SENSOR TECHNOLOGY EXPERIMENTS

EXPERIMENT – 1

MEASUREMENT OF STRAIN AS A FUNCTION OF APPLIED LOAD

AIM:

To measure the strain of a cantilever beam as a function of Applied Load

APPARATUS REQUIRED:

1. Strain gauge setup
2. Weights
3. Signal conditioner circuit
4. Multimeter

THEORY:

When a tensile stress is applied to the member, the length of the wire increases, the cross sectional area decreases and as a result the diameter decreases. This combined effect results in increase in resistance as seen from the following equation,

$$R= [\rho L/A]$$

Where,

R= resistance of the wire

L= the length of the conductor

A= the area of the conductor in m^2

As a result of strain, two physical parameters are of particular interest,

1. The change in gauge resistance
2. The change in length

The measurement of the sensitivity of the material to strain is called the gauge factor (GF). It is the ratio of the change of the change in resistance ($\Delta R/R$) to the change in the length ($\Delta L/L$). Therefore the gauge factor is given as,

$$GF= (\Delta R/R)/ (\Delta L/L)$$

The relationship between strain and gauge factor can be given as,

$$GF= (\Delta R/R)/\sigma$$

Similarly the relationship between Poisson's ratio and gauge factor can be given as,

$$GF= 1+2\upsilon$$

Where, υ = Poisson's ratio= $(\Delta d/d)/ (\Delta L/L)$= the ratio of strain in the lateral direction to strain in axial direction.

Stain is the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length as shown in fig1.

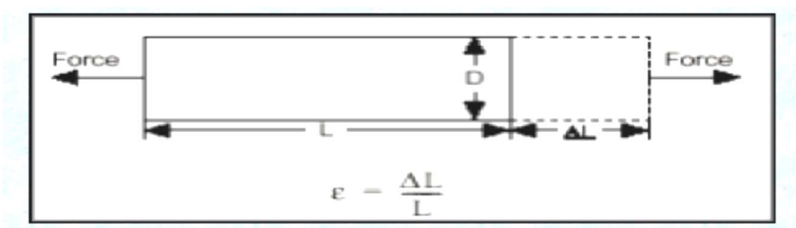


Fig.1: Definition of Strain

Strain can be positive (tensile)or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro-strain, which is 10^{-6}.

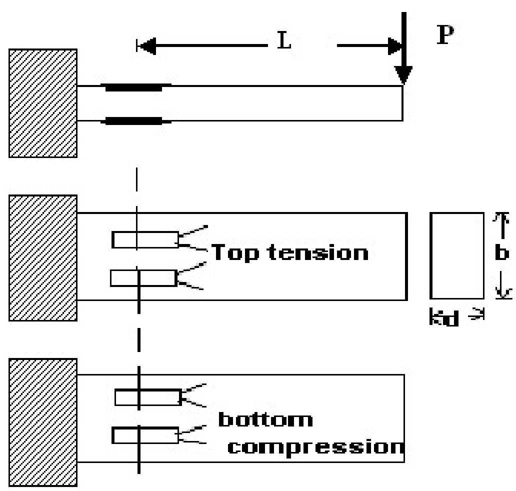
When a bar is strained with a uniaxial force, as in fig.1, a phenomenon known as Poisson strain causes the girth of the bar, D, to contract in the transverse, or perpendicular. Direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's ratio. The Poisson's ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force).

PROCEDURE:

1. The four strain gauges are connected to form a Wheatstone's bridge. Initially the bridge should be balanced, so that the signal conditioner shows zero output.
2. When a load is applied (Add upto 1Kg in 0.1kg steps to the spindle), the strain gauges are subjected to strain which results in bridge unbalance and an output voltage appears. This output voltage is very small and needs to be amplified and this is done

in the signal conditioner with a digital display. The digital display is directly calibrated in terms of microstrain.

3. Note the microstrain for the corresponding load and tabulate it.
4. Find theoretically the microstrain for corresponding weights and tabulate it.
5. Now divide the tabulated value into upper half and lower half. Find the difference between the two halves and tabulate it.



