International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 03 | March - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Thermal Stress Analysis of Furnace Wall by Using Ansys Workbench

Mr. Batchu S Babu[1],Dr. V.N. Sulakhe[2]

[1]PGScholar Department of Mechanical Engineering Sandip University School of Engineering & Technology,Nasik ,India

[2]Asst.Prof. Dr. V.N. Sulakhe Department of Mechanical Engineering Sandip University School of Engineering & Technology,Nasik ,India

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Abstract: Furnaces are most usually utilized for melting of metals. Induction furnaces are more useful as no fuel is utilized. It is an issue to discover life of Induction Furnace wall under thermal condition. The induction furnace wall is designed of composite material which is one type of composite material. The heat loss and furnace wall breakage happen because of repeated thermal stresses. This study based around the subject of ultimate wall thickness for lowest heat losses over the walls of induction furnace. Three materials utilized for furnace wall i.e. Zirconium Oxide, Tungsten Carbide and Boron carbide are utilized. This investigation is done in Ansys Workbench programming and the outcomes are thought about. Temperature conveyance and thermal stress distribution fields of the induction melting furnace refractory wall were figured by utilizing ANSYS finite component investigation programming dependent on the physical description of its failure under thermal conditions.

Keywords: Furnace wall, Thermal analysis, Heat losses, Composite material, Ansys.

1. Introduction

Furnace is a term used to recognize a closed space where heat is connected to a body with the end goal to raise its temperature. An induction furnace is an electrical driven furnace utilized for softening and heating metals. Induction heating is broadly utilized in the present business, in activities, for example, metal solidifying, preheating for manufacturing tasks. The necessities of least electric power losses and environment security have turned out to be critical, that is the minimization of the heat losses. An Induction furnace is an non fuel used furnace in which the heat is connected by induction furnace of a conductive medium in a crucible put in a water-cooled exchanging current solenoid curl. The upside of the induction furnace is a perfect, vital it y proficient and well controllable liquefying process contrasted with most different methods for metal melting. Most current foundries utilize this kind of furnace and now also many iron foundries are supplanting cupolas with furnaces to liquidity cast iron, as the previous produce bunches of residue and different pollutants. Generally, there are heat dissipation by heat transfer and hence the enhancement in best composite material and investigation in thermal conductivity and the wall thickness of the composite material is required. The induction furnace gives a complex challenge to the specialists for the scientific displaying since it includes the diverse fields of material science together and its interaction isn't completely understood till date. The analysts around the world have given their own modeling technique and have confirmed with experimental outcomes with great accuracy.

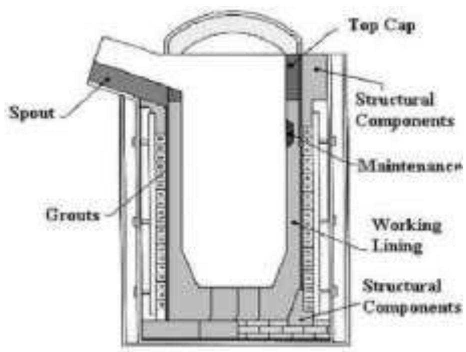

Figure1: Furnace used in industries[13]

2. Heat Losses in Furnaces

The Primary goal of this work is to do investigation of thermal conductivity and wall thickness of Induction heater wall material for least thermal losses during dissolving metal. Figure 1 demonstrates the different area for thermal losses in furnace.

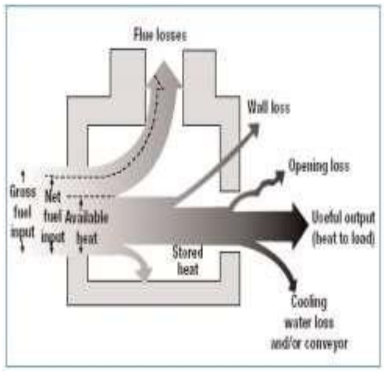

Figure2: Modes of heat losses [6]

These furnace losses consist:

- Heat dissipation from the wall exterior surface area.
- Heat losses due to radiation losses from entrance ,hot exposed areas, etc.
- Hot air moves by the cold air in filtration in to the furnace.
- Hot air moves by the more extra air utilized in the burner.

