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Numerical Analysis of the Performance Characteristics for the Different Configuration ofCirculating Fluidized Bed (CFB) Review

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Abstract: This research work numerically analyze the different configuration of CFB boiler tube model using Ansys 15.0. The detailed analysis has been done for performance parameters such as temperature distribution, heat transfer coefficient on different configurations of CFB boiler tube models. The result has been compared with the reference paper reported in the literature. This paper also show the developed the different configurations of CFB boiler tube with perforations with constant temperature of 673K, 773K and 873K.

***Index Terms* - Computational Fluid Dynamics, Simulation, Conductivity, Heat Flux, Boiler**

I. INTRODUCTION

The circulating fluidized bed (CFB) is a developing technology for coal combustion to achieve lower emission of pollutants. By using this technology, up to 95% of pollutants can be absorbed before being emitted to the atmosphere [1].

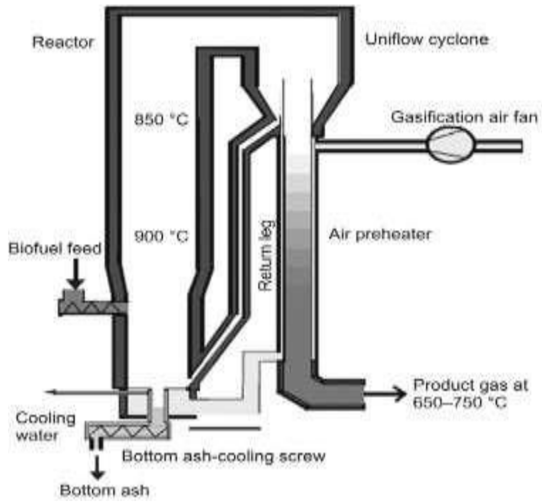

Fig.1. Overview of Circulating fluidized bed [2]

Fluidization is the phenomenon by which solid particles are transported into a fluid like state through suspension in a gas or liquid. In fact, there is a simple and precise way to classify the various fluid-particle beds. Most of the CFB operating and environmental characteristics are the direct results of the hydrodynamic behaviour [3]. Numerous of searchers have studied the hydrodynamics of CFB. The fluidization is a function of several parameters such like the particles' shape, size and density, velocity of the gas, bed's geometries etc. Circulating fluidized bed is a novel technology with the capability to attain lower emission of pollutants. The significance of this technology has developed recently because of constrict environmental policy for pollutant emission. The Mercury and Air Toxic Standards (MATS) ratify in December 2011 by the EPA have compulsory made all the countries in Europe and America to firmly adopt this policy. This means that emanation of pollutants such as acid gases, organic compound, flue gas acids and other pollutants from power plants or industrial have to fulfill the necessary checklist set by EPA. As a result, the requirement for circulating fluidized bed technology is estimated to attract the investors and academician [4].

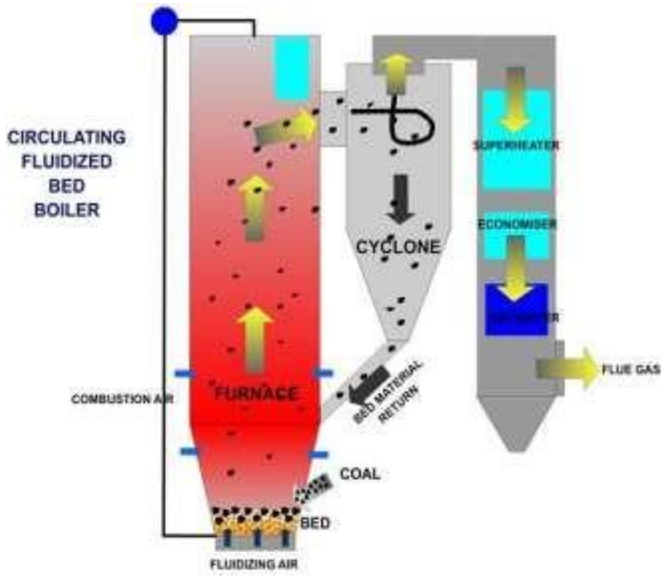

Fig.2 Schematic diagram of a typical circulating fluidized bed [5]

Circulating fluidized bed technology can be used in many diverse fields. This technology is highly required due to its several benefits. Some of the popular purpose of circulating fluidized bed are circulating fluidized bed scrubber and circulating fluidized bed gasification system [5]. Artur Blaszczuk et al. [6] investigates the heat transfer characteristics in a bubbling fluidized bed with a submerged super-heater tube bundles using mechanistic heat transfer model to evaluate heat transfer. The results showed an increase in heat transfer with decreasing bed size. Hong Xu et al. [7] proposed a single tube model based on the finite volume method to evaluate the wall temperature profiles of the surface tubes in power plant. With increasing thickness of outer oxide scale the temperature of the outer wall increases more than inner wall. The higher mass flow rate increases the convection coefficient and decreases the heat flux from the tube metal to the steam. A. Blaszczuk et al. [8] focuses on the evaluation of the impact of bed temperature on the local heat transfer characteristic between a fluidized bed and upright rifled tubes (38mm-O.D.) in a industrial circulating fluidized bed (CFB) boiler. The heat transfer experiments was performed CFB boiler with comprehensive contemplation of the bed-to-wall heat transfer coefficient and the involvement of heat transfer mechanisms within furnace chamber were investigated using mechanistic heat transfer model depending on cluster renewal method. The calculated values of heat transfer coefficient are evaluated with empirical correlation for CFB units in large-scale. A. Arjunwadkar et al [9] studied some essential O&M issue of CFB boilers related to components explicit to CFB boilers and the methods to evade them. Operational problems like agglomeration, gas refluxing, back-sifting and performance associated problems like emission control and bed temperature control are also examined.

The studied does not shows the effect of temperature distribution as per operating temperatures with respect to the effect of thermal conductivity along with this the role of perforation in tube is until not investigated in above literature. The objective of this research work is to numerically analyze the different configuration of CFB boiler tube model using Ansys. The result has been compared with the reference paper reported in the literature. This paper also show the developed the different configurations of CFB boiler tube with perforations with constant temperature of 673K, 773K and 873K. The detailed analysis has been done for performance parameters such as temperature distribution, heat transfer coefficient on different configurations of CFB boiler tube models.

