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A Review Paper on CFD Analysis of Tri-sector Air Preheater for different Primary Air Inlet Opening

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***Abstract*— Air preheaters have a vital role to the improved overall efficiency of fossil-fuel-fired power plants. In this study we used a combination of fluid dynamics and a newly developed three dimensional numerical model for heat transfer as the basis for a theoretical analysis of a tri-sector air preheater. The model enables studies of the flue-gas flow through the preheater and the adjoining channels as well as the regenerative heat transfer and the resulting temperature distribution in the matrix of the preheater for different primary air inlet opening.**

Keyword: Air preheater, Tri-sector Air preheater, Primary Air Inlet Opening, APH, Temperature, CFD

I. INTRODUCTION

Tri-sector air preheater is one of the essential energy recover systems in the steam based power plant which was taken in use in 1920 by Ljungstrom[1]. It transfers heat from the hot stream fluid to the cold one by using a rotating matrix of compact plates as shown in Fig. 1. Considering the important effect of the air preheater on the cycle efficiency, there are many studies talks about preheater efficiency. Warren [2] had published his studies on Ljungstrom as a particular type of air to air exchanger and base on the experimental results confirmed a minimum reduction of 10% in power plants fuel consumption. Skiepko [3,4] had investigated the effects of heat conduction in the matrix, Peclet number and the length of the matrix on the preheater performance [5,6]. Investigating on the effect of separator plate on the preheater performance,Worsoe-Schmidt [7] stated that although the separator decreases the efficiency of the exchanger, but it cannot be removed due to its role in the reduction of the fluid leakage. Based on the several experimental and numerical analyses, Ghodsipour and Sadrameli [8] studied the effect of mass flow rate and rotational speed of the matrix on the preheater performance and showed that the flow rate effect was more significant than the rotational speed. Numerical and experimental methods to estimate the pattern of Ljungstrom exhaust gas temperature and specified the importance of optimizing the speeds of rotation and mass flow rate by using analytical relationships and empirical models. Using a three-dimensional rotary preheater model, Wang et al. [9] obtained the temperature distribution in the exchanger through a semi-analytical method.

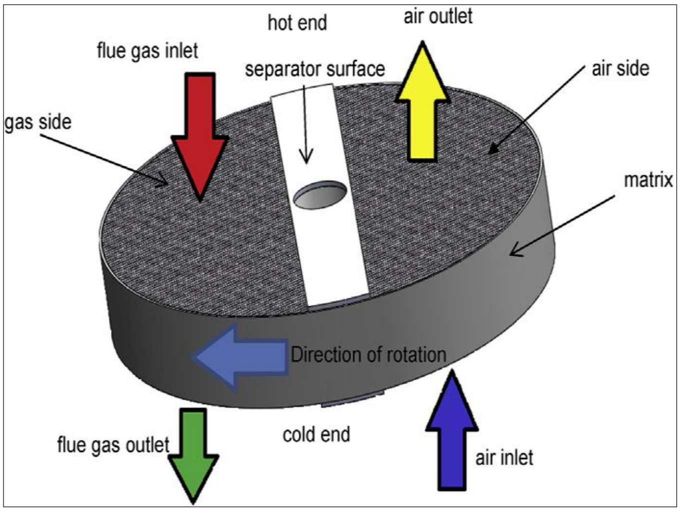

Fig. 1 A view of a rotary pre-heater.

Despite many studies in this area, there are more rooms for better understanding of the periodic nature of heat transfer process. in the rotary preheater. For example, three-dimensional temperature distribution of a preheater has not accurately been presented yet. Furthermore, the effects of influential parameters on the temperature distribution of the matrix have not been addressed sufficiently. In the present study, using three-dimensional approach and considering rotary matrix as a

