DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- IV

INSTRUMENTATION CONTROL
Subject code: LC-ME-220G

Prepared by:

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DEPARTMENT OF MECHANICAL ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

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Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and managers competent to match the expending expectations of the Corporate World has been ever enlarging vision extending to new horizons of Dronacharya College of Engineering.

Mission:

1. To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.

2. To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.

3. Educate students in the best practices of the field as well as integrate the latest research into the academics.

4. Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.

5. To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Mechanical Department

Vision:

"To become a Centre of Excellence in teaching and research in the field of Mechanical Engineering for producing skilled professionals having a zeal to serve society."

Mission:

M1: To create an environment where students can be equipped with strong fundamental concepts, various experiments and problem solving skills.

M2: To provide an exposure to emerging technologies by providing hands on experience for generating competent professionals.

M3: To promote Research and Development in the frontier areas of Mechanical Engineering and encourage students for pursuing higher education

M4: To inculcate in students ethics, professional values, team work and leadership skills.

Programme Educational Objectives (PEOs)

PEO 1: Engineers will practice the profession of engineering using a systems perspective and analyze, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

Over completion of the Course our graduates will have ability to

1. Apply knowledge of computing, mathematical foundations, algorithmic principles, and engineering theory in the modeling and design of systems to real-world problems (fundamental engineering analysis skills).
2. Apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.
3. Design and conduct experiments, as well as to analyze and interpret data (information retrieval skills). Practical application of engineering skills, combining theory and experience, and use of other relevant knowledge and skills.
4. Analyze a problem, identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution(engineering problem solving skills).
5. Understand the appropriate codes of practice and industry standards.
6. Identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques.
7. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.
8. Communicate effectively, both in writing and orally (speaking / writing skills).
9. Understand professional, ethical, legal, security and social issues and responsibilities (professional integrity).
10. Understand customer and user needs and the importance of considerations such as Aesthetics.
11. Use creativity to establish innovative solutions.
12. Adapt to a rapidly changing environment by having learned and applied new skills and new technologies.
13. To Significantly contribute to delivery of desired component, product, or process.
14. Formulate and solve moderately complex engineering problems, accounting for hardware/software/human interactions.
15. Recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in computing.
16. Apply the Knowledge of management techniques which may be used to achieve engineering Objectives within that context.

Program Specific Outcomes (PSOs)

On successful completion of the Mechanical Engineering Degree programme, the Graduates shall exhibit the following:

PSO1: Apply the knowledge gained in Mechanical Engineering for design and development and manufacture of engineering systems.

PSO2: Apply the knowledge acquired to investigate research-oriented problems in mechanical engineering with due consideration for environmental and social impacts

PSO3: Use the engineering analysis and data management tools for effective management of multidisciplinary projects.

University Syllabus

List of Experiments :

1. To Study various Temperature Measuring Instruments (a) Mercury – in glass thermometer (b) Thermocouple

2. To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a dead-weight pressure gauge calibration set up.

3. To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement.

4. To measure load (tensile/compressive) using load cell on a tutor.

5. To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer.

6. To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric).

7. To measure the stress & strain using strain gauges mounted on simply supported beam/cantilever beam.

8. To measure static/dynamic pressure of fluid in pipe/tube using pressure transducer/pressure cell.

9. To test experimental data for Normal Distribution using Chi Square test.

10. Vibration measurement.

11. To study various types of measurement Error

Course Outcomes (COs)

Upon successful completion of the course, the students will be able to:

C220.1: To understand about the applications of measurement systems

C220.2: To understand about the basics and working principle of pressure, temperature and flow measurement.

C220.3: Identify the different variation of measurement parameter with various input conditions.

C220.4: To analyze the primary, secondary and tertiary measurements.

C220.5: To learn about the various control devices and parts of measurement systems

CO-PO Mapping

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PO14	PO15	PO16
C220.1	3	3	3	-	2	-	3	3	3	2	-	3	3	-	-	3
C220.2	-	2	-	2	2	3	-	-		2	3	3	-	-	2	3
C220.3	3	-	3	3	2	3	-	-	3	-	3	-	3	3	-	
C220.4	3	-	3	-	3	-	3	3	-	2	-	3	3	3	2	3
C220.5	3	3	-	3	-	3	-	2	3	2	3	-	3	3	2	3

CO-PSO Mapping

	PSO1	PSO2	PSO3
C220.1	3	3	-
C220.2	2	3	-
C220.3	2	3	-
C220.4	3	2	3
C220.5	3	3	3

Course Overview

Instrumentation and Control is a multidisciplinary subject that focuses on the principles, techniques, and applications of measuring and controlling physical variables in various engineering systems. It plays a crucial role in fields such as chemical engineering, mechanical engineering, electrical engineering, and industrial automation. Throughout the course, students are typically exposed to hands-on laboratory work, simulation exercises, and case studies to reinforce theoretical concepts and develop practical skills in instrumentation and control. The course aims to equip students with the knowledge and skills required to design, analyze, and maintain instrumentation and control systems in various industrial settings.

LIST OF THE EXPERIMENT mapped with COs

Sr. NO.	NAME OF THE EXPERIMENT	COs
1.	To Study various Temperature Measuring Instruments and to Estimate their Response times. (a) Mercury – in glass thermometer (b) Thermocouple	C220.2
2.	To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration set up.	C220.2
3.	To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement.	C220.1
4.	To measure load (tensile /compressive) using load cell on a tutor.	C220.4
5.	To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer.	C220.5
6.	To measure the speed of a motor shaft with the help of non –contact type pick-ups (magnetic or photoelectric).	C220.3
7.	To measure the stress &strain using strain gauge mounted on cantilever beam.	C220.4
8.	To measure the static/dynamics pressure of fluid in pipe/tube using pressure transducer /pressure cell.	C220.3

DOs and DON'Ts

DOs

1. Work deliberately and carefully.
2. Keep your work area clean.
3. Students must wear college uniform and carry their college ID.
4. Students should have separate note book for practical.
5. Students should have their own pencil, eraser, scale, along with pen and lab note book.
6. Handle the equipment /models carefully.

DON'Ts

1. Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.
2. Do not eat food, drink beverages or chew gum in the laboratory.
3. Do not open any irrelevant internet sites on lab computer.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

Emergency: Reception

Security : Main Gate

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows:

1) All files must contain a title page followed by an index page. The files will not be signed by the faculty without an entry in the index page.

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab assessment criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes areassessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

GradingCriteria	**Exemplary (4)**	**Competent (3)**	**Needs Improvement (2)**	**Poor (1)**
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined conceptis written but procedure is incomplete	Not able to writeconcept and procedure	Underlined concept is not clearly understood
AC2: Manual Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed &correct solution designed	Assigned problem is properly analyzed and corrected
AC3: Identification & Removal of errors	Able to identify errors and remove them	Able to identify errors/and remove them with little bit of guidance	Is dependent totallyon someone for identification of errors and their removal	Unable to understand the reason for errors even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested,Solution is well demonstrated and implemented concept is clearlyexplained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained

AC5:Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % ofthe assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 40 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output

Experiment No: 1

Aim: To Study various Temperature Measuring Instruments and to Estimate their Response times.
(a) Mercury – in glass thermometer
(b) Thermocouple

Apparatus used: Mercury thermometer, Thermocouple setup, Platinum thermometer and Bi-metallicstrip.

Theory:

(a) Mercury – in glass thermometer:

A liquid-in-glass thermometer is widely used due to its accuracy for the temperature range -200 to 600°C. Compared to other thermometers, it is simple and no other equipment beyond the human eye is required. The LIG thermometer is one of the earliest thermometers. It has been used in medicine, metrology and industry. In the LIG thermometer the thermally sensitive element is a liquid contained in a graduated glass envelope. The principle used to measure temperature is that of the apparent thermal expansion of the liquid. It is the difference between the volumetric reversible thermal expansion of the liquid and its glass container that makes it possible to measure temperature.
The liquid-in-glass thermometer comprises of

1. A bulb, a reservoir in which the working liquid can expand or contract in volume
2. A stem, a glass tube containing a tiny capillary connected to the bulb and enlarged at the bottom into a bulb that is partially filled with a working liquid. The tube's bore is extremely small - less than 0.02 inch (0.5 millimetre) in diameter
3. A temperature scale is fixed or engraved on the stem supporting the capillary tube to indicate the range and the value of the temperature. It is the case for the precision thermometers whereas for the low accurate thermometers such as industrial thermometer, the scale is printed on a separate card and then protected from the environment. The liquid-in-glass thermometers is usually calibrated against a standard thermometer and at the melting point of water
4. A reference point, a calibration point, the most common being the ice point
5. A working liquid, usually mercury or alcohol
6. An inert gas is used for mercury intended to high temperature. The thermometer is filled with an inert gas such as argon or nitrogen above the mercury to reduce its volatilization.

