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DESIGNING A BOILER CHIMNEY HEAT RECOVERY SYSTEM AGAINST FOULING.

A Review

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Abstract An initial design of chimney heat recovery heat exchanger was provided. The design had a completely fabricated exchange core but an incomplete ducting system . This report is based on the work undertaken to complete and test the gas to gas heat recovery system. This system was specifically designed for boiler chimney and therefore the systems ducting was designed to conform to the general boiler stack. In the completion of the design, the major factor to consider was to design against fouling. The system was therefore designed with means of reducing fouling such as provision for easily replaceable particulate filter and quick washing system. The project was hence done in the following manner. 1. Completing of the fabrication. 2. Research on ways of minimizing fouling . 3. Incorporating the ways arrived at in 1 above into the system design. 4. Testing of the model under forced convection condition. The gases from a furnace were used to simulate industrial flue gases. The performance of the model was used to project the optimum of prototype.

INTRODUCTION

Industrial Waste Heat: his is heat lost in industries through ways such as discharge of hot combustion gases to the atmosphere through chimneys, discharge of hot waste water, heat transfer from hot surfaces. This energy loss can be recovered through heat exchangers and be put to other use such as preheating other industrial fluids such as water or air. This project focuses on recovering heat that is lost through boiler chimney flue gas. The advantages of heat recovery include: i). Increasing the energy efficiency of the boiler. ii). Decreasing thermal and air pollution dramatically.

Design Considerations: n the designing of the exchanger following factors were put to consideration. 1. The exchanger surface has to be the most efficient and suitable for gas-gas heat exchange. 2. The design has to consider the fouling effect of the flue gases. 3. The design has to allow for quick maintenance without interfering with the boiler operations. 4. The ducting design has to conform to the boiler chimney design. Based on the above factors, the exchanger was designed to be of compact plate type. Various designs for the exchange core were considered including cylindrical type (ducts). The plate type was found to be more efficient and simpler in design. It was also more suitable for gas - to gas heat exchange as it offers higher surface for heat transfer.

Challenges to recovering law temperature waste heat (Hodge B.K 1990) : Corrosion of heat exchanger surface: as the water vapor contained in the exhaust gas cools some of it will condense and deposit corrosive solids and liquids on the heat exchanger surface. The heat exchanger must be designed to withstand exposure to these corrosive deposits. This You created this PDF from an application that is not licensed to print to nova PDF printer 2 generally requires using advanced materials, or frequently replacing components of the heat exchanger, which is often uneconomical. Large heat exchanger surface required for heat transfer; since low temperature waste heat will involve a smaller temperature gradient between two fluid streams, larger surface areas are required for heat transfer. This limits the economy of heat exchangers. Finding use for low grade heat: recovering heat in low temperatures range will only make sense if the plant has use for low temperature heat.

The host gases from the grate pass through the flue pipe to the combustion chamber. The hot gases from the combustion chamber flow through the horizontal fire tubes and transfer the heat to the water by convection. The flue gases coming out of fire tubes pass through the smoke box and are exhausted to the atmosphere through the chimney. Smoke box is provided with a door for cleaning the fire tubes and smoke box

Types of Heat Exchangers

Double pipe heat exchanger: Consists of two concentric pipes of different diameter. In application, one fluid passes through the pipe of smaller diameter while the other flows through the annular space between the two pipes. The flow of fluids can be arranged into:-

i). Parallel flow (Cengel, 2002)

Both fluids (hot fluid and cold fluid) enter the heat exchanger at the same end and move in the same direction to leave at the other end.

(ii). Counter flow (Cengel, 2002)

In these types of arrangement, the cold and hot fluids enter the exchanger at opposite ends and flow in opposite directions

2.2.2 The compact heat exchanger

This type of heat exchanger is designed to allow a large heat transfer surface area per unit volume. The ratio of the heat transfer surface area of a heat exchanger to its volume is called the area density β. Heat exchangers with β >700 are classified as compact heat exchanger e.g. car radiator, human lung am0ongest others. They allow high heat transfer rates between fluids in a small volume. They are therefore best suited for applications with strict limitations on the weight and volume of heat exchanger. They are mostly used in gas-to-gas and gas-to-liquid heat exchanger to counteract the low heat transfer coefficient associated with fluid flow with increased surface area. The two fluids in this type of heat exchangers move in directions perpendicular to each other, a flow configuration referred to as cross-flow. This type of flow may be classified as unmixed or mixed.

i). Unmixed flow: Plate fins force the fluid to flow through a particular inter-fin spacing and prevent it from moving in the transverse direction.

ii). Mixed flow: The fluid is free to move in the transverse direction. The presence of mixing can have adverse and significant effects on the heat transfer characteristics of a heat exchanger. Plate heat exchangers (Ozisk, 1985) They are usually constructed of thin plates which may be smooth or corrugated. Since the plates cannot sustain as high pressure and or temperatures as circular tubs, they are generally used for small and low to moderate pressure/temperatures. Their compactness factor is also low compared to other types of heat exchangers. The plates can be arranged in such a way that there is cross-flow i.e. the hot and cold fluids flowing in directions perpendicular to each other to enhance the heat transfer characteristic.

Forms of Fouling

Scaling/precipitation: - scaling/precipitation occur as a result crystallization of dissolved substance on to the heat transfer surface. These deposits can be removed by scratching or by cleaning via chemical treatment. This isthemost common type of fouling. Scaling/precipitation can be reduced by treating the fluid flowing past the heat exchanger before it reaches the heat exchanger surface. 2.Particulate fouling This result from the accumulation of solid particles suspended in the process fluid onto the heat transfer surface. Such solid particles can be removed by use of filters to treat the process fluid before it reaches the heat exchanger surface. 3 Chemical /corrosion fouling In this case, the surfaces are fouled by accumulation of the products of chemical reactions on the surfaces. This form of fouling can be avoided by coating the heat exchanger surfaces by glass. Heat exchanger surfaces can also be fouled by growth of algae in warm fluids (chemical fouling) which can be prevented by chemical treatment. 4 Solidification fouling The crystallization of a pure liquid or one component of the liquid phase on a sub cooled heat transfer surface. The mechanism of fouling is complicated and no reliable techniques are available but there are means of reducing fouling. The methods mostly used to reduce fouling include use of filters and increasing the fluid flow to ensure turbulent.

Provision of particulate filters

At the entry of the flue gas duct is attached, a cone shaped duct to whose narrower end can be attached diesel particulate filter. The particulate filter is designed to remove fuel particulate matter (soot) from the fuel gases. The efficiency of the filter is inversely proportional to the pressure that is build up due to resistance to gas flow. It is therefore difficult to achieve 100 percent efficiency through filtration, as there must be a compromise between efficiency and pressure buildup .the best filters are therefore broad band filters that can filter particles of diameters between 0.2-150µm. The filters can easily be removed through a door on the side of the side duct for cleaning..

Components and Properties

Funnel shaped duct

This is a short cone shaped duct that is welded of the entry to the flue gas duck upstream of the exchanger core. It provides an end that can be covered by laid during cleaning to prevent water from entering the boiler. Small holes are left at its joint to the gas duct to allow water out During normal boiler operation gas filler can be put at this narrow end to trap carbon particles from reaching the exchanger core. It was constructed from mild steel sheet (16 gauge)

Problem Statement

The industrial boilers are working on very high temperature & pressure. And the some flue gasses forms in the boiler which required exhausting in atmosphere. Because of this the boiler chimneys are provided to the boiler. Through the chimney that gasses are exhausted to the atmosphere. During this process some fouling are formed on the heat exchanger, furnace system. And after some period fouling will become considerable & heat transfer rate reduces drastically. Therefore this will reduce the efficiency of boiler and increase the chances of accident. This project is to redesigning of the boiler chimney to reduce the fouling creation in furnace, heat exchanger area & ducting system mixing with each other. Heat transfer in heat exchangers involves convection in each fluid and conduction through the wall separating the two fluids. In order to account for the contribution of all the effects of convection and conduction, an overall heat transfer coefficient (U), is used in the analysis. Heat transfer rate depends on the temperature differences between the two fluids at the location and the velocity of the fluids (time of interaction) between the fluids. The industrial boilers are working on very high temperature & pressure. And some flue gasses forms in the boiler which required exhausting in atmosphere through chimney. During this process some fouling are formed on the boiler chimney surface. And after some period fouling will become considerable which affects life of chimney. This project is to redesigning of the boiler chimney to reduce the fouling creation in furnace, boiler surface area & duct system.

