Experimentation and Analysis of Heat Transfer Developed on Portable Induction Furnace

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***Abstract*- Now a days, the technology has influenced and also elevated by the extent to which it can easily harness and convert the available mineral resources as per requirement. for metal melting process we are using induction furnace , which uses the copper coil as heater to melt non- ferrous metals .This melting process in industries is costly for small operators or foundries as well as they have to buy that in bulk . So, this paper aims to make it first affordable for small operators or foundries, increased in efficiency and also some modification in shape and size of heating chamber of portable induction furnace.**

The design of this portable induction furnace is made by the use of CATIA software and also taken into account many important points such as heating mechanism in chamber, furnace efficiency, heat transfer rate, shape and size of crucible and mobility of furnace. By experimenting in the furnace we have found out that it takes approximately around 30-45 minutes for melting of aluminium completely at 660oC about a quantity of 250 gm.

INTRODUCTION

There are various kind of furnaces to melt the metal some of the furnaces which are commonly used are- basic oxygen furnace, electric induction furnace and immersion furnace. In every furnace heat transfer rate is the major phenomenon to enhance the efficiency of the furnace [1]. The portable electric induction furnace has good capacity, easy to handle, energy efficient .This furnace does not requires any kind of high quality and expensive fuels. As our main reason to build this furnace is for small operators or foundries therefore, the capacity of this furnace is upto 1 kg and also depending upon the density of the materials. A further purpose is to provide a Crucible which can be used in the furnace for melting the metal and then used for transporting the molten metal to the point of end usage [2]. In this portable induction furnace the graphite crucible ins surrounded by POP lining which has copper coil helically wounded around it After that again a POP lining is given about 4mm and beyond that it is filled with glass wool material. The insulating materials we are using in this furnace is Plaster of Paris (POP) and glass wool as their melting point is very high[3]. This whole setup is covered in with mild steel .The furnace is illustrated in figure below.

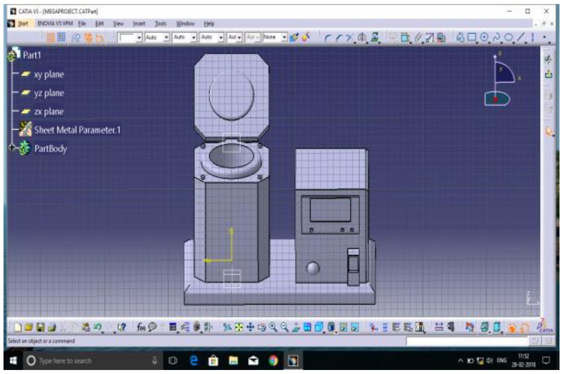
LITERATURE REVIEW

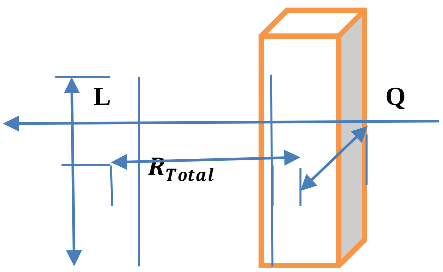
Prof. Muhammad Mansoor and Muhammad Shahid reviewed on the designing, efficiency, and stirring force of an induction coil for the processing of prototype as based nanocomposites. They have calculated stirring force of the coil. They determine using FEMM. The design coil yielded more than 60% of the total energy supplied into thermal efficiency by using stirring force <3Mn.

Prof. Dharmendra .K. Dadiya reviewed optimisation of wall thickness and thermal conductivity for minimum heat losses for induction furnace. They have done the study on steady state thermal analysis of the induction furnace for different thermal conductivity and thickness of furnace wall in order to minimize heat loss.

Prof. Yu Yanjun reviewed on the research and development of heat insulation material with low thermal conductivity in high temperature. They give various heat insulation materials with maximum efficiency in induction furnace. They mainly discusses characteristics of the current several heat insulation materials used.

Furnace description –





CALCULATION

$L_{POP1}=6\times10^{-3}m$

$K_{POP}=0.7992\ \frac{w}{m-k}$, [4]

$L_{COPPER1}=8\times10^{-3}m$

$K_{GLASSWOOL}=0.0372\ \frac{w}{m-k}$

$L_{POP}=10\times10^{-3}m$

$K_{COPPER}=386\ \frac{w}{m-k}$

$L_{GLASSWOOL}=45\times10^{-3}m$

$h_{a=50}\ \frac{w}{m^2-k}$.

