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Heat recovery analysis of boiler furnace using refractory materials

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ABSTRACT

Now a day failure of refractory material in boiler furnace which is applied for different sites and different applications is the major problem has been faced by boiler manufacturing industries and they are trying to solve this. Different reasons of failure can be inappropriate transportation problem and loose application of refractory, excessive temperature developed in shell, sigma phase embrittlement, failure of anchors, improper storage of material etc. The materials and its properties used for refractory are studied here with its different types. This report is related to thermal analysis of refractory which is 305 mm thick and temperature distribution at certain distance by using ANSYS software.3D Model is drawn in solid works and then imported to ANSYS for next analysis. By applying thermal conditions we get the results. This project is sponsored by Thermax where they want to get temperature distribution and surface temperature of ceramic paper which is on outer side of refractory facing to environment.

Keywords: *Refractory, Anchors, Boiler Furnace, Thermal Analysis etc.*

1. INTRODUCTION

Refractory is material that retains its strength at high temperatures and non-metallic materials having those chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above 1,000 °F (811 K; 538 °C).The applications of refractory materials are for furnaces, kilns, incinerators, and reactors. Where the temperature is to high to bare by material refractories are applied at such conditions to protect from getting damaged or burst. The material used in industry are of different types for different boiler as per temperature requirement.

For this case castable refractories are used**.** Refractory structures used in power boilers use stainless steel anchors for reinforcement. Failure of refractories in the form of cracks leading to falling off them were observed in operation. Often the refractories themselves are not the cause of failure rather the reinforcing metallic anchors were found to be the one. Wrong choice of material, inadequate design of refractory structure, over temperatures leading to anchor material deterioration, are among the main reasons for anchor failures.

The reason of refractory failure mostly due to transportation problem, as well as excessive temperature inside the furnace are observed.

Fig.1 Different Forms of Refractories

Fig.2 Refractory Inside Boiler Furnace

Fig.3 Refractory Failure inside Boiler

2. LITERATURE REVIEW

C.Soupramanien et al states that the present study analyse the refractory structure failure in the bull nose - hot face area of cyclone. Failed anchor rods made of AIS309 SS were analyzed. Sigma (s) phase induced embrittlement caused failure of anchor at the non-welded end. At the anchor-MS plate weld, poor quality of the weld was noted. Overheating from flue gas entry in the gaps caused by inadequate expansion joints resulted in damage to the backup insulation layers. At such high temperatures, the SS anchor-MS weld will have a lesser strength and weld failure occurred. Loss of anchor reinforcement resulted in falling of refractories. [1]

Mohammed Qazam Naser et al states that A pressure vessel is a container used to contain things at higher pressure this means that if can withstand greater than normal amounts of pressure without bursting. Pressure vessels are used to contain a multitude of things, including air, water, chemicals, nitrogen, and fuel. They are used in paper and pulp, energy, food and beverage, and chemical industries. Since the pressure in the vessel is high, it has to with stand both thermal as well as structural. The aim of this project is to design a pressure vessel whose sole purpose is to withstand the pressure of the substance stored in it. Modeling has been done in Pro-E modeling software and analysis is done using ANSYS. The dimensions of the vessel have been arrived by analytical calculations as per ASME standards. Finally the design calculations and the values obtained by analysis are compared to do the final design. The above results are verified in software by using ANSYS-14.5. The pressure vessel is analyzed for the thermal loads, pressure loads and combined pressure as well as thermal loads, also analyzed for induced stresses to show that the developed stresses and temperatures are within the controlled values.[2]

J. D. Gilchrist states this chapter tells us uses and properties of special refractories. Electrocast blocks, alumina, laboratory aluminosilicates, laboratory silica, beryllia, magnesia, thoria, zirconia, zircon, and silicon carbide are some of special refractories. Special refractories are mostly made from pure compounds rather than raw ores and the incorporation of fluxes for bonding is not so possible. Any temporary bonds which is added must be burned out in firing. Special refractories are often formed by slip casting. Very fine grinding to a few microns is needed and the particles are dispersed in slightly acid water. Such fine material leads to impermeable ware and assists the sintering process by which the particles are bonded together. This diffusion process continues very slowly in the solid state except at very high temperatures, so firing is carried out at temperatures to much higher than usual with ordinary bricks. The use of these special refractories is very limited, but can be used in researches and in nuclear technology, aircrafts, and rockets. [3]

V. Ashok Kumar et al presented the steam flow in steam boiler tubes is modelled with the help of PRO-E design software. The paper will focus on thermal and CFD analysis with different velocities (25, 30, 35& 40m/s). Thermal analysis done for the steam boiler by steel, stainless steel& brass at different heat transfer coefficient values. These values are taken from CFD analysis at different velocities. In this paper the CFD analysis to determine the heat transfer coefficient, heat transfer rate, mass flow rate, pressure drop and thermal analysis to determine the temperature distribution, heat flux with different materials. 3D modelling is parametric software Pro-Engineer and analysis done in ANSYS.[4]

