

Analysis of Steady State Heat Conduction in Different Composite Wall

Rajendra P. Patil ¹, Dr. Atul Patil ², Prof. Vijay H.Patil ³, Prof.T. A. Koli ⁴

P.G. Student, Department of Mechanical Engineering, GF's Godavari College of Engineering, Jalgaon, Maharashtra, India ¹

Assistant Professor, Department of Mechanical Engineering, GF's Godavari College of Engineering, Jalgaon, Maharashtra, India ²

HOD, Department of Mechanical Engineering, GF's Godavari College of Engineering, Jalgaon, Maharashtra, India ³

Assistant Professor, Department of Mechanical Engineering, GF's Godavari College of Engineering, Jalgaon, Maharashtra, India ⁴

ABSTRACT: It is very difficult to calculate and analyze with precision the thermal behavior of the walls of different materials attached to each other. The study of composite materials thermal behavior is useful for the determination of heat transfer rate and heat flux. These composite materials which can be implemented to many applications such as thermal ventilations, Insulators, metallic multiwall thermal protection systems, etc. In this study we are going to analyze the thermal behavior of two composites. For finding heat flux and heat flow rate the finite element program ANSYS is used. The experimental test is carried out for heat flux and heat flow rate of composite materials. Experimental Results are compared with the finite element ANSYS results and the validation is done.

KEYWORDS: Thermal conductivity, Composite materials, Heat flux, Conduction, Heat Flow Rate

I. INTRODUCTION

1.1 Composite:

A composite (or composite material) is defined as a material that consists of at least two constituents (distinct phases or combinations of phases) which are bonded together along the interface in the composite, each of which originates from a separate ingredient material which pre-exists the composite.

1.2 Heat Transfer

Heat is a form of energy in transit due to temperature difference. Heat transfer is transmission of energy from one region to another region as a result of temperature difference between them. Whenever there is temperature difference in mediums or within a media, heat transfer must occur. The amount of heat transferred per unit time is called heat transfer rate and is denoted by Q. The heat transfer rate has unit J/s which is equivalent to Watt.

When the rate of heat transfer Q is available, then total amount of heat energy transferred ΔU during a time interval Δt can be obtained from

$$\Delta U = \int_0^{\Delta t} Q dt = Q \Delta t \quad \text{(Joule)} \quad \text{-----} \quad (1)$$

The rate of heat transfer per unit area normal to the direction of heat flow is called heat flux and is expressed as

$$q = \frac{Q}{A} \quad \text{-----} \quad (2)$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

1.2.1 Steady and unsteady state heat transfer

For analysis of heat transfer problems, two types of heat transfer are considered-steady state and unsteady state. In case of steady state heat transfer, the temperature at any location on the system does not vary with time. The temperature is a function of space coordinates only, but it is independent of time

Mathematically, for rectangular coordinate system;

$$T = f(x, y, z) \text{----- (3)}$$

During steady state conditions, the heat transfer rate is constant and there is no change of internal energy of the system. For example, the heat transfer in coolers, heat exchangers, heat transfer from large furnaces etc.

1.2.2 Conduction Heat Transfer

Conduction is a process of heat transfer generated by molecular vibration within an object. The object has no motion of the material during the heat transfer process. The example below well explained about conduction heat transfer. As Figure 1.1, there is a metal stick. Using a candle to heat the left side of the stick for a while, then the right side of the stick will be found to be hot as well. It is because the energy has been transferred from the left side of the stick to the right side. And this kind of heat transfer is conduction.



Fig. 1.1 Conduction Heat Transfer

1.2.3 Conduction rate equation

Conduction is the heat transfer from one end to the other end, it is important for calculating about the heat transfer rate. For one dimension conduction heat transfer in a plane wall, the amount of heat energy being transferred per unit time is proportional to the normal temperature gradient and the cross-sectional area A, this can be expressed as

$$Q = -KA \frac{dT}{dx} \text{----- (4)}$$

Where

- Q is heat transfer rate, W
- A is cross-sectional area, m²
- K is the thermal conductivity of the material, W/mk
- dT/dx is the temperature gradient

1.3 Materials and Methods

Fiber Glass: It is the one of the most widely used reinforcements. Fiber Glass is formed when thin strands of silica based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The first commercial production of glass fiber was in 1936. Glass fiber is considered as a filler material because of its low density (1.5 gm/cm³); also it happens to be extremely strong and robust material.

Materials and their properties:

Materials	Thermal conductivity (W/m °C)
MS	60.5
Fiber Glass	0.0275
Hylum	0.017
Wood	0.052
Brick	1.07

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 7, July 2015

II. RELATED WORK

A lot of research is going on to study the heat transfer through composite. The research papers dealing with the thermal analysis of composite have been studied. Some of the research papers reviews are given below

J. Raymond, and et al, studied thermal and ventilation performance in composite walls of traditional wood frame single houses. For a standard composite wall, the channel width and its surface emissivities are varied and their effect on the overall performance is evaluated. There is no optimum width to minimize the heat transfer or to maximize the humidity transport.

Wei Chen explained heat transfer and flow in a composite solar wall with porous absorber. The excess heat is stored in the porous absorber and wall by the incident solar radiation and there is a temperature gradient in the porous layer. Therefore, the porous absorber works as thermal insulator in a degree when no solar shining is available.

Abdulaziz Almujaheed1, et al, studied the heat transfer across building wall systems is now a globally important research topic that bears wide consequences on energy consumption as well as conservation in buildings.

III. MATHEMATICAL MODELING

The mathematical modelling is the idealisation of the physical problem until a well-defined set of (mathematical) constraints, representing the main features, is established. Mathematical modelling is required not only in analytical work but also in actual heat-transfer practice, where a large commercial computer package is used; the user has to identify and approximate the actual geometry of the system, has to select the most appropriate terms from the list of supplementary effects in the PDE, must approximate the boundary conditions according to specific package procedures, and, most important of all, the user has to give knowledgeable feed-back on possible weaknesses and improvements, since heat-transfer analysis, as any other engineering activity, is an iterative process that must be refined as needed; effort proportional to expected utility. Mathematical modelling is the most creative part in the whole process of solving heat-transfer problems. Modelling usually implies approximating the geometry, materials properties, and the heat transfer equations.

3.1 Conduction Heat Transfer through A Composite Plane Wall

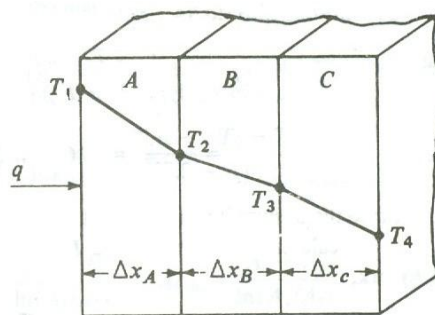


Fig.3.1 Heat flow through multilayer wall

Consider the heat flow through composite wall made of several materials of different thermal conductivities and thicknesses. An example is a wall of a cold storage, constructed of different layers of materials of different insulating properties. All materials are arranged in series in the direction of heat transfer, as shown in the above Figure.

The thickness of the walls is x_1 , x_2 , and x_3 and the thermal conductivities of the walls are K_1 , K_2 , and K_3 , respectively. The temperatures at the contact surfaces are T_2 , T_3 , and T_4 .

From Fourier's Law,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

$$\frac{q}{A} = -K \frac{dT}{dx}$$
$$T_1 - T_2 = \frac{x_1}{k_1 A} q$$
$$T_2 - T_3 = \frac{x_2}{k_2 A} q$$
$$T_3 - T_4 = \frac{x_3}{k_3 A} q$$

Total temperature difference,

$$\Delta T = \Delta T_1 + \Delta T_2 + \Delta T_3$$

$$T_1 - T_4 = q \left[\frac{x_1}{k_1 A} + \frac{x_2}{k_2 A} + \frac{x_3}{k_3 A} \right]$$

Total heat flow through composite wall is

$$q = \frac{T_1 - T_4}{R_1 + R_2 + R_3} \text{----- (5)}$$

IV. METHODOLOGY

In engineering applications, we deal with many problems. Heat Transfer through composite walls is one of them. It is the transport of energy between two or more bodies of different thermal conductivity arranged in series or parallel. For example, a fastener joining two mediums also acts as one of the layers between these mediums. Hence, the thermal conductivity of the fastener is also very much necessary in determining the overall heat transfer through the medium.

