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Evaluation And Effect Of Convective Resistance And Convective Heat Transfer Coefficient On Heat Transfer Rate In Composite Structure

Dr.R.Uday Kumar

Associate Professor
Dept.of Mechanical Engineering
Mahatma Gandhi Institute of Technology
Gandipet, Hyderabad. 500075.

Abstract* — Heat is a form of energy in transmits 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 medium or within a media, heat transfer must occur. The amount of heat transferred per unit time is called heat transfer rate. The composite structures are the combination of different materials to form a single component. These components are used to study of heat transfer through it. The composite structures for heat transfer are cylindrical shells, spherical shells and plane walls. They have wide range of applications in heat transfer are cold storage walls, internal combustion engines chambers, steam pipes and, metallic multi wall thermal protection systems. Heat transfers through the systems are in radial flow and inline flow direction. The heat transfer occurs in composite structures are conduction, convection and radiation. In this paper, the methodology for evaluation and study of convective heat transfer coefficient and convective resistance of composite structure. The influence of these parameters on performance of composite system is analyzed. Heat transfer is increased with decreases in convective resistance and increases with convective heat transfer coefficient of composite structure obtained.

Keywords- Heat transfer, composite structure, conduction, convection.

I. INTRODUCTION

There are three modes of heat transfer, conduction, convection and radiation. Conduction takes place by the drift of free electrons in metallic solids and by molecular interaction in liquids or gases. Convection takes place by movement of fluid over a surface. Radiation heat transfer is by electromagnetic wave phenomenon. For radiation, no medium is required.Radiation is more effective in vacuum. A lot of research is going on to study the heat transfer through composite structure. The research papers dealing with the thermal analysis of composite have been studied. Some of the research papers reviews studied thermal and ventilation performance in composite walls of traditional wood frame single houses[1-3]. 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. 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. 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[4-8].Conduction is essentially due to random molecular motion, the concept is termed as microform of heat transfer and is usually referred to as diffusion of energy. Heat transfer in metal rods, in heat treatment of steel forgings and through the walls of heat exchange equipment is some examples of heat conduction and also boilers, steam turbines blades, gas turbines blades, condensers, refrigerators, heat exchangers, steam nozzles.

A. Fourier's law of heat conduction

The rate of flow of heat through a simple homogeneous solid is directly proportional to the area of the section at right angles to the direction of heat flow, and to change of temperature with respect to the length of the path of the heat flow. Mathematically, it can be represented by the equation:

$$Q \propto A.dt/dx$$

Where,
Q = Heat flow through a body per unit time (in watts) or rate of heat flow, W
A = Cross sectional area of heat flow (perpendicular to the direction of flow), m^2
dt = Temperature difference of the faces of block (homogeneous solid) of thickness dx through which heat flows , ^{0}C or K
dx = Thickness of body in the direction of flow , m

Thus, $Q = - k\, A.dt/dx$

Where, k = Constant of proportionality and known as thermal conductivity of the body
The ratio dt/dx represents the change in temperature per unit thickness, i.e., the temperature gradient. The negative sign indicates that the heat flow is in the direction of negative temperature gradient, and that serves to make the heat flow positive.

B. Convection law

Regardless of the particular nature (free or forced), the appropriate rate equation for the convective heat transfer between a solid surface and adjacent fluid is prescribed by Newton's law of cooling

$$Q = h\, A\, (t_s - t_f)$$

Where Q is the convective heat flow rate (W) , A is the surface area exposed to heat transfer (m^2), t_s is the surface temperature of solid (K) and t_f is the undisturbed temperature of fluid (K). The constant of proportionality h relates the heat transfer per unit time and unit area to the over all temperature difference. The SI units for h is W/m^2K. It is also referred to as convective heat transfer coefficient, the surface conductance or film coefficient. The value of film coefficient is depends upon surface roughness, cleanliness of surface, geometry and orientation of the surface, thermo-physical properties of the fluid such as density, viscosity, specific heat , coefficient of expansion and thermal conductivity and nature of fluid flow is laminar or turbulent. Convection mechanisms involving phase changes lead to important fields of boiling and condensation[9-12]. The convection coefficient for boiling and condensation lie in the range 2500 – 1000000 (W/m^2K).Unlike thermal conductivity, heat transfer coefficient is not a property of medium. It is a flow property.
The determination of heat transfer coefficient is a complex task. It can be done using the following techniques
(a) Analytical
(b) Numerical
(c)Experimental

C. Convective resistance and conductance

The term thermal conductance does not possess any physical significance for the case of convective and radiative heat transfer. It is, however, observed that in many engineering problems involving these modes of heat transfer, the usage of this term simplifies their solution. The values of K' the conductance and R is the resistance for convective (K'_c and R_c) heat transfer processes respectively, are obtained as below
Convection Process :

$$Q = hA(t_s - t_f)$$

$$Q = hA\,\Delta T \qquad \text{where } \Delta T = (t_s - t_f)$$

$$Q = K'_c\,\Delta T$$

$$\text{where } K'_c = hA$$

K'_c is called Convective conductance ; $K'_c = hA$
and therefore convective resistance $R_c = 1/hA$
SI units for R_c : K/ W

