DESIGN AND ANALYSIS OF STEAM BOILER USED IN POWERPLANTS

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Abstract *Steam boiler is a closed vessel in which water or other fluid is heated under pressure and the steam released out by the boiler is used for various heating applications. The main considerations in the design of a boiler for a particular application are Thermal design and analysis, Design for manufacture, physical size and cost.*

In this thesis the steam flow in steam boiler is modeled using CATIA parametric design software. The thesis will focus on thermal and CFD analysis with different inlet velocities (10, 25, 35& 45m/s).

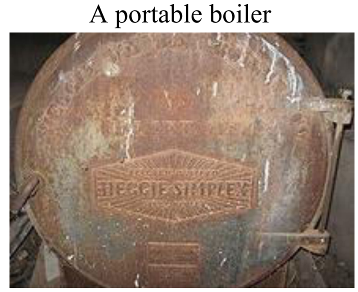
In this thesis the CFD analysis to determine the heat transfer coefficient, heat transfer rate, mass flow rate, pressure drop. Thermal analysis to determine the temperature distribution, heat flux for models steam boiler with different materials such as EN 31 steel, stainless steel 316L and copper.

3D modeled in parametric software CATIA and analysis done in ANSYS.

I. INTRODUCTION

A boiler is a closed vessel in which fluid (generally water) is heated. The fluid does not necessarily boil. (In North America, the term "furnace" is normally used if the purpose is not to boil the fluid.[citation needed]) The heated or vaporized fluid exits the boiler for use in various processes or heating applications, including water heating, central heating, boiler-based power generation, cooking, and sanitation.

A portable boiler



A stationary boiler

In a fossil fuel power plant using a steam cycle for power generation, the primary heat source will be combustion of coal, oil, or natural gas. In some cases byproduct fuel such as the carbon-monoxide rich off gasses of a coke battery can be burned to heat a boiler; bio fuels such as bagasse, where economically available, can also be used. In a nuclear power plant, boilers called steam generators are heated by the heat produced by nuclear fission. Where a large volume of hot gas is available from some process, a heat recovery steam generator or recovery boiler can use the heat to produce steam, with little or no extra fuel consumed; such a configuration is common in a combined cycle power plant where a gas turbine and a steam boiler are used.

II. LITERATURE REVIEWS

Shuhas R Bamrotwar, 2014 This paper illustrates cause & effect analysis of boiler tube failures. The data pertaining to boiler tube failures for one of Thermal Power Plant in Maharashtra State of last ten years was referred. Out of total 144 failures, 43 failures were observed in economizer zone. Economizer is the main part of the boiler in the furnace second pass. It is the medium for transportation of the feed water to boiler drum.

Madhav et al..,2013: Steam generators are widely used in industries for several purposes like power production, processing, heating etc. In industry steam generators are the major fuel consumers. In a normal steam generator about 4% of hot water is wasted as blow down.

Song et., Biomass has attracted more and more attention in the world as renewable energy. Biomass direct-fired technology is a relatively mature technology with wide application in China. Due to the high content of alkali metals and chlorine in the biomass fuel, biomass direct-fired power plant suffers from ash-deposition and corrosion problems of low-temperature heating surface in boiler, accordingly affecting the security and economy of boiler.

Kumar and Rao, 2013 The results from the energy audit of KOTHAGUDEM Thermal power station, Andhra Pradesh has been presented in this paper. The scope of any energy audit in a thermal power plant should include the study of the coal flow, air and flue gas flow, excess air factors and oxygen in the flue gas; study of the heat transfer, effectiveness, proportioning of heat and pressure drop in the heat-exchangers of the water-steam circuit; study of the auxiliary power consumption; the overall performance evaluation such as the gross and the net overall efficiencies, boiler efficiency, boiler feed pump efficiency, air compressor efficiency, evaporation losses and blow down losses of cooling tower etc. Results from such a study at a 500 MW power plant were presented in this report.

