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RESEARCH ARTICLE

# HIGH SPEED INFRARED SOLID STATE HEATING FURNACE

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**ABSTRACT**

This project is designed to improve Electrical versus Thermal efficiency. We have used infrared penetration heating system to improve efficiency up to 95% thermal efficiency and 100% electrical efficiency. We are going to construct a furnace model to improve our system by reducing the weight factor of the furnace by changing the forming procedure of the furnace casing by using of composite insulation material. A real fabrication model is to analyze IR heating system. IR lamps will be used to provide heat. From the furnace, the temperature is sensed by the thermocouple, which is based on the principle of See back effect. Temperature acquired from the thermocouple is indicated on the screen of the computer. The computer will also compare the temperature acquired with the set temperature and control action if any will be done by the solid-state relay that avoids instantaneous heating. The infrared (IR) heating has the potential to be used for solutionizing of metal forgings with benefits of reduced energy consumption, increased productivity, and improved microstructure and mechanical properties.



## INTRODUCTION

### General

A furnace is a device used for heating. The term furnace is used exclusively to mean industrial furnaces which are used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns.
The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking. The benefits of infrared (IR) heating, including short heat-up times, good temperature control, and energy efficiency. Significantly higher heating rates and better temperature control is possible than in conventional convection furnaces. Since heating is on a demand basis, reduced energy consumption is a major advantage, in addition to the shorter production times. For solution treating of forged alloy parts, the improved control at higher heating rates provides the flexibility to solutionize at temperatures closer to the solidus, and for shorter soak times.

### Literature Review

### History of Furnace

A furnace is a device used for heating. The term furnace is used exclusively to mean industrial furnaces which are used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns. The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking and are part of the Standard English names for many metallurgical furnaces worldwide. Up to 1709, furnaces could only use charcoal to produce iron. However, wood (which is what charcoal is made from) was becoming more expensive, as forests were being cleared for farmland and timber. Coal was a possible alternative to wood, but although it was cheap and plentiful, it wasn't a feasible fuel for making iron, because it contained sulphur, and this made the iron too brittle to be of any use.

### IR Furnace History

In 1800 William Herschel, a German astronomer and composer, while testing filters to observe sun spots passed sunlight through a prism, observed a heating effect in the visible red portion of the spectrum. Testing further, he detected the presence of the greatest amount of heat in the area just beyond the red end of the visible spectrum now called Near-Infrared (NIR. Thirty-five years later Andre-Marie Ampere employed the newly invented thermocouple to demonstrate that near-IR (NIR) radiation was in fact invisible light. It wasn't until 1900 that the term infrared was applied to the part of invisible spectrum contiguous to the red end of the visible spectrum that comprises wavelengths from 0.74 microns to 300 microns. Near IR Furnaces

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Over 30 years ago, Radiant Technology Corporation pioneered the development of short wavelength infrared continuous belt ovens and furnaces. In the '70's RTC introduced the first high-temperature infrared furnace capable of operating at 1000°C with extremely tight temperature control.

**Design of Working Model**

**Objective**

In our project we intend using Infra Red Heating. Heating process is attained through infra red lamps. At a wavelength of 680nm of the infra red lamp, the heating effect starts. We are applying a wavelength of 980 nm. This method offers following advantages over the conventional heating:

- 90% of energy is transmitted as infrared
- Instant, accurately controllable radiant heat
- Easy installation
- High-efficiency, low energy costs

Temperature in the furnace is usually controlled by a conventional relay. But a conventional relay is said to work for only one million operations and hence the lifetime is very less. In order to avoid this difficulty and control the temperature for N number of operations and N number of years, we are using a solid-state relay, which is a combination of OPTO TRIAC and SCR connected back to back. The furnace consists of the infra red lamp which is the heat source. The temperature of the component which is heated is measured using a thermocouple. The output of the thermocouple is conditioned and amplified using signal conditioning equipment. The amplified output is sent to the controller. The controller receives the signal and displays the temperature for the user to see. It also compares the temperature to the required set point temperature and controls the solid state relay accordingly. The solid state relay controls the input to the lamp in the furnace according to the command of the controller. If the actual temperature is lesser than the set temperature, the lam is switched ON. If the actual temperature exceeds the required temperature then power to the infra red lamp is cut OFF.