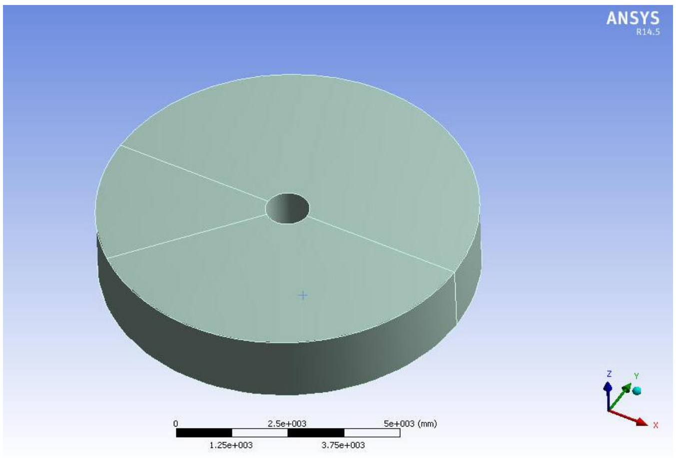

Fig. 2 CAD Modeling of Tri-sector Air Preheater

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porous media, the governing equations of a full scale rotary preheater located in Ramin power plant located in India is simulated to clarify the exact temperature distribution inside the preheater. Moreover, the effects of some variables such as rotational speed of the matrix, fluid mass flow rate, plates material, and inlet fluid preheating on the temperature distribution and the exchanger performance are investigated.

Considering the narrow passages of fluids compared to the overall dimensions of the preheater [Fig. 2], a porous media approach can be used to simulate fluids flows in the air heater matrix [10, 11]. Using this approach can reduce the computational time while maintaining the results with acceptable accuracy. By experimental measurements of the volume, weight, and dimensions of the compact plates within the rotary preheater matrix, it was found that the porosity in the hot and cold layers is 0.84 and 0.76, respectively. To simulate the flow and heat transfer within the exchanger Navier Stokes equations in the porous medium can be used.

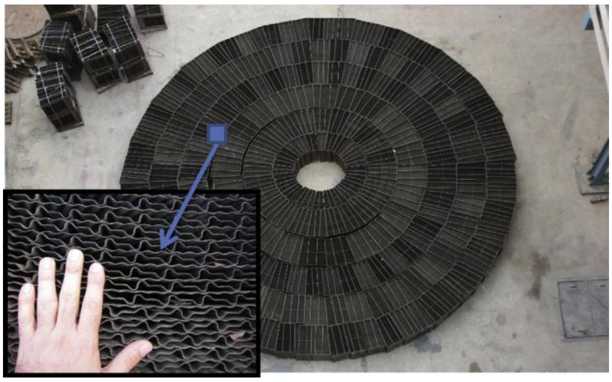

Fig. 3. The actual shape of the plates used in the matrix.

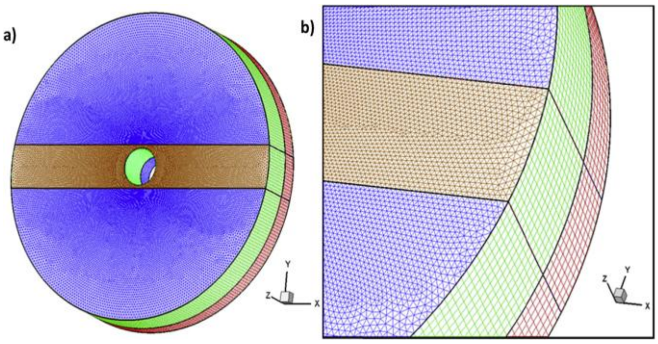

Fig. 4. Computational grids of rotary preheater and matrix.

II. LITERATURE REVIEW

The Ljungstrom air preheater Dilip S. Patel (2015), is a regenerative type heat exchanger used for preheating the combustion air, mainly in steam power plant. The warm gas and cool air ducts are arranged to allow both the flue gas and inlet air to flow simultaneously through the air preheater. The hot flue gas heats the rotor material and as the rotor rotates, the hot rotor section moves into the flow of the cold air and preheats it. If the incoming air is not preheated, then some additional energy must be supplied to heat the air to a temperature required to facilitate combustion. Due to this, more fuel will be consumed which decreases overall efficiency of the power plant. In this paper different techniques used to optimize the process parameters of rotary regenerator are discussed.

