

Design and Thermal Analysis of Steam Boiler used in Powerplants

P. Harika¹, K. Madan Mohan¹, C. Sai Srjuan², J. Akhil Kumar², J. Pavan²

¹Assistant Professor, ²UG Student, ^{1,2}Department of Mechanical Engineering

^{1,2}Kommuri Pratap Reddy Institute of Technology, Ghatkesar, Hyderabad, Telangana

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. 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 paper, 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.

Keywords: CFD analysis, CATIA, ANSYS and velocities.

1. INTRODUCTION

A boiler is a closed vessel in which fluid (generally water) is heated. The liquid doesn't really bubble. (In North America, the expression "heater" is regularly utilized if the design isn't to heat up the liquid. The warmed or disintegrated liquid leaves the evaporator for use in different procedures or warming applications, including water warming, focal warming, heater based force age, cooking, and sanitation. Water-tube heater: In this sort, tubes loaded up with water are orchestrated inside a heater in various potential arrangements. Regularly the water tubes interface huge drums, the lower ones containing water and the upper ones steam and water; in different cases, for example, a mono-tube heater, water is coursed by a siphon through a progression of curls. This sort for the most part gives high steam creation rates, however less capacity limit than the abovementioned. Water tube boilers can be intended to misuse any warmth source and are commonly favored in high-pressure applications since the high-pressure water/steam is contained inside little breadth pipes which can withstand the weight with a more slender divider. These boilers are generally built set up, generally square fit as a fiddle, and can be various stories tall.

Steam Boiler

At the point when water is heated up the outcome is soaked steam, additionally alluded to as "wet steam." Saturated steam, while generally comprising of water fume, conveys some unelaborated water as beads. Soaked steam is helpful for some reasons, for example, cooking, warming and sanitation, yet isn't alluring when steam is relied upon to pass on vitality to apparatus, for example, a boat's impetus framework or the "movement" of a steam train. This is on the grounds that unavoidable temperature as well as weight misfortune that happens as steam ventures out from the heater to the hardware will cause some buildup, bringing about fluid water being conveyed into the apparatus. The water entrained in the steam may harm

turbine edges or on account of a responding steam motor, may cause genuine mechanical harm because of hydrostatic lock.

2. LITERATURE SURVEY

Structural and thermal analysis of a boiler using finite element Analysis [1] Steam boiler is a closed vessel in which water or other liquid is warmed under tension and the steam discharged out by the kettle is utilized for different warming applications. The primary contemplations in the structure of a kettle for a specific application are Thermal plan and investigation, Design for produce, physical size and cost. In the current work a fire tube kettle is dissected for static and Thermal stacking. The geometric model of kettle is made in CATIA V5 programming according to the drawing. This model is imported to HYPERMESH through IGES arrangement and FEA model with combined work is created utilizing shell components. To this FEA model different stacking conditions like plan pressure, warm loads and working conditions are applied. One of the supporting legs is captured in all the headings and the other one is captured uniquely in X, Z-bearings and all turns. All these are made by utilizing HYPERMESH and it is sent out to ANSYS for answer for acquire the redirections, stresses. Those qualities are associated with material reasonable qualities according to the ASME Section VIII Division. Analysis of New Boiler Technologies [2] The thermodynamics of fare cogeneration direct that higher HP steam conditions bring about greater power created, something which has driven the business to accomplish ever higher weights and temperatures without thinking about the financial aspects. Practically speaking, as conditions are expanded, the extra capital expense surpasses the extra power. The higher HP conditions have likewise determined a second pattern: to receive single drum boilers as opposed to proceeding to utilize bi-drum plans. While this is the correct methodology at high conditions, care should be taken in choosing the subtleties of the design. A Study Analysis and Performance of High Pressure Boilers with its Accessories [3] Power establishes the fundamental and basic contribution for quick financial improvement. Right now vitality place a crucial job both in modern improvement, which thusly prompts the thriving age offices created in AP to satisfy developing need for power. By utilizing adornments in the evaporator. The effectiveness of the plant increments. For instance the extras like Economizer expands the feed water temperature while super radiator builds the temperature of the steam created in the heater. The air pre radiator expands the delta air temperature, which goes into the heater. The fundamental goal of present undertaking work is to break down the proficiency of economizer, super heater& air pre warmer by changing the different parameters in evaporator section. Design and examination of the model of kettle for steam pressure control [4] to get high vitality productive force plant activity it is important to effectively control the steam pressure. Thus an exertion has been made right now control such a basic parameter for example steam pressure by building up a model of kettle pack utilizing PLC based PID controller which utilizes IMC strategy for tuning the parameters of the PID. Introduced work additionally incorporates the demonstrating of the procedure and reenactment has been finished with the fitting exchange work utilizing feed forward input control methodology. Further down to earth reactions and hypothetical reaction has been thought about. Likewise open circle approval has been done to approve the model model. Shuhas R Bamrotwar, [6], 2014 Boiler tube disappointment is the prime explanation of

