ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 1, Issue 7, October 2014

Linear Coefficient Of Thermal Expansion Measuring Apparatus

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1. Introduction

- Thermal expansion is the tendency of a matter to change in its volume in response to the change in temperature.
- When heat is given to a substance, the particles of the substance begin to move more and thus, usually maintain a greater average separation (the number of materials which contract with increasing temperature is verylow).

The coefficient of thermal expansion can be defined:-

- the degree of expansion divided by the change in temperature.
- Materials expand because an increase in temperature leads to greater thermal vibration of the atoms in a material, and hence to an increase in the average separation distance of adjacent atoms.
- The linear coefficient of thermal expansion a (Greek letter alpha) describes by how much a material will expand for each degree of temperature increase, as given by the formula:

$$\alpha = \frac{dl}{l \times dT}$$

Where, dl = the change in length of material in the direction being measured
l = overall length of material in the direction being measured
dT = the change in temperature over which dl is measured

Units Of Coefficient Of Linear Thermal Expansion
Coefficient of Linear thermal expansion (CLTE) = α
α=(change in length)/(original length*change in temp.)=Metre/(metre*Celcius)=m/mC (meters cancel leaving...)=1/C=C^{-1}

2. Coefficient Of Thermal Expansion (Cte) Variation With Materials :

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The magnitude of the CTE depends on the structure of the material. As can be visualised from Figure 1, the atoms would only stay at a constant separation at absolute zero; above that, their increasing thermal energy generates some movement about the mean, and the mean itself increases slightly because the bond energy curve has an asymmetric shape.

