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A Thermal Expansion Measurement System Using A High Temperature Unguided Half Bridge Displacement Transducer

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Abstract - ***In this paper, a temperature and vacuum rate controllable furnace which is suitable for thermal expansion measurement of metal samples having predefined standard dimensions is designed and realized[1]***

I. INTRODUCTION

Thermal expansion measurement of materials must be done under controlled temperature program using a system that has a wide range of instruments called as Thermal Analysis System. In thermal analysis systems, various methods are used listed below[2]:

Dilatometry and Thermomechanical Analysis, Thermogravimetric Analysis or Thermogravimetry, Differential Thermal Analysis and Differential Calorimetric Scanning, Laser Flash Analysis and Thermal Conductivity Analysis[2].

The designed and realized system described in this paper uses dilatometry method. Dilatometry is a technique in which a dimension of a sample under negligible load is measured as a function of temperature while the sample is subjected to a controlled temperature program[3-5]. In this system, the pushrod movement resulting from the change in length of the sample is detected by a Linearly Variable Displacement Transducer (LVDT), giving rise to an electrical signal which is transmitted to the data acqusition card via a suitable signal conditioner circuit[7-8].

At the system shown in Figure 1, the measurement apparatus is set vertically and the temperature can be set from room temperature to 600°C by using a Fuzzy Logic Controller[1].

II. SYSTEM DESCRIPTION

The schematic diagram of realized thermal expansion measurement system is shown in Fig 1. The measurement system consists of

- a K-type thermocouple and its signal conditioner circuit (AD595) to measure the inner furnace temperature[9-10].
- an LVDT (LIN156) to measure displacement or thermal expansion of metals and a S7AC signal conditioner circuit to convert the displacement into voltage[11-12].
- a pressure transducer (BTE6N01G0) to measure the vacuum rate of inner furnace.
- an actuator in order to move the furnace bottom plate up or down, drived by L298 step motor driver IC.
- A Data Acqusition Card (Advantech PCL812-PG) to acquire the anolog data from system and also to send data from computer to system [13-14].

As shown in Fig.1, expansion measurement apparatus consists of 4 parts: First part is metal sample and its seramic holder has a shape of hole cylinder. Second one is transducer group including LIN 156 LVDT, an up-down movable free armature (some transducer has spring return), a seramic push rod between sample and armature to keep the transducer away from heat. Third one is LVDT signal conditioner circuit S7AC and finally the last one is a PC including AI connector of the PC Labcard. After analog data is first logged, this initial value stored as a reference. Then each measured data is compared the initial value (measured value minus initial value) and displacement (expansion-Δl) can be calculated by software.

The metal samples must have a pre-defined geometry (a cylinder having a length of 88-90 mm and diameter of 16 mm) because of sample holder's shape. In addition, the length of the sample is important to keep the sample contact with the push rod and also LVDT's armature after the furnace bottom plate closed.

Transducer is mounted by clamping the body. In installation of the transducer, armature's initial position is important so that armature must leave 40 mm away from the body as shown in Fig. 2. At this position a zero output signal is produced. (electrical zero position or equilibrium) But in this work, the

