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Heat Transfer Coefficient and Tube Diameter Optimization of Air Preheater Using Neural Network Tool

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Abstract: In this present investigation is to modified the existing design which are mentioned in good literature Das et. al [5] and Vivek et. al. [6]. In this investigation also modified the design using ANSYS CFX tool and optimizing using Neural Network tools. The Neural Network Tool, a non-traditional global optimization technique has been used as the solution methodology for its inherent advantages. Optimal results so obtained are compared with remodeled diameter of tube with heat transfer rate maximizing effect considered as a key factor. The aim of the project is to investigate to calculate the minimum diameter of tubes in tubular shell tube heat exchanger using Artificial Neural Network (ANN) tool.

Keywords: Air preheater, ANSYS CFX, ANN Tool.

I. INTRODUCTION

The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the conveyance system and the flue gas stack. It also allows control over the temperature of gases leaving the stack (to meet emissions regulations). [3]

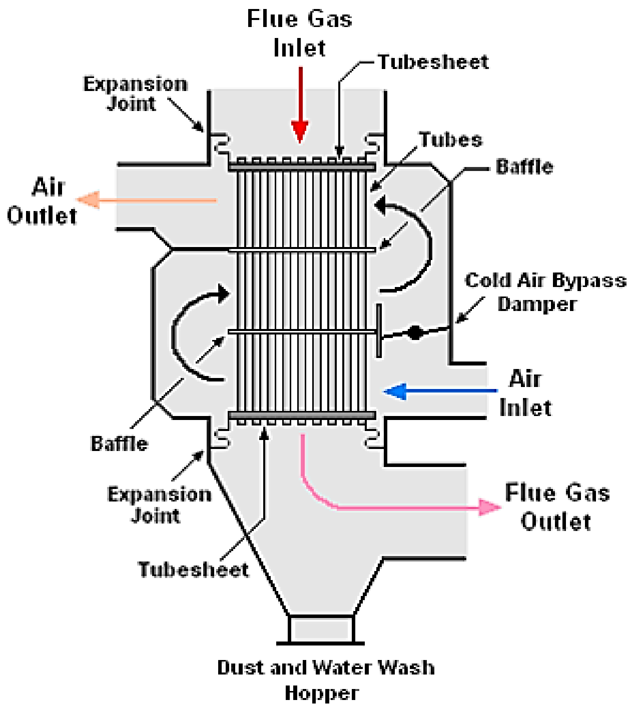

Fig 1: Air Preheater [4]

II. MATHEMATICAL MODELING

2.1 Governing Equations of Fluid Flow and Heat Transfer

Following fundamental laws can be used to derive governing differential equations that are solved in a Computational Fluid Dynamics (CFD/CFX) study [1]

- conservation of mass
- conservation of linear momentum (Newton's second law)
- conservation of energy (First law of thermodynamics)

2.1.1 Conservation of Mass (Continuity Equation)

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho\vec{V}) = 0 \text{ ------------------ (2.1)}$$

or equally

$$\frac{D\rho}{Dt} + \rho(\nabla.\vec{V}) = 0 \text{ ----------------------- (2.2)}$$

2.1.2 Conservation of Linear Momentum

Equation for the conservation of linear momentum is also known as the Navier-Stokes equation (In CFD literature the term Navier-Stokes is usually used to include both momentum and continuity equations and even energy equation sometimes). It is possible to write it in many different forms. One possibility is

$$\rho\frac{D\vec{V}}{Dt} = -\nabla p + \nabla\cdot\bar{\bar{\tau}} + \rho\vec{f} \text{ ----------------------- (2.3)}$$

2.1.3 Conservation of Energy

Energy equation can be written in many different ways, such as the one given below

$$\rho\left[\frac{\partial h}{\partial t} + \nabla\cdot(h\vec{V})\right] = -\frac{Dp}{Dt} + \nabla\cdot(k\,\nabla T) + \phi \text{ ------------------- (2.4)}$$

Where is the specific enthalpy which is related to specific internal energy as $h = e + p/\rho.T$ is the absolute temperature and Φ is the dissipation function representing the work done against viscous forces, which is irreversibly converted into internal energy. It is defined as

$$\phi = (\bar{\bar{\tau}}\cdot\nabla)\vec{V} = \tau_{ij}\frac{\partial V_i}{\partial x_j} \text{ --------------- (2.5)}$$

III. METHODOLOGY

3.1 Geometric Modeling of Air Preheater

In this investigations the air preheater is design or modeled by using Creo parametric software, which is geometric construction tool can easily create 3D model. After geometry has been done, the hole assembly is export (*.STP file) from Creo parametric to ANSYS CFX Tool.

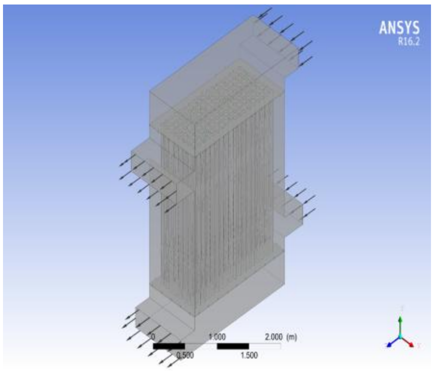

Fig 2: 3D Modeling of Air Preheater

3.2 Meshing of Model

After importing the product in ANSYS CFX and generate mesh in model. In this process can uses unstructured meshing method as shown in Figure 3 respectively.

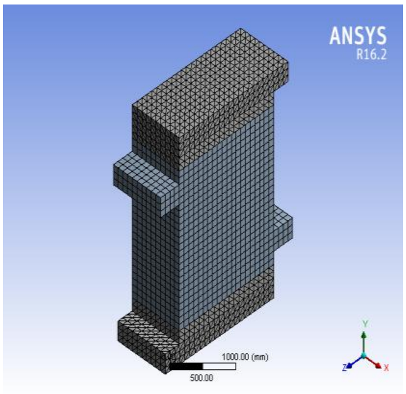

Fig 3: Meshing view of Air Preheater

3.3 Boundary Conditions

It has many surface boundaries like Air inlet and outlet, Flue gas inlet and outlet and Walls. Outer surface of tube and duct are defined as wall. Wall motion is stationary. No slip is taken in shear condition.

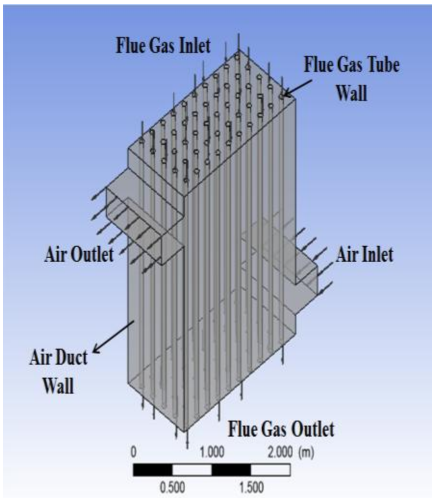

Fig 4: Boundary Conditions of Air Preheater

Table 1: Parameters for Air Preheater [5]

S. No.	Parameters	Symbol	Unit	Quantity
1.	Gas quantity	Wg	Kg/hr	54628.39
2.	Air quantity	Wa	Kg/hr	47,000
3.	Air inlet temperature	t1	°C	36.75
4.	Air outlet temperature	t2	°C	150.2
5.	Flue gas inlet temperature	T1	°C	253.708
6.	Heat transfer	Q	KW	1488.55
7.	Flue gas outlet temperature	T2	°C	156
8.	Density of flue gas	ρ_g	Kg/m3	0.752
9.	Width of air preheater	W	m	2.82
10.	Depth of air preheater	D	m	2.286
11.	Specific heat of air	Cpa	Kcal/kg°C	0.2418
12.	Specific heat of gas	Cpg	Kcal/kg°C	0.2596
13.	Thermal conductivity of air	ka	Kcal/mh°C	0.0253
14.	Thermal conductivity of flue gas	Kg	Kcal/mh°C	0.0303

IV. RESULTS AND DISCUSSIONS

The various results obtained from analysis and optimization using ANSYS CFX and ANN Tool.

