Measurement of Thermal Diffusivity by Development of Simple Test RIG

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Abstract— An experimental method of measuring thermal diffusivity of liquid samples has been developed. Now a days the transient techniques have achieved popularity over the conventional steady state methods because the transient technique requires much less precise alignment, dimensional knowledge, short measuring time and stability. Also, with the proliferation of modern computer based data acquisition systems, it is possible to design a strategy for accurately computing thermophysical properties from the measured temperature data. Hence, to find out thermophysical properties experimentally, in this paper a simple and reasonably accurate test rig has been developed and described. This can be fabricated with simple and basic equipments available almost everywhere.

Keywords- thermal diffusivity, transient technique, data acquisition, short measuring time

I. INTRODUCTION (HEADING I)
Thermophysical properties, such as thermal conductivity and thermal diffusivity, are very important liquid properties. Due to the unique characteristics of liquids, measurement of the thermal conductivity and thermal diffusivity is more challenging for liquids than for solids. Liquids do not maintain any fixed shape and can be easily changed compositionally, which alters their properties. Also, since liquids cannot sustain a shear stress, convection can occur in the presence of temperature gradients, which is one of the major error sources for many conventional techniques that measure liquid thermal conductivity and thermal diffusivity. A.Tomokiyo and T. Okada [1] measured thermal diffusivity of solids when one end is changed sinusoidal with constant angular frequency and other end of the rod connected to a heat sink maintained constant at lower temperature. E Lopez Baeza et al. [2] measured thermal diffusivity of semiconductors when one end is heated sinusoidally and other is thermally isolated. Czarnetzki and Roetzel [3] have continued the development of this method and used it for simultaneous measurement of the thermal diffusivity and the thermal conductivity of solids, liquids and gases when periodic surface temperature oscillation are generated on both sides of the slab with the same constant angular frequency, amplitude and phase. In the earlier experimental work, the temperature oscillations are established by oscillating the heat flux by an electrical heating. A disadvantage of the resistance heater is that the time average of the heat supplied during each cycle cannot be equal to zero. This leads to an increase in the mean temperature of the bar during each cycle. This precludes the measurements at the initially specified temperature. These inherent drawbacks have been overcome by using the peltier heating. The heating and cooling can be carried out by the application of sinusoidal periodic voltage to the peltier element where one side of this element is kept at a constant temperature bath. Considering the intricacy in the measurement of thermal diffusivity of liquids, a considerable attention has been given in designing the sample holder along with its accessories and measuring instruments.

II. TEST RIG
The proposed test rig consists of various component parts fulfilling specific purpose. The major components are as follows;
1. Test cell,
2. Thermostatic Bath,
3. Power Supply System and Signal Generator
4. Data Acquisition System
A complete diagram of the test rig has been shown in figure 1. The functional utility of various component parts are discussed in sections to follow.

A. Test Cell:
The fabricated test cell consists of a cylindrical well bore in a block of POM (polyoxymethylene material), which can be machined and drilled accurately. The diameter of the bore is 26 mm, outer diameter 70 mm and the length 52 mm. It contains test liquid, which acts as a semi-infinite medium. The cavity is closed on both the sides by the removable discs of copper material of dimension 26 mm diameter and 12 mm axial length. Thus, the space for the sample has a dimension of 26 mm diameter and 28 mm length. For filling the sample liquid, a small hole is provided on the body of the test cell. The copper discs act as heating and cooling surface respectively. Between the disc and the water-cooling chamber, a Peltier element (melcore type, CP-07) square 40 mm x 40 mm is sandwiched which generates the required temperature oscillation with the help of a function generator attached to the D.C. supply. The Peltier elements are thermoelectric modules, which are solid-state devices (no moving parts) that convert electrical signal.
into a temperature gradient. The electrical signal supplied through the function generator is consists of oscillating voltage of the required frequency modulated over a D.C. voltage. The cooling chambers located at the outer surface of the Peltier element are maintained at a constant temperature by circulating water from the constant temperature bath. Thus the Peltier element whose one side is kept at a constant temperature generates a regulated oscillating temperature over a mean temperature. For a semi-infinite system, the Peltier element at the far end of the sample is excited with a D.C. signal to maintain a constant mean temperature along the sample length.

At the interface of the sample material and the copper disc, a thermocouple of 0.2 mm wire diameter is affixed. This represents the response of input signal. For the output signal in the thermocouple probe of 0.5 mm diameter is inserted at a distance of 5 mm in the sample holder. The third thermocouple is placed at a similar location as that of the first one to ensure semi-infinite assumption of the sample and to correct the mean temperature. All the thermocouples are K-type and these are located along the axis of the test cell. The signals of the thermocouples are amplified and filtered before connecting to data acquisition system, which in turn connected to a PC for recording the data.

B. Thermostatic Bath:
This unit comprises a cooling system, heating system, temperature controller and water circulating pump. It is an automatic control device system, which maintains constant temperature between 0.00°C to 500°C with an accuracy of 0.10°C. The function of the temperature bath is to maintain a constant temperature at one side face of the Peltier element by water circulation in the cooling chamber. The constant temperature of the bath is used to maintain a constant mean temperature at the other surface of the Peltier element. However any further control of the mean temperature is done by controlling the D.C. component of the modulated signal feed to the Peltier element.

C. Power Supply System and Signal Generator:
The line voltage, 230V A.C., 50Hz is stabilized (servo voltage stabilizer) before feeding to different equipment/instruments. The signal generator generates the oscillating signal (0-5V) of required frequency. The time period of this signal can be varied from 20s to 400s depending on the requirement. If two different signals are required, two channels signal generator with phase shifter has to be incorporated. The D.C. (0-15V) power supply is used to modulate the oscillating signal over the D.C. voltage. The role of the amplifier is to regulate the amplitude of the oscillating part and also regulates the current rating (0.5-4A) for the Peltier element. The regulation of D.C. power source regulates the mean temperature of the Peltier element whose other surface is maintained at constant temperatures. This type of two-frequency signal generator is not available commercially. For this experiment it has been specially fabricated. However, in semi-infinite samples one signal generator is adopted.

D. Data Acquisition System:
The temperature at the input and output of the sample are measured by K-type thermocouple probe (0.5 mm). These thermocouples are connected to a PC through ADAM 4000 series data acquisition modules. These data acquisition modules consist of ADAM 4018 (8-channel) thermocouple input module and ADAM 4520 (isolated RS-232 to RS-422/485) converter. The converter is connected to the COM port of the PC. The temperature data collected from the two channels are stored in computer for further analysis.

III. TEST PROCEDURE
At the beginning of experiment the distance between thermocouples are checked accurately. Then the test section is filled with liquid through a hole provided in middle of the cell. The liquid used in experiments are ethylene glycol, ethanol, glycerol and water. The temperature of copper disc is given periodic oscillation by Peltier element at one side of the sample with a constant frequency. The cooling chamber is supplied with water from a constant temperature bath, which act as a partial controller of the mean temperature of oscillation. The temperature oscillation in this element is further controlled by adjusting the D.C. component and oscillating component. The measurements of temperatures are made at different positions; at the interface of the copper disc and on the sample, 5.0 mm from the first thermocouple, and at other end of the sample similar to the first location. For this purpose two K-type thermocouples of 0.2 mm diameter are used at the interfaces of the copper disc and the liquid sample and one 0.5 mm diameter K-type thermocouple probe. Response of the thermocouples is connected to data acquisition system. This data acquisition system is connected to a PC for data recording and analysis. The initial oscillations are not used for computation because of their transient nature. After the equilibrium condition has been reached, temperature oscillation is recorded for a number of cycles. Thermocouples attached in the interface between far end and liquid sample assures that the oscillations are completely died down and thus the approximation of semi-infinite medium holds true. It may be noted that spacing between the two thermocouples may be adjusted depending on the sample to get a semi-infinite medium.

The thermocouple at the 5 mm inside the specimen is used to collect the output response for the input response at one end of the sample. By evaluating amplitude or phase of the temperature oscillation at the two points, the thermal diffusivity can be determined. In the present experiment, the amplitude ratio is considered.
IV. CONCLUSIONS

The objective of the author was to develop an effective and economical test rig for measurement of thermal diffusivity. An effective test rig was developed and experiments were successfully conducted on it. The performance of the test rig was found to be very satisfactory.

Figure 1. Experimental setup: (1) Test Cell, (2) Thermostatic Bath, (3) Data Acquisition System, (4) DC Power Supply, (5) Signal Generator, (6) Amplifier, (7) PC.

REFERENCES