FORMULA:

Theoretical strain

$$\varepsilon = \frac{6PL}{bd^2E}$$

Where ε = micro strain

E = Young's modulus in Kg/mm^2

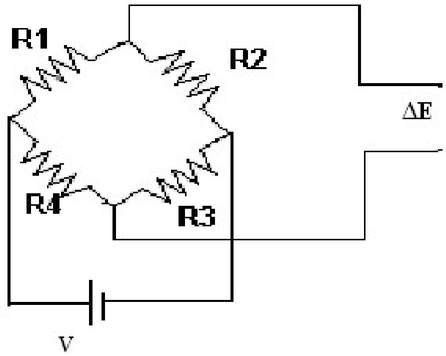
P = load in Kg

L = length in mm

b = breadth in mm

d = thickness in mm

CIRCUIT DIAGRAM:



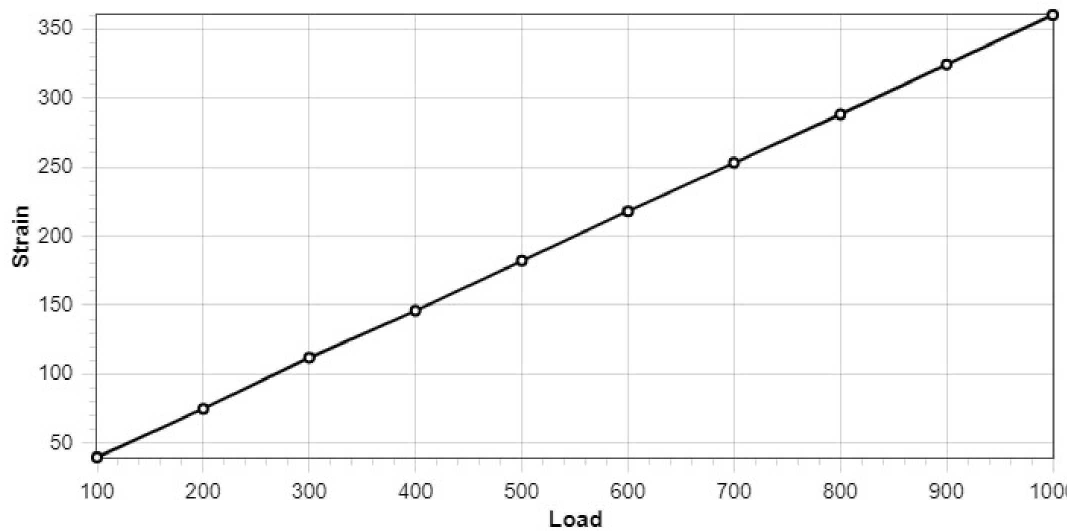
OBSERVATIONS:

LOAD MEASUREMENT:

S. No	Weight (Gm)	Micro Strain		
		Theoretical	Loading	Unloading
1	100	37.714	40	40
2	200	75.428	75	75
3	300	113.142	112	112
4	400	150.856	146	146
5	500	188.57	182	182
6	600	226.284	218	218
7	700	263.998	253	253
8	800	301.712	288	288
9	900	339.426	324	324
10	1000	377.14	360	360

GRAPH:

Load Vs Strain



RESULTS:

Hence measured the **s**train of a cantilever beam as a function of Applied Load

EXPERIMENT - 2

SHEAR STRAIN AND ANGLE OF SHIFT MEASUREMENT OF HOLLOW SHAFT

AIM:

i). To determine the shear strain due to the Torque applied

ii). To determine the angle of twist

APPARATUS:

- Torsion Setup
- Scale and telescope
- Signal Conditioner

PROCEDURE:

1. Connect strain gauges to the signal conditioner and do the zero adjustment without any load and set the calibration value to 500.
2. Adjust the scale and telescope so that the image of the scale reflected from the mirror attached to the tube is seen through the telescope. Align the horizontal cross wire in the telescope to coincide with one of the scale divisions.
3. Add loads in steps of 100 gms on both sides of the lever arms.
4. The corresponding values shown by the signal conditioner and the changes in the scale readings are recorded.