II. METHODOLY

To achieve the objectives of present research work, the flow chart of the action plan is shown in Figure 3.

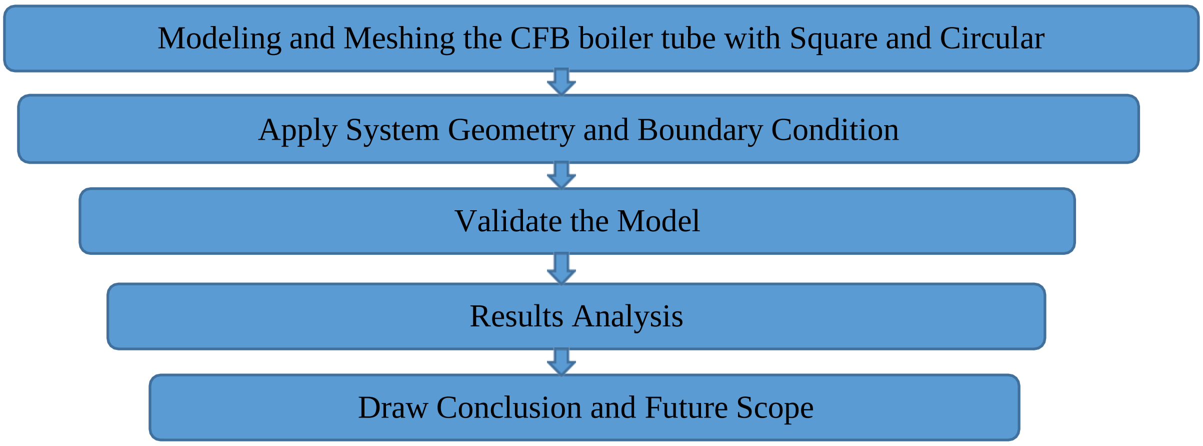

Fig 3. Flow Chart for Achieve desirable Objectives

Initially, review of literature in the field of analysis of CBF boiler tubes with different shapes is to be carried out to find the research gap. Then on the basis of research gap, research objectives of the present research are to be finalized. Then after, setup the model and then validating using ANSYS and then finally results are to be concluded.

III. MODELING AND MESH GENERATION

The dimensions of the computational domain of CFB boiler tube were based on the work done by Yuge Yao [10] author of base paper that was considered for present simulation of CFB boiler tube model. After this process the constraints were applied and this way the model was created in modelling software UNI -GRAPHICS NX-8.0 The following Table 1 show basic geometric parameters of CFB boiler tube.

Table 1 Basic Geometry Parameters of CFB Boiler Tubes

Geometric Parameter	Value × 10^3
Inner Diameter of the Tube (di)/m	38
Outer Diameter of the Tube (do)/m	50
Thickness of membrane fin (lm)/m	6
Tube Pitch (lp)/m	60
Thermocouple Diameter (dt)/m	2
Characteristics deposition thickness (ld)/m	1.5

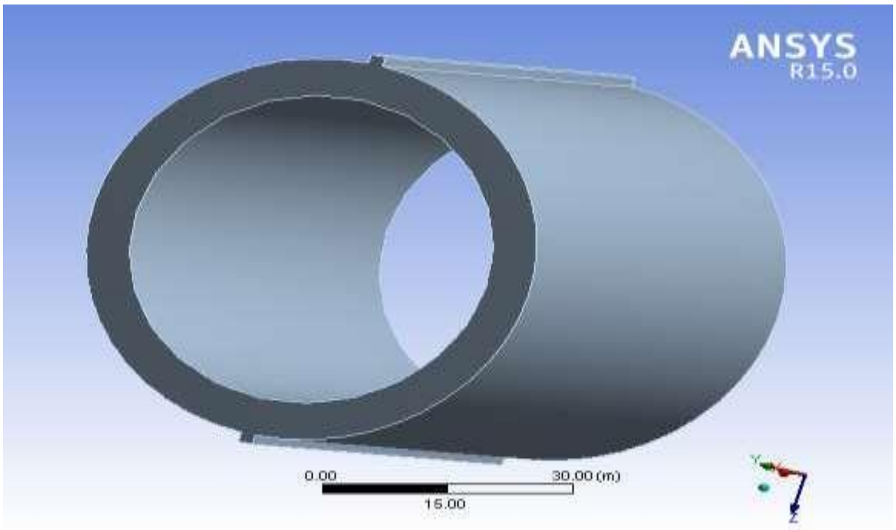

Fig 4. 3D model of CFB boiler tube with fin (Validation model)