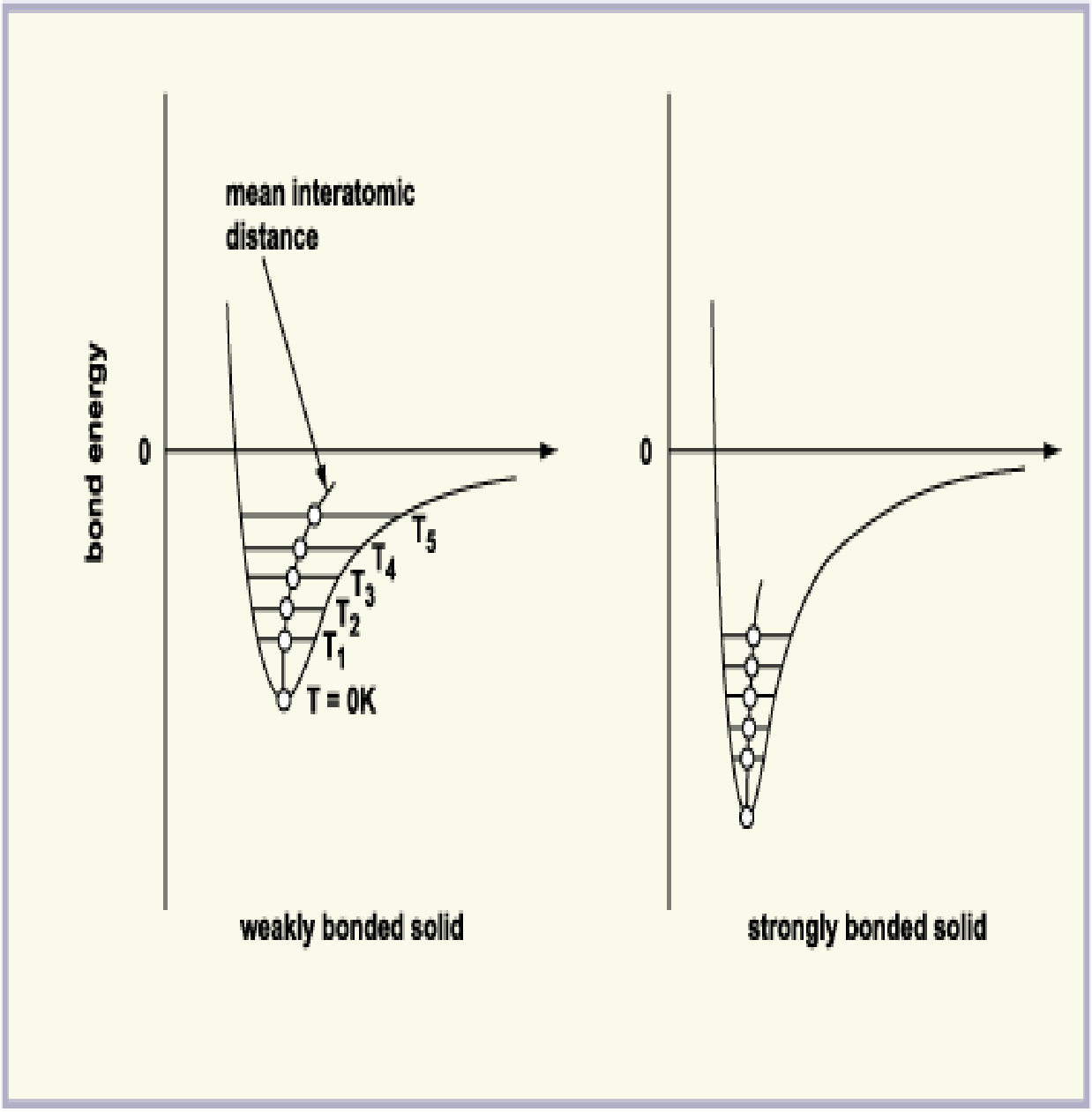

Fig.1 CTE variation with materials.

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3. Different Materials and their Linear Coefficient of Expansion :

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Material	Linear coefficient, α, at 20 °C (10^{-6}/°C)	Material	Linear coefficient, α, at 20 °C (10^{-6}/°C)
Aluminium	23	Nickel	13
Benzocyclobutene	42	Oak	54 [13]
Brass	19	Douglas-fir	27 [14]
Carbon steel	10.8	Douglas-fir	45 [14]
Concrete	12	Douglas-fir	3.5 [14]
Copper	17	Platinum	9
Diamond	1	PVC	52
Ethanol	250	Quartz (fused)	0.59
Gallium(III) arsenide	5.8	Quartz	0.33
Gasoline	317	Rubber	77
Glass	8.5	Sapphire	5.3[15]
Glass, borosilicate	3.3	Silicon Carbide	2.77 [16]
Gold	14	Silicon	3
Indium phosphide	4.6	Silver	18[17]
Invar	1.2	Sitall	0.15[18]
Iron	11.8	Stainless steel	17.3
Kapton	20[10]	Steel	11.0 ~ 13.0
Lead	29	Titanium	8.6
MACOR	9.3[11]	Tungsten	4.5
Magnesium	26	Water	69
Mercury	61	YbGaGe	≈0
Molybdenum	4.8		

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Fig. 2 Table for different material and their linear coefficient of thermal expansion.

4. Thermal Expansion Coefficients of different material at 20° C:

Thermal Expansion Coefficients at 20 C

Material	Fractional expansion per degree C x10^-6
Glass, ordinary	9
Glass, pyrex	4
Quartz, fused	0.59
Aluminum	24
Brass	19
Copper	17
Iron	12
Steel	13
Platinum	9
Tungsten	4.3
Gold	14
Silver	18

Fig. 3 Thermal expansion coefficient at 20 C.

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5. Construction

The overall construction of the apparatus has been divided into two major parts -
1.ExternalBody
2. Internal Structure

External Body –

The external body of the apparatus is actually a Copper tube of a diameter 8 mm which is covered on the circumference by three heaters and also by the asbestos cloth. This complete thing is rested on an Iron framework, which acts as the base for this experiment. The basic function of this setup is to act like an oven. The heaters are provided to heat the Copper tube and the asbestos cloth provides insulation, hence partially blocking the heat to go into the surroundings. Copper tube is used because of it's excellent property of thermal conduction. Not only it grabs heat from the heater, but also loses it to the inner structure quickly, which is one of the requirements of the experiment. The external body also includes various measuring instruments, for the measurement of the different quantities required. These instruments include