THEORETICAL CALCULATION:

The Torsional strain $\varepsilon = \frac{\tau}{G} = \frac{TR_0}{GJ}$

Where Torsional maximum stress $\tau = \frac{TR_0}{J}$ kg/cm^2

Shear modulus $G = \frac{E}{2(1+\upsilon)}$ kg/cm^2

Where,

T = Applied torque given by the one of the loads multiplied by the total Torsion of area length = P x L

R_0= Outer Radius of the Tube subjected to torque

$R_0 = \frac{D_0}{2} = \frac{19}{2} = 9.5$ mm

D_0= Outer diameter

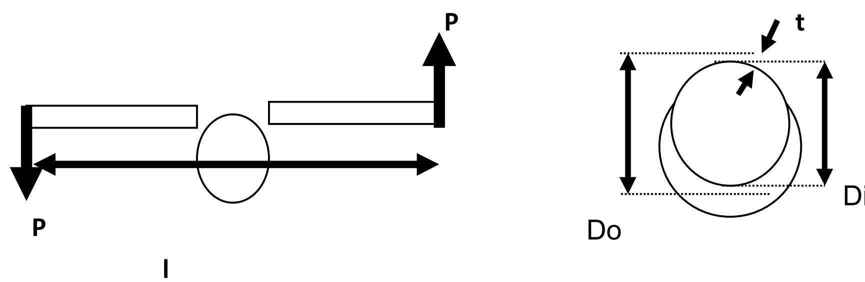
Di = Inner diameter

J = Polar moment of inner dia

$= \frac{\pi}{32} [D_0^4 - D_i^4]$ cm^4

E= young's modulus or modulus of elasticity

ν =Poisson's ratio



For aluminium

E =$0.7x10^6$ Kg/Cm^2

ν = 0.3

ANGLE OF TWIST

$\Phi = \frac{TL}{GJ}$

where Φ= Total angle of twist where the mirror is located

OBSERVATION:

SHEAR STRAIN

S. No	Load in (Kg)	Arm length L (cm)	Applied torque T (Kg. Cm)	Shear Strain as indicated $x10^{-6}$
1	0.1	39.5	3.95	26
2	0.2	39.5	7.9	57
3	0.3	39.5	11.85	87
4	0.4	39.5	15.8	109
5	0.5	39.5	19.75	137

L= distance of the center of the mirror from the fixed end

ANGLE OF TWIST

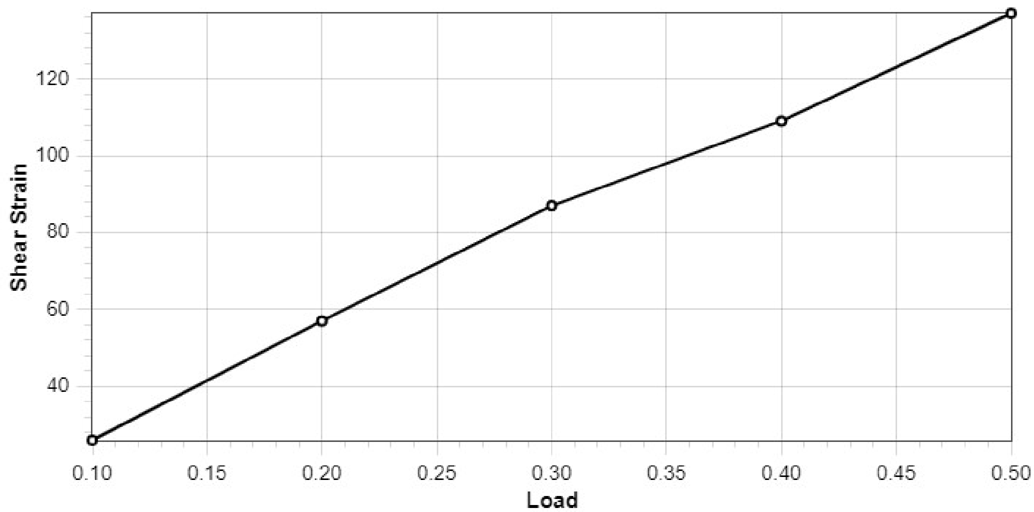
Distance of the Telescope from the mirror (D)= 97 cms,

$S_0 = 10$

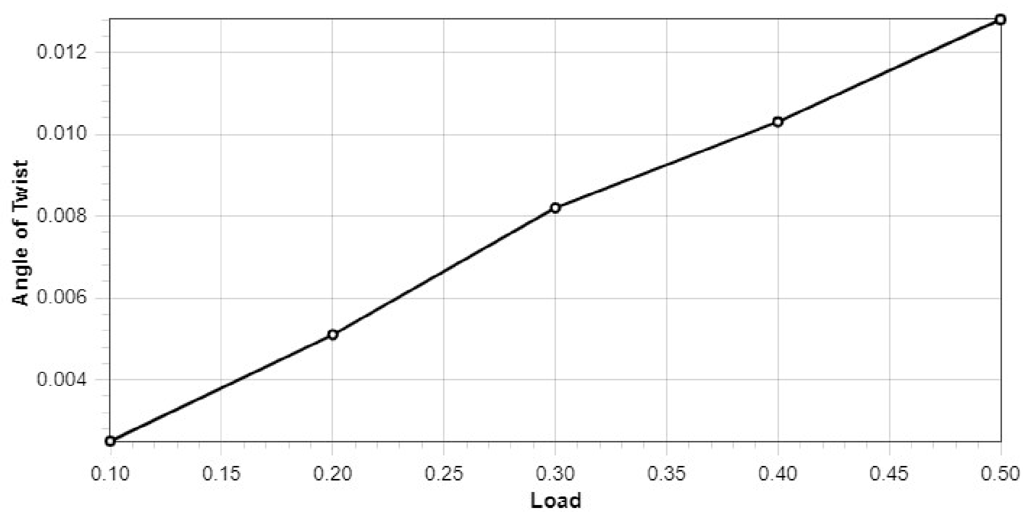
S. No	Load Kg	Arm Length l(cm)	Applied torque T (Kg .cm)	Scale reading in the telescope S_1	Different in reading $d=S_0-S_1$	$\phi = \frac{d}{2D}$ rad
1	0.1	39.5	3.95	10.5	-0.5	0.0025
2	0.2	39.5	7.9	11	-1	0.0051
3	0.3	39.5	11.85	11.6	-1.6	0.0082
4	0.4	39.5	15.8	15	-2	0.0103
5	0.5	39.5	19.75	12.5	-2.5	0.0128

GRAPH:

Load Vs Shear Strain



Load Vs Angle of Twist



RESULT:

Here, we calculated the shear strain due to the torque applied and the angle of the twist.

EXPERIMENT - 3

MEASUREMENT OF DISPLACEMENT USING LVDT

AIM:

To understand the operating principle of LVDT and to plot the output voltage of LVDT as a function of core displacement

APPARATUS:

- LVDT
- Signal Conditioning Unit
- Digital Multi-meters

THEORY:

A Linear Variable Differential Transformer, a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal. LVDT linear position sensors are readily available that can measure movements as small as a few millionths of an inch up to several inches, but are also capable of measuring positions up to ±20 inches (±0.5 m

Fig.1 shows the components of a typical LVDT. The transformer's internal structure consists of a primary winding centered between a pair of identically wound secondary windings, symmetrically spaced about the primary. The coils are wound on a one-piece hollow form of thermally stable glass reinforced polymer, encapsulated against moisture, wrapped in a high permeability magnetic shield, and then secured in cylindrical stainless steel housing. This coil assembly is usually the stationary element of the position sensor.

The moving element of an LVDT is a separate tubular armature of magnetically permeable material called the core, which is free to move axially within the coil's hollow bore, and mechanically coupled to the object whose position is being measured. This bore is typically large enough to provide substantial radial clearance between the core and bore, with no physical contact between it and the coil.

In operation, the LVDT's primary winding is energized by alternating current of appropriate amplitude and frequency, known as the primary excitation. The LVDT's electrical output signal is the differential AC voltage between the two secondary windings, which varies with the axial position of the core within the LVDT coil.

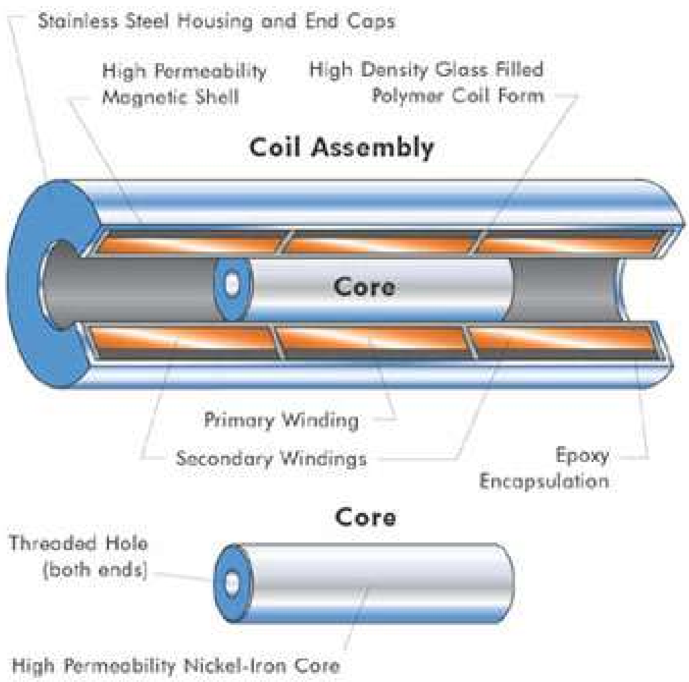


Fig 1 Components of LVDT

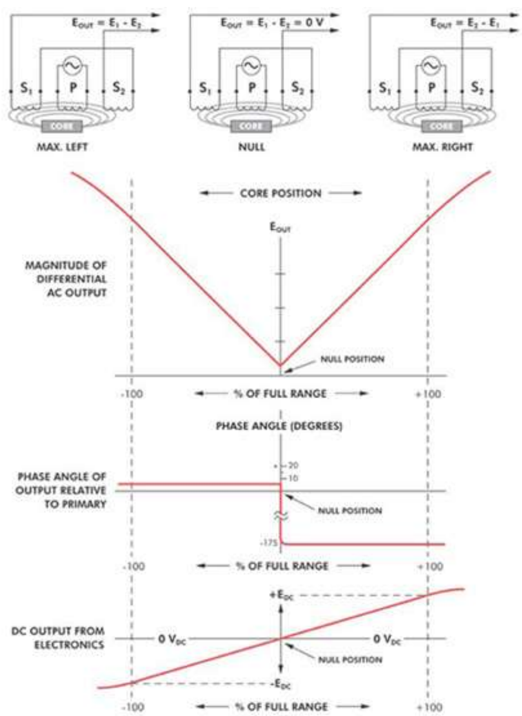


Fig.2 Response in different core Positions

Figure 2 illustrates what happens when the LVDT's core is in different axial positions. The LVDT's primary winding, P, is energized by a constant amplitude AC source. The magnetic flux thus developed is coupled by the core to the adjacent secondary windings, S1 and S2 . If the core is located midway between S1 and S2 , equal flux is coupled to each secondary so the voltages, E1 and E2 , induced in windings S1 and S2 respectively, are equal. At this reference midway core position, known as the null point, the differential voltage output, (E1 – E2), is essentially zero.

If the core is moved closer to S1 than to S2 , more flux is coupled to S1 and less to S2 , so the induced voltage E1 is increased while E2 is decreased, resulting in the differential voltage (E1 – E2). Conversely, if the core is moved closer to S2 , more flux is coupled to S2 and less to S1 , so E2 is increased as E1 is decreased, resulting in the differential voltage (E2 – E1).

