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Design and construction of an electrical furnace chamber based on RERIH system for high temperature

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Abstract. One of the important parts of an electric furnace is the combustion chamber which is used to heat or melt materials. The chamber system which is based on the refractory, element, Rockwool, insulator, and Hebel (RERIH) has been successfully designed to reach high temperatures up to 1200°C. The refractory layer is designed from a mixture of trimortar cement and water. To obtain one side of the refractory, the composition of trimortar cement used is 2 kg mixed with 1 liter of water. The number of refractory sides needed for the electric furnace chamber is six sides, each of which is placed on the front, back, top, bottom, left side, and right side. To retain heat in the chamber, the refractory is covered with heat-resistant ceramic fibers (Rockwool). The Rockwool used has a density of 160 Kg / m³ and a thermal conductivity of 0.23 W / m.K. The maximum temperature that this Rockwool can withstand is 1260°C. The third layer as a heat barrier in the chamber is an insulator, which is a lightweight brick block made of a mixture of alumina. This refractory thermal insulation brick contains more than 48% alumina oxide so it has lower thermal conductivity and better heat insulation qualities. Meanwhile, the last layer is the placement of Hebel or light cement blocks made from lime which is usually used for building walls. This Hebel has dimensions (w x w x h) of 600 x 200 x 100 mm³.

1. Introduction

An electric furnace is a means of burning or heating or smelting a solid material using electric power. In general, materials that are burned or smelted in an electric furnace are ceramic, rice husks, shells, iron, steel, metals, glass, and other solid materials [1]. In general, the combustion and melting of solid materials are carried out in an electric furnace to keep the desired parameters achieved. In addition to temperature parameters, maintaining the pressure and purity level of the material is an important reason for the use of electric furnaces [2]. In terms of fuel sources, electric furnaces use electrical energy which is converted into heat energy. Furthermore, this heat energy will ripen or melt the solid material until it is desired [3]. Combustion with an electric furnace is the easiest and most efficient method of combustion because, in an electric furnace, it is usually equipped with adequate control equipment, such as a switch/ignition switch which also functions as a regulator (electric energy regulator), combustion program (burning time and temperature), thermocouple -pyrometer as an indicator of the temperature of the burn [4-6]. An electric furnace consists of several components



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including the combustion chamber (chamber), thermocouple, heating element, temperature measuring device (pyrometer), ventilation, control panel, indicator light, and fuse.

The heating room is also stated as a kitchen that receives heat for the combustion or smelting process. To be able to retain heat in the electric furnace room, the furnace layer is given refractory material. This material is a kind of fine powder mixture that is molded into a certain shape and withstands high temperatures (above 1200°C) to maintain its strength. In general, this refractory material is used in lining furnaces, clinics, incinerators, reactors, and also for the manufacture of crucibles. Apart from being fireproof, this material must be resistant to chemical treatment and be physically stable at high temperatures. Depending on the operating environment, the refractory material must also be resistant to thermal shock, chemically, and/or have a certain range of thermal conductivity and coefficient of thermal expansion.

Some electric furnaces that have been produced and are on the market today still have several weaknesses, including the heating element that is embedded in the heating chamber tend to not last long to high temperatures. This causes frequent cutouts in the circuit of these elements [7]. The insulator designed in the furnace wall also still conducts a lot of heat outside the system so that the heating system is inefficient and causes thermal leakage. Another weakness that is no less important is the control system and the room temperature reading in the furnace which is often inaccurate and does not match the actual heat [8]. Incidents like this are very fatal in the use of an electric furnace, where the material that is being heated or melted will experience a production failure. The integration of important elements in the electric furnace heating system really needs to be considered and analyzed in depth. The high thermal leakage and material contained in the furnace will cause huge losses, especially in the user's work safety. The uneven thermal expansion in the electric furnace will also lead to unequal heating or material melting resulting in product failure as well.

