Design of an Efficient Domestic Gas Oven

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

____
(Ir. Kamarudin Shehabuddeen)

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TRONOH, PERAK
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD AZMEER BIN ROZMAN

ABSTRACT

This report basically discuss about the research done and investigations of the propose topic, which is to design an efficient domestic gas oven. The objective of this project is to design an efficient domestic gas oven through heat transfer analysis in order to reduce consumer’s burden because the price of energy increases every day. The design will be focus on performing heat transfer analysis of heat insulation materials. The main objectives of this research are to design an efficient domestic gas oven through heat transfer analysis and design the domestic gas oven using most suitable heat insulation material with most appropriate thickness.

The challenging part of this project is to find the best design of an efficient gas oven by theoretically or by using computer simulation. The scope of work for this project includes the simulation using CATIA software to design the domestic gas oven. ANSYS software will be used to investigate heat transfer on the domestic gas oven. In order to execute this project, research had been done through several methods such as studied on previous gas oven development and discuss with FYP supervisor on weekly basis. Approach several lecturers regarding the project by ask about suitable material to be use in domestic gas oven.

Throughout the project, activities will start from problem identification until completion of designing an efficient domestic gas oven. Once the heat transfer analysis of the domestic gas oven is successfully performed, the domestic gas oven will be design using most suitable insulation material. In the end of the semester, project works and result will be presented during seminar and oral presentation.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

A gas oven is a domestic oven that is powered by gas. A gas oven is often topped with its own separate cooking unit that includes gas-powered burners. Gas ovens have become more versatile in recent years. When gas ovens were first introduced, they were very basic and did not come in a wide variety of models. Nowadays, there are many types of gas oven that can be chosen. There are generally two types of ignition systems available in gas ovens which are hot surface ignition and pilot flame ignition. Gas ovens are made out of ceramic or stainless steel. Stainless steel models are usually more expensive than ceramics. Convection oven is one of the more significant developments in commercial cooking equipment. It originated as a modified conventional or standard oven developed to overcome the problem of uneven heat distribution in the cooking cavity to provide more production capacity for a given size.

The convection oven has naturally spawned a vast number of variations based on these attributes in terms of size, technology, capacity and type. Convection oven is also available in gas type model. Forced convection gas oven can reduce the cook time significantly on long to cook items and also allow foods to be cooked in short period of time. Convection ovens use the fans at the back of the oven to circulate the heated air around in the convection gas oven compartment, it distributing the heat more evenly throughout the oven than a regular oven. Gas convection ovens are available in single or multiple burners. Most of the gas convection ovens are indirectly fired and burners are usually located at the bottom of the oven cavity or between the cavity and also the insulated walls. In general, gas convection ovens offer more control over the cooking process than standard ovens.

1.2 Problem Statement

The rate of energy sources price increases every day, globally. To reduce consumer's burden, it becomes sufficiently important and necessary to develop an efficient domestic gas oven through heat transfer analysis and also to design the domestic gas oven using most suitable heat insulation material with appropriate thickness.

1.2.1 Problem Identification

Research has been done from existing design of domestic gas oven. The findings can be described below:

i. Insulation material that been used in the oven make a major changes in terms of efficiency.
ii. Design of the domestic gas oven, the heat insulation materials and their thickness are important criteria to increase the efficiency of gas oven.

Thus, in order to produce an efficient domestic gas oven with minimal trouble and high reliability, a more innovative and systematic development of gas oven is needed.

1.2.2 Significance of Project

The significance of this project is that in the future, companies that are manufacturing domestic gas oven would be able to refer to this project as a benchmark and will be able to design their own oven with the data that is founded from this project. Companies as well as universities would be able to use this research to update the uncertainties when dealing with insulation material or heat transfer analysis and is capable to produce domestic gas oven with high efficiency.

1.3 Objectives and scope of study

The main objectives of this research are:

1. To design an efficient domestic gas oven through heat transfer analysis.
2. To design the domestic gas oven using most suitable heat insulation material with appropriate thickness.

The scope of work for this project includes the simulation using ANSYS software which is to investigate heat transfer on the domestic gas oven. CATIA software will be used to design the domestic gas oven and finally the analysis of heat transfer is been used to study the feasibility of the design.

1.3.1 Relevancy of Project

This project is relevant to the study of heat transfer analysis as well as the study of insulation of material. This project is also relevant to the recent design of gas oven where people are paying more attention to get higher efficiency domestic gas oven to reduce energy usage of gas oven and get same amount of output produce.

1.3.2 Feasibility of Project Within

The project is feasible as it utilizes a program called ANSYS and analyzes the data which can be obtained from the existing design of domestic gas oven. This project is low in cost for analysis and brings huge benefits for the future.

CHAPTER 2

LITERATURE REVIEW/THEORY

2.0 LITERATURE REVIEW/ THEORY

2.1 Domestic Gas Oven

Nowadays, many food service operations rely heavily on versatility of oven. As a result of oven versatility, it became widely used in appliance for food service industry. An oven describe as a fully enclosed insulated chamber used to heat food. CP Publishing, Inc. (1990) stated that convection oven is one of the more significant developments in commercial cooking equipment. It originated as a modified conventional or standard oven developed to overcome the problem of uneven heat distribution in the cooking cavity to provide more production capacity for a given size. CP Publishing, Inc. (1990) also explained that the concept behind the forced air convection oven is simple one when food is cooking inside an oven; it is surrounded by an insulating layer of air that is cooler than the overall oven cavity temperature. A motorized fan (or blower) forced the air to move throughout the oven's cavity, stripping away the layer of cooler air next to the food. The result is a faster, more even cooking process than that provided by standard, natural convection or radiant heat ovens.[1]

As for conduction gas oven, Esource Inc. (1995) detailing explained that heat is transfer to the foods via direct contact with a heated medium. For example, many pizza ovens incorporate a firebrick or composite hearth with burners or elements underneath the hearth. The bottom of the pizza is cooked by direct contact with the hot hearthstone. This process of conduction, combined with the circulation of hot air above pizza, allow good control of the cooking speed and texture of both the crust and toppings. The heat is conducted directly through the shelves to the pans and subsequently to the food. This method of heat transfer, according to the manufacturer, allow food to be brought evenly to a cooked state without burning or drying.[2]

2.2 Efficiency of Domestic Gas Oven

Energy input rate is one of the important consideration in order to select the oven. The maximum rate of the oven can be express in *kBtu/h* or *kW*. By definition, energy efficient of the oven is when the oven can operate with lower input rate and still can produce the same amount of output as lower quality design. Even though initial cost price of energy efficient oven might be slightly higher, but the long term operating cost will be lower.

According to American Society for Testing Materials (1999)

> The work of an oven can be outlined as bringing the cavity from room temperature up to cooking temperature (preheating), holding the cavity at cooking temperature until cooking begins (idling), and restoring heat to the cavity when cold food is placed into the oven (recovery). The Food Service Technology Centre has developed several Standard Test Methods for assessing the performance of ovens, which have been ratified by American Society for Testing and Materials (ASTM).[3]

Architectural Energy Corporation (1991) stated that the cooking-energy efficiency is the ratio of energy added to the food and total energy supplied to appliance during cooking:

$$\textit{Cooking efficiency} = E_{Food} / E_{Appliance} \times 100\% \qquad (2.1)$$

The ASTM standard test methods define cooking rates and efficiencies for heavy-load (full-cavity), medium-load (half-capacity) and light-load (single-pan) conditions. Due to variances in burner and heat exchanger design, gas oven demonstrate a dramatic difference in heavy-load cooking energy efficiencies.[4] Heat can be transferred in 3 different ways which are conduction, convection and radiation. All mode of heat transfer required the existence of temperature difference, and all mode of heat transfer are from high temperature to a lower temperature medium.

Saeed Moaveni (1999) stated that conduction refers to that mode of heat transfer that occurs when there exists a temperature gradient in a medium. The energy is transported from high temperature region to the low temperature region by molecular activities.[5] For example, a cold canned drink in a warm room eventually warms up to the room temperature as a result of heat transfer from the room to the drink through aluminium can by conduction (Figure 2.1).

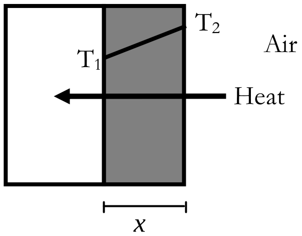


Figure 2.1 *Conduction through a solid object*

$$Q_{cond} = kA\,\Delta T/\Delta x \tag{2.2}$$

k= thermal conductivity of material.

The heat conduction Q_{cond} through a layer of constant thickness Δx is proportional to the temperature difference ΔT across the layer and the area A normal to the direction of heat transfer and inversely proportional to the thickness of the layer. Materials such as copper and silver, which are good electric and heat conductor because have high k value. However, materials such as wood, rubber and Styrofoam are poor conductors of heat and therefore have low values of k. Cengel and Boles (2007) supported that temperature is a measure of the kinetic energies of molecules. In solids, heat conduction is due to two effects: the lattice vibrational waves induced by the vibrational motions of the molecules positioned at relatively fixed position in a periodic manner called a *lattice* and the energy transported via the free flow of electrons in the solid. The thermal conductivity of solid is obtained by adding the lattice and the electronic components. The thermal conductivity of pure metals is primarily due to electronic component, whereas the thermal conductivity of non-metals is primarily due to the lattice component. The lattice component of thermal conductivity strongly depends on the way the molecules are arranged.[6]

2.3 Thermal Insulation in Domestic Gas Oven

Thermal insulation is very important in order to improve energy efficiency and safety in cooking appliances especially gas oven. Thermal insulation is widely used by manufacturers or designers and has routinely chosen fibreglass as thermal insulation material. According to Thomas Rebernak (2012) while fiberglass meets less demanding performance requirements, makers of mid-range and high performance cooking appliances, especially those with self-cleaning cycles, have recently been turning to newer alkaline earth silicate wool (AES) materials, such as Superwool® Plus^{TM} insulating fiber. These materials offer significant advantages in high temperature insulation applications, including low thermal conductivity and low linear shrinkage. In addition, they are widely appreciated for their low bio-persistence, which means that there are no regulations preventing their use in domestic appliances in any region of the world. In the past, many appliances relied on air as the primary insulation. Air is composed of gases that do not transfer heat very well because the molecules are so far apart from each other. The use of only air as oven insulation has been largely curtailed in many countries due to safety considerations, but it is still used in low end appliances.[7] By theory, if the thermal conductivity of material is bad, it will restricts the flow of energy from high to low temperature better. Thermal conductivity of a material is measure by the material ability to transfer energy from high to low temperature. So, the lower thermal conductivity will be chosen as thermal insulator because it will give a greater temperature difference between the hot and cold faces and less energy losses.

2.4 Convection Ovens

Reflecting years of technological refinements, convection oven is one of the more significant developments in commercial cooking equipment. It originated as a modified conventional or standard oven developed to overcome the problem of uneven heat distribution in the cooking cavity to provide more production capacity for a given size. According to Blessent (1992) based on this attributes, the convection oven has naturally spawned a vast number of variations based on these attributes in terms of size, technology, capacity and type. Forced convection gas oven can reduce the cook time significantly on long to cook items and also allow foods to be cooked in short period of time. Convection ovens use the fans at the back of the oven to circulate the heated air around in the convection gas oven compartment, it distributing the heat more evenly throughout the oven than a regular oven. Gas convection ovens are available in single or multiple burners. Most of the gas convection ovens are indirectly fired and burners are usually located at the bottom of the oven cavity or between the cavity and also the insulated walls. In general, gas convection ovens offer more control over the cooking process than standard ovens.[8]

Figure 2.2 *Convection oven*

CP Publishing, Inc. (1990) stated that convection ovens have more advantages rather than disadvantages. The first advantage of convection oven is the food inside it heated more evenly and less burning. Second advantage is foods can cook faster at low temperature and save the gas energy usage. Some convection ovens come with a built in rotisserie rack, because the more evenly distributed heat makes roasting better. Next is a convection oven is not necessarily the ideal appliance for all of a cook's baking or roasting needs, but it does have some major advantages over standard radiant ovens. Foods can be reheated in a convection oven faster than a conventional oven, without the risk of dehydration or uneven heating often experienced in a microwave.[1]

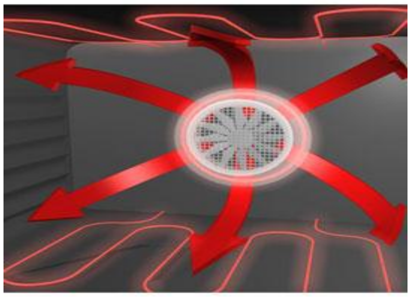


Figure 2.3 *Hot air circulations*

In general, convection ovens offer more control over the cooking process than standard ovens. Upgraded controls include more accurate electronics sensors and thermostats, electronic ignition system (on gas models), programmable cooking computers which recall several cooking sequences by simple press of a button. Some of these ovens can be programmed to first cook and then hold food products. Food may be cooked at a high temperature with convection and then held for extended period at a lower temperature with the fan off. Convection ovens allow user to control cooking by regulating fan speed, temperature, humidity and cooking time. The speed of the fan affects cooking time and uniformity, as does the pattern of airflow through the interior. For combination ovens for example, a cooking cycle can be programmed to begin with high steam and convection, then continue the cooking with convection phase only and later hold the finished product at low temperature and moderate humidity. Low speed fan setting also offered in one of these ovens to permit cooking of delicate items and a rapid cool down mode to facilitate going from oven to steaming quickly.

2.5 Finite Element Method and ANSYS on Heat Transfer Analysis Problem.

According to Saeed Moaveni (1999), the finite element method is a numerical procedure that can be applied to obtain solutions to a variety of problems in engineering. The problems that can be analyzed using finite element methods are steady, transient, linear or nonlinear problems in stress analysis, **heat transfer**, fluid flow and electromagnetism problems. Zienkiewicz and Cheung (1967) wrote the first book entirely devoted to finite element method in 1967. Eventually on 1971, ANSYS was released for the first time. General purpose of ANSYS is comprehensive finite element program that contains more than 100,000 lines of code. ANSYS can be use to performing static, dynamic, heat transfer, fluid flow and electromagnetism analyses. In order to use ANSYS software, it is important that to fully understands the basic concept and limitations of finite element methods.[5]

Basic Steps In The Finite Element Method

Finite element method can be dividing into 3 phases:

Preprocessing Phase

1. Create and discretize the solution domain into finite element; that is, subdivide the problem into nodes and elements.
2. Assume a shape function to represent the physical behavior of an element; that is, a continuous function is assumed to represent the approximate behavior solution of an element.
3. Develop equations for an element.

4. Assemble the element to present the entire problem. Construct the global stiffness matrix.
5. Apply boundary conditions, initial conditions and loading.

<u>Solution Phase</u>

6. Solve a set of linear or nonlinear algebraic equations simultaneously to obtain nodal results, such as displacement values at different nodes or temperature values at different nodes in a heat transfer problem.

<u>Post-processing Phase</u>

7. Obtain other important information. At this point, can be used values for example values of principal stresses, heat fluxes and so on.

For example: <u>A Composite Wall Problem</u>

A wall of an industrial oven consists of three different materials, Figure 2.4. The first layer is composed of *5 cm* of insulating cement with a clay binder that has a thermal conductivity of *0.08 W/m.K*. The second layer is made from *15 cm* of 6-ply asbestos board with a thermal conductivity of *0.074 W/m.K (W/m. °C)*. Determine the temperature distributing along the composite wall.

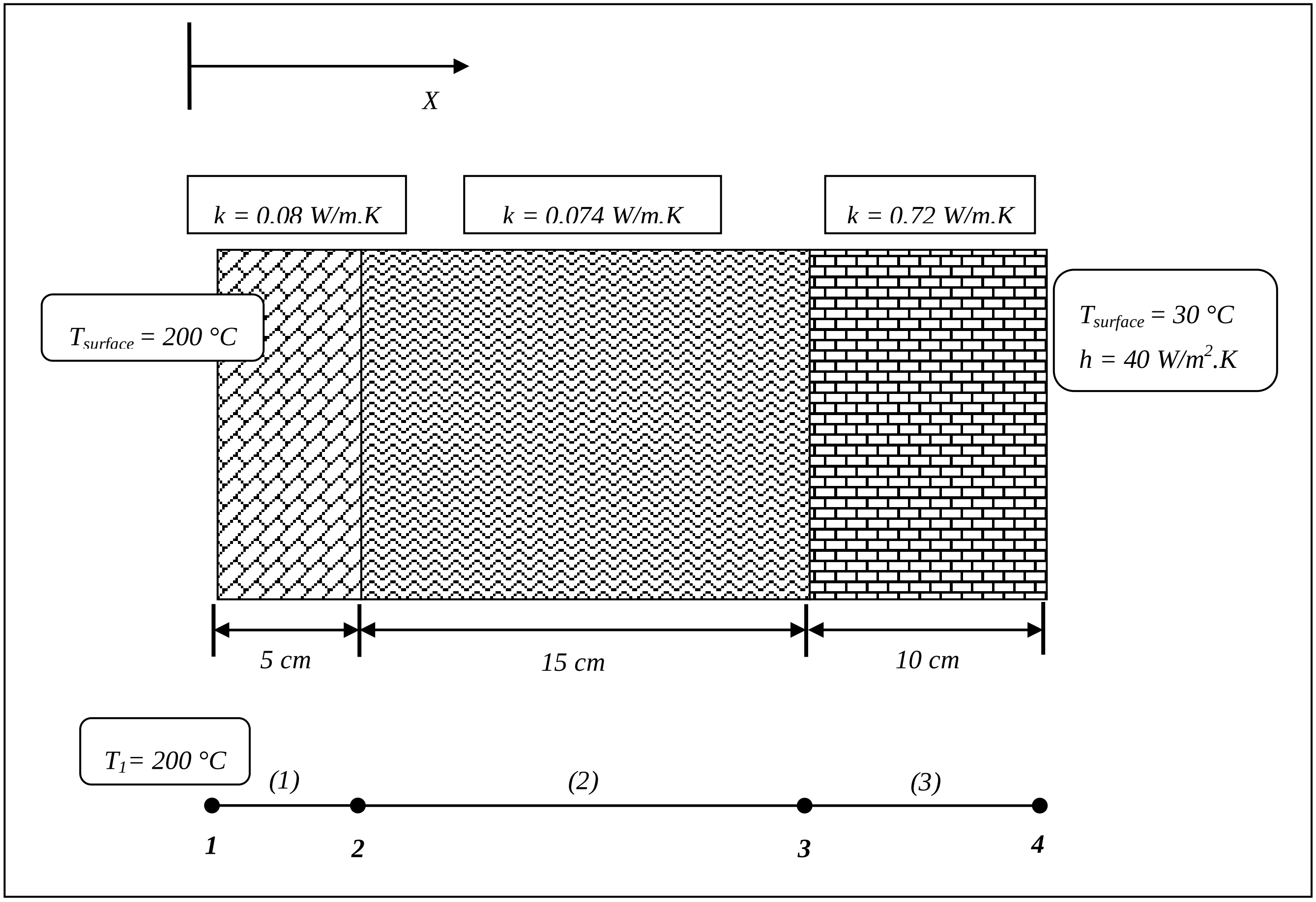


Figure 2.4 *Industrial Oven*

$$c_1 \frac{d^2\Psi}{dX^2} + c_2\Psi + c_3 = 0 \tag{2.3}$$

The heat conduction problem is governed by the equation

$$kA \frac{d^2T}{dX^2} = 0 \tag{2.4}$$

and is subjected to boundary conditions T_1= 200 °C and $-kA\frac{dT}{dX}|_{x=30cm} = hA(T_4-T_f)$. For this example, compare Eq. (2.4) to Eq. (2.3), finding that $c_1 = kA$, $c_2 = 0$, $c_3=0$ and $\Psi = T$. Thus, for element (1);

$$[K]^{(1)} = \frac{kA}{l}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} = \frac{(0.08)1}{0.05}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} = \begin{bmatrix} 1.6 & -1.6 \\ -1.6 & 1.6 \end{bmatrix}\frac{W}{°\mathrm{C}}$$

$$\{F\}^{(1)} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} W$$

For element (2);

$$[K]^{(2)} = \frac{kA}{l}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} = \frac{(0.074)1}{0.15}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} = \begin{bmatrix} 0.493 & -0.493 \\ -0.493 & 0.493 \end{bmatrix}\frac{W}{°\mathrm{C}}$$

$$\{F\}^{(2)} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} W$$

For element (3), including the boundary condition at node 4;

$$[K]^{(3)} = \frac{kA}{l}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & hA \end{bmatrix} = \frac{(0.72)1}{0.1}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & (40 \text{ x } 1) \end{bmatrix} = \begin{bmatrix} 7.2 & -7.2 \\ -7.2 & 47.2 \end{bmatrix}\frac{W}{°\mathrm{C}}$$

$$\{F\}^{(3)} = \begin{bmatrix} 0 \\ hAT_f \end{bmatrix} = \begin{bmatrix} 0 \\ (40 \text{ x } 1 \text{ x } 30) \end{bmatrix} = \begin{bmatrix} 0 \\ 1200 \end{bmatrix} W$$

Assembling elements, can obtain;

$$[K]^{(G)} = \begin{bmatrix} 1.6 & -1.6 & 0 & 0 \\ -1.6 & 1.6 + 0.493 & -0.493 & 0 \\ 0 & -0.493 & 0.493 + 7.2 & -7.2 \\ 0 & 0 & -7.2 & 47.2 \end{bmatrix}$$

$$\{F\}^{(G)} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1200 \end{bmatrix} W$$

Applying the boundary condition at the inside furnace wall;

$$\begin{bmatrix} 1.6 & -1.6 & 0 & 0 \\ -1.6 & 1.6 + 0.493 & -0.493 & 0 \\ 0 & -0.493 & 0.493 + 7.2 & -7.2 \\ 0 & 0 & -7.2 & 47.2 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix} = \begin{bmatrix} 200 \\ 0 \\ 0 \\ 1200 \end{bmatrix}$$

and solving the set of linear equations, the following are results;

$$\begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix} = \begin{bmatrix} 200 \\ 162.3 \\ 39.9 \\ 31.5 \end{bmatrix} {}^\circ\mathrm{C}$$

Solve a Composite Wall Problem Using ANSYS

The following steps demonstrate how to create one-dimensional conduction problems with convective boundary conditions in ANSYS. This task includes choosing appropriate element types, assigning attributes, applying boundary conditions and obtaining results.

