JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

COMPACT ELECTRIC FURNACE

[1]Suprit A. Upadhye, [2]Anuja D. Yamajale, [3]Harshad R. Ekshinge, [4]Mayur P. Davani, [5]Prof. Prakash S. Gaikwad

[1]B.E. Student, [2]B.E. Student, [3]B.E. Student, [4]B.E. Student, [5]Assistant Professor

Department of Mechanical Engineering,

I.S.B.& M. College of Engineering, Pune, India

Abstract : The current work includes the design of Compact and portable Electric Furnace where its design is almost done in order to analyse and manufacture it. The design is done on the basis of the actual electric furnace used in the industry. The furnace is designed based on the induction concept and used the coil as the heater to melt the metals. The conceptual design of the furnace is done using Catia V5 software. Our aim is to melt the metal in less time and in more efficient way. So we design Electric furnace which is compact in size, portable and consumes low energy to melt the metal. For small production also it is profitable because it consumes less amount of energy as compared to other furnaces. The cost of our furnace is also less and profitable.

We are using tubular Nichrome coil as a heating element. Crucible used is a solid state container used to hold metal for melting in a furnace. It must have much higher melting point then that of metal being melted and it must have good strength even while hot. Our Crucible is made-up of Silicon Carbide Graphite which can withstand the high temperature, and has good resistance to chemical erosion and thermal shocks. External shell and shell cover used is made up of Mild Steel (M.S.) Sheet. A fire brick is used between eternal shell and coil to withstand heat. Special purpose bricks are used to hold the coil. Also ceramic fiber wool is used for insulation.

Key points: - Induction Furnace, Compact Furnace, ANSYS

I. INTRODUCTION

A Electric furnace is a device used for high-temperature heating. This high temperature heating is produced by coils by electric resistance. This high temperature is used for melt the metal for casting process.

The Electric coil is a tubular Nichrome coil with specific number of turns. An alternating current (A.C) passes through it and magnetic flux is generated within the conductor. The magnetic flux generated induces eddy currents that enable the heating and subsequently the melting process in the crucible

In many foundries big induction furnaces are available but for small production it's not profitable. It can consume more energy and sometime production cost is increased. In some foundries Cupola furnace is available to melt the metal. But in cupola furnace, it needs fuel to burn and it emits polluting gases which pollute the whole environment.

To overcome this problem its necessary to make the furnace which is compact in size, non-pollutant, fast and easy to operate and less energy consumable and also its profitable for small production.

The purpose of project is to melt the metal in less time and in more efficient way. There are many furnaces used in foundries such as Cupola Furnace, which consumes lot of fuel and emits harmful polluting gases, which are harmful to whole society. But Electric furnace is clean, non-polluting, and economical and uses very less amount of energy. We make Electric furnace which is compact in size, portable and consumes low energy to melt the metal

II. PROBLEM STATEMENT :

- In many Industries/Foundries different types of furnaces are used to melt the metal such as Cupola furnace and large Electric furnaces.
- In cupola furnace the problem is that it consumes lots of fuel and also it emits polluting gases after burning fuels and this gases are harmful to our society which can cause different diseases. Cupola furnace takes more time to melt the metal and is not clean and eco-friendly. Also it occupies more space in foundry.
- In Foundries some big electric furnaces are used to melt the metal but for small production it is not profitable and consumes high energy than that of production which is not profitable for the industry/foundry.

- To overcome this all the problems we designed the Electric furnace, which is compact in size, portable, clean and Eco friendly, and for small production also it is profitable because it consumes less amount of energy as compared to other furnaces. The cost of our furnace is also less and profitable.

III. OBJECTIVE :

The objective of this project is to design an efficient and controlled Electric furnace especially dedicated to Small Scale production/ Job Production which melts the metal in less time and economical way. We have made an compact and portable electric furnace with enough power output to melt the metal and maintain temperature with easy controllable electric panel. We have designed this furnace especially for small foundry production and also to make profitable production in economical way.

1. To design and develop a working prototype of Compact Electric furnace.
2. The main objective of project is to build compact size furnace for small scale production or for job production.
3. To save energy and consumption for small scale Casting production.
4. To perform Ansys and Simulation using Ansys Software.