3. Analysis of Induction Furnace wall by Finite Element Analysis (FEA)

Finite Element technique is a numerical strategy for simplifying a differential or integral condition. It has been connected to various physical issues, where the overseeing differential conditions are accessible. The strategy basically comprises of expecting the piece wise consistent capacity for the arrangement and getting the parameters of the capacities in a way that decreases the error in the arrangement. Numerous physical phenomena in building and science can be depicted as far as partially differential conditions .in general, simplifying these conditions by traditional logical techniques for self-assertive shapes is relatively impossible. The finite element method (FEM) is a numerical methodology by which these PDE can be settled roughly. The FEM is a capacity/premise-based way to deal with comprehends PDE. FE are broadly utilized in diverse fields to solve static and dynamic issues − Solid or liquid mechanics, electromagnetic, biomechanics, and so on. Finite Element method (FEM) uses discrete components to acquire the estimated arrangement of the overseeing differential condition. The last FEM framework condition is built from the discrete component conditions. FEM depends on the possibility that isolating the framework condition into limited components and utilizing component conditions so that the assembled components represent to the first system.

4. Design and Analysis of Furnace Wall

Furnace wall models designed with the material selection of Zirconium Oxide, Tungsten Carbide and Boron carbide materials used to designed here four layers designed in wall sample. And compositions of materials vary in all four compositions. The practical use of finite element modeling is known as FEA which is best understood during the real problem solving. FEA has been broadly utilized by the automotive business. It is an extremely prominent instrument for configuration builds in the product development technique. It is imperative to comprehend the FEA basics and design technique, demonstrating systems, the inherent mistakes and their impacts on the nature of the outcomes to render FEA as an effective design tool. FEA is also used as a computational tool for carrying out engineering problem analyses.

a. *Modeling of Furnace wall Model*

Furnace wall sample designed in Ansys for optimizing minimum heat losses by applying three types of composite material with various composition of used material. Length of Block is 24 cm and width of block is 24 cm. upper- and Lower-layer thickness is 8 cm & middle layers thickness for both layers is 4 cm. figure 1 shows the design of furnace wall sample designed in Ansys.

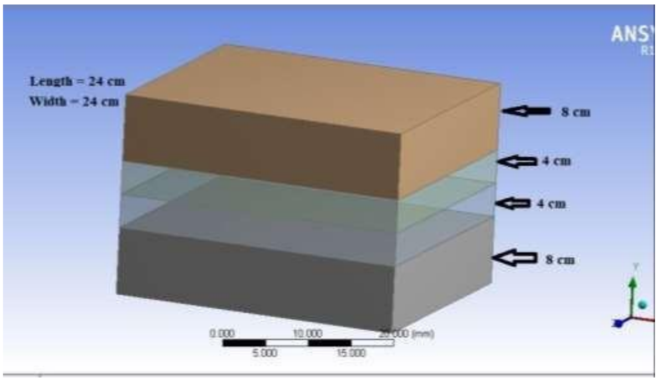

Figure3: Model of Furnace Wall in Ansys

b. *Applying boundary conditions*

After designing model of furnace wall with four layers, applied air convection temperature is 22 °C and lower layer select for applying 1600° C temperature for checking maximum or minimum heat transfer and thermal stresses.

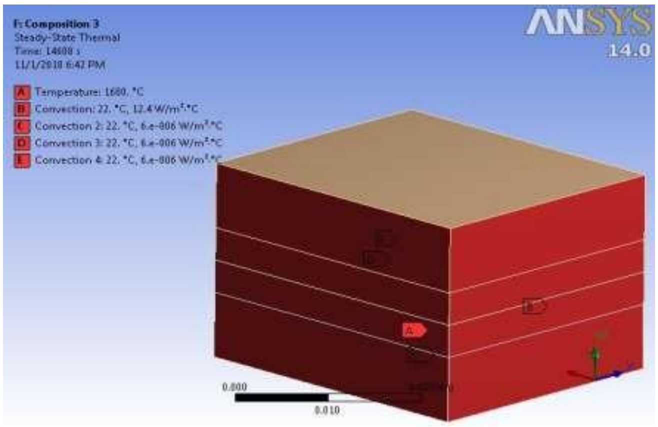

Figure4: Applying Boundary conditions of Furnace wall

5. Material Properties and Composition of material used in Furnace wall Layers

In this study three types of materials i.e. Zirconium Oxide, Tungsten Carbide and Boron carbide are used for analyzing minimum heat losses in furnace by using composite material in furnace wall. Properties of materials are described below in table.

