HEAT TRANSFER THROUGH COMPOSITE WALL (HT-101)

HEAT TRANSFER THROUGH COMPOSITE WALL

1. OBJECTIVE:

To study the heat transfer through conduction in composite wall.

2. AIM:

2.1 To calculate total thermal resistance of composite wall.

2.2 To calculate total thermal conductivity of composite wall.

2.3 To calculate thermal conductivity of one material in composite wall.

2.4 To plot the temperature profile along the composite wall.

3. INTRODUCTION:

When a temperature gradient exists in a body, there is an energy transfer from the high temperature region to the low temperature region. Energy is transferred by conduction and heat transfer rate per unit area is proportional to the normal temperature gradient:

$$\frac{q}{A} \alpha \frac{\Delta T}{\Delta X}$$

When the proportionality constant is inserted,

$$q = -kA\frac{\Delta T}{\Delta X}$$

Where q is the amount of heat transfer and $\Delta T/ \Delta X$ is the temperature gradient in the direction of heat flow. The constant k is called thermal conductivity of the material.

4. THEORY:

A direct application of fourier's law is the plane wall.

Fourier's equation:

$$Q = \frac{-kA}{\Delta X}(T_2 - T_1)$$

Where the thermal conductivity is considered constant. The wall thickness is ΔX, Q, A are amount of heat transfer and heat transfer area respectively. T_1 and T_2 are surface

temperatures. If more than one material is present, as in the multilayer wall, the analysis would proceed as follows:

The temperature gradients in the three materials (A, B, C), the heat flow may be written

$$Q = -k_A A \frac{\Delta T_A}{\Delta X_A} = -k_B A \frac{\Delta T_B}{\Delta X_B} = -k_C A \frac{\Delta T_C}{\Delta X_C}$$

$$q = \frac{Q}{A}$$

For material A thermal conductivity can be calculated as following:

$$k_A = \frac{q \Delta X_A}{\Delta T_A}$$

5. DESCRIPTION:

The apparatus consists of a heater sandwiched between two asbestos sheets. Three slabs of different material are provided on both sides of heater, which forms a composite structure. A small press- frame is provided to ensure the perfect contact between the slabs. A variac is provided for varying the input to the heater and measurement of input power is carried out by a digital voltmeter & digital ammeter. Eight temperature sensor are embedded between inter faces of the slab, to read the temperature at the surface.

6. UTILITIES REQUIRED:

6.1 Electricity Supply: Single Phase, 220 V AC, 50 Hz, 5-15 Amp combined socket with earth connection.

6.2 Bench Area Required: 1m x 1m.

7. EXPERIMENTAL PROCEDURE:

7.1 STARTING PROCEDURE:

7.1.1 Ensure that mains ON/OFF switch given on the panel is at OFF position & dimmer stat is at zero position.

7.1.2 Connect electric supply to the set up.

7.1.3 Switch ON the mains ON / OFF switch.

7.1.4 Set the heater input by the dimmer stat, voltmeter in the range 40 to 100 volt.

7.1.5 After 1.5 hrs. note down the reading of voltmeter, ampere meter and temperature sensors in the observation table after every 10 minutes interval till observing change in consecutive readings of temperatures (± 0.2 °C).

7.2 Closing Procedure:

7.2.1 When experiment is over set the dimmer stat to zero position.

7.2.2 Switch OFF the mains ON/OFF switch.

7.2.3 Switch OFF the power supply to the set up.

8. Observation & Calculation:

8.1 Data:

Thermal conductivity of cast iron k_1 = 52 W/m°C	Cast iron thickness X_1 = 0.02 m
Thermal conductivity of bakelite k_2 = 1.4 W/m°C	Bakelite thickness X_2 = 0.015 m
Diameter of slab d = 0.25 m	Press wood thickness X_3 = 0.012 m

8.2 Observation Table:

Sr. No.	V (Volt)	I (Amp)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)