The response of the thermometer depends on the bulb volume, bulb thickness, total weight and type of thermometer. The sensitivity depends on the reversible thermal expansion of the liquid compared to the glass. The greater the fluid expansion, the more sensitive the thermometer. Mercury was the liquid the most often used because of its good reaction time, repeatability, linear coefficient of expansion and large temperature range. But it is poisonous and so other working liquids are used.

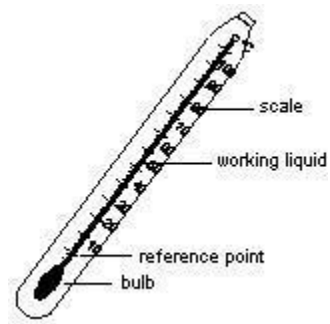

Fig: Liquid in Glass Thermometer

A **mercury-in-glass thermometer**, also known as a mercury thermometer, consisting of mercury in a glass tube. Calibrated marks on the tube allow the temperature to be read by the length of the mercury within the tube, which varies according to the heat given to it. To increase the sensitivity, there is usually a bulb of mercury at the end of the thermometer which contains most of the mercury; expansion and contraction of this volume of mercury is then amplified in the much narrower bore of the tube. The response time of the thermometer is nothing but as time constant or the time of consideration for measuring particular temperature.

(b) Thermocouple:

Thermocouple rely on the physical principle that, when any two different Metals are connected together, an e.m.f., which is a function of the temperature, is Generated at the junction between the metals. The construction of a thermocouple is quite simple. It consists of two wires of different metals twisted and brazed or welded together with each wire covered with insulation .Thermocouples are manufactured from various combinations of the base metals copper and iron, the base-metal alloys of alumel (Ni/Mn/Al/Si), chromel (Ni/Cr),constantan (Cu/Ni), nicrosil (Ni/Cr/Si) and nisil (Ni/Si/Mn), the noble metals platinum and tungsten, and the noble-metal alloys of platinum/rhodium and tungsten/rhenium. Only certain combinations of these are used as thermocouples and each standard combination is known by an internationally recognized type letter, for instance type K is chromel–alumel.

An electric current flows in a closed circuit of two dissimilar metals if their two junctions are at different temperatures. The thermoelectric voltage produced depends on the metals used and on the temperature relationship between the junctions. If the same temperature exists at the two junctions, the voltage produced at each junction cancel each other out and no current flows in the circuit. With different temperatures at each junction, different voltage is produced and current flows in the circuit. A thermocouple can therefore only measure temperature differences between the two junctions.

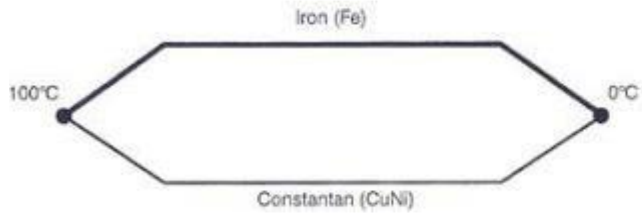

Fig: Thermocouple

Thermocouples response time is measured as a "time constant." The time constant is defined as the time required for a thermocouple‶s voltage to reach 63.2% of its final value in response to a sudden change in temperature. It takes five time constants for the voltage to approach 100% of the new temperature value. Thermocouples attached to a heavy mass will respond much slower than one that is left free standing

because its value is governed by the temperature of the large mass. A free standing (exposed or bare wire) thermocouple‶s response time is a function of the wire size (or mass of the thermocouple bead) and the conducting medium. A thermocouple of a given size will react much faster if the conducting medium is water compared to still air.

Conclusion: Hence the study of various temperature measuring instruments and their response times is completed.

Experiment -2

Aim: To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in adeadweight pressure gauge calibration set up.

Apparatus used: Deadweight Pressure Gauge calibration set up

Theory: These are used for measurement of pressure and vacuum and are suitable for all clean and non-clogging liquid and gaseous media. Bourdon gauge consists of a hollow metal tube with an oval cross section, bent in the shape of a hook. One end of the tube is closed, the other open and connected to the measurement region. If pressure (above local atmospheric pressure) is applied, the oval cross section willbecome circular, and at the same time the tube will straighten out slightly. The resulting motion of the closed end, proportional to the pressure, can then be measured via a pointer or needle connected to the end through a suitable linkage.

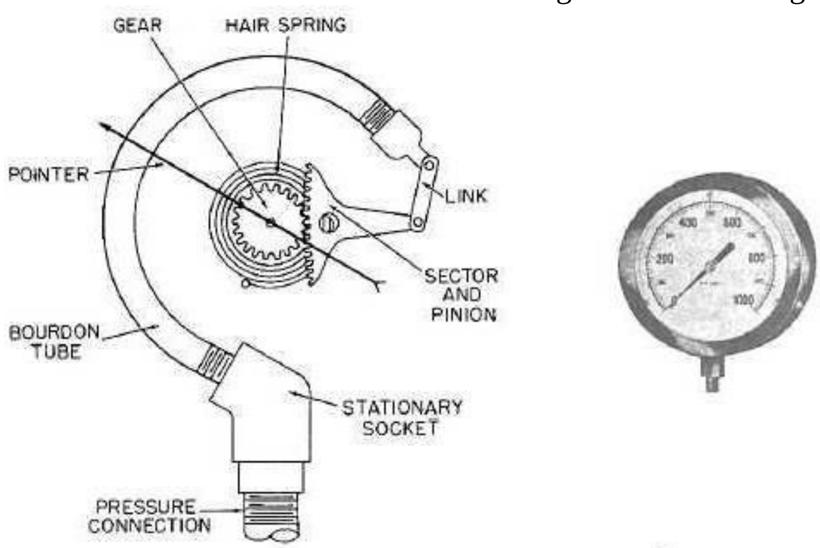

Fig: Bourdan Tube Gauge

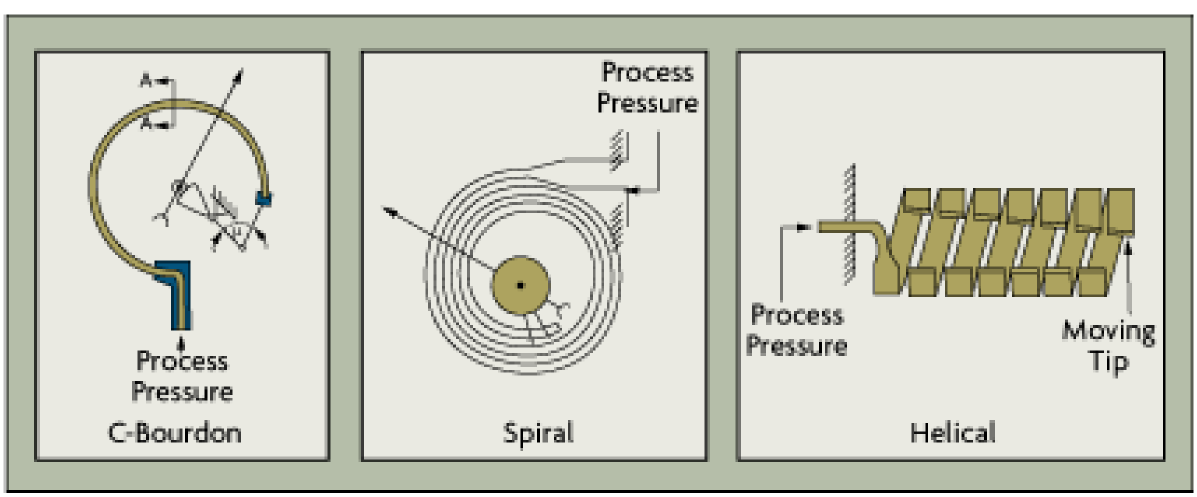

Fig: Bourdon Tube Designs

Working of the Bourdon Pressure Gauge: In order to understand the working of the bourdon pressure gauge, we need to consider a cross-section of the Bourdon tube, as shown in the figure.

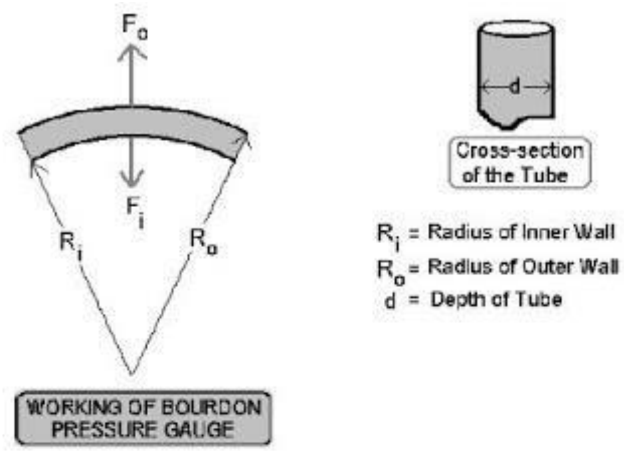

Fig: Working of Bourdon Gauge

Assume that a pressure P, which is greater than the atmospheric pressure, acts on at the pressure inlet ofthe gauge. According to the Pascal"s Law, the pressure is transmitted equally in all directions. Therefore, Pressure acting on the Inner Wall = Pressure acting on the Outer Wall.
Now,
Area of Outer Wall projected to the pressure = $2\pi R_o d$

Therefore,
Force on Outer wall = F_o = Pressure x Area = $2P\pi R_o d$

Similarly,
Force on Inner Wall = $F_i = 2P\pi R_i d$

Since, Ro>Ri then, Fo>Fi.
So, the force that tries to unwind the tube is greater than the force that tries to bend it further. Therefore, the tube unwinds due to the extra pressure exerted on it. This unwinding is then recorded on a scale by using a series of gears and a pointer.

Calibration is the name of the term applied to checking the accuracy or the working condition of the concerned device. So, the calibration of Bourdon Pressure Gauge refers to the checking of its accuracy or reliability in taking a reading. The apparatus used for this purpose is called the Dead-Weight Gauge Tester.

Working of the Dead-Weight Gauge Tester: The working of this gauge tester can be understood easily with the help of the following diagram.

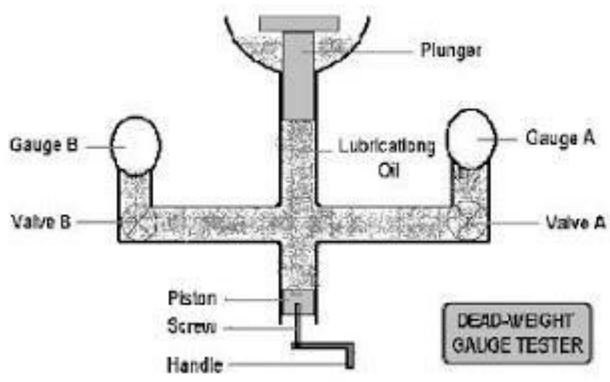

Fig: Dead-Weight Gauge Tester

In this figure gauge A and B are the ones to be calculated. We can at any stage disengage any gauge byclosing the respective valve.
For the illustration purpose, we will just consider the calibration of Gauge A and assume that valve Bremains closed.

Let
Weight of Plunger = W
Cross-sectional Area of the stem of Plunger = A

Therefore,
Pressure exerted on the fluid = P = W/A

Now, according to Pascal‟s Law, pressure is transmitted equally in all direction. Therefore pressure encountered at the inlet of Gauge A is the same as P

Now,
if Pressure registered by Gauge A = P_A = P
within experimental limits, then the gauge is working properly. If not, then there is some problem whichmust be detected and accounted for.

Procedure:

1. Fix the gauge to be tested on one end of the Dead-Weight Gauge tester and make sure that the valve is fully opened. Meanwhile close the other valve tightly so that no leakage of fluid is ensured.
2. Next, gently place the plunger in the tester ensuring that the plunger should not touch the edges of the bowl. Allow some time for the system to attain equilibrium, than take the reading from the gauge. Record both the applied and registered pressure in a table of values. Now, remove the plunger and once again after some time record the reading on the gauge. Record it in the table.
3. Now place some weights on the plunger so that the applied pressure is varied. Then, repeat the above mentioned procedure until there are at least six readings. Record them all in the table.

Conclusion: Hence the working of Bourdon Pressure Gauge and checking of calibration on a deadweightpressure gauge is completed.

Experiment No: 3

Aim: To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental setup to measure a small displacement.

Apparatus used: LVDT setup

Theory: The letters LVDT are an acronym for Linear Variable Differential Transformer, a common typeof electromechanical transducer that can convert the rectilinear motion of an object to which it is coupledmechanically 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). The transformer's internal structure consists ofa 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 ofthe position sensor. The moving element of an LVDT is a separate tubular armature of magnet i cal l
y 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 enoughto provide substantial radial clearance between the core and bore, with no physical contact between it andthe coil.

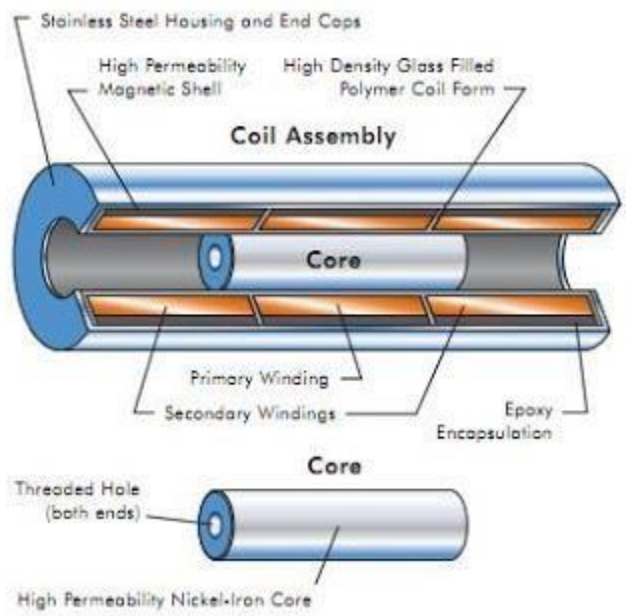

Fig: LVDT

The device consists of a primary coil, two secondary coils, and a moveable magnetic core which is connected to an external device whose position is of interest. A sinusoidal excitation is applied to the primary coil, which couples with the secondary coils through the magnetic core (ie. voltages are induced in the secondary coils). The position of the magnetic core determines the strength of coupling between the primary and each of the secondary cores, and the difference between the voltages generated across each of the secondary cores is proportional to the displacement of the core from the neutral position, or null point.