To solve this problem using ANSYS, the following steps need to be employ:

Refer appendix 6.1

The result of the ANSYS analysis as Table 2.1

Table 2.1 Nodal Temperature

Node Number	Temperature (°C)
1	200.00
2	162.27
3	39.894
4	31.509
5	30.000

The inside temperature of the oven was set to 200°C and room temperature was set to 30°C. Generally, a heat transfer problem under steady state conditions applied in conservation of energy to control the volume surrounding an arbitrary node must be satisfied. For this example, heat loss through each layer must be equal the heat removed by the surrounding air. So,

$$Q^{(1)} = Q^{(2)} = Q^{(3)} = Q^{(4)}$$

$$Q^{(1)} = \frac{kA}{l}\Delta T = \frac{0.08(1)}{0.05}(200 - 162.27) = 60.368 \approx 60W$$

$$Q^{(2)} = \frac{0.074(1)}{0.15}(162.27 - 39.894) = 60.372 \approx 60W$$

$$Q^{(3)} = \frac{0.72(1)}{0.1}(39.894 - 31.509) = 60.372 \approx 60W$$

For the heat removal by the fluid is given by;

$$Q^{(4)} = hA\Delta T = (40)\,(1)\,(31.509\text{-}30) = 60.36 \approx 60W$$

Another check of the validity of this results can be get from the examining the slopes of the temperature in each layer. The first layer of this example which is insulating cement with a clay binder has the temperature slope of 754 °C/m. For the second layer which is 6-ply asbestos board, the temperature slope is 816 °C/m. These two layers consist of material with relatively low thermal conductivity and large temperature drop. The slope of the temperature in exterior wall is made from material with relatively high thermal conductivity. So, the temperature drops through this layer not to be as significant as the other layers.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The project started with the research to understand the basic principle of domestic gas oven. The research includes review of different types of oven and how the oven works. There many variation and basic concept in the domestic oven. The construction of a modern mass production domestic gas oven is relatively very simple concept. The cooking compartment of domestic gas oven consist a pressed steel cavity which is wrapped the thermal insulation material, with a hinged door and a flue gas or a vent. In order to maintain the external surface temperatures as low as possible, the door is usually double glazed with an infrared reflective coating material applied to the inner part of the pane. The air temperature of the gas oven is usually regulated by thermostatic control of the gas supply to the burner.

There are many numbers of gas oven types and arrangements available in the commercial market. However, the basic thermal design and constructional mass production of domestic gas oven are broadly similar in respect regarding the size, brand or the manufacturer. Thermal insulation is very important in order to improve energy efficiency and safety in cooking appliances especially gas oven. Thermal insulation is widely used by manufacturers or designers and has routinely chosen fibreglass as thermal insulation material. By theory, if the thermal conductivity of material is bad, it will restricts the flow of energy from high to low temperature better than material that has high value of thermal conductivity. Thermal conductivity of a material is measure by the material ability to transfer energy from high to low temperature. So, the lower thermal conductivity will be chosen as thermal insulator because it will give a greater temperature difference between the hot and cold faces and less energy losses.

In order to proceed with this project, the conceptual design of domestic gas oven is construct and design by using CATIA software. The figure 3.1 shows the finalized conceptual design of domestic gas oven. This design only focused on constructed domestic gas oven without topped with its own separate cooking unit. The design of domestic gas oven is based on the design of microwave oven that available in the market. This design of domestic gas oven is much simpler than old design. So, it will be easy to use and can be move easily by the consumers.

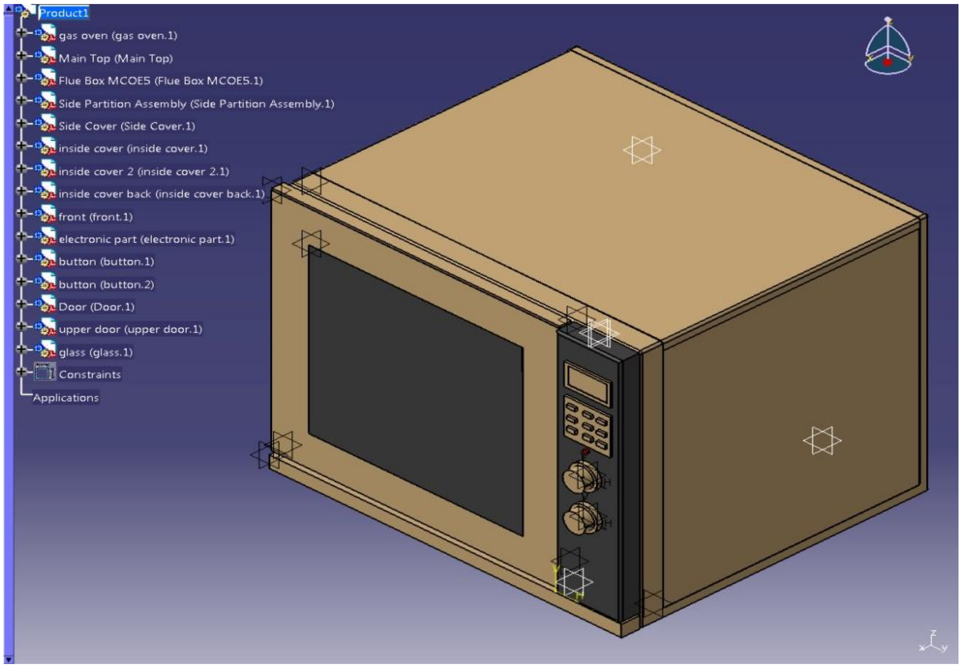


Figure 3.1*Conceptual Design of Domestic Gas Oven*

The design of domestic gas oven was constructed based on a review of the available literature that has been study. A research patents relating to efficiency improvement was also made. Finally, the best conceptual design of domestic gas oven (Figure 3.1) is constructed by using CATIA software.

The common materials used to build the domestic gas oven are stainless steel. The thermal conductivity of stainless steel is very low which 16 W/mK. In theory, thermal conductivity is the property of materials ability to conduct heat. So by using stainless steel as major material in construct gas oven is good because it can prevent the heat from going outside of gas oven easily. The table 3.1 shows the properties of stainless steel.

Table 3.1 Properties of Stainless Steel

Material	Thermal conductivity (W/m K)	Specific heat (J/kg K)	Density (kg/m³)
Stainless steel	16	500	8000

In this project will be focusing on thermal insulation material of domestic gas oven. Thermal insulation material is very important part in order to increase the efficiency of domestic gas oven. In this project, the lower thermal conductivity will be chosen as thermal insulator because it will give a greater temperature difference between the hot and cold faces and less energy losses. However, to choose thermal insulation for domestic gas oven, the material must safely for the foods and do not give hazard to the food. The figure 3.2 shows the part of domestic gas oven (thermal insulation material) that will be analyzing using ANSYS software.

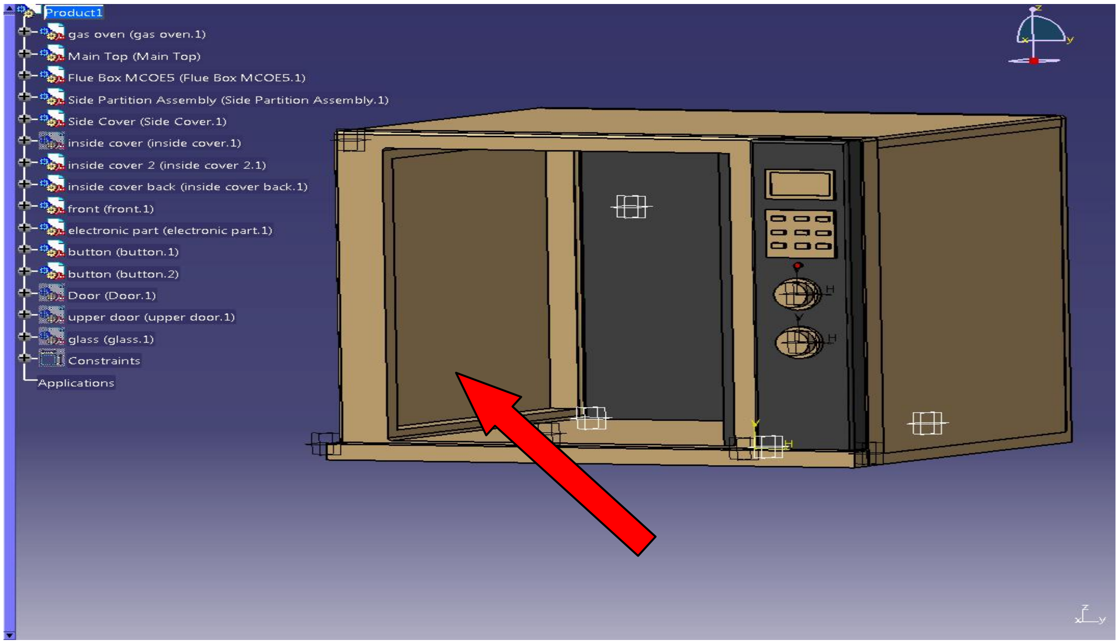


Figure 3.2 *Analysis Part*

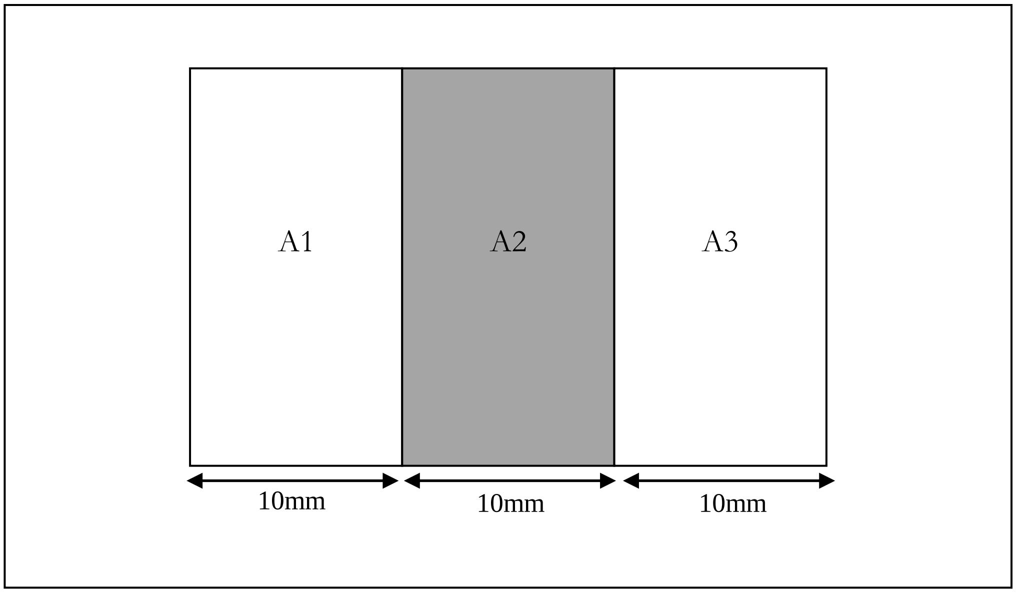


Figure 3.3 *Details of Analysis Part*

Figure 3.3 show the details of analysis part in domestic gas oven that will be focused on. Basically, domestic gas oven have three (3) layers of materials. The three layer of domestic gas oven are inner part of gas oven, thermal insulation part and outside part of gas oven. In this analysis of domestic gas oven, the inner part and outside part of domestic gas oven will be using stainless steel as a material. Stainless steel will be constant throughout the analysis and only the thermal insulation material will be changes. The thermal insulation materials that will be used in this domestic gas oven analysis are show in table 3.2. For the first analysis of domestic gas oven all the thickness for three layers will be constant which is 10mm will be applied.

The table 3.2 shows the list of material that will be used as thermal insulation material of domestic gas oven.

Table 3.2 Thermal Insulation Material Properties

Material	Thermal conductivity (W/m K)	Specific heat (J/kg K)	Density (kg/m^3)
Alumina ceramics, Al_2O_3 (A5)	30	780	3760
Alumina ceramics, Al_2O_3 (A7)	20	760	3600
Alumina ceramics, Al_2O_3 (A9)	15	750	3300

The analysis of thermal insulation material in this project can be divides into two analyses. The first analysis of this thermal insulation material will be using different type of materials of thermal insulation and the thickness of thermal insulation material will be constant which is in 10mm. The basic material that has been used in this gas oven analysis is stainless steel. The thickness of stainless steel has been set to 10mm. The figure 3.3 shows the example area of material in the domestic gas oven that will be analyzed in the first analysis of this project.

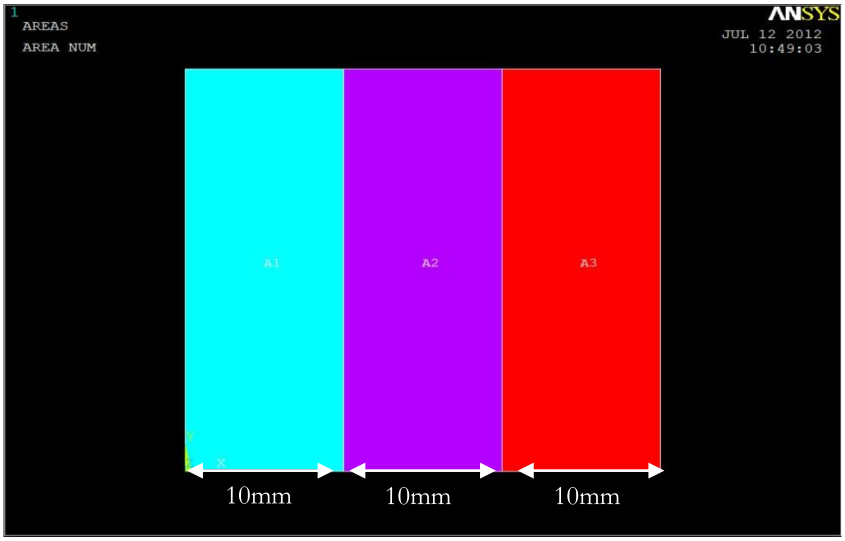


Figure 3.4 *Area of materials of domestic gas oven in ANSYS*

The two-dimensional analysis will be used in order to analyze the domestic gas oven to increase the efficiency of domestic gas oven. All the properties of material that been used to build the gas oven will be gather and will be put into the analysis. The details procedure of the analysis will be explain appropriately in the appendix 6.2.

Solve a composite wall of domestic gas oven using ANSYS for different thermal insulation material

The following steps demonstrate how to do two-dimensional analysis of domestic gas oven based on conduction problems with convective boundary conditions in ANSYS software. This task includes choosing appropriate element types, assigning attributes, applying boundary conditions and obtaining results.

To solve this problem using ANSYS, the following steps need to be employ:

Refer appendix 6.2

After all the analysis have been done for different thermal insulation material, the result for all the analysis will be compare and the best thermal insulation material will be choose for next analysis.

The second analysis will be using different thickness of thermal insulation material from 5, 10, 15, 20, 25 and 30mm. However, the material for thermal insulation will be the same (the best material from previous analysis) and stainless steel will be used in inner and outside part of the domestic gas oven. The thickness inner and outside part will be constant (10mm) throughout the analysis.

To solve this problem using ANSYS, the following steps need to be employ:

Refer appendix 6.2

#however, for steps 8 will change the dimension of thickness for insulation material (Alumina ceramics, Al_2O_3, A9) according to parameter that have been decide earlier (5, 10, 15, 20, 25 and 30mm).

Finally, after all the analysis have been done for different thickness of thermal insulation material. The appropriate thickness will be decided for domestic gas oven.

Figure below shows the project methodology for the design of an efficient domestic gas oven:

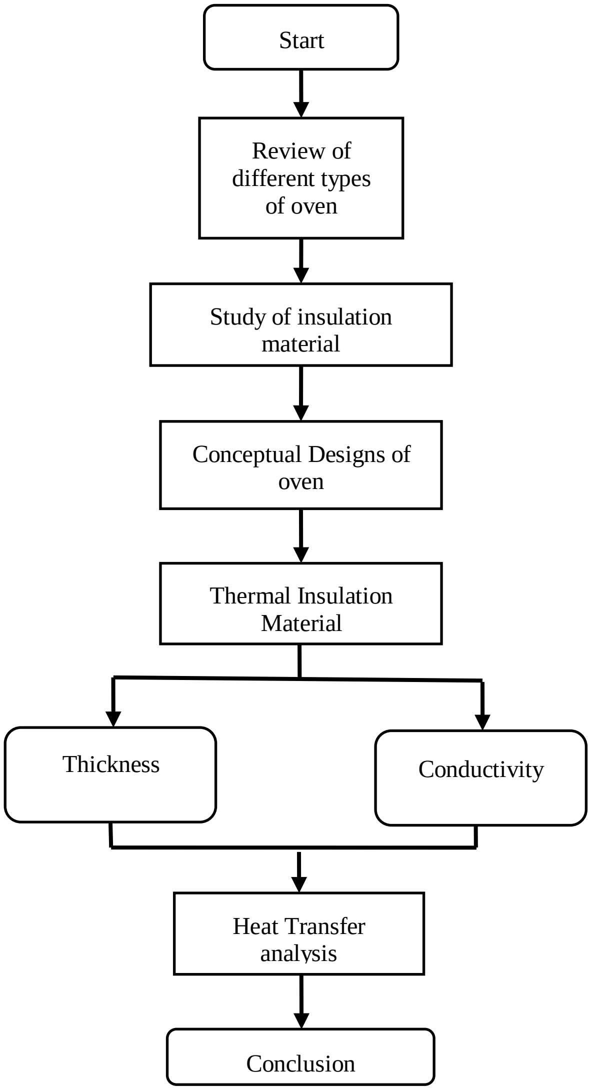
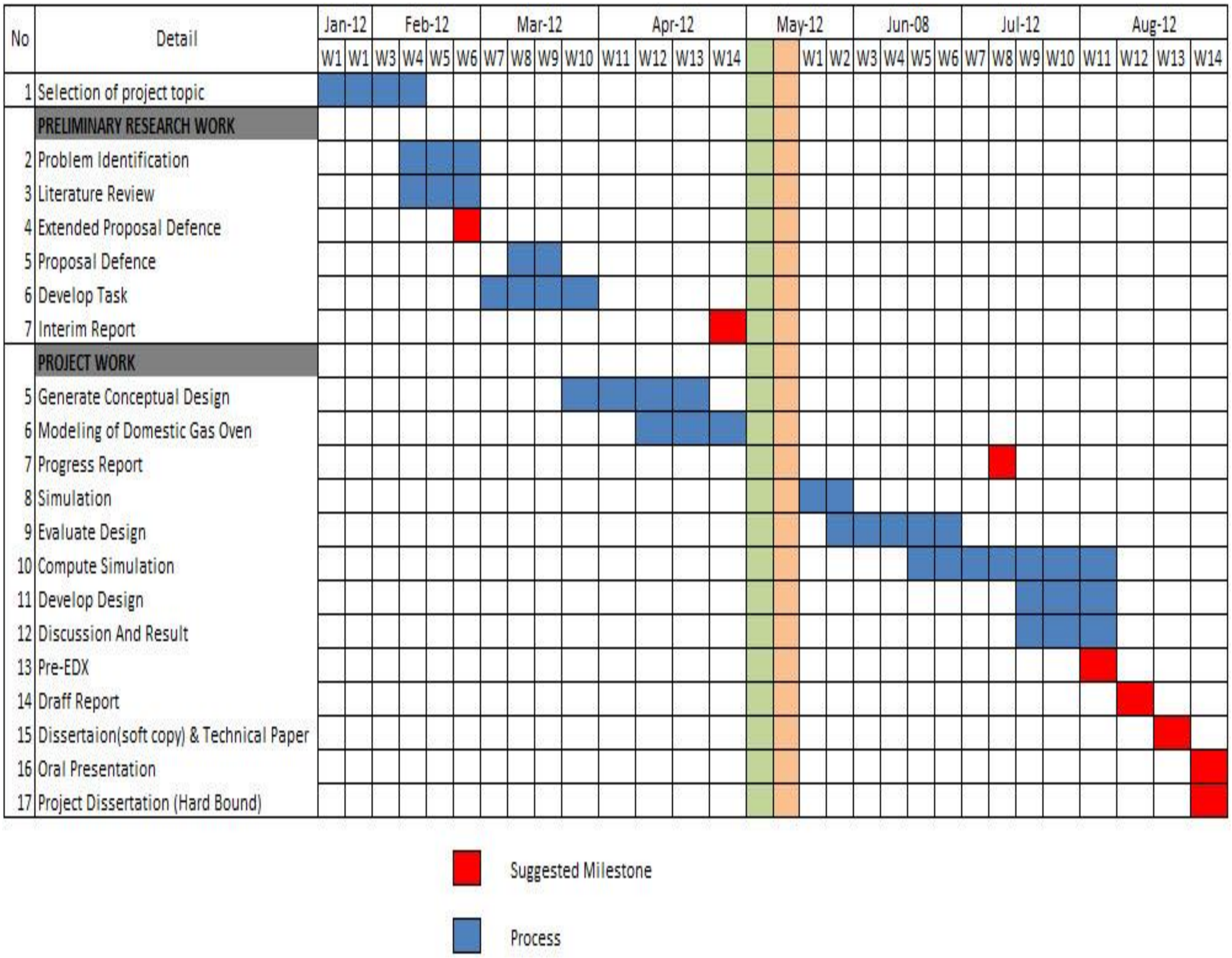


***Figure* 3.5** *Project Methodology*

3.2 Project Activities



No	Detail	Jan-12		Feb-12				Mar-12				Apr-12				May-12				Jun-08				Jul-12				Aug-12			
		W1	W1	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Selection of project topic	🟦	🟦	🟦	🟦																										
	PRELIMINARY RESEARCH WORK																														
2	Problem Identification				🟦	🟦	🟦																								
3	Literature Review				🟦	🟦	🟦																								
4	Extended Proposal Defence						🟥																								
5	Proposal Defence								🟦	🟦																					
6	Develop Task							🟦	🟦	🟦	🟦																				
7	Interim Report														🟥																
	PROJECT WORK																														
5	Generate Conceptual Design										🟦	🟦	🟦	🟦																	
6	Modeling of Domestic Gas Oven												🟦	🟦	🟦																
7	Progress Report																								🟥						
8	Simulation																	🟦	🟦												
9	Evaluate Design																		🟦	🟦	🟦	🟦	🟦								
10	Compute Simulation																					🟦	🟦	🟦	🟦	🟦	🟦	🟦			
11	Develop Design																									🟦	🟦	🟦			
12	Discussion And Result																									🟦	🟦	🟦			
13	Pre-EDX																											🟥			
14	Draff Report																												🟥		
15	Dissertaion(soft copy) & Technical Paper																													🟥	
16	Oral Presentation																														🟥
17	Project Dissertation (Hard Bound)																														🟥

🟥 Suggested Milestone

🟦 Process

Figure 3.6 Gantt Chart and Milestone

3.3 Tools Required

No	Tools	Function
1	MS Excel	Manual finite element calculation
2	CATIA software	Design of domestic gas oven
3	ANSYS software	Heat transfer analysis

Table 3.3 Tools required

CHAPTER 4

RESULT AND DISCUSSION

4.1 Various Thermal Insulation Material Analysis

After all the analysis has been done for different thermal insulation material, the result for all the analysis will be shows in the figure below. Comparing all the results and the best thermal insulation material will be choosing for next analysis.