Limitations and shortcomings in electric furnaces can be overcome through several measures such as designing a temperature control system based on a thermal sensor with a heat resistance level exceeding the working temperature of the heating system. The element damage detector also needs to be inserted in the heating furnace room which is equipped with a real-time reporting monitoring system. The furnace space must be designed in proportion to the number of sets of heating elements, the thickness of the ceramic insulator, and the outer steel layer to obtain high efficiency of the furnace [9]. Likewise, with the installation of a hot blower, rotation speed, noise level, and the circulation system in the furnace room need to be considered high to get an energy-efficient electric furnace [10]. To optimize the heating or melting of the material, the rate of increase or decrease in temperature in the furnace is very necessary to be adjusted by utilizing the right blower.

2. Methodology

This research is focused on the formation of a coating system for the combustion chamber (chamber) so that it can withstand high temperatures up to a temperature of 1200°C. The layer composition of the chamber consists of a refractory, cotton fiber ceramic fireproof (Rockwool), refractory alumina brick (insulator), and light brick block (Hebel). The refractory layer is designed from a mixture of trimortar cement and water. To obtain one side of the refractory, the composition of trimortar cement used is 2 kg mixed with 1 liter of water. The number of refractory sides needed for the electric furnace chamber is six sides, each of which is placed on the front, back, top, bottom, left side, and right side. To be able to keep the heat in the chamber, the refractory is coated with heat-resistant ceramic fiber (Rockwool). The Rockwool used has a density of 160 Kg / m³ and a thermal conductivity of 0.23 W / m.K. The maximum temperature that this Rockwool can withstand is 1260°C. The third layer as a heat barrier in the chamber is an insulator, which is a lightweight brick block made of a mixture of alumina. This refractory thermal insulation brick contains more than 48% alumina oxide so it has lower thermal conductivity and better heat insulation qualities. Meanwhile, the last layer is the placement of Hebel or light cement blocks made from lime which is usually used for building walls. This Hebel has dimensions (width × height × length) of 600 × 200 × 100 mm³.

3. Result and Discussions

The refractory layer resulting from the invention is a mixture of trimortar cement and water. To get one side of the refractory, the composition of trimortar cement used is 2 kg mixed with 1 liter of water. Before mixing with water, trimortar cement is first sieved to separate fine cement from coarse cement. After obtaining fine cement, it is mixed with water and stirred until evenly and in the form of a pulp. This mixture is kept so that it is not too runny and wait up to 10 minutes before it is cast into the mold. When casting, the mold surface is made flat to maintain an even heat distribution in the chamber. After being cast, the refractory is dried in the sun for 28 days. After it is completely dry, the refractory is ready to be installed into the electric furnace. The refractory model that has been designed is shown for the six sides of the chamber space as shown in Figures 1 - 5 below:

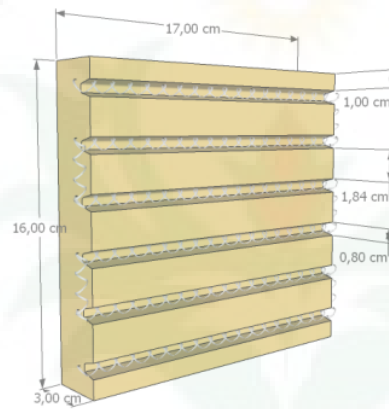


Figure 1. Rear side refractory design and dimensions

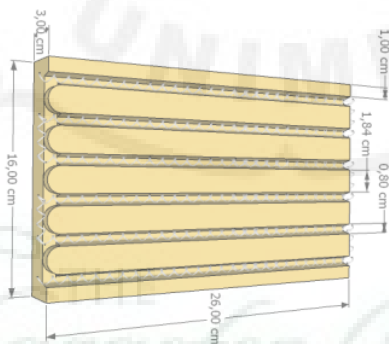


Figure 2. Left side refractory design and dimensions

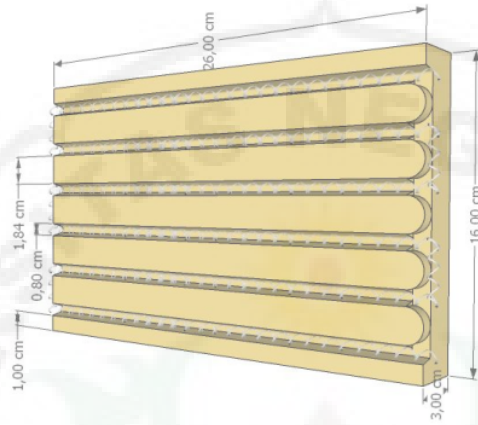


Figure 3. Right side refractory design and dimensions

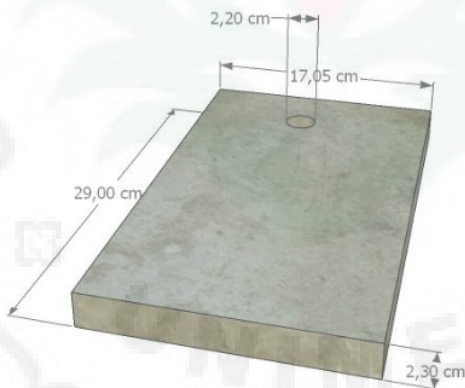


Figure 4. Topside refractory design and dimensions

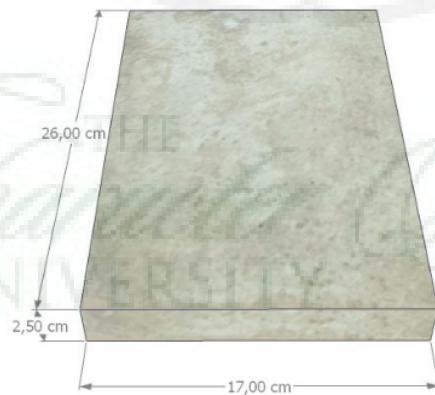


Figure 5. Bottom side refractory design and dimensions

3.1 Rockwool Lining

After the refractory is arranged in a cube shape, the outside of the refractory is covered with a refractory ceramic fiber cotton (Rockwool) with a thickness of 1.5 cm. This fireproof cotton wrapped covers the entire outside of the refractory completely

3.2 Insulator Lining

A lightweight brick insulator made of an alumina mixture is used as a heat insulator. This brick mold is used in the third layer of the electric furnace chamber which is directly adjacent to the inside with ceramic fiber cotton. A total of six bricks were used to cover the six sides of the chamber (left, right, top, bottom, front, and back).

3.3 Hebel Lining

The final layer of this chamber is a lightweight concrete block made of several materials such as cement, lime, fly ash, and other chemical compounds. The size and thermal conductivity of the lightweight bricks used in this invention are $600 (w) \times 200 (h) \times 100 (l) \text{ mm}^3$ and 0.13 W / m.k , respectively. While the Hebel compressive strength used is approximately 3 N / mm^2 . As it is known that the Hebel used is a type of concrete that is very easy to find on the market because it is very often used as a wall for tall buildings. The use of Hebel brick as the coating for the electric furnace chamber is designed to be something new and is offered in this invention because it is very easy to obtain and shape.

3.4 Whole Composition of Chamber

After each element is designed and formed, the next step is to unite each element to get a complete furnace chamber. The arrangement and shape of the electric furnace chamber proposed in this invention are shown in Figure 6.

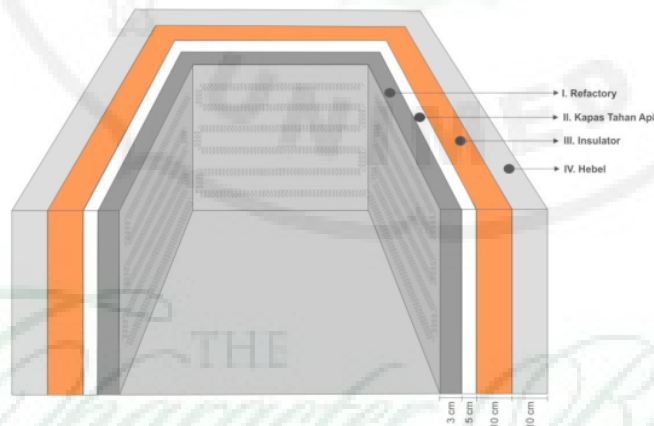


Figure 6. Lining elements and electric furnace chamber shapes are proposed in the present invention. It can be seen in Figure 17 that the chamber element lining consists of four layers of varying thickness. Seen in the image of the arrangement of the heating elements implanted in the left, right, and rear refractory

3.5 Electric Furnace Full Overview

Electric Furnace Full Overview which is a combination of refractories, electrical systems, temperature detectors, casings, indicators can be seen in Figure 7. It can be seen that the furnace control system is at the top which is equipped with air circulation (fan). While the temperature sensor in the form of R type thermocouple is placed at the top of the furnace which is connected to the chamber. To ensure that the furnace can be moved to another room, the furnace system is equipped with wheels so that it is easy to move.