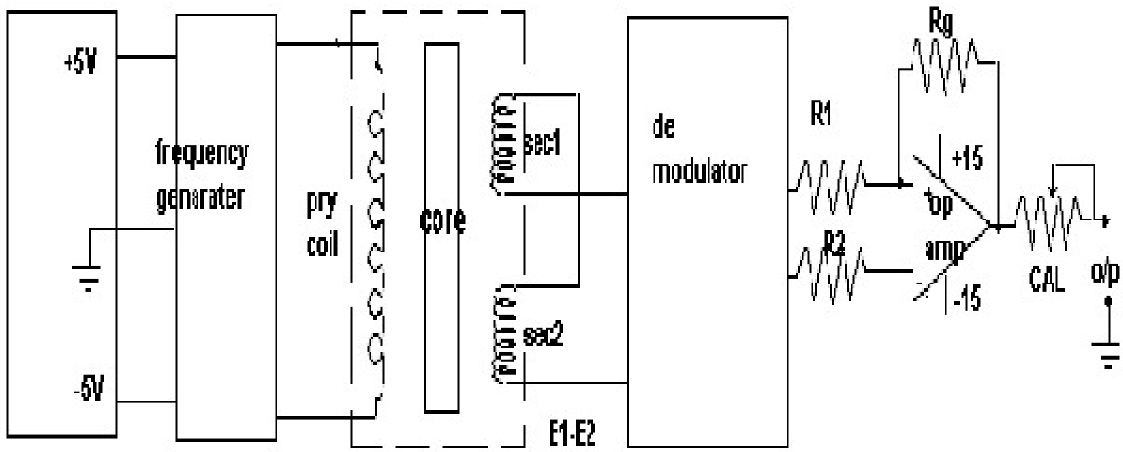
The top graph shows how the magnitude of the differential output voltage, EOUT, varies with core position. The value of E_{OUT} at maximum core displacement from null depends upon the amplitude of the primary excitation voltage and the sensitivity factor of the particular LVDT, but is typically several volts RMS. The phase angle of this AC output voltage, EOUT, referenced to the primary excitation voltage, stays constant until the center of the core passes the null point, where the phase angle changes abruptly by 180 degrees, as shown in the middle graph.

This 180 degree phase shift can be used to determine the direction of the core from the null point by means of appropriate circuitry. This is shown in the bottom graph, where the polarity of the output signal represents the core's positional relationship to the null point. The figure shows also that the output of an LVDT is very linear over its specified range of core motion, but that the sensor can be used over an extended range with some reduction in output linearity. The output characteristics of an LVDT vary with different positions of the core. Full range output is a large signal, typically a volt or more, and often requires no amplification. Note that an LVDT continues to operate beyond 100% of full range, but with degraded linearity.

PROCEDURE:

1. The LVDT is connected to supply and signal conditioning unit.
2. Zero position is adjusted by keeping the core in the middle of the LVDT
3. Move the core in one direction using screw gauge and take 10 readings of sc1 and sc2. Now rotate the screw in opposite direction and note another 10 readings and come back to the zero position. Now move it other direction and take the reading as explained above

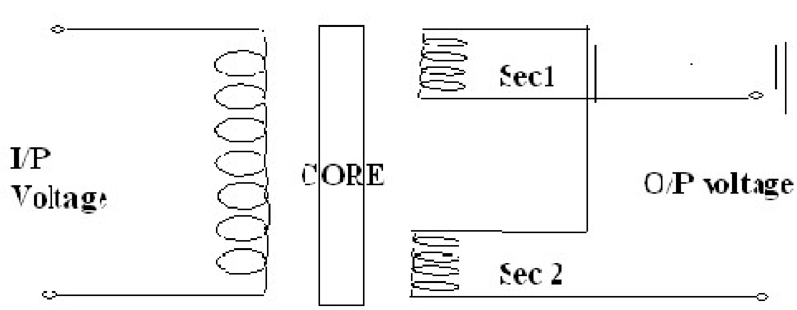
4. The o/p voltage is calculated using the formula Sc_2-Sc_1 voltage
5. A graph of displacement Vs o/p voltage should be plotted.