Table 2: Improvement Results obtained from ANSYS CFX and Actual (ANN Tool)

Tube Dia, d	Flue Gas Inlet Temperature, oC	Air Inlet Temperature, oC	Flue Gas Outlet Temperature, oC	Air Outlet Temperature, oC	Heat Transfer Coefficient W/m2 oC
55	253.708	36.75	245.24	231.11	21.72
50	253.708	36.75	238.7	237.56	22.15
45	253.708	36.75	231.25	244.54	23.96
40	253.708	36.75	219.367	236.5	24.3567
35	253.708	36.75	207.96	235.613	22.02834
30	253.708	36.75	195.354	234.516	21.79691
25	253.708	36.75	181.537	233.178	21.54398
20	253.708	36.75	166.523	231.569	21.2682
15	253.708	36.75	150.356	229.664	20.96843
10	253.708	36.75	133.111	227.438	20.64385
5	253.708	36.75	114.896	224.875	20.29409

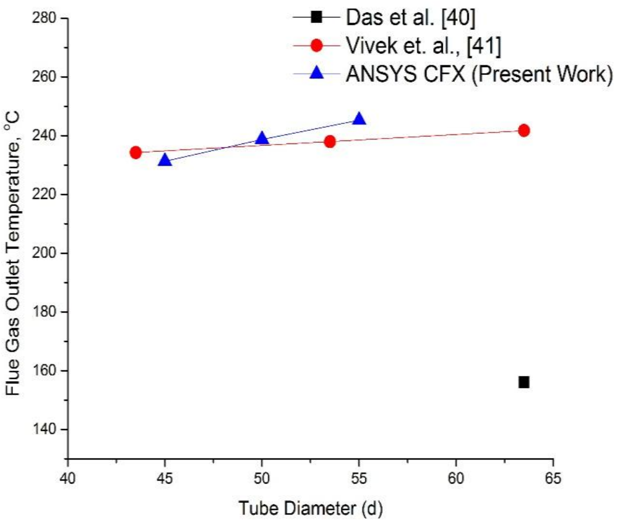

Fig 5 Graph plotted between Flue gas outlet temperature and different tube diameter in Das et al. [5], Vivek et al. [6] and ANSYS CFX (Present) result

The figure 5 indicates that the outlet flue gas temperature of ANSYS CFX result is less than the Das et al [5] and Vivek et al. [6].

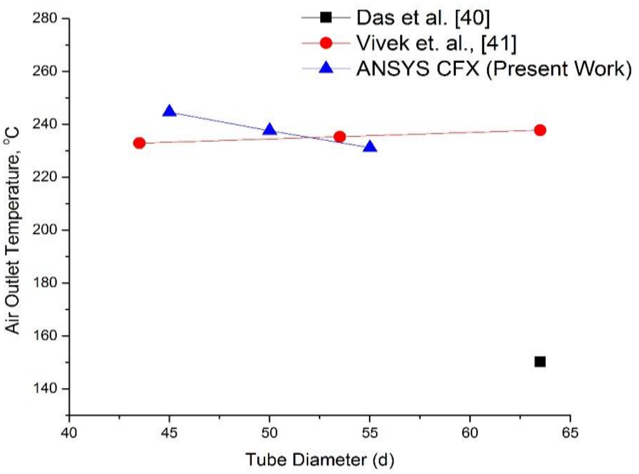

Fig 6: Graph plotted between air outlet temperature and different tube diameter in Das et al. [5], Vivek et al. [6] and ANSYS CFX (Present) result

The figure 6 indicates that the outlet air gas temperature of ANSYS CFX result is more than the Das et al [5] and Vivek et al. [6].

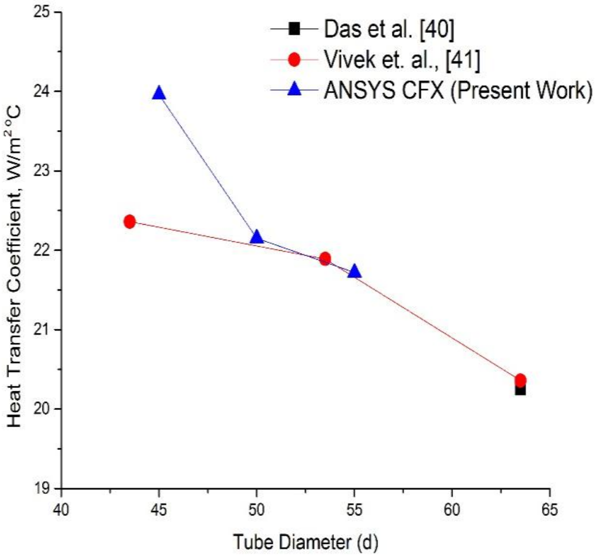

Fig 7: Graph plotted between heat transfer coefficient and different tube diameter in Das et al. [5], Vivek et al. [6] and ANSYS CFX (Present) result

The figure 7 shows the graph between heat transfer coefficient and different tube diameters.