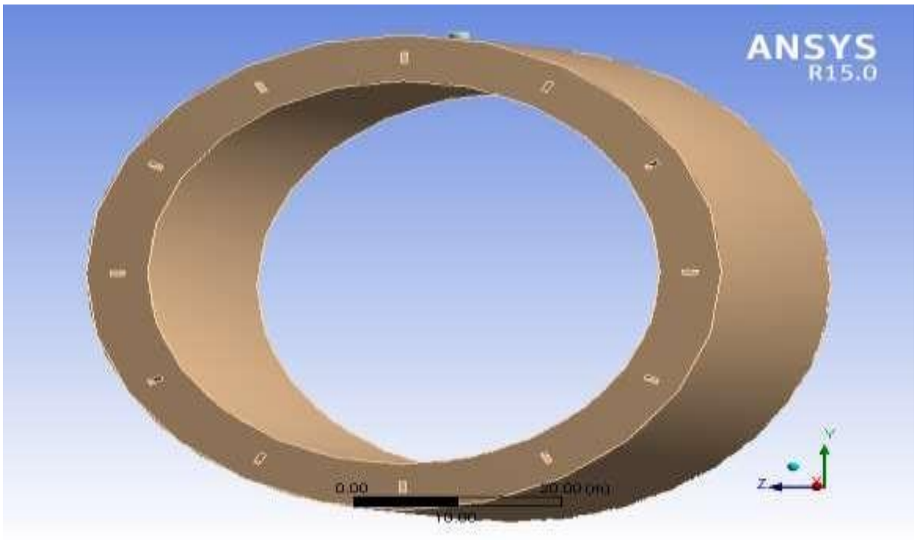

Fig. 5 3D model of CFB boiler tube with square shaped perforations

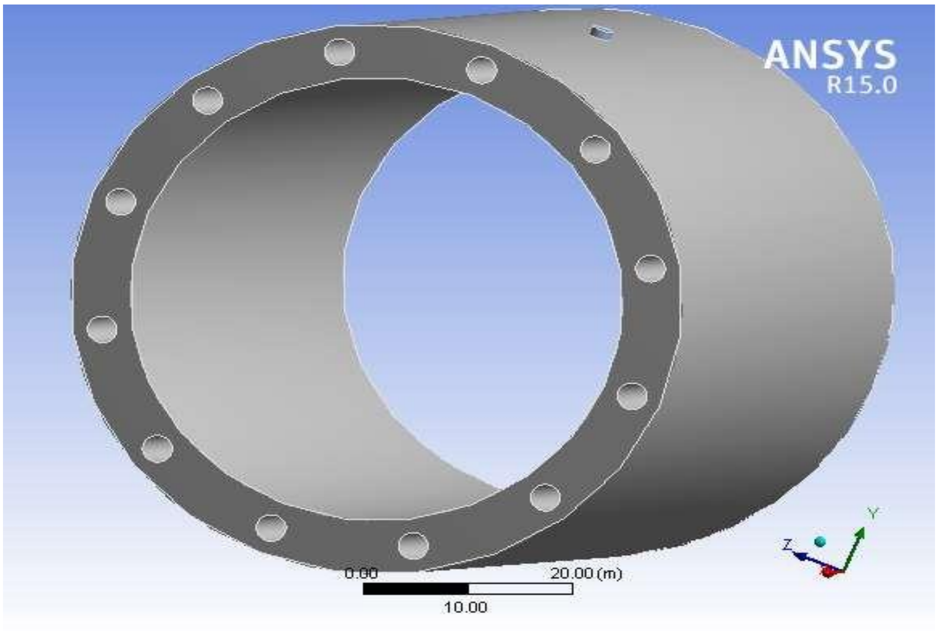

Fig 6 3D model of CFB boiler tube with circular shaped perforations

Above depicted figures 4, 5 and 6 shows the three dimensional model of CFB boiler tube of validation, square shape and circulating shape respectively. The total number of elements of 58200 & nodes of 266169 were employed to assess the grid independence in the CFB boiler tube case. The total number of elements is higher in the CFB boiler tube (circular perforation) case. It is clear that the present results have good agreement with the available data in the literature.

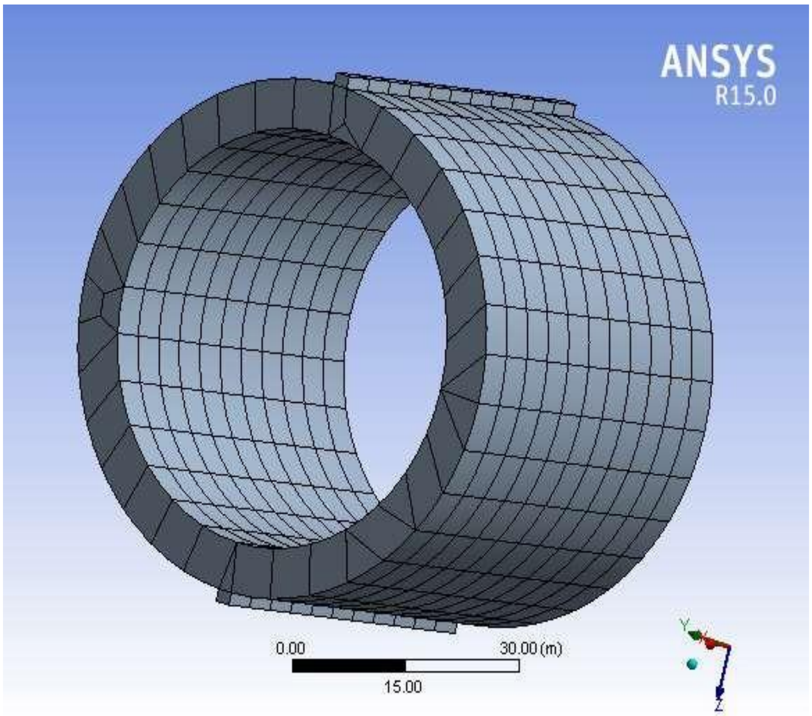

Fig. 7 Mesh of CFB boiler tube with fin (Validation model)