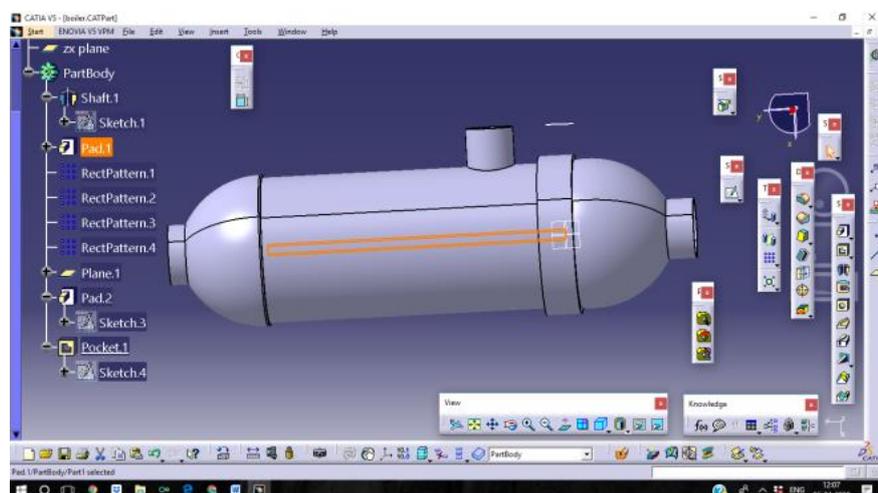
constrained blackouts at coal terminated warm force plants. With consistently expanding interest for power, it is exceptionally important for the force plants to create power without constrained blackouts. This paper delineates cause and impact examination of kettle tube disappointments. The information relating to heater tube disappointments for one of Thermal Power Plant in Maharashtra State of most recent ten years was alluded. Out of all out 144 disappointments, 43 disappointments were seen in economizer zone. Economizer is the fundamental piece of the heater in the heater second pass. It is the mechanism for transportation of the feed water to kettle drum. It assists with expanding the heater proficiency.

3. PROBLEM DESCRIPTION

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:
- Create a 3D model of the steam Boiler assembly using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform thermal analysis on the steam Boiler assembly for thermal loads.
- 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.