Lv Tai lst,,2012: The heat of waste gas emitted to the atmosphere can be recovered to increase efficiency of boiler. For power plant boiler, if the exhaust gas temperature decreases by 15~20℃, the boiler thermal efficiency increases about 1%. In this study a waste heat exchanger was added, so that large amount of waste heat in waste gas was recycled.

III PROBLEM DESCRIPTION AND METHODOLOGY

The objective of this project is to make a 3D model of the steam boiler and study the CFD and thermal behavior of the steam boiler by performing the finite element analysis.3D modeling software (CATIA) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis.

The methodology followed in the project is as follows:

1. Create a 3D model of the steam Boiler assembly using parametric software CATIA.
2. Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
3. Perform thermal analysis on the steam Boiler assembly for thermal loads.
4. Perform CFD analysis on the existing model of the surface steam boiler for Velocity inlet to find out the mass flow rate, heat transfer rate, pressure drop.

IV MODELING AND ANALYSIS

CAD (Computer Aided Design) is the use of computer software to design and document a product's design process.

Engineering drawing entails the use of graphical symbols such as points, lines, curves, planes and shapes. Essentially, it gives detailed description about any component in a graphical form.

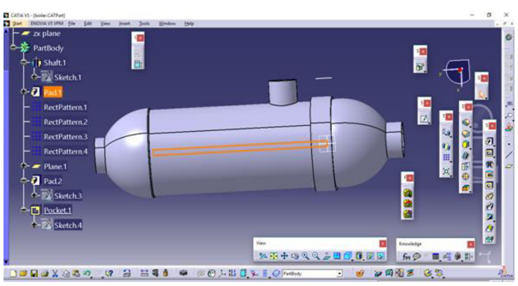
CAD is used to accomplish preliminary design and layouts, design details and calculations, creating 3-D models, creating and releasing drawings, as well as interfacing with analysis, marketing, manufacturing, and end-user personnel.

CATIA

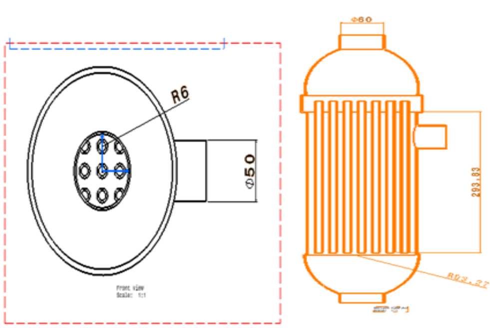
CATIA is an acronym for Computer Aided Three-dimensional Interactive Application. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products. CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative. Since Dassault Systemes did not have an expertise in marketing, they had revenue sharing tie-up with IBM which proved extremely fruitful to both the companies to market CATIA.

CFD analysis

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.



3D CATIA model for steam boiler

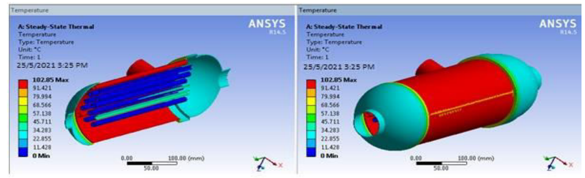


2D CATIA model for steam boiler

V RESULTS AND ANALYSIS

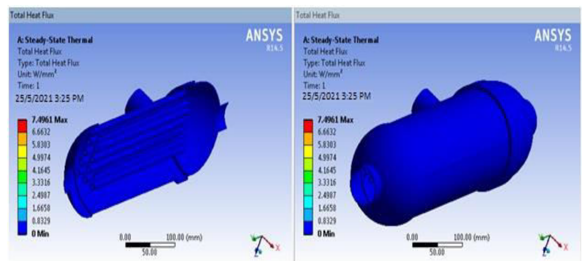
Case 1: Steel for boiler casing, copper for tubes

Temperature



According to the contour plot, the temperature distribution maximum temperature at tubes because the steam passing inside of the tube. So we are applying the temperature inside of the tube and applying the convection except inside the tubes. Then the maximum temperature at tubes and minimum temperature at steam boiler casing.

