Analysis of Steady State Heat Conduction in Different Composite Wall

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Abstract

As we all know that composite material are widely used in industries because of their incredibly high strength-to-weight and stiffness-to-weight ratios 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

A. *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.

B. *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.

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

The rate of heat transfer per unit area normal to the direction of heat flow is called heat flux and is expressed as $q = Q/A$

II. MATERIALS & 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	*Thermal conductivity (W/m 0C)*
MS	*60.5*
Fiber Glass	*0.0275*
Hylum	*0.017*
Wood	*0.052*

III. 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 emissivity 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 Almujahid1, 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.

IV. NEED OF COMPOSITE MATERIAL

Composite materials are the versatility in their properties which enables them to be applied in large number of fields. Other reasons are their light weight, corrosion resistance and durability. Nowadays, composite materials are used in large number of vast engineering fields such as aviation, automobile and robotics. The metals are equally strong in all directions, but the composites can be designed and engineered to be strong in a specific direction. Thermoset Composites give designers nearly unlimited flexibility in designing shapes and forms. Because thermoset composites can be precisely moulded, there is little waste and therefore significantly lower overall material costs than metals products. The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

V. MATHEMATICAL MODELING

The mathematical modeling is the idealization of the physical problem until a well-defined set of (mathematical) constraints, representing the main features, is established. Mathematical modeling 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 modeling is the most creative part in the whole process of solving heat-transfer problems. Modeling usually implies approximating the geometry, materials properties, and the heat transfer equations.

Conduction Heat Transfer through A Composite Plane Wall

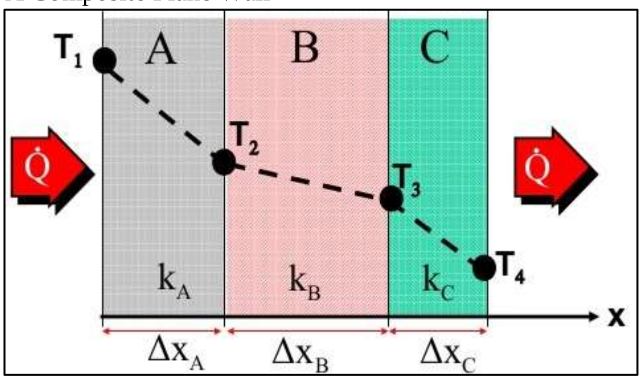


Fig. 1: Heat Flow through Multilayer Wall

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 x1, x2, and x3 and the thermal conductivities of the walls are K1, K2, and K3, respectively. The temperatures at the contact surfaces are T2, T3, and T4.

From Fourier's Law,

$$Q = -kA\frac{dT}{dx}$$

This may be written as,

$$\Delta T = T_1 - T_2 = -\frac{Q\Delta x}{KA}$$

$$T_1 - T_2 = \frac{x_1}{k_1 A}Q$$

$$T_2 - T_3 = \frac{X_2}{K_2 A}Q$$

$$T_3 - T_4 = \frac{X_3}{K_3 A} Q$$

$$T4 - T5 = \frac{1}{h_0 A} Q$$

Total temperature difference,

$$\Delta T = \Delta T_1 + \Delta T_2 + \Delta T_3 + \Delta T_4$$

$$T_1 - T_5 = Q \left[\frac{x_1}{k_1 A} + = \frac{X_2}{K_2 A} + \frac{X_3}{K_3 A} + \frac{1}{h_0 A} \right]$$

Where,

T_1-T_5= thermal potential responsible for heat flow

$[\frac{x_1}{k_1 A} + \frac{X_2}{K_2 A} + \frac{X_3}{K_3 A} + \frac{1}{h_0 A}]$ is known as the total thermal resistance of the composite.

It is similar to the electrical resistance in series.

Total heat flow through composite wall is

$$Q = \frac{T_1 - T_2}{R_{th1} + R_{th2} + R_{th3} + R_{cov0}}$$

VI. 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 dimmer stat used for varying the input to the heater and the volt meter and ammeter readings were recorded. Thermocouples are placed between interfaces of the slabs, to read the temperature at the surface.

A. Composition of Materials

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

VII. F.E.M (ANSYS)

A. For MS-Hylum-Wood

1) Temperature Distribution & Heat Flux

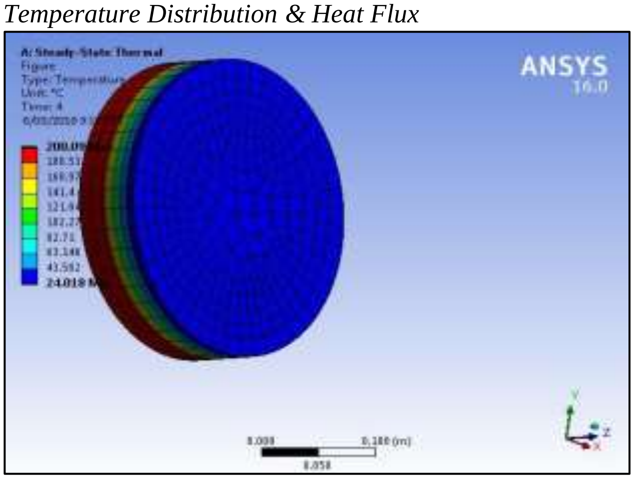


Fig. 2: (a) Temperature Distribution at 200^0C

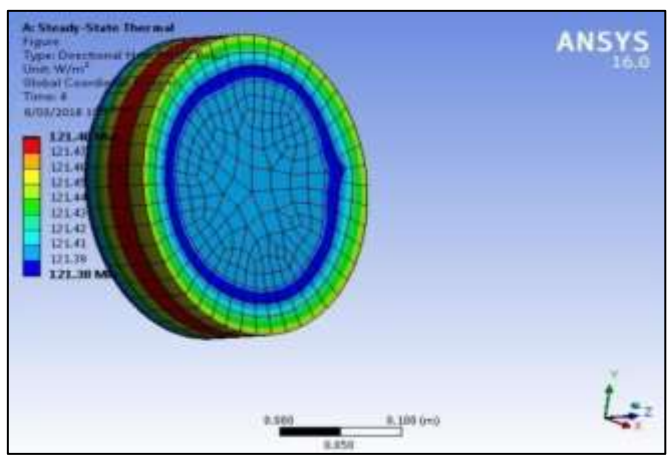


Fig. 2: (b) Heat Flux at 200^0C

From this fig (a & b) it is clear that for composite of MS-Hylum-Wood for given input temperature of 200^0C the output temperature is 24^0C and heat flux for 200^0C is 121.38W/m2.

