ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Thermal Analysis of a Super Critical CFB Boiler

Veeranki Vishnu Kumar
Elenki Institute of Engineering & Technology,
Telangana, India.

Sri Aparna
Elenki Institute of Engineering & Technology,
Telangana, India.

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.

INTRODUCTION TO SUPERCRITICAL BOILER

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.

BENEFITS OF SUPERCRITICAL BOILERS

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.

After some problems in the 1960s and 1970s, supercritical technology began to hit its stride in the 1980s and has been yielding better performance statistics ever since. With increasing government and industry pressures to reduce emissions and increase efficiency, supercritical boilers (or "steam generators," since no actual boiling occurs in supercritical units) promise to be a part of the overall solution by using less fuel and helping coal-burning plants comply with more and more stringent emissions regulations.

Supercritical boilers offer benefits in the three interrelated areas that mean the most to plant owners and operators today: efficiency, emissions, and cost. While supercritical boilers cost more than comparably sized subcritical boilers, the larger initial capital investment can be offset by the lifecycle savings yielded by the technology's improved efficiency, reduced emissions, and lower operating costs —all due to its higher steam temperature and pressure parameters.

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IMPROVED EFFICIENCY

Supercritical and ultra-supercritical boilers' ability to operate at much higher pressures and temperatures than subcritical boilers translates into noticeably better efficiency ratings.

Subcritical boilers typically run at 2400 psi/1000°F. By way of contrast, modern supercritical units can go as high as 3900 psi/1100°F. The even more advance ultra-supercritical units reach pressures and temperatures as high as 4600 psi/1120°F. Current research goals are set as high as 5300 psi/1300°F and seem to be on the horizon.

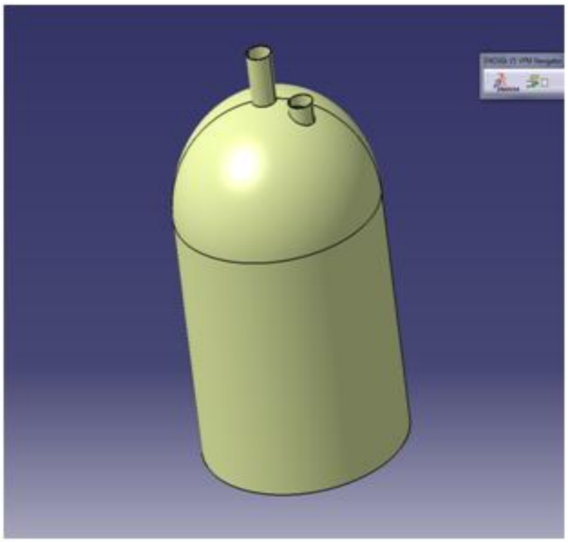
REDUCED EMISSIONS

Improved plant efficiency also translates into reduced emissions, particularly of CO_2 and mercury, which are difficult to manage otherwise. The general rule of thumb is that each percentage point of efficiency improvement yields 2–3% less CO_2.

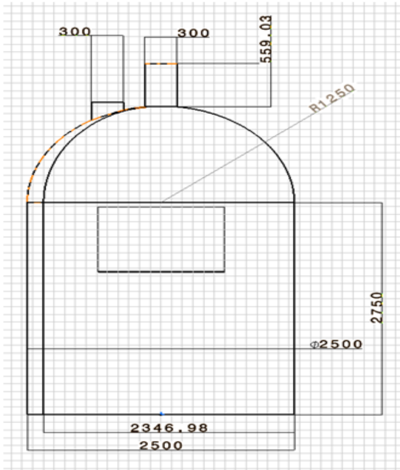
LOWER OPERATING COSTS

For all fossil fuel–fired plants, fuel represents the largest operating cost. By reducing the amount of fuel needed to yield the requisite energy, supercritical plants make a noticeable dent in bottom lines when compared to subcritical plants