Scope

1. In this project, an initial design of chimney for 15 TPH boiler, 16 bar pressure is provided.
2. This project is based on the work undertaken to redesign the flue gas duct in chimney to reduce the formation of fouling which affect the efficiency of the boiler.
3. This system was specifically designed for boiler chimney. In the completion of the design, the flappers are providing in the flue gas duct (segment II).
4. The attempt of project is to reduce the cross- section area in that particular segment to increase the flow of flue gases.

Design against Fouling

In this system, the effect of fouling upon the component performance during the specific operation lifetime and for sufficient extra capacity to ensure the exchange will meet process specifications up-to shut down for cleaning are considered. It is also focused the mechanical arrangements that are necessary to permit easy cleaning. In this project work, the following measures have been taken to reduce the rate of fouling.

1. Provision for particulate filters.
2. Introduction of turbulent flow upstream of the exchanger core

Table 2: Boiler Specifications

Boiler steam capacity	15 TPH	Surface temp of boiler	65 °C
Working steam pressure	15 bars	Wind velocity around boiler	4 m/sec
Fuel	Coal	Total surface area of boiler	118 mm^2
Fuel firing rate	2023 kg/hr	G cv of bottom ash	700 K.cal/kg
Steam generation rate	8954 kg/hr	G cv of fly ash	395 k.cal/kg
Steam pressure	14 bars	Ratio of b. A/ f.a	90;10
Feed water temperature	90°C	Fuel analysis in %	
% Of co2 in flue gases	8%	Ash content in fuel	7.80%
% Of coin flue gases	167	moisture in coal	29%
Average flue gas temperature	210 °C	carbon content	38%
Ambient temperature	027 °C	Humidity in ambient air	0.018kj/kg of dry

Table 3: Data Required for Design Calculation

	Top diameter (mm)	Bottom diameter (mm)	Height (mm)	Shell thickness (mm)	Avg. diameter (mm)
Seg 1	900	900	5000	6	900
Seg 2	900	900	5000	6	900
Seg 3	900	900	5000	6	900
Seg 4	900	900	5000	8	900
Seg 5	900	1575	5000	10	1237.5
Seg 6	1575	2250	5000	10	1912.5

- Height of flare = H = 1/3(30) = 10 m
- Vb = basic wind speed at the site =37m/s for Pune.
- adopting a shape factor of 0.7, wind pressure fz= (Pz.D.Δz) 0.7.
- Total W= (241.482+12.074) =253.556KN
- The maximum compressive force per unit length = 147.1520 KN/m
- Allowable bearing pressure, σc=4N/mm2
- Width =147.1520/4 =36.788mm, Provide 37 mm wide base plate.
- Provide 4 bolts of 39mm nominal diameter on a circle diameter

LITERATURE SURVEY:

Moni Kuntal Bora1 and S. Nakkeeran [1] Explained convergent on the diverse aspects of the operation of Boiler efficiently. Efficient operation of boiler is likely to play a very big role in following years to come. Industries all over the world are going through increased and powerful competition and increased automation of plants. The suspension cost of such system is expected to be very high. To get away with this challenge, it is clearer by this paper. We have to use the advanced technology and management skills in all spheres of activities to perform its effective role in the turnover of the company.[1]Rahul Dev Gupta,