B. For MS- Fiber Glass-Brick

1) Temperature Distribution & Heat Flux

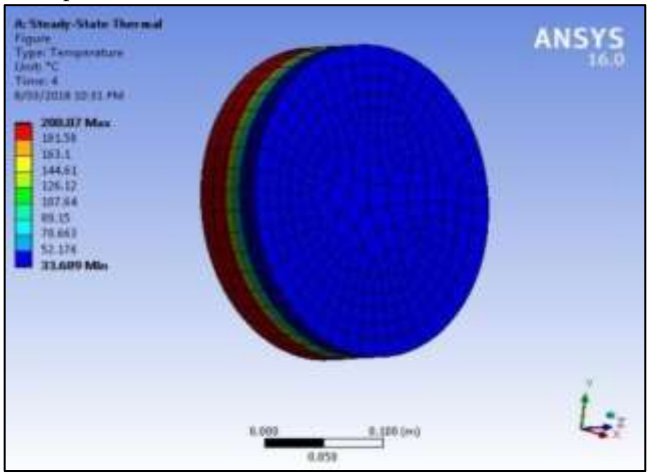


Fig. 2: (c) Temperature Distribution at 200^0C

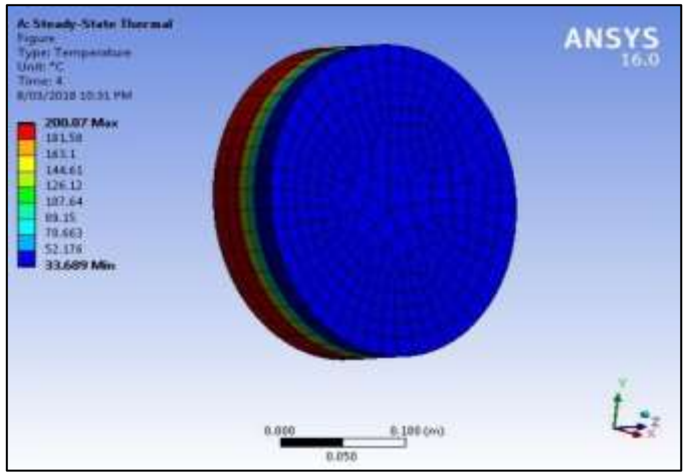


Fig. 2: (d) Heat Flux at 200^0C

From this fig (c & d) it is clear that the for composite of MS-Fiber Glass- Brick for given input temperature of 200^0C the output temperature is 33.68^0C and heat flux for 224.2 ^{0}C is 121.38 W/m2.

VIII. RESULTS

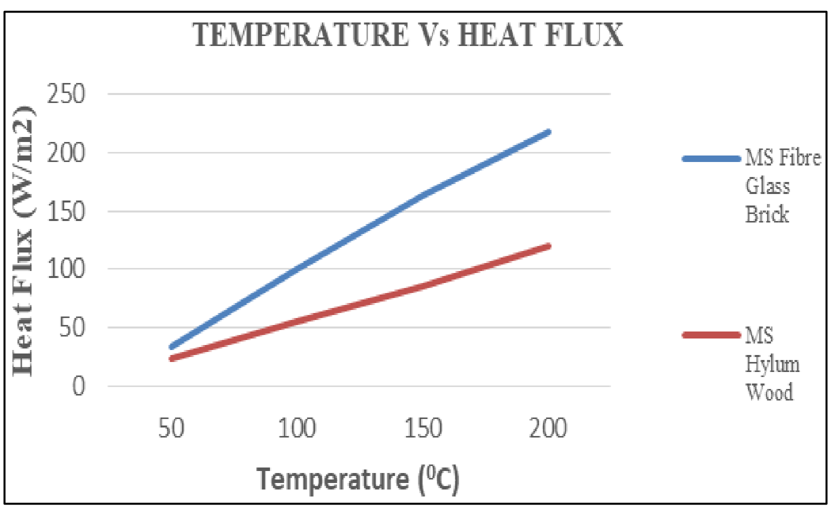
Table No.1 is the experimental heat flux reading for MS-Hylum-Wood and MS-Fiber Glass-Brick and Table No. 2 is the experimental temperature distribution reading for different thickness at variable temperature for both composites.

Table – 1
Experimental Heat Flux Reading

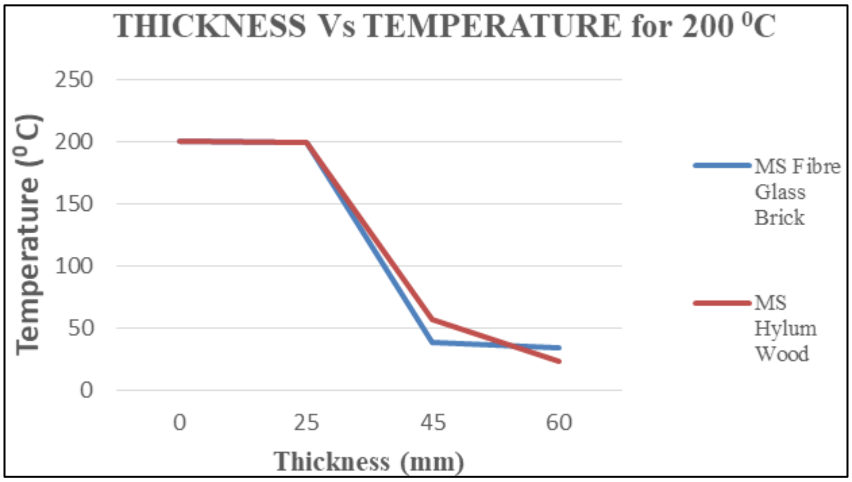
Temperature	*MS Fibre Glass Brick*	*MS Hylum Wood*
50	*33.95*	*24.07*
100	*99.15*	*55.24*
150	*163.59*	*84.98*
200	*216.71*	*120.39*

Table – 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

IX. CONCLUSION

1) 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.
2) Graph 2 shows variations of Thickness Vs Temperature for both composites at 200 0C.The temperature distribution is minimum for MS-Hylum-Wood than MS-Fiber Glass-Brick. 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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