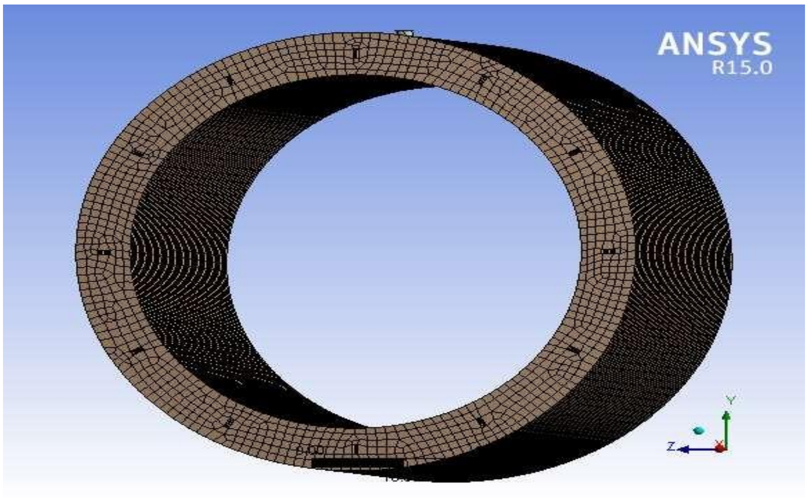

Fig. 8 Mesh of CFB boiler tube with square shaped perforations

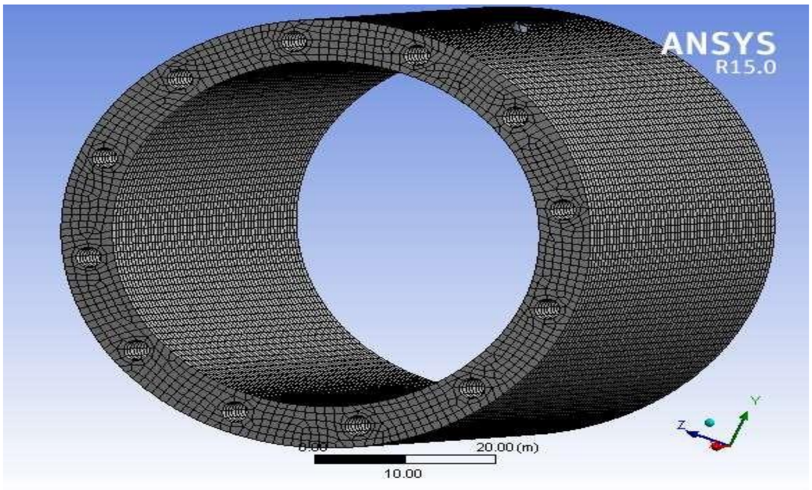

Fig. 9 Mesh of CFB boiler tube with circular shaped perforations

The above figures 7, 8 and 9 shows the meshing of three dimensional model CFB boiler tube for validation, square shape and circulating shape respectively.

Boundary Condition

Given the periodic structure of the CFB boiler tube, the two thermal parameter is investigated. Thermal domain employed. The material of the CFB boiler tube is 15crmo. The circumference of inside tube is heated at a constant heat transfer rate of 873K that is the and at different profiles of CFB boiler tube i.e. tube with square, circular, elliptical perforations. The temperature is assumed to be constant Radiation effect is ignored.

Governing Equation

The governing equations in the form of continuity, momentum and energy are shown below [11, 12]. The continuity equation is written as

$$\frac{\partial(\rho u_j)}{\partial x_i} = 0 \quad (1)$$

The momentum equation is written as

$$\frac{\partial(\rho u_i u_j)}{\partial(x_j)} = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right) - \frac{\partial(\overline{\tau_{ij}})}{\partial x_j} \quad (2)$$

The energy equation is represented as

$$\frac{\partial}{\partial x_i}(u_j(\rho e + p)) = \frac{\partial}{\partial x_j}\left(\lambda \frac{\partial T}{\partial x_j}\right) \quad (3)$$

where p is pressure, ρ is the fluid density, T is fluid temperature, λ is thermal conductivity and μ is fluid viscosity respectively. The Re-Normalisation Group (RNG) version of k-ε model is used in this numerical study. The Turbulent kinetic energy k is

$$\frac{\partial}{\partial x_j}(\rho k u_j) = \frac{\partial}{\partial x_j}\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\lambda \frac{\partial k}{\partial x_j}\right) + G_k - \rho\varepsilon \qquad (4)$$

IV. RESULT AND DISCUSSION

The three-dimensional models of different CFB boiler tube are developed to investigate thermal performance in the (perforation in tube) CFB boiler tube for temperature distributions. A series of numerical calculations have been conducted using steady state thermal domain and the results are presented in order to show the effects of temperature distribution and heat transfer coefficients CFB boiler tube profiles.

The validation of the results is done by carrying out the simulations work on the CFB boiler tube using ANSYS on steady state thermal domain 15.0 Workbench. This work has been validated by Yuge Yao et al. [10]. To determine the validation graphs and data evaluated using formulas for convergence between temperature and heat transfer coefficients with respect to constant temperatures.

Simulation Results for Different Configurations of CFB boiler tube Models

The Existing simulation results are obtained for temperature distribution and heat transfer coefficients, constant temperature ranging from 673K to 873K. The results are in graphs show less than 15% deviations between existing simulation results. But the deviations are not so large, and thus the existing simulation results of different configurations of different CFB boiler tube models in the research work can be regarded as considerable.

Validation of existing simulation results for different configuration of CFB boiler tube model with Yuge Yao et al. geometry shown in the figure 10 and 11 below, in which figure 10 shows that the temperature distribution of CFB boiler tube with fin (validation model) and also the heat temperature co-efficient shown in the figure 11.

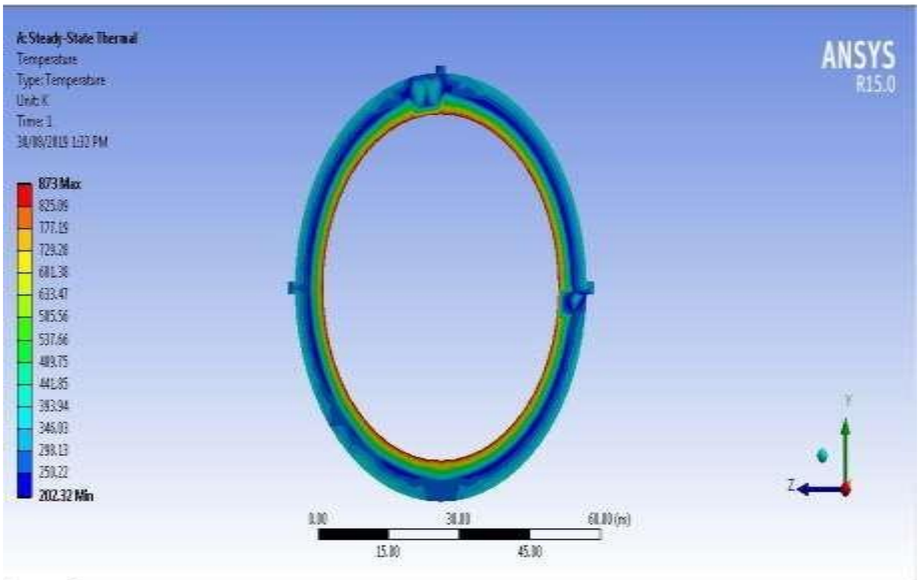

Fig. 10 Temperature distribution of CFB boiler tube with fin (Validation model)