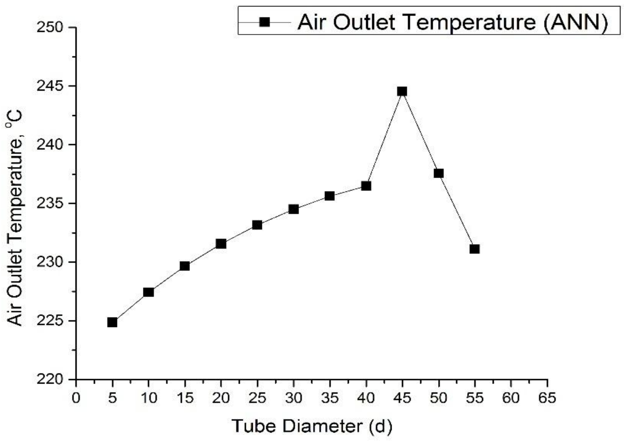

Fig 8: Graph plotted between Air outlet temperature with different tube diameter.

The graph 8 indicates that outlet air temperature air preheater duct. It is indicated that when diameter is reducing, outlet temperature increases but after 40mm diameter of tube the outlet temperature are falling down.

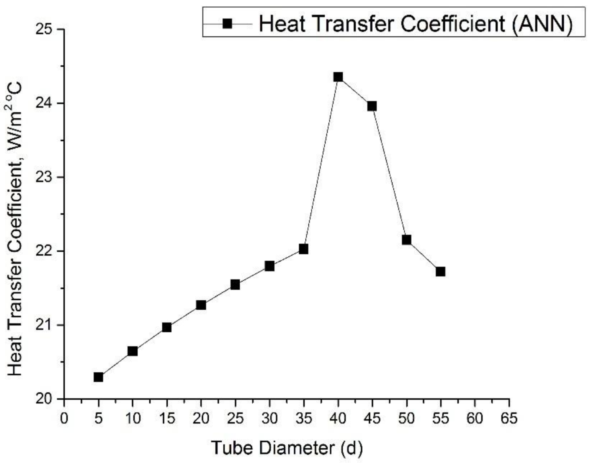

Fig 9: Graph plotted between prediction result obtained from ANN tool vs different tubes diameter

The above figure 9 shows that optimized results obtained from ANN tool. The prediction output is out from different tube diameters. The figure indicates when diameter of tube is reducing 55mm to 5mm, then the heat transfer coefficient is increases but at a time (after 40mm) the heat transfer coefficient are falling down.

V. CONCLUSION AND SCOPE OF FURTHER WORK

- The main objective of the thesis to concluded the minimum/optimized results for tubular air preheater design.
- In this investigation the mostly preferred the ANSYS CFX and Artificial Neural Network (ANN) software tools which are gives the useful results.
- In this investigation has been concluded that when diameter of the tube is reducing by 13%, 6.5 % and 13 then the flue gas outlet temperature is falling down 1%, 0.3% and 36.6% Das et. al. [5] and Vivek et. al. [6] respectively.
- It has been also concluded that when diameter of the tube is reducing by 13%, 6.5 % and 13% then the air outlet temperature is raised 2.78%, 0.9% and 0.36% in Das et. al. [5] and Vivek et. al. [6] respectively.
- If diameter of tube is reducing by 13%, 6.5% and 36.3 % then heat transfer coefficient is raised by 6%, 1% and 6.76% in Das et. al. [5] and Vivek et. al. [6] respectively.
- In this investigation when diameter is reducing, outlet temperature increases but after 40mm diameter of tube the outlet temperature are falling down, and when diameter of tube is reducing 55mm to 5mm, then the heat transfer coefficient is increases but at a time (after 40mm) the heat transfer coefficient are also falling down.
- Form the above all results (validation, improvement and optimization), it is concluded that the 40mm of tube diameter is more efficient for air preheater which is gives more output.

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