Sudhir Ghai1, Ajai Jain[2]The above Paper says that idea for findings of boiler house efficiency improveement study carried out in a large boiler house unit of a pulp and paper mill has been presented. The causes of poor boiler efficiency were various heat losses such as loss due to unborn carbon in refuse, loss due to dry flue gas, loss due to moisture in fuel, loss due to radiation, loss due to blow down, and loss due to burning hydrogen, etc. The various heat losses were analyzed and a set of recommendations were made to the plant management for implementation, so that efficiency of boiler can be increased. Five important recommendations were implemented by plant management, and it has been seen that there is tremendous increase in boiler efficiency. This work, with only five recommendations implemented, has resulted in net increase of 2% in overall boiler efficiency. In addition, it is observed that carefulness in the operation of boiler can help a great deal in energy efficiency improvement in boiler.
[3] Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from Macro fouling is caused by coarse matter of either biological or inorganic origin, as an example industrially created refuse. Such matter enters into the cooling water circuit through the cooling water pumps from sources just like the open ocean,rivers or lakes. In closed circuits, like cooling towers, the ingress of macro fouling into the cooling basin is feasible through open canals or by the wind. Sometimes, components of the cooling internals detach themselves and area unit carried into the cooling water circuit. Such substances will foul the surfaces of warmth exchangers and will cause deterioration of the relevant heat transfer constant. they will additionally produce flow blockages, spread the flow within the parts, or cause fretting harm. Examples• Manmade refuse;• Detached internal components of components;• Tools and alternative "foreign objects" accidentally left when maintenance;• Mussels; Algae;• Leaves, components of plants up to entire trunks.

2. **Micro-fouling** Scaling or precipitation fouling, as crystallization of solid salts, oxides and hydroxides from water solutions, as an example, carbonate or atomic number 20 sulfate; Particulate fouling, i.e., accumulation of particles, generally mixture particles, on a surface; Corrosion fouling, i.e., unchanged growth of corrosion deposits, as an example, iron ore on steel surfaces; reaction fouling, as an example, decomposition or chemical change of organic matter on heating surfaces; curing fouling - once parts of the flowing fluid with a high-melting purpose freeze onto a sub-cooled surface; Bio-fouling, like settlements of bacterium and algae; Composite fouling, whereby fouling involves quite one foul ant or fouling mechanism.
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3. Precipitation fouling Scaling or precipitation fouling involves crystallization of solid salts, oxides and hydroxides from solutions. These area unit most frequently water solutions, however non-aqueous precipitation fouling is additionally noted. Precipitation fouling could be a quite common downside in boilers and warmth exchangers operative with H2O and sometimes ends up in lime scale. Through changes in temperature, or solvent evaporation or degasification, the concentration of salts might exceed the saturation, resulting in a precipitation of solids (usually crystals). The following lists a number of the industrially common phases of precipitation fouling deposits ascertained in apply to create from liquid solutions.
Calcium carbonate (calcite, mineral sometimes at t > ~50 °C, or seldom vaterite); Calcium sulfate (anhydrite, hemihydrates, gypsum);Calcium salt (e.g., beer stone); Barium sulfate (barite).

Solidification fouling :The crystallization of a pure liquid or one component of the liquid phase on a sub cooled heat transfer surface. The mechanism of fouling is complicated and no reliable techniques are available but there are means of reducing fouling. The methods mostly used to reduce fouling include use of filters and increasing the fluid flow to ensure turbulent flow.

4. Ulrich Kleinhansa, Christoph Wielanda et. Al Ash formation and deposition in coal and biomass fired combustion systems: Progress and challenges in the field of ash particle sticking and rebound behaviour, ELSEVIER, 2018. Reviewed on ash formation, ash particle transport and deposition during solid fuel combustion, with emphasis on particle sticking and rebound behaviour. a link between the viscosity and amount of liquid phase can be modeled from the chemical and physical structure

5. Akash Singh Vivek Sharma et. Al An overview of problems and solutions for components subjected to fireside of boilers, Springer (2018) Problems (such as agglomeration, slogging, fouling, caustic embrittlement, fatigue failure and high temperature corrosion) related to boilers and their possible solutions Pulse detonation wave technology, intelligent soot blower, and chemical treatment technology can be used to minimize the effects of fouling.

6. Ming-Jia Li, Song-Zhen Tang et.al "Gas-side fouling, erosion and corrosion of heat exchangers for middle/low temperature waste heat utilization: A review on simulation and experiment", ELSEVIER (2017) Simulations and experimental studies for the fouling, erosion and corrosion of heat exchangers Heat exchanger designs modifications.