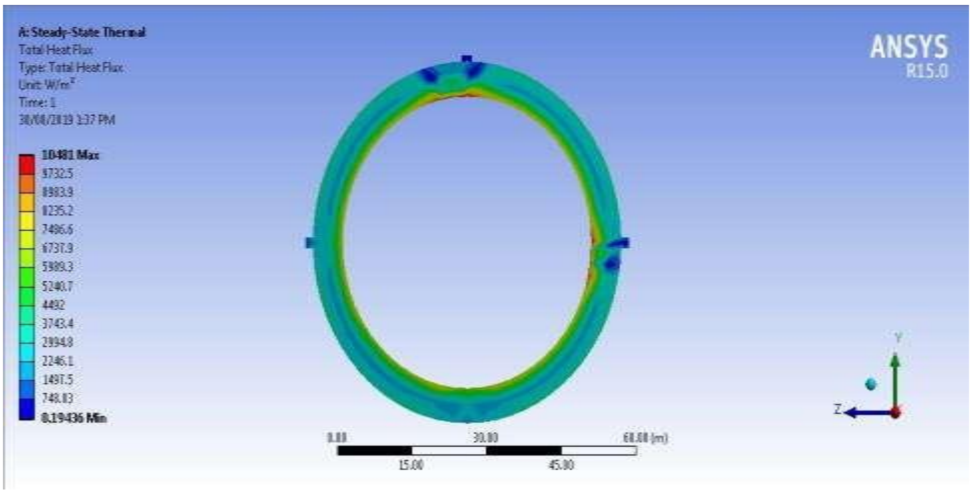

Fig. 11 Heat Transfer Coefficient of CFB boiler tube with fin (Validation model)

Table 2 Temperature distribution and heat transfer coefficient in CFB boiler tube with fin (Validation model)

Validation			
Heat Flux	Tf=673K	Tf= 773	Tf=873
1000	4.4	3.5	2.4
1500	3.3	2.6	1.9
2000	2.7	2.1	1.5
2500	2.2	1.7	1.2
3500	1.9	1.3	0.9

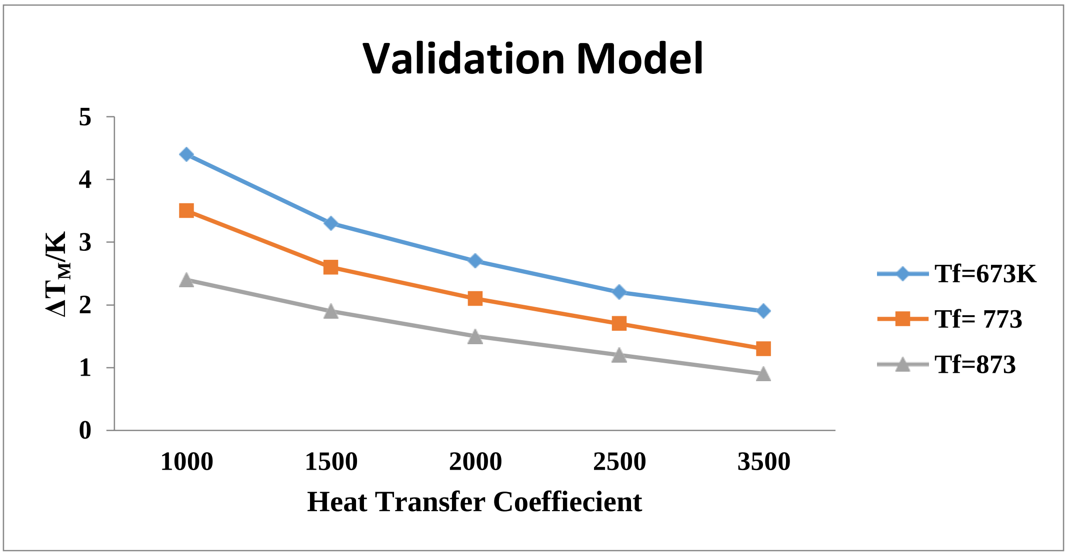

Fig. 13 Temperature distribution and heat transfer coefficient in CFB boiler tube with fin (Validation model)

The table 2 shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (validation model) at value of Tf = (673K), Tf = (773K), and Tf = (873K). The figure 13 shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (validation model) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and concluded The difference in temperature constant heating power 873K, thermal resistance decreases and by these effects of heat transfer coefficient increases.

Table 3 Temperature distribution and thermal conductivities in CFB boiler tube with fin (Validation model)

Validation			
Thermal Conductivities	Tf=673K	Tf= 773	Tf=873
24.33	3.6	2.9	1.9
23.38	2.5	2.1	1.2
22.34	1.9	1.3	0.9
21.48	1.4	0.9	0.6
20.4	1.1	0.6	0.4