1. Alumina ceramics, Al_2O_3 (A5)

Table 4.1 *List of temperature for each mm*

Thickness (mm)	Node	Temp.
0	131	200.000
1	219	189.930
2	307	179.870
3	395	169.820
4	483	159.800
5	571	149.810
6	659	139.860
7	747	129.950
8	835	120.070
9	923	110.240
10	52	100.430
11	1139	97.110
12	1227	93.817
13	1315	90.553
14	1403	87.316
15	1491	84.105
16	1579	80.917
17	1667	77.750
18	1755	74.604
19	1843	71.476
20	1032	68.366
21	2059	64.476
22	2147	60.602
23	2235	56.742
24	2323	52.895
25	2411	49.060
26	2499	45.235
27	2578	41.349
28	2675	37.609
29	2763	33.803
30	1952	30.000

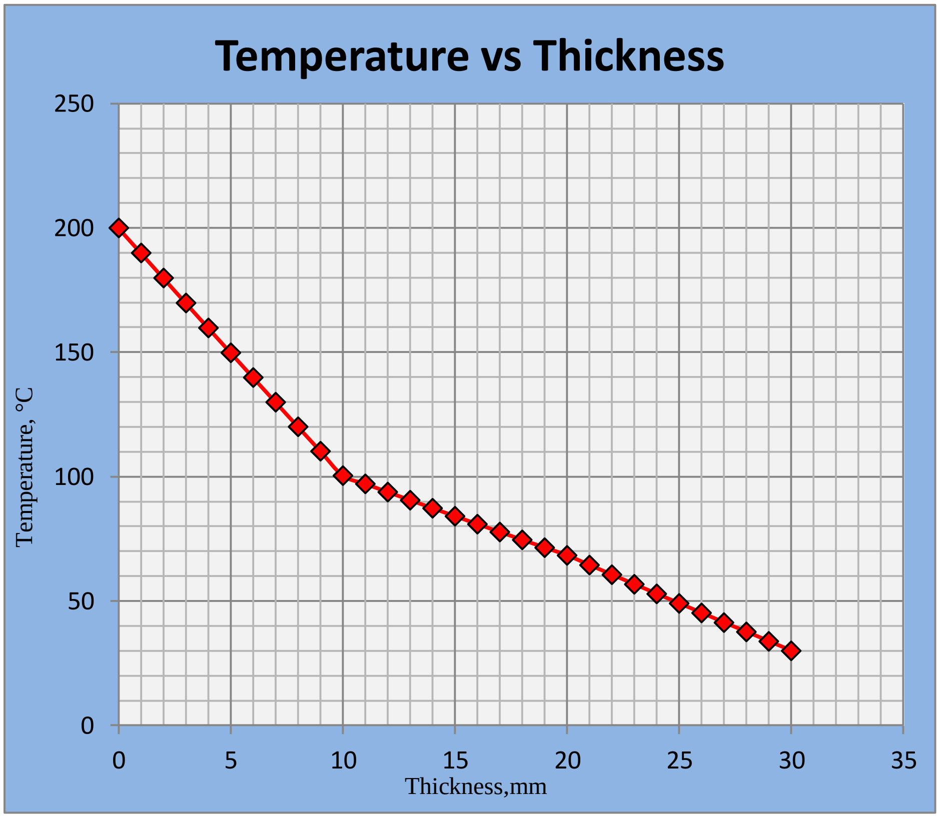


Figure 4.1 *Graph of temperature against thickness for* Alumina ceramics, Al_2O_3 (A5)

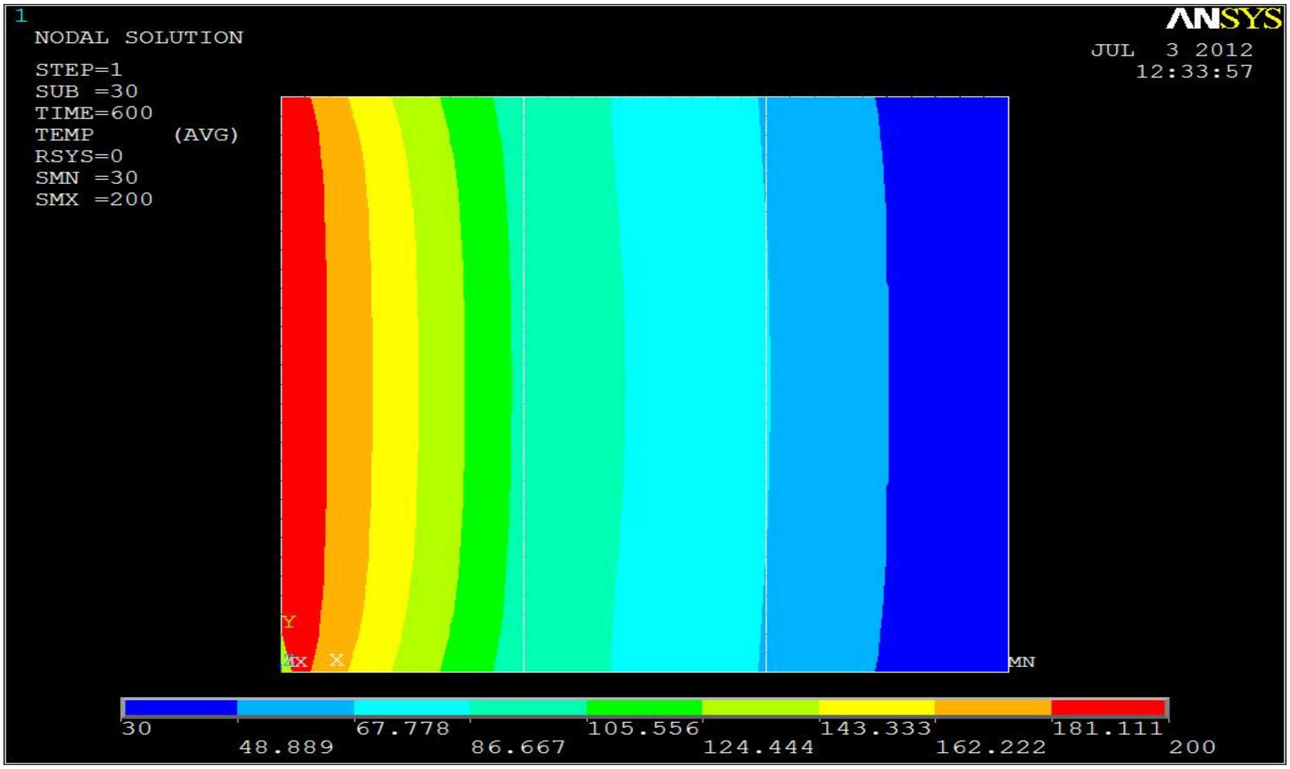


Figure 4.2 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A5)

$$m_5 = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{68.366 - 100.430}{20 - 10}$$

$$= |-3.2064|$$

$$= 3.2064$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(200.000 - 100.430)$$

$$= 47.7936W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{30(0.01x\ 0.03)}{0.01}(100.430 - 68.366)$$

$$= 28.8576W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(68.366 - 30.000)$$

$$= 16.5902W$$

2. Alumina ceramics, Al_2O_3 (A7)

Table 4.2 *List of temperature for each mm*

Thickness (mm)	Node	Temp.
0	131	200.000
1	219	190.430
2	307	180.880
3	395	171.340
4	483	161.830
5	571	152.360
6	659	142.930
7	747	133.540
8	835	124.190
9	923	114.890
10	52	105.630
11	1139	101.290
12	1227	96.981
13	1315	92.709
14	1403	88.471
15	1491	84.263
16	1579	80.083
17	1667	75.928
18	1755	71.797
19	1843	67.687
20	1032	63.596
21	2059	60.182
22	2147	56.784
23	2235	53.401
24	2323	53.151
25	2411	46.673
26	2499	43.326
27	2578	39.918
28	2675	36.654
29	2763	33.326
30	1952	30.000

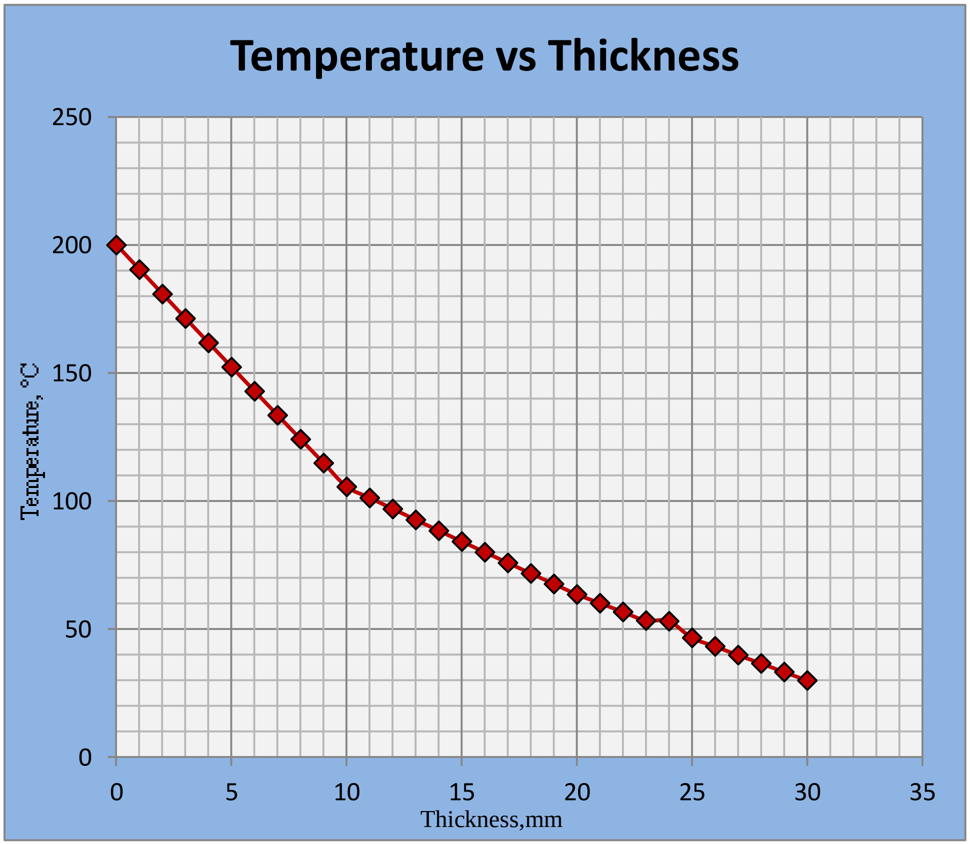


Figure 4.3 *Graph of temperature against thickness for* Alumina ceramics, Al_2O_3 (A7)

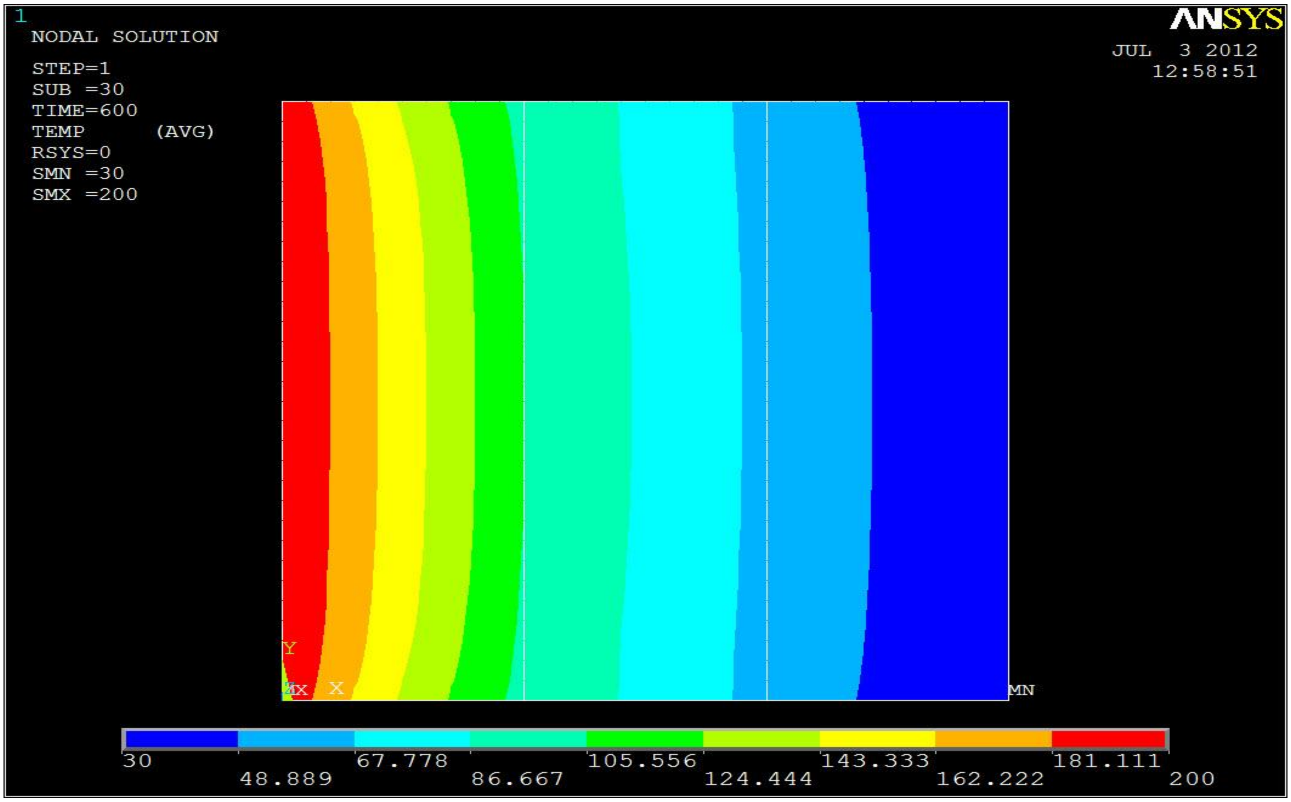


Figure 4.4 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A7)

$$m_7 = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{63.596 - 105.630}{20 - 10}$$

$$= |-4.2034|$$

$$= 4.2034$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(200.000 - 105.630)$$

$$= 45.2976W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{20(0.01x\ 0.03)}{0.01}(105.630 - 63.596)$$

$$= 25.2204W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(63.596 - 30.000)$$

$$= 16.12608W$$

3. Alumina ceramics, Al_2O_3 (A9)

***Table 4.3** List of temperature for each mm*

Thickness (mm)	Node	Temp.
0	131	200.00
1	219	190.820
2	307	181.660
3	395	172.510
4	483	163.40
5	571	154.320
6	659	145.290
7	747	136.310
8	835	127.370
9	923	118.480
10	52	109.640
11	1139	104.510
12	1227	99.416
13	1315	94.365
14	1403	89.350
15	1491	84.370
16	1579	79.420
17	1667	74.499
18	1755	69.602
19	1843	64.727
20	1032	59.873
21	2059	56.832
22	2147	53.807
23	2235	50.797
24	2323	47.800
25	2411	44.815
26	2499	41.839
27	2578	38.806
28	2675	35.911
29	2763	32.955
30	1952	30.000

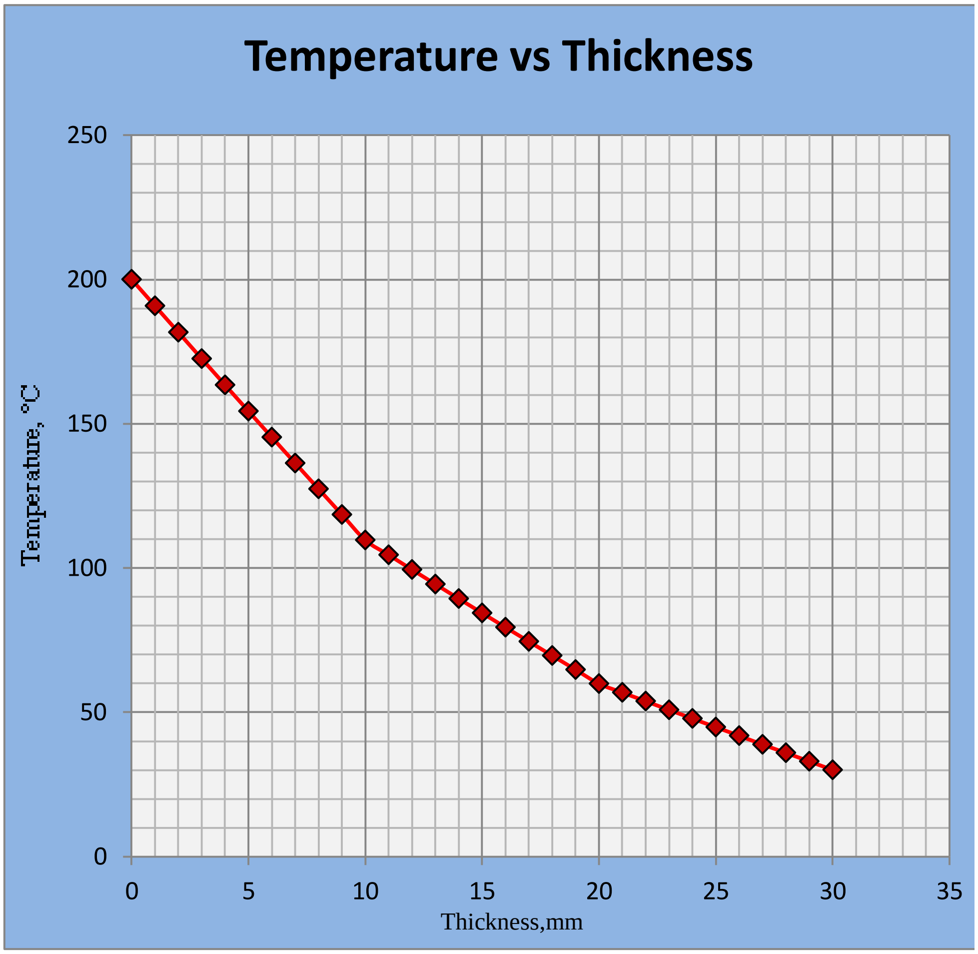
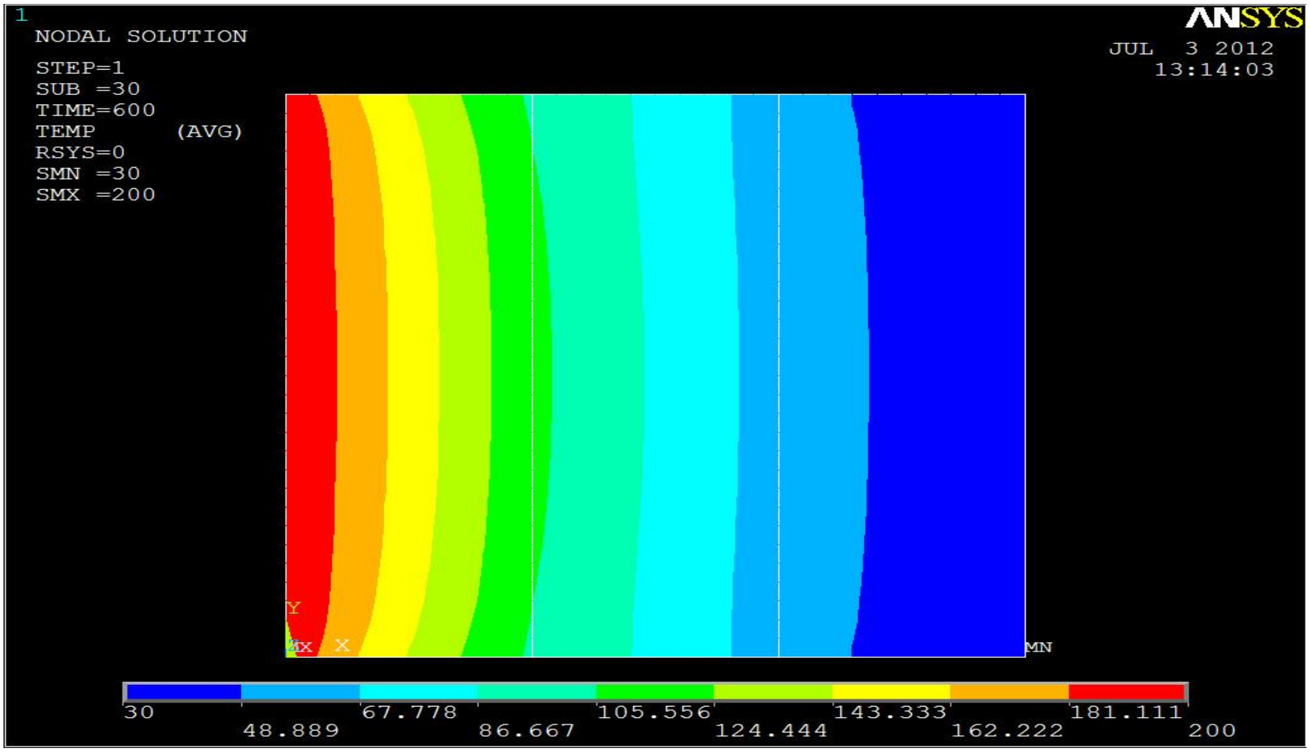


***Figure 4.5** Graph of temperature against thickness for* Alumina ceramics, Al_2O_3 (A9)



```
1
NODAL SOLUTION

STEP=1
SUB =30
TIME=600
TEMP        (AVG)
RSYS=0
SMN =30
SMX =200
```

Figure 4.6 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A9)

$$m_9 = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{59.873 - 109.640}{20 - 10}$$

$$= |-4.9767|$$

$$= 4.9767$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(200.000 - 109.640)$$

$$= 43.3728W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.01x\ 0.03)}{0.01}(109.640 - 59.873)$$

$$= 22.39515W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(59.873 - 30.000)$$

$$= 14.33904W$$

Based on the results of the analysis of thermal insulation for different types of material, it can be conclude that the material with low thermal conductivity will be choose as a thermal insulation material for domestic gas oven which is in this case is Alumina ceramics, Al_2O_3 (A9). By comparing the result of all the analysis, temperature gradient with high value will be selected. In this case, Alumina ceramics, Al_2O_3 (A9) will be selected because it gives high temperature gradient which is 4.9767. Alumina ceramics, Al_2O_3 (A9) has the highest temperature gradient by comparing with other insulation material. Alumina ceramics, Al_2O_3 (A5) and Alumina ceramics, Al_2O_3 (A7) gives less value of temperature gradient which is 3.2064 and 4.2034 respectively.