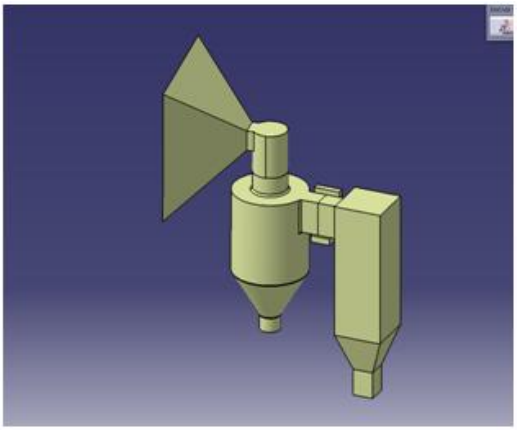
DESIGN OF BASIC BOILER



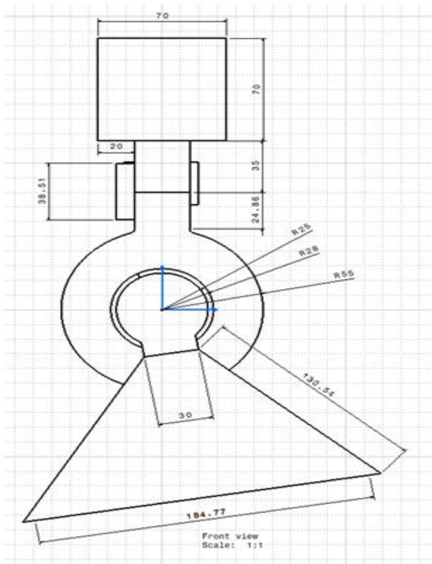
Draft of basic model



CFB BOILER DESIGN



Draft of cfb boiler



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MATERIAL PROPERTIES

BRASS

Thermal conductivity: 233W/mk
Melting point: 1030^{o}C

COMPOSITION OF BRASS:

Aluminium 0.421%
Antimony 0.09%
Arsenic 0.123%
Bismuth 1.27%
Copper 68.7%
Iron 0.114%
Zinc 30.3%