$L_{MILDSTEEL}=1\times10^{-3}m$

$R_{pop}=\frac{L_{pop}}{K_{pop}\times A_{pop}}$

$=\frac{10\times10^{-3}}{0.7792\times0.0133}$

$R_{pop}\quad=0.964\ \frac{k}{w}$

$R_{glasswool}=\frac{L_{glasswool}}{K_{glasswool}\times A_{glasswool}}$

$=\frac{45\times10^{-3}}{0.0372\times0.0133}$

$R_{glasswool}\quad=90.953\ \frac{k}{w}$

$R_{mildsteel}\ \frac{1}{H_0\times A_0}$

$=\frac{1}{50\times0.0133}$

$R_{mildsteel}=1.503\ \frac{k}{w}$

$R_{Total}=R_{pop}+R_{glasswool}+R_{mildsteel}$

$=0.964+90.953+1.503$

$R_{Total}\quad=93.420\ \frac{k}{w}$

HEAT LOSS

1. Heat loss by conduction[5]

$Q_{loss}=\frac{T_{max}-T_6}{R_{Total}}$

$=\frac{1200-30}{93.420}$

$Q_{loss}=12.524\ \ W$

2. Heat loss by Radiation

$Q_{Radiation=}\sigma\times A_s\times(T^4-T_a^4)$

Where $\sigma=5.67\times10^{-8}\ \frac{w}{m^2-k^4}$

$A_s=n\times2\times\pi\times r\times l$

$=8\times2\times\pi\times3\times10^{-3}\times65\times10^{-3}$

$A_s=9.801\times10^{-3}\ m^2$

$Q_{Radiation=}5.67\times10^{-8}\times9.801\times10^{-3}\times[(1473)^4-(303)^4]$

$Q_{Radiation=}\ 2611.476\ \ J$

For steady state condition =10 min

=10×60

= 600 sec.

$Q_{crusible}=Q_{generated}-\frac{(Q_{conduction}+Q_{Radiation})}{TIme}$

$=700-\frac{2611.476}{600}$

$Q_{crusible}=695.624\ w$

Heat loss by Radiation for 10 min $=\frac{2611.476}{600}$

$Q_{Radiation}=4.352\ w$

$Q_{loss}=Q_{conduction}+Q_{Radiation}$

$=12.524+4.37$

$Total_{Qloss}\quad=16.897\ \ w$

$\eta=\frac{Q_{generated}-(Heat\ loss)}{Q_{generated}}$

$=\frac{700-16.897}{700}$

=0.9758=97.58%

At various temperature efficiency and heat loss

i) <u>T=1500°C</u>

$Q_1=\frac{1500-T6}{R\ Total}$

$=\frac{1500-30}{93.524}$

$Q_1=15.1717\ \ W$

$\eta_1=\frac{700-15.717}{700}$

$\eta_1=97.75\%$

ii) <u>At 1200°C</u>

$Q_2=\frac{1200-30}{93..524}$

$Q_2=12.510\ \ W$

$\eta_2=\frac{700-12.51}{700}$

η_2=98.20%

iii) At 1000°C

$Q_3 = \frac{1000-30}{93.524}$

Q_3=10.371 W

$\eta_3 = \frac{700-10.371}{700}$

η_3=98.51 %

iv) At T=800°C

$Q_4 = \frac{800-8.233}{93.524}$

Q_4=8.233 W

$\eta_4 = \frac{700-8.233}{700}$

η_4=98.82 %

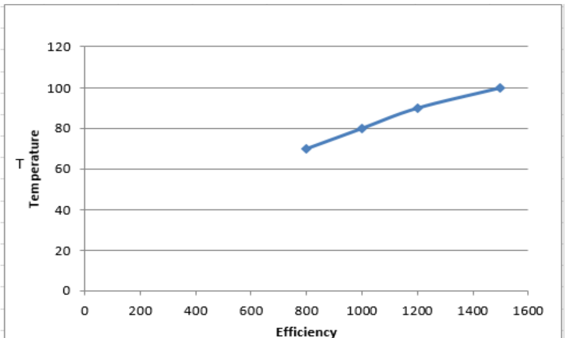
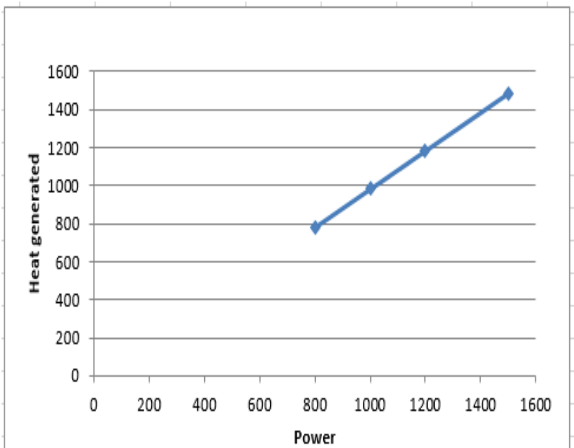