8.3 Calculations:

$$W = V \times I \text{ (W)}$$

$$Q = \frac{W}{2} \text{ (W)}$$

$$A = \frac{\pi}{4} d^2 \ (m^2)$$

$$q = \frac{Q}{A} \ (W/m^2)$$

$$\Delta T = \frac{(T_1 - T_7) + (T_2 - T_8)}{2} \ (^oC)$$

$$R_t = \frac{\Delta T}{q} \ (^oC\ m^2/W)$$

$$\Delta X = X_1 + X_2 + X_3 \ (m)$$

$$K_{eff} = \frac{q \times \Delta X}{\Delta T} \ (W/m\ ^oC)$$

$$k_3 = \frac{X_3}{\left[\frac{\Delta T}{q} - \left(\frac{X_1}{k_1} + \frac{X_2}{k_2}\right)\right]} \ (W/m\ ^oC)$$

$$X_A = 0 \ (m)$$

$$X_{A1} = X_A + X_1 \ (m)$$

$$X_{A2} = X_A + X_1 + X_2 \ (m)$$

$$X_{A3} = X_A + X_1 + X_2 + X_3 \ (m)$$

$$T_{A1} = \frac{(T_1 + T_2)}{2} \ (^oC)$$

$$T_{A2} = \frac{(T_3 + T_4)}{2} \ (^oC)$$

$$T_{A3} = \frac{(T_5 + T_6)}{2} \ (^oC)$$

$$T_{A4} = \frac{(T_7 + T_8)}{2} \ (^oC)$$

CALCULATION TABLE:

Sr. No	Q (W/m^2)	ΔT (°C)	R_t ($°Cm^2/W$)	k_{eff} (W/m°C)	k_3 (W/m°C)	T_{A1} (°C)	T_{A2} (°C)	T_{A3} (°C)	T_{A4} (°C)

To plot the graph of length (X_A, X_{A1}, X_{A2}, X_{A3}) vs temperature (T_{A1}, T_{A2}, T_{A3}, T_{A4}).

9. NOMENCLATURE:

Nom	Column Heading	Units	Type
A	Area of heat transfer	m^2	Calculated
D	Diameter of slab	m	Given
I	Ammeter reading	Amp	Measured
K_{eff}	Total thermal conductivity of composite wall	W/m °C	Calculated
k_1	Thermal conductivity of cast iron	W/m °C	Given
k_2	Thermal conductivity of bakelite	W/m °C	Given
k_3	Thermal conductivity of press wood	W/m °C	Calculated
Q	Amount of heat transfer	W	Calculated
q	Heat flux	W/m^2	Calculated
R_t	Total thermal resistance of composite wall	°C m^2/W	Calculated
T_1-T_2	Interface temperature of cast iron and heater	°C	Measured
T_3-T_4	Interface temperature of cast iron and bakelite	°C	Measured
T_5-T_6	Interface temperature of bakelite and press wood	°C	Measured
T_7-T_8	Top surface temperature of press wood	°C	Measured
T_{A1}	Average temperature at the interface of cast iron slab and heater	°C	Calculated
T_{A2}	Average temperature at the interface of cast iron slab and bakelite slab	°C	Calculated
T_{A3}	Average temperature at the interface of bakelite slab and press wood slab	°C	Calculated
T_{A4}	Average temperature at the surface of press wood slab	°C	Calculated
V	Voltmeter reading	Volt	Measured

W	Heat supplied by the heater	W	Calculated
X_1	Cast iron thickness	m	Given
X_2	Bakelite thickness	m	Given
X_3	Press wood thickness	m	Given
X_A	Reference point to measure distances	m	Calculated
X_{A1}	Distance of reference point to cast iron slab	m	Calculated
X_{A2}	Distance of reference point to bakelite slab	m	Calculated
X_{A3}	Distance of reference point to press wood slab	m	Calculated
ΔT	Overall temperature difference	°C	Calculated
ΔX	Total thickness of wall	m	Calculated

10. Precaution & Maintenance Instructions:

10.1 Never run the apparatus if power supply is less than 200 volts and more than 230 volts.

10.2 Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are at OFF position.

10.3 Operate selector switch of temperature indicator gently.

10.4 Always keep the apparatus free from dust.

11. Troubleshooting:

11.1 If electric panel is not showing the input on the mains light, check the main supply.

11.2 If voltmeter showing the voltage given to heater but ampere meter does not, check the connection of heater in control panel.

12. References:

12.1 Holman, J.P (2008). *Heat Transfer*. 9th Ed. ND: McGraw Hill. pp 23-24.

12.2 Kern, D.Q (2007). *Process Heat Transfer*. 16th Ed. ND: McGraw Hill. pp 14-15.

12.3 Domkundwar A (2003). *A Course in Heat & Mass Transfer*. 6th Ed. NY: S.C Dhanpat Rai & Co. (P) Ltd. pp A.4 – A.5.

13. Block Diagram: