Design and Development of Portable Electrical Resistance Furnace

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Abstract: Casting is a very old technique used for making various parts. There are various types of furnaces used for melting metals and alloys, working on different principles. But we Designed & Developed portable electrical resistance furnace to melt at low cost, environment friendly Metals. Further, the furnace is intended to be able to cling to the melt for necessary amount of time. Both electrical and mechanical aspects of furnace design were presented. Finally, we fabricated a furnace of around 9 kW evaluations with working temperatures closer to 1200°C. Constructions of furnace process are discussed and its heating performance was tested by melting aluminium, brass and its alloys. Its operation was discussed to suit the heating requirements for various metals and alloys.

1. INTRODUCTION

Stated that for a nation to relate, it should be able harness, convert its mineral resources and fabricate its equipment and machines locally. On these lines, this paper its aimed to design and fabricate a to low-cost electrical resistance furnace to fulfil the metal melting requirements in the academic laboratories and research [1]. Metals components which are cast, are widely use in human activities. Designed and constructed an electrical arc furnace using Soderberg electrode technique to melt the 5kg of steel or cast iron scrap which is procured locally. Author performed on the furnace and confirmed that it takes 60minutes to heat up the furnace to 1200°C. To melt the 1st charge of 2kg steel/cast iron scrap at melting rate of 21.05g/min the furnace took 95min [2]. To fire ceramic products designed and constructed an electrical furnace with an automatic control [3]. Manufactured gas furnace using local source of material which had heating rate of 25°C/min and attained the temperature in the heating zone of 1000°C in burning pot and 700°C in the crucible [4]. Expressed that there are various heating methods are available. There might be numerous strategies for providing heat, delivered either by ignition of fuel or electric resistance. By considering cost, security, effortlessness and simplicity of fabrication authors have gone
for an electrical resistance with indirect heating provisions. Further authors extended their work for fabricating stir casting furnace for melting aluminium [5]. Presented the design and fabrication of stir casting setup for preparing the aluminium, magnesium and copper-based metal matrix composites. In this setup, a nano particle preheating attachment at the top of the furnace was incorporated. It is a direct result of red hot condition with consistent temperature of nano particles infused by push bar into the liquid metal. The stirrer rod composed by variety of speed (0-2000rpm) for blending purpose [6]. Designed a novel fast quenched stir caster for handling Al–SiC composites in fluid and semisolid state [7]. Designed an electrical furnace. Some authors considered its appearance method of heating, extreme temperature, included cost, weight static and furnace that can be easily carried or moved. From the simulation, it is found that convection of heat flow collects the entire space in furnace and aluminium is completely melted. To melt complete 1kg of aluminium it took 45minutes, which is almost 62.55% quicker contrasted with the ordinary 2hours from utilising convectional technique. The cost of producing this revised plan of electric heater is considerably less expensive since the aggregate cost of material expected to manufacture this heater is just RM 5160. It gives the most temperature and moderate cost for an effective electric heater (pro-efficiency 78.53%) to be utilized as a part of the little scaled craft industries [8].

2. MATERIALS AND METHODOLOGY
The following are the basic logical steps involved in the design and fabrication of the proposed furnace.

1) Deciding the furnace specifications: The furnace specifications consider the following points:
   - Power requirement
   - Temperature to be achieved
   - Sizes of crucibles that the furnace can hold.

2) Preparation of the list of elements and components required for the furnace: A list of items which are going to be part of the furnace are prepared.

3) Making design calculations: Design calculations need to be carried out to satisfy the specifications of the items in the above list.

4) Geometry and layout of furnace: Since it is a portable furnace, the geometry and feasibility of transporting it has to be checked.

5) Fabrication of the furnace: Incorporating all the contents and meeting the design specifications, the furnace is fabricated.

6) Seasoning of the furnace: This is done in order to remove the existing moisture content and make the furnace suitable for further use.

2.1 MODEL & DRAWING
Figure 1. Design of the furnace

Figure 2. Heating Coil

Figure 3. Heating coil arranged in the refractory bricks

2.2 **MAJOR COMPONENTS OF FURNACE**

Silica Bricks: Silica bricks or fire brick is a block of refractory silica material used in lining of furnaces and kilns. Here we are using 40% silica bricks. Each brick weighs up to 4.2~4.5 Kg.

- Good corrosion resistance of acid slag.
- Good stability under the high temperature.
- Low thermal conductivity.
- Good air tightness.
- True density of 2.35g/cc.

Commercially available silica bricks were purchased and arranged in circular way as shown in the figure below.
Ceramic wool: Ceramic wool or ceramic fibre blanket is made of ceramic needle like minute particles. It is light in weight, flexible, excellent in fire protection, contain very low thermal conductivity, and store low heat, thermal shock resistant and corrosion resistant. It is a commercially available in various densities, thicknesses, widths and lengths. The ceramic blanket used in the present furnace is 1 inch thick is shown in Fig.5

Properties of ceramic wool:
- Excellent handling strength.
- Excellent hot strength.
- Low thermal conductivity.
- Light weight.
- Thermal shock resistance.
- High heat reflectance.
- Excellent corrosion resistance.
- Excellent thermal stability.

2.3 SUPPLEMENTARY COMPONENTS:
Other components were used in order to fabricate the furnace. These components help in the improvement of strength and efficiency of the furnace. The various components used are:
1. Silica bricks
2. Ceramic wool
3. Thermocouple
4. Sheet metal cabin
5. Heat resistant wire
6. Refractory cement
7. Solid state relay+
8. Fully packed furnace
9. Auto transformer
Figure 6. Thermocouple

Figure 7. Sheet metal cabin

Figure 8. Heat Resistant wire

Figure 9. Refractory cement

Figure 10. Solid state relay+

Figure 11. Fully packed furnace

Figure 12. Variable auto transformer

2.4 METALS THAT CAN BE MELTED

| Metals          | Temperature in Degrees Centigrade |
|-----------------|-----------------------------------|
| Brass           | 900-940                           |
| Aluminum        | 660                               |
| Brass (Rod)     | 990-1025                          |
| Cadmium         | 321                               |
| Copper          | 1084                              |
| Gray Cast Iron  | 1127-1200                         |
| Ductile iron    | 1149                              |
2.5 WORK CARRIED OUT:

Initially we studied what type of heating element is suitable for our requirement by carrying out thorough literature survey. We then decided to use Kanthal A1 grade coil owing to its availability and economic feasibility. The heating element was then wound into to spring shape having diameter of 200mm, height of 180mm, pitch of 30mm and having 8 number of turns. Along with the heating element we procured two separate rods of 120mm length & 8mm diameter for making the necessary electrical connections. These two rods were soldered at the both ends of the heating element which is one at the top and one at the bottom. 20 silica bricks were purchased that had 40% silica in it. Grooves were cut in the bricks to accommodate the heating coil. Eight grooves were cut in the bricks by using the cutting machine. The bricks were then arranged properly in a circular manner and then polished on both side. The next step was to cover this assembly with the refractory cement to ensure stability of the furnace. Some bricks were cut to the smaller dimensions to create the base for the crucible. The remaining bricks were arranged as per the design. A sheet metal cabin of size 500mm×500mm×500 mm was fabricated to hold all the components in it. For lifting and transportation purpose, handles and wheels were attached to this sheet metal box. A lid is also provided to have easy access to the inner furnace. Insulation was ensured by using ceramic wool at the suitable places. This does not allow the heat to escape from the cabin. A groove is cut on the top of any one brick to insert the thermocouple. Finally, all the electrical connections are made to supply the power to heating element. Control units such as solid-state switch, auto transformer etc. are placed outside the cabin to prevent them from getting damaged due to extreme temperatures. After providing the power, testing of the furnace was carried out.
Final assembled furnace:

Figure 13. Furnace setup
### Table 2. List of components used

| Sl. No. | Components            | Quantity |
|---------|-----------------------|----------|
| 1.      | Fire clay cement      | 1 Bag    |
| 2.      | Silica bricks         | 20 Pc    |
| 3.      | Box fabrication       | 1 No’s   |
| 4.      | Thermocouple          | 1 No’s   |
| 5.      | PID Controller        | 1 No’s   |
| 6.      | Heat Resistant Wire   | 6 Metres |
| 7.      | Crucible              | 1 No’s   |
| 8.      | Heating Element       | 8 Turns  |
| 9.      | Glass Wool            | 4 mm²    |
| 10.     | Solid State Switch    | 1 No     |
| 11.     | Dimmer                | 1 No     |
| 12.     | Auto transformer      | 1 No     |

### Table 3. Thermal conductivity of various materials

| Sl. No | Material     | Component            | Thermal Conductivity |
|--------|--------------|----------------------|----------------------|
| 1      | Cement       | Fire clay cement     | 2.8 W/m °C           |
| 2      | Ceramic Wool | Ceramic Wool         | 0.25 W/m °C          |
| 3      | Crucible     | Crucible             | 6 W/m °C             |
| 4      | Putting Wool + Cement | Door | 0.25 W/m °C          |
| 5      | Silica Bricks| Silica Bricks        | 0.85 W/m °C          |

The find out the variation of thermal properties in the furnace following boundary conditions were applied as shown in Fig. 14

- To heating coil temperature of 1473K was applied
- For better insulation (i.e. heat flow q =0), was applied to the ceramic wood
- Convection boundary conditions were applied on the outer surfaces of the furnace with heat transfer co-efficient of 50e6 W/m² K and ambient temperature of 300K.

### 3. RESULTS OF FINITE ELEMENT ANALYSIS

The furnace was meshed having 25459 nodes and 11243 elements with default settings of mesh. Fig.15 shows temperature distribution of the furnace with the maximum temperature of 1718.3K and minimum temperature of 144.81K at the outer surface of the furnace. This indicates that inside part of the furnace will be maintained at the maximum temperature. This temperature distribution is clearly visible in the cut section of the furnace as shown in Fig 16. Fig.17 Shows heat flux for the furnace with the maximum heat flux of 2.56e5 W/m².
4. CONCLUSION

- A low-cost metal melting furnace for melting cast iron and its alloys is designed and fabricated. Both mechanical and electrical parameters were considered in designing the furnace.
- This furnace is suitable for melting and holding small quantities of metals whose melting points are less than 1473K like cast-iron, Al, Zn, and their alloys for laboratory and research purposes. The heating rate, melting rate are comparable to existing standard furnaces attaining a temperature of well over 1273K. The work is completed up to 95% with all necessary equipment and precautions.
- The approximate error between the FEA results and the experimental results (actual temperature achieved was 1693K) was found to be 1.5% which is acceptable.
5. REFERENCES

[1] Bala k 2005 Design analysis of an electric induction furnace for melting aluminium scrap, *AU Journal of Technology*, 2, P. 83-88.

[2] Oyawale F and Olawale D 2007 Design and prototype development of a mini-electric arc furnace, *Pacific Journal of Science and Technology*, 8 (1), P. 12-16.

[3] Bayindir R 2007 Design and construction of an electrical furnace to fire ceramic product, 66, P. 135-140.

[4] Abed E.J 2013 Manufacture and performance of gas furnace. *International Journal Metallurgical & Materials Science and Engineering*, 3 (1), P. 109-118.

[5] Sahoo M and Rout S and Patra R 2015 Design and fabrication of a stir casting furnace set-up. *International Journal of Engineering Research and Applications*, 5 (7).

[6] Sekar K and Allesu K 2013 Design of stir casting machine, *American Int. Journal of research in science, Technology, Engineering & Mathematics*, P. 2328-3491.

[7] Sahoo N Introduction to refractory and insulating material.

[8] Ariff T and Zakaria.A 2015 Enhanced heating mechanism of electrical metal melting furnace in traditional foundry, 10,9659.