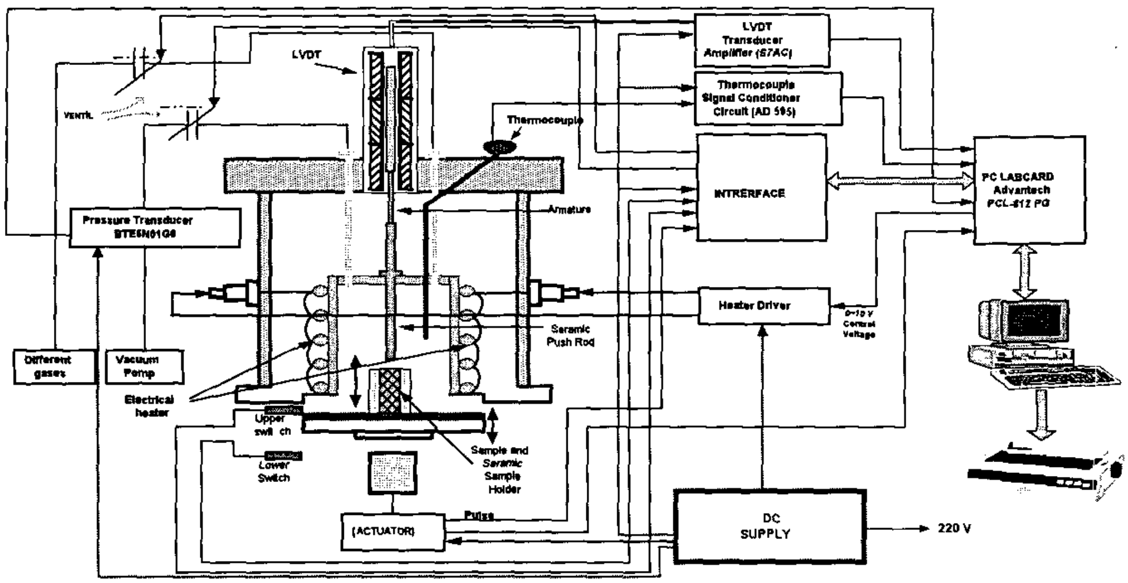

Fig. 1. Schematic of the measurement system[1]

at this point a 5V output is produced by adjusting S7AC circuit. The S7AC is a signal conditioning unit for use with transducers requiring AC excitation and synchronous demodulation, producing a DC output voltage or current[15]. In this work some arrangements are used on S7AC circuit in order to produce a voltage in a range of 0-10V and also to produce a 5V at zero position. In addition two bridge completion resistors of 1K are mounted on the circuit in R11 and R12 locations[15]. But in this work, zero position is shifted above and initial output voltage is produced as 6.2158V

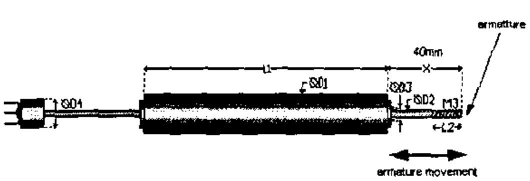

Fig. 2. LIN series High Temperature Unguided Half Bridge Transducers[7-8]

III. DISPLACEMENT TO VOLTAGE TRANSFORMATION CURVE

In order to get the displacement (mm) to voltage (Volts) transformation curve of LIN 156 displacement transducer, the apparatus shown in Fig. 3 is set. In this set, the handle of the micrometer is wond 100 times per 1 mm by manually.

The results are measured and recorded by FLUKE 45 dual display multimeter and then plotted in Microsoft Excell 2000.

This procedure is repeated 3 or 4 times to show repeatibilty. According to the fitted curve shown in Figure 3, the below equation is get:

$$V_{\Delta Lx} = 0.1868 \times \Delta Lx + 5.1052 \quad (1)$$

where

ΔLx, displacement amount in mm and $V_{\Delta Lx}$, the DC voltage at the output of the S7AC circuit.

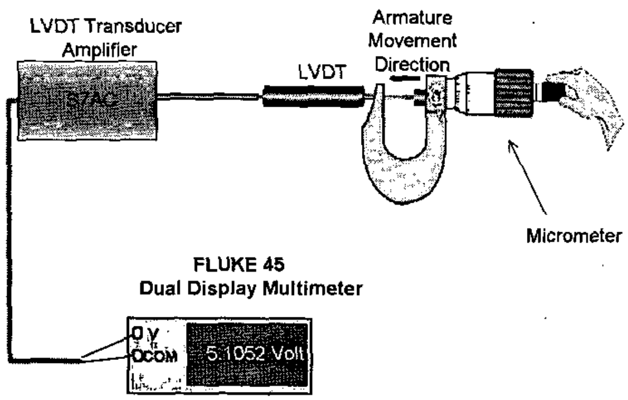

Fig. 3. The apparatus set in order to get transformation curve.

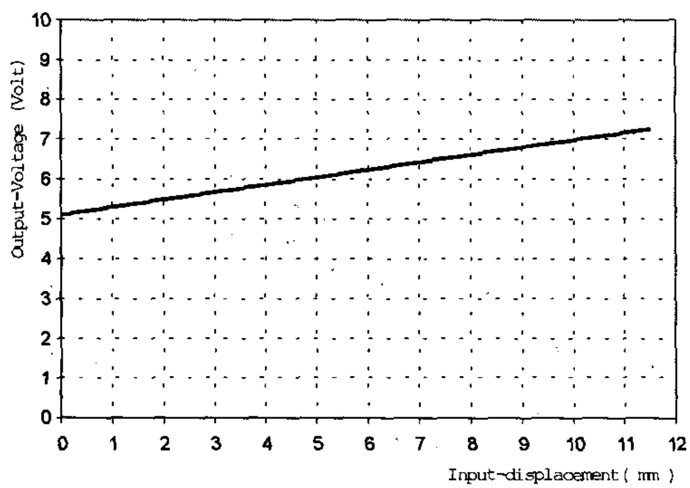

Fig. 4. Displacement to voltage transformation curve

IV. EXPERIMENTAL RESULTS

As mentioned before, thermal expansion measurements must be done under low heating rates (5-20°K/minutes) [2,3]. In this work, measurements are carried out in two different heating rate as shown in Figure 5.