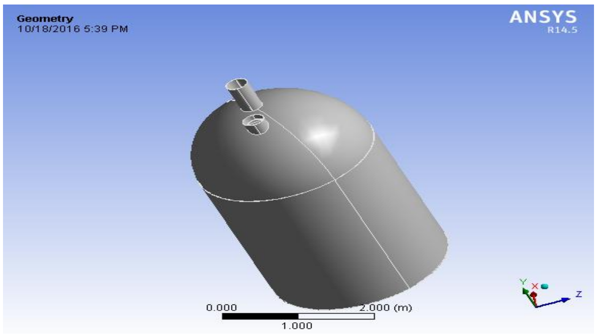
COPPER

Thermal conductivity: 385W/mk
Melting point: 1083.6 ^{o}C

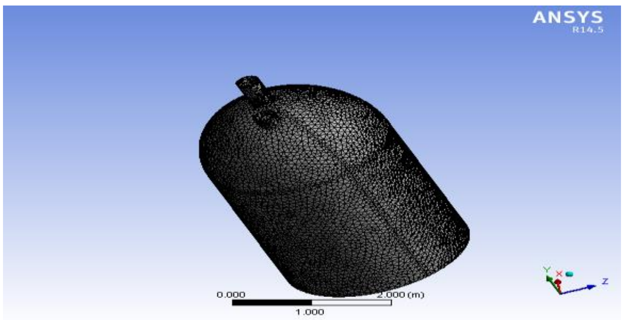
COMPOSITION OF COPPER

Copper 100%

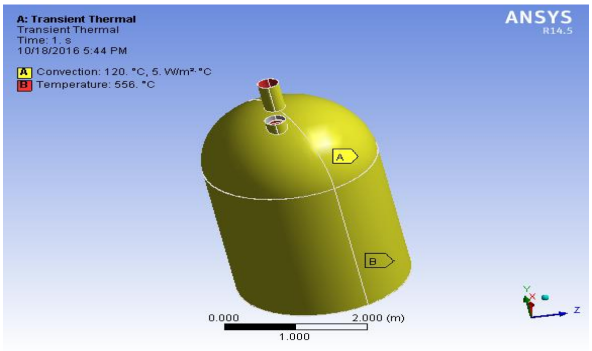
TRANSIENT THERMAL ANALYSIS OF BASIC MODEL OF BOILER MADE OF BRASS



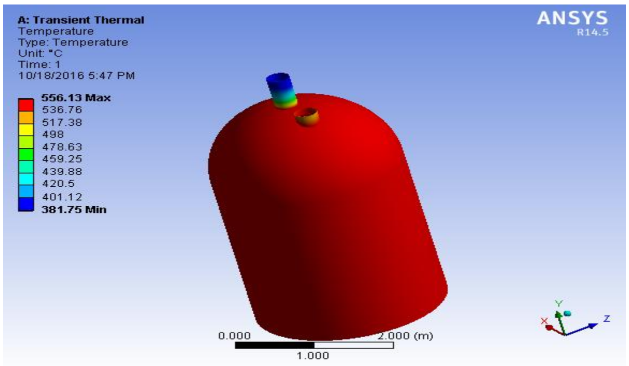
MESHED MODEL



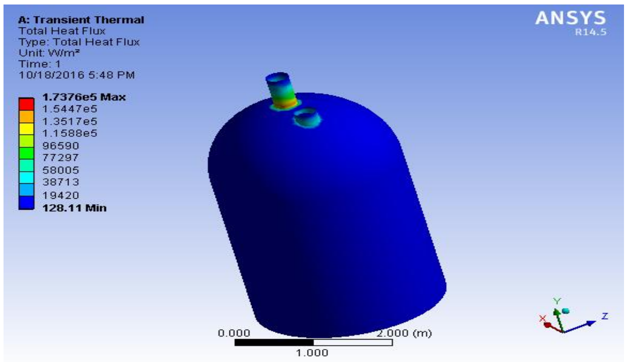
BOUNDARY CONDITIONS



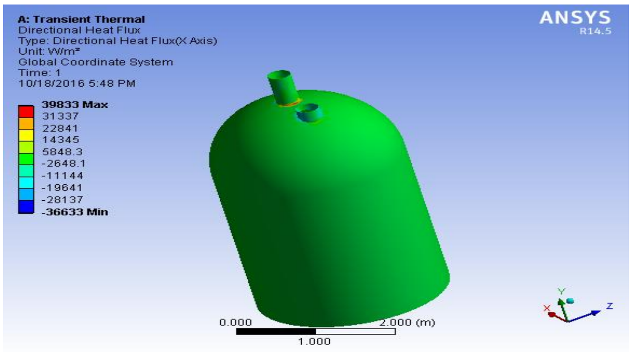
TEMPERATURE DISTRIBUTION



THERMAL FLUXES



DIRECTIONAL HEAT FLUX



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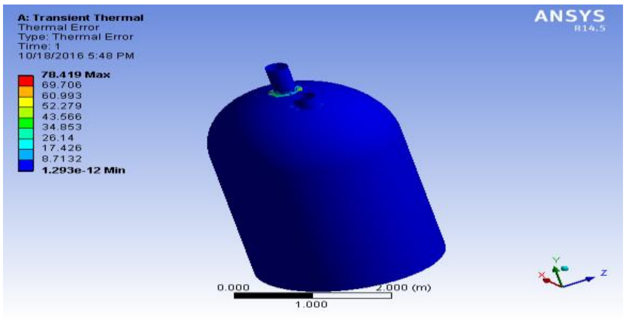
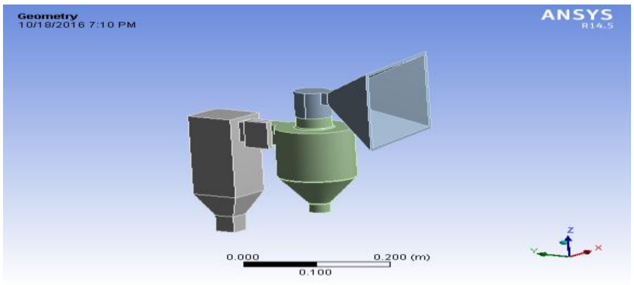
THERMAL ERROR