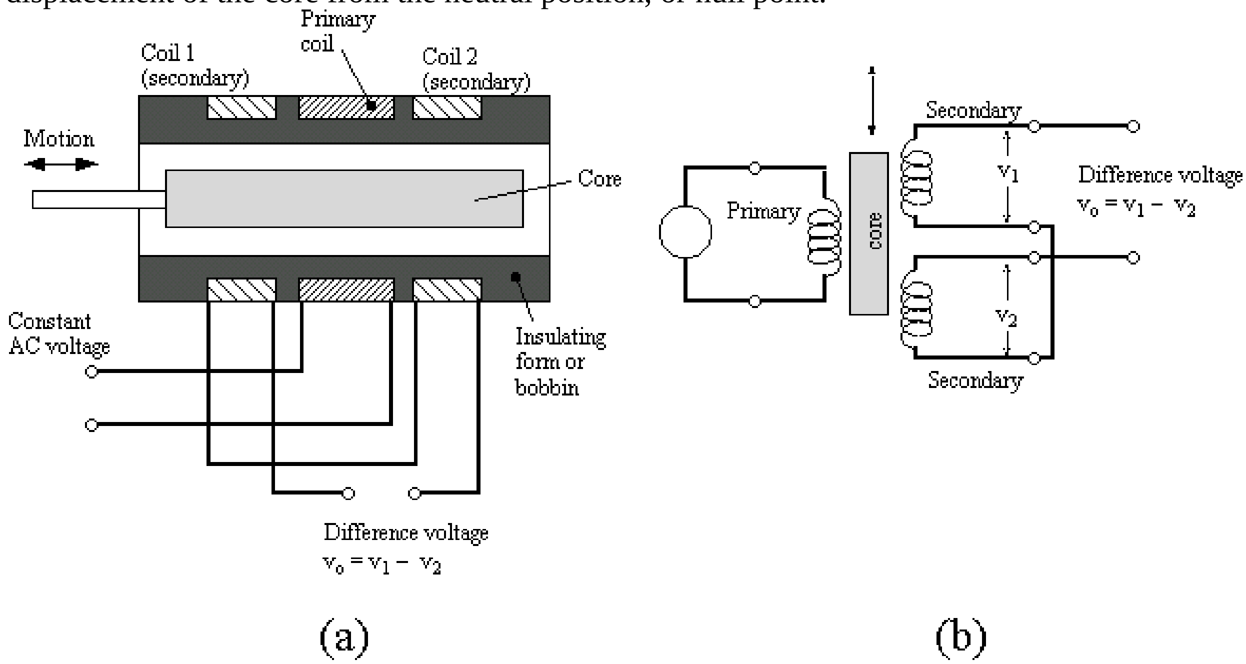

Fig: LVDT Principle

Merits: -

1. It has been infinite resolution.
2. No sliding parts, so some reliable device.
3. Output impedance of LVDT remains constant.
4. It has low hysterias & a good repeatability.
5. It consumes very less power.
6. Good frequency response.
7. It has almost linear characteristic.
8. It can tolerate shock & vibration.

Demerits: -

1. Sensitive to stay magnetic field.
2. Relatively large displacement required.
3. Sometimes, the transducer performance is affective by the vibration.

Application: -

LVDT are suitable for use in applications where the displacements are too large for strain gauge to handle. There are often employed together other transducers for measurement of force, weight pressure etc.

Procedure:

1. Arrange all the instruments respectively.
2. Set micrometer at predefined place.
3. With the help of span knob adjust the zero reading
4. Rotate the micrometer knob and note the micrometer displacement.
5. Measure the value of voltage from Digital Voltmeter.
6. Repeat the procedure.
7. Plot the graph (Displacement vs Voltage)
8. Make an unknown displacement and find corresponding voltage.
9. Find the unknown displacement from the graph for voltage.

Observations & Calculations:

S. No	Displacement (mm)	Voltage		
		Vi	Vf	$V=V_f-V_i$
1				
2				
3				
4				
5				
6	Unknown			

Graph:

Precautions:

1. All connections should be neat and clean.
2. Micrometer should be maintained properly.
3. Voltmeter should show reading accurately.

Conclusion: Graph between voltage and displacement is plotted. Hence, from graph, the measurement ofa unknown displacement using LVDT is_.

Experiment No: 4

Aim: To measure (tensile/compressive)using load cell on a tutor.

Apparatus used: Load cell on a tutor.

Theory: A Load Cell is defined as a transducer that converts an input mechanical force into an electricaloutput signal. Load Cells are also commonly known as Load Transducers or Load Sensors.

Load cell designs can be distinguished according to the type of output signal generated (pneumatic,hydraulic, electric) or according to the way they detect weight (bending, shear, compression, tension, etc.)

1. **Diaphragm gauges**: Diaphragm gauges is a thin plate of circular shape clamped firmly around its edges. The diaphragm gets deflected in accordance with the pressure differential across the sides, deflection being towards the law pressure side. The deflection can be sensed by an appropriate displacement transducer i.e. it may be converted into electrical signal or may undergo in mechanical amplification to permit display of the O/P of an indicator dial.

These are two basic types of diaphragms element design.

a. Metallic diaphragm which depends upon its own resilience for its operation.
b. Non-metallic or stuck diaphragm which employs a soft-flexible material with no elastic characteristics. The movements of the diaphragm are opposed by a spring which determines the deflection for given pressure.

The general requirement of the diaphragm are :

1. Dimensions and total load must be comparable with physical properties of intermediate used.
2. Flexibility must be such as to provides the sensitivity required by secondary transducer.
3. Volume of displacement should be minimize to provide the reasonable dynamic response.
4. Natural frequency of diaphragm should be sufficiently high to provide satisfactory frequency response.
5. The O / P should be linear.
6. The diaphragm to response linearly its maximum deflection „y" should be less than 1/3 of its thickness.

The deflection for diaphragm is given by

$$y = \frac{3}{16} \frac{P(1-\nu^2)}{Et^2}\left(R^2 - r^2\right)^2$$

Where P = Pressure

 = Poisson‟s ratio
E = Modules of elasticity of diaphragm.
R = radius of diaphragm
r = radius at point of interest

The natural frequency of diaphragm should be high enough for good dynamic response.

Advantages of Diaphragm :

Relatively small size and moderate cost.

1. Capability to withstand high over pressure and maintain good linearity over a wide range.
2. Availability of gauges for absolute and differential pressure.
3. Minimum of hysteretic k no permanent zero shift.

Disadvantages of diaphragm pressure cell:

1. Need protection from shock and vibration.
2. Cannot be used to measure high pressure & is difficult to repair.

Application of diaphragm pressure cell:

Typical applications are low pressure- absolute pressure gauges and many types of recorders and controllers operating in low range of direct or diff. pressure.

2. **Hydraulic load cells** are force -balance devices, measuring weight as a change in pressure of the internal filling fluid. In a rolling diaphragm type hydraulic load cell, a load or force acting on a loading head is transferred to a piston that in turn compresses a filling fluid confined within an elastomeric diaphragm chamber. As force increases, the pressure of the hydraulic fluid rises. This pressure can be locally indicated or transmitted for remote indication or control. Output is linear and relatively unaffected by the amount of the filling fluid or by its temperature. If the load cells have been properly installed and calibrated, accuracy can be within 0.25% full scale or better, acceptable for most process weighing applications. Because this sensor has no electric components, it is ideal for use in hazardous areas. Typical hydraulic load cell applications include tank, bin, and hopper weighing. For maximum accuracy, the weight of the tank should be obtained by locating one load cell at each point of support and summing their outputs.

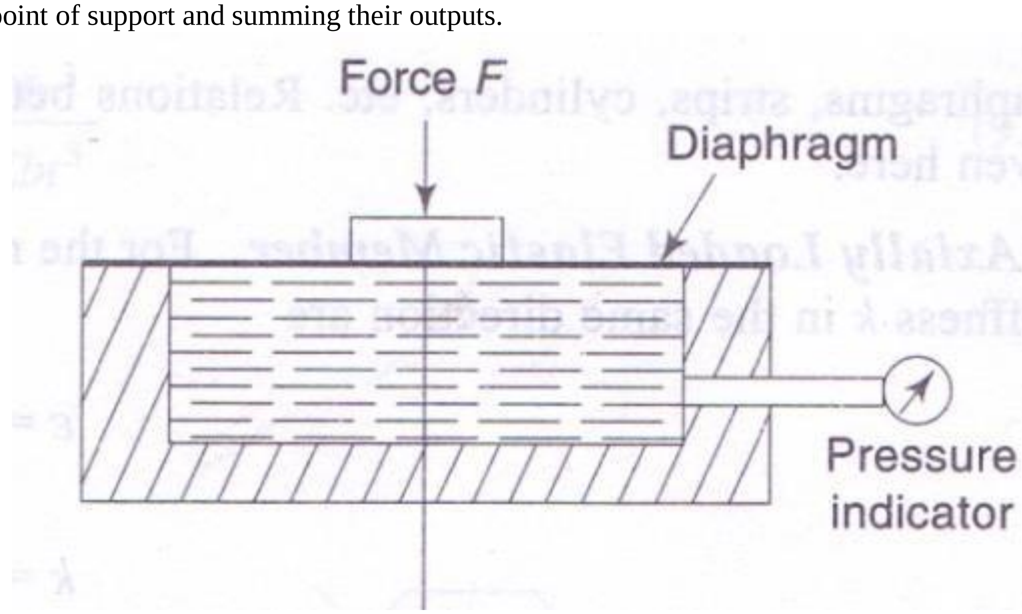

Fig: Hydraulic Load Cell

3. **Pneumatic load cells** also operate on the force-balance principle. These devices use multiple dampener chambers to provide higher accuracy than can a hydraulic device. In some designs, the first dampener chamber is used as a tare weight chamber. Pneumatic load cells are often used to measure relatively small weights in industries where cleanliness and safety are of prime concern. The advantages of this type of load cell include their being inherently explosion proof and insensitive to temperature variations. Additionally, they contain no fluids that might contaminate the process if the diaphragm ruptures. Disadvantages include relatively slow speed of response and the need for clean, dry, regulated air or nitrogen.