D. Kondayya states that steam boiler is a closed vessel in which water or other fluid is heated under pressure and steam which is 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 paper a fire tube boiler is analysed for static and Thermal loading. The geometric model of boiler is created in CATIA V5 software as per the drawing in 2D. This model is imported to HYPERMESH through IGES format and FEA model with converged mesh is developed using shell elements. To this FEA model various loading conditions like design pressure, thermal loads and operating conditions are applied for solution. One of the supporting legs is arrested in all the directions and the other one is arrested only in X, Z-directions and all rotations. All these are created by using HYPERMESH and it is exported to ANSYS for solution to obtain the deflections, stresses. Those values that are obtained are correlated with material allowable values as per the ASME Section VIII Division 2[5]

Y. Venkat et al states that this paper discusses an improvement in shell refractoriness and dimensional stability of columnar grained (CG) low pressure turbine blade castings which is made up of Ni base superalloy by directional solidification process (DS). Two ceramic shell systems were adopted, called shell system I and II. Shell moulds were prepared by using ceramic slurries containing zircon flour as a filler material and colloidal silica as a binder. As compared to shell system II (zircon filler with colloidal silica binder and fine alumina), shell system I (zircon filler with colloidal silica binder) showed lower refractoriness. Shell system II showed flexural strength increases in both the green as well as in fired conditions. Shells made from shell system II showed about 13% higher green strength and 55% higher fired strength as compared to shell system I. Shell system II also exhibited superior self sag resistance up to 1625°C. Moulds prepared from this shell system yielded aeronautical grade casting with high dimensional accuracy even at a metal pouring temperature of 1550°C. Moulds from shell system I, on the other side underwent sagging even at metal pouring temperature of 1500°C, which leads to dimensionally unacceptable castings. The superior performance of shells prepared from shell system II can be ascribed to the presence of fine alumina in the shell. [6]

3. RESEARCH GAP

- Most of the literature papers are related to the boiler and refractories materials and its applications according to their uses. What are refractories, its classification, compositions are also maintained in many.
- The method of boiler analysis or pressure vessel analysis are found in some papers. Where the estimation of boiler design in software is done and then model is imported to software for getting solution.
- 3.There is no any paper which will properly give the failure reasons of refractory and thermal analysis of boiler furnace refractory whose inside surface is exposed to high temperature.
- This paper gives the material of refractory used in industries and the thermal analysis of boiler furnace. First the modelling is drawn in solid works and then temperature distribution is carried out by using ANSYS 16.0.

4. ORIGIN OF RESEARCH PROBLEM

The problem itself is asked by Thermax Ltd. Pune that the high flue gases are flowing inside the furnace with temperature of 1200ºc inside. The Furnace is fitted inside with refractory (AC 62 D and AC INS 45) is of 150 mm each and then outer surface is covered with ceramic paper of 5mm thick. The thermal analysis is carried out for the insulating part.

5. METHODOLOGY USED

- Defining problem and Literature review
- To study causes of refractory failure
- Create the model in solid works
- Import the geometry in ANSYS
- Apply boundary conditions and get thermal analysis
- Result and conclusion.

6. MATERIAL AND SPECIFICATIONS

- AC 62 D
- AC INS 135
- CERAMIC PAPER

A. AC 62 D

Type: It is type of 62% alumina brick
Nature of bond: Ceramic
Shaping: Dry pressed

Fig. No. 4 refractory bricks

B. AC INS 135

Type: Insulating bricks for 1350ºc service temperature.
Nature of bond: Ceramic
Shaping: Plastically moulded

Fig.No.5 Insulating Brick

C. Ceramic paper:

Produced by washing process

Fig.No.6 Ceramic Paper

7. STEPS TO SOLVE

- Understand the drawing given by company.
- To create 3D model in Solid works
- Create drafting for dimensions.
- Import the geometry to ANSYS 16.0
- Generate the mesh.
- Assign the name to parts that are drawn.
- Give the specifications of material
- Apply Thermal conditions
- Generate the solutions
- Get the temperature distribution values.

8. INTRODUCTION TO SOLI WORKS

The SOLIDWORKS CAD software is a mechanical design application software that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings for getting the proper view.

9. INTRODUCTION TO ANSYS

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, thermal, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. In this case we are using Ansys fluent.

