Engineering Growth Connection

THERMAL CONDUCTIVITY OF METAL ROD (HT-105)

THERMAL CONDUCTIVITY OF METAL ROD

1. OBJECTIVE:

To study the heat transfer through conduction in metal rod.

2. AIM:

2.1 To calculate the thermal conductivity of metal rod.

2.2 To plot the temperature distribution along the length of rod.

3. INTRODUCTION:

Thermal conductivity of substance is a physical property, defined as the ability of a substance to conduct heat. Thermal conductivity of material depends on chemical composition; state of matter, crystalline structure of a solid, the temperature, pressure and weather.

4. THEORY:

The heater will heat the rod on its one end and heat will be conducted through the rod to the other end. Since the rod is insulated from outside, it can be safely assumed that the heat transfer along the copper rod is mainly due to axial conduction and at steady state the heat conducted shall be equal to the heat absorbed by water at the cooling end. The heat conducted at steady state shall create a temperature profile within the rod. (T = f (x))The steady state heat balance at the rear end of the rod is:

Heat absorbed by cooling water,

$$Q = MC_p \Delta T$$

Heat conducted through the rod in axial direction:

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

At steady state:

$$Q = -kA\frac{dT}{dX} = MC_p \Delta T$$

So thermal conductivity of rod may be expressed as:

$$k = \frac{MC_p \Delta T}{-A\left(\frac{dT}{dX}\right)}$$

5. DESCRIPTION:

The apparatus consists of a metal rod, one end of which is heated by an electric heater while the other end of the rod projects inside the cooling water jacket. The middle portion of the rod is surrounded by a cylindrical shell filled with the asbestos insulating powder. Six temperature sensors are provided to measure temperature of rod at different section. The heater is provided with a dimmer stat for controlling the heat input. Water under constant head conditions is circulated through the jacket and its flow rate and temperature rise are noted by two temperature sensors provided at the inlet and outlet of the water.

6. UTILITIES REQUIRED:

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

6.2 Water Supply: Continuous @ 2 LPM at 1 Bar.

6.3 Floor Drain Required.

6.4 Bench Area Required: 1m x 1m.

6.5 Stop watch.

7. EXPERIMENTAL PROCEDURE:

7.1 STARTING PROCEDURE:

7.1.1 Close all the valves V_1-V_2.

7.1.2 Connect continuous water supply to the inlet of water chamber.

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

7.1.4 Connect electric supply to the set up.

7.1.5 Switch ON the mains ON / OFF switch.

7.1.6 Set the heater input by the dimmer stat, voltmeter in the range 40 to 100 V.

7.1.7 Open the valve V_1 and start the flow of water.

7.1.8 Start the stop watch and collect the water in measuring cylinder.

7.1.9 Note down the time and volume of water.

7.1.10 After 1.5 hrs. note down the reading of voltmeter, ampere meter and temperature sensors at 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 Stop the water supply by closing the valve V_1.

7.2.3 Switch OFF the mains ON/OFF switch.

7.2.4 Switch OFF electric supply to the set up.

7.2.5 Drain the water by open the valve V_2.

8. Observation & Calculation:

8.1 Data:	
Specific heat of water C_p	= 4186 J/kg °C
Density of water ρ_w	= 1000 kg/m^3
Diameter of rod d	= 0.025 m
Distance of first temperature sensor (T_1) from the one end point of pipe X_1	= 0.035 m
Distance of second temperature sensor (T_2) from the one end point of pipe X_2	= 0.075 m
Distance of third temperature sensor (T_3) from the one end point of pipe X_3	= 0.115 m
Distance of fourth temperature sensor (T_4) from the one end point of pipe X_4	= 0.155 m
Distance of fifth temperature sensor (T_5) from the one end point of pipe X_5	= 0.195 m
Distance of sixth temperature sensor (T_6) from the one end point of pipe X_6	= 0.235 m

8.2 Observation Table:

V = _____ Volts						I = _____ Amp.					
Sr. No	F (ml)	t_1 (sec)	t (sec)	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:

$$M = \frac{F \times \rho \times 10^{-6}}{t_1} \text{ (kg/sec)}$$

$$Q = MC_p\left(T_8 - T_7\right) \text{ (W)}$$

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

Plot a graph of temperature (T_1, T_2, T_3, T_4, T_5, T_6) vs. length (X_1, X_2, X_3, X_4, X_5, X_6)

and find slope $\left(\frac{dT}{dX}\right)$.

$$k = \frac{Q}{-A \times \left(\frac{dT}{dX}\right)} \text{ (W/m °C)}$$

Calculation Table:		
Sr. No.	Q (W)	k (W/m °C)

9. NOMENCLATURE:

Nom	Column Heading	Units	Type
A	Cross-sectional area of the metal rod	m^2	Calculated
C_p	Specific heat of water	J/kg °C	Given
d	Diameter of rod	m	Given
$\frac{dT}{dX}$	Slope of graph temperature (T_1, T_2, T_3, T_4, T_5, T_6) vs. length (X_1, X_2, X_3, X_4, X_5, X_6).	°C/m	Calculated
F	Volume of water collected for flow measurement	ml	Measured
I	Ammeter reading	Amp	Measured
k	Thermal conductivity of metal rod	W/m °C	Calculated
M	Mass flow rate of cooling water	kg/sec	Calculated
Q	Heat gained by water	W	Calculated
t	Time	sec	Measured
T_1-T_6	Temperature of metal rod along the length from heater to cooling jacket	°C	Measured
T_7	Inlet temp of cold water	°C	Measured
T_8	Outlet temp of cold water	°C	Measured
t_1	Time taken to collect volume of water	sec	Measured
V	Volt meter reading	volts	Measured
X_1	Distance of first temperature sensor (T_1) from the one end point of pipe	m	Given
X_2	Distance of second temperature sensor (T_2) from the one end point of pipe	m	Given
X_3	Distance of third temperature sensor (T_3) from the one end point of pipe	m	Given
X_4	Distance of fourth temperature sensor (T_4) from the one end point of pipe	m	Given
X_5	Distance of fifth temperature sensor (T_5) from the one end point of pipe	m	Given
X_6	Distance of sixth temperature sensor (T_1) from the one end point of pipe	m	Given
ρ_w	Density of water	kg/m^3	Given

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 D.S Kumar, **"Heat & Mass Transfer"**, 7th ed, S.K Kataria & Sons, ND, 2008, Page 5.

13. Block Diagram: