# THERMAL ANALYSIS ENERGY PERFORMANCE AND PARAMETER IDENTIFICATION OF A STAINLESS STEEL ANNEALING FURNACE USING ANSYS

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**Abstract-**

Various types of furnaces are available for numerous heating applications and also several problems associated with their operations non uniform thermal conditions on the load ineffective heat transfer from heat sources to the load, difficulty in controlling atmosphere inside the furnace, high energy losses etc are some of the important problems in furnace operations. Heating power produced by radiant tubes and its temperature distribution of continuous annealing furnace were analyzed using Ansys. Here in this project I am modeling of heating zone of continous annealing furnace by using creo3.0 and simulating the furnace heating zone using Ansys15.0 The objective of my project is to improve the heating capability of radiant tubes. By varying parameters of radiant tube materials for corresponding emissivities are analyzed by using steady state thermal analysis in ANSYS. By this we how emissivity will effect the heat transfer in steel strip By validating results with temperature distribution and Heat flux.

## I. INTRODUCTION

A furnace is a device used for high-temperature heating. The name derives from Latin word fornax, which means oven. The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through induction heating in induction furnaces.

### 1.1 CONSTRUCTION AND WORKING OF CONTINOUS ANNEALING FURNACE

Steel material hardens after cold rolling due to the dislocation tangling generated by plastic deformation. Annealing is therefore carried out to soften the material. The annealing process comprises heating, holding of the material at an elevated temperature (soaking), and cooling of the material. Heating facilitates the movement of iron atoms, resulting in the disappearance of tangled dislocations and the formation and growth of new grains of various sizes, which depend on the heating and soaking conditions. These phenomena make hardened steel crystals recover and recrystallize to be softened.

Furthermore, precipitates decompose to solute atoms which subsequently dissolve into the steel matrix on heating and holding, then reprecipitate in various sizes and distributions, depending on the rate of cooling. These changes in the size and distribution of the grains and precipitates also affect the hardness of the material.

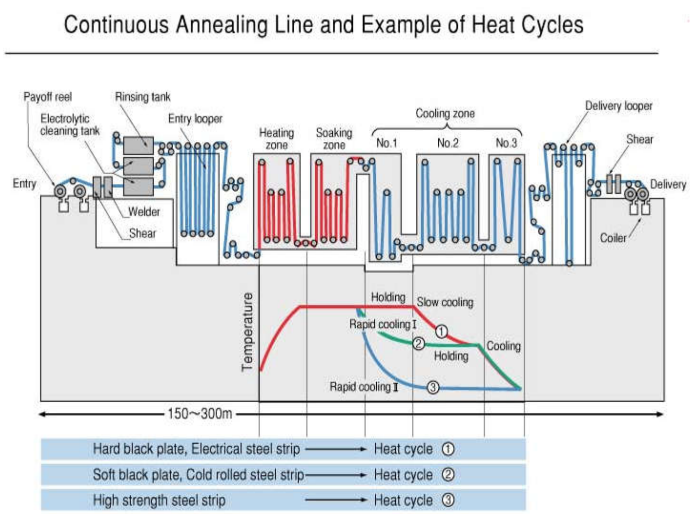


**FIG 1.1 CONTINUOUS ANNEAING FURNACE WORKING PROCESS**

The annealing of cold rolled coils has conventionally been conducted by grouping and annealing the coils in batches stacked in a bell-type furnace. This process is called batch annealing. However, continuous annealing is now more commonly used. This type of annealing involves uncoiling, and welding strips together, passing the welded strips continuously through a heating furnace, and then dividing and recoiling the strips. The figure shows a continuous annealing line, which is composed of the entry-side equipment, furnace section, and delivery-side equipment The main entry-side equipment comprises payoff reels, a welder, an electrolytic cleaning tank, and an entry looper.

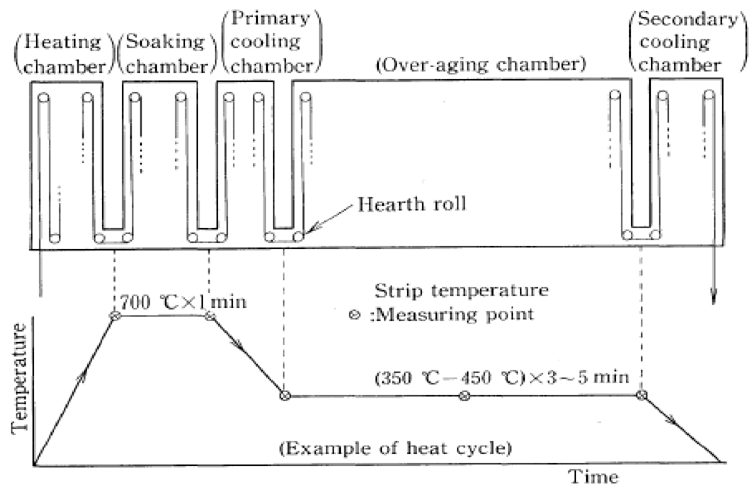


**FIG 1.2 TEMPERATURE VS TIME CURVE THROUGH OUT THE PROCESS**

The furnace section comprises a heating zone, soaking zone, and cooling zone. The cooling zone is divided into three sub-zones so that complex cooling patterns such as cooling-heating-holding-cooling can be performed. The delivery equipment comprises a delivery looper, shears, and coilers, and may be linked to a temper rolling mill and plating equipment as part of a larger continuous line.