3D Model of steam boiler

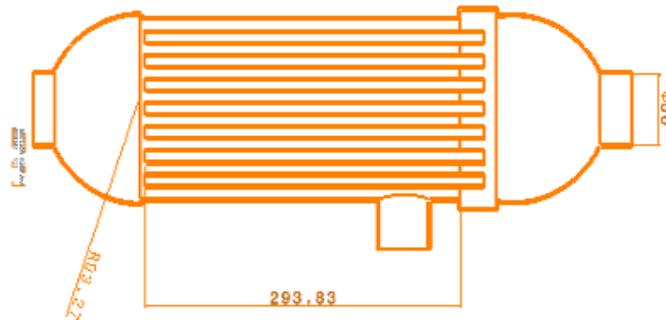


4. MODELING AND ANALYSIS

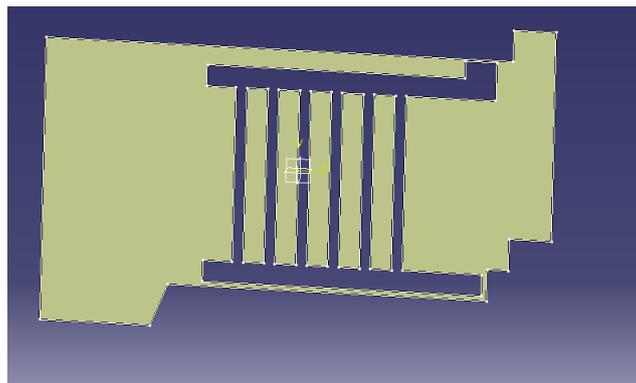
Computer-aided design (CAD) is the use of computer systems (or workstations) to help in the creation, alteration, investigation, or upgrade of a structure. PC supported structure writing computer programs is used to grow the productivity of the organizer, improve the idea of arrangement, improve correspondences through documentation, and to make a database for amassing. PC helped configuration yield is normally as electronic records for print,

machining, or other gathering assignments. The term CADD (for Computer Aided Design and Drafting) is moreover used. CATIA is a condensing for Computer Aided Three-dimensional Interactive Application. It is one of the fundamental 3D programming used by relationship in different organizations stretching out from flight, vehicle to purchaser things. CATIA is a multi organize 3D programming suite made by Systems, including CAD, CAM similarly as CAE. Dassault is a French structure mammoth dynamic in the field of flying, 3D structure, 3D progressed bogus ups, and thing lifecycle the officials (PLM) programming.

2D model of steam boiler



Surface model of boiler



FEM/FEA helps in evaluating complicated structures in a system during the planning stage. The strength and design of the model can be improved with the help of computers and FEA which justifies the cost of the analysis. FEA has prominently increased the design of the structures that were built many years ago.

CFD

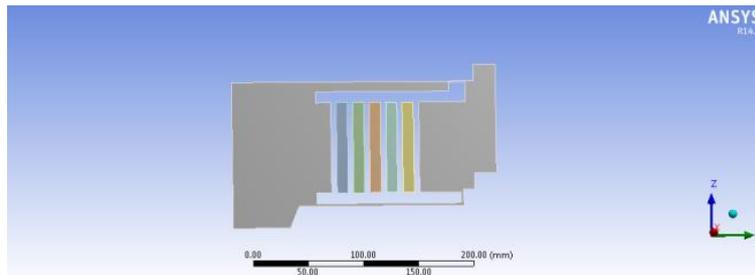
Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows.

CFD analysis of steam boiler

Geometry

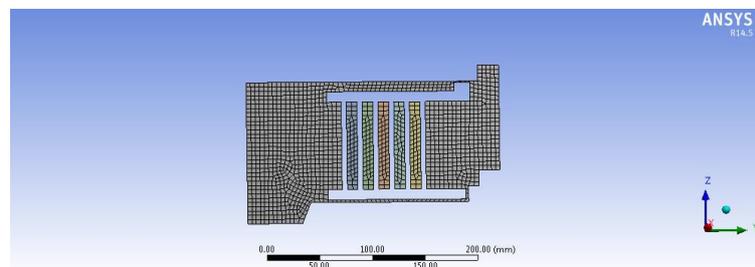
Steam boiler is built in the ANSYS workbench design module. It is a counter-flow Steam boiler. First, the fluid flow (fluent) module from the workbench is selected. The design modeler opens as a new window as the geometry is double clicked.

Imported model



Meshing

The model is designed with the help of CATIA and then import on ANSYS for Meshing and analysis. The analysis by CFD is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 6576 and 3344.



Steam boiler model after Meshing

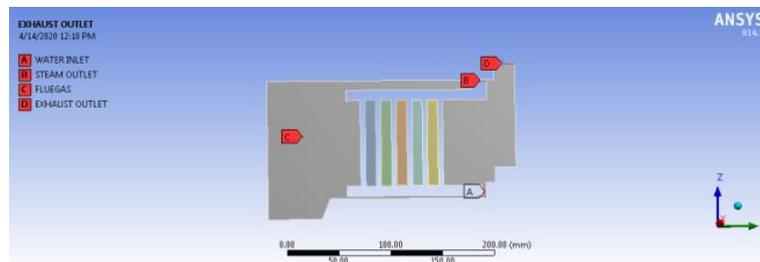
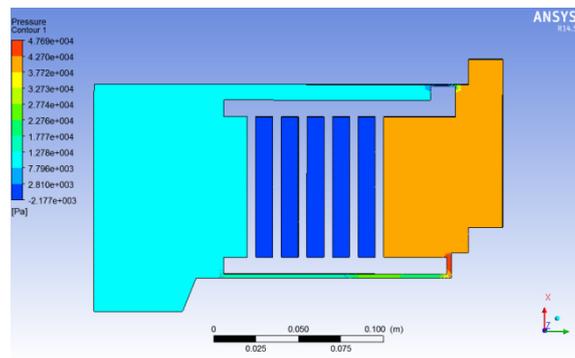