In this analysis not only comparing the temperature gradient of the insulation material but the analysis are tried to comparing the heat distribution of thermal insulation. The figure 4.6 showed that size of heat distribution which 30^oC (blue in colour) are thicker for Alumina ceramics, Al_2O_3 (A9) rather than Alumina ceramics, Al_2O_3 (A5) and Alumina ceramics, Al_2O_3 (A7). After the first analysis which is comparing the various types of thermal insulation material by using heat transfer analysis in ANSYS software.

So, the next analysis will be proceed by using the best thermal insulation material (Alumina ceramics, Al_2O_3 [A9]) by changing different thickness of thermal insulation material from 5mm until 30mm. However, the inner and outside part of the gas oven will be using the same material which is Stainless Steel with constant thickness of 10mm.

4.2 Various Thickness Thermal Insulation Material Analysis

After all the analysis has been done for various thickness of thermal insulation material, the result for all the analysis will be shows in the figure below. By comparing all the results and the best thickness of thermal insulation material will be suggest and chosen to construct the domestic gas oven in order to increase the efficiency of domestic gas oven.

1. 5mm Alumina ceramics, Al_2O_3 (A9)

Table 4.4 *List of temperature for each mm*

Thickness (mm)	Node	Temp.
0	131	200.000
1	219	189.970
2	307	179.950
3	395	169.950
4	483	159.980
5	571	150.050
6	659	140.160
7	747	130.310
8	835	120.520
9	923	110.770
10	52	101.070
11	1119	94.564
12	1207	88.097
13	1295	81.671
14	1383	75.281
15	1022	68.926
16	1599	64.942
17	1687	60.987
18	1775	57.056
19	1863	53.148
20	1951	49.259
21	2039	45.387
22	2127	41.528
23	2215	37.68
24	2303	33.838
25	1492	30.000

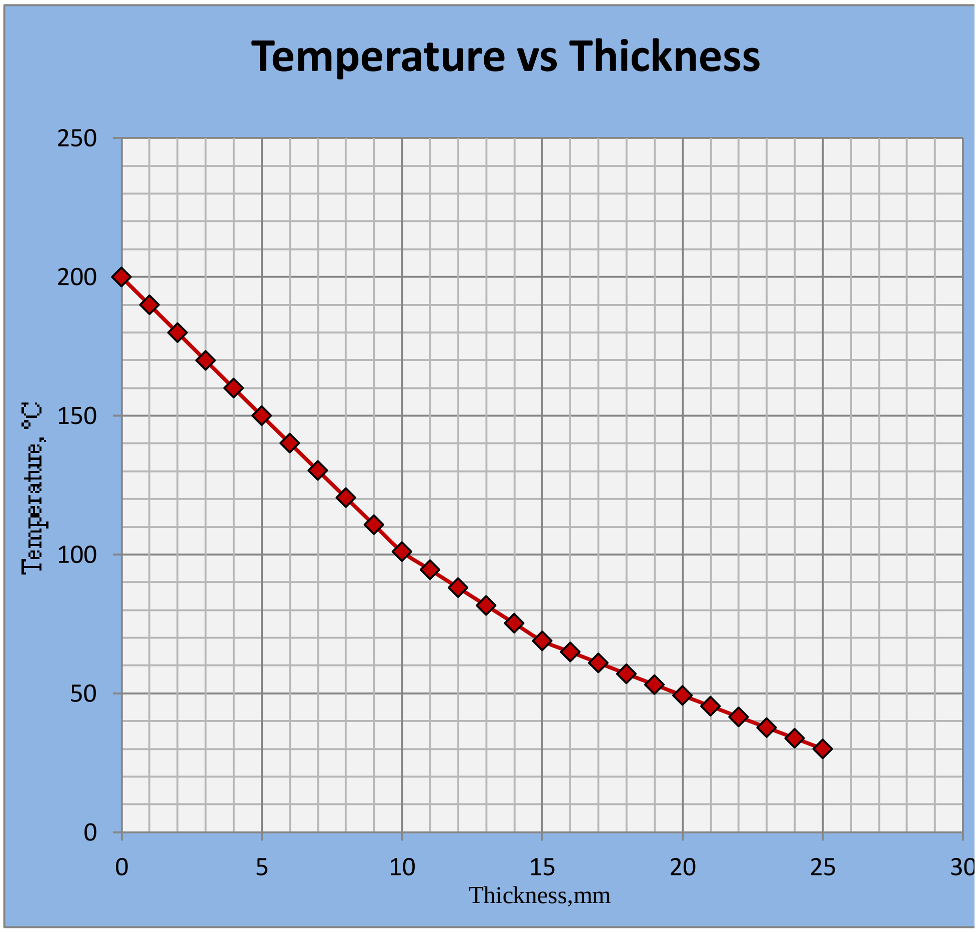
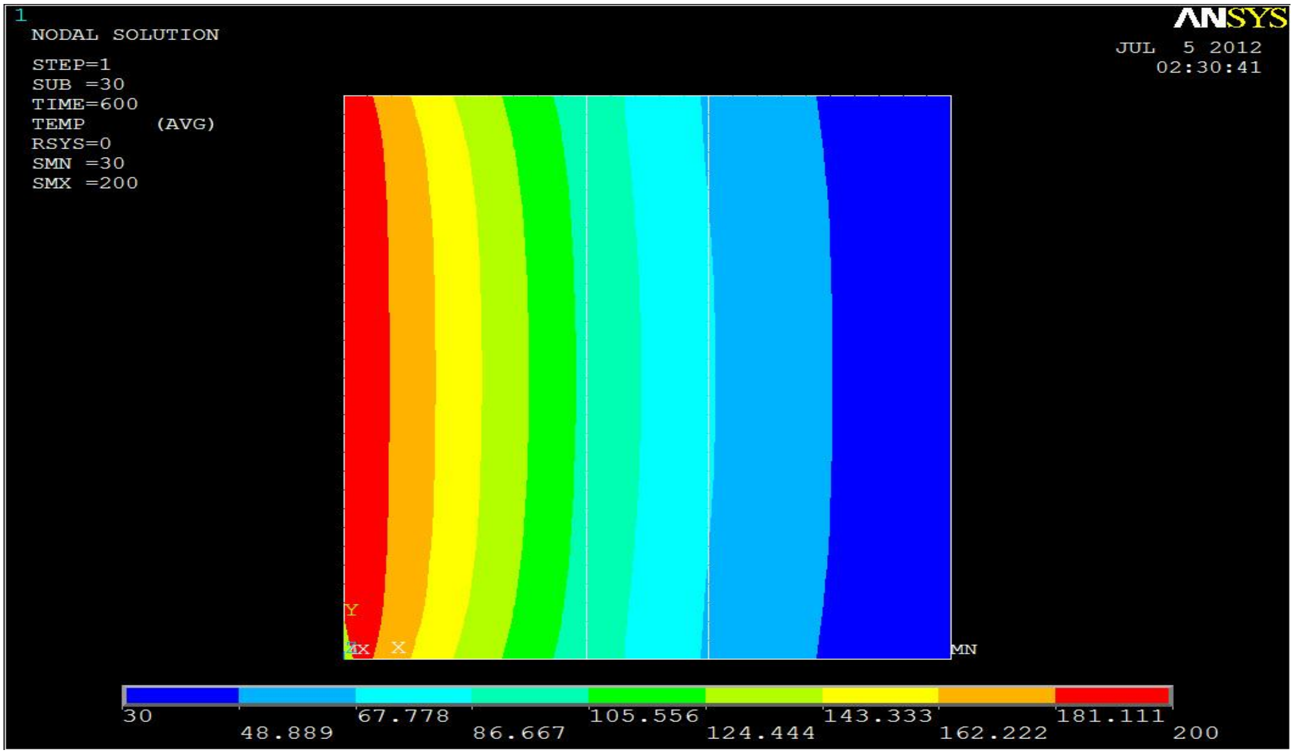


Figure 4.7 *Graph of temperature against thickness (5mm) for* Alumina ceramics, Al_2O_3 (A9)



```
1
NODAL SOLUTION

STEP=1
SUB =30
TIME=600
TEMP      (AVG)
RSYS=0
SMN =30
SMX =200
```

Figure 4.8 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A9)

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{68.926 - 101.070}{15 - 10}$$

$$= |-3.2144|$$

$$= 3.2144$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01\ x\ 0.03)}{0.01}(200.000 - 101.070)$$

$$= 47.4864W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.005\ x\ 0.03)}{0.005}(101.070 - 68.926)$$

$$= 14.4648W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(68.926 - 30.000)$$

$$= 18.68448W$$

2. 15mm Alumina ceramics, Al_2O_3 (A9)

Table 4.5 *List of temperature for each mm*

Thickness (mm)	Node	Temp.
0	131	200.000
1	219	191.360
2	307	182.740
3	395	174.140
4	483	165.570
5	571	158.110
6	659	148.540
7	747	140.100
8	835	131.710
9	923	123.370
10	52	115.080
11	1159	110.810
12	1247	106.590
13	1335	102.420
14	1423	98.272
15	1511	94.162
16	1599	90.081
17	1687	86.026
18	1775	81.995
19	1863	77.984
20	1951	73.992
21	2039	70.015
22	2127	66.054
23	2215	62.105
24	2303	58.169
25	1042	54.243
26	2519	51.785
27	2607	49.337
28	2695	46.897
29	2783	44.466
30	2871	42.042
31	2959	39.625
32	3047	37.214
33	3135	34.807
34	3223	32.403
35	2412	30.000

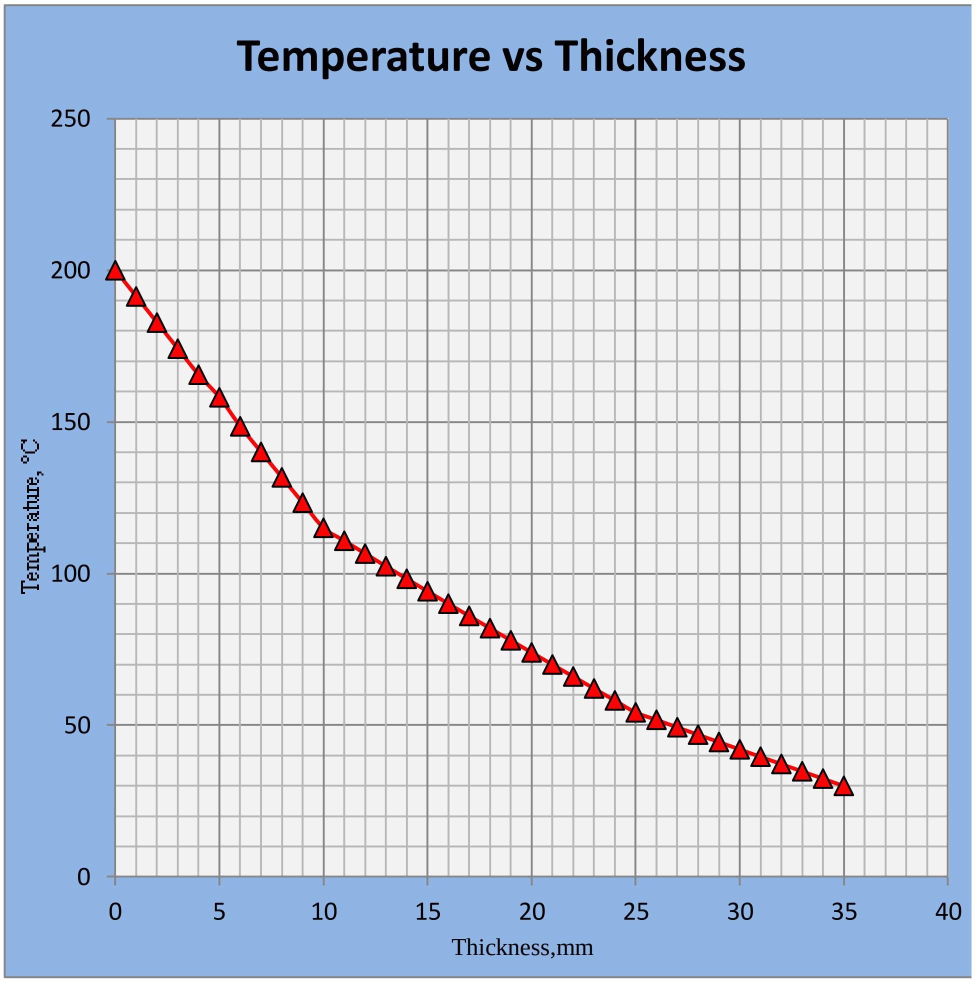


Figure 4.9 *Graph of temperature against thickness (15mm) for* Alumina ceramics, Al_2O_3 (A9)

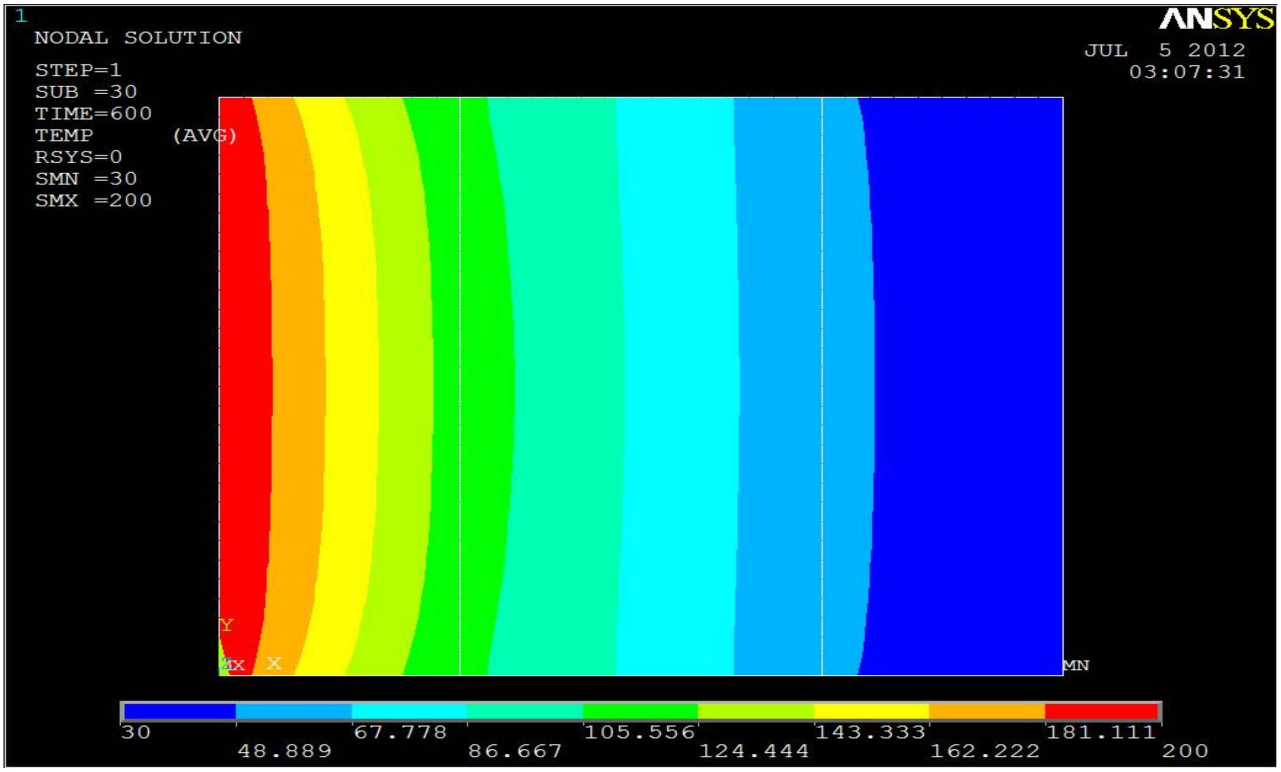


Figure 4.10 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A9)

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{68.926 - 101.070}{15 - 10}$$

$$= |-3.2144|$$

$$= 3.2144$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01 \ x \ 0.03)}{0.01}(200.000 - 101.070)$$

$$= 47.4864W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.005 \ x \ 0.03)}{0.005}(101.070 - 68.926)$$

$$= 14.4648W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x \ 0.03)}{0.01}(68.926 - 30.000)$$

$$= 18.68448W$$

3. 20mm Alumina ceramics, Al_2O_3 (A9)

Table 4.6 *List of temperature for each mm*

Distance (mm)	Node	Temp.
0	131	200.000
1	219	191.740
2	307	183.490
3	395	175.260
4	483	167.060
5	571	158.90
6	659	150.790
7	747	142.720
8	835	134.710
9	923	126.740
10	52	118.830
11	1179	115.170
12	1267	111.560
13	1355	107.980
14	1443	104.440
15	1531	100.940
16	1619	97.459
17	1707	94.007
18	1795	90.578
19	1883	87.168
20	1971	83.774
21	2059	80.394
22	2147	77.027
23	2235	73.672
24	2323	70.326
25	2411	66.988
26	2499	63.660
27	2587	60.338
28	2675	57.025
29	2763	53.718
30	1052	50.419
31	2979	48.352
32	3067	46.293
33	3155	44.239
34	3243	42.192
35	3331	40.151
36	3419	38.114
37	3507	36.082
38	3595	34.053
39	3683	32.026
40	2872	30.000

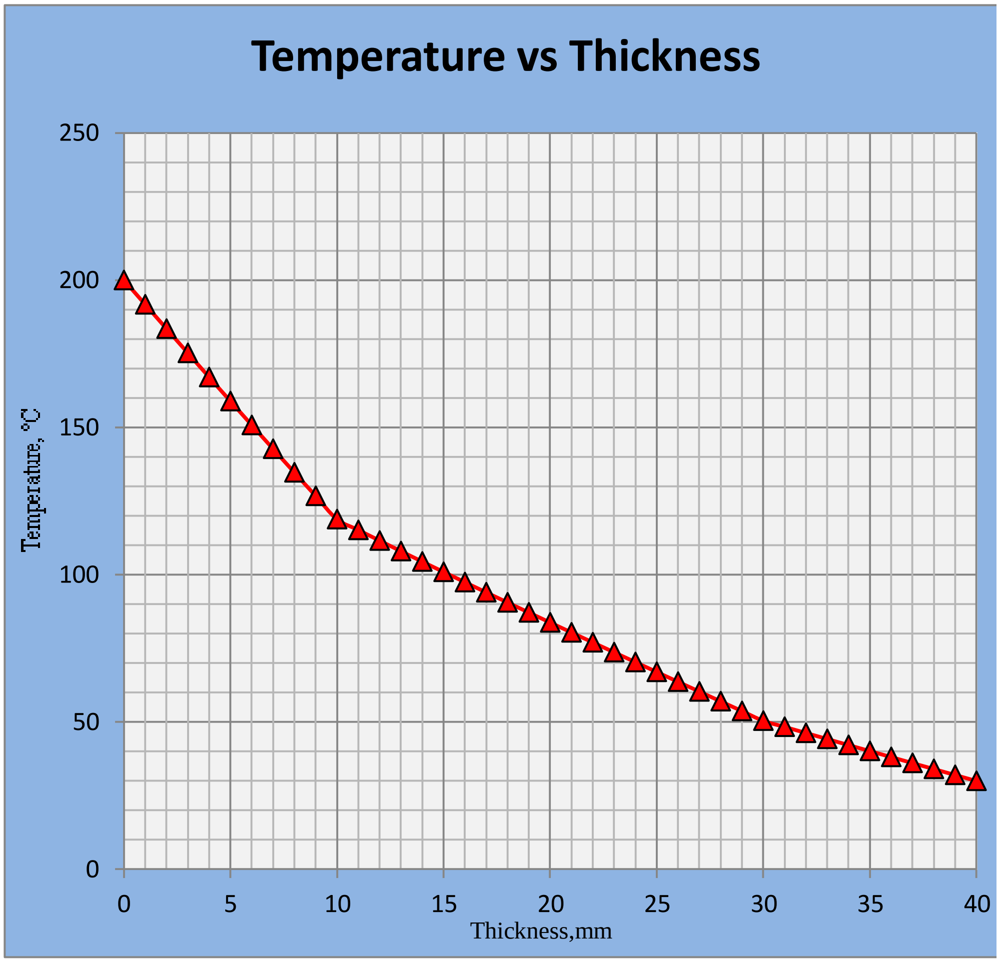


Figure 4.11 *Graph of temperature against thickness (20mm) for* Alumina ceramics, Al_2O_3 (A9)

