Design And Analysis Of Fire Tube Boiler With Heat Flow Analysis

S. Gopalakrishnan, M. Makesh

Abstract: Boilers are used to generate steam that provides heat or power. Water is converted to steam in the boiler. This steam travels through the heating apparatus which any piece of equipment that requires steam for operation. In fire tube boilers, the combustion gases travel within the tubes to heat the surrounding water. In water tube boilers, on the other hand, the water travels inside the tubes and the heat on the outside. The objective of this project work is to improve the heat transfer rate of Fire tube boiler using various materials. The following materials are considered for designing fire tube of boiler such as Copper, Aluminium, Chromium. The model of fire tube boiler is modeled through CREO software. The Three different models are create with same shape and size but different such as copper, aluminum and chromium. The models made up of different material are numerically analyzed for its various thermal behaviors through the analyzing software ANSYS from analysis we obtained different temperature and heat flux for all three materials respectively. The three analysis shows copper performance is more effective than aluminum and chromium.

Key words: Boiler heat flow analysis, Fire tube Boiler.

I. INTRODUCTION

The purpose of boiler is to convert water into steam. The steam can be used for various usages such as driving an engine to generate electricity, heating purpose and for other industrial process applications. The boiler consists of several types, which include water tube boiler, fire tube boiler, packaged boiler, fluidized bed combustion (FBC) boiler, atmospheric fluidized bed combustion (AFBC) boiler and so forth. The most popular boilers that used in many industries are water tube and fire tube boiler. Water tube boiler is the one with water flowing through the tubes that enclosed in a furnace heated externally while fire tube boiler comprises of fire or hot flue gas directed through tubes surrounded by water. Heat recovery steam generator (HRSG) is a good example of system in power plant that utilizes the boiler tube, typically a water tube boiler. In a combined cycle gas turbine power plant, there are three major systems incorporated together, which are gas turbine, steam turbine and HRSG. According to Ganapathy (2003), the combined cycle plant incurs lower capital costs than the other power plants such as conventional fossil power plants, and it is the most efficient electric generating system available today. The function of HRSG is to recover heat from the exhaust gas discharged from the gas turbine and makes use of the heat energy to produce steam. The steam produced will flow through steam turbine to generate electricity. A fire-tube boiler is a type of boiler in which hot gases pass from a fire through one or (many) more tubes running through a sealed container of water. The heat of the gases is transferred through the walls of the tubes by thermal conduction, heating the water and ultimately creating steam. The fire-tube boiler developed as the third of the four major historical types of boilers: low-pressure tank or "haystack" boilers, fluid boilers with one or two large flues, fire-tube boilers with many small tubes, and high-pressure water-tube boilers. Their advantage over fluid boilers with a single large flue is that the many small tubes offer far greater heating surface area for the same overall boiler volume. The general construction is as a tank of water penetrated by tubes that carry the hot flue gases from the fire.