IV. METHODOLOGY:

The simulation was used at the design stage to optimize the basic geometry of the furnace. The performances of the furnace were studied according to the heat distribution in the combustion chamber of the furnace. Then, the fluid domain, the boundary conditions, the initial guess, the meshing and the solver control were determined by the design parameters given (Table-3). In applying this process, there are several engineering software that were used; i.e. Gambit and Fluent 6.3.
Our current Project is Prototype based on Heavy duty Induction furnace which designed on the basis of ratio of 10:1 i.e. Dimensions are taken 1/10 for designing this furnace

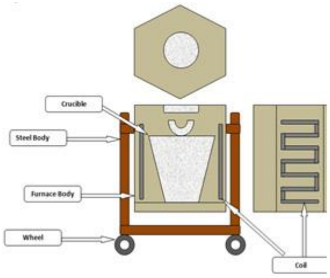


Fig. 1 Conceptual design 1

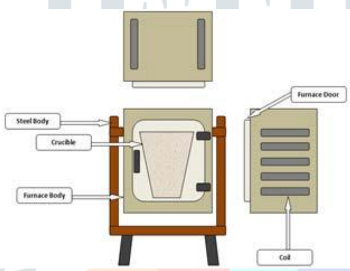


Fig. 2 Conceptual design 2

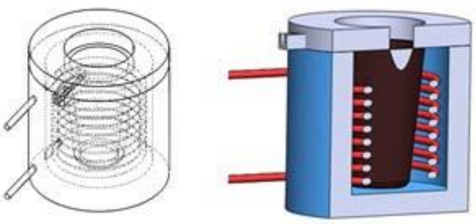


Fig. 3 Conceptual design 3

Table-2. Comparison between the conceptual designs 1, 2 and 3 with the datum.

No.	Criteria	Interest criteria	Concept 1	Concept 2	Concept 3	Concept reference
1.	Efficiency	5	-	-	S	D A T U M
2.	Commercial design	4	-	-	+	
3.	Cost	4	+	+	+	
4.	Heating mechanism	3	-	-	S	
5.	Heat chamber shape	5	+	S	+	
6.	Combustion flow	5	-	-	S	
7.	Mobility	4	+	+	+	
8.	Total +		3	2	4	0
9.	Total -		4	4	0	0
10.	Total overall		-1	-2	4	0
11.	Total actual		-4	-9	17	0

V. MATERIAL SELECTION :

The proper selection of material for the different part of a project is the main objective. In the fabrication of project. For a design engineer it is must that he be familiar with the effect, which the manufacturing process and heat treatment have on the properties of materials. The Choice of material for engineering purposes depends upon the following factors:

1. Availability of the materials.
2. Suitability of materials for the working condition in service.
3. The cost of materials.
4. Physical and chemical properties of material.
5. Mechanical properties of material.
6. Factor of safety

Following Materials are selected and used in this furnace:

1.Crucible : Crucible is a solid state container used to hold metal for melting in a furnace and is needed to withstand the extreme temperatures encountered in melting metals. We have chosen Silicon Graphite Crucible for our operations, having molten metal capacity of 6-8Kg. crucible dimensions are- Depth -300mm, diameter – 250mm.

2. External Shell and External Lid : External shell cover is made up of Mild Steel. External Shell lid is filled with cement which will resist the heat to come outside.

External Shell used is made up of Mild Steel Sheet. Shell is used to support whole assembly of furnace elements and it is also called as supporting member of furnace. Metal Sheet is rolled by rolling process to get proper round shape.

3. Fire Bricks : In an electric or natural gas fired kiln, more porous bricks, commonly known as "kiln bricks" are a better choice. They are weaker, but they are much lighter, easier to form, and insulate far better than dense bricks. In any case, firebricks should not spall, and their strength should hold up well during rapid temperature changes. This bricks also Protect outer shell from getting hot.

4. Grooved Fire Bricks : This bricks are special purpose bricks which are used to hold electric coil which is used for heating purpose in the furnace. This bricks are made up of clay and are light in weight. They are weaker , but they are much lighter, easier to form, and insulate far better than dense bricks.