7.Sagar Kafle , Seung HeeEuh et.al "Tar fouling reduction in wood pellet boiler using additives and study the effects of additives on the characteristics of pellets" Four different of control pellets without additives and three other samples each with 2% additives (dolomite and/or lime) The detailed performance and further economic study on varying rates of different additives.

OBJECTIVES:

1.The main objective of this project was redesigning and testing of boiler chimney to reduce fouling but also not to affect efficiency.
2. An attempt is made by material modification and by introducing flappers in the fifth section of the chimney. Flappers were properly installed at various angles like 10̊, 12̊, 15̊ and results analyzed by comparing all of them.
3. Material modification by selecting material which can reduce the chances of fouling.
4. Design modification of chimney by introducing the flappers and verification of the same through FEA and validating it with actual results given by customer end.
5. Transient Analysis to determine the time it took for the exit temperature to reach a constant value. (Time response).
6. Forced Convection Test for Different Air Flow Rates for checking velocity and pressure variation of flue gases so as to reduce the time of contact between gas particles and chimney surfaces.
7.To redesign the boiler chimney against fouling.
8. To enhance the efficiency of boiler by reducing the fouling creates in chimney.
9. To fabricate the chimney
10. Testing of the model under forced convection condition.
11. The gases from a furnace were used to simulate industrial flue gases.

SUMMARY OF REVIEW:-

The objective of this project was completion and testing of boiler chimney heat recovery heat money handler system that might be accustomed recover heat lost through flue gases. A plate kind heat money handler was employed in the look. The systems model was completed and tested underneath forced Convection conditions..

1. The objective of this project was completion and testing of boiler chimney heat recovery heat exchanger system that could be used to recover heat lost through flue gases and reduces the effects of fouling.
   2. Design calculation with specified working parameters in order to reduce the fouling on boiler chimney surface were validated and implemented successfully.
   3. The systems model was completed and tested under forced convection conditions. From the performance of the model the optimum operating conditions were obtained as:
   • Overall heat transfer coefficient U= 0.778kW/m2K
   • Amount of heat recovered Q =3.4 kW Effectiveness ε = 40%
   • T air in = 22.70C, T air out = 1940C, T g in = 4820C, T g out 2530C
   4. Attempts were made to reduce fouling by introducing flappers in the fifth section of the chimney. Flappers were installed at various angles like 10̊, 12̊, 15̊ and analysis is done on the results by comparing all of them.
   5. Analysis results showed that, the flappers installed at 15̊ is the best choice to reduce soot formation i.e., fouling which eventually increases the efficiency of the chimney and also the life of chimney.
   6. The effects of pressure and velocities of flue gases on the boiler chimney surface are analysed through finite element method, the results of which were validated with the actual with satisfactory results.

