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Thermal Analysis of a Supercritical CFB Boiler

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ABSTRACT:

A boiler is a closed vessel in which water or other fluid is heated. The fluid does not necessarily boil. The heated or vaporized fluid exits the boiler for use in various processes or heating applications, including central heating, boiler-based power generation, cooking, and sanitation.

Supercritical Circulating Fluidized Bed (CFB) boiler becomes an important development trend for coal-fired power plant and thermal-hydraulic analysis is a key factor for the design and operation of water wall.

In this thesis, a simple boiler and a CFB boiler are compared for the better heat transfer performance. The 3D modeling of simple boiler and CFB boiler is done in Pro/Engineer and Heat transfer analysis is done in Ansys.

The material used for boiler is steel. In this thesis, it is to be replaced with copper and brass. Thermal analysis is done to verify the better heat transfer rate by comparing simple and CFB boilers and better material. And even CFD analysis is done for verifying the heat transfer in the CFB boiler.

I. INTRODUCTION

A supercritical boiler is a type of steam generator that operates at supercritical pressure, frequently used in the production of electric power.

In contrast to a subcritical boiler, a supercritical steam generator operates at pressures above the critical pressure — 3,200 psi or 22 MPa — in which bubbles can form. Instead, liquid water immediately becomes steam. Water passes below the critical point as it does work in a high pressure turbine and enters the generator's condenser, resulting in slightly less fuel use and therefore less greenhouse gas production.

Technically, the term "boiler" should not be used for a supercritical pressure steam generator as no "boiling" actually occurs in the device.

WORKING OF SUPERCRITICAL BOILERS:

A supercritical boiler burns pulverized coal and is a once-through boiler, meaning that it doesn't require a drum to separate steam from water. Rather than boiling water to produce steam and then using that steam to turn a plant's turbine, a supercritical boiler operates at such high pressure (3,208 psi/221.2 bar or above) that the fluid matrix in it ceases to be liquid or gas. Instead, it becomes what is known as a "supercritical fluid."

This supercritical fluid turns the turbine that generates electricity. As it does so, it drops below the critical pressure point and becomes a mix of steam and water, passing into a condenser. In the process, less fuel is consumed than in a traditional drum boiler, making supercritical boilers more efficient than their subcritical counterparts.

It's hard to believe, but supercritical boiler technology is almost 100 years old. Granted, it didn't look anything like what it does today when Mark Benson first obtained a patent to convert water into steam at high pressure levels in 1922, but the drive to improve the power industry's ability to burn coal through supercritical means has been constant throughout the history of modern boiler engineering.

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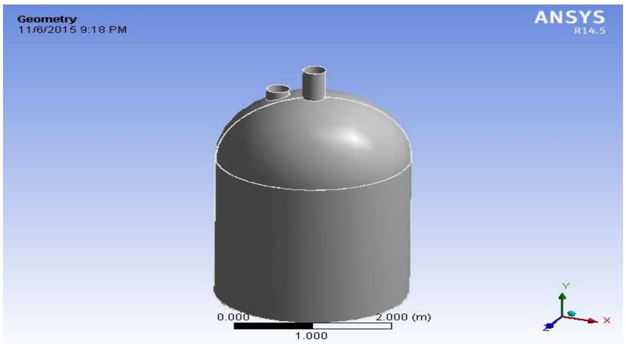
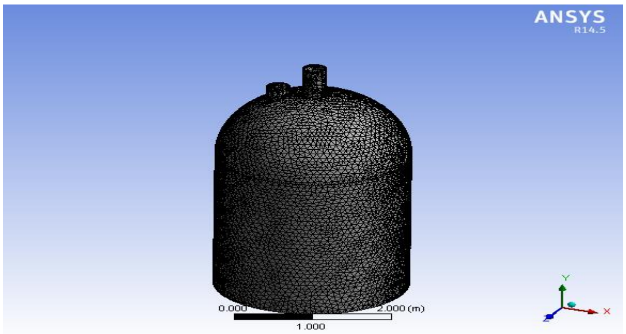
STUDY STATE THERMAL ANALYSIS OF BASIC MODEL OF BOILER MADE OF BRASS