**Specifications**

***Furnace Specification***

Max. Temperature : 300°C.
Furnace cube material : Mild steel sheet (20 gauges).
Insulation material : Mineral wool.
Inner coating : Aluminium Alloy coating.
Area occupied : 1.5Feet square.
Utilization area : 1 feet square

***Infra Red Lamp Specification***

Number of lamps : 2.
Heating type : Radiation heating.
Input power : 500 watts.
Wavelength : 980 nm.
Max. Temperature : Up to 1000°C.

***Thermocouple Specification***

Type : K type thermocouple.
Composition : Ni Chromel- Ni Alumel.
Range : 0 - 1350°C.
Speed: 1 microsecond

**Components Used**

- Furnace cubes
- Insulator material
- Furnace door
- Infra red lamps
- Aluminium alloy coating
- Thermocouple

**Furnace Cubes**

The furnace cubes are made from mild steel sheets of thickness 18 gauge. The oven is of double walled construction, the gap between the two walls being 50.8 mm. The sheets are folded and welded to form two identical cubes. One of the cubes is made larger than the other. The inner cube is made closed on all sides except the front. It is made to the dimensions of 1 feet cube. That is 1 feet on all sides. The outer cube is made 1.33 feet on all sides. The edges are welded and the closing side of the outer cube is bolted closed. Mild steel sheets can handle high temperatures and also form a hard structure to the furnace.

**Fig. 3.1. Fabricated model of furnace cube**

**Insulator Material**

The insulator used in the furnace is mineral wool. This is a very effective insulator. It is similar to glass wool but more effective. Insulator material is packed in between the outer and inner mild steel cabins. The insulator is loosely packed. It has very low thermal conductivity of k = 0.06 W/mk. Since the mineral wool is loosely packed, the air packets will further increase the thermal resistance, thereby reducing the conduction losses. It may be pointed that air is an excellent insulator having k = 0.02 W/mk. Mineral wool is also called marganite wool. This insulator is so effective that when the inner cabin is at a temperature of around 325°C, the outer surface of the cabin remains only slightly higher than the room temperature. This makes this type of furnace safer and environment friendly.

**Fig. 3.2. Dumping of mineral wool inside the hollow casing**

### Power Rating

The oven has a rating of 500W and can be operated on 230V, single phase, AC supply. The maximum temperature inside the oven is restricted to 325 degree Celsius.

### Infra Red Lamp

Industrial manufacturing processes are becoming more and more rationalized. Automation increases and production rates rise. To gain the competitive edge, industry today demands innovative, effective heating solutions that will optimize cost of ownership. Infrared heat is transferred from the heat source to the object to be heated without any intermediary. In our project we have used two Infra Red Lamps each having a capacity of 250 Watts. They transfer heat on to component by means of radiation heat transfer as described in the operation section of our project.

**Fig. 3.3. IR lamp**

### Aluminium alloy coating

- Inner side of the cube is coated with BERGER ALLOY.
- It act as an insulation medium.
- It can withstand up to 1000°C

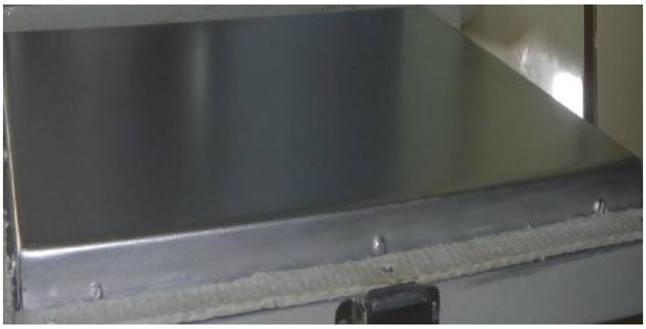


**Fig. 3.4. Aluminium alloy coating**

### Thermocouple

Two strips of dissimilar metals joined to form junction called thermocouple. If the junction is heated and a milli-voltmeter is connected across the free ends away from the junction, there will be found a voltage present. This voltage is caused by the different work -function of the metals forming the junction and is dependent upon both the temperature and the types of metals used. Since the voltage across the thermocouple junction is proportional to temperature we may use it in thermometry. The voltage is not, however, not linear function of temperature, and that tends to limit the application somewhat. It is important to know over what range the thermocouples linear so that error will not be excessive.

### K Type Thermocouple

Type K (chromel-alumel) is the most commonly used general purpose thermocouple. It is inexpensive and, owing to its popularity, available in a wide variety of probes. They are available in the −200 °C to +1200 °C range. The type K was specified at a time when metallurgy was less advanced than it is today and, consequently, characteristics vary considerably between examples. Another potential problem arises in some situations since one of the constituent metals, nickel, is magnetic. The characteristic of the thermocouple undergoes a step change when a magnetic material reaches its Curie point. This occurs for this thermocouple at 354°C.

### Fabrication of Working Model

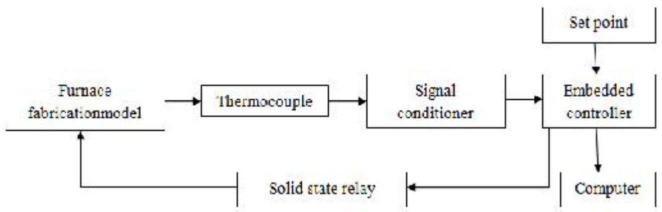
### Manufacturing Processes

Furnace fabrication involves bulk deformation processes like sheet metal bending, deep drawing, etc. to obtain the outer casing of the furnace. The first process is the bending of sheet using highly precise anvil, hammer arrangement and skilled labour. The material used is 20 SWG Mild Steel sheet. This material is strong enough to withstand very high temperatures and also well suited for the manufacture furnace casing. Since the material is to be deformed to bring it to the required shape, plastic deformation and yield criteria need to be developed upon. Plastic deformation of a material depends upon two principal laws of solid mechanics namely, Von – Misces Theory and Guest – Tresca Theory. Both these theories give us the yielding criteria for a specimen based on maximum shear stress and maximum normal stress respectively. The process involves bending and deforming the sheet to the required specifications and dimensions as given by the customer. Sheets of sizes 400mm and 300mm are made from huge cold rolled sheet to make the furnace casing. The reason behind using cold rolled sheets is that material undergoes heat treatment processes in cold rolling process and hence is devoid of any porosity. The sheets are bent to the required dimensions. Once the shaped is obtained the inner and outer casing are welded together using clamps within the gap between the walls. The joining process used here, welding is highly precise as any small mistake could lead to an improper alignment of the walls.

**Operation**

Mass production of painted components can be achieved either by dip coating on a conveyor or spray painting using spray painting booths. After spray painting the component has to be baked at a required temperature as recommended by the paint manufacturer. This being a project, the operation is intended to be carried out on small components using a prototype oven. The initial warm-up time may be about 30 minutes to 45 minutes. After this the component is placed inside the oven. There will be a temperature drop and it may take about 10 minutes for the oven to attain the set temperature. The subsequent holding time in conventional heating is about 20 minutes to make sure that the baking has been uniform. In Infra Red heating, because of the advantages outlined in section it is seen that the time for baking is only 7 minutes.

**Block diagram of the setup**




**Mechanism of Heat Transfer**

**Radiation**

The method of heat transfer is primarily through radiation which is governed by Stefan- Boltzmann law, Wien's law and Planck distribution law. Radiation heat transfer is caused as a result of vibrational and rotational movements of molecules, atoms and electrons. The energy is transported by electromagnetic waves (photons). Radiation requires no medium for propagation, therefore can take place also in vacuum. All matters emit radiation as long they have a finite temperature. The rate at which radiation energy is emitted is usually quantified by Stefan – Boltzmann law

$q = \varepsilon\sigma AT4$

Where the emissivity ε, is a property of the surface characterizing how effectively the surface radiates compared to a black body.

- σ – Stefan - Boltzmann constant (W/m2 K4).
- T - absolute temperature of the surface in Kelvin.

**Performance Test**

**Performance Terms and Definitions**

Performance test of the furnace is done

- To find out the efficiency of the furnace
- To find out the Specific energy consumption

The purpose of the performance test is to determine efficiency of the furnace and specific energy consumption for comparing with design values or best practice norms. There are many factors affecting furnace performance such as capacity utilization of furnaces, excess air ratio, final heating temperature etc. It is the key for assessing current level of performances and finding the scope for improvements and productivity.

Heat Balance of a Furnace

Heat balance helps us to numerically understand the present heat loss and efficiency and improve the furnace operation using these data. Thus, preparation of heat balance is a pre-requirement for assessing energy conservation potential.

Reference Standards

In addition to conventional methods, Japanese Industrial Standard (JIS) GO702 "Method of heat balance for continuous furnaces for steel" is used for the purpose of establishing the heat losses and efficiency of reheating furnaces.

**Furnace Efficiency Testing Method**

The energy required to increase the temperature of a material is the product of the mass, the change in temperature and the specific heat.

i.e. Energy = Mass x Specific Heat x rise in temperature.

The specific heat of the material can be obtained from a reference manual and describes the amount of energy required by different materials to raise a unit of weight through one degree of temperature. If the process requires a change in state, from solid to liquid, or liquid to gas, then an additional quantity of energy is required called the latent heat of fusion or latent heat of evaporation and this quantity of energy needs to be added to the total energy requirement. However in this section melting furnaces are not considered.

The various losses that occur in the furnace are listed below.

1. Heat lost through exhaust gases either as sensible heat or as incomplete combustion
2. Heat loss through furnace walls and hearth
3. Heat loss to the surroundings by radiation and convection from the outer surface of the walls
4. Heat loss through gases leaking through cracks, openings and doors.

The efficiency of a furnace is the ratio of useful output to heat input. The furnace efficiency can be determined by both direct and indirect method.

**Direct Method Testing**

The efficiency of the furnace can be computed by measuring the amount of fuel consumed per unit weight of material produced from the furnace.

$$\text{Thermal efficiency of the furnace} = \frac{\text{Heat in the stock}}{\text{Heat in the fuel consumed}}$$

The quantity of heat to be imparted (Q) to the stock can be found from the formula

$$Q = m \times C_p \times (t_2 - t_1)$$

Where

Q = Quantity of heat in kCal
m = Weight of the material in kg
$C_p$ = Mean specific heat, kCal/kg$^o$C
$t_2$ = Final temperature desired, $^o$C
$t_1$ = Initial temperature of the charge before it enters the furnace, $^o$C

**Indirect Method Testing**

In order to find out furnace efficiency using indirect method, various parameters that are required are hourly furnace oil consumption, material output, excess air quantity, temperature of flue gas, temperature of furnace at various zones, skin temperature and hot combustion air temperature. Efficiency is determined by subtracting all the heat losses from 100. Instruments like infrared thermometer, fuel consumption monitor, surface thermocouple and other measuring devices are required to measure the above parameters. Reference manual should be referred for data like specific heat, humidity etc.

**Advantages**

- Low weight when compared to existing.
- No chance of triggering noise.
- Low thermal inertia.

**Disadvantages**

- Nonlinear
- Requires cold junction compensation

**Conclusion**

We have designed and fabricated a prototype of an infra red solid state heating furnace in which heat radiated from infra red lamp is used to achieve quicker and effective heating. Thus we have developed a method to reduce the weight with a considerable thermal conductivity with low cost . Moreover the life of the furnace and components is also increased. The electrical circuit is also accurate and durable hence reducing the cost of maintenance and repair which is a problem with the existing furnaces.

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