Figures 7. Electric Furnace overview

3.6 Temperature Increase Rate of Chamber

Observation and test chamber of electric furnaces have been carried out through chamber temperature treatments ranging from the initial temperature of 57 °C to 1200 °C. Based on observations, the increase in the rate of increase in temperature is as shown in Figure 8. Based on the observations it is known that from the initial temperature (57 °C to 300 °C) there is a very fast increase in temperature in space following the face of the exponent. Meanwhile, the temperature increase from 300 °C to 1200 °C can be reached in an interval of about 8 hours 2 minutes 36 seconds. So that the rate of increase in temperature in the room when the observation is made is 1.87 degrees per minute. In addition to information on the increase in the rate of increase in temperature in the room, it is known that there is no leakage of temperature in the room, this can be seen from the plot generated by the temperature (T_{SV}) and readable temperature (T_{PV}) program. These two temperature temperatures are mutually exclusive so that there is almost no temperature difference caused by these two settings [11]. Based on the data and phenomena shown in the graph in Figure 8, it is known that this designed electric furnace chamber has high efficiency.

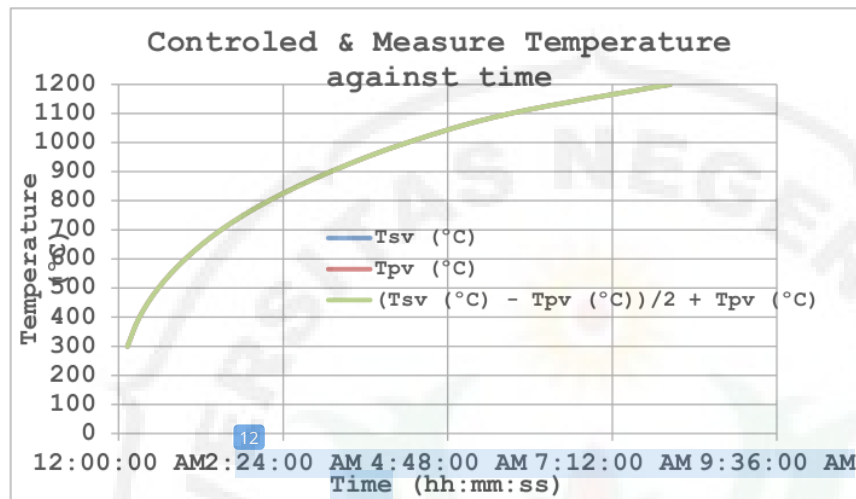


Figure 8. temperature increase rate of electric furnace chamber from 57 °C towards 1200 °C.

4. Conclusion

The furnace lining system has been successfully designed to operate at high temperatures (up to 1200 oC). The arrangement of the lining room consists of refractory as the first layer, cotton fiber ceramic refractory (Rockwool) the second lining, refractory alumina brick (insulator) as the third lining, and lightweight brick blocks (Hebel) as the outer lining. The refractory lining is designed from a mixture of trimortar cement and water. To achieve one side of the refractory, the composition of the trimortar cement used is 2 kg consisting of 1 liter of water. The number of refractory sides formed for the electric furnace chamber is six sides which are placed respectively on the front, rear, top, bottom, left, and right sides. To be able to keep heat in the chamber, the refractories are coated by heat-resistant ceramic fibers (Rockwool). The Rockwool used has a density of 160 Kg / m³ and a thermal conductivity of 0.23 W / m.K. The maximum temperature that can reach this Rockwool is 1260 oC. The third layer as a heat barrier in the chamber is an insulator, which is a lightweight brick block made of a mixture of alumina. This refractory thermal insulation brick contains more than 48% alumina oxide so it has lower thermal conductivity and better heat insulation qualities. Meanwhile, the last layer is the placement of Hebel or light cement blocks made from lime which is usually used for building walls. This Hebel has dimensions (width x height x length) of 600 x 200 x 100 mm³.

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