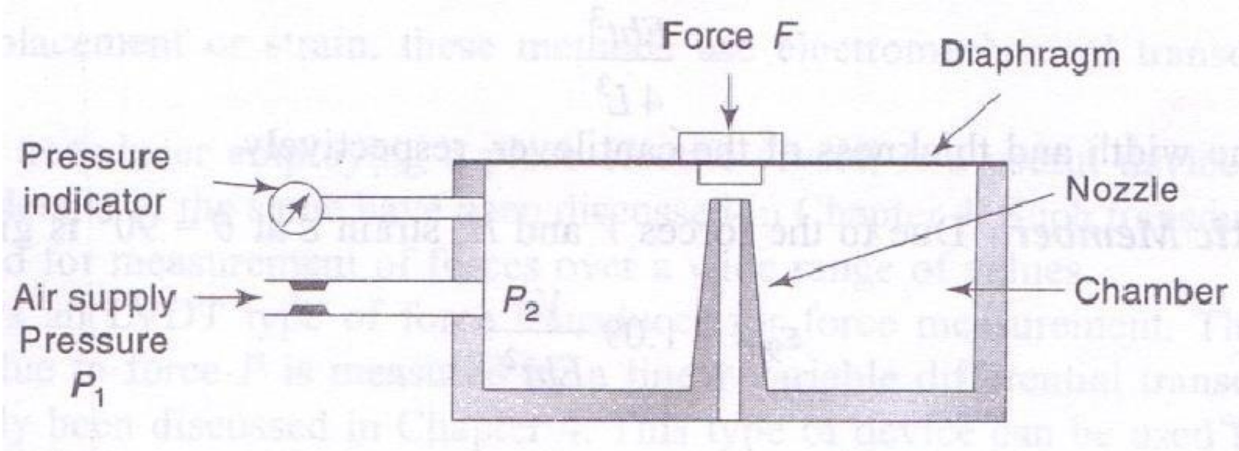

Fig. Pneumatic Load Cell

4. **Elastic type devices**

a. <u>**Mechanical Method**</u>

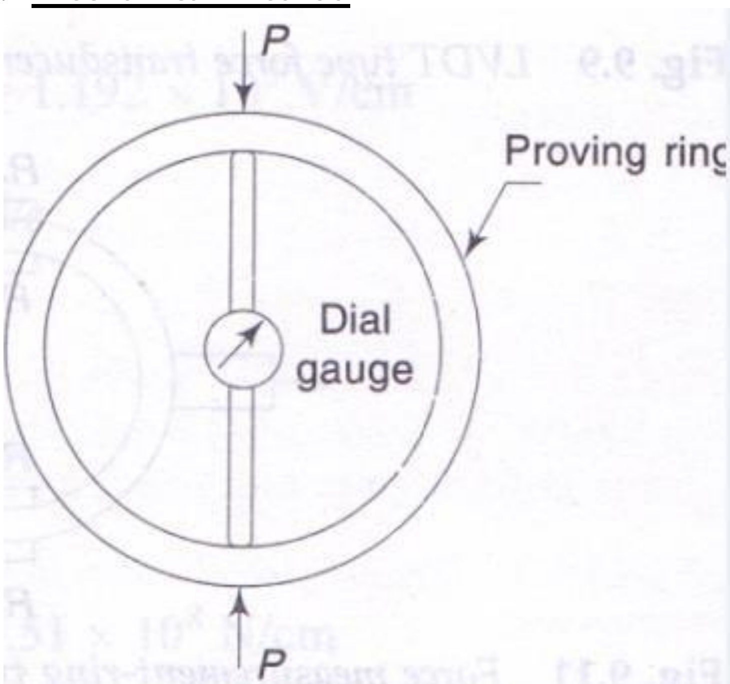

Fig: Proving Ring

b. Electromechanical Methods:

i. LVDT type force transducer
ii. Strain Gauge type force transducer
   1. Cantilever type load cell
   2. Ring type load cell
   3. Cylindrical type load cell

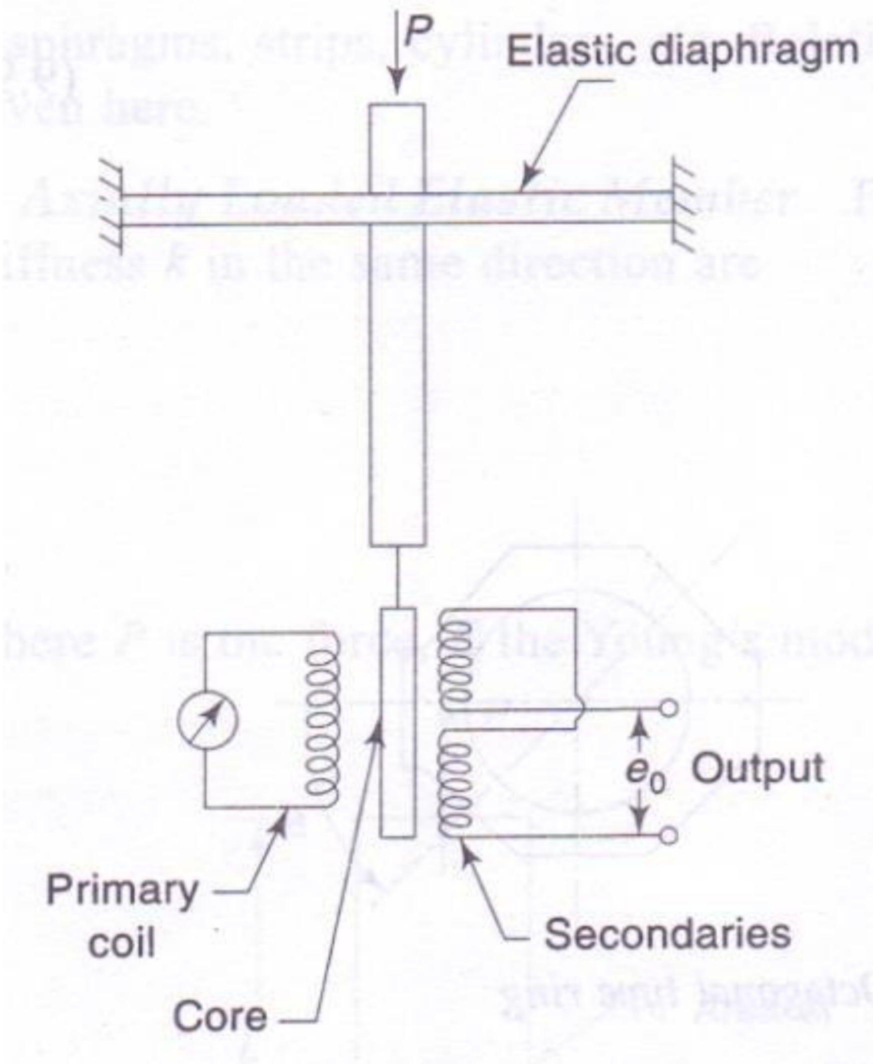

Fig. LVDT type Force Transducer

5. **Strain-gauge load cells** convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gages are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are fading into obscurity, as strain gage load cells continue to increase their accuracy and lower their unit costs.