II. METHODOLOGY

Heat transfer through composite structure 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.The composite system consists of three circular slabs made up of copper(k_1 = 379 W/mK), asbestos(k_2= 0.74 W/mK) and brass(k_3 = 110 W/mK) having equal diameter and thickness. Each of diameter is 10cm and thickness is 6mm.They are connected together in series. In all a total of twelve thermocouples are provided on the two extreme faces and on the two mating surfaces of the composite slab structure. Heating of the composite slab system is accomplished by means of a heater placed underneath the composite slab system. The dimmerstat such as heat input to the system can be regulated by means of a voltage regulator included in the circuit. The upper surface of the slab is provided with a coolant tank containing water flowing at constant known discharge. Three types of slabs are provided on heater which forms a composite structure. A small hand press frame wire provided to ensure the contact between the slabs. A dimmerstat used for varying the input to the heater and the voltmeter and ammeter readings were recorded. The heat is transferred through the composite structure slabs by conduction and then by convection from upper most slab to water. By giving to heat input to the composite system we can evaluated convective resistance, convective heat transfer coefficient through system. Water flow rate is maintained constant through the composite structure.

III. RESULTS AND DISCUSSION

Evaluation of convective heat transfer coefficient and convective resistance of composite structure as follows.
The heat transfer through the composite structure is given by

$Q = hA\Delta T$ Where $\Delta T = T_4^1 - T_w^{'}$, h = Convective heat transfer coefficient

$T_w^{'}$ = Average temperature of water, T_4^1 = Average Temperature at brass slab

Composite System given input Voltage V = 100V and Current I = 0.9 Amp
Discharge of water Q = 200ml/min, then mass flow rate of water m = 12kg/hr
Water temperature at inlet of system $T_i = 26^oC$
Water temperature at outlet of system $T_o = 31^oC$
Average Temperature at brass slab which is contact with water chamber $T_4^1 = 75^0C$. It is obtained from thermocouple

and $$T_w^{'} = \frac{T_i + T_o}{2} = \frac{26+31}{2} = 28.5\,^0C$$

Diameter of each slab d = 10cm , Area of each slab A = 0.0078m^2
So area of Heat transfer A = 0.0078m^2

Specific heat of water $c_p = 4.18\times10^3\, J/kgK$

But Heat conducted through the each slab is equal to heat conducted through entire composite system
Heat conducted (Transferred) through the composite structure

$$Q = mc_p(T_o - T_i)$$

$$= \frac{12\times4.18\times10^3\times(31-26)}{3600} = 69.67 \text{ Watts}$$

Then

$$Q = hA(T_4^1 - T_w^{'})$$

$$h = \frac{Q}{A(T_4^1 - T_w^{'})}$$

$$= \frac{69.67}{0.0078(75-28.5)} = 190.85 \text{W/m}^2\text{K}$$

$$h = 190.85 \text{ W/m}^2\text{K}$$

Convective heat transfer coefficient of composite structure h = 190.85 W/m^{2}K

We know that convective resistance R_c is given by

$$R_c = \frac{1}{hA}$$

$$= \frac{1}{190.85\times0.0078} = 0.6675 \text{ K/W}$$

$$\therefore \quad R_c = 0.6675 \text{ K/W}$$

Convective resistance of composite structure R_c = 0.6675 K/W

The results of composite structure presented in Fig.1 and Fig.2 for various heat input (voltage) given to system and calculated heat transfer rate through composite structure, convective heat transfer coefficient and convective resistance of composite structure. Convective resistance is decreasing with increases in heat transfer through composite structure. Convective heat transfer coefficient is increases with increasing in heat transfer through composite structure. Heat transfer rate is depends on heat input such as voltage and current to composite system. Heat transfer rate through composite structure is higher level when heat input to system is in high. So higher the voltage to system, high in heat transfer rate obtained.

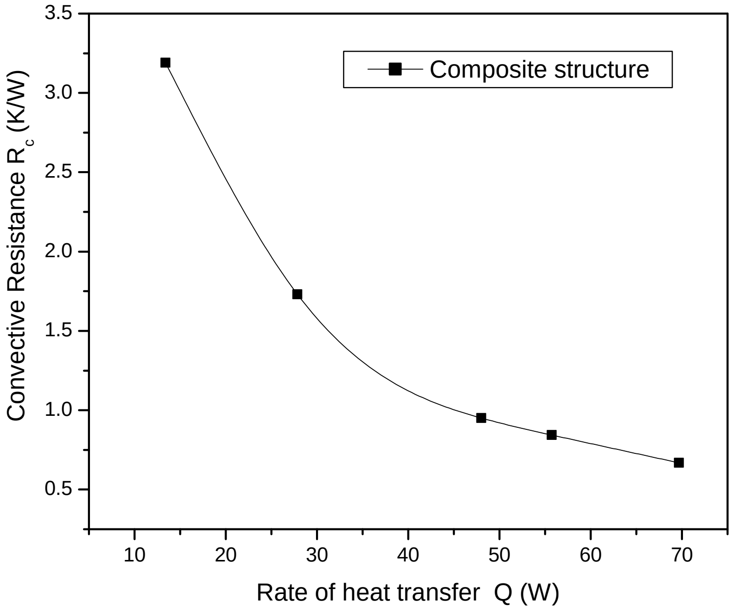

Figure 1. Variation of convective resistance with heat transfer rate through composite structure

