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EXPERIMENTAL COMPARISON STUDY BETWEEN LINE HEAT SOURCE AND PLANE HEAT SOURCE METHOD TO ESTIMATE THE THERMAL CONDUCTIVITY OF TWO-PHASE MATERIALS

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ABSTRACT: *In this article, the experimental setup based on line heat source and plane heat source method has been developed and interconnected with LabVIEW to estimate the effective thermal conductivity of two-phase materials. The effective thermal conductivity of two phase materials at various temperatures is found by line heat source and plane heat source experimental setup. The results obtained by plane heat source method were compared with the results obtained by line heat source method. LabVIEW software is used to interconnect the experimental setup to computer for continuous recording of temperature with respect to time.*
KEYWORDS: *Effective thermal conductivity, Line heat source, Plane heat source, LabVIEW*

INTRODUCTION

Estimation of thermal conductivity of two phase materials is becoming important in technological development and many applications such as heat exchangers, solar collectors and heat recovery process. Fabrication of experimental set up based on line heat source (LHS) and plane heat source (PHS) method. The automated data acquisition software (LabVIEW) has been used for measuring thermal conductivity developed by A.P.Senthil Kumar et al (1). Uses of probes for measuring thermal conductivity described by Messmer(2), Carslaw &Jaeger(3) was used for transient heat flow method based on line source.

EXPERIMENTAL SETUP

The experimental set up is fabricated based on LHS and PHS methods, the schematic diagram of both experimental set up shown in Figure 1 and Figure 2 respectively.

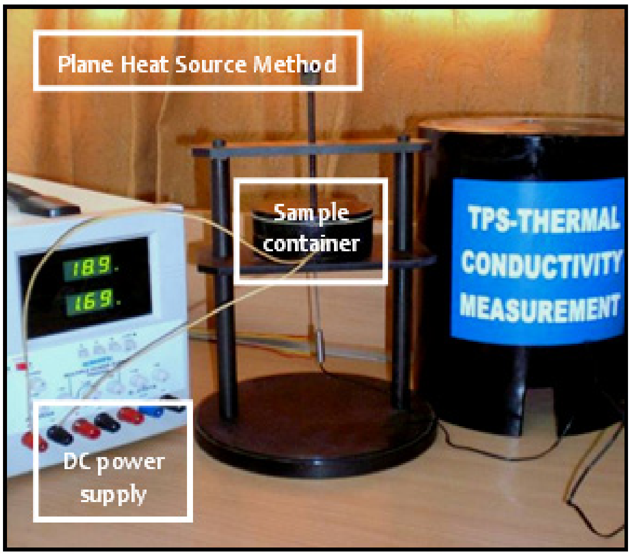

Figure 1. Experimental set up – Transient plane source theory

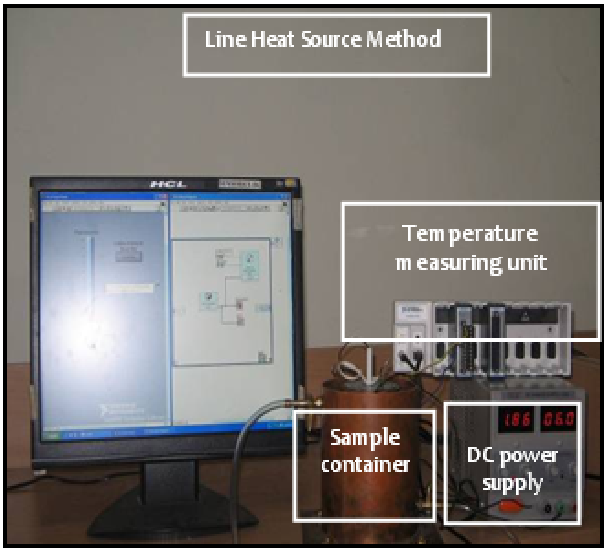

Figure 2. Experimental set up – Line heat source theory

DATA ACQUISITION

In order to reduce the errors and to record readings on a computer directly, a separate data acquisition system is used. National Instruments popular product LabVIEW is meant for its continuous data monitoring and acquisition. The J type thermocouple which is of junction type in nature is *interfaced with the LabVIEW software through the NI DAQ- 9211 Data logger. It is programmed to take readings every 30 seconds. The readings can be recorded in the folder automatically.*

LabVIEW PROGRAM

- *Open LabVIEW 8.2 from the desktop or from the Start menu*
- *Create a new VI by selecting New --> Blank VI on the dialog box that appears. A 'Front panel' and a 'Block diagram' will appear.*
- *Press Ctrl+T to tile both the windows for better visibility.*
- *Right click on the block diagram and from the functions palette that appears, select Measurement I/O --> DAQmx --> DAQ Assist.*
- *A dialog box appears which is used to configure data acquisition. Select Analog Input --> Temperature --> Thermocouple on the right side menu.*
- *Select the appropriate channel through which you have connected the wires (ai0, ai1, etc) and click Next.*
- *In the next dialog box select the*
- *Voltage Range --> 0-20 V*
- *Terminal Configuration --> RSE(Reference Single Ended)*
- *Acquisition mode --> N samples (preferable)*
- *Also specify the Number of Samples and Rate of Acquisition. Number of Samples corresponds to the Bandwidth of data which is acquired from the sensor per single acquisition. Acquisition rate corresponds to the update interval between each acquisition. The block diagram is shown in the Figure 3.*

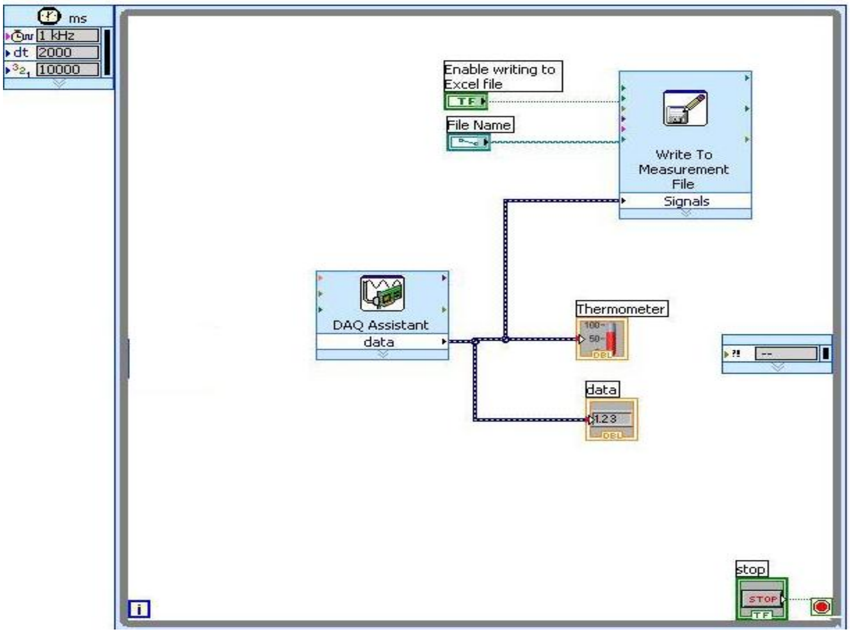

Figure 3. LabVIEW Block Diagram

- *The temperature data from the sensor will now be available in the DAQ Assist control in the block diagram. This data shall be used for programming the logic based on the application.*
- *It is strongly recommended to enclose the entire program inside a While loop, available in Functions palette -->Execution Control -->While loop, and execute it using Run Once button.*
- *Right click on the front panel and select Indicators --> Thermometer from the Functions palette. Wire the Thermometer in the block diagram to the DAQ Assist control. It shall be named as Temperature.*
- *Click Controls palette --> Numerical indicators --> numerical indicator to display the Temperature in a digital display.*

EXPERIMENTAL PROCEDURE

Interfacings of thermocouple with LabVIEW (NI 9211 Q-DATA LOGGER), samples and the experimental set-up kept ready for measurement.

The experimental procedure for line heat source and plane heat source are same and given as follows:

- *DC power supply is switched on and adjusted to the required voltage.*
- *The data acquisition system is switched on and the LabVIEW software is opened. VI is kept ready to run.*
- *The whole experimental set-up is left for sometime say 10 minutes. This is done to avoid initial lag errors in the calculation as mentioned earlier and the set-up is allowed to reach in thermal equilibrium.*
- *Now, the LabVIEW VI is made to run and the variation of temperature of heating coil for constant time intervals say every 30 seconds, are recorded down.*
- *The program is closed once the temperature crosses 5-10 degree Celsius more than the temperature at which the thermal conductivity is to be calculated.*
- *Then the power supply is switched off.*
- *The set-up is left free for some time. Once the sample in the container cools down to room temperature, it is taken off and the container is cleaned thoroughly.*
- *The output of LabVIEW is exported as Excel sheet and is used for further thermal conductivity calculations.*
- *Now, the set-up is dried and LabVIEW new VI is opened. The experiment can be repeated for any number of samples.*

THERMAL CONDUCTIVITY CALCULATION

Thermal conductivity of any material depends upon various factors like density, moisture content, structure, composition and operating temperature of materials. Thermal conductivity of glycerin, saw dust, iron powder, cement and aluminum scrap was evaluated at various temperature based on line heat source and plane heat source method. Reliability tests are conducted for both the experimental set up on glycerin to validate the experimental setup. Errors in experimental set up are found to be very less i.e. 2%, which is acceptable range.

PLANE HEAT SOURCE METHOD

The output from the LabVIEW is used for thermal conductivity calculations. From the time (x) - temperature (T) table obtained, a new table of ln x- T entries is calculated. With the values a graph is drawn for ln X Vs T and the slope of the graph at the required temperature is found out. According to the transient plane source theory, based on which the set-up is designed, the slope of the graph should be equal to

$$Slope = \frac{Po}{\pi^{3/2} ak}$$

where, 'P_o' - amount of heat supplied to the heating coil per unit length (W/m), 'K' – effective thermal conductivity of two-phase material (W/m°C); 'a' - radius of heating coil (m)

Knowing the amount of heat supplied and the slope of the graph, the effective thermal conductivity is calculated.

LINE HEAT SOURCE METHOD

The procedure to find slope for line source method is similar to plane heat source method. According to the line heat source theory, based on which the set-up is designed, the slope of the graph should be equal to $q/4\pi k$

$$Slope,\ m = q/4\pi k$$

where, 'q' - amount of heat supplied to the probe per unit length (W/m), 'k' – effective thermal conductivity of two-phase material (W/m°C)

Knowing the amount of heat supplied and the slope of the graph, according to line heat source theory

$$K = q/(slope*4\pi)$$

Hence, the effective thermal conductivity value (k) for any material is calculated using the above method.

RESULTS AND DISCUSSION

The results obtained from TPS are compared with LHS. The percentage of deviation is within 10%.

From the Table 1 Brick powder is having minimum deviation and Aluminium scrap is having maximum deviation.

Table 1. Comparsion between Transient plane source (TPS) experimental set up and line heat source (LHS) experimental set up

Sample tested	'k' Value by Transient Plane Source Theory (W/m°C)	'k' Value by Line Heat Source Theory (W/m°C)	Deviation (%) from Line heat source theory
Iron powder	0.689	0.640	7.65
Aluminium scrap	0.43	0.388	10.8
Cement	0.29	0.275	5.45
Brick powder	0.606	0.610	0.65
Limestone	0.49	0.467	4.9

CONCLUSIONS

An experimental setup was fabricated based on line heat source and plane heat source method. Both the experimental setup was automated with data monitoring and data acquisition (LabVIEW). Due to these features, errors accompanied with thermal conductivity measurement are greatly reduced.

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