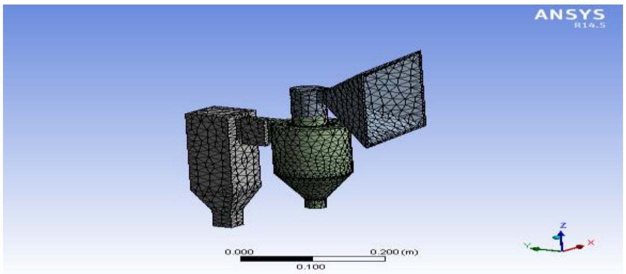


REGULAR MODEL	temperature		thermal flux		directional flux (x)		Thermal error	
	min	max	min	max	min	max	min	max
brass	381.75	556.13	128.11	1.7376e5	-36633	39833	1.293e-12	78.419
copper	454.09	556.08	141.89	2.0262e5	-42728	46415	2.378e-12	51.236

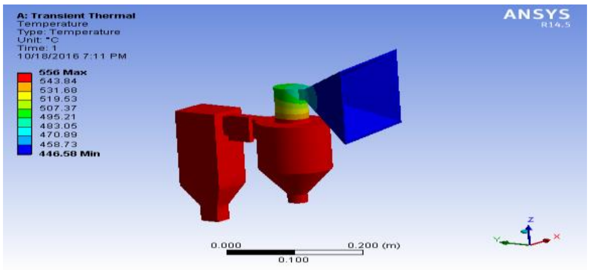
TRANSIENT THERMAL ANALYSIS OF CFB MODEL OF BOILER MADE WITH BRASS IMPORTED MODE



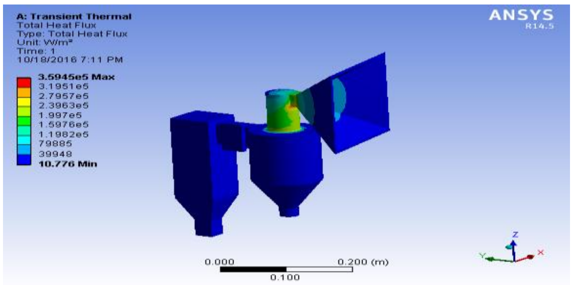
MESHED MODEL



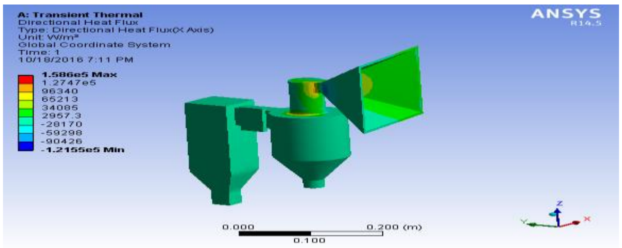
TEMPERATURE DISTRIBUTION



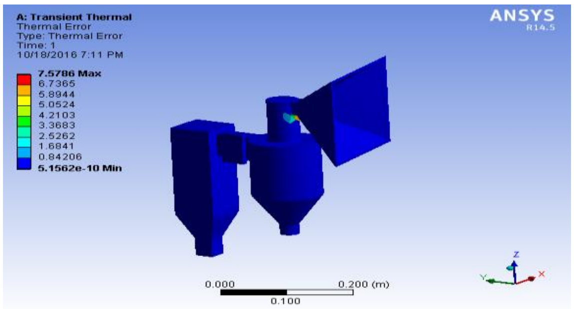
THERMAL FLUXES



DIRECTIONAL HEAT FLUX



THERMAL ERROR



CFB BOILER	temperature		thermal flux		directional flux (x)		Thermal error	
	min	max	min	max	min	max	min	max
brass	446.58	556	10.776	3.55945E5	-1.2155E5	1.586E5	5.1562E-10	7.5786
copper	496.19	556	448.03	4.0751E5	-1.3592E5	1.8112E5	2.4724E-10	4.6693