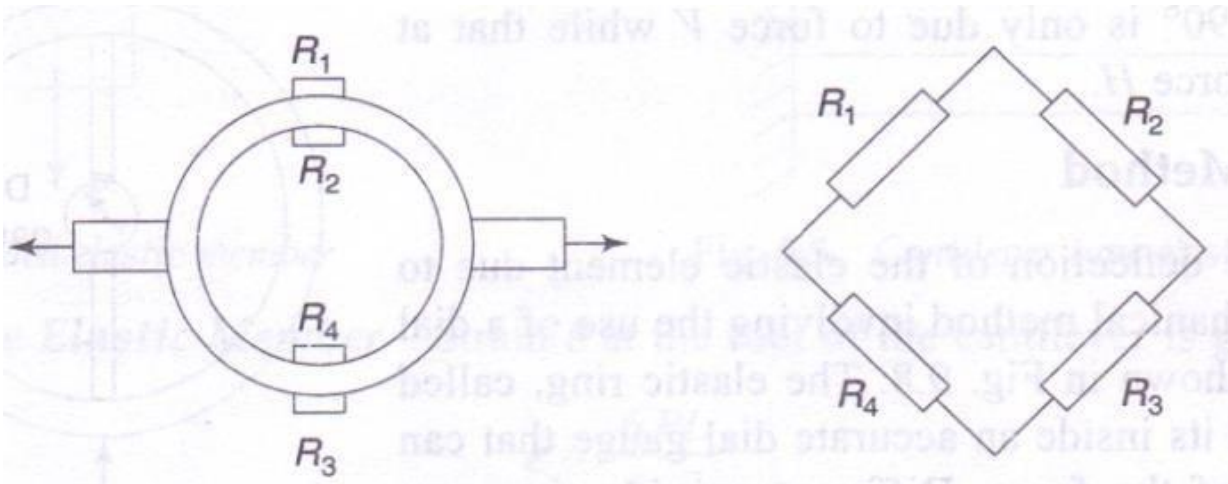

Fig. Ring type Load cell

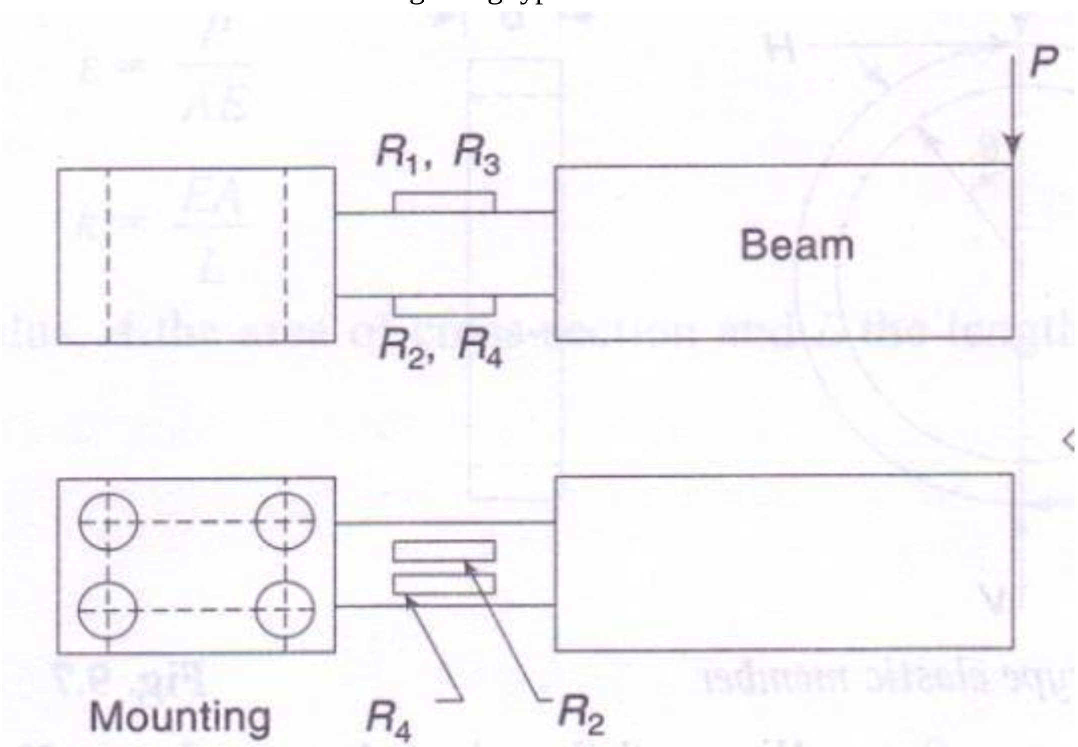

Fig. Cantilever type Load cell

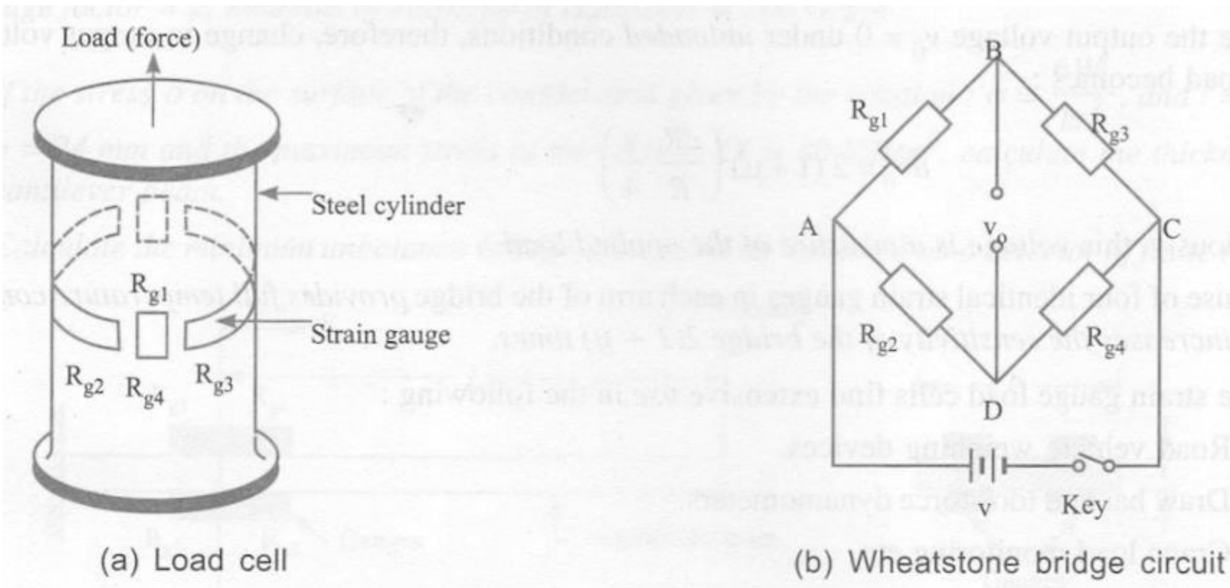

Fig. Strain Gauge Load Cell

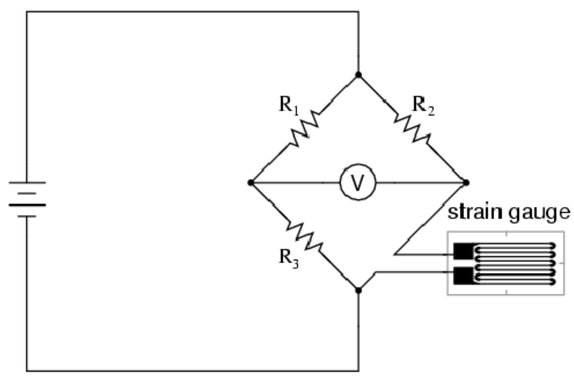

Fig. Quarter-bridge strain gauge circuit

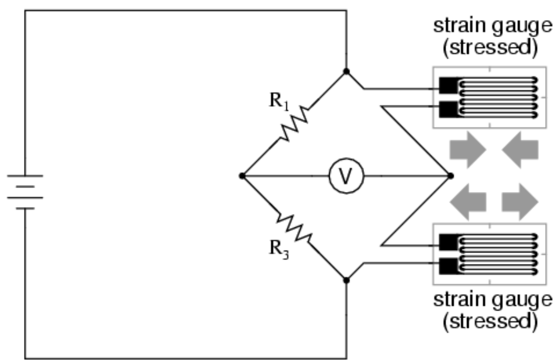

Fig. Half-bridge strain gauge circuit

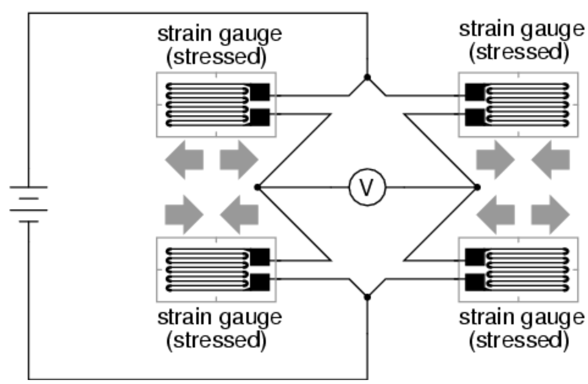

Fig. Full-bridge strain gauge circuit

Both half-bridge and full-bridge configurations grant greater sensitivity over the quarter-bridge circuit, but often it is not possible to bond complementary pairs of strain gauges to the test specimen. Thus, the quarter-bridge circuit is frequently used in strain measurement systems.