Heat flux

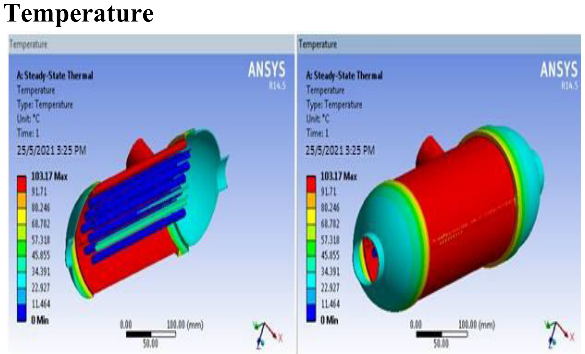


According to the contour plot, the maximum heat flux at inside the tubes because the steam passing inside of the tube. So we are applying the temperature inside of the tube and applying the convection except inside the tubes. Then the maximum heat flux at inside the tubes and minimum heat flux at steam boiler casing and outside of the tubes.

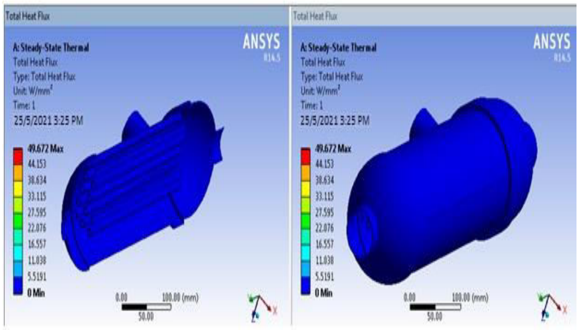
According to the above contour plot, the maximum heat flux is 7.496 w/mm^2 and minimum heat flux is 0.8329 w/mm^2.

Case 2: Copper for boiler casing, copper for tubes

Temperature

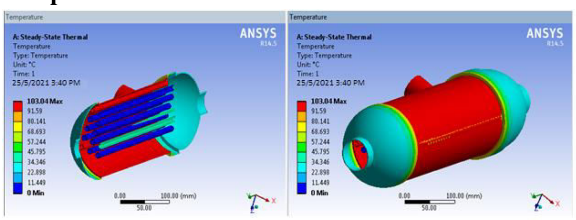


Heat flux

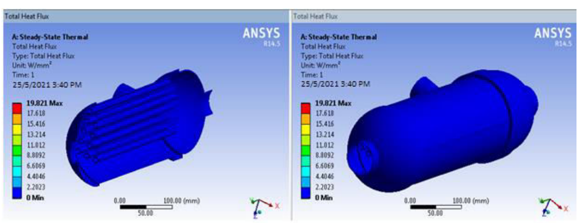


Case 3: Stainless steel 316l for boiler casing, copper for tubes

Temperature



Heat flux



RESULTS AND DISCUSSIONS

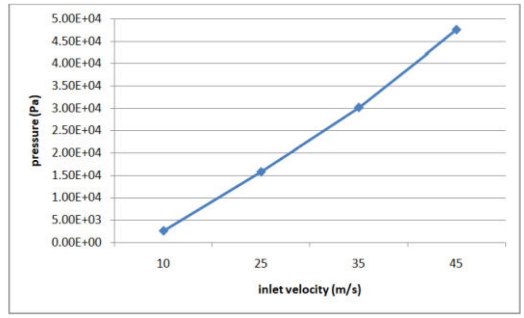
CFD analysis result

Velocity (m/s)	Pressure (Pa)	Velocity (m/s)	Mass flow rate (kg/s)	Heat transfer Rate(W)
10	2.60e+03	2.51e+01	0.04368	21681.532
25	1.58e+04	5.14e+01	0.11344	52773.632
35	3.02e+04	7.13e+01	0.15603	9596.454
45	4.76e+04	9.62e+01	0.19589	81304.165