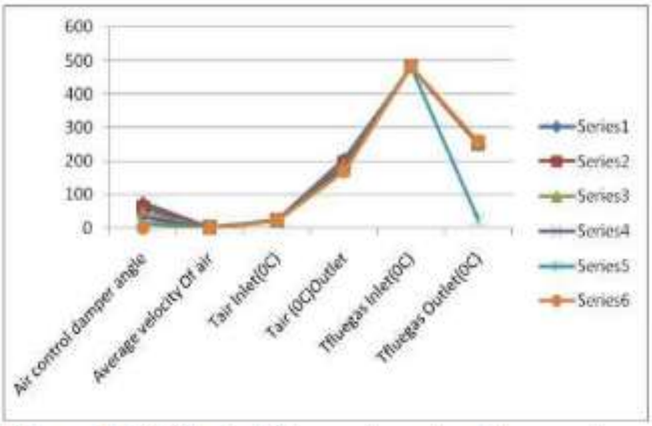

Figure 14: Effect of Flow rate against temperatures

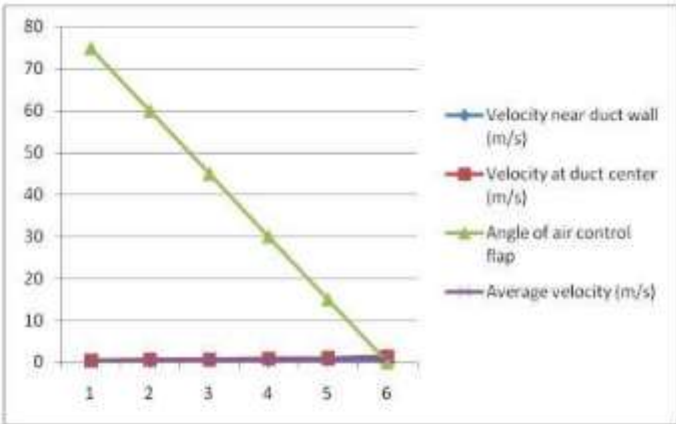

Figure 15: Effect of Air Flow rate

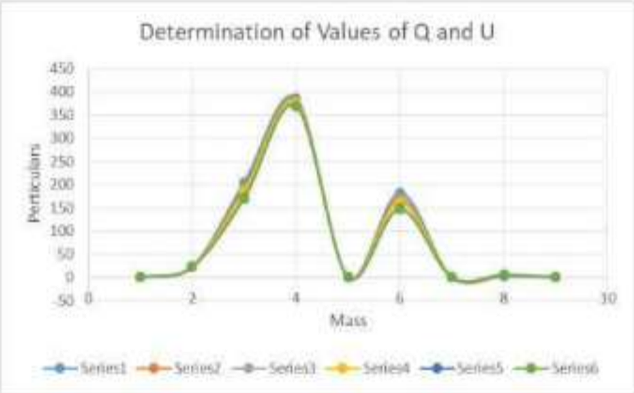

Figure 18: Determined Values of Q and U.

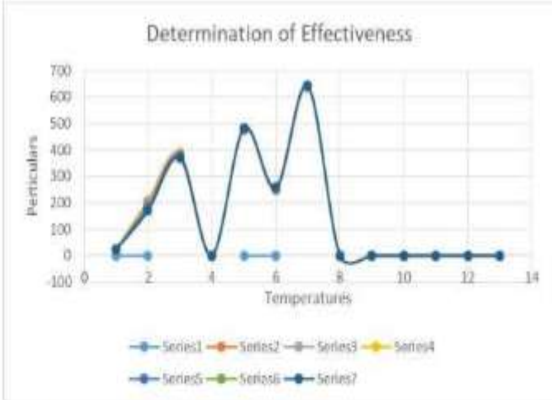

Table 19: Determination of Dwell Time and Normalized Time

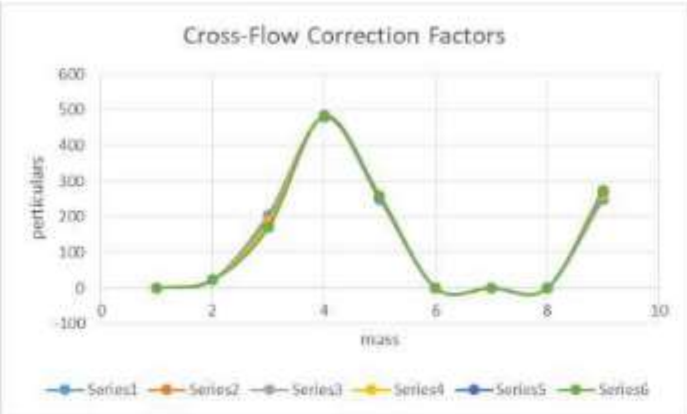

Figure 17: Cross flow correction factors

Figure 16: Transient test Results

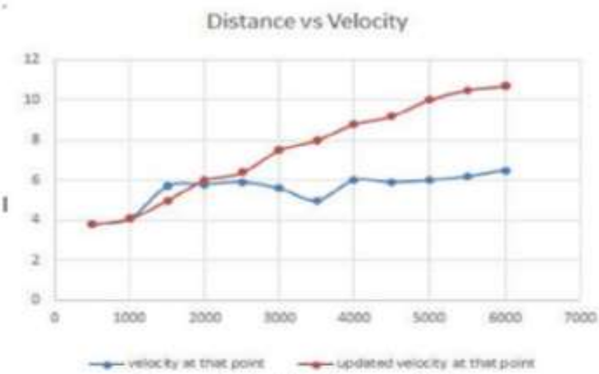

Figure 32: Graph 1- Distance vs Velocity.