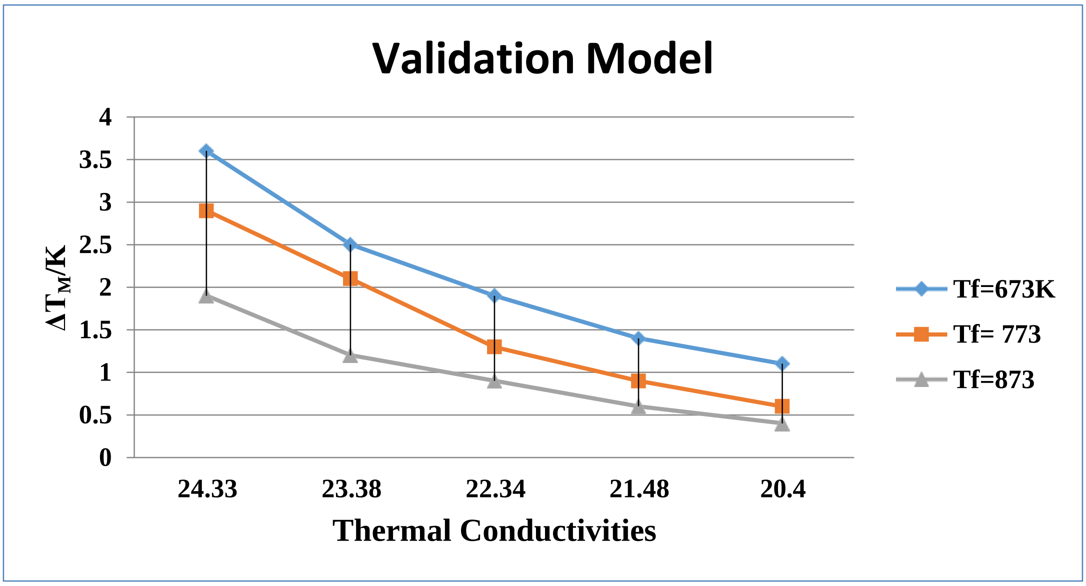

Fig. 14: Temperature distribution and thermal conductivities in CFB boiler tube with fin (Validation model)

The table 3 shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (validation model) at value of Tf = (673K), Tf = (773K), and Tf = (873K). As above depicted figure 14 graph shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (validation model) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and perforation in circumference of tube of deposited material the effect of thermal conductivity at 673K of constant temperature enhances maximum temperature distribution in tube wall.

Temperature Distribution with Heat Transfer Coefficient of CFB boiler tube with Square Perforations

The square shaped perforation of CFB boiler tube models are simulated and optimization results of temperature distribution, heat transfer coefficient at constant operating temperatures are presented in figure 15 and 16 below.

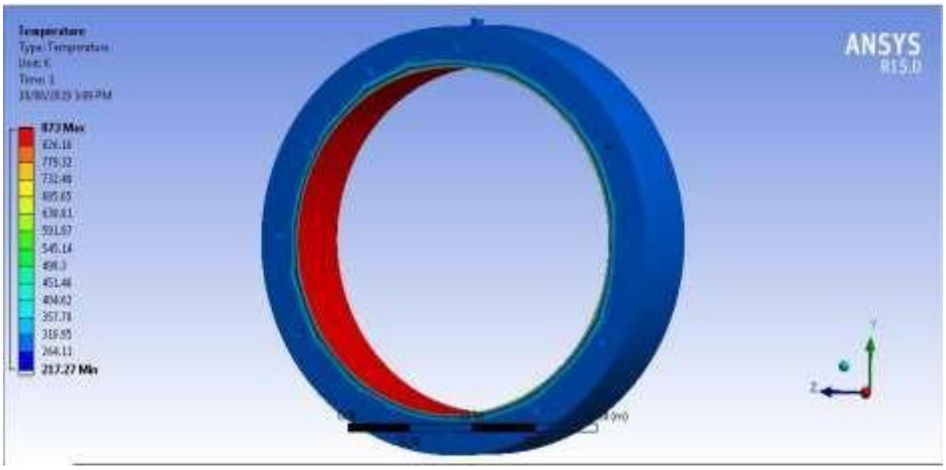

Fig. 15 Temperature distribution in CFB boiler tube with square shaped perforations

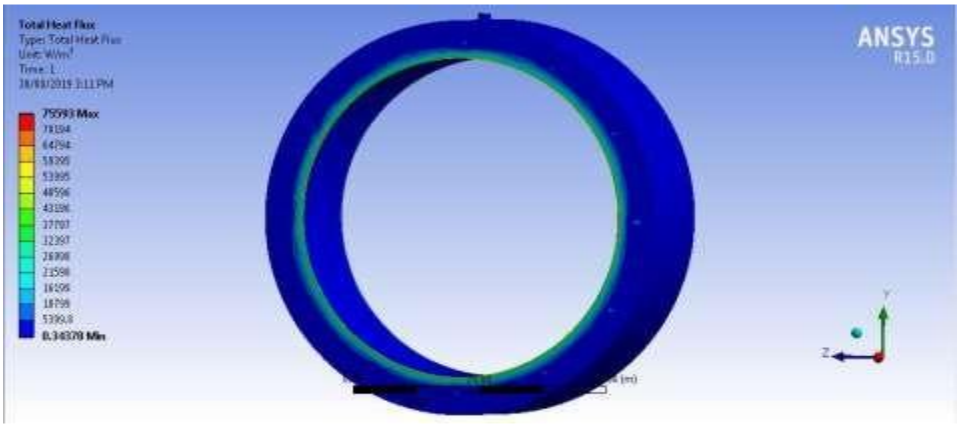

Fig. 16 Heat flux distribution CFB boiler tube with square shaped perforations

Table 4 Temperature distribution and heat transfer coefficients in CFB boiler tube with square shaped perforations

Square Perforation			
Heat Flux	Tf=673K	Tf= 773	Tf=873
500	4.2	3.3	2.2
1580	3.1	2.4	1.7
3044	2.5	1.9	1.3
4568	1.9	1.5	1
5399	1.6	1.2	0.7