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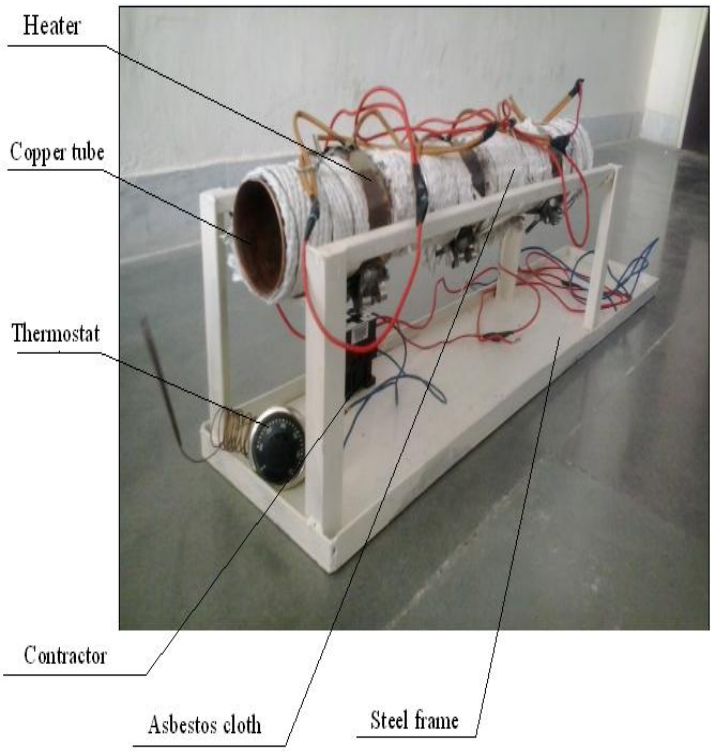

Fig. 4 External body of the apparatus.

Internal Structure –

The internal structure, unlike the external body, is a bit more complex. It includes a removable frame, made of Iron discs and rods of various dimensions. These discs and rods have been carefully measured and formed as per the requirement of the project.

There are three Iron discs which are supported by two supporting rods, again made of Iron. These discs are welded on the rods, two at the extreme ends and third one at the centre. The discs have holes, either throughout or till some fixed distance into them. This way, they are fixed on the rods (supporting rods). Each disc has three holes on a fixed diameter line at suitable distances from each other.

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The end holes are the ones fixed to the rods, but the middle hole (the one at the centre) is not welded to any rod and is actually the place for the test rod, which is to be used for the experiment and calculations.

This internal frame is detachable and can be totally removed from the external body with the help of the support rods (their lengths are greater than those of the copper tube itself, hence handling becomes easy).

When inside the external body, the test rod is inserted through the mid hole (which peeks out from the body even when completely inserted) and a dial indicator is kept just touching it.

Fig. 5 Internal structure of the apparatus.

6. List and details of parts involved:-

1. Copper tube : A Copper tube of length = 600 mm has been used as the basic thermal conducting object. It forms the outer circle for the complete inner structure.

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Fig.6Coppertube

2. **Heaters** :

Three heaters have been employed at each of the two ends and one at the middle for even circulation and variation of temperature inside the Copper tube.

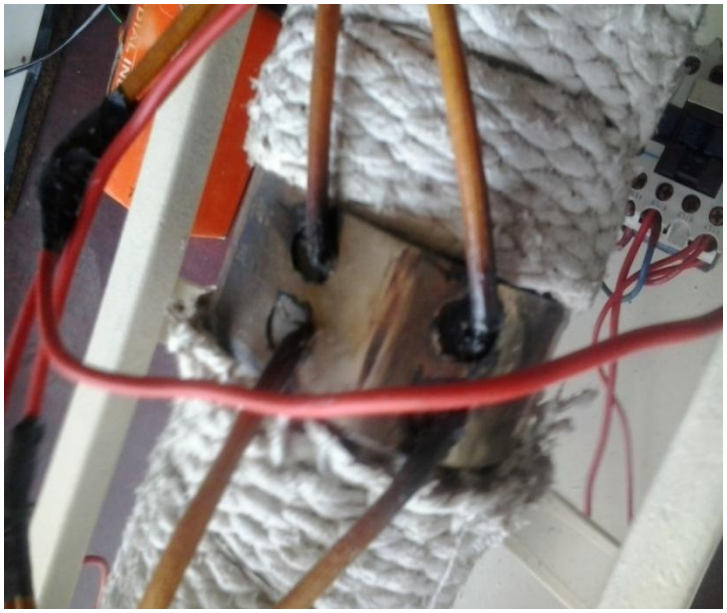

Fig.7.Industrial Coil heaters.

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3. **Asbestos Cloth** :
   The linings of this special property cloth material are done on the naked circumferential surface of the Copper tube, that is, the exposed area of the tube after the placement of the heaters. This cloth doesn't allow the transfer of heat through it and hence it saves a lot of energy from going into the surroundings.