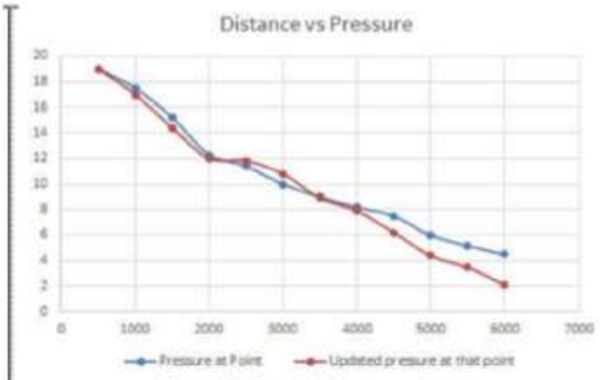

Figure 33: Graph - Distance vs Pressure.

FEA Results

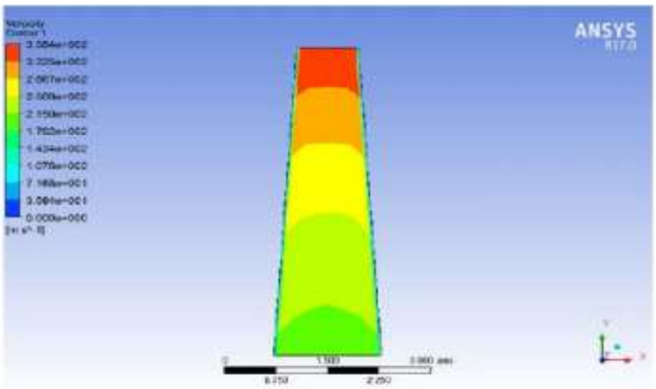

Figure 28: Velocity obtained in without modification

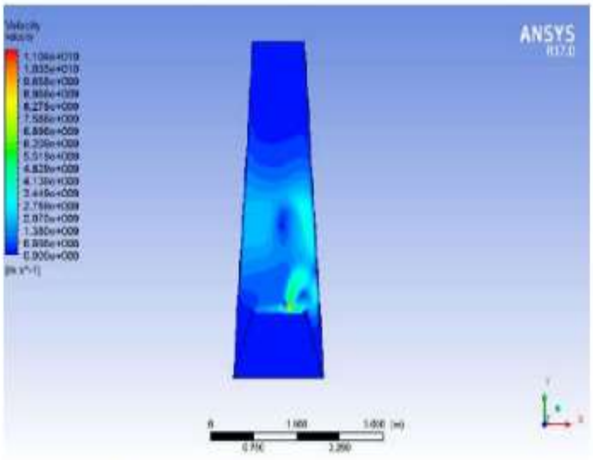

Figure 29: Velocity obtained in with modification

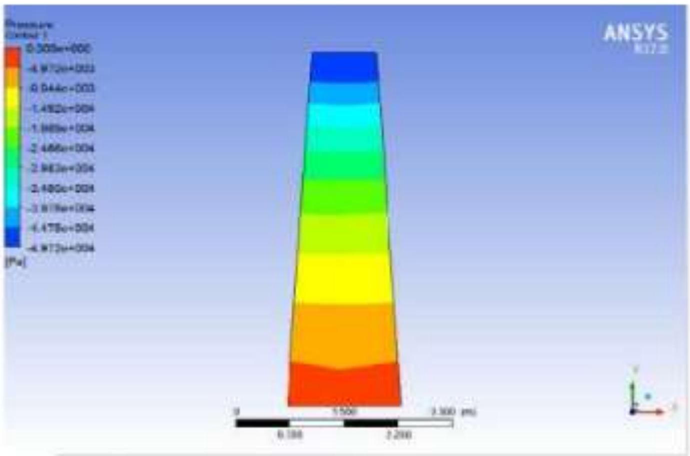

Figure 30: Pressure obtained in without modification

REFERENCES

[1] Ulrich Kleinhansa, Christoph Wielanda, Flemming J. Frandsenc, Hartmut Spliethoffa,b in ELSAVIER journal of Progress in Energy and Combustion Science, in paper entitled(4 February 2018) , "Ash formation and deposition in coal and biomass fired combustion systems: Progress and challenges in the field of ash particle sticking and rebound behaviour".