The heating cycle applied to strips by continuous annealing differs from product to product, but the three patterns shown in the figure are typical. For cold-rolled strips for general use, it is normal practice to adopt a heating pattern in which the strip is heated to 973K (700℃) for about 1 minute, rapidly cooled, held at about 673K (400℃) for 1 to 3 minutes to precipitate the solute carbon, and then cooled to room temperature.

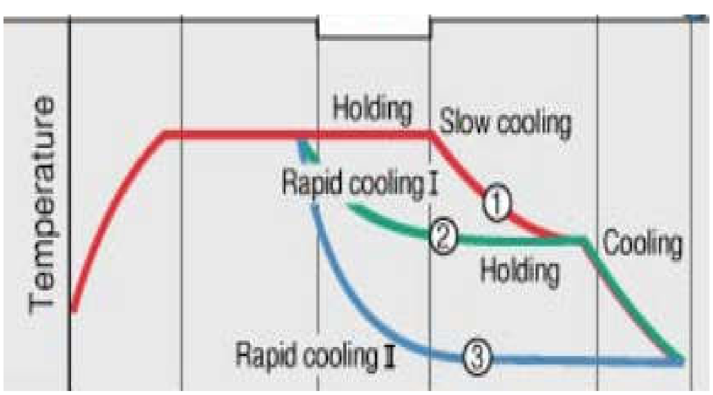


**FIG 1.3 ANNEALING PROCESS(heating and cooling) TEMPERATURE VS TIME CURVE**

Although the total equipment length is 150 to 300m, the total length of the strip in the line is as much as 2,000m. The travel speed of the strip is 200 to 700 m/min. However, a recently developed line for can material passes strip 0.15mm in thickness at a maximum speed of 1,000 m/min. To operate such lines, speed control, tension control, and tracking control of the strip are necessary, in addition to a high level of automatic temperature and atmosphere control.

## 1.2 TYPES OF FURNACES

The furnaces used in the heat treating process can be classified in several different ways. The most popular classification method is shown in Fig.

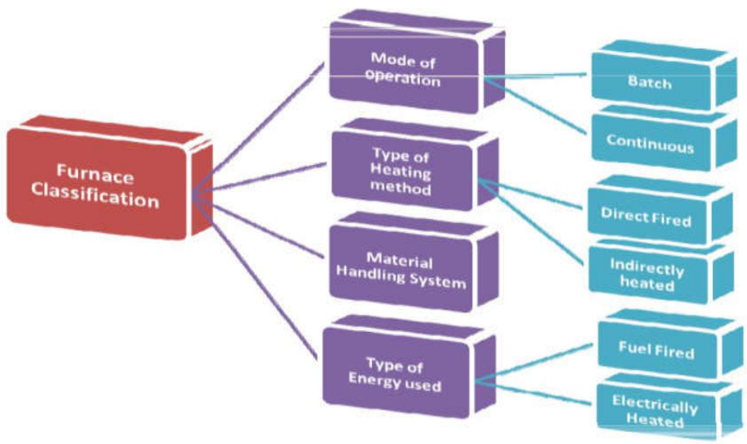


**FIG 1.4 CLASSIFICATION**

Here Iam taking type of heating method the furnaces are classified into fallowing two types they are