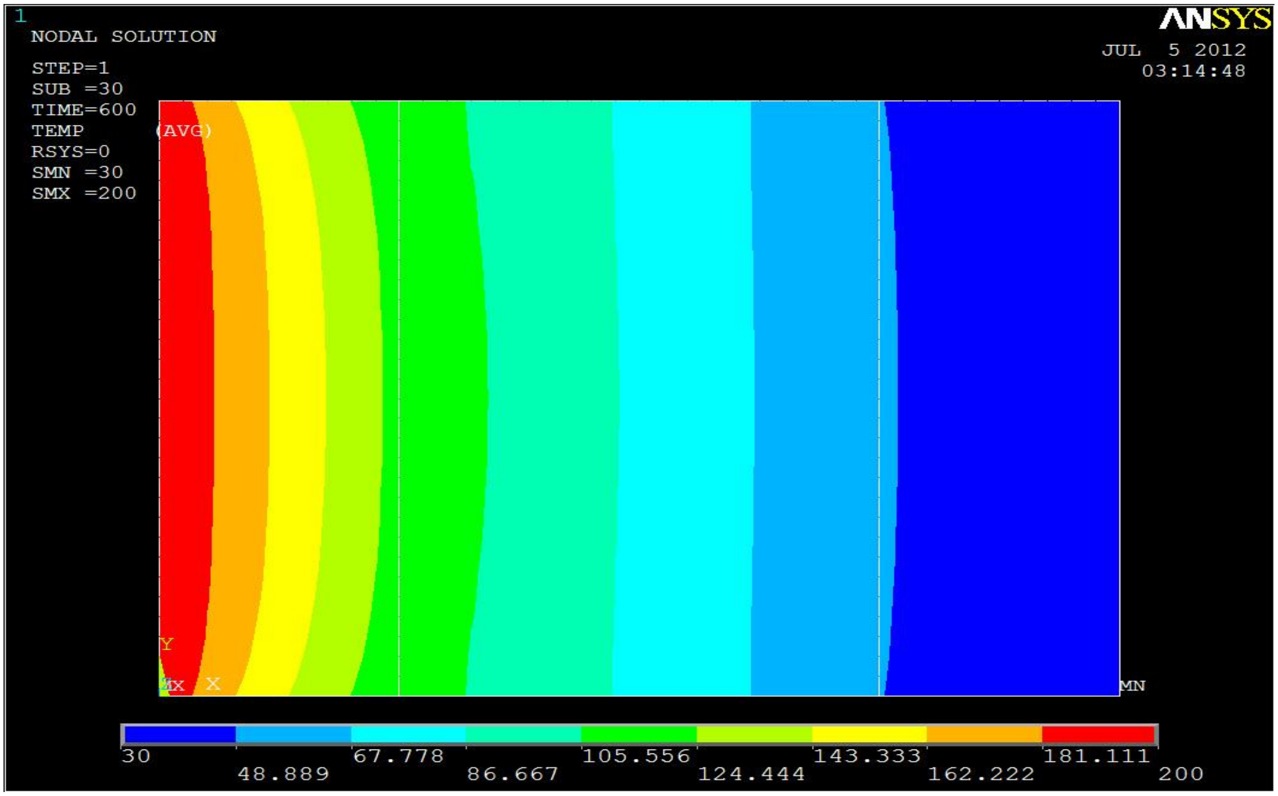


Figure 4.12 *Heat Transfer of Insulation Material for* Alumina ceramics, Al_2O_3 (A9)

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{50.419 - 118.830}{30 - 10}$$

$$= |-6.8411|$$

$$= 6.8411$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01 \; x \; 0.03)}{0.01}(200.000 - 118.830)$$

$$= 38.9616W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.02 \; x \; 0.03)}{0.02}(118.830 - 50.419)$$

$$= 30.7849W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x \; 0.03)}{0.01}(50.419 - 30.000)$$

$$= 9.8011W$$

4. 25mm Alumina ceramics, Al_2O_3 (A9)

Table 4.7 *List of temperature for each mm*

Distance (mm)	Node	Temp.
0	131	200.000
1	219	192.010
2	307	184.030
3	395	176.080
4	483	168.150
5	571	160.270
6	659	152.430
7	747	144.640
8	835	136.900
9	923	129.210
10	52	121.570
11	1199	118.360
12	1287	115.190
13	1375	112.050
14	1463	108.960
15	1551	105.900
16	1639	102.860
17	1727	99.856
18	1815	96.870
19	1903	93.903
20	1991	90.952
21	2079	88.014
22	2167	85.088
23	2255	82.171
24	2343	79.263
25	2431	76.362
26	2519	73.468
27	2607	70.579
28	2695	67.696
29	2783	64.817
30	2871	61.944
31	2959	59.075
32	3047	56.211
33	3135	53.351
34	3223	50.497
35	1062	47.648
36	3439	45.864
37	3527	44.084
38	3615	42.310
39	3703	40.541
40	3791	38.776
41	3879	37.016
42	3967	35.259
43	4055	33.504
44	4143	31.752
45	3332	30.000

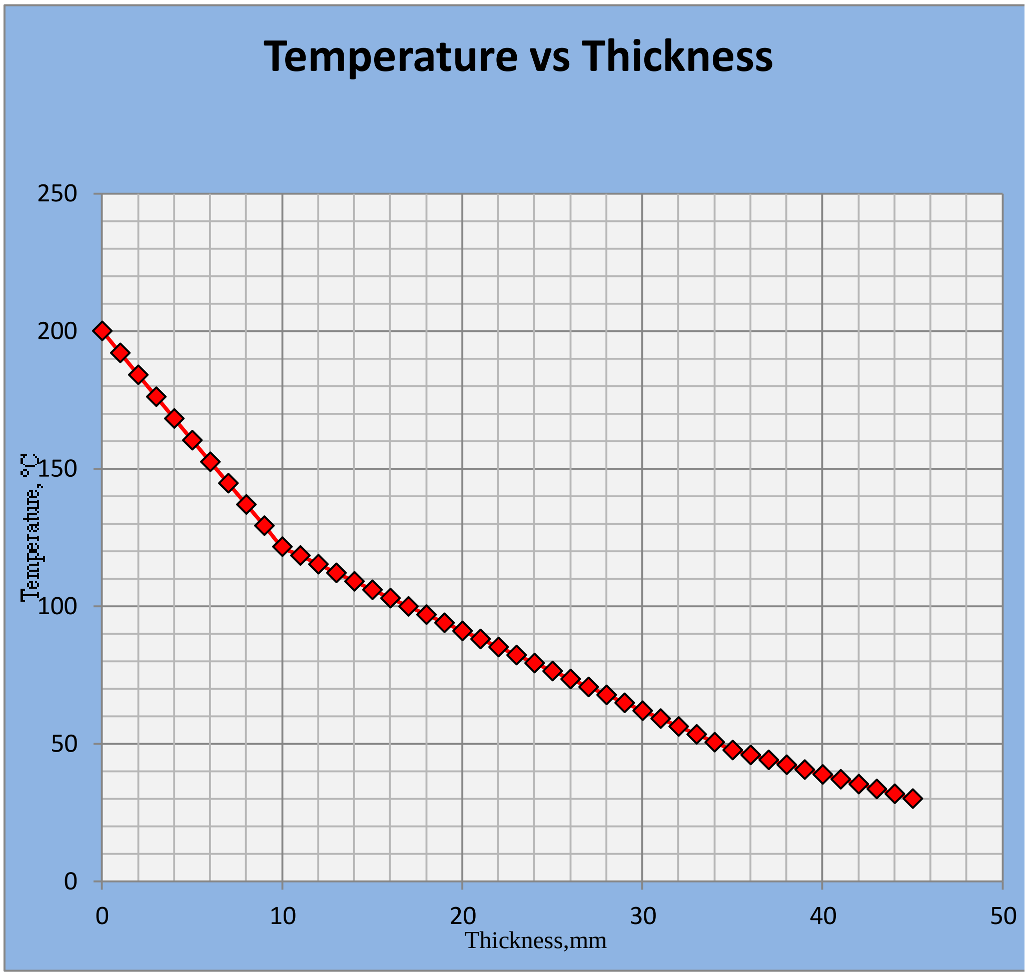


Figure 4.13*Graph of temperature against thickness (25mm) for* Alumina ceramics, Al_2O_3 (A9)

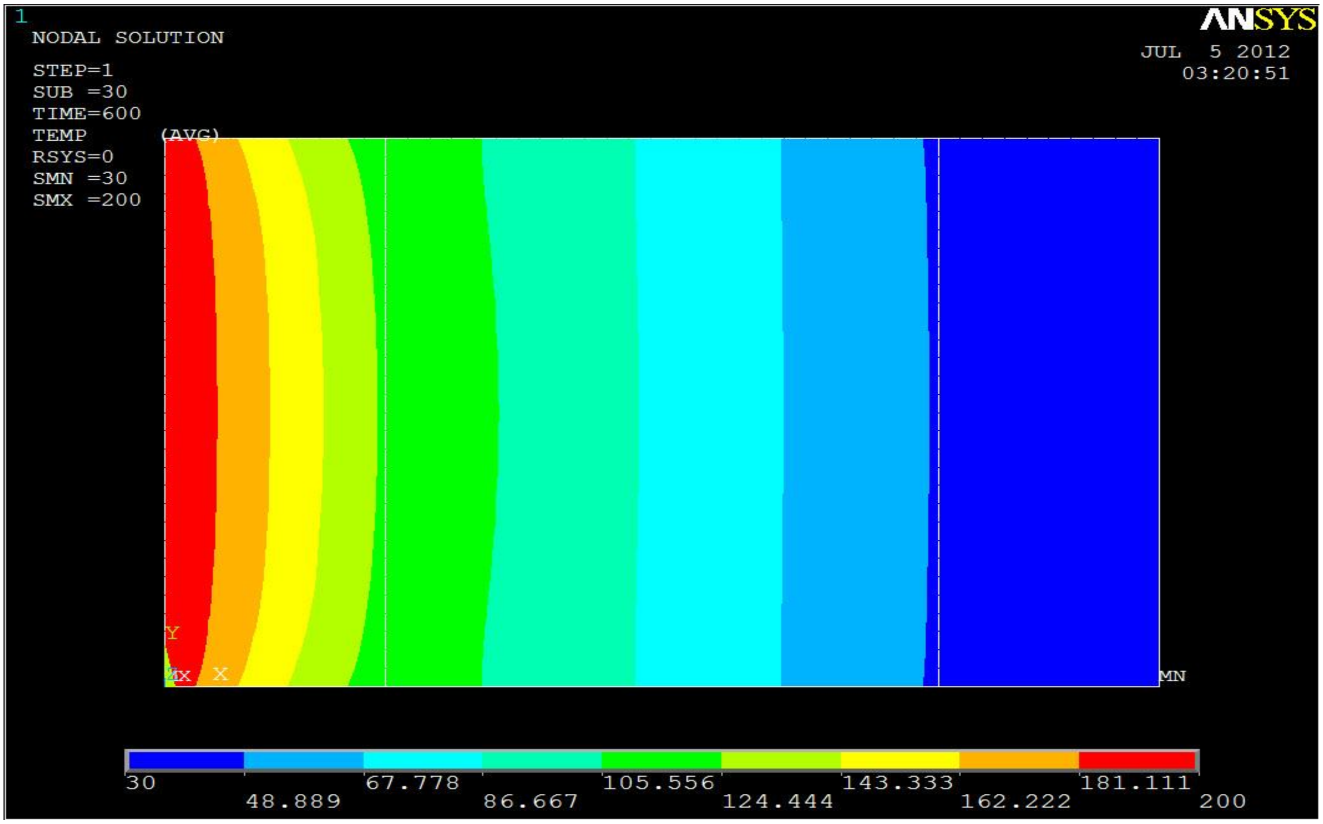


Figure 4.14 *Heat Transfer of Insulation Material for* Alumina ceramics, Al_2O_3 (A9)

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{47.648 - 121.570}{35 - 10}$$

$$= |-7.3922|$$

$$= 7.3922$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01\ x\ 0.03)}{0.01}(200.000 - 121.570)$$

$$= 37.6464W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.025\ x\ 0.03)}{0.025}(121.570 - 47.648)$$

$$= 33.2649W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x\ 0.03)}{0.01}(47.648 - 30.000)$$

$$= 8.4710W$$

5. 30mm Alumina ceramics, Al_2O_3 (A9)

Table 4.8 *List of temperature for each mm*

Distance (mm)	Node	Temp.
0	131	200.000
1	219	192.220
2	307	184.450
3	395	176.700
4	483	168.980
5	571	161.310
6	659	153.680
7	747	146.100
8	835	138.570
9	923	131.090
10	52	123.670
11	1219	120.790
12	1307	117.960
13	1395	115.160
14	1483	112.410
15	1571	109.680
16	1659	106.990
17	1747	104.320
18	1835	101.680
19	1923	99.048
20	2011	96.437
21	2099	93.838
22	2187	91.251
23	2275	88.673
24	2363	86.103
25	2451	83.540
26	2539	80.982
27	2627	78.429
28	2715	75.880
29	2803	73.334
30	2891	70.792
31	2979	68.253
32	3067	65.717
33	3155	63.184
34	3243	60.654
35	3331	58.127
36	3419	55.603
37	3507	53.083
38	3595	50.566
39	3683	48.053
40	1072	45.544
41	3899	43.974
42	3987	42.407
43	4075	40.844
44	4163	39.286
45	4251	37.732
46	4339	36.181
47	4427	34.633
48	4515	33.087
49	4603	31.543
50	3792	30.000

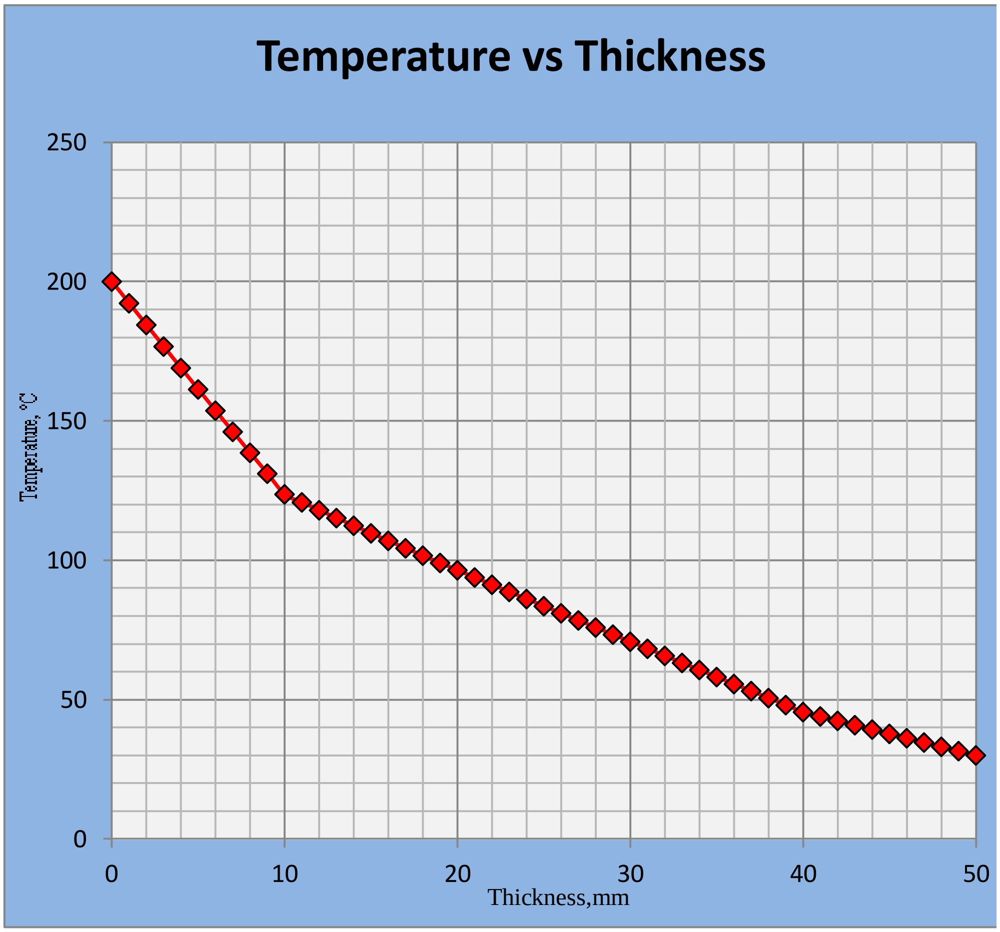


Figure 4.15 *Graph of temperature against thickness (30mm) for* Alumina ceramics, Al_2O_3 (A9)

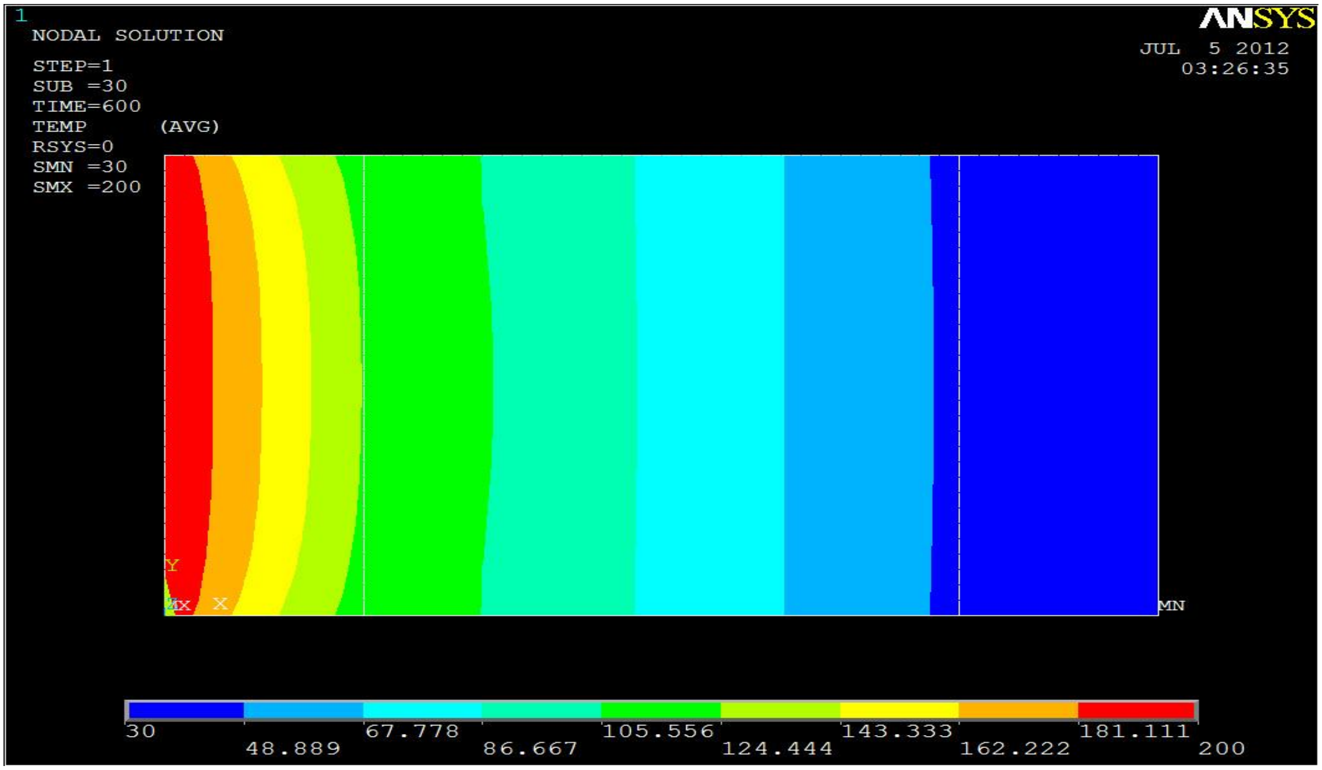


Figure 4.16 *Heat Transfer of Insulation Material for A*lumina ceramics, Al_2O_3 (A9)

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{45.544 - 123.670}{40 - 10}$$

$$= |-7.8126|$$

$$= 7.8126$$

$$Q^{(1)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01 \ x \ 0.03)}{0.01}(200.000 - 125.011)$$

$$= 35.9947W \approx 36W$$

$$Q^{(2)} = \frac{kA}{l}\Delta T$$

$$= \frac{15(0.03 \ x \ 0.03)}{0.03}(125.011 - 45.544)$$

$$= 35.7602W \approx 36W$$

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{16(0.01x \ 0.03)}{0.01}(45.544 - 30.000)$$

$$= 7.46112W$$

Based on the results for the thermal insulation material analysis for variant thickness, it can be conclude that the thermal insulation material with the thicker thickness is better in terms of temperature gradient. However, the right thickness must appropriately be choose to construct or to built the better domestic gas oven. In this case study analysis of various thickness of thermal insulation material, the most appropriately thickness is 30mm. It can be seen by the value of temperature gradient of thermal insulation material. The value of temperature gradient for 30mm Alumina ceramics, Al_2O_3 (A9) is the highest compare with other thickness of Alumina ceramics, Al_2O_3 (A9) that be using in this analysis which is 5, 10, 15, 20 and 25mm. The value of temperature gradient for 30mm Alumina ceramics, Al_2O_3 (A9) is 7.8126 much better than 10mm Alumina ceramics, Al_2O_3 (A9) which is only 4.9767.