[2] Akash Singh, Vivek Sharma, Siddhant Mittal, Gopesh Pandey, Deepa Mudgal, Pallav Gupta in Springer International Journal of Industrial Chemistry (2018) in paper entitled, "An overview of problems and solutions for components subjected to freside of boilers".

[3] Ming-Jia Li, Song-Zhen Tang, Fei-long Wang, Qin-Xin Zhao, Wen-Quan Tao, in ELSEVIER journal, (2017) titled, "Gas-side fouling, erosion and corrosion of heat exchangers for middle/low temperature waste heat utilization: A review on simulation and experiment".

[4] Sagar Kafle a, b, Seung HeeEuh a, Lahoon Cho a, Yun Seong Nam a, Kwang Cheol Oh a, Yun Sung Choia, c, Jae-Heun Oh c, Dae Hyun Kim a, in ELSEVIER Energy Journal, (2017) "Tar fouling reduction in wood pellet boiler using additives and study the effects of additives on the characteristics of pellets".

[5] Lara Febrero, Enrique Granada, Araceli Regueiro and José Luis Míguez in Energy article (2015), "Influence] of Combustion Parameters on Fouling Composition after Wood Pellet Burning in a Lab-Scale Low-Power Boiler"

[6] R. K. Mishra, in Springer journal technical article, "Fouling and Corrosion in an Aero Gas Turbine Compressor", (2015).

[7] Suhas R Bamrotwar, Dr. V. S. Deshpande, in journal (2014) IOSR-JMCE, named "Root Cause Analysis and Economic Implication of Boiler Tube Failures in 210 MW Thermal Power Plant".

[8] K.T. Ajayi and A. A. Akande, in JETEAS (2012) paper published "Effect of Fouling on Heat Transfer Surfaces in Boilers".

[9] Kilkovský B., Turek V., Jegla Z. and Stehlík P.*, in 8th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics 11 – 13 July 2011, in paper published "Aspects of Fouling In Case Of Heat Exchangers With Polluted Gas".

[10] Mostafa M. Awad Mansoura University, Faculty of Engineering, Mech. Power Eng. Dept., Egypt (2011), in "Fouling of Heat Transfer Surfaces".

[11] Panayiotis Andreou, in his master thesis on "Behaviour, Analysis and Design of Steel Chimneys" (Oct 2011).

[12] Aleksandar M. Simonovic1, Slobodan N. Stupar2, Ognjen M. Pekovic3, in FME Transactions (2008) 36, 119-125, in paper published, "Stress Distribution as a Cause of Industrial Steel Chimney Root Section Failure".

[13] Mathew A. Eaton in 15th North American Waste to Energy Conference

[14] May 21-23, 2007 "Analysis of Boiler Fouling and Boiler Cleaning Methods at the Commerce Refuse-To- Energy Facility".

[15] K B MCINTYRE,Proc S AfrSugTechnol Ass (2002), "A Review of the Common Causes of Boiler Failure in the Sugar Industry".

[16] YiminZeng, Kaiyang Li, Robin Hughes and Jing-Li Luo, in I&EC Research journal in paper,(2018) "Corrosion Mechanisms and Materials Selection for the Construction of Flue Gas Component in Advanced Heat and Power Systems".

[17] Moni Kuntal Bora1 and S. kafle, International Journal of Advanced Research, (2014) “Performance Analysis from the Efficiency Estimation of Coal Fired Boiler”

[18] Rahul Dev Gupta, Sudhir Ghai1, Ajai Jain, “Energy Efficiency Improvement Strategies for Industrial Boilers: A Case Study”.