Table 1: Properties of material

Materials	Density (Kg/m3)	Poisson ratio	Thermal Conductivity (W/Mk)	Young's Modulus (GPa)
Zirconium Oxide	6.15e-6	0.32	2.7	250
Tungsten Carbide	15.88e-6	0.22	88	686
Boron Carbide	2.52	0.21	42	470

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Table 2: Material Composition in percentage

Composition of material varies with different percentage of material used in all four layers and three types of composition used in study which is described in tables below.

Composition1:-

Table1: First composition of materials for furnace wall

Layers in Geometry	Zirconium Oxide	Tungsten Carbide	Boron carbide
Bottom Layer	100%	0%	0%
2nd Layer	40%	30%	30%
3rd Layer	20%	40%	40%
Top Layer	0%	50%	50%

Composition2:-

Table2: Second composition of materials for furnace wall

Layers in Geometry	Zirconium Oxide	Tungsten Carbide	Boron carbide
Bottom Layer	100%	0%	0%
2nd Layer	80%	10%	10%
3rd Layer	60%	20%	20%
Top Layer	0%	50%	50%

Sr. No	Compositions Vol%	Density (kg/m3)	Poisson ratio	Thermal Conductivity (W/Mk)	Young's Modulus (Gpa)
1	Zro 2100% Tungsten Carbide 0% Boron Carbide 0%	6.15e-6	0.32	2.7	250
2	Zro 280% Tungsten Carbide 10% Boron Carbide 10%	6.76e-6	0.29	15.16	315.6
3	Zro 260% Tungsten Carbide 20% Boron Carbide 20%	7.37e-6	0.27	27.62	381.29
4	Zro 240% Tungsten Carbide 30% Boron Carbide 30%	7.96e-6	0.25	40.08	446.8
5	Zro 220% Tungsten Carbide 40% Boron Carbide 40%	8.59e-6	0.23	52.54	512.4
6	Zro 20% Tungsten Carbide 50% Boron Carbide 50%	9.29e-6	0.21	65	578

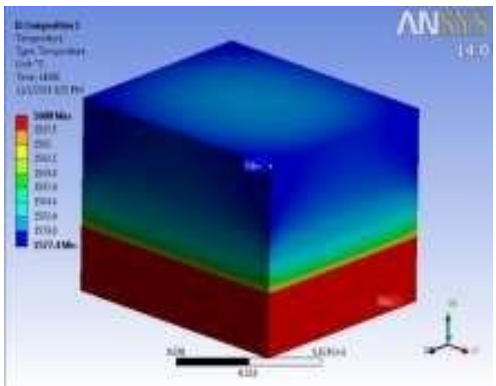
Composition3:-

Table3: Third composition of materials for furnace wall

Layers in Geometry	Zirconium Oxide	Tungsten Carbide	Boron carbide
Bottom Layer	80%	10%	10%
2nd Layer	60%	20%	20%
3rd Layer	40%	30%	30%
Top Layer	20%	40%	40%

6. Results and Discussion

As per Thermal analysis of Furnace wall with various compositions of material it is shown and explained in figures below.