5. Ceramic fiber wool : Ceramic fiber wool withstands temperature above 1000˚C. This wool is used for insulation purposes and It is widely used to hold or keep out high temperatures

6. Electric Panel : Electric Panel has following components used :

- On-Off Switch
- Solid State Relay - A solid-state relay is an ON-OFF control device in which the load current is conducted by one or more semiconductors. Like all relays, the SSR requires relatively low control circuit energy to switch the output state from OFF to ON, or vice versa
- Digital seven segment Display - Digital Display is used to indicate and control the temperature of furnace. It show the temperature of furnace while working by sensing the temperature in the furnace. For sensing the temperature in the furnace Thermocouple Sensor is used. Upper 7 segment display displays Actual temperature and lower 7 segment display displays setting temperature.

7. **Temperature Sensor :** For sensing temperature inside furnace we have used Thermocouple sensor. This is most commonly used temperature sensor and not so costly. And also accurate in temperature detection.

8. **Electric Nichrome Coil :** Electric Coil used is Electric Resistance coil made up of Nichrome material. This coil heats at high temperature by resisting electric current on the principle of Joules Heating. Nichrome coil has high resistance to electricity which helps in producing heat by means of joules law.

VI. WORKING PRINCIPLE :

The Electric furnace works on the principle of induction heating. The principle of induction heating is that a high voltage electrical source from a primary coil induces a low voltage, high current in the metal or secondary coil. Induction heating is simply a method of transferring heat energy.
The principle of induction heating is mainly based on two well-known physics phenomena :
1. Electromagnetic induction
2. The Joule Effect

1. Electromagnetic induction :

The energy transfer to the object to be heated occurs by means of electromagnetic induction. Any electrically conductive material placed in a variable magnetic field is the site of induced electric currents, called eddy currents, which will eventually lead to joule heating. The high frequency induction furnaces use the heat produced by eddy currents generated by a high frequency alternating field. The inductor is usually made of Nichrome In order to limit the electric losses.

2. The Joule Effect :

Joule heating, also known as ohmic heating and resistive heating, is the process by which the passage of an electric current through a conductor releases heat. Joule heating is generation of heat by passing an electric current through a metal.
Joule‘s law states that the power of heating generated by an electrical conductor is proportional to the product of its resistance and the square of the current.
$Q \propto I^2.R$

VII. WORKING :

The Electric furnace consists basically of a crucible, Electric resistance Nichrome coil, and shell. The crucible is formed from refractory material of Graphite, which the furnace coils is lined with. This crucible holds the charge material and subsequently the melt. The durability of the crucible depends on the grain size, ramming technique, charge analysis and rate of heating and cooling the furnace. The Electric coil is a tubular Nichrome coil with specific number of turns. An alternating current (A.C) passes through it and magnetic flux is generated within the conductor. The magnetic flux generated induces eddy currents that enable the heating and subsequently the melting process in the crucible.

The heart of the Electric furnace is the coil, which consists of heavy duty, high conductivity Nichrome tubing which is wound around the Crucible. The Single phase alternating current flows through the nichrome coil. The coil creates a rapidly reversing magnetic field that penetrates the metal. The magnetic field induces eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating.

The heated Nichrome coil is heated at very high temperature which increases the temperature inside the furnace and due to this crucible heats which melts the metal charge in the crucible.. Nichrome Coil heats up to 1000ºC – 1200ºC. As per requirement of melting point of metal we have to set the temperature of heating in the temperature meter.

E.g. We have to melt Aluminium, melting point of aluminium is 660ºC , then set the minimum temperature 660ºC and press the button, after reaching temperature of coil up to the melting temperature of melting metal, metal starts melting rapidly. Thermocouple sensor senses the temperature of furnace and gives the reading. When temperature of coil reaches up to set up temperature, the SSR circuit stops the heating At a time up to 7 to 8 Kg of metal is melted in this furnace with efficient way.

VIII. CALCULATIONS :

- **Crucible :**

$\rho = 4.84$ mg/m^3 ; $\alpha = 4\times10^{-6}$

k = 120 W/mK ; Cp = 750 J/kgK

…. (Material: Silicon Carbide Graphite)

Where, ρ = Resistivity
α = Coefficient of thermal expansion
k = Thermal Conductivity
Cp = Specific Heat

- Compressive Strength = 139.5 MPa

T_{max} = 1955 K (T_{melt} Crucible)

T_0 = 300 K

Due to heating, thermal stresses acting at bottom of crucible.