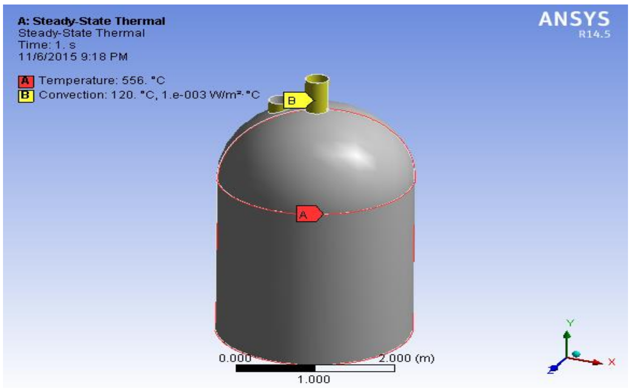
IMPORTED MODEL



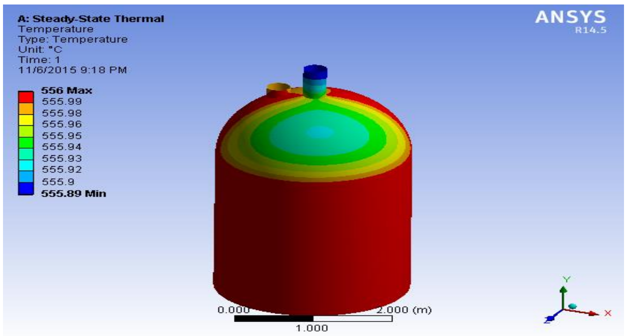
MESHED MODEL



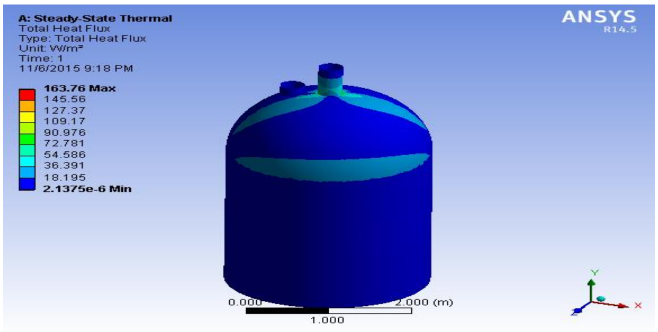
BOUNDARY CONDITIONS



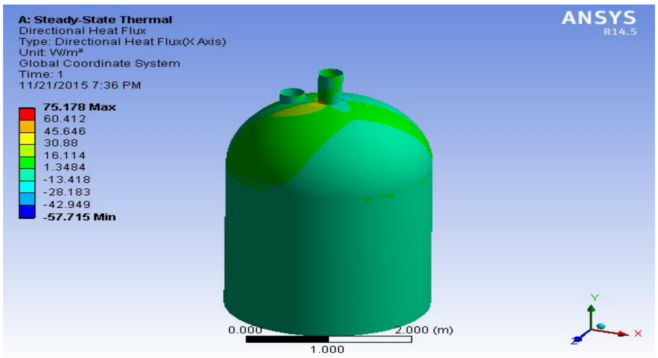
TEMPERATURE DISTRIBUTION



THERMAL FLUXES

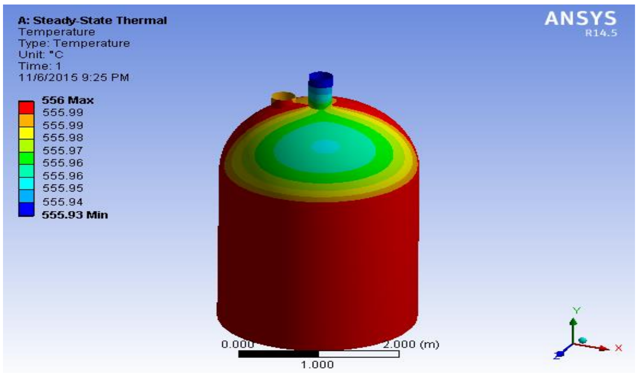


DIRECTIONAL HEAT FLUX

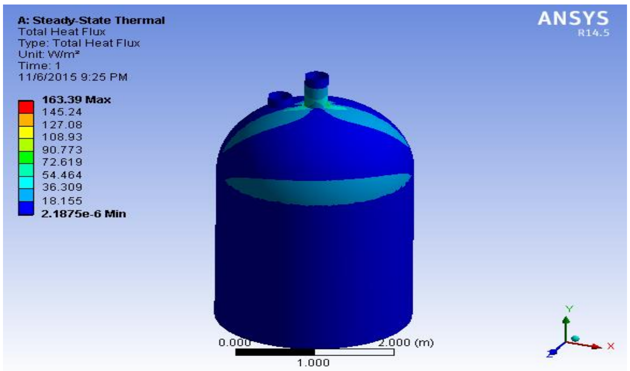


STUDY STATE THERMAL ANALYSIS OF BASIC MODEL OF BOILER MADE OF COPPER

TEMPERATURE DISTRIBUTION