A composite slab consists of slab of three different materials which are MS, Fiber Glass, & Brick for one composite and MS, Hylum, Wood for another composite. Slabs & heating element are circular in cross section. The experimental set up consists of three disks of equal diameters but variable thickness arranged to form a slab of same diameter and the heater ware placed at one side of composite wall. Three types of slabs are provided on heater which forms a composite structure. A small hand press frame ware provided to ensure the perfect contact between the slabs. A dimmerstat used for varying the input to the heater and the volt meter and ammeter readings ware recorded. Thermocouples are placed between interfaces of the slabs, to read the temperature at the surface.

Composition of materials:

1. MS-Fiber Glass-Brick
2. MS-Hylum-wood

V. EXPERIMENTAL & ANSYS RESULTS

5.1 For MS-Hylum-Wood

5.1.1 Temperature Distribution and Heat Flux

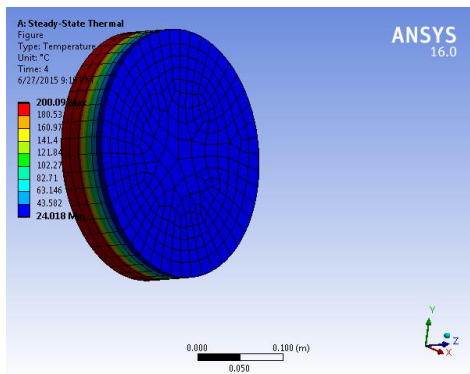


Fig.(a)Temperature Distribution at 200 °C

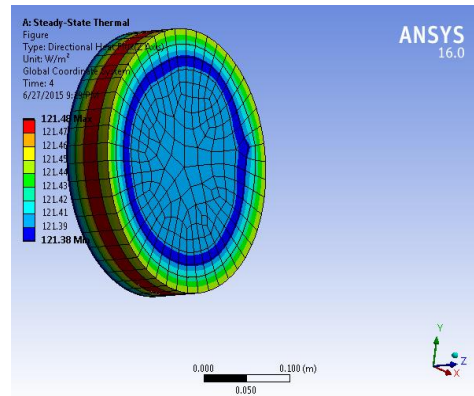


Fig.(b) Heat Flux at 200 °C

From this fig (a & b) it is clear that the for composite of MS-Hylum-Wood for given input temperature of 200 °C the output temperature is 24° C and heat flux for 200 °C is 121.38W/m².

5.2 For MS- Fiber Glass-Brick

5.2.1 Temperature Distribution and Heat Flux

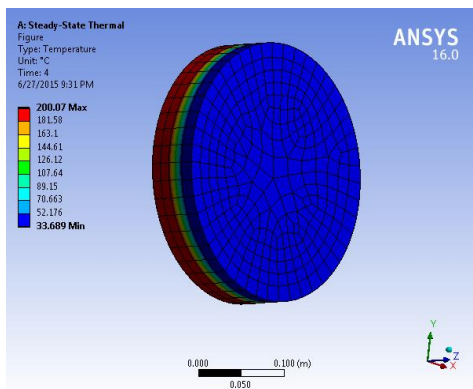


Fig.(c)Temperature Distribution at 200 °C

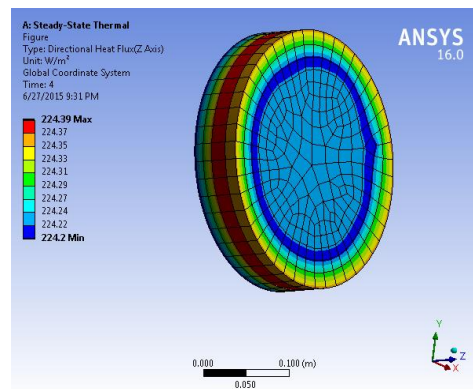


Fig.(d) Heat Flux at 200 °C

From this fig (c & d) it is clear that the for composite of MS-Fiber Glass- Brick for given input temperature of 200 °C the output temperature is 33.68° C and heat flux for 224.2° C is 121.38 W/m².

5.3 Graphical Results

Table No. 1 is the experimental heat flux reading for MS-Hylum-Wood and MS-Fiber Glass-Brick and Table No. 2 is the experimental temperature distribution reading for different thickness at variable temperature for both composites.

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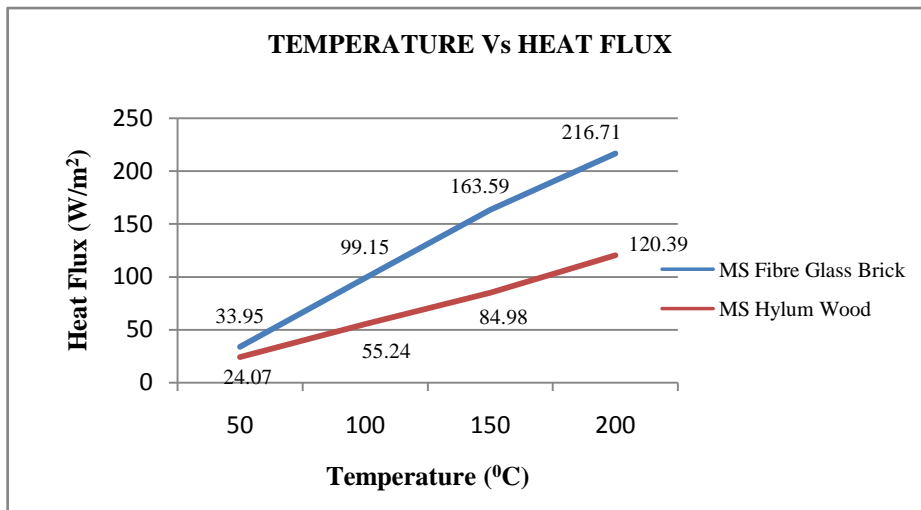
Vol. 4, Issue 7, July 2015

Table no.1 Experimental heat flux reading

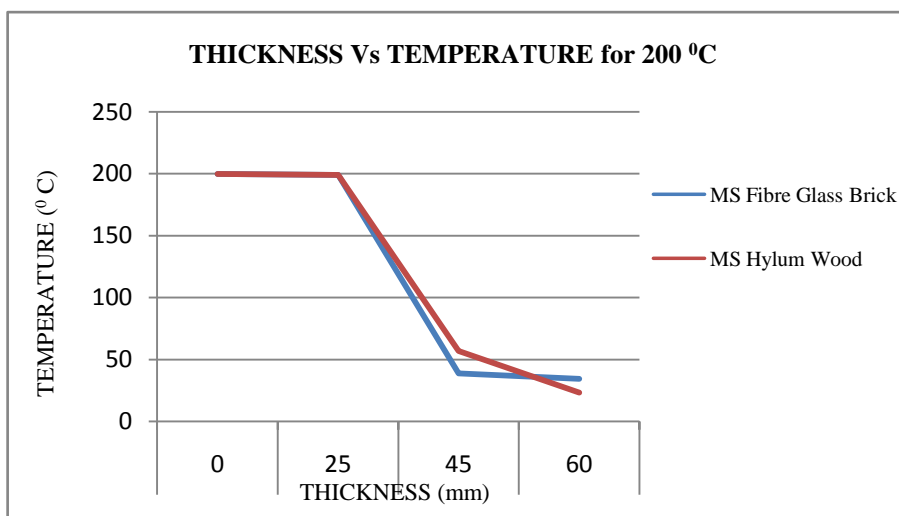
Temperature	MS Fibre Glass Brick	MS Hylum Wood
50	33.95	24.07
100	99.15	55.24
150	163.59	84.98
200	216.71	120.39

Table no.2 Experimental temperature distribution reading

Temperature	T1	T2	T3	T4
Thickness	0	25	45	60
MS Fibre Glass Brick	200	199.2	38.7	34.3
MS Hylum Wood	200	199.3	57.03	23.3



Graph:1 Temperature Vs Heat Flux for Two Composite



Graph: 2 Thickness Vs Temperature Distribution for Two Composite

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Graph 1 shows variations of Temperature Vs Heat Flux at all temperature for both composites. From this graph it is clear that the heat flux is minimum for MS-Hylum-Wood at all temperature than the MS-Fiber Glass-Brick. As the temperature increases the heat flux also increases for both composites.

Graph 2 shows variations of Thickness Vs Temperature for both composites at 200 °C. The temperature distribution is minimum for MS-Hylum-Wood than MS-Fiber Glass-Brick.

VI. CONCLUSION

From this result we conclude that the composite MS-Hylum-Wood has minimum heat flux and temperature distribution than the composite MS-Fiber Glass- Brick .So the composite MS-Hylum-Wood is better for heat resistive.

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