1. Indirect fired furnace
2. Direct fired furnace

### 1.2.1 Indirect Fired (Radiant-tube) Furnaces

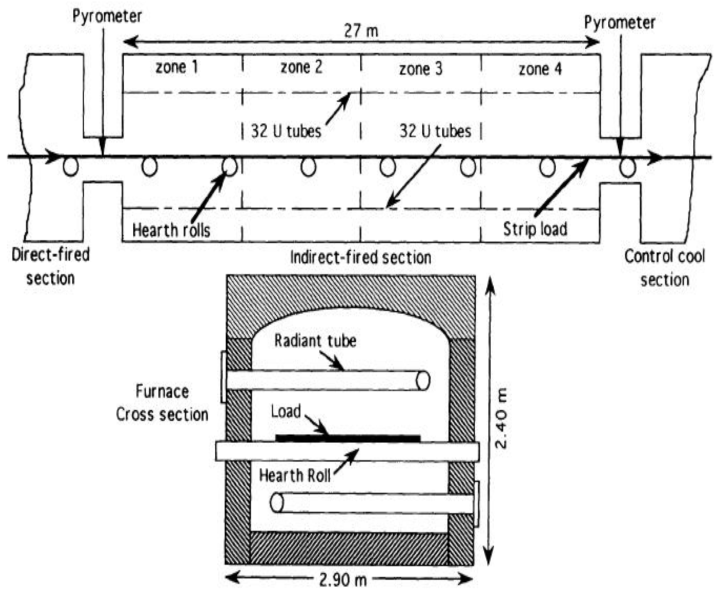


FIG 1.5 SCHEMATIC OF THE INDIRECT-FIRED SECTION OF THE INLAND STEEL ANNEALING FURNACE

'A Thermal System Model for a Radiant-Tube Continuous Reheating Furnace' discusses about a thermal system mathematical model developed for a gas-fired radiant-tube continuous reheating furnace. The mathematical model of the furnace integrates sub models for combustion and heat transfer within the radiant tube with models for the furnace enclosure. The transport processes occurring in the radiant tube are treated using a one-dimensional scheme, and the radiation exchange between the load, the radiant-tube surfaces, and the furnace refractories are analyzed using the radiosity method. The continuous furnace operation is simulated under steady-state conditions. The scope and flexibility of the model are assessed by performing parametric studies using furnace geometry, material properties, and operating conditions as input parameters in the model and predicting the thermal performance of the furnace. The various parameters studied include the effects of load and refractory emissivities, load velocities, properties of the stock material.

Another study is conducted to access the different types of radiant tube designs. Figure which shows the variations in the load surface temperature for the same net fuel firing rate in the radiant tubes, indicates that the load surface temperatures are the highest for the W-type tube design, followed by the U-type and then the straight-through tubes. The lower load surface temperatures for the straight-through tubes in the furnace are due to the incomplete burning of fuel in the radiant tubes. A considerable amount of energy is lost in the form of unburned fuel at the exhaust of the straight-through tube. However, in the U-type and W-type tubes, further burning of the unburned fuel from the first branch takes place, resulting in a higher average tube wall temperature in the successive branches of the tube.

**1.3 Issues in Furnace design**

1) Source of energy in processing of raw materials is fossil fuel in most cases. Even if electric energy is used, it is also derived from fossil fuels.

2) In chemical processing, fluid flow is important. Liquid and gases are flowing at high temperature so erosion and corrosion of the refractory is important. In addition, fluid flow also influences the rates of heat and mass transfer.

3) Atmosphere in the furnace is also important to avoid oxidation of the material being heated

4) Control of furnace temperature is also an important issue. Overheating and under-heating lead to inefficient utilization of fuel and also overheating or under-heating equip

5) Furnaces are both batch and continuous type. In the continuous type for example in heating of ferrous material for hot working, the furnace chamber consists of preheating, heating and soaking zones. The material enters through the preheating zone and exits the soaking zone for rolling. But the flow of products of combustion is in the reverse direction. Furnace design is recuperative type in that discharge the preheating zone at the lowest possible temperature. Different types of continuous furnaces are in use, like walking beam type, pusher type, roller hearth type, screw conveyor type etc.

**2 MODELING OF CONTINOUS ANNEALING FURNACE BY USING CREO 3.0**

Creo Parametric is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operations. The system uses a 3D solid modeling system as the core, and applies the feature-based, parametric modeling method. In short, Creo Parametric is a feature-based, parametric solid modeling system with many extended design and manufacturing applications.

## 2.1 PART NAME: FURNACE HEATING CHAMBER

**MATERIAL: REFRACTORY MATERIAL**

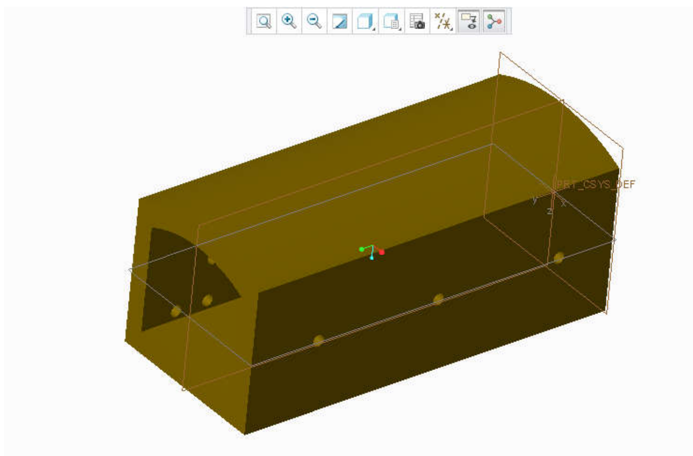

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**FIG 1. 6 HEATING CHAMBER FOR ANALYSIS**