THERMAL FLUXES



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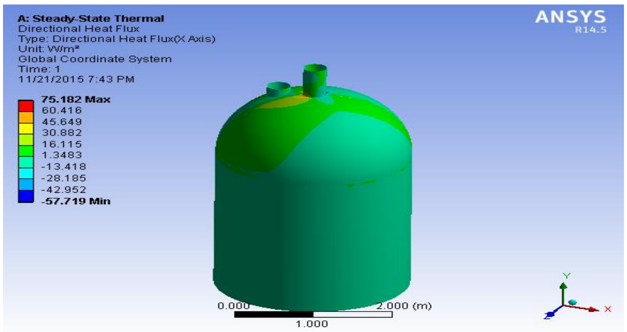
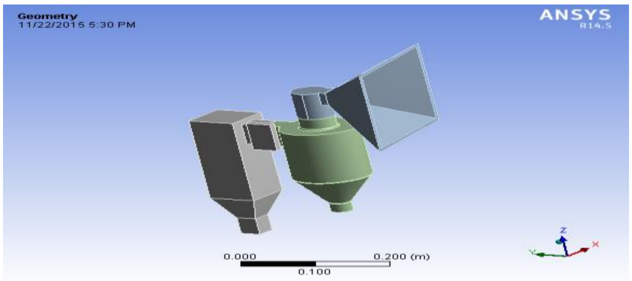
DIRECTIONAL HEAT FLUX



STUDY STATE THERMAL ANALYSIS OF CFB MODEL OF BOILER MADE WITH BRASS IMPORTED MODEL



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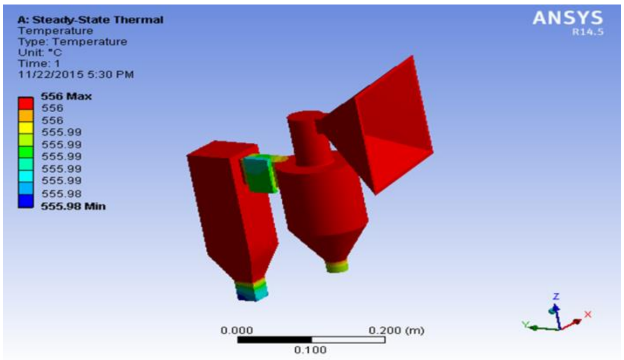

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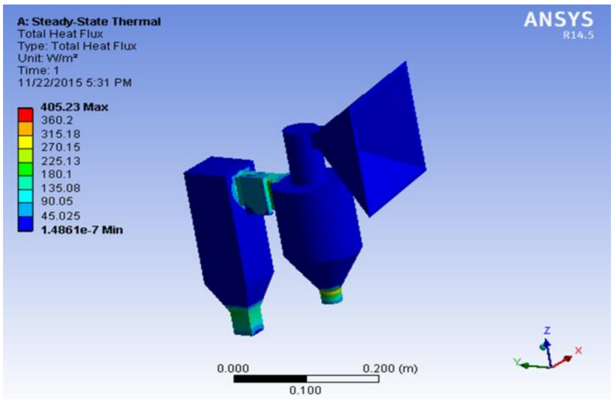