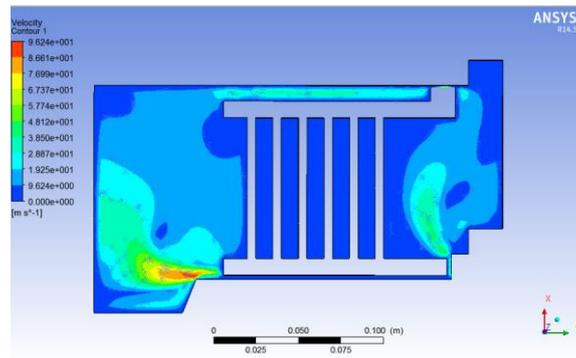
Fig: inlet and outlet conditions

Inlet velocity-45 m/s

Static Pressure



Velocity Magnitude



Mass flow rate

Mass Flow Rate	(kg/s)
interior-fluegas	23.602331
interior-split.2	0
steam_outlet	-0.47910237
wall-fluegas	0
wall-split.2	0
water_inlet	0.67500001
Net	0.19589764

Heat transfer rate

Total Heat Transfer Rate	(w)
steam_outlet	-143318.86
wall-fluegas	0
wall-split.2	-0.0010746096
water_inlet	224623.13
Net	81304.265

Thermal analysis of steam boiler

Used Materials steel, copper, brass & stainless steel

Copper material for tube

EN 31 Steel, brass & stainless steel 316L for boiler casing

Copper material properties

Thermal conductivity = 385w/m-k
 Specific heat = 0.385j/g⁰C
 Density = 0.00000776kg/mm³

Steel material properties

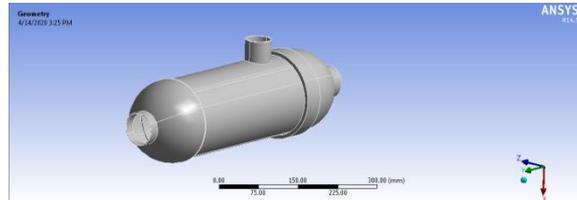
Thermal conductivity = 93.0w/m-k
 Specific heat = 0.669j/g⁰C
 Density = 0.0000075kg/mm³

Stainless Steel material properties

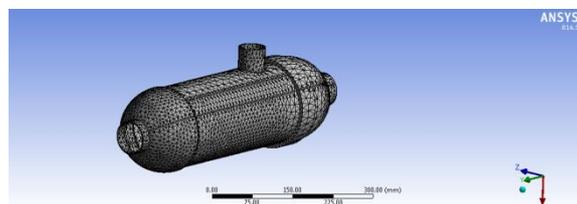
Thermal conductivity = 34.3w/m-k

Specific heat = 0.620j/g⁰C Density = 0.00000901kg/mm³

Imported Model

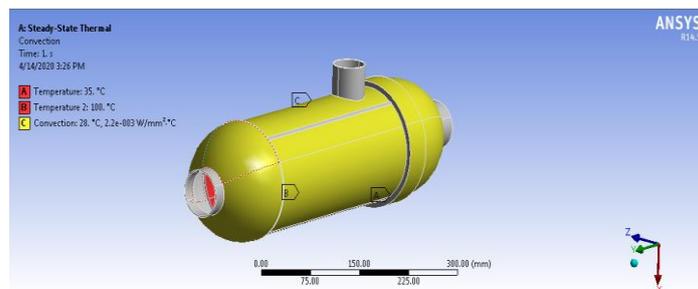


Meshed model



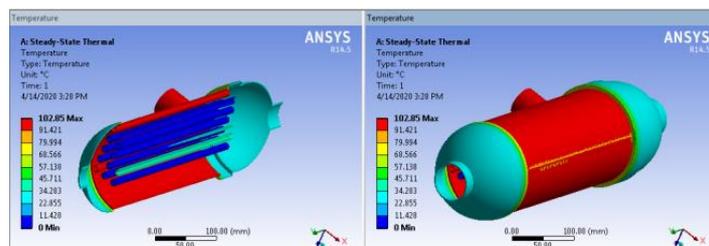
Finite element analysis or FEA representing a real project as a “mesh” a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

Boundary Conditions



material- steel for boiler casing, copper for tubes

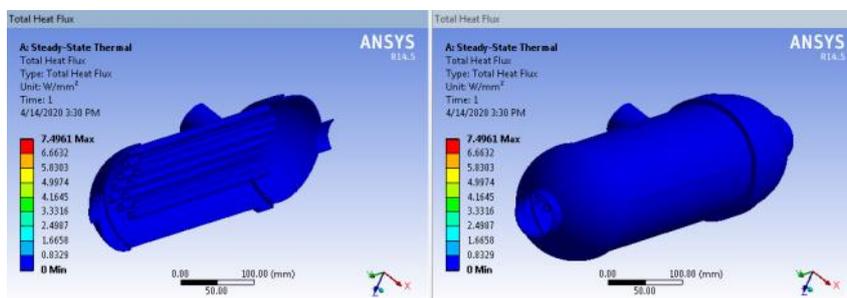
Temperature



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.

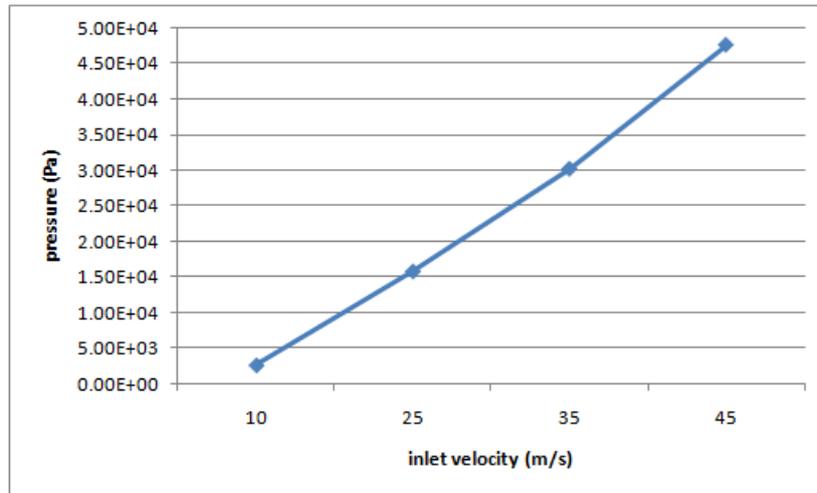
According to the above contour plot, the maximum heat flux is 7.496 w/mm² and minimum heat flux is 0.8329 w/mm².

5. RESULTS

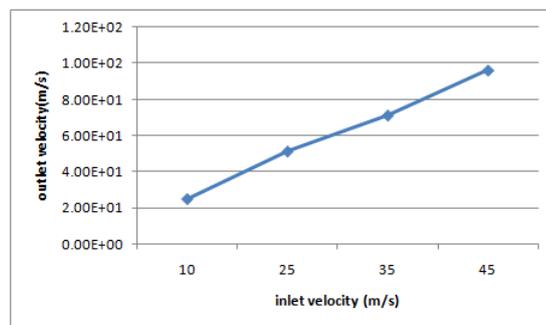
Velocity (m/s)	Pressure (Pa)	Velocity (m/s)	Mass flow rate (kg/s)	Heat transfer Rate (W)
10	2.60e+03	2.51e+01	0.04368	21681.532
25	1.58e+04	5.14e+01	0.11344	52773.632
35	3.02e+04	7.13e+01	0.15603	9596.454
45	4.76e+04	9.62e+01	0.19589	81304.165