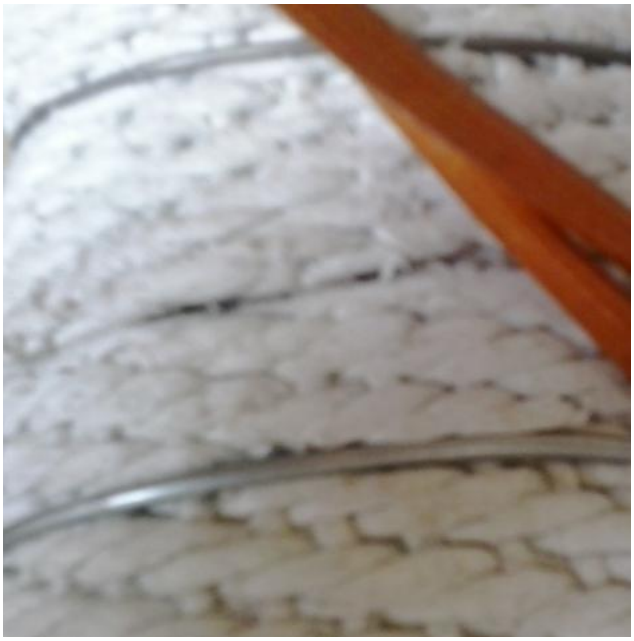
Fig.8 Asbestos Cloth (insulating material).

4. **Iron rods (supporting rods)** :There are two of these rods, which have been included so as to support the entire inner frame from the possible effects of buckling etc. The right end side these support rods can also be used to remove the entire inner frame from the outer body. Each of these two rods has a diameter of 10 mm and lengths of 650mm.

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Fig.9 Iron rods (supporting members).

5. **Iron Discs**:There are three Iron discs, each of 76 mm diameter, but of varying thickness. Each of them can be understoodas follows –

- Left-most disc – This disc of thickness = 30 mm is placed at the left end of the apparatus and has three major holes, out of which none is completely through. However, it sports an extra hole (minor) throughout. This minor hole is used for the detection of temperature inside the oven using a Thermostat.

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Fig.10 Left most iron disc.

- Middle disc – The middle disc has a thickness of 10 mm. Three out of three holes in it are completely throughout.

- Right-most disc – This is the most right hand side placed disc of thickness = 20 mm. Again, like the others, it also has three holes, all completely throughout. The supporting rods (welded) and the test rod (unfixed) peep out from the middle hole of this disc.

6. Test Rod :Only one test rod can be placed inside the apparatus at a time. The test rods (diameter = 10 mm) can be of Aluminium, Brass etc.

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Fig.11 Test rod (centre one) with supporting rods.

7. **Temperature Sensors** :
   An analog temperature sensor cum controller is used at the left most end of this apparatus. It's work is to sense the temperature inside the oven by using the sensor lead through the minor hole of the left most Iron disc. After this, it cuts off the electrical supply to the apparatus whenever the temperature rises above that required.

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Fig.12 Temperature sensor (thermostat)

8. **Dial Indicator**:
   This is a very accurate measuring instrument which has been employed at the right most end of the apparatus. At the instance when the experiment hasn't started, the tip of this very sensitive instrument is kept just in touch with the test rod coming out of the right most disc.

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Fig.13 Dial Indicator.

9. **Contractor** : Contractor is an electrical device used to connect and disconnect the electrical mains supply according to the temperature limit inside the Copper tube. The directions for connecting or disconnecting the mains supply depends upon the preset temperature sensor.