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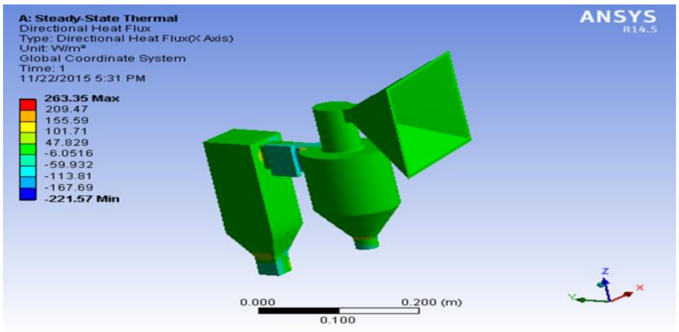
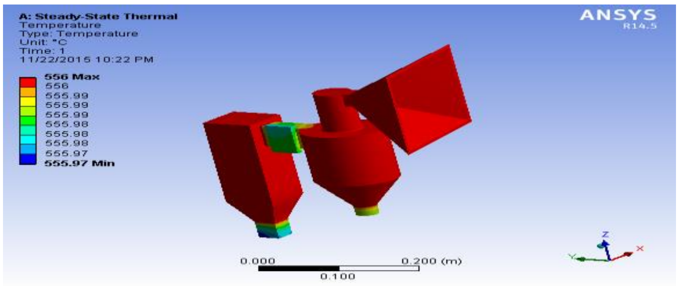
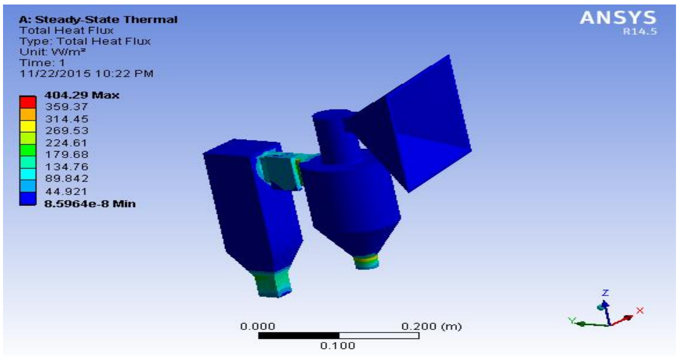


STUDY STATE THERMAL ANALYSIS OF CFB MODEL OF BOILER MADE WITH COPPER TEMPERATURE DISTRIBUTION



THERMAL FLUXES



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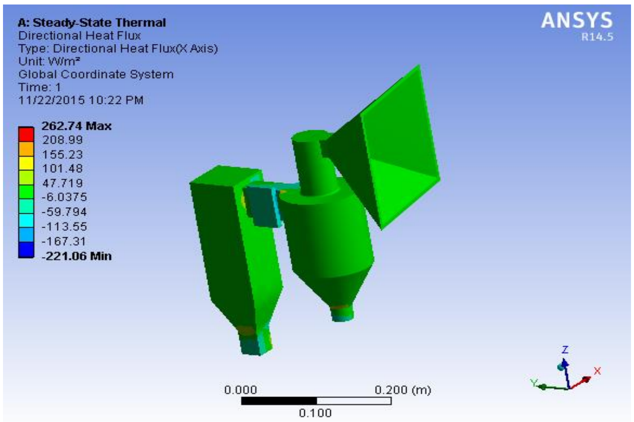

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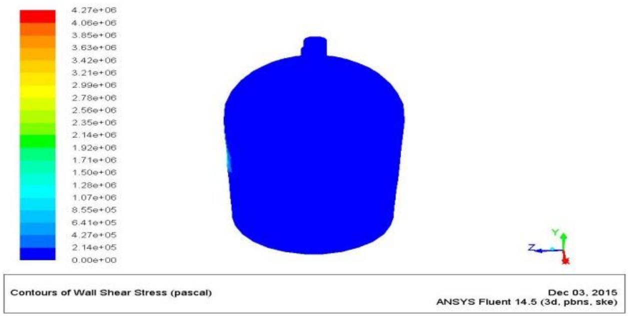
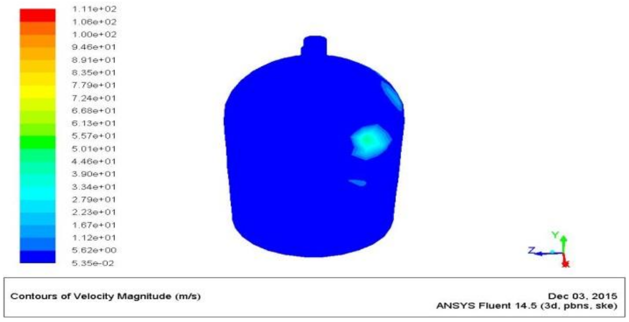
CFD ANALYSIS OF SIMPLE BOILER