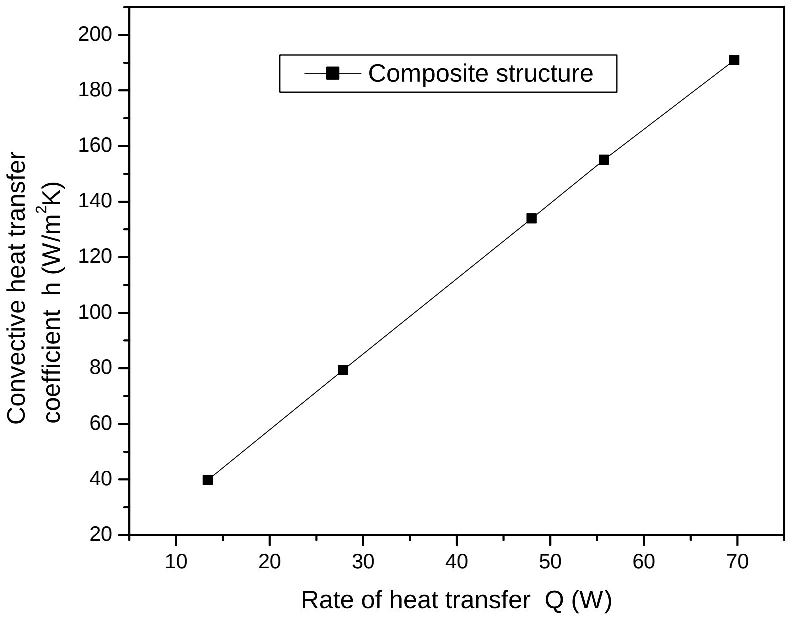

Figure 2. Variation of convective heat transfer coefficient with heat transfer rate through composite structure

IV. CONCLUSIONS

- Convective resistance is decreased with increases in rate of heat transfer through composite structure. The nature of graph is parabolic.
- Convective resistance is inversely proportional to heat transfer rate.
- The heat input to the composite structure is directly proportional to the heat transfer rate through the composite structure. The heat input to the system is voltage and current.
- Convective heat transfer coefficient is increased with increasing in heat transfer rate in composite structure. The relationship between them is linier.
- Convective heat transfer coefficient directly proportional to rate of heat transfer.
- Mass flow rate of water through the structure is 12kg/hr
- In real composite structures, the contact surfaces touch only at a discrete locations due to surface roughness, interspersed with void spaces which are usually filled with air. Obviously, there is not a single plane of contact.

REFERENCES

[1] J. Raymond, E. Bilgen," On the thermal and ventilation performance of composite walls", Energy and Buildings 39 1041 - 1046 (2007).

[2] Engineering heat transfer by Gupta and Prakash

[3] G.K.Sharma,S.P.Sukhatme; "Combined free and forced convection heat transfer from heated tube to transverse air stream", J. of Heat Transfer,Trans. ASME Vol. 91, pp. 457, 1969.

[4] H.S.Carslaw and J. C. Jaeger, Conduction of Heat in Solids, 2nd ed., Oxford University Press, London, 1986.

[5] Fundamentals of engineering heat and mass transfer by R.C. Sachdeva

[6] Abdulaziz Almujahid Zakariya Kaneesamkandi, "Construction of a test room for Evaluation Thermal Performance of Building Wall System under Real Conditions," International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 6, June 2013.

[7] Wei Chen, "A Study of Heat Transfer in a Composite Wall Collector System with Porous", Renewable Energy Resources and a Greener Future Vol. VIII-3-1.

[8] Hu Xiaojun, Zhu Wei, "Analysis of Application of External Wall Thermal insulating Technology in Affordable Housing in Tonglu County",Energy Procediab14 488 - 492 (2012).

[9] G.K. Sharma, V.S.Protopopov; "Experimental investigation of natural convection heat transfer from a vertical surface to carbon-di-oxide at supercritica1 pressure", Proc., Third National Heat and Mass Transfer Conference, Bombay, HMT 35-75,1975.

[10] H. Baig and M. A. Antar," Conduction / Natural convection analysis of heat transfer across multi-layer building blocks", 5th European Thermal-Sciences Conference, the Netherlands, 2008.

[11] Jibao Shen, Stephane Lassue, Laurent Zalewski, Dezhong Huang, "Numerical study on thermal behavior of classical or composite Trombe solar, walls", Energy and Buildings 39 962- 974 (2007) .

[12] M.M.Yovanovich, "Recent Developments in Thermal Contact, Gap and Joint Conductance Theories and Experiment," Vol. 1, New York, 1986, pp. 35-45