- **Composition1**

Figure 5: Temperature flow in Wall

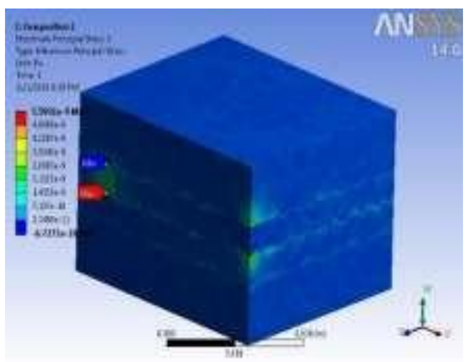


Figure 6: Thermal Stresses in Furnace Wall

- **Composition2**

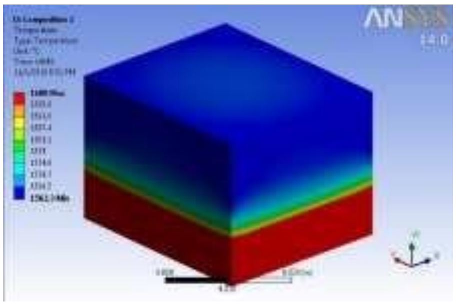


Figure 7: Temperature flow in Wall

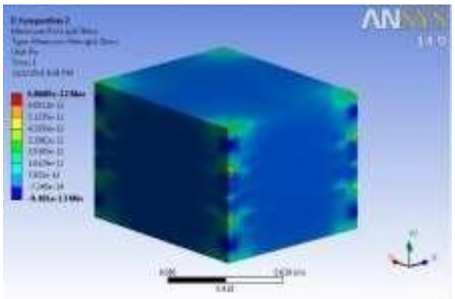


Figure 8: Thermal Stresses in Furnace Wall

- **Composition3**

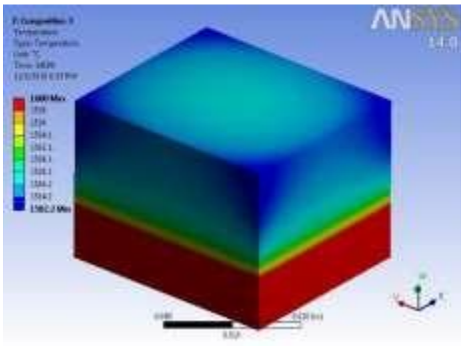


Figure 9: Temperature flow in Wall

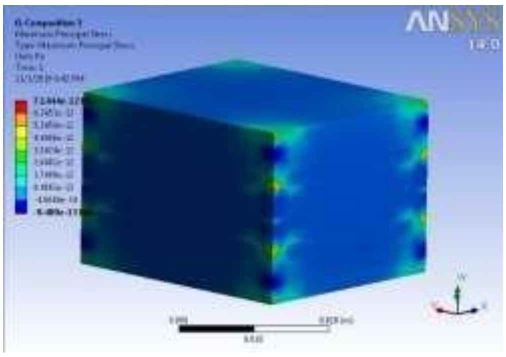


Figure 10 : Thermal Stresses in Furnace Wall

As per compositions of materials Maximum and minimum temperatures shows in table below.

Table 4: Temperature variations in furnace wall

Compositions	Maximum Temperature(°C)	Minimum Temperature(°C)
Composition 1	1600	1577.4
Composition 2	1600	1562.3
Composition 3	1600	1582.2

Table 4: Comparison of Results with various compositions of material

Figure6: Thermalstressesinfurnacewa

Figure8:Thermalstressesinfurnacewall

Compositions	Max Temp drop (°C)	Equivalent Von mises Thermal Stress	Max Principal Thermal Stress	Total Heat Flux
Composition 1	22.6	6.22E-09	5.37E-09	8.02E+05
Composition 2	37.7	1.40E-11	6.87E-12	2.56E+05
Composition 3	17.8	1.41E-11	7.14E-12	1.71E+05

In this work we will do the modification in material compositions of existing furnace wall. We have made the heat flow curve for composite material of furnace wall by FEA. Then we have made the comparison of materials composition sand temperature and thermal stresses and find the best optimum thickness for which minimum heat flow occurs over the wall.

Now for finding the optimum material composition of induction furnace wall for minimum heat loss, so compare the results of heat flow, thermal stresses maximum temperature drops for different compositions of wall as shown in table. From this comparison It is concluded that the optimum composition of furnace wall for lowest heat loss i.e. composition 2 because it shown the minimum temperature transfer outer wall. So as per low or minimum heat loss for furnace wall it is a suitable composition of material.