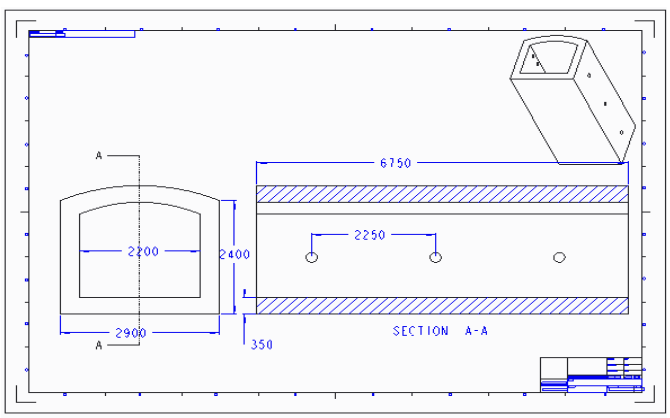



**FIG 1. 7 DETAILED DRAWING HEATING CHAMBER FOR ANALYSIS**

## 2.2 PART NAME: RADIEANT TUBES MATERIAL: COPPER ALLOY

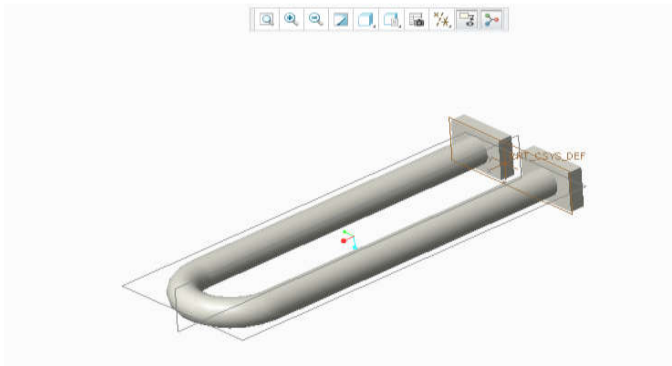


FIG 1. 8 3D MODELS OF RADIANT TUBES

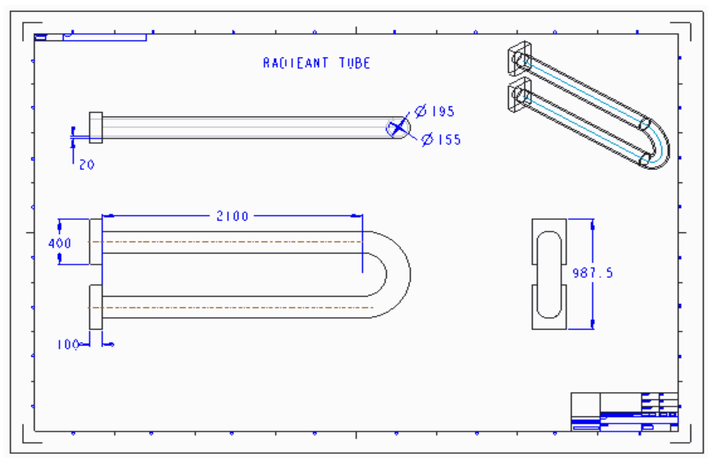



FIG 1. 9 3D DETAILED DRAWING OF RADIANT TUBES

## 2.3 PART NAME: STRIP MATERIAL: STAINLESS STEEL

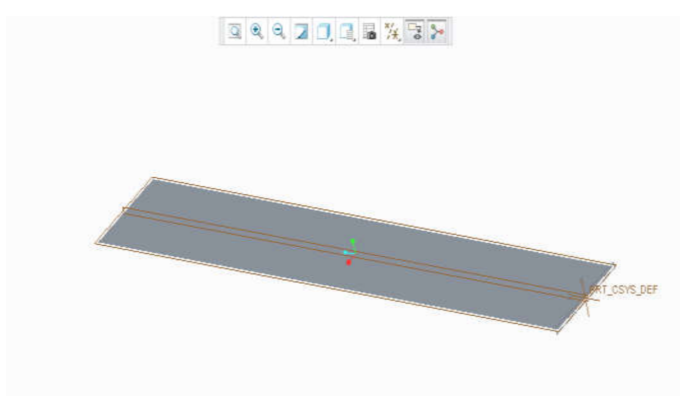


FIG 2.0 3D MODEL OF STRIP

## 2.4 ASSEMBLY OF ANNEALING FURNACE

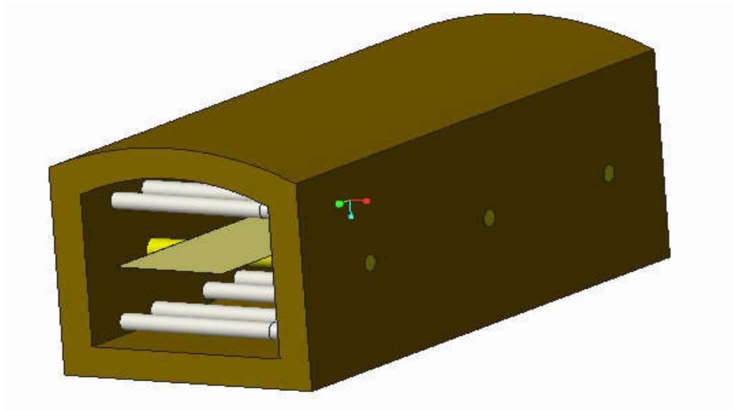


**FIG 2.1 CREO ASSEMBLY MODELING**

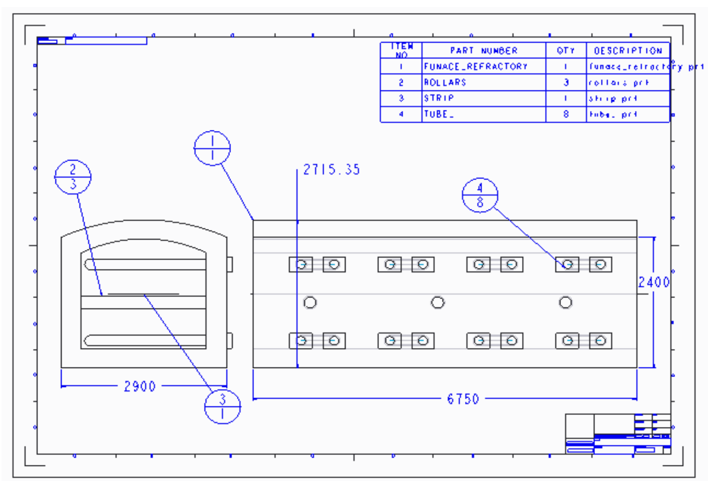



**FIG 2.2 ASSEMBLY MODELING**

## 2.5 SECTIONAL VIEW OF ANNEALING FURNACE

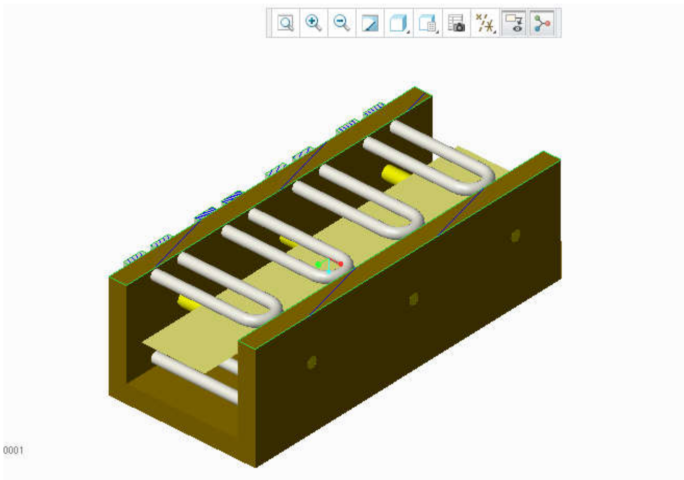
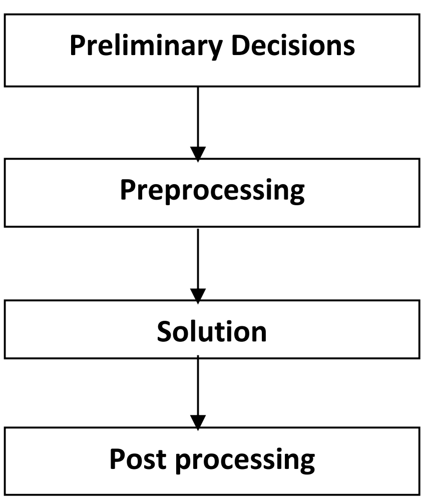


**FIG 2.2 ASSEMBLY MODELING**

# 3 ANALYSIS OF ANNEALING FURNACE

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.

**Every analysis involves four main steps**



## 3.1 IMPORTED MODEL FOR ANSYS:

I have taken one zone of heating furnace for analysis purpose it consists of 8 no of radiant tubes and the zone length is nearly 7 m and rollers and continuous chip

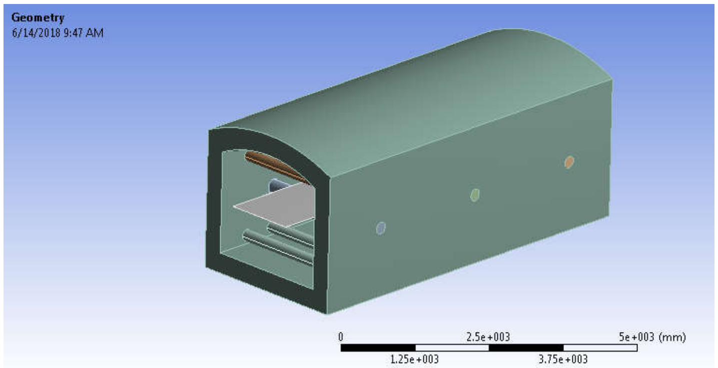



**FIG 3.1 FURNACE GEOMETRY**

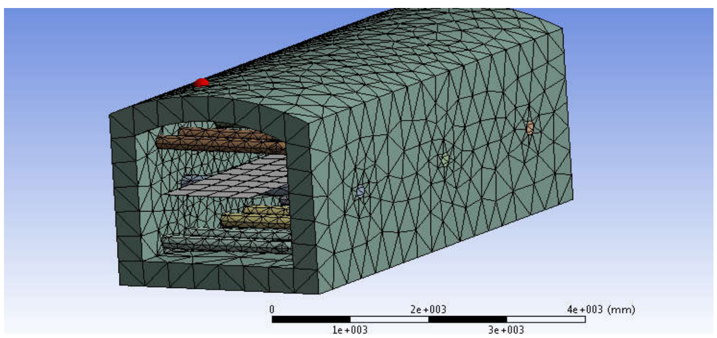



**FIG 3.2 MESHING**

## 3.2 ANALYSIS IS DONE IN DIFFERENT CASES:

**CASE 1:**

COPPER TUBES (EMMISIVITY=0.77 MAXIMUM AT 700$^{O}$C)