Thermal Analysis Result Table

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

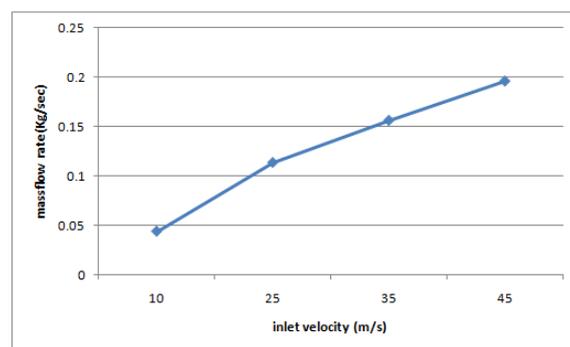


A plot between maximum pressure and velocities by FEA approach is shown in above fig. From the plot the variation of maximum static pressure is observed. Maximum static pressure increases with increases in velocities.

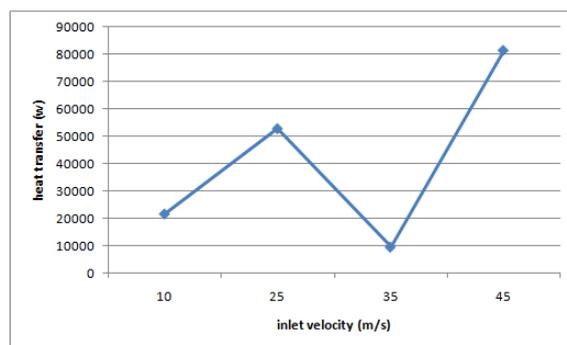


A plot between maximum velocity and velocities by FEA approach is shown in above fig. From the plot the variation of maximum static velocity is observed. Maximum velocity increases with increases in velocities.

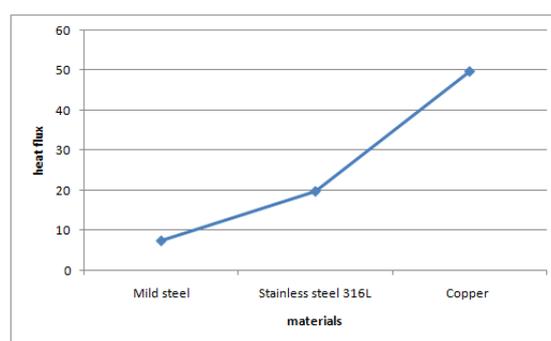
Mass Flow Rate Plot



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.



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.



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.

6. CONCLUSION

In this work, the steam boiler is modeled using CATIA design software is implemented. 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.

- By observing the CFD analysis the pressure drops, velocity, heat transfer coefficient, mass flow rate & heat transfer rate increases by increasing the inlet velocities.
- 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.
- So we can conclude the brass material is better for steam boiler.

REFERENCES

- [1] M. Suri Babu, Dr. B. Subbaratnam, "Finite Element Analysis of Steam Boiler used in Power Plants," SSRG International Journal of Mechanical Engineering, vol. 1, no. 6, 2014.
- [2] D. Kondayya, "Structural and warm examination of a kettle utilizing limited component Analysis,"
- [3] Dr Mike Inkson, Analysis of New Boiler Technologies, Thermal Energy Systems.

- [4] J. Suresh Babu, R. Latha, B. Praveen, V. Anil Kumar, R Rama Kumar, S. Peerulla, "A Study Analysis and Performance of High-Pressure Boilers With its Accessories," International Research Journal of High Pressure Boilers with Its Accessories, vol. 2, no. 1, 2015.
- [5] Akanksha Bhoursae, Jalpa Shah, Nishith Bhatt, Design and investigation of the model of heater for steam pressure control.
- [6] Lou Roussinos, P. E., "Kettle Design and Efficiency" [online], Available: <http://www.forestprod.org/drying06williamson.pdf>.
- [7] Murdock, K. L., "3ds max 9 Bible, Wiley Publishing Inc. Indianapolis, Indiana, 2007.
- [8] Nagpal, G. R., 1998, Power Plant Engineering, Khanna, Delhi.
- [9] Steam Pressure Reduction: Opportunities and Issues by U.S Department of vitality,