Experiment No. 8: Linear Heat Conduction

Introduction:

Heat transfer is a common phenomenon encountered in many areas in daily life. It is an important subject in science and even more so in engineering and the field of environmental physics.

Knowledge about heat transfer is essential for the various possible ways to cut down in energy use. For example, to economies on home – heating one has optimize insulation, i.e. minimize heat transfer. Improving cooling processes on the other hand implies maximizing heat transfer to the coolant. Engineering problems that involve heat transfer are generally concerned with optimization of heat transfer processes.

Engineers learning about thermodynamics and heat transfer need to know how different materials and shapes conduct heat. They can use this information to predict how heat energy will move through their own designs. This experiment show the student how heat transfers through different materials using (TD 1002), with the linear heat conduction experiment (TD 1002A) shown in fig.1.

Fig. 1: (TD 1002), with the linear heat conduction experiment (TD 1002A)

Objectives:

1. To define thermal conductivity.
2. To know the methods of heat transfer through deferent types of materials.
3. To Demonstrate the linear heat conduction
4. To calculate thermal conductivity for different types of materials and compare the actual values with the theory.
5. To show the temperature gradient through different materials.
6. To identify the sources of error in the results and to conclude how to obtain the best results with any given specimen.

Parts needed:

The main parts of the apparatus are shown in fig. 2:

1. Base unit of heat transfer experiment (TD 1002)..
2. Linear heat conduction unit (TD 1002A).
3. Called water supply for the cooler.
4. four specimens each of different metal with thermocouple.

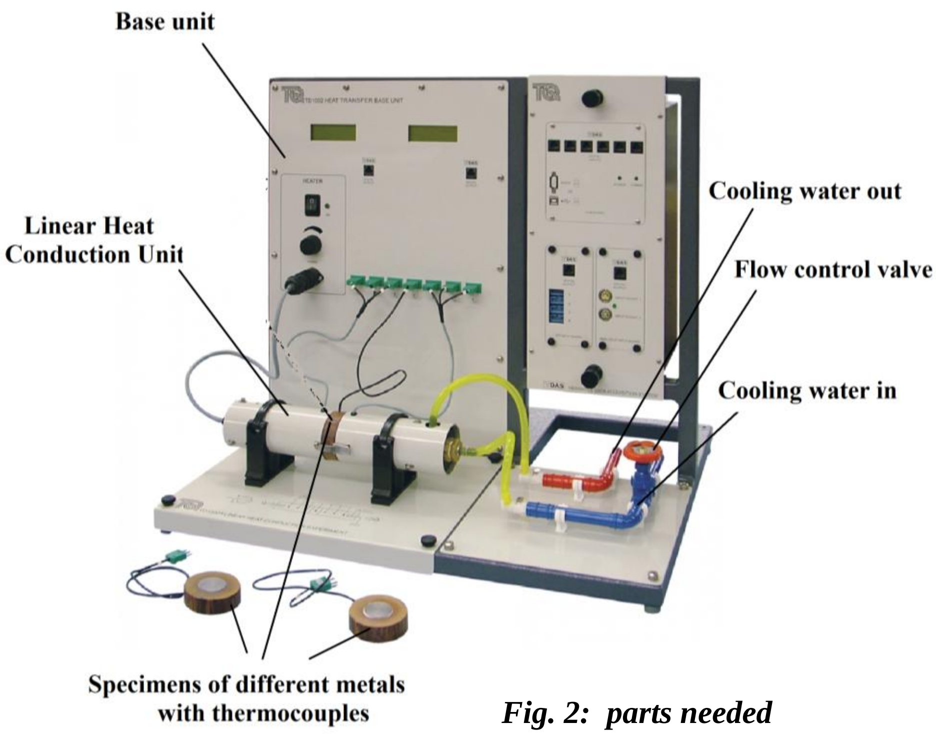

Fig. 2: parts needed

Theory:

Assuming ideal conditions, the electrical power supplied to the heater on the experiment gives a direct and accurate value of the heat energy that it emits or conducts.

The electrical power in to the heater is the product of the voltage and current supplied to it , so:

Electrical power (W) = Voltage (V) across the heater * current (I) passing through the heater.

Or

$$W = V * I$$

Heat quantity or heat energy (Q) is an amount of energy, usually specified in joules (j).

A rate of heat energy transfer is a given amount heat energy transferred in a given time, or Q / t. To simplify the equations, you put a mark above the symbol Q to present this, so:

$$Q / t = Q^\bullet$$

the unit (watt) of electrical power is also a measurement of rate of energy transfer (one joule per second), so:

$$W = Q^\bullet$$

This shows that the rate of electrical energy supplied to the heater is equal to the energy (heate) transfer rate from the heater.

Consider a bar of circular cross-section as shown in fig. 3, where the temperature at T1 is greater than at T2. The heat energy flows from the hotter end at temperature T1 to the cooler at temperature T2.

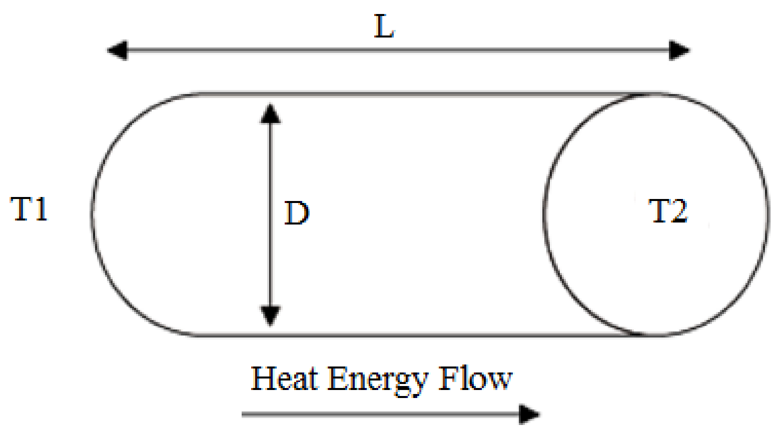

Figure 3. Illustration of a metallic cylinder of length L and diameter D, whose faces sit at temperatures T1 and T2. Heat conduction occurs from face 1 to face 2 given that T1>T2.

The linear temperature gradient along a material is the temperature change per unit length. So, for the example in fig. 3 the temperature gradient is:

$$(T1 - T2) / L$$

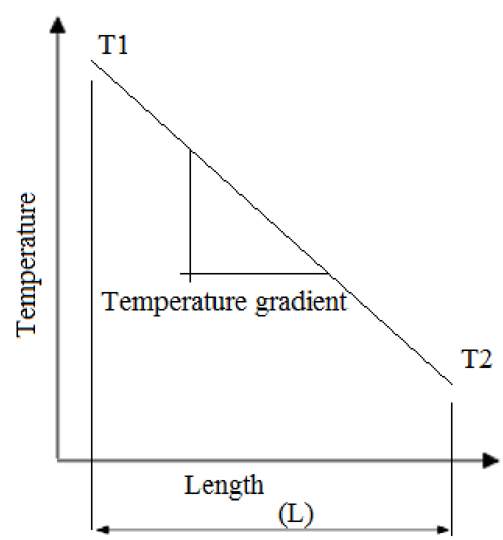

Fig. 4: Linear temperature gradient

A good thermal conductor has a low temperature gradient and a bad thermal conductor (or insulator) has a high temperature gradient.

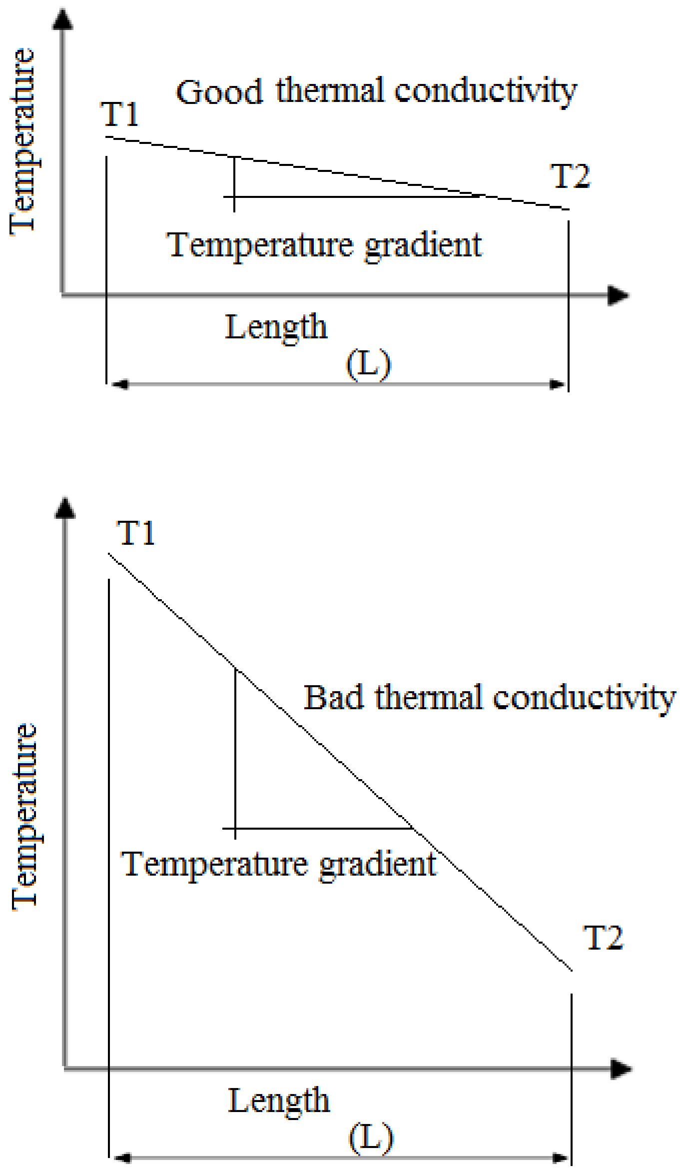

Fig. 5: Good and bad thermal conductors

As mentioned earlier, thermal conductivity is a measure of how quickly heat energy travels along a unit length of material of a unit cross – sectional area. So for the solid bar of circular cross section, the equation includes the area (A) of the cross – section and the length between the two measured temperatures:

$$Q/t = KA\,(T1 - T2) / L$$

Or as shown earlier:

$$W = KA\,(T1 - T2) / L$$

For reference only, The standard form of this equation is:

$$Q / At = K\,(T1 - T2) / L$$

Therefore, to calculate the thermal conductivity of material, the equation must rearranged to give:

$$K = QL / (T1-T2)\,At$$

The units of thermal conductivity are (J / s m k). However, as Joule per second (J / s) is equal to watt (W), it is more useful to write as (W/ m.k).

And, as shown earlier , you may substitute Q/t with W, so:

$$K = WL /A\,(T1-T2)$$

Note that these equations assume ideal conditions where all heat transfer is by conduction and no heat lost to the surroundings by convection or radiation.

The equations for thermal conductivity use material dimensions, but it is actually a measure of the material properties, irrespective of shape or size, for example, a large piece of steel has the same thermal conductivity as a small piece of steel.

Procedure:

1. Make sure that the apparatus is in a place where the temperature is stable and has been in position for at least three hours, so that it is at the same temperature as the room it is in.
2. Create a blank table of results for each specimen metal similar to table 1.
3. Fit the linear heat conduction experiment as shown in fig. 2.
4. Connect the cold water incoming and drain connections of the base unit to your cold water supply and drain.
5. Connect the electrical supply cable from the back of the base unit to your electrical supply.
6. Switch on the electrical supply, and the cold water supply.
7. Switch on the heater power from the front of the base unit.
8. Setup the required heater power according to table 1.
9. Wait about 20 to 25 minutes for the steady state condition to be achieved before recording the temperature values along the unit.
10. Record the temperature values in table 1.
11. Repeat steps 8 to 10 for the other values of heater power.
12. Switch of f the heater power.
13. Repeat steps 7 to 12 for the other specimens for testing the other metals.
14. Switch off the electrical supply and the water supply.
15. Plot the temperature values against the distance from the heater to Graph the temperature gradient.
16. Determine the overall thermal conductivity.
17. Conclude your results.

Specimen metal:							
Heater power	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
20							
40							
60							

Table 1: a blank table for Results

Questions for further discussion:

Decide wither of these statements True or false:

1. the thermal conductivity is the heat energy transferred per unit volume.
2. Steady state conduction is said to exist when the temperature at all locations of a substance is constant with time.
3. In a steady- state conduction, the temperature is a function of position only and rate of heat transfer at any point is constant.
4. In unsteady- state heat conduction the temperature varies with both time and location.
5. Wood is an example of material having a high thermal conductivity.
6. Normally the insulation material have a high thermal conductivity.

Conclusion:

Student should write a conclusion upon his results and the objectives achievement.