OBSERVATION:

OUTPUT OF LVTD

GENERAL DIAGRAM:



Anti-Clockwise:

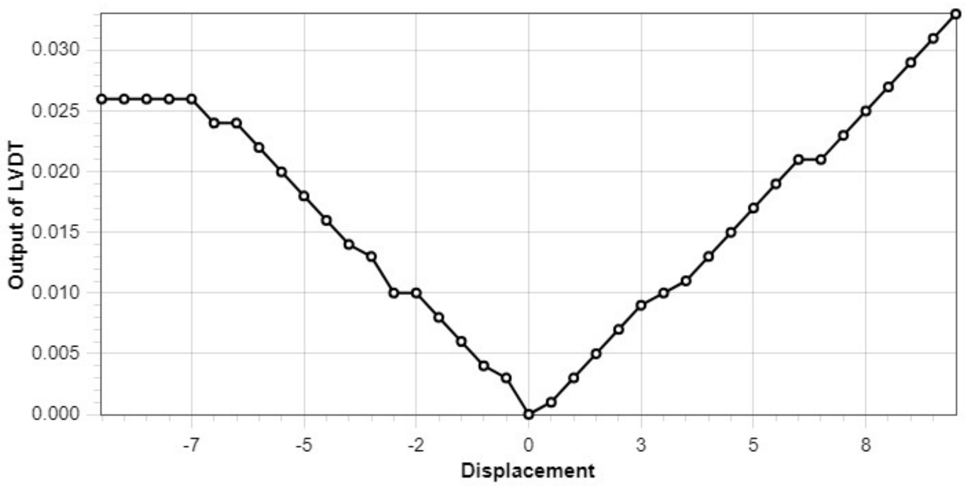
S.No	Displacement (mm)	Output if LVDT		
		SC_1	SC_2	SC_2-SC1
1	0	0.144	0.144	0
2	0.5	0.144	0.143	0.001
3	1	0.145	0.142	0.003
4	1.5	0.146	0.141	0.005
5	2	0.147	0.140	0.007
6	2.5	0.148	0.139	0.009
7	3	0.149	0.139	0.01
8	3.5	0.149	0.138	0.011
9	4	0.150	0.137	0.013
10	4.5	0.151	0.136	0.015
11	5	0.152	0.135	0.017
12	5.5	0.153	0.134	0.019
13	6	0.154	0.133	0.021
14	6.5	0.154	0.133	0.021
15	7	0.155	0.132	0.023
16	7.5	0.156	0.131	0.025
17	8	0.157	0.130	0.027
18	8.5	0.158	0.129	0.029
19	9	0.159	0.128	0.031
20	9.5	0.160	0.127	0.033

Clock wise

S.No	Displacement (mm)	Output if LVDT		
		SC_1	SC_2	SC_2SC_1
1	0	0.144	0.144	0
2	0.5	0.142	0.145	0.003
3	1	0.141	0.145	0.004
4	1.5	0.140	0.146	0.006
5	2	0.139	0.147	0.008
6	2.5	0.138	0.148	0.01
7	3	0.138	0.148	0.01
8	3.5	0.137	0.150	0.013
9	4	0.136	0.150	0.014
10	4.5	0.135	0.151	0.016
11	5	0.134	0.152	0.018
12	5.5	0.133	0.153	0.02
13	6	0.132	0.154	0.022
14	6.5	0.131	0.155	0.024
15	7	0.131	0.155	0.024
16	7.5	0.130	0.156	0.026
17	8	0.130	0.156	0.026
18	8.5	0.130	0.156	0.026
19	9	0.130	0.156	0.026
20	9.5	0.130	0.156	0.026

GRAPH:

Displacement Vs (SC_2SC_1)



RESULT :

From this experiment we got to know that operating principle of LVDT works its electromagnetic induction mechanism. Plotting LVDT output voltage against core displacement reveals a linear relationship.