Thermal analysis result

Materials	Temperature (°C)	Heat flux
Mild steel	102.85	7.4961
Stainless steel 316L	103.04	19.821
Copper	103.17	49.672

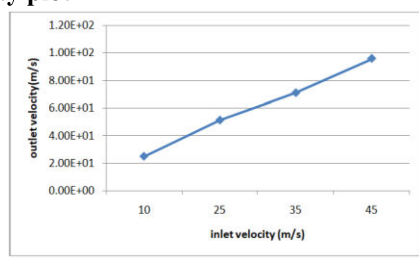
Maximum pressure



Variation of maximum pressure for various velocities

A plot between maximum pressure and velocities by FEA approach is shown in above fig. From the plot the variation of maximum static pressure is observed. Maximum static pressure increases with increases in velocities.

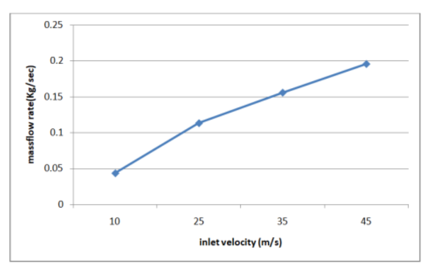
Velocity plot



Variation of maximum velocity for various velocities

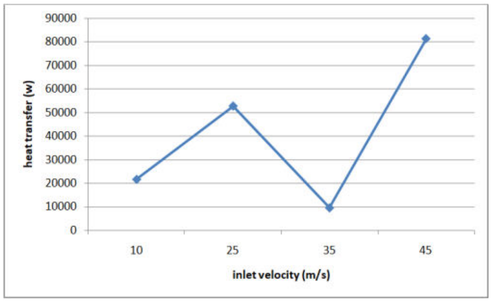
A plot between maximum velocity and velocities by FEA approach is shown in above fig. From the plot the variation of maximum static velocity is observed. Maximum velocity increases with increases in velocities.

Mass flow rate plot



A plot between maximum mass flow rate and velocities by FEA approach is shown in above fig. From the plot the variation of maximum mass flow rate is observed. Maximum mass flow rate increases with increases in velocities.

Heat transfer rate plot

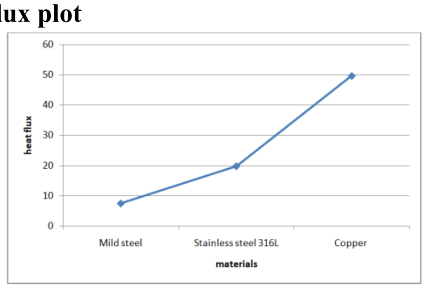


Variation of maximum heat transfer rate for various velocities

A plot between maximum heat transfer rate and velocities by FEA approach is shown in above fig. From the plot the variation of maximum heat transfer rate is observed. Maximum heat transfer rate increases with increases in velocities.

VI THERMAL ANALYSIS

Heat flux plot



Variation of maximum heat flux for various velocities

A plot between maximum heat flux and velocities by FEA approach is shown in above fig. From the plot the variation of maximum heat flux is observed. Maximum heat flux increases with increases in velocities. Heat flux value is decreases steel than stainless steel &copper.

VII CONCLUSIONS

1. In this thesis, the steam boiler is modeled using CATIA design software. The thesis will focus on thermal and CFD analysis with different velocities (10, 25, 35& 45m/s). Thermal analysis done for the steam boiler by steel, stainless steel& copper.
2. By observing the CFD analysis the pressure drop, velocity, heat transfer coefficient, mass flow rate & heat transfer rate increases by increasing the inlet velocities.
3. By observing the thermal analysis, the taken heat transfer coefficient values are from CFD analysis. Heat flux value is more for copper material than steel& stainless steel.
4. So we can conclude the brass material is better for steam boiler.

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