$\sigma_t = E*\alpha*\Delta*T$

$=1245\times4\times10^{-6}\times(1150\text{-}50)$

σ_t = 1165 MPa

σt is less than compressive strength of crucible material. So material is safe.

- Volume $= \frac{1}{3}\times h(R^2+R^*r+r^2)$

$= \frac{1}{3}\times 400(R300^2+300^*150+150^2)$

$= 21\times10^6\ mm^3$

Volume = 0.021 m^3

Taking **Aluminium** for calculations

T_{melt} = 660.3°C ; $\rho = 2.6898$ g/cm^3

$\rho = \frac{m}{v}$

$m = \rho*v = 2.6898\times21\times10^6$

m = 56.48 kg

- ***Capacity = 50 kg***

Heat required to melt metal at constant (P = C) $Q = mC_p(T_{melt}-T_{atm})$

$= 1\times0.903\times(660.3\text{-}30)$

Q = 569.16 KJ …. (1)

➢ ***90 turns of nichrome coil***

i. Length of coil at upper region = 160 cm

ii. Length of coil at middle region = 180 cm

iii. Length of coil at bottom region = 180 cm

- ***Total length of coil = 520 cm***

We have taken 5.2 m length of wire

- $R_{total} = R_1 + R_2 + R_3$

$$= \frac{\rho l_1}{A} + \frac{\rho l_2}{A} + \frac{\rho l_3}{A}$$

$$= \frac{\rho}{A}(l_1 + l_2 + l_3)$$

$$= ((1.1\times10^{-6})/\ (\tfrac{\pi}{4}(1.2\times10^{-3})^2)(0.16+0.18+0.18)$$

R_{total} = 5.04 Ω

Resistivity of Nichrome coil (ρ) = 1.1×10^{-6} Ωm
Resistance of wire = $^{\rho l}$ =$(1.1\times10^{6}\times5.04)/(\pi(1.2)^{2})$

R = 4.90 Ω

Heat produced by Joule effect in metal = I^2R
We supplied 5 A current,

= $5^2\times4.90$
= 122.5 W
H = 1.225KW

- **Time required to melt 1 kg of Aluminum**

$$= \frac{\text{Heat supplied to melt AL}}{\text{Heat supplied}}$$

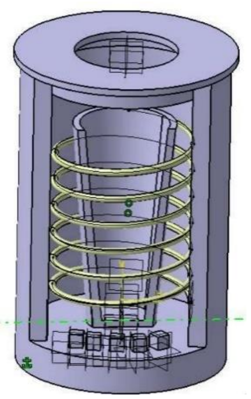
$$= \frac{\mathbf{569160}}{\mathbf{122.5}}$$

= 4646.2040 second

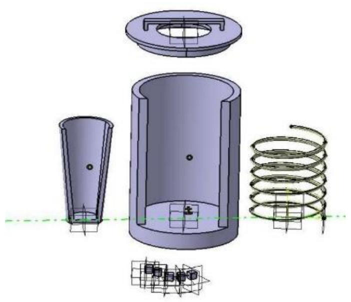
= 77.43 minutes

T = 78 minutes (approx.)

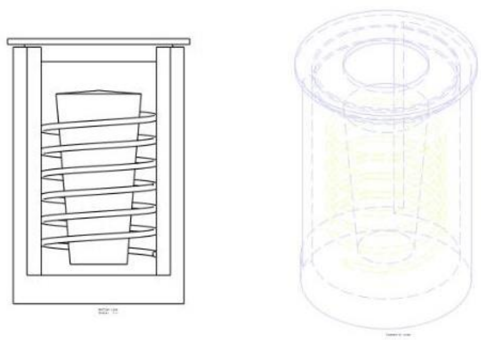
IX. CATIA MODEL AND ANSYS SIMULATION :