Changed voltage obtained can be used for measuring the applied load, where change in voltage is givenby

$$dV_0 = 2(1+\nu)\left(\frac{dR}{R}\right)\left(\frac{V}{4}\right)$$

where V is applied source and dV_0 is changed output voltage.R = resistance of gauges = $R_{g1} = R_{g2} = R_{g3} = R_{g4}$

Uses:

Strain Gauge Load cells can be used in

1. Road Vehicle weighing devices
2. Draw bar and tool-force dynamometers
3. Crane load monitoring, etc.

Procedure:

1. Make setup of load cell and tutor.
2. Place weight on the load cell.
3. Note down the reading given by tutor separately for compression and tension.
4. Take 8-10 readings by increasing weight.
5. Compare actual weight & weight given by tutor.

Conclusion:

1. Actual tensile & compression loads are________&__________.
2. Tutor tensile & compression loads are________&__________.

Experiment No: 5

Aim: To measure torque of a rotating shaft using torsion meter/strain gauge torque transducer.

Apparatus used: Torsion meter/strain gauge torque transducer.

Theory:

Torque is the tendency of a force to rotate an object about an axis, fulcrum, or pivot. (or) Torque isdefined as a force around a given point, applied at a radius from that point.
An engine produces power by providing a rotating shaft which can exert a given amount of torque on aload at a given rpm. The amount of torque the engine can exert usually varies with rpm.

Facts about calculations:

1. Power (the rate of doing work) is dependent on **torque** and rpm.
2. **Torque** and rpm are the measured quantities of engine output.
3. Power is calculated from **torque** and rpm, by the following equation: P = **Torque** x RPM

The power transmitted can be calculated from the torque, using the equation

$$P = \omega T$$

where,

P is the power (in watts), **T** is torque (N m), and **ω** is angular speed (rad / s).

The deflection measuring system is called torsion meter. An instrument for determining the torque on a shaft, and hence the horse power of an engine by measuring the amount of twist of a given length of the shaft. When a shaft is connected between a driving engine and driven load, a twist (angular displacement) occurs on the shaft between its ends. This angle of twist is measured and calibrated in terms of torque.

Devices used for power measurement are also known as dynamometers and may be classified into three types, depending on the nature of machine arrangement, for which torque or power is to be measured. Thethree types are: -

1. Transmission type dynamometers, in which the power being transmitted through the device is measured. The device is neither a power generator nor a power absorber and is used on the shaft transmitting power, between the prime mover and the load.
2. Driving type dynamometer, in which drive is obtained from the dynamometer itself or the dynamometer is the power generator like an electric motor.
3. Absorption type dynamometer, in which mechanical energy is absorbed after it is measured. The power generator may be an engine or a motor.

Construction of mechanical torsion meter: The main parts of the mechanical torsion meter are as follows: A shaft which has two drums and two flanges mounted on its ends as shown in the diagram. One drum carries a pointer and other drum has a torque calibrated scale. A stroboscope is used to take readingson a rotating shaft.

Operation of mechanical torsion meter: One end of the shaft of the torsion meter is connected to the driving engine and its other end to the driven load. An angle of twist is experienced by the shaft along its

length between the two flanges which is proportional to the torque applied to the shaft. A measure of this angle of twist becomes a measure of torque when calibrated. The angular twist caused is observed on the torque calibrated scale corresponding to the position of the pointer. As the scale on the drum is rotating, reading cannot be taken directly. Hence a stroboscope is used. The stroboscope‟s flashing light is made to fall on the scale and the flashing frequency is adjusted till a stationary image is obtained. Then the scale reading is noted.

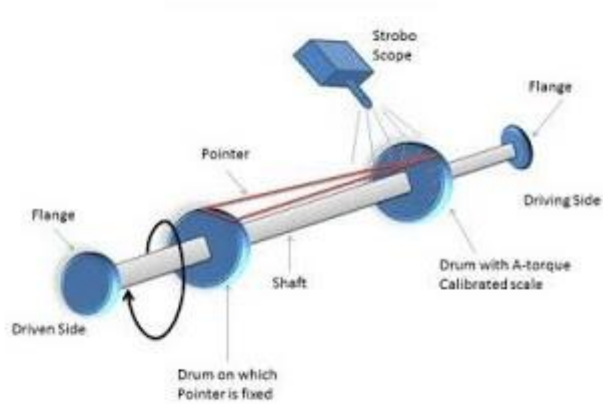

Fig. Mechanical Torsion Meter

The strain monitoring system is called torque meter (or) strain gauge torque transducer.
A Torque sensor is a transducer that converts a torsional mechanical input into an electrical output signal. Torque Sensor, are also commonly known as a Torque Transducer.
Torque is measured by either sensing the actual shaft deflection caused by a twisting force, or by detecting the effects of this deflection. The surface of a shaft under torque will experience compression and tension, as shown in figure below.

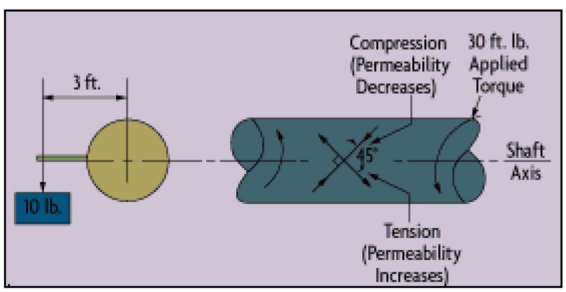

Fig: Strain Gauge Torque Transducer

To measure torque, strain gage elements usually are mounted in pairs on the shaft, one gauge measuring the increase in length (in the direction in which the surface is under tension), the other measuring the decrease in length in the other direction.
A strain gage can be installed directly on a shaft. Because the shaft is rotating, the torque sensor

can be connected to its power source and signal conditioning electronics via a slip ring. The strain gage also can be connected via a transformer, eliminating the need for high maintenance slip rings. The excitation voltage for the strain gage is inductively coupled, and the strain gage output is converted to a modulated pulse frequency as shown in figure. Maximum speed of such an arrangement is 15,000 rpm.

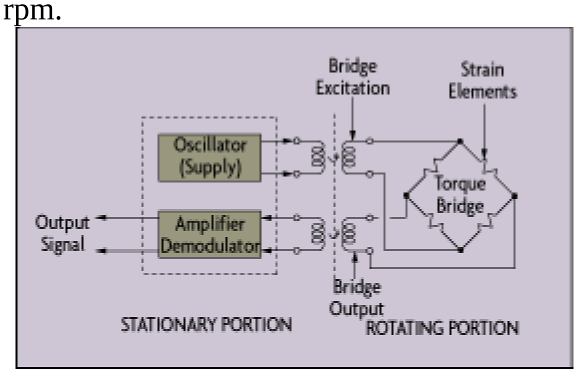

Fig: Strain Gauge Working

Procedure:

1. Arrange all the instruments respectively.
2. With the help of Set knob adjust the zero reading.
3. Set the range with the help of Span knob.
4. Place the weight in the pan.
5. Measure the value of voltage from Digital Voltmeter.
6. Repeat the procedure.
7. Compare actual and displaced values.
8. Plot the graph (Voltage vs Torque).
9. Place unknown mass and measure the voltage.
10. Obtain the value of torque from the graph for the obtained voltage.

Observations & Calculations:

S. No	Mass (gms)	Torque generated (kg-cm f or N-m)	Voltage		
			V_i	V_f	$V=V_i-V_f$
1					
2					
3					
4					
5					
6	Unknown	Unknown			

Conclusion: Hence the torque obtained for the unknown weight is___N-m.

Experiment No: 6

Aim: To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric).

