Republic of Iraq

Ministry of Higher Education

and Scientific

Al-Mustaqbal University College

Chemical Engineering and Petroleum Industries

Department

Subject: Heat Transfer Lab.

Third Class

Lecture One

THERMAL CONDUCTIVITY OF A METAL ROD

1.1: AIM OF THE EXPERMENT:

a) To measure the temperature gradient ($\Delta T/ \Delta X$) along the length of the metal (copper) rod.

b) To determine the co-efficient of thermal conductivity of the metal (copper).

1.2: INTRODUCTION:

Conduction is a process of heat transfer through solids. When a temperature gradient exists in a body, experience has shown that there is a transfer of heat from the high temperature region to the low temperature region. Thermal conductivity of material is found to depend on the chemical composition of the substance, the phase(gas, liquid or solid)in which it exist, its crystalline structure if a solid, the temperature and pressure to which it is subjected, and whether or not it is homogeneous material. The heat transfer rate per unit area is proportional to the temperature gradient given by:

$q/A \ \alpha \ \Delta T \ \Delta X$ --- Eq (1)

Where, ‘q’ is the heat transfer rate (watts), A is the area of heat transfer (m^2), $\Delta T/ \Delta X$ is the temperature gradient in the direction of heat flow (°C/m). Fourier's law of conduction is given by the following relationship:

$q = - K A (\Delta T/\Delta X)$ ---Eq (2)

The positive constant ‘k’ is called the co-efficient of thermal Conductivity of the material. The negative sign indicates that heat transfer takes place in the direction of decreasing temperature. Co-efficient of thermal conductivity has the units of watts/m°C. ΔX is the distance between two thermocouples of interest**. Note that** heat flow rate is involved and the numerical value of the co- efficient of thermal conductivity indicates how fast heat will flow in a given material.

The rate of the heat transfer can also be calculated by the voltage V (volts) and the current I (ampere):

$$\mathbf{Q=V*I}$$

Thermal conductivity co- efficient is a physical property of the material. Although it is fairly constant in a narrow temperature range, it varies over a wide temperature range. Metals which are good conductors of heat have high 3 values of co-efficient of thermal conductivity; for example, 385 watts/m°C for copper. Insulating materials have low values of co-efficient of thermal conductivity – for example 0.048 watt/m°C for fiber insulating board. In any conduction heat transfer problem, it is essential to have the knowledge of co-efficient of thermal conductivity of the material involved in the heat transfer process. This set-up has been designed to measure the temperature gradient along the length of the rod and to determine its co- efficient of the thermal conductivity.

The cross sectional area of the metal bar is given by:

$$\mathbf{A=(\pi/4) *d^2}$$

1.3:Mechanism of Thermal Energy Conduction in Metals:

Thermal energy may be conducted in solids by two modes:

1. Lattice vibration.
2. Transport by free electrons.

In good electrical conductors a rather large number of free electrons move about in the lattice structure of the material. Just as these electrons may transport electric charge, they may also carry thermal energy from a high temperature region. In fact, these electrons are frequently referred as the electrons gas.

Energy may also be transmitted as vibrational energy in the lattice structure of the material. In general, however, this latter mode of energy is not as large as electron transport and it is for this reason that good electrical conductors are almost always good heat conductors, i.e. copper, aluminum and silver. With increase in temperature; however the increased lattice vibrations come in the way of the transport by free electrons for most of the pure metals the thermal conductivity decreases with increases in the temperature for some metals. The will heat the bar at its end and heat will be conducted through the bar to other end.

In another way, When the free electrons absorb **heat energy**, they move much faster. As they move through the **metal**, free electrons crash into **metal** ions. Some of the kinetic **energy** of the free electron is absorbed by the ions and it vibrates faster and with greater amplitude.

1.3:APPARATUS:

It consists of a copper rod one end of which is heated by an electric heater and the other end projects inside the cooling water jacket. The middle portion of the rod is thermally insulated from the surroundings using asbestos rope. The temperature of the rod is measured at four, namely (1 to 4), different locations along its length while the radial temperature distribution is measured by two separate thermocouples (5 and 6) at two different sections in the insulating shell. Following are the important features of the experimental setup.

a) Copper rod, Length : 410mm, Diameter : 25mm, No. of thermocouples mounted : 4 (at the interval of 58 mm) a long the length

b) Band heater used to heat up one end.

c) Thermal insulation covering the copper rod to reduce heat losses to the surroundings.

d) Cooling water jacket at the other end with water supply connections and thermocouples at both inlet T5 and outlet T6. Water jacket diameter is 80 mm.

e) Heat controller or regulator to vary input power to the heater.

f) Measuring jar to measure water flow rate in the cooling water jacket.

g) Thermocouples to measure temperatures at 1, 2, 3 & 4 along the length of the copper rod and 5 & 6 to measure temperatures at inlet & outlet of water jacket. 4

h) Digital temperature indicator and channel selector.

i)Voltmeter (0-300) volts.

j)Ammeter (0-2) Ampere.

1.4:PROCEDURE:

a) Switch ON the mains.

b) Open the valve at the inlet of the cooling water jacket and maintain constant water flow rate.

c) Switch ON the heater.

d) Set the heat control or regulator and adjust the power input to the heater.

e) Wait for reasonable time till the temperatures T1 toT4 are fairly constant with time that is steady state is reached.

f) Read the temperatures T1 to T4 on the metal rod using channel selector and digital temperature indicator.

g) Read inlet and outlet water temperatures (T5 & T6) of the cooling water jacket.

h) Measure the cooling water flow rate using measuring jar and stop watch.

i) Using the measured temperatures and water flow rate, the temperature gradient along the length of the brass rod and co- efficient of thermal conductivity of copper are calculated using the procedure given below.

1.6:Calculation:

Test no.	V (volt)	I (ampere)	Q= V*I	T1 Ċ	T2 Ċ	T3 Ċ	T4 Ċ	T5 Ċ	T6 Ċ	dt/dx	K

1.6:Quesstion for discussion:

1. Is there any difference between the theoretical and experimental results?
2. Does the thermal conductivity values of solid materials change by changing the temperature?
3. Plot the heat supplied (Q) against thermal conductivity(K)?
4. On what does thermal conductivity depend?