In the first experiments, the objective is to reach the reference temperature in the shortest time nonlinearly (curve number 1 in Figure 5). In these experiments, theoretical and experimental expansion results are in good agreement after the set point is reached and the temparature value kepts constant. However a small difference between experimental and theoretical results is obtained from room temperature to set point (rising time) Experimental expansion values are lower than the theoretical ones as shown in Figure 6. To increase the agreement between experimental and theoretical values, the rate of change of the temperature is decreased until the curve 2 becomes similar to the dotted line shown in Figure 5. The dotted line shows the linear temperature rising at the rate of 10 °C/minutes. In the experiment done at the lower heating rates, the difference between theoretical and experimental expansion values are smaller than curve 1.

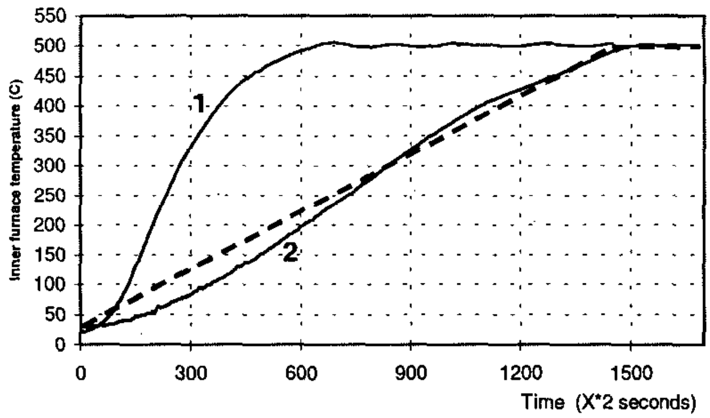

Fig. 5. The temperature rising curves in two different heating rates.

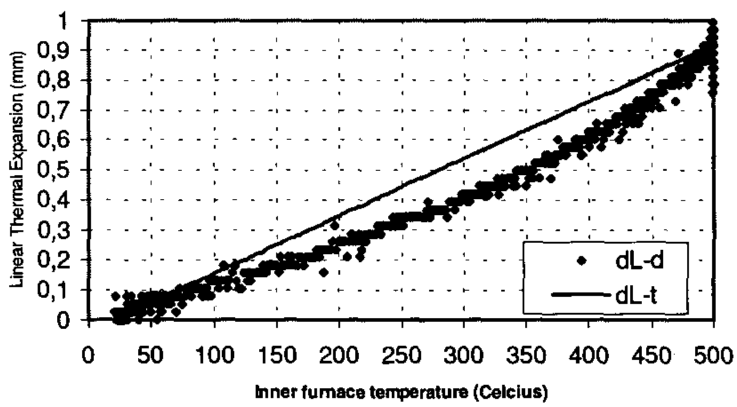

Fig. 6. When the temperature is rising at higher rates nonlinearly, the comparison of the theoretical and experiemental expansion values of aluminium.(dL-d experimental and dL-t theoretical data)

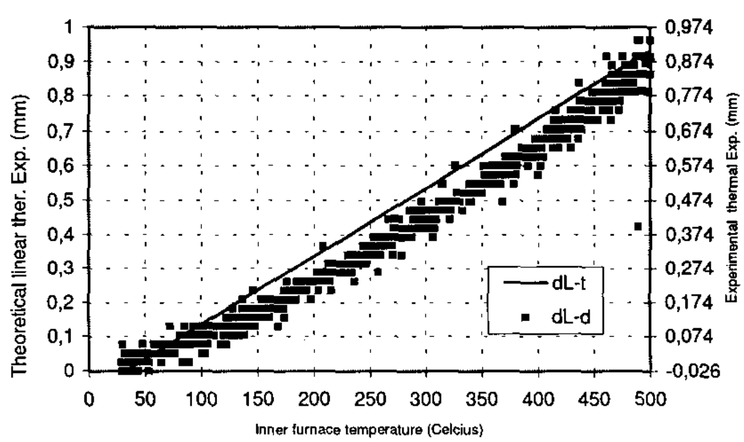

Fig. 7. The comparison of the theoretical and experiemental expansion values of aluminium in the lower heating rates. (dL-d experimental and dL-t theoretical data)

The obtained expansion values from experiment 150 (curve 2) and the recommended expansion values existing on the literature are plotted together in order to compare them. As shown in Figure 8, a measurement error is obtained in the range of tolerance band of 3 % [3,16]. The experimental and literature values are tabulated in Table 1 simultaneosly.