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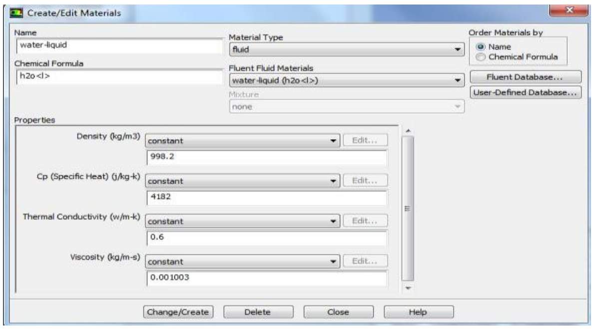
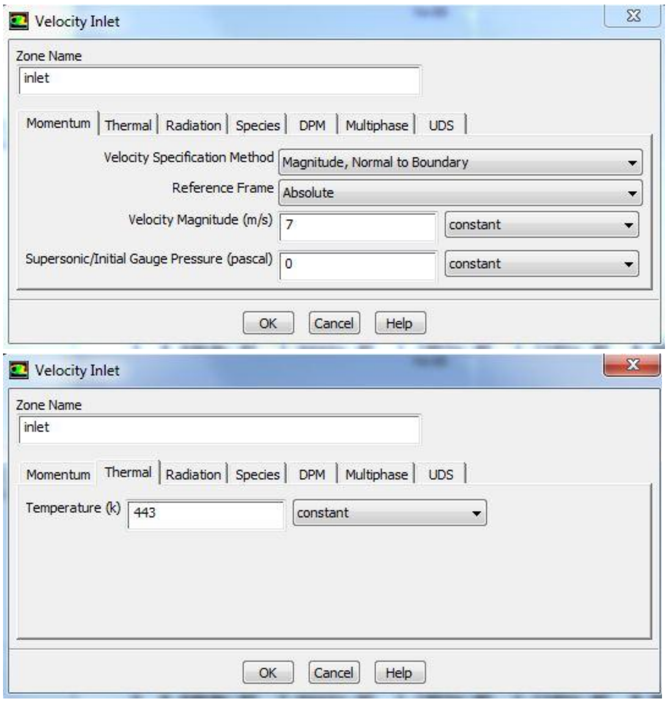
CFD ANALYSIS OF SIMPLE BOILER

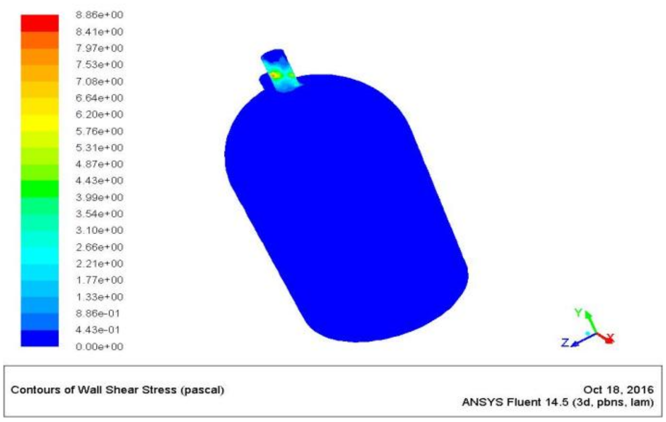
MATERIAL DATA



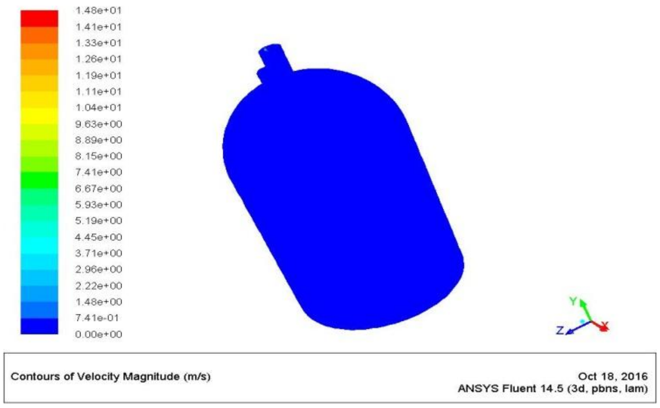
BOUNDARY CONDITION



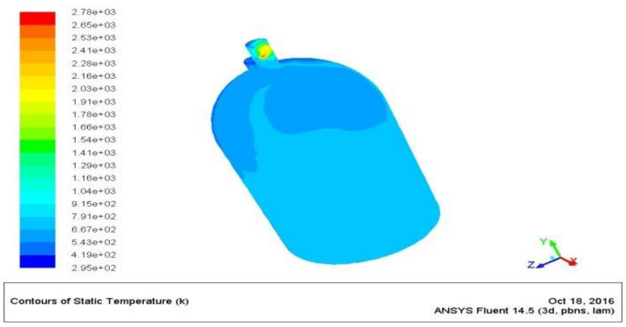
WALL SHEAR STRESS



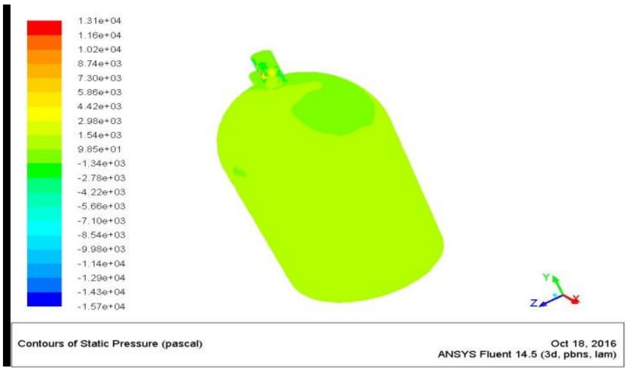
VELOCITY MAGNITUDE



STATIC TEMPRATURE



STATIC PRESSURE



Cfd analysis report of SIMPLE BOILER

	min	max
sheer stress	0	8.86E+00
velocity magnitude	0	1.48E+01
temperature	2.95E+02	2.78E+03
static pressure	-1.57E+04	1.31E+04
density	1.23E+00	

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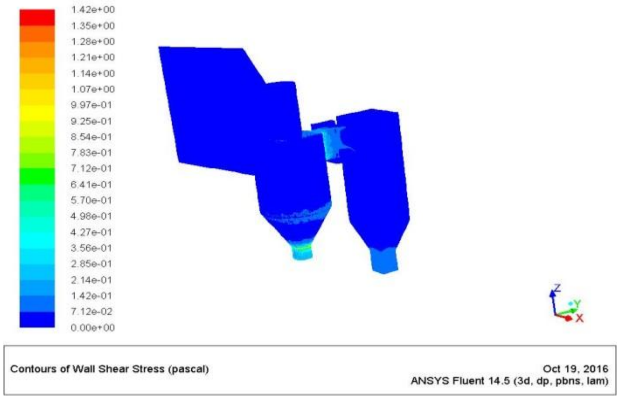
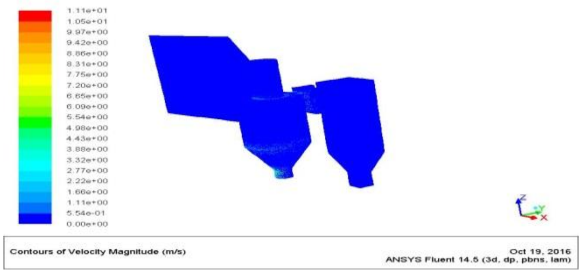
CFD ANALYSIS OF CIRCULATING FLUIDIZED-BED BOILER

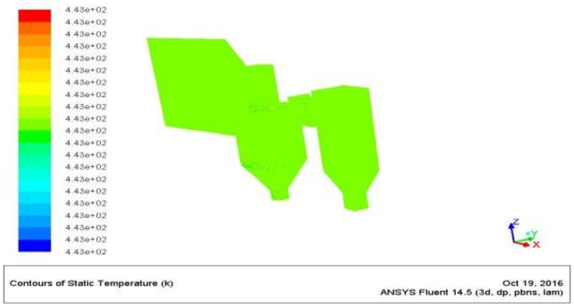
WALL SHEAR STRESS



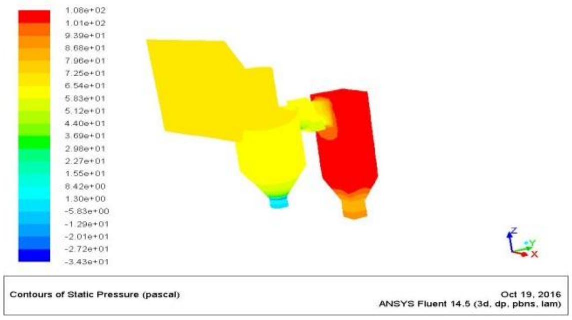
VELOCITY MAGNITUDE



STATIC TEMPRATURE



STATIC PRESSURE

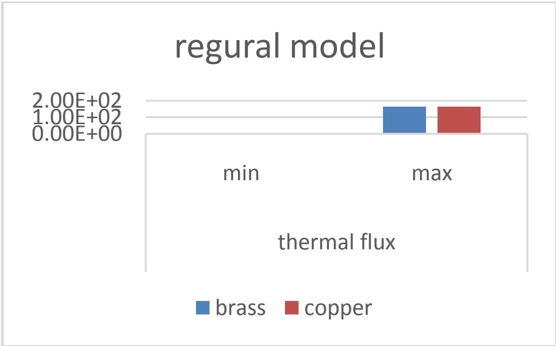


Cfd analysis report of CFB BOILER

	min	max
sheer stress	0	1.42E+00
velocity magnitude	0	1.11E+01
temperature	4.43E+02	4.43E+02
static pressure	-3.43E+01	1.08E+02
density	1.23E+00	

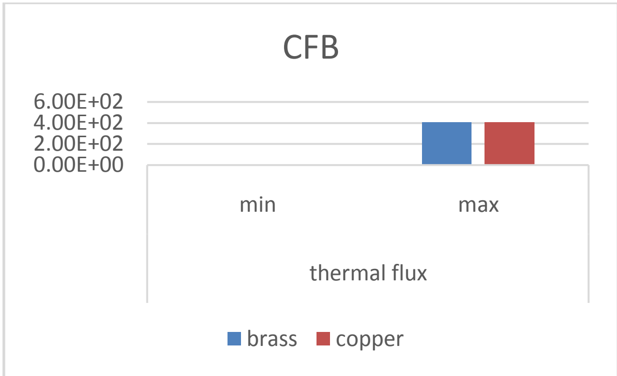
REGULAR MODEL GRAPHS

Thermal fluxes



CFB BOILER GRAPHES

Thermal fluxes



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.

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- Techno-economic analysis of PC versus CFB No 13/14 November 2013 combustion technology
- 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.
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Author Details

Veeranki Vishnu Kumar Received the B.Tech degree in Mechanical Engineering from Turbomachinery Institute of Technology and Sciences, JNTU, Hyderabad, Telangana, India, in 2014 year, and perusing M.Tech in THERMAL ENGINEERING from ELENKI INSTITUTE OF ENGINEERING & TECHNOLOGY, JNTU, Telangana Hyderabad, India.

Sri. Aparna M.Tech, Assistant professor, ELENKI INSTITUTE OF ENGINEERING & TECHNOLOGY, Telangana Hyderabad, India.