Figure - Temperature vs. Efficiency

Power generated and heat loss[3]

POWER (W)= Power –heat loss	Heat Generated(W)
1500-16.897	1483.103
1200-16.897	1183.103
1000-16.897	983.103
800-16.897	783.103



HEAT LOSS

Experimentation for various Material (At different melting point) and their heat loss

For P=700 w

$$T_{max} = 1200°C$$

$$Q_{loss} = \frac{1200-30}{93.420}$$

$$Q_{loss} = 12.524\ w$$

$$Q_{loss} = Q_{conduction} + Q_{Radiation}$$

= 12.524+4.373

= 16.897 w

For copper

$$T_{max} = 1085°C$$

$$Q_{copper} = \frac{1085-30}{93.420}$$

$$Q_{copper} = 11.293\ w$$

$$Q_{radiation} = \frac{Heat\ loss}{Melting\ time}$$

$$= \frac{2611.476}{15\times60}$$

$$Q_{radiation} = 2.901\ w$$

= 11.293+2.901

$$Q_{copper} = 14.194\ w$$

For Brass

$$T_{max} = 930°C$$

$$Q_{Brass} = \frac{930-30}{93.420}$$

Q_{Brass} =9.633w

$$Q_{Radiation} = \frac{2611.476}{14\times60}$$

$$Q_{Radiation} = 3.108\ w$$

=9.633+3.108

Q_{Brass} =12.741w

For Aluminium

$$T_{max} = 660.3°C$$

$$Q_{Aluminium} = \frac{660.3-30}{94.420}$$

$$Q_{Aluminium} = 6.675W$$

$$Q_{Radiation} = \frac{2611.476}{13\times60}$$

$$Q_{Radiation} = 3.348w$$

$$Q_{Aluminium} = 6.675 + 3.348$$

$$Q_{Aluminium} = 10.023w$$

For Zinc

$$T_{max} = 419.5°C$$

$$Q_{Zinc} = \frac{419.5-30}{93.420}$$

$$Q_{Zinc} = 4.169w$$

$$Q_{Radiation} = \frac{2611.476}{12\times60}$$

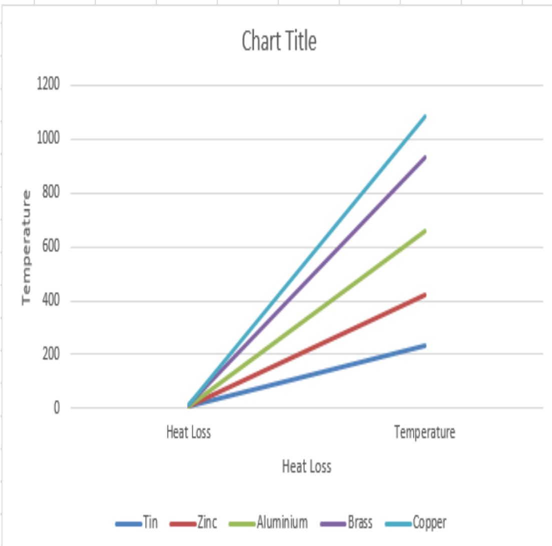
$$Q_{Radiation} = 3.627w$$

Q_{Zinc} =4.169+3.627

$$Q_{Zinc} = 7.796w$$

For Tin

$$T_{max} = 231.9℃$$
$$Q_{TIn} = \frac{231.9 - 30}{93.420}$$
$$Q_{Tin} = 2.161w$$
$$Q_{Radiation} = \frac{2611.476}{10 \times 60}$$
$$Q_{Radiation} = 4.352w$$
$$Q_{Tin} = 2.161 + 4.352$$
$$Q_{Tin} = 6.513w$$



FORMULAE USED:[5]

1. For resistance:

R=$\frac{L}{K\times A}$

2. For convection resistance:

R=$\frac{1}{h\times A}$

3. Area:

A=L× A

4. Efficiency:

$$\eta = \frac{Q_{generated-(Heat\ loss)}}{Q_{generated}}$$

5. Heat Loss:

$$Q_{loss} = \frac{\Delta t}{R_{Total}}$$

Or $Q_{loss} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{Total}}$

6. Heat transfer by radiation

$$Q_{Radiation} = \sigma \times A_s \times T^4$$

Where:

σ=5.67× $10^{-8} \frac{w}{m^2 - k^4}$

7. Surface Area

$$A_s = n \times 2\pi rl$$

CONCLUSION

Through this paper we have got a brief review about the induction furnace, its different types, modification. Safety measures required for proper functioning. By using modern techniques like insulating materials, etc. we have increase furnace efficiency and decrease heat loss. While designing a furnace cost is a measure issue that's why we reduces the cost of induction furnace by providing portability and low cost insulating material.

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