WALL RADIATION AT 1000$^{O}$C EMMISSIVITY=0.385

## BOUNDARY CONDITIONS:

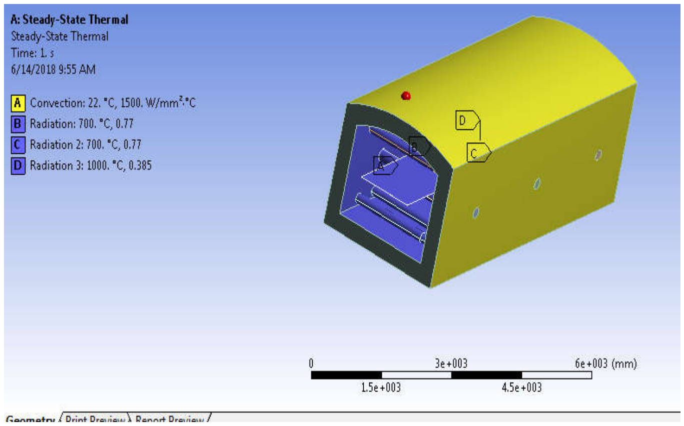



**FIG 3.3 BOUNDARY CONDITIONS**

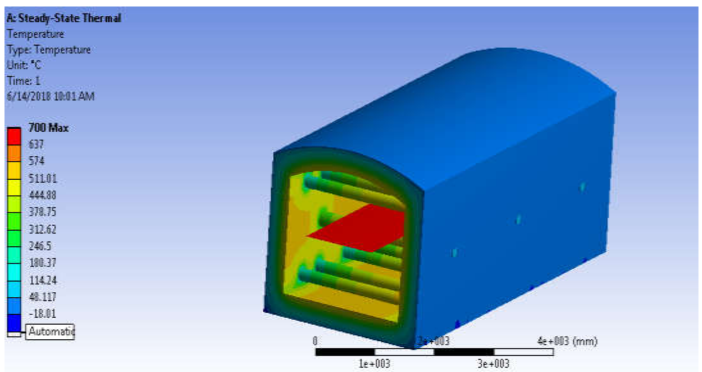



**FIG 3.4 TEMPERATURE DISTRIBUTION**

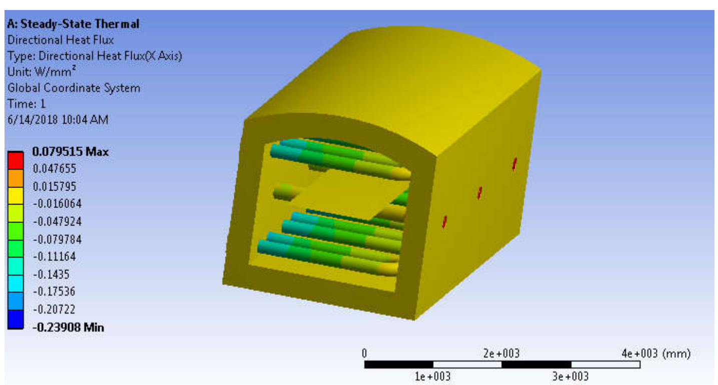



**FIG 3.5 DIRCTIONAL HEAT FLUX(here it shows heat transfer rate)**

**CASE2:**

CERAMIC TUBES (EMMISIVITY=0.94 AT 1000 $^{O}$C)

