plants from which thermal power plant uses Pulverized coal as fuel. Pulverized coal tangentially fired furnaces are used extensively in power generation worldwide due to a number of their advantages, like uniform heat flux to the furnace walls and NO emission lower than in other firing types. Further study of the furnaces is needed by both experiments and simulations. While full-scale measurements are restricted by considerably high expenses, numerical simulation provides a cost-effective and powerful engineering tool, complementing experimental investigations. Because of the peculiar aerodynamics of the tangentially fired furnaces, the flow inside the furnaces, as well as the combustion processes were found to be complicated for modeling. Still, comprehensive combustion models of large-scale tangentially fired furnaces, based on numerical solution of three-dimensional differential conservation equations, have been the subject of many investigations. The models are similar in many ways to each other and to the model presented in this paper.

The majority use variations of the SIMPLE algorithm and the k–e gas turbulence model, or some derivatives, like RNG k–emodelor k–e–kp two-phase turbulence model. Gasphase conservation equations are mostly time-averaged,but some suggest the Favre-averaged equations instead. A two-phase flow is usually described by Eulerian–Lagrangian approach and PSI-Cell method for couplingof phases, with some exceptions using Eulerian–Eulerian approach, or two-fluid trajectory model. Most ofthe combustion submodels given in treat particle devolatilization, char oxidation and additional gas phasereactions separately.

TABLE:1 SUMMARY OF RECENT RPI LOW NOX RETROFIT PROJECTS USING CFD MODELING

Furnace Type	Fuel Type	Steam Flow KPPH	Description
Turbo	PRB Coal	4,700	Install LNB & overfire air (OFA)
Wall-Fired	Bit Coal/Pet Coke	2 x 750	Reduce high CO & opacity
Down-Fired	NG, Oil, Waste Fuels	258	Install LNB & OFA
Wall-Fired	Oil, NG	870	Install OFA & upgraded burners
Wall-Fired	Bit Coal	1,800	Modify B&W XCL burner & install OFA

This work presents selected results of numerical simulations of processes in utility boiler pulverized coal tangentially fired dry-bottom furnace. The simulations of the processes are based on a comprehensive 2D differential mathematical model, specially developed for the purpose. The model offers such a composition of sub models and modeling approaches so as to balance sub model sophistication with computational practicality. A 2D geometry, Eulerian – Lagrangian approach, k–e gas turbulence model,particles-to-turbulence interaction, diffusion model of particle dispersion.

II. SIMULATION SET UP AND DATA INPUT

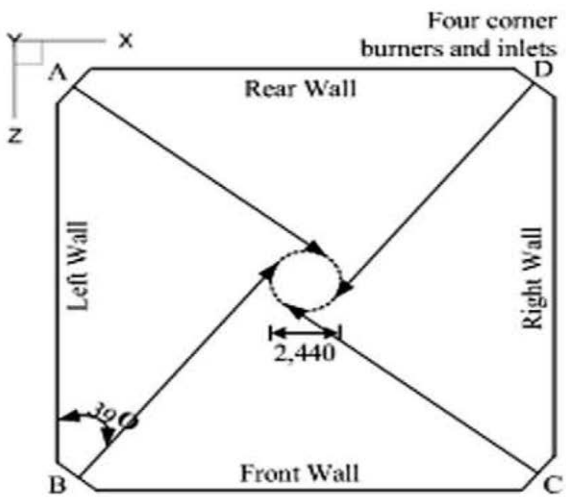

Figure:1 Vortex formation from tangential fired burners

In ANSYS, the governing equations are discredited by using the finite Volume method The pressure velocity coupling is achieved through the SIMPLE -algorithm. The grid-independent study is done for all cases. All simulations are run in ANSYS K-ε reliable model. Boundary conditions used are flue gas mass flow rate and temperature. It is assumed that all particles have attended their terminal velocity and have entered perpendicular to the tube. The geometry of actual flue gas duct, its internal, tubes created in ANSYS design modeler. Drawings of duct are used for geometry creation. Meshing is done in ANSYS meshing

III. PROBLEM DEFINITION

Objective : To design furnace burner for efficient combustion

1- To check the effect of velocity on flame propagation
2- To check the effect of burner size on combustion
3- To understand turbulence effect
4- To understand Pulverized gas particles on the flow field

Steps

- Set up and solve a coal combustion case.
- Use the Eddy Break Up (EBU) model.
- Solve the case using appropriate solver settings.
- Post process the resulting data. And results are presented

IV. PROPOSED METHODOLOGY

a. To model the burner for the given size and the present input parameters in Gambit
b. To model the design parameters for the burner
c. To check the turbulence model suitability for the current design
d. To simulate the base case and perform parametric study based on design of experiments
e. To understand effect of velocity and size on flame propagation
f. To simulate the particle interaction with flow field using Lagrangian-Eleriuan model
g. To select the best combinations of parameters which affect the burner efficiency and flame propation in the boiler.

V. MATHEMATICAL MODEL UNDERSTANDING

Mathematical model and numerical method explains that developed comprehensive model extended available sub models by describing fully the 3D flow, combustion and heat transfer in existing geometry, with in details modeling of the interactions between turbulence and particles and by including chemical kinetics of the coals considered and real coal particle size distribution. Turbulent flow of multicomponent gaseous phase is described by time-averaged Eulerian partial differential conservation equations for mass, momentum, energy, concentrations of gaseous components, as well as the turbulence kinetic energy and its rate of dissipation.

$$\frac{\partial}{\partial x_j}(\rho U_j \Phi) = \frac{\partial}{\partial x_j}\left(\Gamma_\Phi \frac{\partial \Phi}{\partial x_j}\right) + S_\Phi + S_{\mathrm{p}}^{\Phi}$$

Where Φ is the dependent variable and *uj* is the velocity component along the coordinate direction j x .ρ is the fluid density; Φ Γ is the diffusion coefficient and Φ S is the source term.

when Φ = 1; the momentum conservation

equation when Φ is a velocity component; the energy equation when Φ is the stagnation enthalpy; or the transport equation of a scalar when Φ is a scalar variable such as mixture fraction. The present work utilizes the K-ε model of Versteeg and Malalasekera (1995). The Reynolds stresses and turbulent scalar fluxes in the model are related to the gradients of the mean velocities and scalar variable, respectively, via exchange coefficients as follows

Expected Outcome:

1. Effect of burner size on combustion efficiency in power plant
2. Effect of velocity on flame propagation effectively
3. Effect of particle pulverization/size on vortex generation
4. Effect of turbulence models for the burner design

Facilities required:

Fluent, Gambit, Pro-E Softwares

VI. CONCLUSIONS

The main objective of the present study was to investigate how the results obtained with three radioactive heat transfer methods, the P1 approximation method, Discrete transfer and the DO method, fit the temperature field in a boiler furnace on pulverized coal, with implemented OFA ports. Despite the evident discrepancies, in general, the both thermal radiation modeling approaches, with the DO, DT and the P-1 models, give fair representation of the experimental results. The obtained temperature profiles with P-1 model are somewhat lower than in the case when DO model is used. In that sense, the results obtained with the DO, DT model better fit the measurements. The main differences between the modeling and the measurement values appear in the burnout zone, near the air/fuel injections, and need further investigation for appropriate explanation. In general, they can be addressed to several reasons: peculiarities of the flow field in the near-burner region, including the particles-turbulence interaction; the utilized thermal radiation models; and the variability of coal properties that requires much characterization data for validation purposes of the boiler furnace processes. Finally, it must be noted that the computation with the DO and DT model is more time consuming.

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