In this analysis not only comparing the temperature gradient of the insulation material but the analysis are tried to comparing the heat distribution of thermal insulation. The figure 4.16 showed that size of heat distribution which 30^{o}C (blue in colour) are thicker for 30mm Alumina ceramics, Al_2O_3 (A9) rather than other thickness (5, 10, 15, 20 and 25mm) of Alumina ceramics, Al_2O_3 (A9). The heat distribution for 30mm Alumina ceramics, Al_2O_3 (A9) is the best because for the outside part of the domestic gas oven is only 30^{o}C. So, the user or consumer will not feel the heat of gas oven because the temperature for outside part of gas oven is same with room temperature.

Based on the **equation 2.2**, the heat conduction Q_{cond} through a layer of constant thickness Δx is proportional to the temperature difference ΔT across the layer and the area A normal to the direction of heat transfer and inversely proportional to the thickness of the layer. The temperature of the inside domestic gas oven was set to 200°C and room temperature that will take is 30°C. Generally, a heat transfer problem under steady state conditions applied in conservation of energy to control the volume surrounding an arbitrary node must be satisfied. For this analysis of various thickness of 30mm Alumina ceramics, Al_2O_3 (A9), heat loss through each layer must be equal the heat removed by the surrounding air. So,

$$Q^{(1)} = Q^{(2)} = Q^{(3)}$$

In this analysis of various thickness thermal insulation material, $Q^{(1)}$ *and* $Q^{(2)}$ *are satisfied the heat loss through a layer because* $Q^{(1)} = Q^{(2)}$. However, $Q^{(3)}$ are not satisfied the heat loss through a layer because $Q^{(3)} \neq Q^{(1)} \neq Q^{(2)}$.

In order to satisfy the heat loss through a layer for $Q^{(3)}$, the material for outside part of the gas oven must be changed. For $Q^{(3)}$ to get Q = 36W, the outside part of domestic gas oven must be change from stainless steel to cast iron because cast iron has thermal conductivity, k = 77 W/m K. So,

$$Q^{(3)} = \frac{kA}{l}\Delta T$$

$$= \frac{77(0.01x\ 0.03)}{0.01}(45.544 - 30.000)$$

$$= 35.9066W \approx 36W$$

By changing the material for outside part of domestic gas oven from stainless steel to cast iron, it is satisfied the heat loss through a layer because $Q^{(1)} = Q^{(2)} = Q^{(3)}$. So, the ideal material of domestic gas oven is shown in figure 4.17 below.

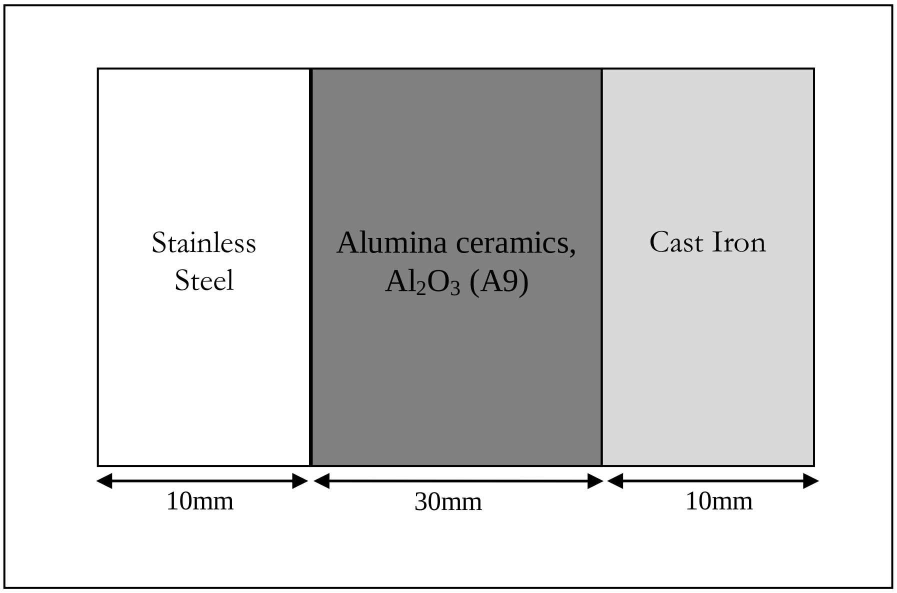


Figure 4.17 *Ideal materials for domestic gas oven*

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As by reaching the end of the semester, the aim of design of an efficient domestic gas oven was achieved. From the result that have been obtained from the analysis, it can be conclude that the design of an efficient domestic gas oven is acceptable after considering several limitations and analysis using ANSYS software

As for the conclusion, it can be conclude that the project already reach the objectives of the project which is to increase the efficiency of domestic gas oven. Based on the result from the thermal insulation material analysis, 30mm **Alumina ceramics, Al_2O_3 (A9)** is the most suitable thermal insulation material because it has the highest value of temperature gradient. In order to increase the efficiency of domestic gas oven, the material for outside part of domestic gas oven must be changed from stainless steel to cast iron. So, it can satisfied the heat loss through a layer $Q^{(1)} = Q^{(2)} = Q^{(3)}$.

5.2 Recommendation

To improve the design of an efficient domestic gas oven, several methods can be used:

i. **Build a prototype of domestic gas oven based on this project analysis**

In order to prove that the analysis in this project can increase the efficiency of domestic gas oven, the prototype of domestic gas oven can be build to verify the truth of analysis.

ii. **Time constraint**

In order to succeed in this project by increasing the efficiency of domestic gas oven, the student must be given more time to do this final year project because one semester is not enough to study about domestic gas oven, to do the design and analysis of domestic gas oven and also to build the prototype of domestic gas oven.

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APPENDICES

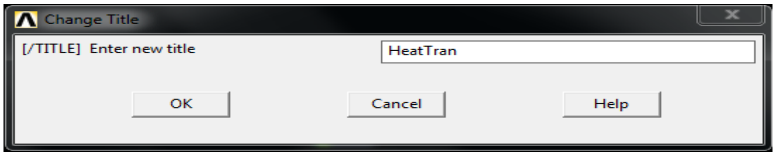
6.1 Steps to create one-dimensional (1D) conduction problems with convective boundary conditions in ANSYS

1. Enter the **ANSYS** program using the Launcher.

2. Type **HeatTran** (or file name of your choice) in the **Jobname** entry field of the dialog box and pick **Run** to start the GUI.

3. Create a title for the problem. This will appear on ANSYS display windows to provide a simple way of identifying the displays:

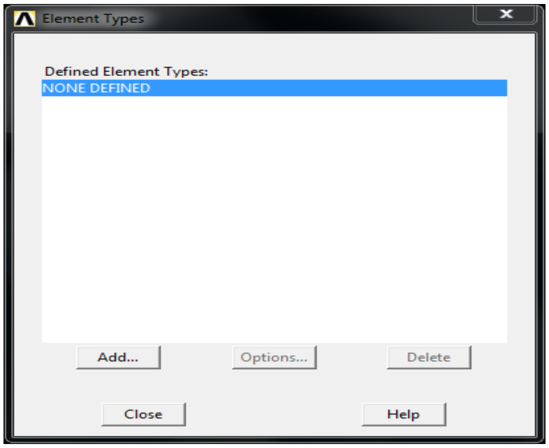
   Utility menu: **File → Change Title**



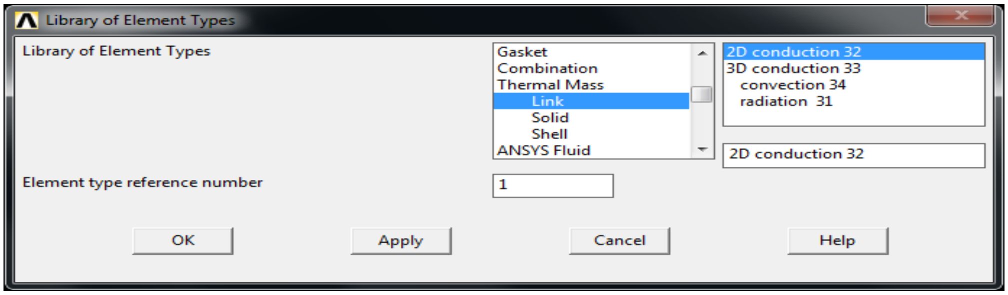
[/TITLE] Enter new title: HeatTran

4. Define the element type and material properties:

   Main menu: **Preprocessor → Element Type → Add/ Edit/ Delete**

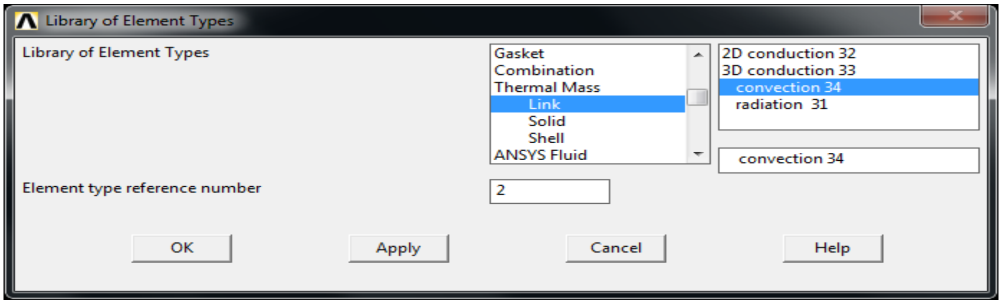


Defined Element Types:
NONE DEFINED



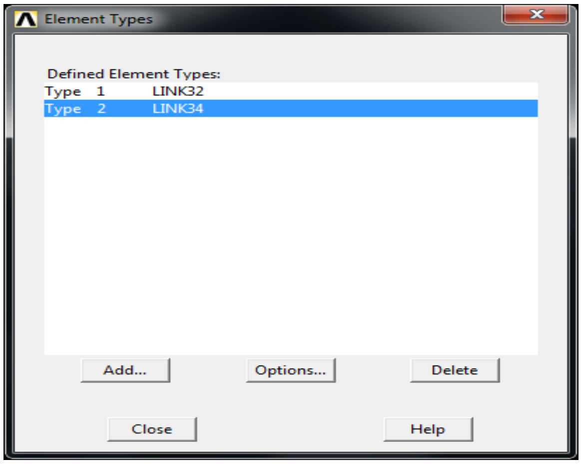
Library of Element Types: Link, 2D conduction 32

Element type reference number: 1



convection 34

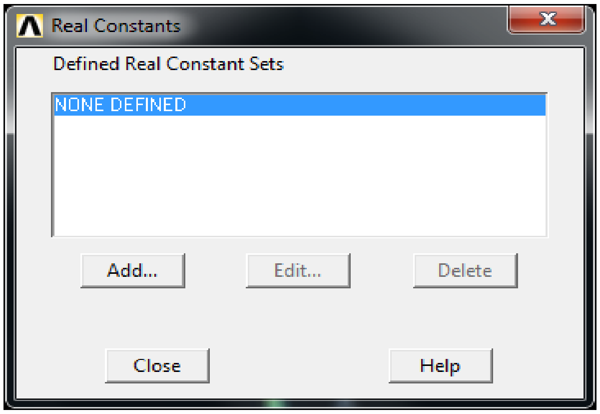
Element type reference number 2

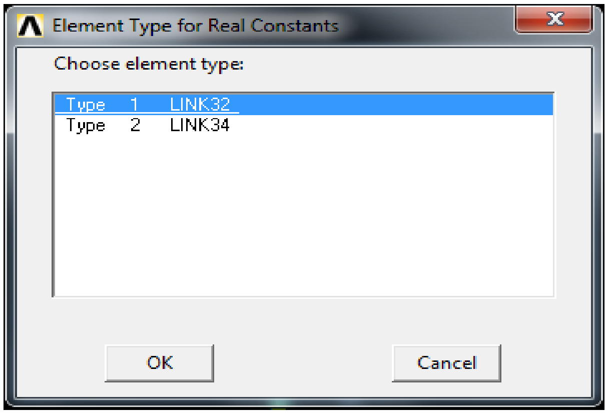


Defined Element Types:
Type 1 LINK32
Type 2 LINK34

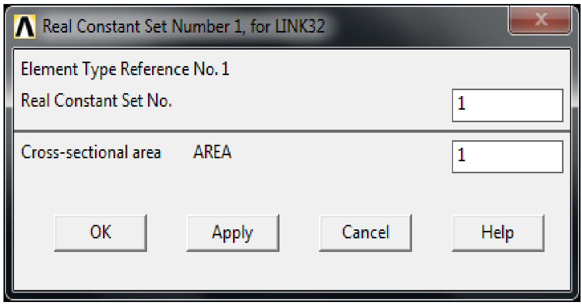
5. Assign the cross-sectional area of the wall.

Main menu: **Prepocessor → Real Constants → Add/ Edit/ Delete**

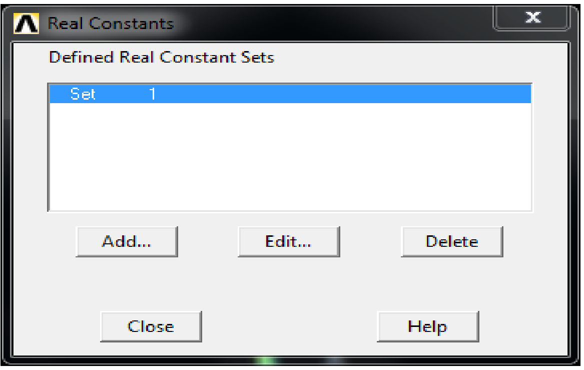




Choose element type:
Type 1 LINK32
Type 2 LINK34

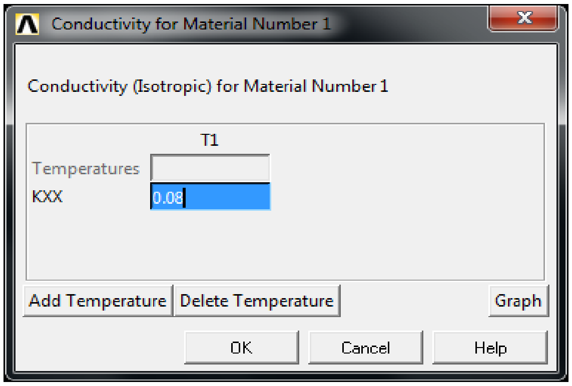


Element Type Reference No. 1
Real Constant Set No. 1
Cross-sectional area AREA 1



6. Assign the thermal conductivity values.

   Main menu: **Preprocessor → Material Props→ Material Models → Thermal → Conductivity → Isotropic**



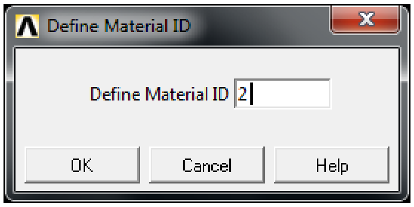
Conductivity (Isotropic) for Material Number 1

Temperatures

KXX 0.08

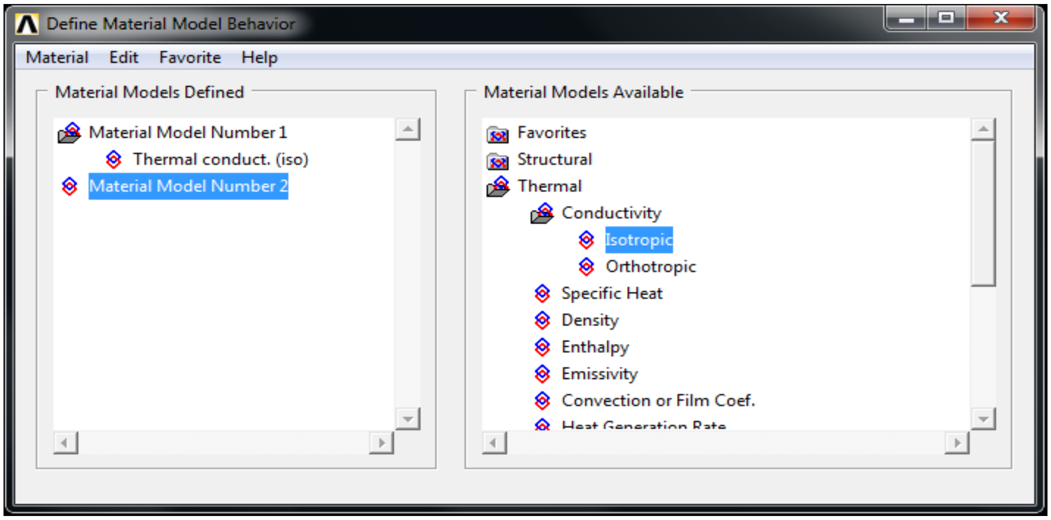
7. From the Define Material Model Behavior window:

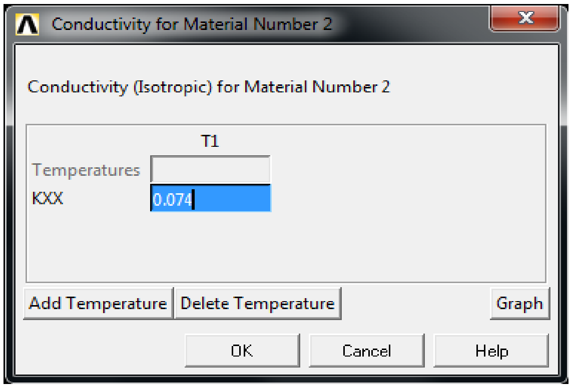
   Material → New Model



Define Material ID 2

8. Now double-click on **Isotropic**

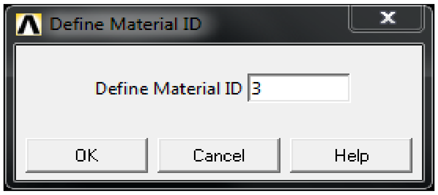




KXX 0.074

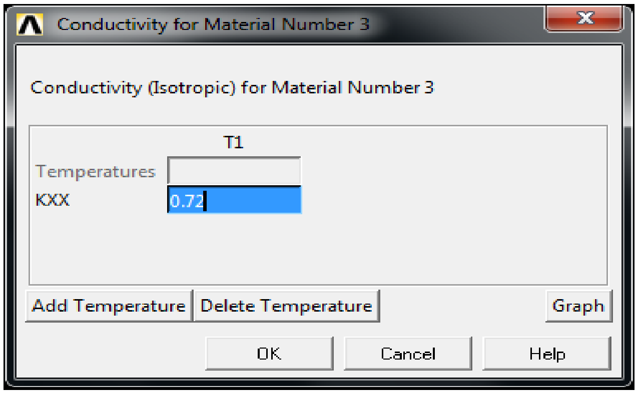
9. From the Define Material Model Behaviour window:

Material → New Model



Define Material ID 3

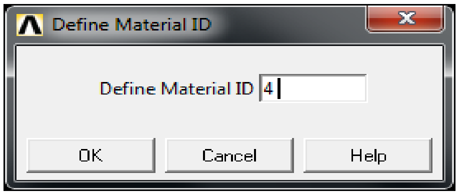
10. Assign the thermal conductivity of the third layer by double clicking on **Isotropic** again.



KXX 0.72

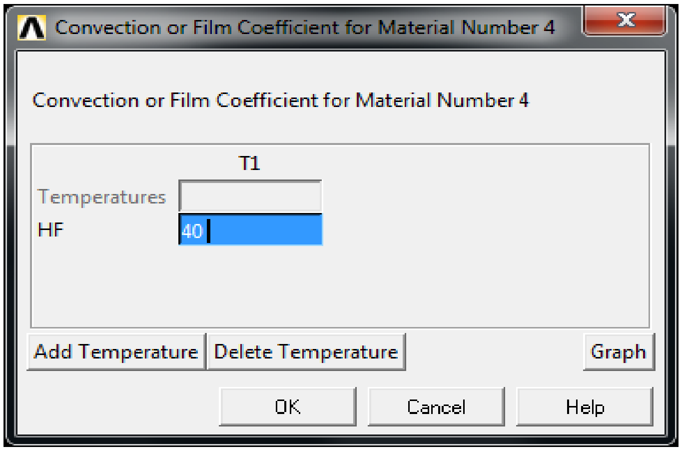
11. From the Define Material Model Behavior window:

Material → New Model



Define Material ID 4

12. Assign the heat transfer coefficient by double-clicking on **Convection or Film Coef.**



Convection or Film Coefficient for Material Number 4

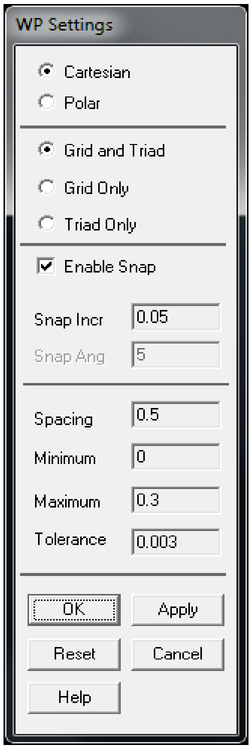
Convection or Film Coefficient for Material Number 4

	T1
Temperatures	
HF	40

ANSYS Toolbar: **SAVE_DB**

13. Setup the graphics area (i.e., workplane, zoom, etc.):

Utility menu: **Workplace→ WP Settings**



WP Settings

● Cartesian
○ Polar

● Grid and Triad
○ Grid Only
○ Triad Only

☑ Enable Snap

Snap Incr 0.05
Snap Ang 5

Spacing 0.5
Minimum 0
Maximum 0.3
Tolerance 0.003

14. Toggle on the workplane by the following sequence:

Utility menu: **Workplane → Display Working Plane**

15. Bring the workplane to view using the following sequence:

    Utility menu: **PlotCtrls → Pan, Zoom, Rotate**

16. Create nodes by picking points on the workplane:

    Main menu: **Preprocessor → Modeling → Create → Nodes→ On Working Plane**

17. On workplane, pick the location of nodes and apply them:

    🖱 **[WP = 0,0]**

    🖱 **[WP = 0.05,0]**

    🖱 **[WP = 0.2,0]**

    🖱 **[WP = 0.3,0]**

18. Create the node for the convection element:

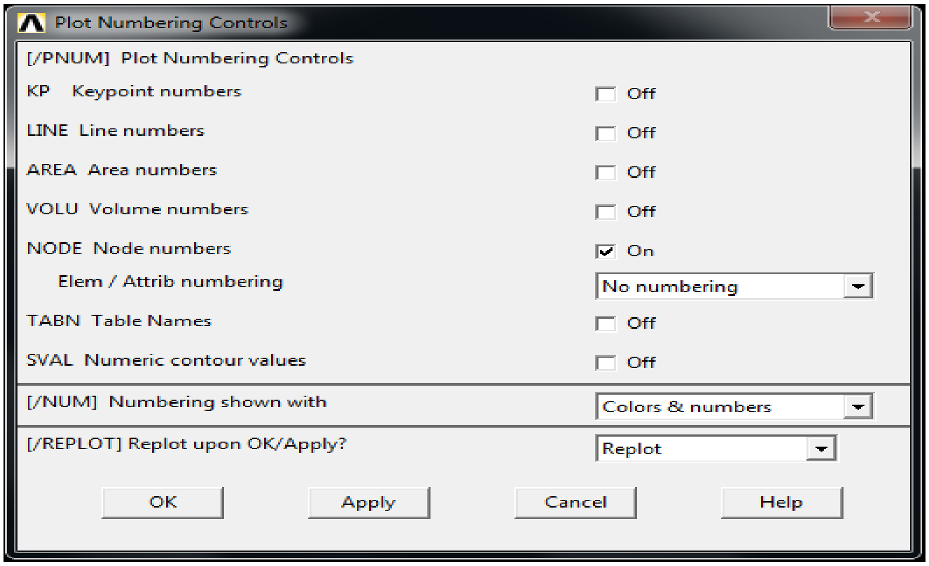
    🖱 **[WP = 0.3,0]**

    OK

19. Turn off the workplane now and turn on node numbering:

Utility menu: **Workplace → Display working plane**

Utility menu: **PlotCtrls → Numbering**


Plot Numbering Controls

[/PNUM] Plot Numbering Controls

KP Keypoint numbers ☐ Off

LINE Line numbers ☐ Off

AREA Area numbers ☐ Off

VOLU Volume numbers ☐ Off

NODE Node numbers ☑ On

Elem / Attrib numbering: No numbering

TABN Table Names ☐ Off

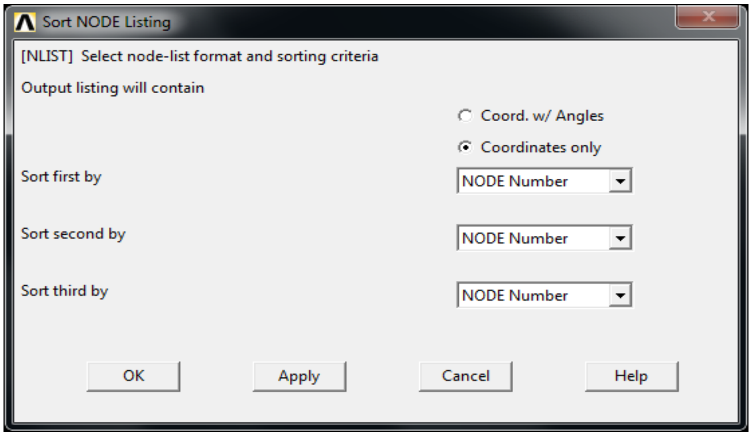
SVAL Numeric contour values ☐ Off

[/NUM] Numbering shown with: Colors & numbers

[/REPLOT] Replot upon OK/Apply?: Replot

20. List all the nodes at this point in order to check the work:

Utility menu: **List → Nodes**


Sort NODE Listing

[NLIST] Select node-list format and sorting criteria

Output listing will contain

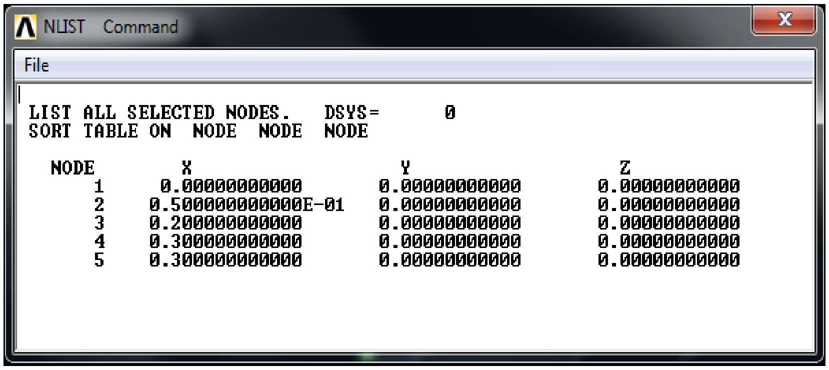
○ Coord. w/ Angles

● Coordinates only

Sort first by: NODE Number

Sort second by: NODE Number

Sort third by: NODE Number



```
LIST ALL SELECTED NODES.   DSYS=      0
SORT TABLE ON  NODE  NODE  NODE

  NODE        X                   Y                   Z
      1     0.00000000000       0.00000000000       0.00000000000
      2    0.500000000000E-01   0.00000000000       0.00000000000
      3    0.200000000000       0.00000000000       0.00000000000
      4    0.300000000000       0.00000000000       0.00000000000
      5    0.300000000000       0.00000000000       0.00000000000
```

Close

ANSYS Toolbar : **SAVE_DB**

21. Define elements by picking nodes:

Main menu: **Preprocessor → Modelling → Create → Elements → Auto Numbered → Thru Nodes**

■□□ **[node 1 and then node 2]**

□■□ **[use the middle button anywhere in the ANSYS graphics window to apply.]**

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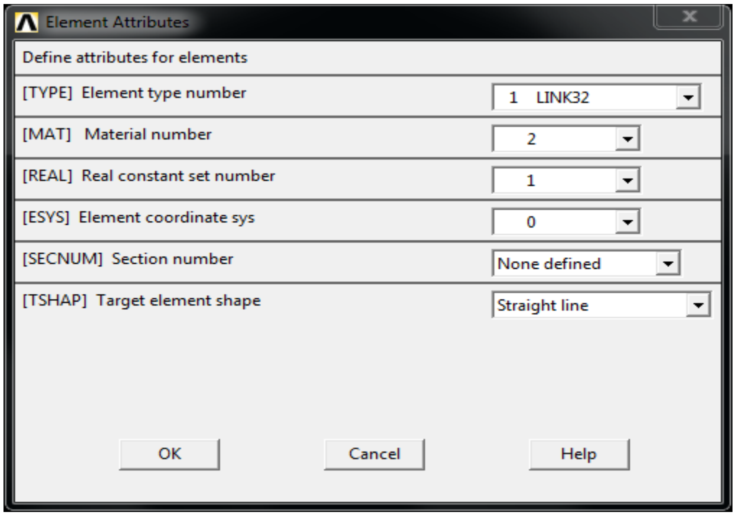
OK

22. Assign the thermal conductivity of the second layer (element) and then connect the nodes to define the element:

Main menu: **Preprocessor → Modeling → Create → Elements → Element Attributes**



Element Attributes

Define attributes for elements

[TYPE] Element type number: 1 LINK32

[MAT] Material number: 2

[REAL] Real constant set number: 1

[ESYS] Element coordinate sys: 0

[SECNUM] Section number: None defined

[TSHAP] Target element shape: Straight line

Main menu: **Preprocessor → Modeling → Create → Elements → Auto Numbered → Thru Nodes**

■□□ **[node 2 and then node 3]**

□■□ **[anywhere in the ANSYS graphics window]**

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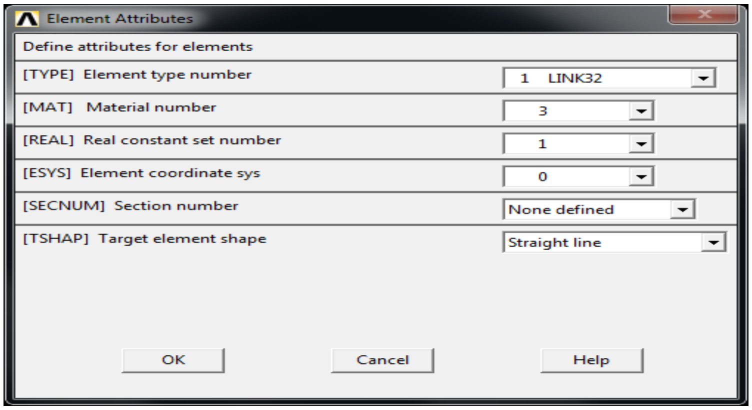
23. Assign the thermal conductivity of the third layer (element) and then connect the nodes to define the element:

Main menu: **Preprocessor → Modeling → Create → Elements → Element Attributes**



Element Attributes

Define attributes for elements

[TYPE] Element type number: 1 LINK32

[MAT] Material number: 3

[REAL] Real constant set number: 1

[ESYS] Element coordinate sys: 0

[SECNUM] Section number: None defined

[TSHAP] Target element shape: Straight line

Main menu: **Preprocessor → Modeling → Create → Elements → Auto Numbered → Thru Nodes**

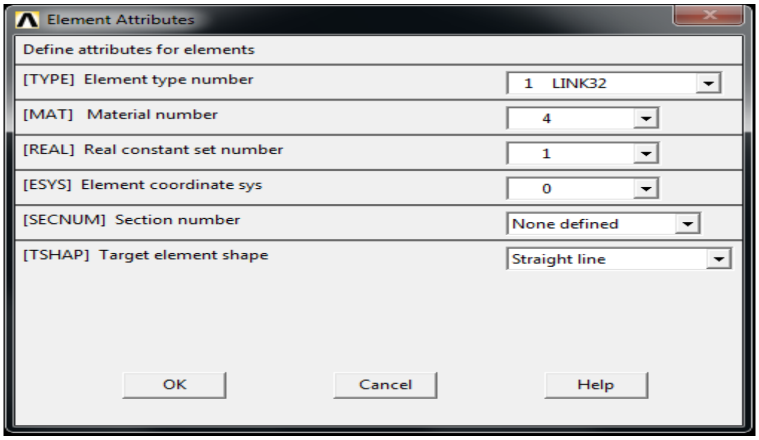
[node 3 and then node 4*]

[anywhere in the ANSYS graphics window]

OK

24. Create the convection link:

Main menu: **Preprocessor → Modeling → Create → Elements → Element Attributes**



Element Attributes

Define attributes for elements

[TYPE] Element type number: 1 LINK32

[MAT] Material number: 4

[REAL] Real constant set number: 1

[ESYS] Element coordinate sys: 0

[SECNUM] Section number: None defined

[TSHAP] Target element shape: Straight line

Main menu: **Preprocessor → Modeling → Create → Elements → Auto Numbered → Thru Nodes**

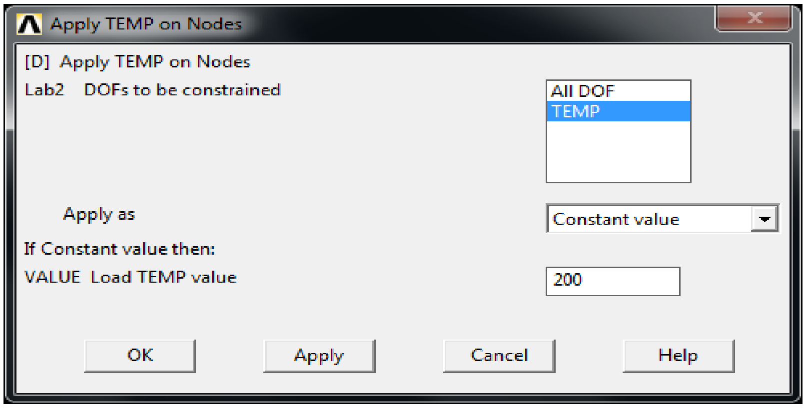
[node 4† and then 5‡]

OK

ANSYS Toolbar: **SAVE_DB**

25. Apply boundary conditions:

Main menu: **Solution → Define Loads → Apply → Thermal → Temperature → On Nodes**



[D] Apply TEMP on Nodes

Lab2 DOFs to be constrained: TEMP

Apply as: Constant value

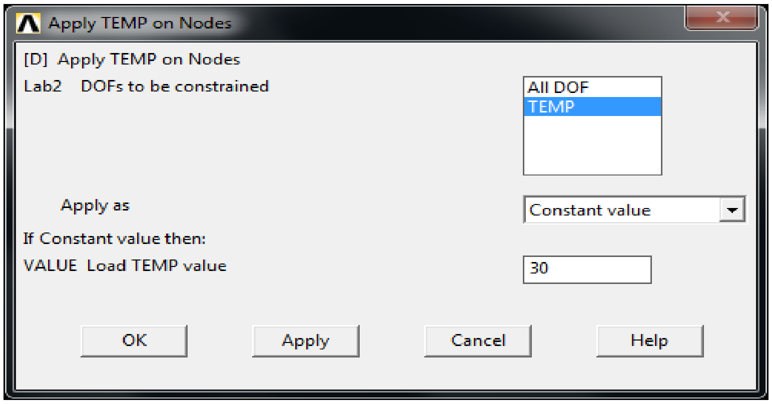
If Constant value then:

VALUE Load TEMP value: 200

[node 1]

[anywhere in the ANSYS graphics window]

Main menu: **Solution → Define Loads → Apply → Thermal → Temperature → On Nodes**



[D] Apply TEMP on Nodes

Lab2 DOFs to be constrained: All DOF / TEMP (TEMP selected)

Apply as: Constant value

If Constant value then:

VALUE Load TEMP value: 30

[node 5*]

[anywhere in the ANSYS graphics window]

ANSYS Toolbar: **SAVE_DB**

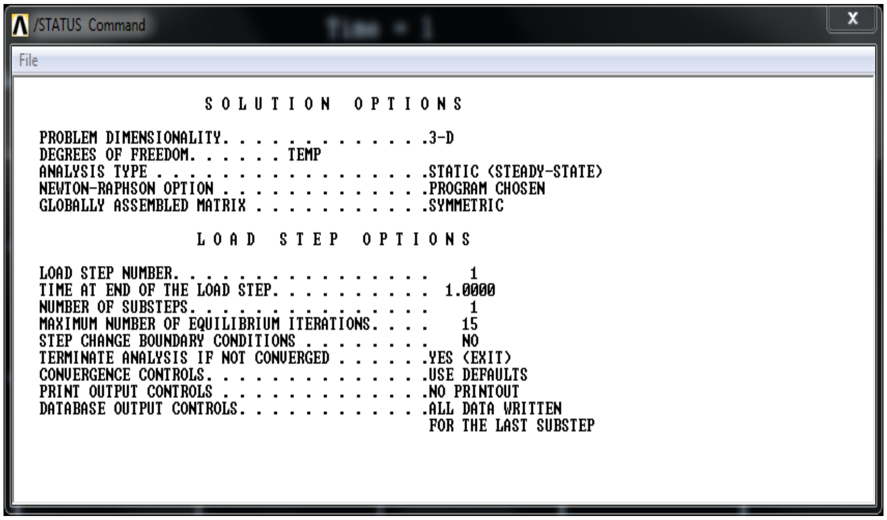
26. Solve the problem:

Main menu: **Solution → Solve → Current LS**

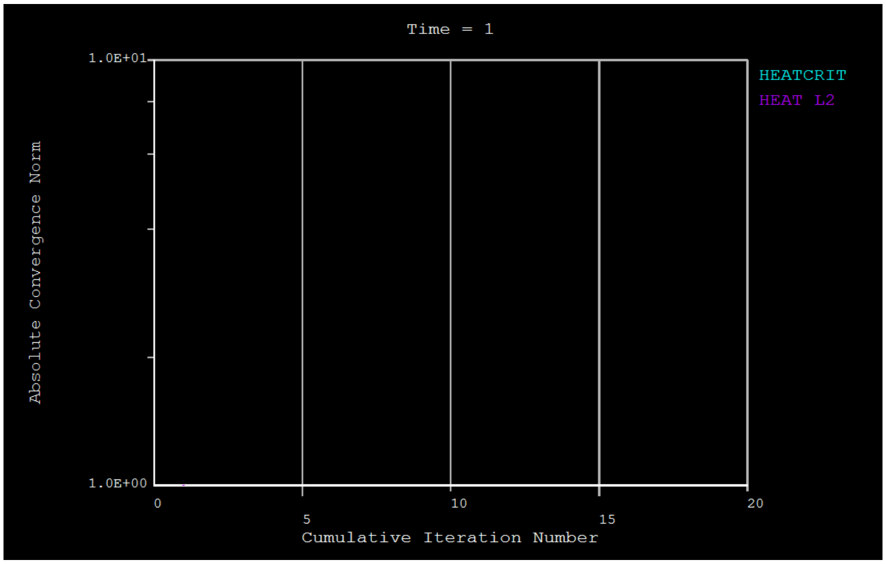
OK

Close (the solution is done!) window.

Close (the/ STAT Command) window.

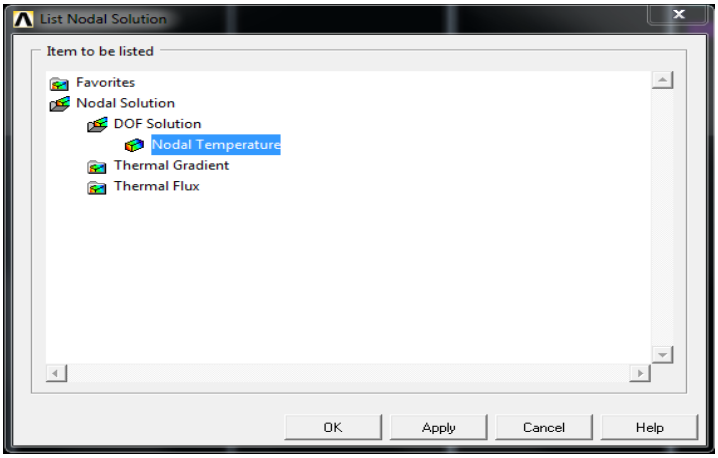


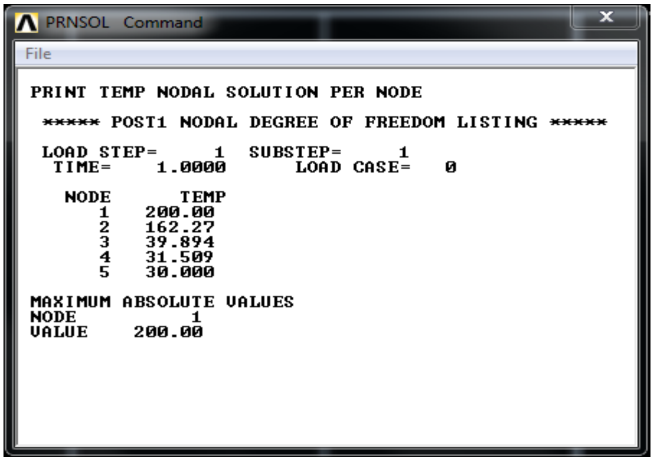
```
                    S O L U T I O N   O P T I O N S

   PROBLEM DIMENSIONALITY. . . . . . . . . . . . .3-D
   DEGREES OF FREEDOM. . . . . . TEMP
   ANALYSIS TYPE . . . . . . . . . . . . . . . . .STATIC (STEADY-STATE)
   NEWTON-RAPHSON OPTION . . . . . . . . . . . . .PROGRAM CHOSEN
   GLOBALLY ASSEMBLED MATRIX . . . . . . . . . . .SYMMETRIC

                      L O A D   S T E P   O P T I O N S

   LOAD STEP NUMBER. . . . . . . . . . . . . . . .     1
   TIME AT END OF THE LOAD STEP. . . . . . . . . .  1.0000
   NUMBER OF SUBSTEPS. . . . . . . . . . . . . . .     1
   MAXIMUM NUMBER OF EQUILIBRIUM ITERATIONS. . . .    15
   STEP CHANGE BOUNDARY CONDITIONS . . . . . . . .    NO
   TERMINATE ANALYSIS IF NOT CONVERGED . . . . . .YES (EXIT)
   CONVERGENCE CONTROLS. . . . . . . . . . . . . .USE DEFAULTS
   PRINT OUTPUT CONTROLS . . . . . . . . . . . . .NO PRINTOUT
   DATABASE OUTPUT CONTROLS. . . . . . . . . . . .ALL DATA WRITTEN
                                                  FOR THE LAST SUBSTEP
```



27. For the postprocessing phase, obtain information such as nodal temperatures:

Main menu: **General Postproc → List Results → Nodal Solution**



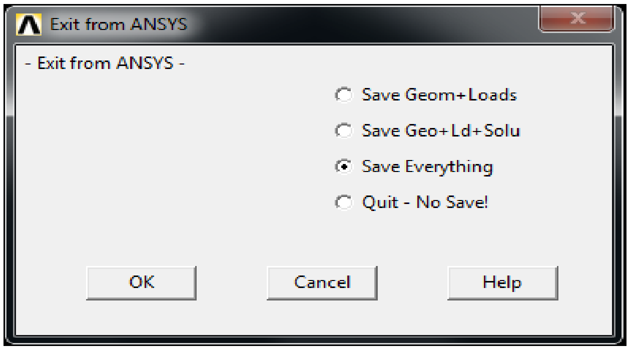


```
PRINT TEMP NODAL SOLUTION PER NODE

 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

   NODE       TEMP
      1    200.00
      2    162.27
      3    39.894
      4    31.509
      5    30.000

MAXIMUM ABSOLUTE VALUES
NODE           1
VALUE    200.00
```

Close

28. Exit ANSYS and save everything.

Toolbar: **QUIT**



Exit from ANSYS

- Exit from ANSYS -

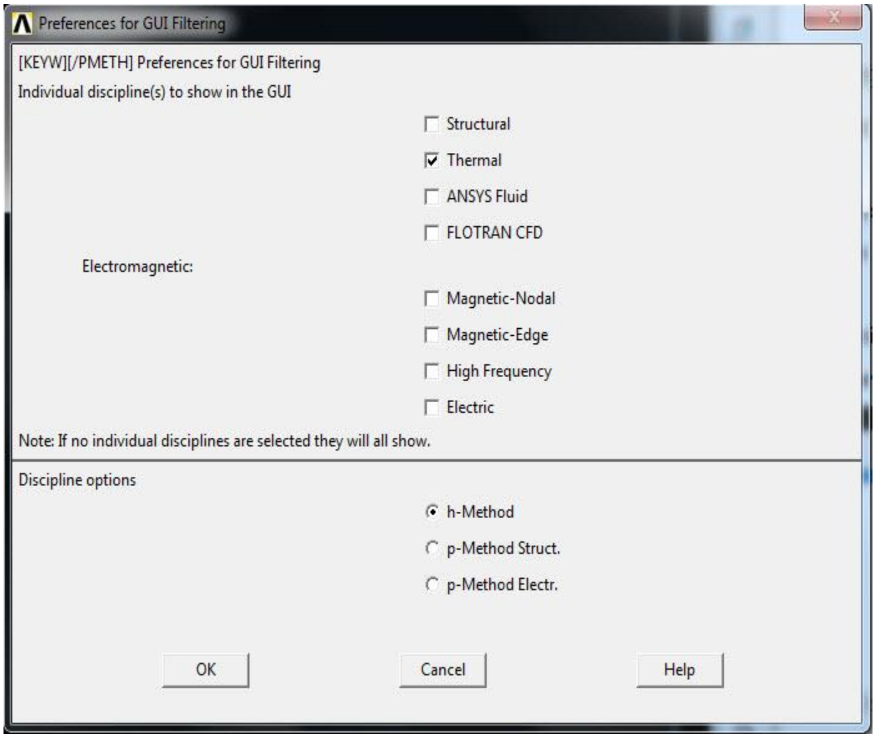
○ Save Geom+Loads
○ Save Geo+Ld+Solu
● Save Everything
○ Quit - No Save!