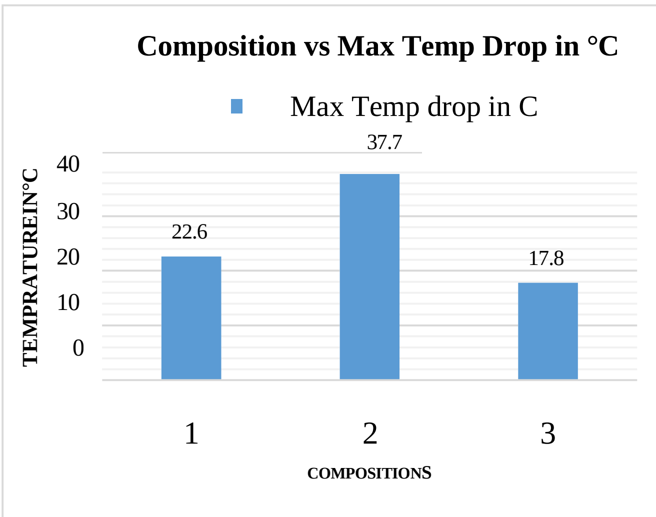


Figure 11: Temperature drop in wall

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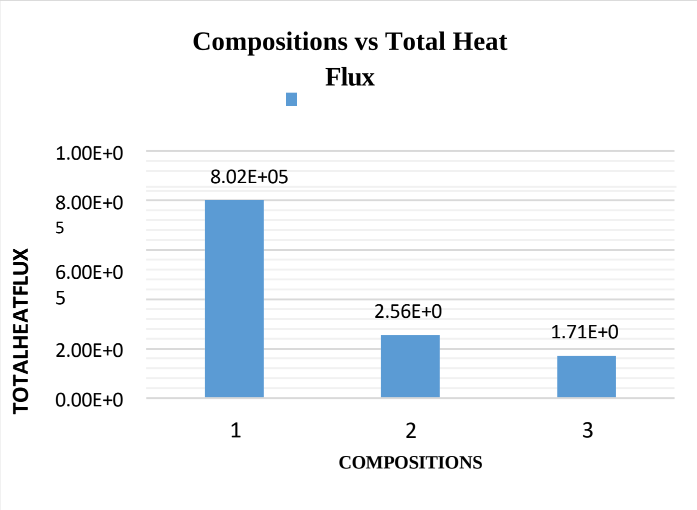

Figure 12: Heat flux in furnace wall

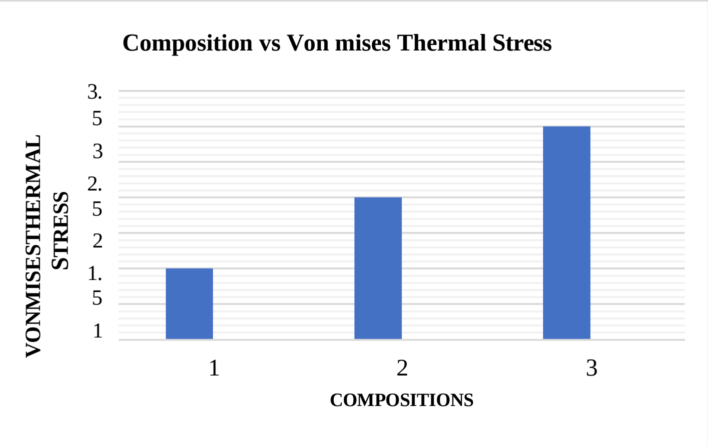

Figure 12: Thermal Stress of furnace wall

7. Conclusion

After per above study it is concluded that in this study, the Steady state Thermal analysis of the furnace wall for various thermal conductivity and three type of material compositions by using three different material i.e. Zirconium Oxide, Tungsten Carbide and Boron carbide in order to minimize heat loss.

The composite material plays an important role to decrease heat losses and offers a good temperature circulation outline. The analysis result shows that, heat flow in the process of melting decreases with decreasing thermal conductivity of wall material. So, I have found and confirmed the optimum thermal behavior of furnace wall made with compositions of composite material. As per results of steady state thermal analysis in ANSYS, in compositions 1, maximum temperature drops from 1600 °C to 1577.4 °C and in compositions 2, temperature transfer from 1600 °C to 1662.3 °C. In compositions 3 temperature drops from 1600 °C to 1582.2 °C. So as per study is concluded that composition 2 is the best suitable compositions for minimum heat losses for furnace wall.

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