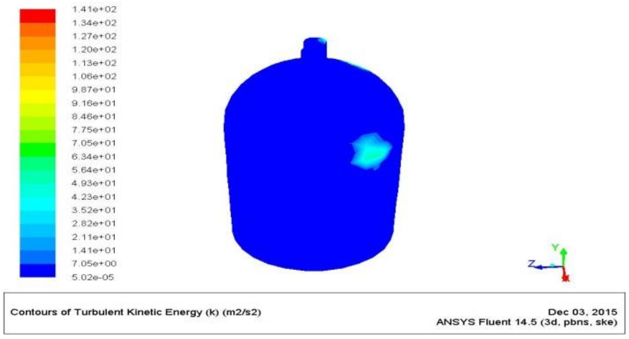
Wall shear stress



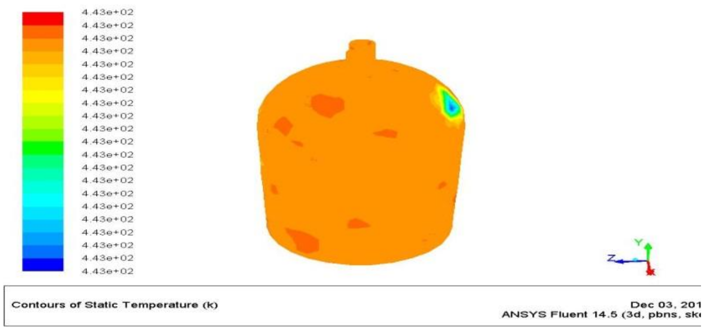
VELOCITY MAGNITUDE



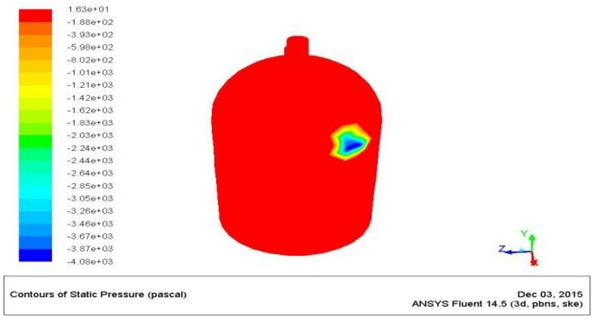
TURBULENT KINETIC ENERGY



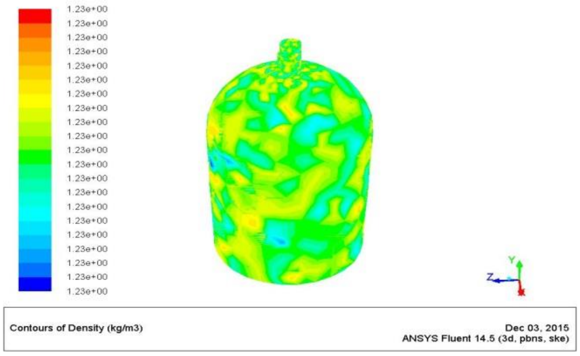
STATIC TEMPRATURE



STATIC PRESSURE



DENSITY

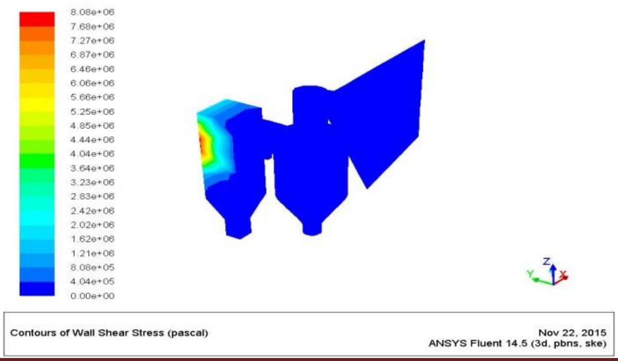


"Flux Report"

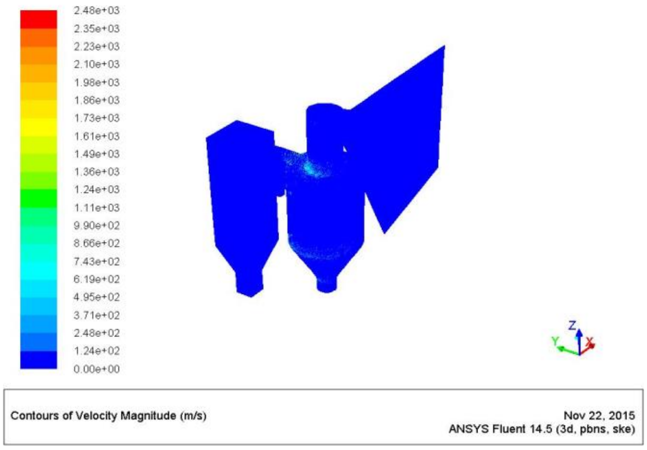
Mass Flow Rate	(kg/s)
interior-body.3__	-1661.7729
wall-body.3__	77.949783
Net	77.949783

CFD ANALYSIS OF CIRCULATING FLUIDIZED-BED BOILER

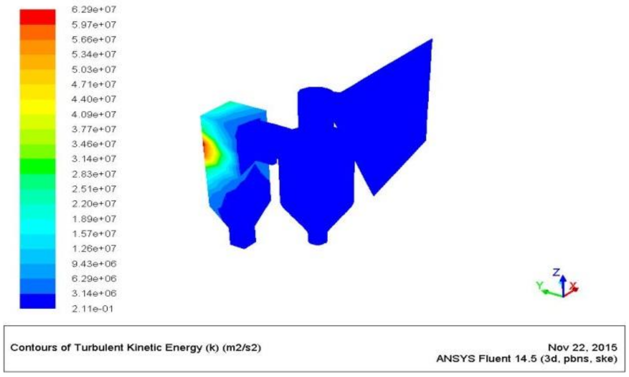
Wall shear stress



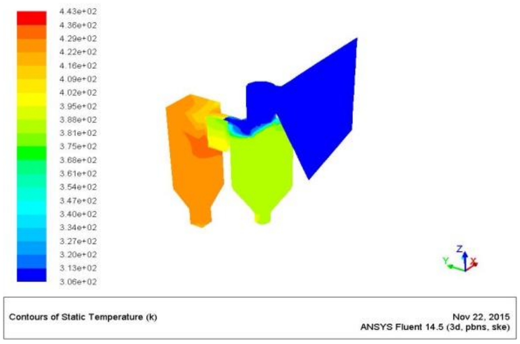
VELOCITY MAGNITUDE



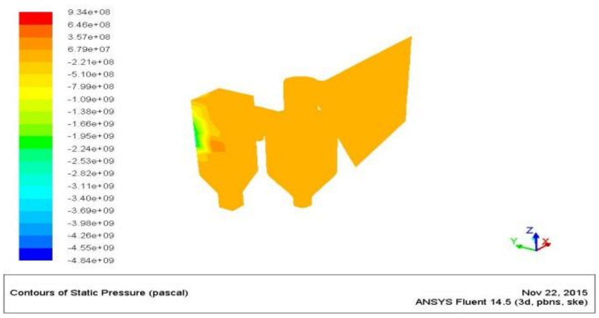
TURBULENT KINETIC ENERGY



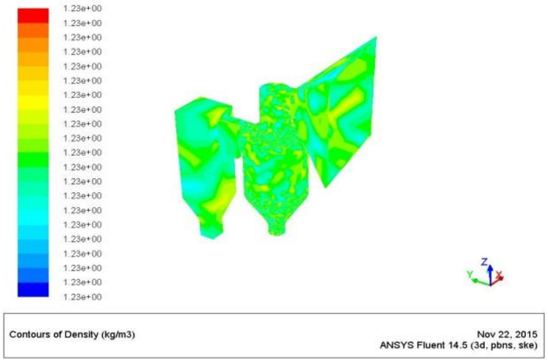
STATIC TEMPRATURE



STATIC PRESSURE



DENSITY



"Flux Report"

Mass Flow Rate	(kg/s)
contact_region-src	0.31978279
contact_region-trg	-0.3197827
contact_region_2-src	-0.53881907
contact_region_2-trg	0.53881907
inlet	0.53315008
interior-11	0.31978282
interior-20	-0.53881907
interior-part_1	23.687399
interior-part_2	-14.561291
interior-part_3	-14.009184
outlet	-3.0983152
wall-18	0
wall-19	0
wall-21	0
wall-22	0
wall-part_1	0
wall-part_2	0

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wall-part_3 0

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Net -2.5651651

"Flux Report"

Total Heat Transfer Rate (w)

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contact_region-src 0

contact_region-trg 0

contact_region_2-src 0

contact_region_2-trg 0

inlet 7968.188

outlet -376083.59

wall-18 0

wall-19 0

wall-21 0

wall-22 0

wall-part_1 0

wall-part_2 0

wall-part_3 0

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Net -368115.41

RESULTS TABLE

Thermal analysis tables

REGULAR MODEL	temperature		thermal flux		directional flux (x)	
	min	max	min	max	min	max
brass	555.89	556	2.14E-06	163.76	-57.715	75.178
copper	555.93	556	2.19E-06	163.39	-57.719	75.182

CFB BOILER	temperature		thermal flux		directional flux (x)	
	min	max	min	max	min	max
brass	555.97	556	8.60E-08	404.29	-221.06	262.74
copper	555.98	556	1.49E-07	405.23	-221.57	263.35

Cfd analysis report of SIMPLE BOILER

	min	max
sheer stress	0.00E+00	4.27E+06
velocity magnitude	5.35E-02	1.11E+02
turbulent kinetic energy	5.02E-05	1.41E+02
temperature	4.43E+02	4.43E+02
static pressure	-4.08E+03	1.63E+01
density	1.23E+00	

Cfd analysis report of CFB BOILER

	min	max
sheer stress	0	8.08E+06
velocity magnitude	0	2.48E+03
turbulent kinetic energy	2.11E-01	6.29E+07
temperature	3.06E+02	4.43E+02
static pressure	-4.84E+09	9.34E+08
density	1.23E+00	

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CONCLUSION

In this thesis, a simple boiler and a CFB boiler are compared for the better heat transfer performance. The 3D modeling of simple boiler and CFB boiler is done in Pro/Engineer and Heat transfer analysis is done in Ansys.

The material used for boiler is steel. In this thesis, it is to be replaced with copper and brass. Thermal analysis is done to verify the better heat transfer rate by comparing simple and CFB boilers and better material.

As per the analysis done if we observe the results obtained for the simple boiler, we can find that the brass material is the best material for the simple boiler as the flux obtained is lees compared with the copper.

As in the other case a CFB boiler is considered and analysis is done, as if we compare the results of the CFB boiler we can see that the brass material CFB boiler is much better for the better life output as the stress is very minimum in this material. Her even CFD analysis is done to the CFB boiler to verify the stress and pressure and density values, As if we compare both the results we can conclude that CFB boiler gives much better output for the material and even the temperature and the flux obtained is the best results for the boiler.

REFRENCES

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4) 460 MWe Supercritical CFB Boiler Design for Łagisza Power Plant
5) A MAJOR STEP FORWARD---THE SUPERCRITICAL CFB BOILER by Ragnar Lundqvist
6) IR-CFB Boilers: Supercritical Once through Developments for Power Generation
7) THE ADVANTAGES OF A SUPERCRITICAL CIRCULATING FLUIDIZED BED BOILER
8) Techno-economic analysis of PC versus CFB No 13/14 November 2013 combustion technology
9) Kari Myöhänen, Timo Hyppänen, Jouni Miettinen, Riku Parkkonen, ”Three-Dimensional Modeling and Model Validation of Circulating Fluidized Bed Combustion”, to be presented at the 17th International Conference on Fluidized Bed Combustion, May 18-21, 2003, Jacksonville, Florida, U.S.A.

AUTHOR DETAILS

1. **STUDENT**

Kurapati Nageswara Rao Received the BTech Degree in Mechanical Engineering From Dr.Samuel George Institute Of Engineering and Technology, Markapur, JNTUK, Andhra Pradesh, India, In 2013 Year, and Pursuing MTech In Thermal Engineering from Kakinada Institute of Technology & Science, Divili, Andhra Pradesh, India.

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3. **GUIDE 2**

Mr. K. Mohan Krishna, Assistant professor, Kakinada institute of technology & science, Divili, Andhra Pradesh, India.