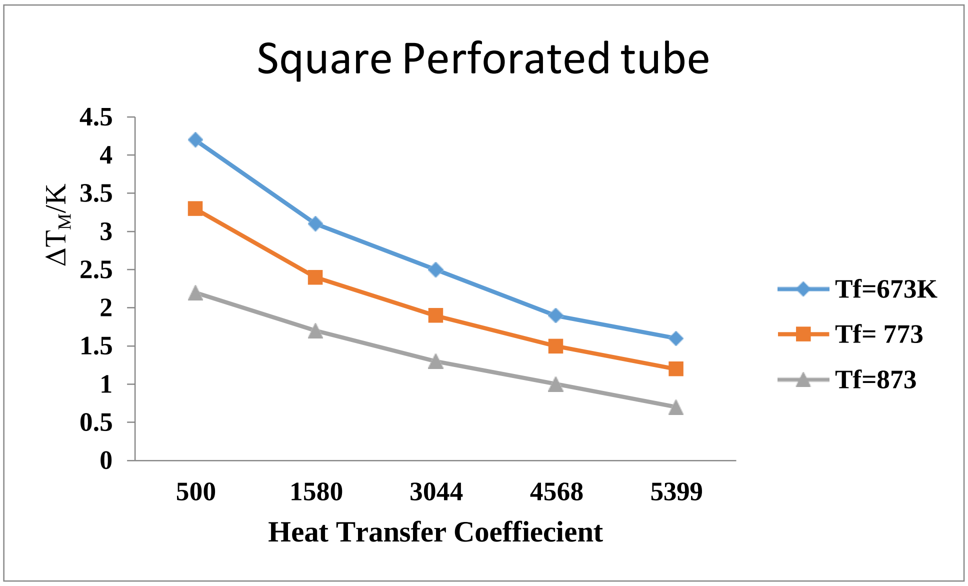

Fig. 17 Temperature distribution and heat transfer coefficients in CFB boiler tube with square shaped perforations

The table 4 shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (Square perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K). The figure 17 graph shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (Square perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and concluded The difference in temperature constant heating power 873K, thermal resistance decreases and by these effects of heat transfer coefficient increases.

Table 5 Temperature distribution and thermal conductivities in CFB boiler tube with square shaped perforations

Square Perforation			
Thermal Conductivities	Tf=673K	Tf= 773	Tf=873
24.33	3.9	3.1	2.1
23.38	2.8	2.2	1.5
22.34	2.3	1.6	1.1
21.48	1.7	1.3	0.8
20.4	1.4	0.9	0.6

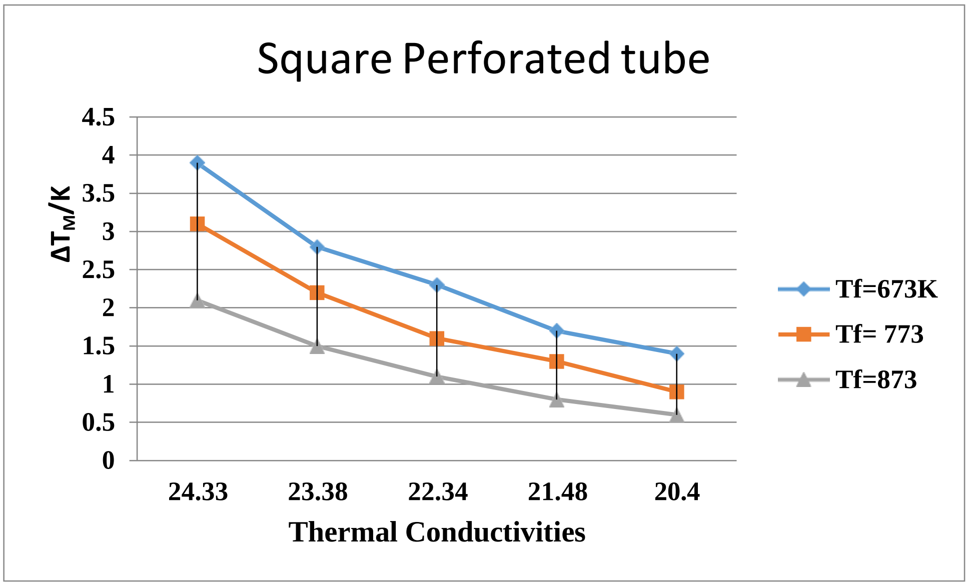

Fig. 18 Temperature distribution and thermal conductivities in CFB boiler tube with square shaped perforations

The 5 shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (Square perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K). The figure 18 graph shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (Square perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and perforation in circumference of tube of deposited material the effect of thermal conductivity at 673K of constant temperature enhances maximum temperature distribution in tube wall.

Temperature Distribution with Heat Transfer Coefficient of CFB boiler tube with Circular Perforations

The circular shaped perforation of CFB boiler tube models are simulated and optimization results of temperature distribution, heat transfer coefficient at constant operating temperatures are presented in figure 19 and 20 below.

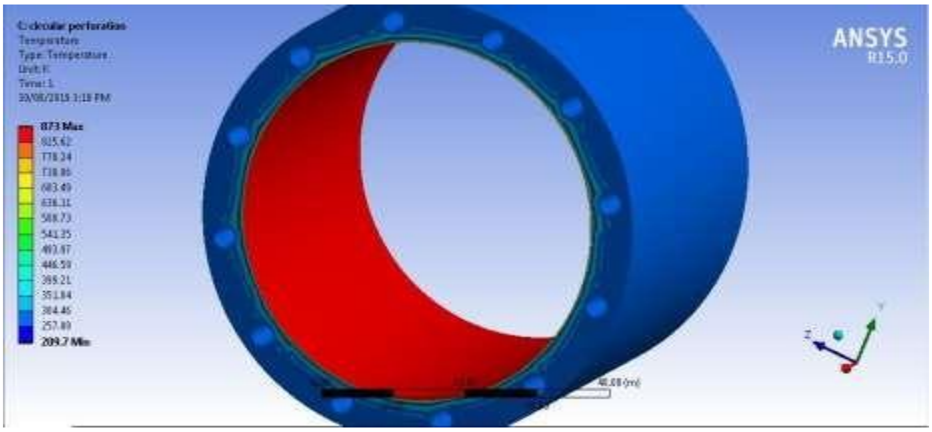

Fig. 19 Temperature distributions in CFB boiler tube with circular shaped perforations