WALL RADIATION AT 1000$^{O}$C EMMISSIVITY=0.385

**BOUNDARY CONDITIONS:**

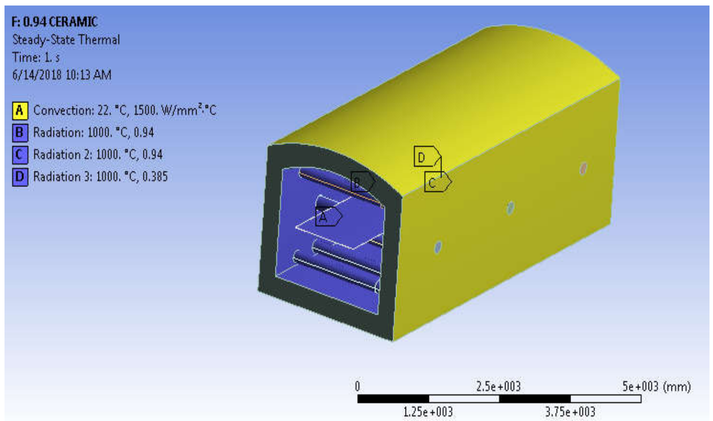



**FIG 3. 6 BOUNDARY CONDITIONS**

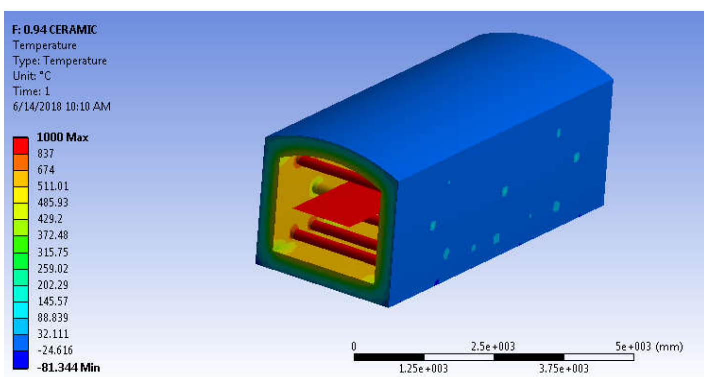



**FIG 3.7 TEMPERATURE DISTRIBUTION**

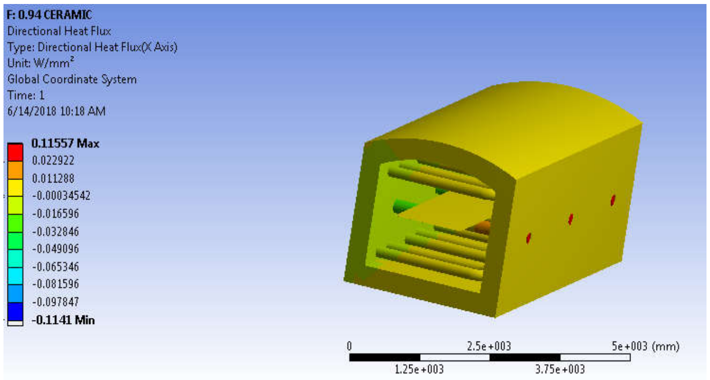



**FIG 3.8 DIRCTIONAL HEAT FLUX**

## CASE3:

STAINLESS STEEL TUBES (EMMISIVITY=0.83 AT 800 $^{O}$C)