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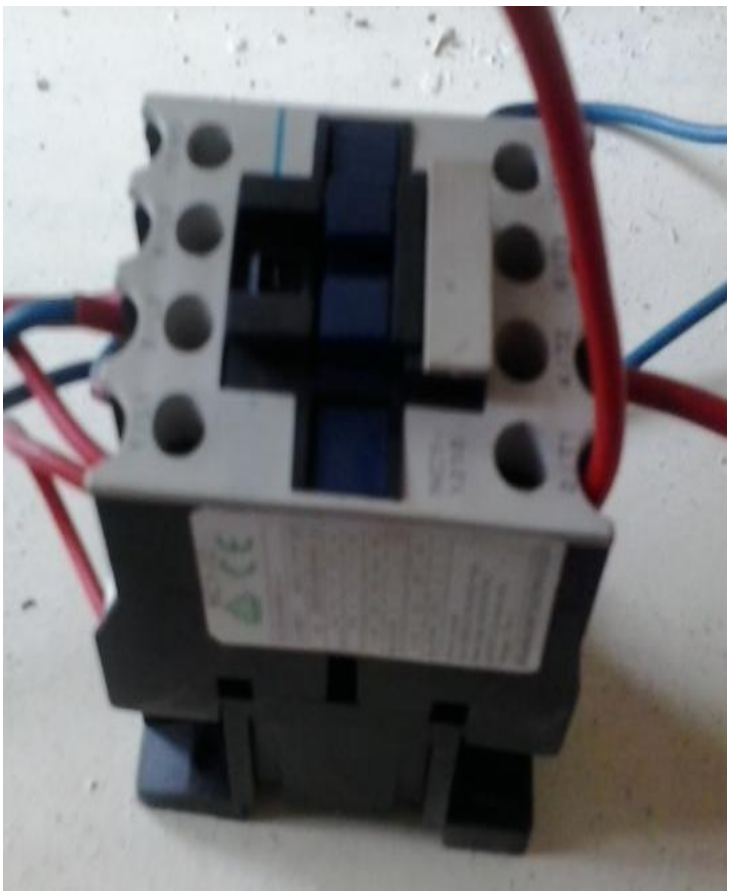

Fig.14Contractor (240v, 50Hz).

7. Working

- Step 1 – The experimental setup is completely arranged properly and the wires are plugged into the 240v, 50Hz A.C supply. Then, the switch is set to ‘on’ position.

- Step 2 –The temperature sensor is set to the first desired temperature reading. This is done by using the analog scale provided. Whenever the temperature inside the oven reaches that set reading, the main electricity supply will be automatically cut off.

- Step 3 – At a particular temperature and time, which actually depends upon the material of the test rod, the expansion will start and the dial indicator pointer will move accordingly.

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- Step 4 – Record every reading at the preset desired temperature and time.

- Step 5 – We plot a graph according to the reading observed from the experiment. After this, the value of the coefficient of linear thermal expansion is calculated.

- Step 6 – After one set of the experiment is completed, the test rod can be easily removed and can be replaced with a rod of another material but same dimensions (diameter and length)

8. Reasons for the choice of materials / instruments :

1. *Tube* used for the oven is made of Copper because of high value of thermal conductivity. Copper is a good conductor of heat, hence it quickly lets the heat from the heater to go through. Also, it quickly loses heat too, making the handling easy.

2. *Asbestos Cloth* is used to cover the exposed part of the Copper tube as it has a special property of blocking heat from its own surface to the other.

3. *Temperature Sensor* is used for the detection of the temperature inside the oven and as soon as it reaches the pre-decided level, main electricity is directly disconnected, so that the reading at a particular instance of time can be recorded easily.

4. *Iron Rods* have been used as a support. Their function is to ensure that no buckling takes place in the test rod.

5. The basic function of *Iron Discs* is to give a platform for the test rod to rest inside the oven. The test rods couldn't be placed inside the oven directly and that's why the need for the Iron discs was recognized. \
6. *Dial Indicator* is a very accurate instrument and since the experiment involves measurements at the minutest level, it was mandatory that we use an instrument with the most accurate and precise abilities.

Scope:-
Significance and Use

1.1 This test method the determine of the linear thermal expansion of rigid solid materials using rod dilatometers. This method is applicable over any practical temperature range where a device can be constructed to satisfy the performance requirements set forth in this standard.

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1.2 For this purpose, a rigid solid is defined as a material that, at test temperature and under the stresses imposed by instrumentation, has a negligible creep or elastic strain rate, or both, thus insignificantly affecting the precision of thermal-length change measurements.

1.3 Computer- or electronic-based instrumentation, techniques, and data analysis systems may be used in conjunction with this test method, as long as it is established that such a system strictly adheres to the principles and computational schemes set forth in this method. Users of the test method are expressly advised that all such instruments or techniques may not be equivalent and may omit or deviate from the methodology described hereunder. It is the responsibility of the user to determine the necessary equivalency prior to use.

9. References

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