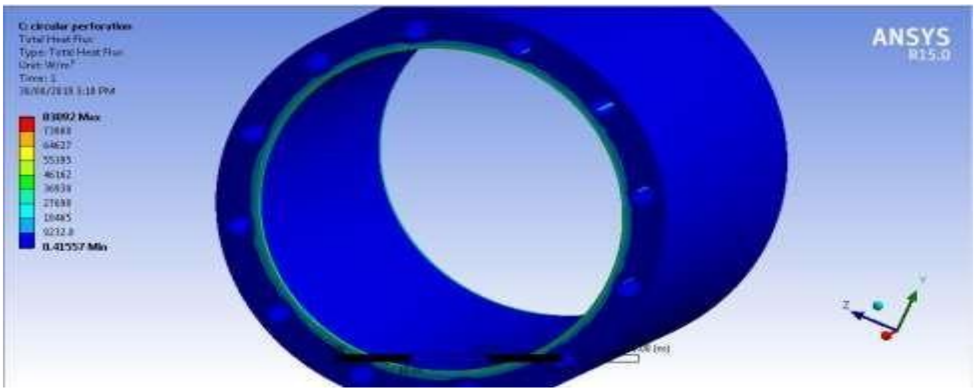

Fig. 20 Heat flux distribution CFB boiler tube with circular shaped perforations

Table 6 Temperature distribution and heat transfer coefficients in CFB boiler tube with circular shaped perforations

Circular Perforation			
Heat Flux	**Tf=673K**	**Tf= 773**	**Tf=873**
500	3.9	3.1	2.1
2578.9	2.8	2.2	1.5
5241.7	2.3	1.6	1.1
7825.3	1.7	1.3	0.8
9232.8	1.4	0.9	0.6

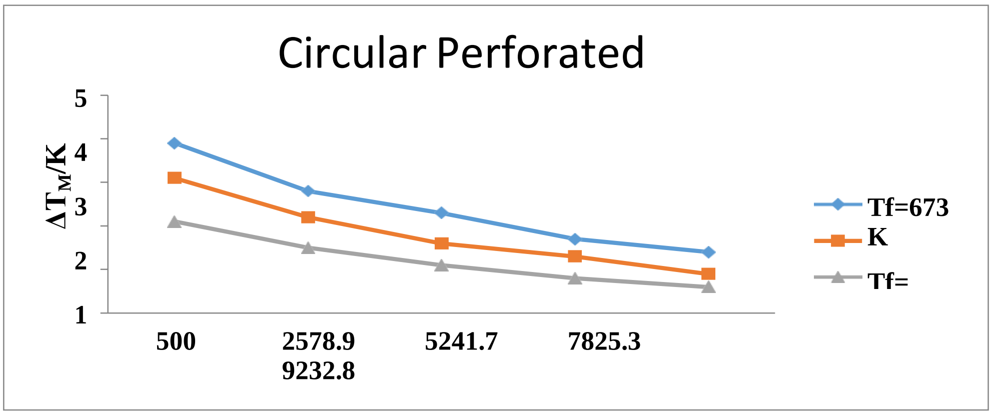

Fig. 21 Temperature distribution and heat transfer coefficients in CFB boiler tube with circular shaped perforations

The table 6 shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (circular perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K). The figure 21 graph shows that temperature distribution and heat co-efficient value in CFB boiler tube with fin (circular perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and concluded The difference in temperature constant heating power 873K, thermal resistance decreases and by these effects of heat transfer coefficient increases.

Table 7 Temperature distribution and thermal conductivities in CFB boiler tube with circular shaped perforations

Circular Perforation			
Thermal Conductivities	Tf=673K	Tf= 773	Tf=873
24.33	4.2	3.3	2.2
23.38	3.1	2.4	1.7
22.34	2.5	1.9	1.3
21.48	1.9	1.5	1
20.4	1.6	1.2	0.7

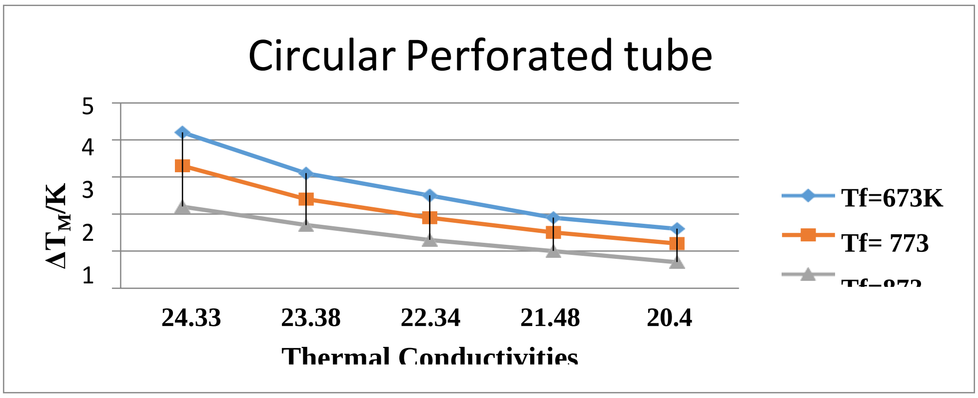

Fig. 22 Temperature distribution and thermal conductivities in CFB boiler tube with circular shaped perforations

The table 7 shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (circular perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K). The figure 22 graph shows that temperature distribution and thermal conductivity value in CFB boiler tube with fin (circular perforated tube) at value of Tf = (673K), Tf = (773K), and Tf = (873K) and perforation in circumference of tube of deposited material the effect of thermal conductivity at 673K of constant temperature enhances maximum temperature distribution in tube wall.

V. CONCLUSION

In this research, detailed analysis of the influences of temperature distribution, heat transfer coefficient and thermal conductivity of CFB boiler tube with different profiles has been conducted by simulations using the ANSYS software on steady state thermal domain 15.0. Work bench. The following conclusions are withdrawn:

- The temperature distribution is the fundamental parameter in the performance of CFB boiler tube different optimized profile of tubes. The tube surface area is varied due effect of perforations of different profile the thermal resistance effect is observed to decrease significantly.
- In the study, CFB boiler tube i.e. tube with square, circular, elliptical perforations are the key geometric parameter on the performance of CFB boiler tube. With an implementation of elliptical perforation in circumference of tube of deposited material the effect of thermal conductivity at 673K of constant temperature enhances maximum temperature distribution in tube wall.
- The proposed types of CFB boiler tube represented on results show that perforation increases surface area, and decreases the thermal barriers due to it can recognize that elliptical shaped perforation is the best configuration.
- The simulations of CFD models of CFB boiler tube with different configurations show a good relation with base paper results presented in the literature.

V. ACKNOWLEDGMENT

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