Table.1. The comparison table for Al sample

T (Kelvin)	T (Celcius)	ΔL/L₀	
		Literature data[15]	Experimental data (Exp. No:150)
5	-	-0,418	-
50	-	-0,413	-
100	-	-0,371	-
200	-	-0,203	-
293	20	0	0
400	127	0,259	0,278
500	227	0,514	0,486
600	327	0,787	0,723
700	427	1,084	0,991
800	527	1,408	-
900	627	1,764	-

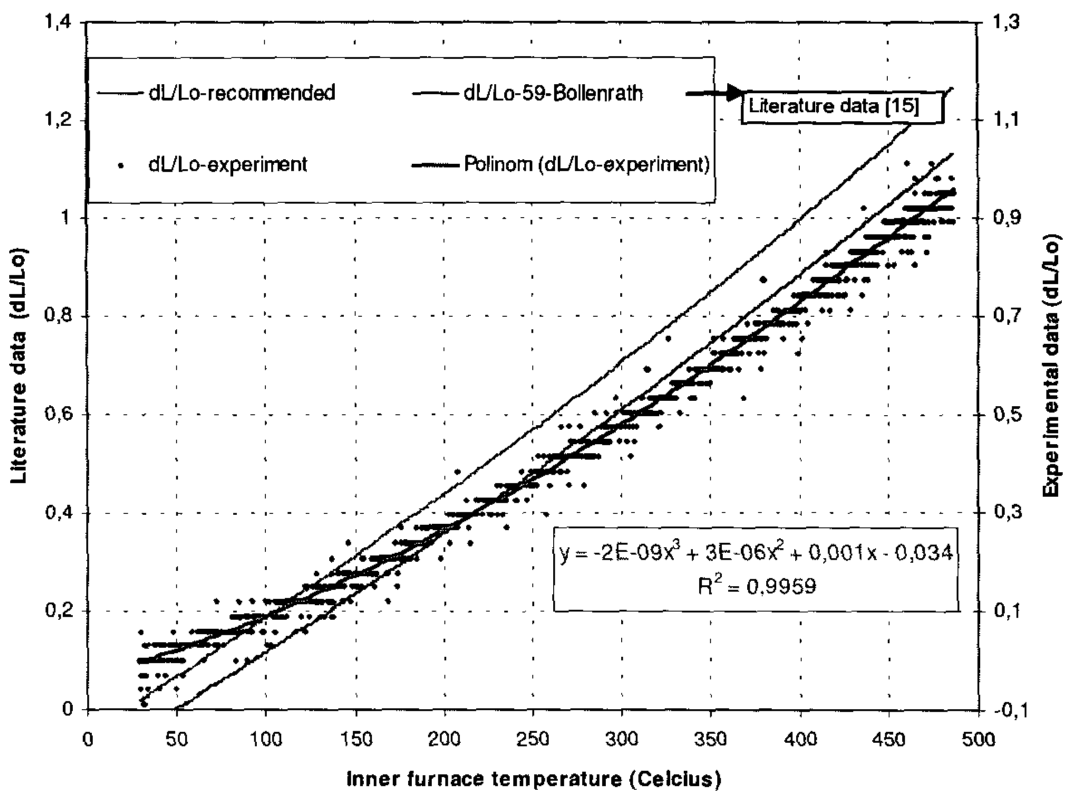

Fig.8. Comparison graph of literature and experimental data

V. CONCLUSION

In the realized system, the measurement error does not exceed the tolerance of 3 % of the recommended values without any correction. But, the thermal expansion values of the Aluminium were corrected by adding a Δl parameter which is caused by the system on the literature. As a result of experiments, in the realized system described in this paper, a new thermal expansion curve for aluminium which has a degree of three is fitted to measured data as shown in Figure 8.

The system is designed and realized in order to use it in education. That's why it is cheaper than the professional thermal analysis equipment. However, the system has not all of the features of proffessional ones.

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