WALL RADIATION

AT 1000$^{O}$C EMMISSIVITY=0.385

## BOUNDARY CONDITIONS:

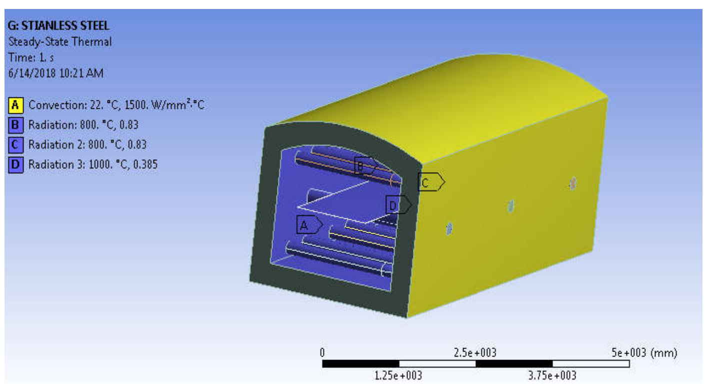



**FIG 3.9 BOUNDARY CONDITIONS.**

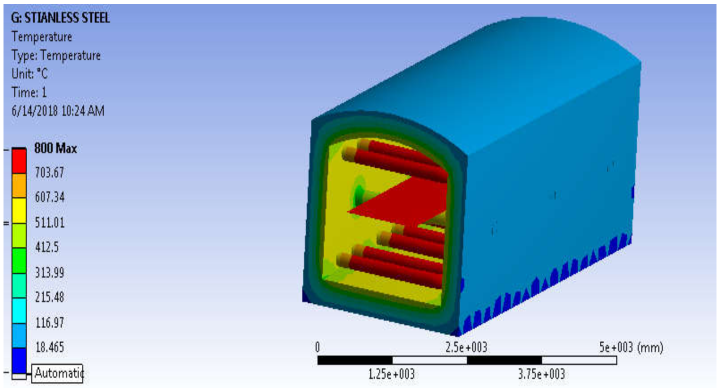



**FIG 4.0 TEMPERATURE DISTRIBUTION**

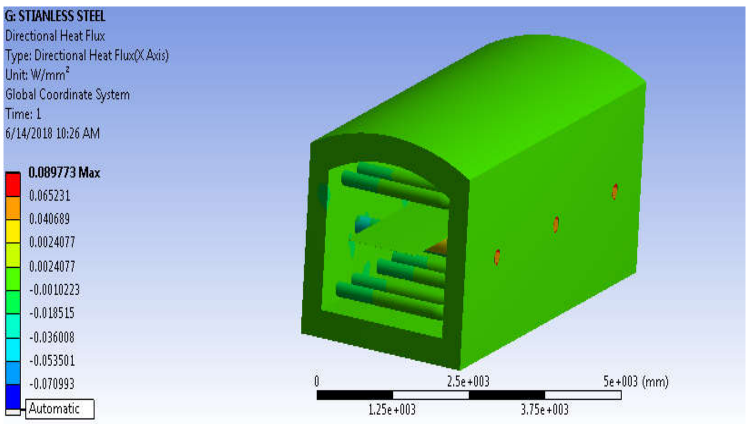



**FIG 4.1 DIRCTIONAL HEAT FLUX**

# 4.0 RESULTS AND DISCUSSION

**4.1 Finite element analysis:**

The continuous annealing furnace heating zone is analyzed in ANSYS 15.0 by importing part in to the work bench. The steady state thermal analysis done on the furnace.

**4.2. Steady state analysis:**

Defining the boundary conditions and loading conditions are the important parameters. First of all we have to define the material properties like mass density, young`s modules, thermal conductivity and Poisson's ratio.

| S.NO | MATERIAL | THEMAL CONDUCTIVITY (W/M C) | DENSITY(KG/M3) |
|---|---|---|---|
| 1 | COPPER | 401 | 8300 |
| 2 | CERAMIC | 4.5 | 4900 |
| 3 | STAINLESS STEEL | 15.1 | 7750 |

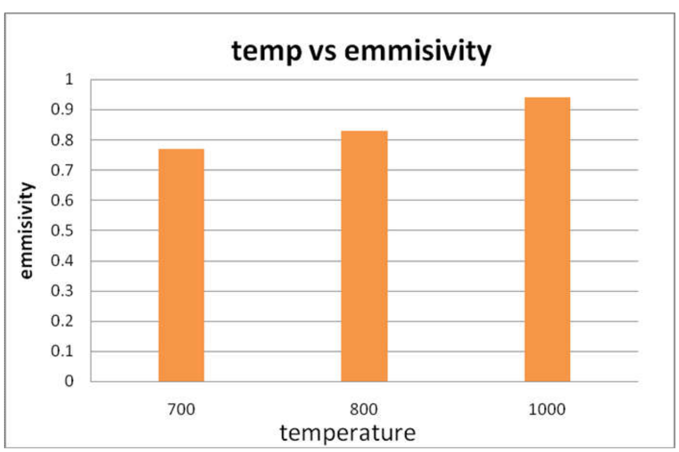
Table 1 shows physical properties of the materials

**4.3 Steady state thermal analysis results table**

| S.NO | MATERIAL | EMMISIVITY | TEMP(DEG) | HEAT FLUX(W/mm2) |
|---|---|---|---|---|
| 1 | COPPER | 0.77 | 700 | 0.079515 |
| 2 | STAINLESS STEEL | 0.83 | 800 | 0.089773 |
| 3 | CERAMIC | 0.94 | 1000 | 0.11557 |

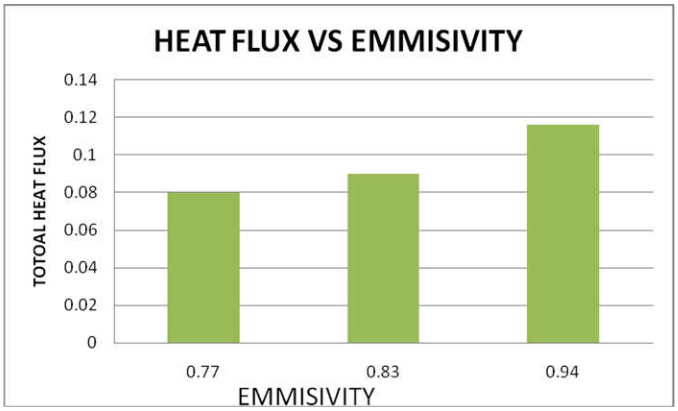
## 5.0 GRAPHICAL REPRESENTATION OF ANALYSIS RESULTS:

## TEMPERATURE VS EMISSIVITY




Graph 1: Graph represent radiation factor vs temperature distribution is indicated

**HEAT FLUX VS EMISSIVITY**




Graph 2: Graph represent radiation factor vs Heat flux distribution flow is indicated

## 6. CONCLUSION

In this project the continuous annealing furnace is designed in CREO 3.0 software. The analysis is done on ANSYS workbench. In this analysis was done by changing the parameters of radiant tube. In this project the materials are considered which have more emissivity.

It was found from results that this model could predict the strip temperature by varying Emissivity parameters for different materials. Model can predict temperature evolutions along the furnace. From the result table it found that heat flow through strip is analyzed. Steady state Thermal Analysis is carried and results gives us variation of heat flux and temperature distribution find out.

From the above observations I conclude that from the graph and results of furnace by changing the radiant tube materials and their corresponding emissivity's the ceramic material have the maximum heat transfer rate .finally by changing the material of the radiant tube the thermal efficiency is increased

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