EXPERIMENT 4

TEMPERATURE MEASUREMENT USING RTD

AIM:

To determine the characteristics of RTD

APPARATUS:

1. Heater
2. RTD
3. Digital Thermometer
4. Multi meter

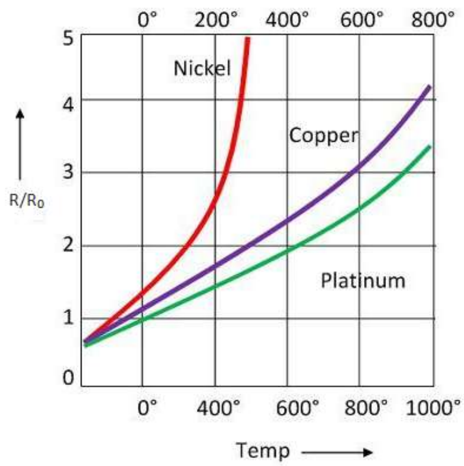
THEORY:

Temperature sensors known as Resistance Temperature Detectors (RTDs) use the electrical resistance principle to monitor temperature. The link between a metal's temperature and electrical resistance is the basis of the basic theory underlying RTDs. Platinum (Pt) wire is commonly used as the sensing element in RTDs because of its consistent and reliable temperature resistance properties. The electrical resistance of the platinum wire increases almost linearly with temperature, according to the positive temperature coefficient of resistance. Within a predetermined temperature range, this linear relationship enables precise and reliable temperature measurements.

By passing a known current through the platinum wire and measuring the voltage drop across it, one can use an RTD to determine temperature. The temperature can be computed using the established temperature resistance relationship by measuring the resistance of the wire using the known current and measured voltage. RTDs are appropriate for a variety of industrial and scientific applications where precise temperature management and measurement are essential due to their sensitivity and accuracy. The International Temperature Scale of 1990 (ITS90) is frequently the basis for the standardized temperature resistance curve for platinum RTDs, which guarantees uniformity and compatibility among various RTD devices and manufacturers.

PROCEDURE:

1. Keep the RTD in the ice bath and note the corresponding resistance
2. Check whether the power to heater is switched ON.
3. Check the set point [set it to 100°C].
4. Now insert the RTD into the heater.
5. Wait for the temperature of the heater to reach 40°c.
6. Now, note down the resistance value of the RTD at regular intervals of 5°C rise upto 100 °C
7. Plot the graph between temperature Vs RTD output

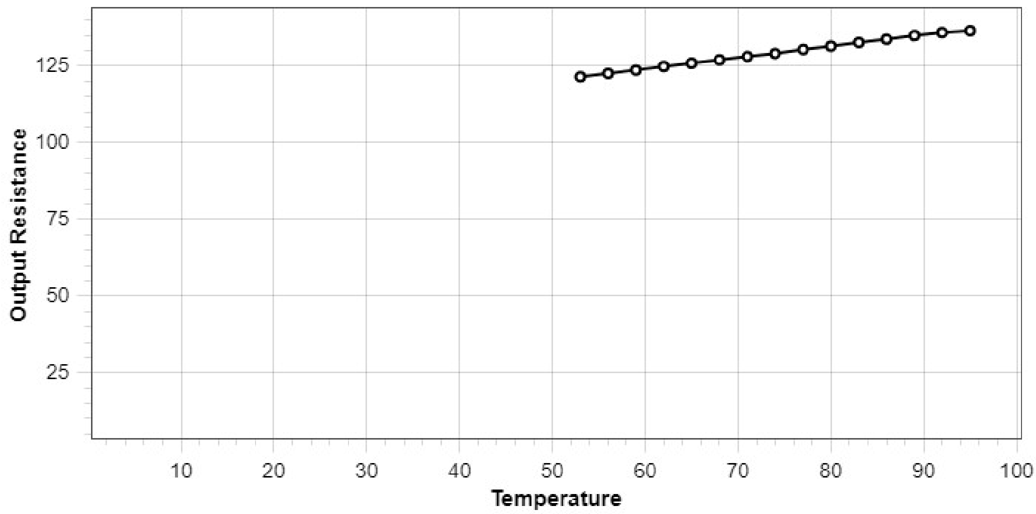


OBSERVATION:

S.No	Temperature (°C)	Output Resistance (Ω)
1	95	136.5
2	92	135.9
3	89	134.9
4	86	133.7
5	83	132.7
6	80	131.5
7	77	130.4
8	74	129.1
9	71	128.1
10	68	127
11	65	125.9
12	62	124.9
13	59	123.7
14	56	122.6
15	53	121.5

GRAPH:

Temperature Vs Output Resistance



RESULT:

Here, we plotted the characteristics of the RTD using above observations.