3D View

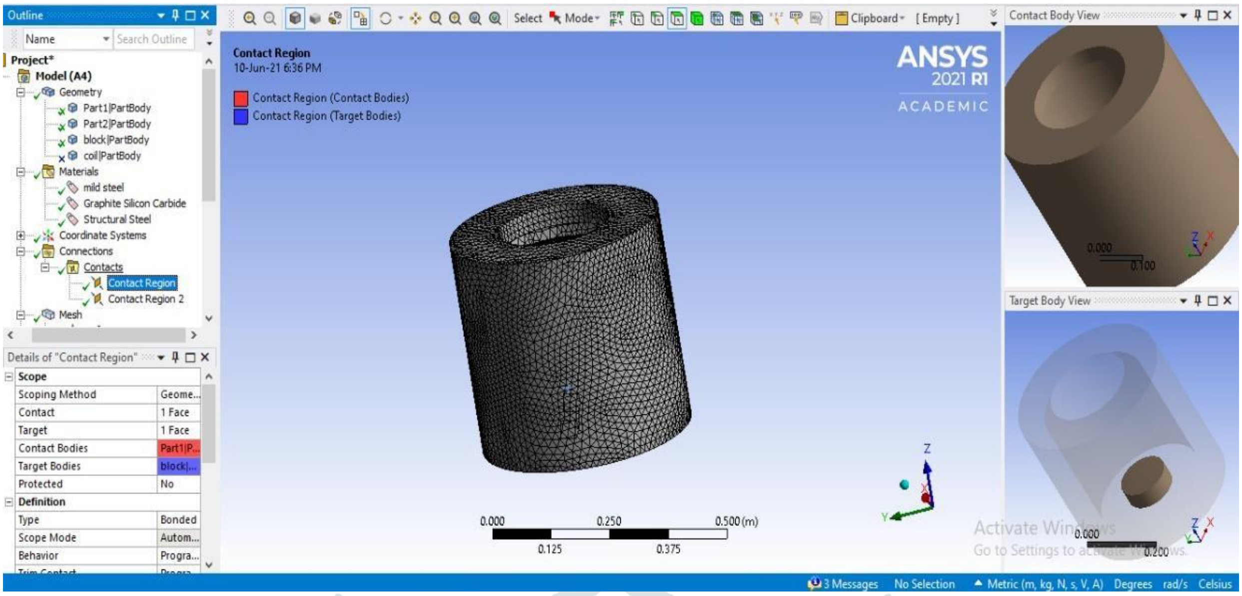


Exploded View

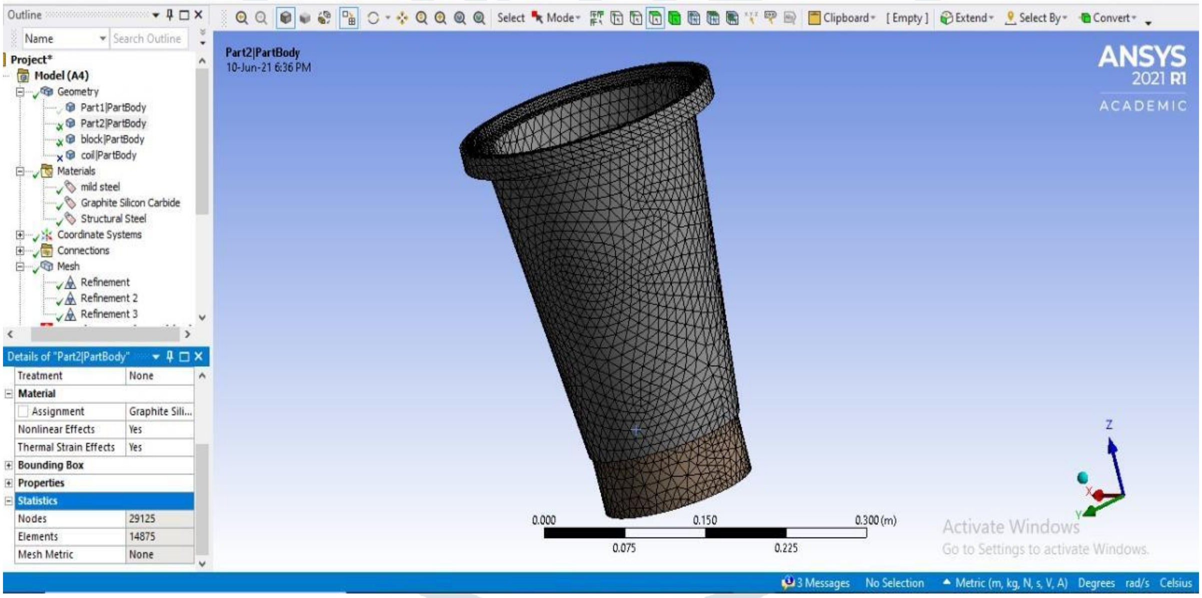