II. LITERATURE REVIEW

The Unit 10 stoker boiler at the University of Iowa (UI) power plant uses moving grate on to which pulverized coal is thrown. The modeling of the combustion ofthe coal on this moving grate is very complex and effort has been made in the past to come up with simplified models for use in CFD. The most common are fixed-bed models, utilizing either transient combustion calculations or approximate reaction equations in order to determine the boundary conditions at the grate resulting from the combustion of the solid fuel on the bed. Due to the popularity of fixed-bed modeling, there are multiple approaches for it found in the literature: one-dimensional in space, onedimensionalin time, two-dimensional in space, and models that combine spatial and transient analyses. Fully three-dimensional models can be developed and solved using methods such as Direct Numerical Simulation, but these are very computationally expensive. The simplest model for fixed bed modeling is a one-dimensional model of the heat release and concentration profiles over the grate length. Goerner and Klasen used this approach to approximate the temperature profile over the grate by integrating theheat generation profile over the grate, which was determined with mathematicalsubmodels created by the Institutes of Environmental Process Engineering and PlantDesign, and by solving basic equations for the relation between temperature and sensibleand latent heat release. They also determined concentration profiles for the species involved in the combustion by using simple balanced reaction equations. In validating their results, the researchers found that while the trends of the measured temperatures and the modeled ones were fairly similar, there was significant error in the magnitude of the temperatures. According to the authors, this error most likely resulted from the simplified reaction equations, which did not include non-stationary process conditions (Goerner2006). A one-dimensional transient model for a fixed bed was developed by Zhou et al.in order to perform numerical simulations of straw combustion (Zhou 2005). The modelis transient only for the reaction calculations for the solid phase combustion, so it was notable to be used to approximate a moving grate. Since it utilized transient combustion, thesolid phase and gas phase reactions were coupled into a four step process: evaporation ofmoisture, volatile release/char formation, burning of the volatiles, and the oxidation ofthe char particles. According to the researchers in the paper's conclusion, results from thesimulation of the numerical model were reasonably consistent with the experimental dataobtained. A two-dimensional mathematical model was developed by van der Lans et al. topredict straw combustion on a moving bed (van der Lans 2000). The model included thehorizontal position of the straw along the grate as well as the vertical position, so it couldbe used to roughly approximate a moving grate using steady state calculations instead ofneeding to solve complex partial differential equations with transient terms. Theresearchers assumed that the O2 from the air only reacted with the carbon left on the grateafter devolatilization of the straw, thereby decoupling the solid phase and gas phasereactions. This is a large simplification, but the bed temperature results from theirsimulations matched up fairly well to their experimental data. Wei et al. also utilized a two dimensional approach in simulating a biomass wasteboiler with an inclined moving grate and a coal boiler with a horizontal moving grate(Wei 2001). For both cases, the researchers reduced the complexity of the bedcombustion by splitting the grate up into well-defined zones and decoupling the gasphase reaction from the solid phase reaction occurring on the bed. The boundaryconditions at the grate bed were then determined using the mass and energy balances ofthe solid fuel combustion. Defining zones on the grate in this way makes it possible tosimulate the moving grate by assuming steady state and a fixed bed, giving a fuel distribution along the bed horizontally and vertically. Another transient combustion model was developed by Ford et al. The researchersdiscretized the fuel bed into a series of boxes, not unlike the zoning carried out by Wei etal. Coal enters as uniform size spherical lumps stacked atop one another. As the fuelmoves along the grate, the size of the box containing the coal may decrease depending onhow much of the coal was burned during the 1-minute long reactions inside each boxalong the grate (Ford 1993). In this model, like most of the other ones, the solidcombustion is separate from the volatile combustion above the grate. However, thetransient nature of the model makes for a good approximation of the moving grate in areal boiler, and the results of the simulation for the fuel bed temperature along the grateand the amount of carbon released from the coal are consistent with measured data. Kaer et al. used Lagrangian tracking and the one-dimensional heat conductionmodel in their simulation of a biomass fuel bed (Kaer 2005).

III.GENERAL PART MODELLING

Many technical designs consist of complex assemblies made from angular shaped parts. This type of design work can be made easier by part and assembly modeling capabilities that are well integrated. The CREO is a 3-D parametric solid modeler with both part and assembly modeling capabilities. You can see the CREO to model piece parts and then combine them into more complex assemblies. With CREO a part is designed by sketching its components shapes and defining their size shape and inters relationships. By successfully creating these features you construct the part in a building block fashion. Since CREO has parametric features, you can change one feature and all related features are automatically updated to reflect the change and its effects throughout the part. It can be used to create angular shaped part, to which 3D surface can be applied to create hybrid parts consisting of mixture of angular and curved shapes. This provides the ability to create model designs with shapes of varying types.

IV .METHODOLOGY

The objective of this project work is to improve the heat transfer rate of Fire tube boiler using various materials. The following materials are considered for designing fire tube of boiler.

Materials: CASE 1 – Copper
CASE 2 - Aluminium
CASE 3 - Chromium

The following software are used for modeling and analysis
CREO for Modeling
ANSYS for Thermal analysis
The following parameters are determined for three cases of materials
Temperature and Heat flux

A.BOILER MODELING

In boiler modeling the following tools are used.
Extrude, Revolve, Pattern

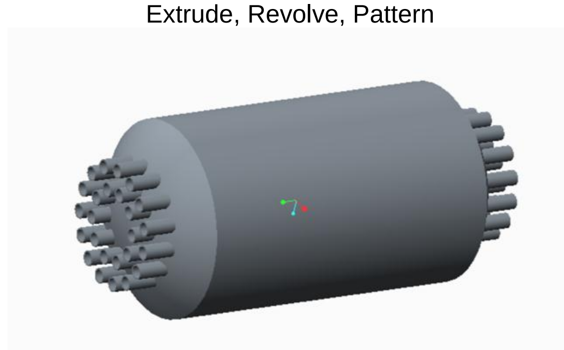

Figure 1*.3D modeling of boiler*

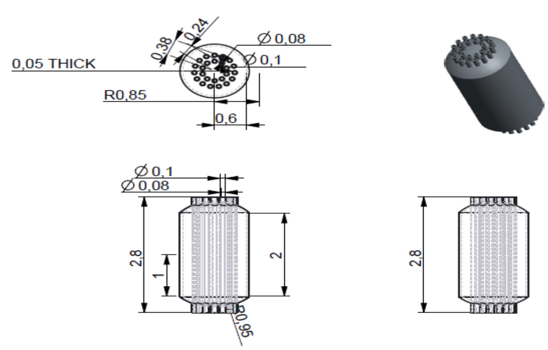

Figure 2. *Boiler dimension*

B.THERMAL ANALYSIS

The thermal analysis is performed in ANSYS software for three cases of materials such as Copper, Aluminium and Chromium.

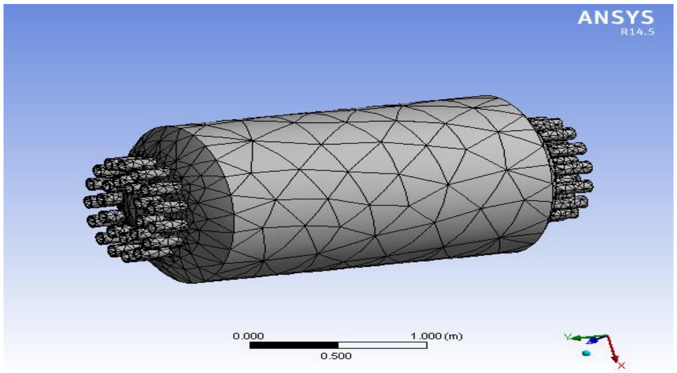

Figure 3.*The meshing of boiler geometry*

The following boundary conditions are given in the thermal analysis.
Temperature of Flue = 150oC
Convective heat transfer Coefficient = 22 W/m2oC
Surface Temperature = 30oC

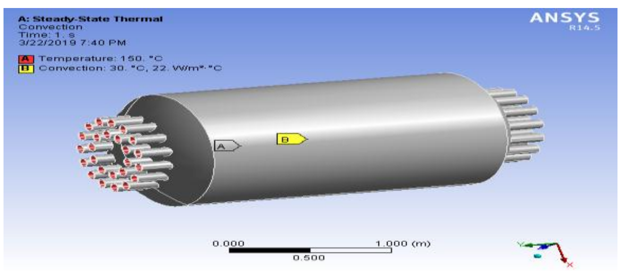

Figure 4.*Steady-state thermal analysis in copper.*

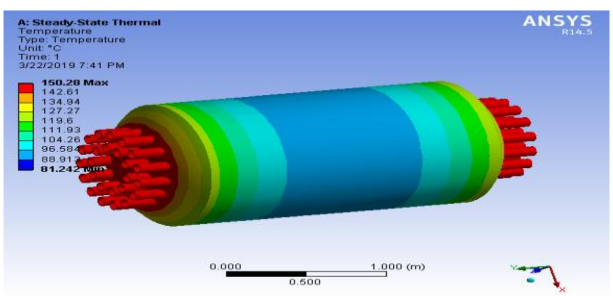

Figure 5.*Steady-state thermal analysis in aluminium.*

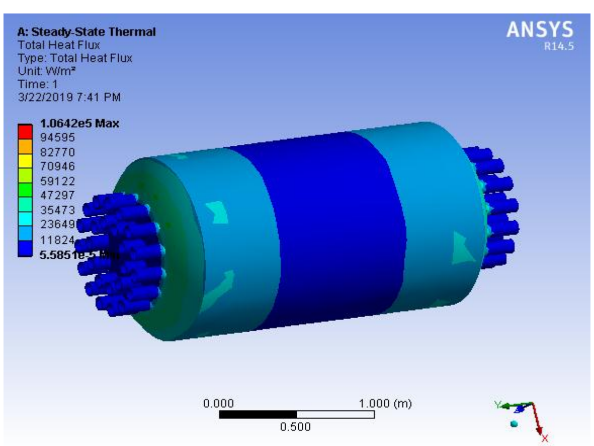

Figure 5.*Steady-state thermal analysis in chromium.*

VI. CONCLUSION

The modeling of Fire tube boiler is performed using CREO software and analysis is done using ANSYS software. Three materials are considered for fire tube of boiler such as Copper, Aluminium and Chromium. The boundary conditions are applied and the temperature and heat flux are determined for three cases.

CASE 1 COPPER	Temperature	Total Heat Flux
Minimum	81.242 °C	5.5851e-005 W/m²
Maximum	150.28 °C	1.0642e+005 W/m²
CASE 2 ALUMINIUM	Temperature	Total Heat Flux
Minimum	63.807 °C	4.0033e-005 W/m²
Maximum	150.36 °C	86771 W/m²
CASE 3 CHROMIUM	Temperature	Total Heat Flux
Minimum	41.325 °C	2.4693e-005 W/m²
Maximum	150.45 °C	54756 W/m²

Copper material has high heat flux as compared to other materials and Aluminium is next to copper and Chromium is next to Aluminium materials. The minium temperature is available is Chromium material fire tube.

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