6.2 Steps to create two-dimensional (2D) conduction problems with convective boundary conditions in ANSYS

1. Enter the **ANSYS** program using the Launcher.

2. Set preferences for thermal analysis

Main menu: **Preferences → Thermal**



Preferences for GUI Filtering

[KEYW][/PMETH] Preferences for GUI Filtering

Individual discipline(s) to show in the GUI

☐ Structural
☑ Thermal
☐ ANSYS Fluid
☐ FLOTRAN CFD

Electromagnetic:

☐ Magnetic-Nodal
☐ Magnetic-Edge
☐ High Frequency
☐ Electric

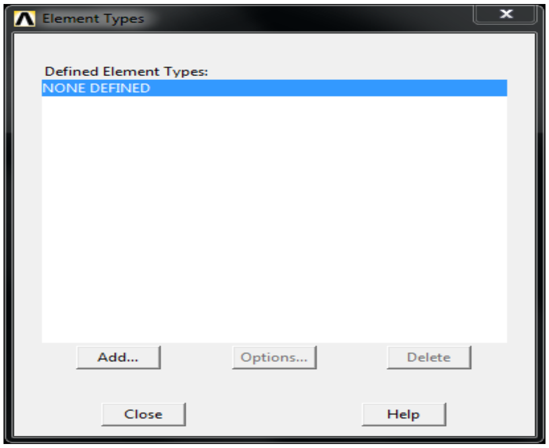
Note: If no individual disciplines are selected they will all show.

Discipline options

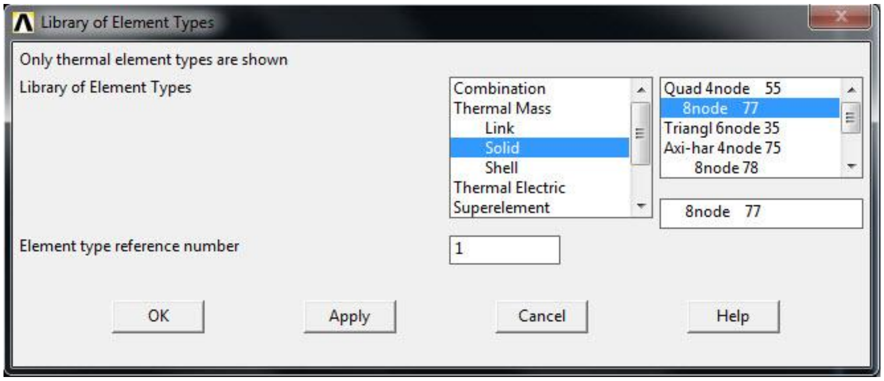
● h-Method
○ p-Method Struct.
○ p-Method Electr.

3. Define the element type and material properties:

Main menu: **Preprocessor → Element Type → Add/ Edit/ Delete**



Defined Element Types:
NONE DEFINED



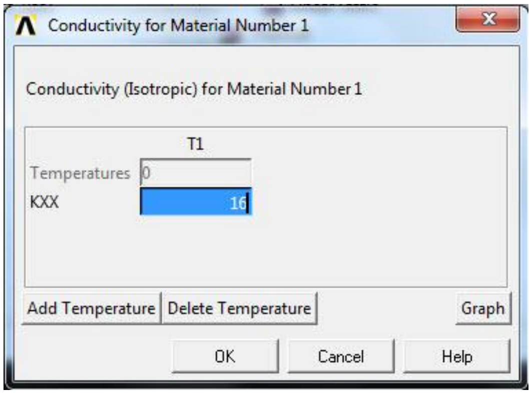
Only thermal element types are shown

Library of Element Types: Solid, 8node 77

Element type reference number: 1

4. Assign the thermal conductivity values.

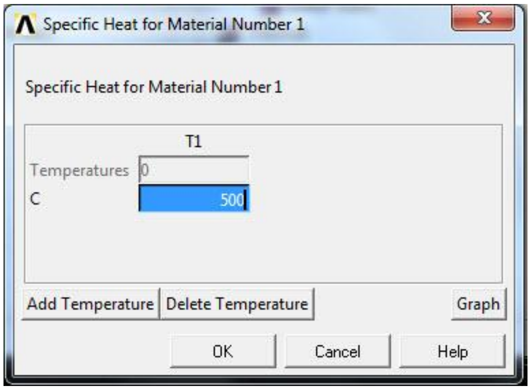
Main menu: **Preprocessor → Material Props→ Material Models → Thermal → Conductivity → Isotropic, Density and Specific Heat**



Conductivity (Isotropic) for Material Number 1

Temperatures: 0

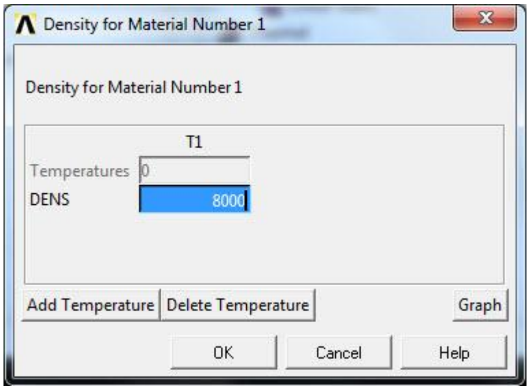
KXX: 16



Specific Heat for Material Number 1

Temperatures: 0

C: 500



Density for Material Number 1

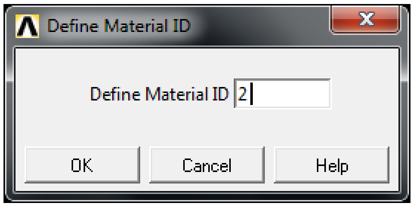
T1

Temperatures 0

DENS 8000

5. From the Define Material Model Behavior window:

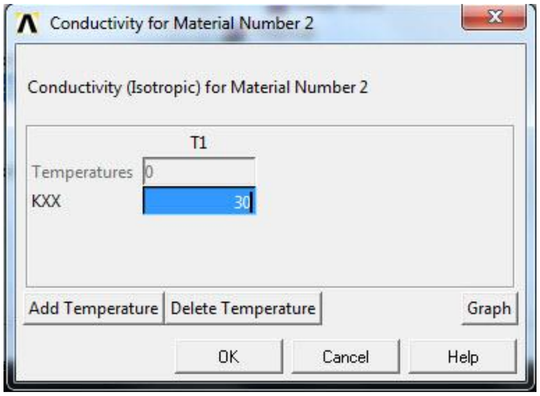
   Material → New Model



Define Material ID 2

6. Assign the thermal conductivity values.

   Main menu: **Preprocessor → Material Props→ Material Models → Thermal → Conductivity → Isotropic, Density and Specific Heat**

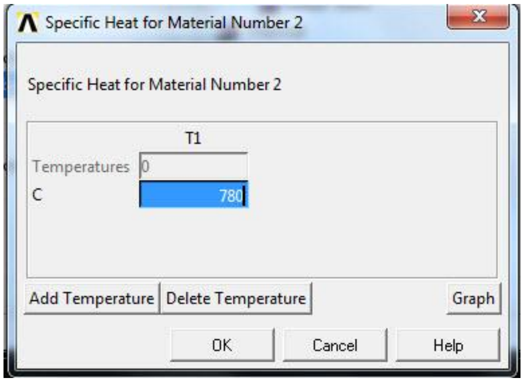


Conductivity (Isotropic) for Material Number 2

T1

Temperatures 0

KXX 30

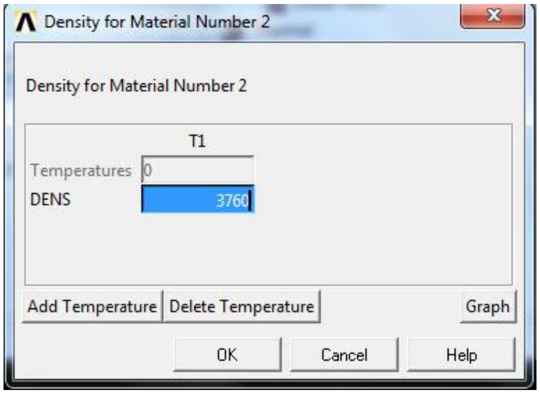


Specific Heat for Material Number 2

T1

Temperatures 0

C 780



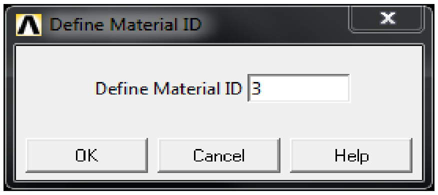
Density for Material Number 2

Temperatures 0

DENS 3760

7. From the Define Material Model Behavior window:

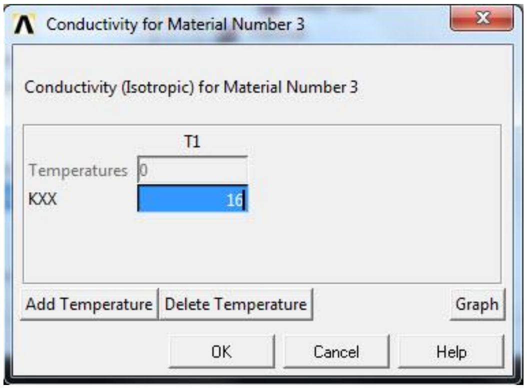
   Material → New Model



Define Material ID 3

8. Assign the thermal conductivity values.

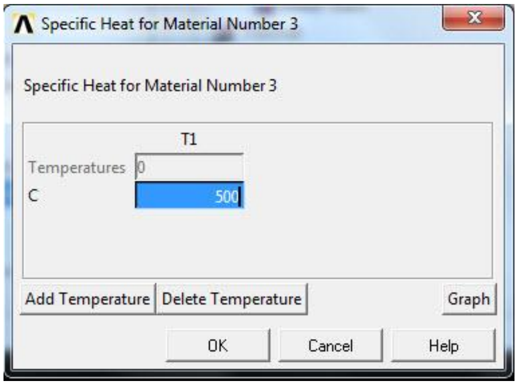
   Main menu: **Preprocessor → Material Props→ Material Models → Thermal → Conductivity → Isotropic, Density and Specific Heat**



Conductivity (Isotropic) for Material Number 3

Temperatures 0

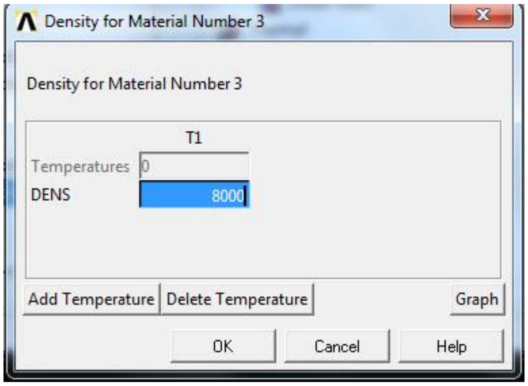
KXX 16



Specific Heat for Material Number 3

Temperatures 0

C 500

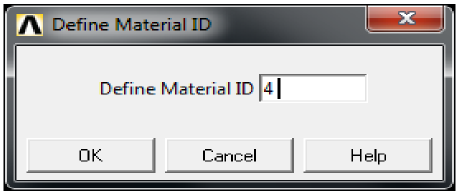

Density for Material Number 3

Density for Material Number 3

T1
Temperatures 0
DENS 8000

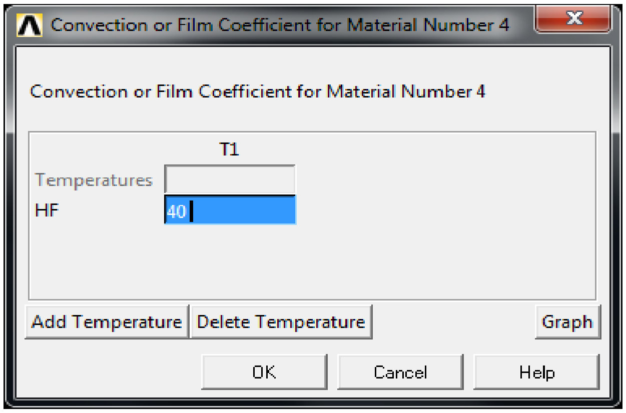
9. From the Define Material Model Behavior window:

   Material → New Model


Define Material ID

Define Material ID 4

10. Assign the heat transfer coefficient by double-clicking on **Convection or Film Coef.**


Convection or Film Coefficient for Material Number 4

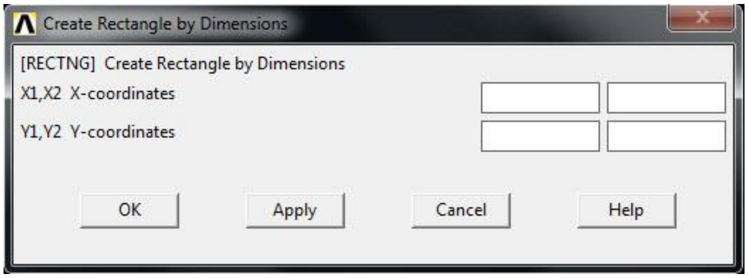
Convection or Film Coefficient for Material Number 4

T1
Temperatures
HF 40

ANSYS Toolbar: **SAVE_DB**

11. Create area for the material to be analyzed:

Main menu: **Preprocessor → Modeling → Create → Area→ Rectangle → By Dimensions**



Create Rectangle by Dimensions

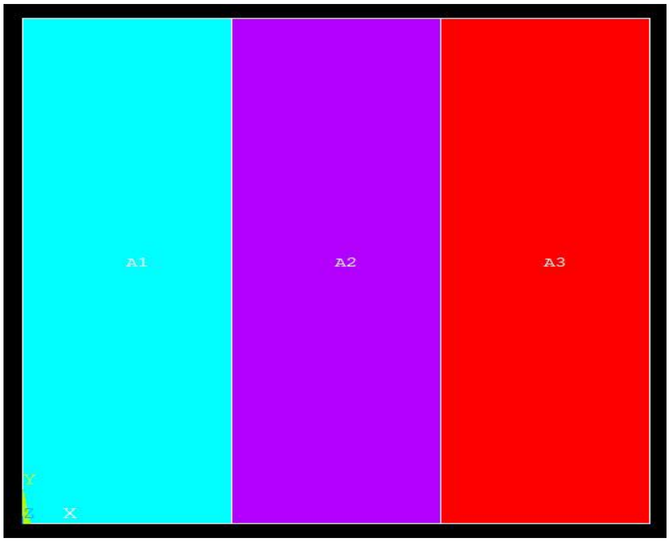
[RECTNG] Create Rectangle by Dimensions

X1,X2 X-coordinates

Y1,Y2 Y-coordinates

Enter dimension for thermal analysis

X_1	0, 0.1	**X_2**	0.1, 0.2	**X_3**	0.2, 0.3
Y_1	0, 0.3	**Y_2**	0, 0.3	**Y_3**	0, 0.3



12. Main menu: **Preprocessor → Modeling → Operate → Booleans→ Add → Areas**

    For area 1, 2 and 3

    OK

13. Main menu: **Preprocessor → Meshing → Mesh tools**

    Line→ NDIV→ input 10 → Space → input 1

14. Define temperature by picking lines:

    Main menu: **Solution → Define Loads → Apply → Thermal → Temperature → On Lines**

15. Create the convection line:

    Main menu: **Solution → Define Loads → Apply → Thermal → Convection → On Lines**

16. Set time, time step size and related parameters

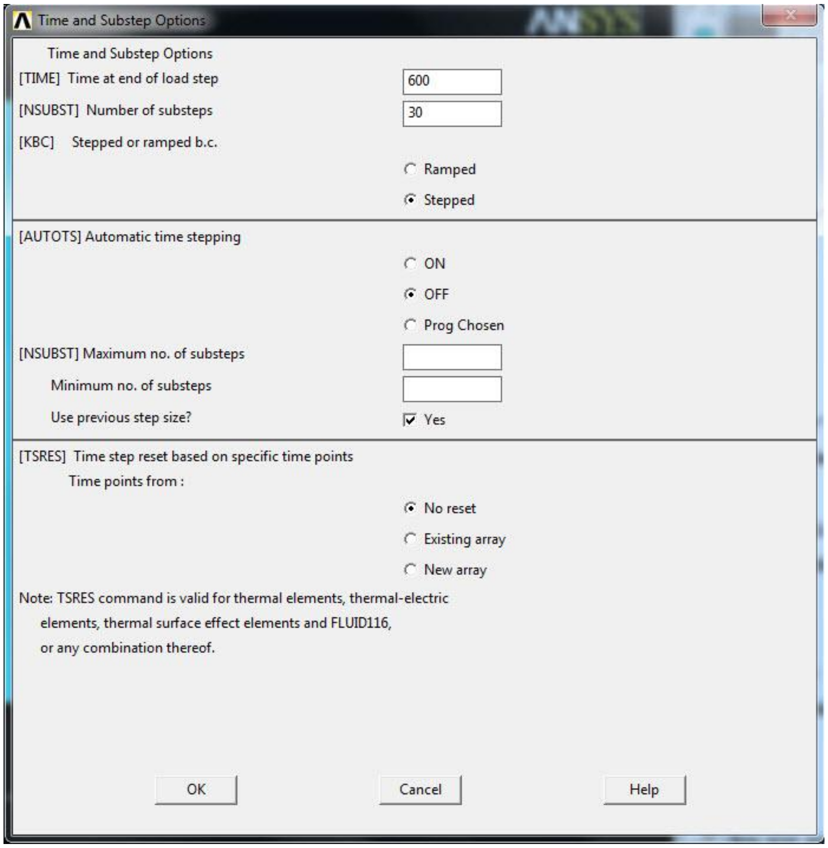
    Main menu: **Solution → Load Step Opts → Time/Frequenc → Time and Substeps**

    Time = 600

    Stepped = checked

    AUTOTS = off

    NSUBST = 30



Time and Substep Options

[TIME] Time at end of load step: 600

[NSUBST] Number of substeps: 30

[KBC] Stepped or ramped b.c.: ○ Ramped ● Stepped

[AUTOTS] Automatic time stepping: ○ ON ● OFF ○ Prog Chosen

[NSUBST] Maximum no. of substeps:

Minimum no. of substeps:

Use previous step size? ☑ Yes

[TSRES] Time step reset based on specific time points

Time points from : ● No reset ○ Existing array ○ New array

Note: TSRES command is valid for thermal elements, thermal-electric elements, thermal surface effect elements and FLUID116, or any combination thereof.

ANSYS Toolbar: **SAVE_DB**

17. Solve the problem:

    Main menu: **Solution → Solve → Current LS**
    OK
    Close (the solution is done!) window.

18. For the postprocessing phase:

    Main menu: **General Postproc → Plot Results → Contour Plot → Nodal Solution**
    Main menu: **General Postproc → List Results → Contour Plot → Nodal Solution**

19. Exit ANSYS and save everything.

Toolbar: **QUIT**