Taware khushal (2015), to increase the efficiency of boiler is achieved by increasing no of tubes & adding super heater. Boiler efficiency also increased by reducing heat losses & increasing heat input. This heat input is increased by adding oxygen in the furnace area so more heat input is transferred to boiler process so increases the efficiency of boiler. By increasing length of tube boiler & adding super heater boiler gives maximum heat input to the process so increases ton capacity of boiler. In this way we get profit by increasing efficiency of boiler. Chayalakshmi C.L (2015),The traditional method for calculation of boiler efficiency using indirect method involves complex mathematical equations, which is a tedious work for operation department people of an industry. Instead of manual calculation, the software system developed in this paper can be easily adopted which provides measurement and monitoring of various losses and boiler efficiency.In indirect method, no need to measure or monitor the parameters which are necessary for finding boiler efficiency and boiler design cannot depict its efficiency. As the performance evaluation of boiler is based on its boiler efficiency, finding boiler efficiency using indirect method is an easy task if the developed application software is used. The error between the boiler efficiency calculated using conventional method and the calculated using application software is very small. Calculation of boiler losses and efficiency is carried out using DASY Lab software package and tested with data obtained from industrial environment.

III. METHODOLOGY

Following fundamental laws can be used to derive governing differential equations that are solved in a Computational Fluid Dynamics (CFD) study [13]

Conservation of mass:

$$\frac{\partial}{\partial x_i}(\rho u_i) = 0$$

The equation of rate change of momentum:

$$\frac{\partial(\rho u_i u_j)}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\mu \frac{\partial u_j}{\partial x_i}\right) - \frac{\partial P}{\partial x_j}$$

Energy equation:

$$\frac{\partial}{\partial x_i}(\rho u_i T) = \frac{\partial}{\partial x_i}\left(\frac{k}{c_p}\frac{\partial u_j}{\partial x_i}\right)$$

In this study we'll consider the motion of single phase fluids, i.e. either liquid or gas, and we'll treat them as continuum. The three primary unknowns that can be obtained by solving these equations are (actually there are five scalar unknowns if we count the three velocity components.

- Velocity vector V
- Pressure P
- Temperature T

But in the governing equations that we solve numerically following four additional variables appear.

- Density ρ
- Enthalpy h (or internal energy e)

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- Viscosity μ
- Thermal conductivity k

Pressure and temperature can be treated as two independent thermodynamic variables that define the equilibrium state of the fluid. Four additional variables listed above are determined in terms of pressure and temperature using tables, charts or additional equations. However, for many problems it is possible to consider ρ, μ and k to be constants and to be proportional to with the proportionally constant being the specific heat.

Due to different mathematical characters of governing equations for compressible and incompressible flows, CFD codes are usually written for only one of them. It is not common to find a code that can effectively and accurately work in both compressible and incompressible flow regimes. In the following two sections we'll provide differential forms of the governing equations used to study compressible and incompressible flows. The heat transfer rate for most heat exchangers can be calculated using the LMTD-method (Log Mean Temperature Difference), if the inlet (T_1) and outlet (T_2) temperatures are known:

$$Q = UA\,\Delta\overline{T}$$

$$\Delta\overline{T} = \frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2/\Delta T_1)}$$

where, U = Overall heat transfer coefficient, W/m^2 °C
A = Effective heat transfer surface area, m^2
$\Delta\overline{T}$ = Log mean temperature difference.

IV. CONCLUSION

The importance of appropriate pressure optimization in tri-sector air preheater requires a suitable method for monitoring of primary air inlet opening. To study the effects that various inlet opening have on the flue-gas properties, a new numerical heat-transfer model was developed. The model enables three-dimensional flow and heat-transfer simulations within tri-sector regenerative heat exchanger, including large steam-boiler air preheater. In the presented study the model was used to calculate the temperature distributions and pressure drops at the flue gas outlet of an air preheater. Furthermore, it is shown that measurement of the temperature at the proposed locations in the outlet channel can provide sufficient information about how air preheater work efficiently.

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