10. INPUT CONDITIONS APPLIED

These are the boundary conditions to be given to the software for analysis:
Material used:
A. AC 62 D

- Thickness – 150mm
- Density-2550 kg/m^3
- Thermal Conductivity – 1.629 w/mk

B. AC INS 135

- Thickness – 150mm
- Density – 1050 kg/m^3
- Thermal conductivity – 0.3035w/mk

C. Ceramic Fibre paper

- Thickness -5 mm
- Density – 200 kg/m^3
- Thermal conductivity – 0.0429
- Outer dia of furnace:3540mm
- Inner dia of furnace:2930mmw/mk
- Vertical Length:9070mm
- Inside temp:1200°c
- Air velocity for static condition:1 m/s

11. FIGURES

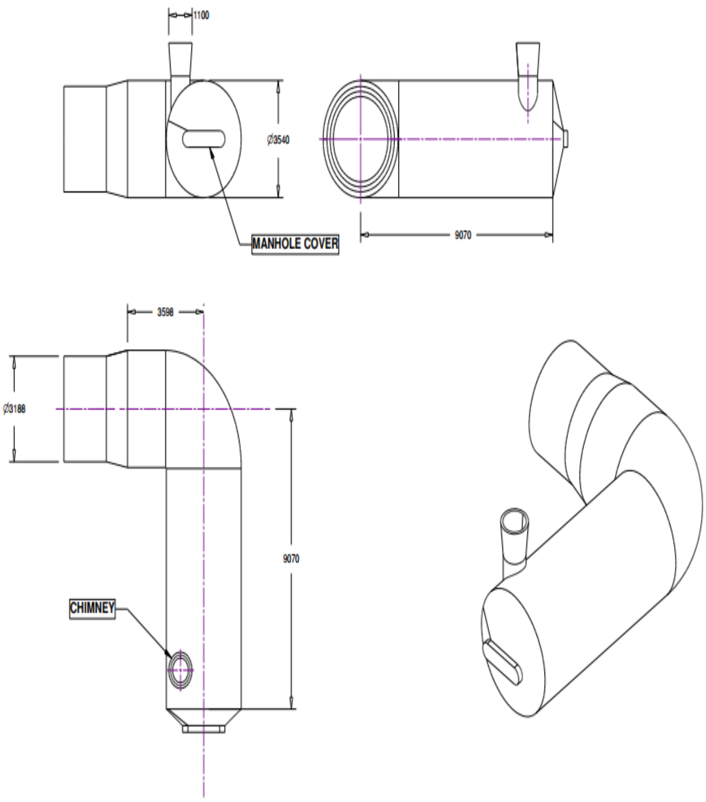


Fig.7 Drafting of Boiler Shell

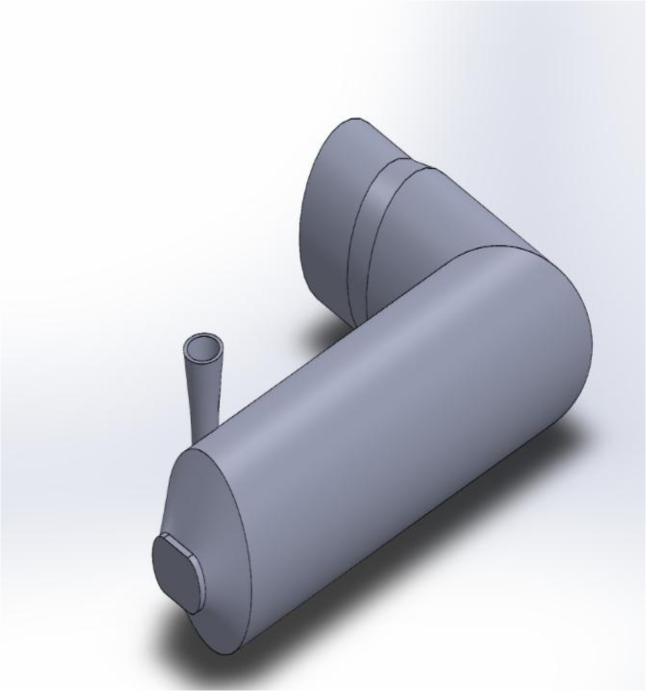


Fig. 8 Modelling RHS View

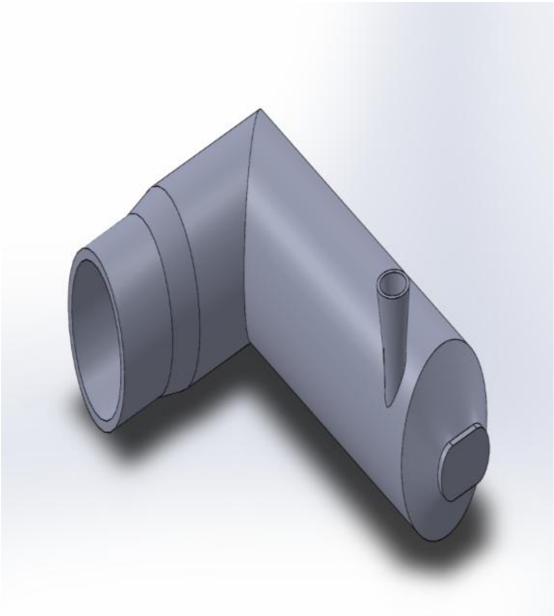


Fig.9 Modelling LHS View

12. IMPORRTED MODEL IN ANSYS

Table No.1

Bodies	**40**
Nodes	4967809
Elements	3128974
Mesh matrix	Skewness

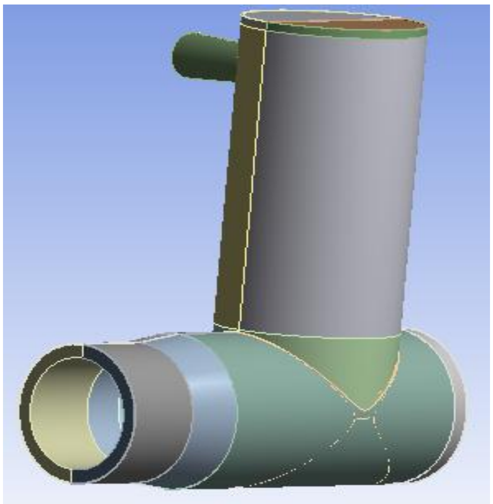


Fig.10 Imported Model

13. MESHED MODEL

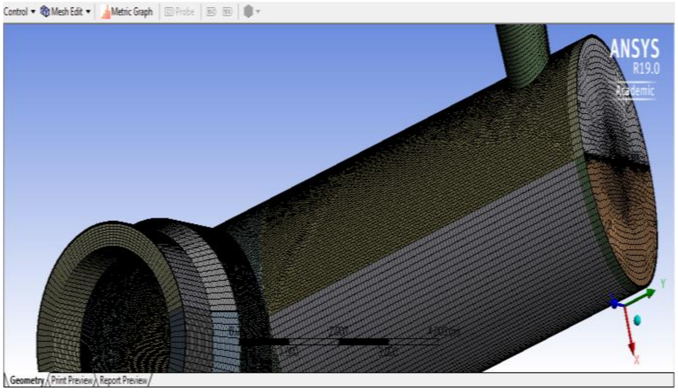
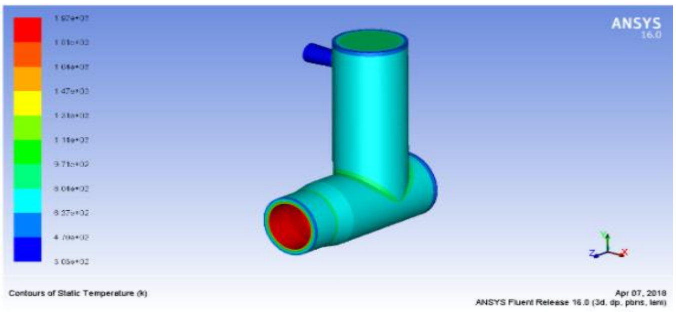


Fig.11 Meshed Model

Table No.2

Size function	Adaptive
Relevance centre	Coarse
Transition	Fast
Span Angle Centre	Coarse
Smoothing	Medium
Mesh	Centre

14. THERMAL ANLYSIS



15. RESULT TABLE

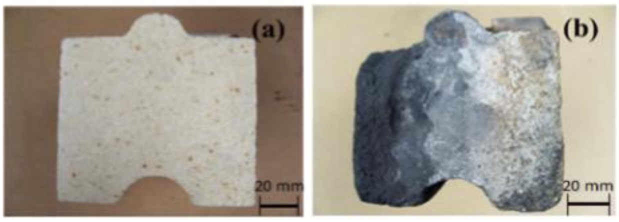
Table No.4

T1	1250	T11	896.4	T21	607.2
T2	1225.1	T12	863.5	T22	579.1
T3	1191.8	T13	834.9	T23	543
T4	1159.5	T14	803.8	T24	514.2
T5	1117.9	T15	767.7	T25	481.1
T6	1073	T16	732.5	T26	450
T7	1042.5	T17	721.2	T27	410
T8	1013	T18	698	T28	372
T9	971.9	T19	666	T29	312
T10	931.4	T20	636	T30	134

16. CONCLUSION

Following points are concluded from the project:

- Changes in refractory after long term use



- The reason of refractory failure found out is due to improper packaging and transportation.
- The refractory materials are properly understood.
- The thermal analysis is carried out on Ansys and temperature distribution in estimated.
- Surface temperature obtained is 134ºc.

17. REFERENCES

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