Drafting

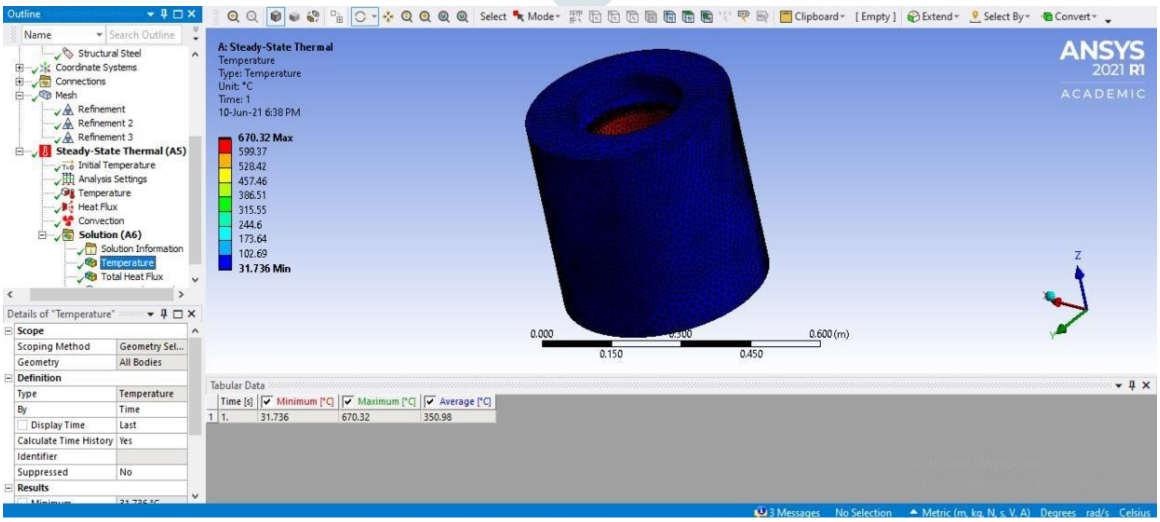
We Did Transient Thermal Analysis using **Ansys workbench :**



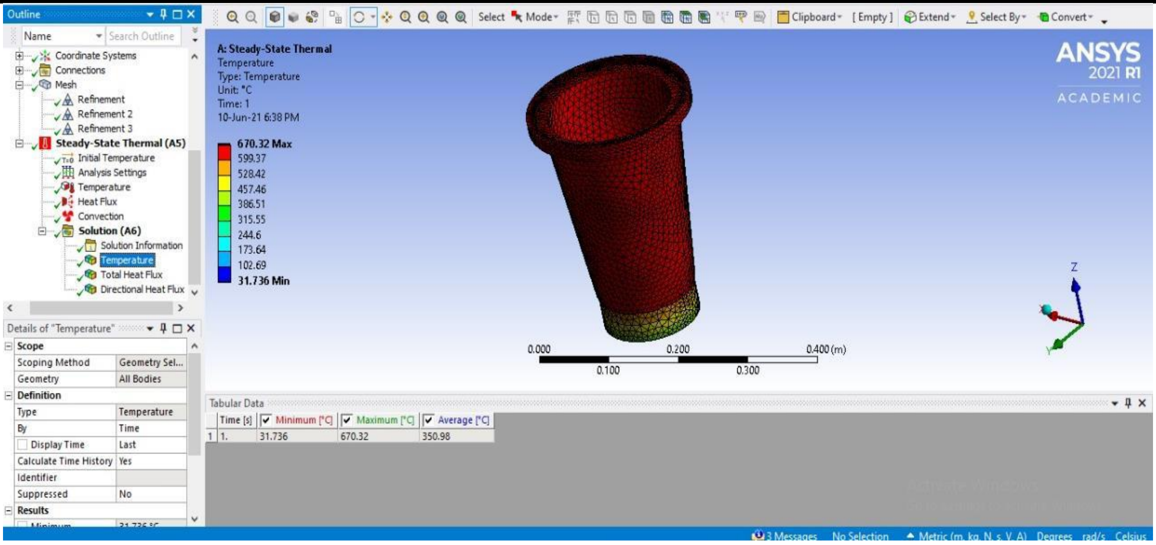
Mesh of External Shell



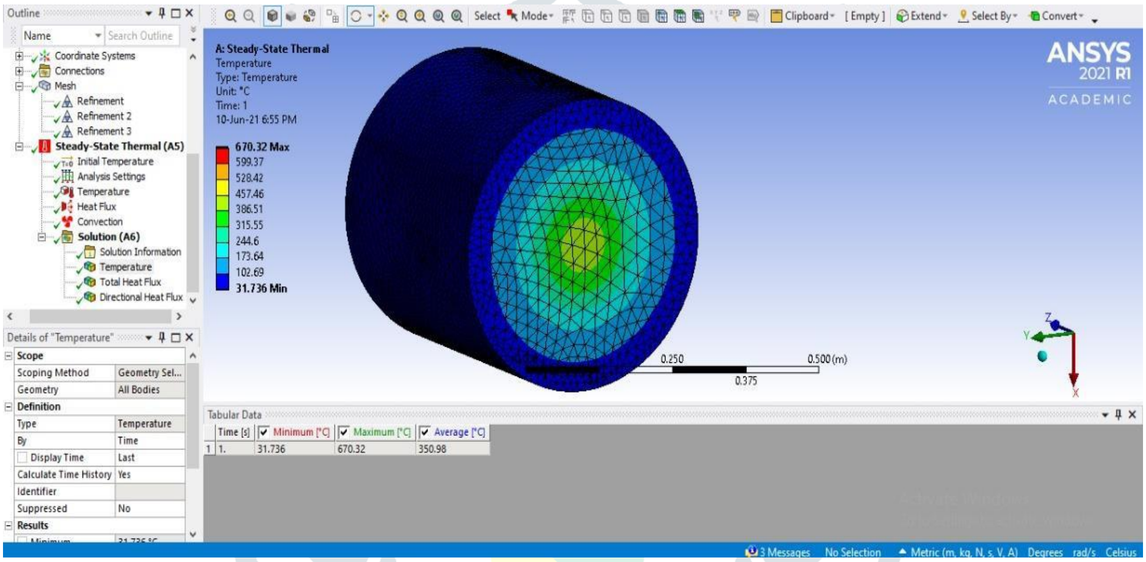
Mesh Of Crucible



Temperature Analysis Of External Shell



Temperature Analysis OF Crucible



Temperature Analysis Of Furnace

X. RESULT AND DISCUSSION :

The computational simulation from Ansys Workbench shows that at the beginning ofthe heating process, the airflow inside the combustion chamber is in random movement. Thereis no temperature increased involved. After a few minutes, the velocity becomes constant withincreasing temperature. Overall, there is a movement of the airflow inside the closed combustion chamber. With the best design selected, the heat convection in the combustion chamber is complete for the spiral shaped flow during heating process.

The Transient thermal analysis from Ansys Workbench shows that Maximum temperature is 670.32 degree Celsius and minimum temp.is 31.76 degree Celsius.
Based on the Calculations, it clearly shows this electric furnace takes less than approx. 78 minutes to completely melt 1kg of aluminium while the coal-fired stove furnace would easily take about 2 hours to reach the melting point of aluminium (660 °C).It saves moretime than the traditional furnace which uses simple coal-fired stove furnace made by small scaled local foundry. Therefore, it can be easily justified that this design of electric furnace has saved time and is definitely more efficient than using traditional means of melting by coalfired method.

XI. CONCLUSION :

The modified electric furnace was successfully designed based upon the conceptual design analysis by taking into account the appearance, the cost involved, the heating mechanism, the maximum temperature and the mobility of the furnace. It is found that from the simulation, the heat flow due to the convection completely melt the aluminum. **The processof melting 1kg of aluminum needed only less than 78 minutes**, which is faster as compared to traditional method. The cost of producing this modified design of electric furnace is much cheaper since the total cost of materials required for manufacturing this furnace is less. It givesthe most economical and affordable price for an efficient electric furnace to be used in the smallscaled industries.

Following are the brief summary of results carried out, under this project work:

1. It can be used for small production of casting, such as Batch and Job production

2. It can be used in small industries where batch and job production is more preferable. Itis designed as a portable one which can be used in various places.
3. The metal melts without using any fuel like coal, wood, etc., so there is no any pollutinggases and pollution.
4. It helps to obtain less effort uniform melting metal in less time.
5. The results indicate that the electric furnace had given better, accurate and fastermelting of metal when compared with other furnaces used in foundries.

XII. APPLICATIONS :

1. This Electric furnace works on the principle of induction heating which melts the metal in very less time. So this furnace is mainly made up for foundry works and casting works.
2. This furnace also can be used in Small scale industries who needs small production of casting in less time with profit.
3. The foundries where Cupola furnaces are used at that place this furnaces can be used by replacing it by investing one time for better profitable business.
4. In collages and technical schools for the study of casting process, and for different projects based on melting process this furnace will be used.
5. For small scale production and for job or batch production this furnace will be economical and profitable for small as well as large scale industries.

XIII. FUTURE IMPROVEMENT :

- Our current Project is Prototype based on Heavy duty Induction furnace which requires some minor changes in it as per our observation.
- This furnace does not have sensors which can identifies type of metal and its melting temperatures computerized automatically which will helps in automatic function so this sensors and computerized function can be installed in future.
- Now a days every Instrument can be operated using software or Android Remotely. A system could be implemented to this feature for remote and automated operation which will reduce manpower fatigue.
- In the current system, the user must have to ensure the state of metal present in the crucible. A monitoring system can be implemented to monitor and inform the user about the state of metal present in the crucible. (means metal is in solid form or in molten form)
- The current design for the prototype has the capability to melt metal upto melting point 1200ºC. In order to melt metal more than 1200ºC improving coil and other parts required.

XIV. REFERANCES :

[1] Tasnim Firdaus Ariff1 and Zairul Azrul Zakaria1,2 . NOVEMBER 2015 , Department of Mechanical Engineering, Politeknik Sultan Haji Ahmad Shah, Kuantan, Pahang, Malaysia. ENHANCED HEATING MECHANISM OF THE ELECTRIC METAL MELTING FURNACE IN TRADITIONAL FOUNDRY. VOL. 10, NO. 21,pp 1-3.

[2] Andrew Kurzawski, Ofodike A. Ezekoye, Michael Baldea, November 13-19, 2015,Thomas F. Edgar, COMPARISON OF MODELING APPROACHES FOR OPEN-FIRE HEARTH FURNACE HEAT TRANSFER, Houston, Texas, pp 6-9.

[3] Lei Shao 1,2, Qilin Xiao 1,2, Chengbo Zhang 1,2, Zongshu Zou 1,2 and Henrik Saxén 3,22 October 2020, Dead-Man Behavior in the Blast Furnace Hearth—A Brief Review, State Key Laboratory of Rolling and Automation, Northeastern University, Shenyang 110819, China, pp 2-4.

[4] J. N. Anderson, 1928 to 1953, Reverberatory Furnace Practice at Noranda,pp 1

[5] Reverberatory Furnace Practice at Noranda, January 2007, Design and Prototype Development of a Mini-Electric Arc Furnace, Department of Industrial and Prod. Engineering, University of Ibadan, Nigeria. pp7-9

[6] Amjad Asada,∗ , Christoph Kratzscha , Steffen Dudczig b , Christos G. Aneziris b , Rüdiger Schwarzea, 10 November 2016,Numerical study of particle filtration in an induction crucible furnace, a Institute of Mechanic and Fluid Dynamics, Technische Universität Bergakademie Freiberg, Germany, pp 4-6