Apparatus used: Optical pick up

Theory:

Magnetic pickup tachometer: A coil wounded on permanent magnet, not on iron core, enable us to measure rotational speed of the systems. In the construction of variable reluctance sensor, we use ferromagnetic gearwheel. As the gearwheel rotates, change in magnetic flux take place in the pickup coil which further induces voltage. This change in magnitude is proportional to the voltage induced in the sensor.

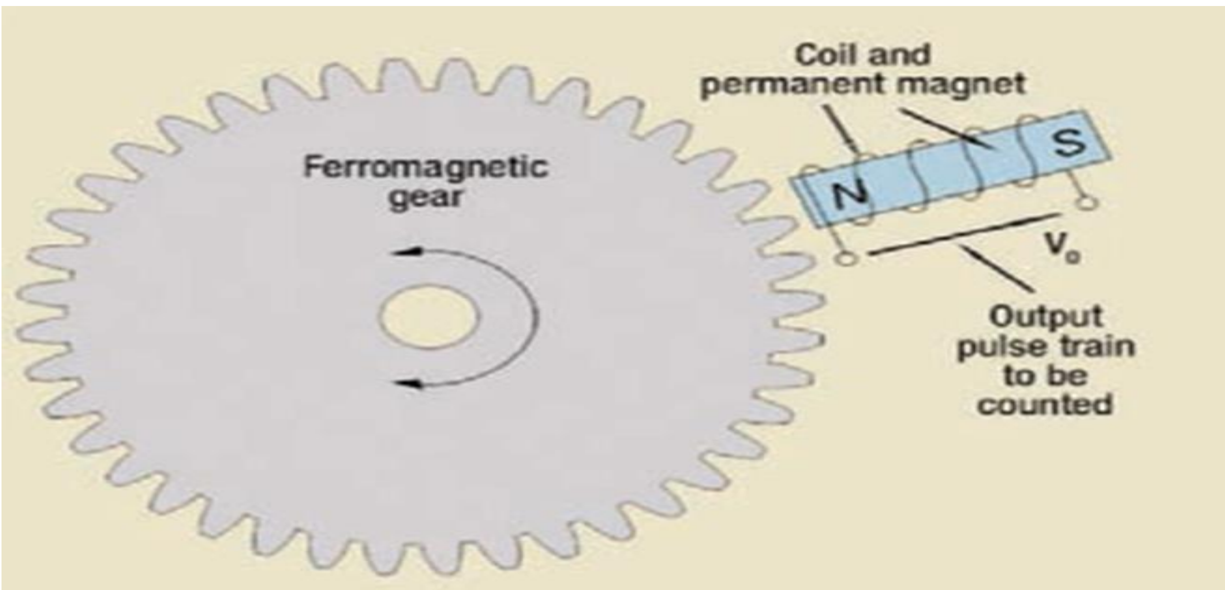

Fig. Magnetic pickup

$$\text{Number of pulses per second} = \frac{\text{reading of digital meter}}{\text{gating period}}$$

$$\text{Speed} = \frac{\text{number of pulses per second}}{\text{number of teeth}}$$

Photo-electric tachometer: It consists of a opaque disc mounted on the shaft whose speed is to be measured. The disc has a number of equivalent holes around the periphery. On one side of the disc, there is a source of light (L) while on the other side there is a light sensor (may be a photosensitive device or photo-tube) in line with it (light-source).

On the rotation of the disc, holes and opaque portions of the disc come alternately in between the light source and the light sensor. When a hole comes in between the two, light passes through the holes and falls on the light sensor, with the result that an output pulse is generated. But when the opaque portion of the disc comes in between, the light from the source is blocked and hence there is no pulse output.

Thus whenever a hole comes in line with the light source and sensor, a pulse is generated. These pulses are counted/ measured through an electronic counter.

The number of pulses generated depends upon the following factors:

i. The number of holes in the disc;
ii. The shaft speed.

Since the number of holes is fixed, therefore, the number of pulses generated depends on the speed of the shaft only. The electronic counter may therefore be calibrated in terms of speed (r.p.m.)

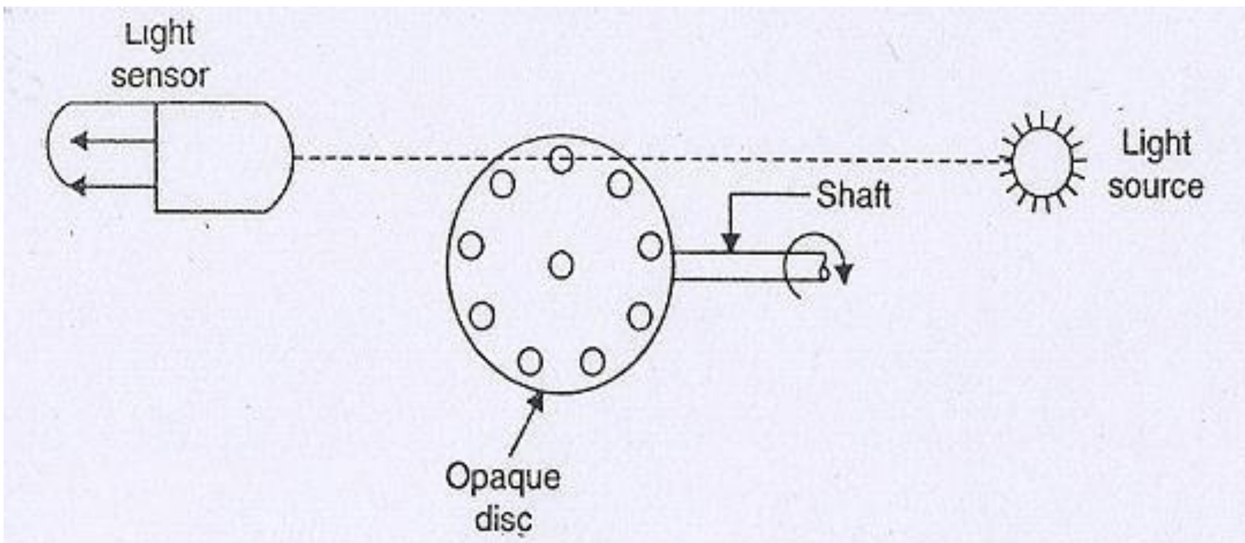

Fig. Photo-electric tachometer

Stroboscope: The instrument operates on the principle that if a repeating event is only viewed when at one particular point in its cycle it appears to be stationary. A mark is made on rotating shaft, and a flashing light is subjected on the shaft. The frequency of the flashing is one very short flash per revolution.

To determine the shaft speed we increases the frequency of flashing gradually from small value until the rotating shaft appears to be stationary, then note the frequency. The frequency then doubled, if there is still one apparent stationary image, the frequency is again doubled. This continued until two images appear 180 degrees apart. When first appear for these two images the flash frequency is twice the speed of rotation.

Stroboscopes are used to measure angular speed between 600 to 20000 rpm. Its advantage is that it doesn‟t need to make contact with the rotating shaft.

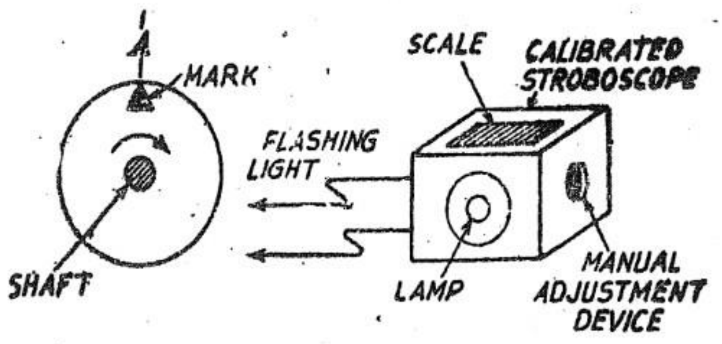

Fig. Shaft speed measurement using Stroboscope

Finding exact value of speed: Single line image is obtained by adjusting the stroboscope at its highest flashing frequency (f_m). The flashing rate is gradually reduced and the flashing frequencies are noted for all single line images (m different flashing rates).

$$N = \frac{f_m f_1 (m - 1)}{f_m - f_1}$$

If the shaft rotates at speed slightly higher than the primary speed, the pattern appears to rotate slowly forward. On the other hand, If the shaft rotates at speed slightly less than the primary speed, the pattern appears to rotate in the reverse direction to that of the direction of rotation of shaft.

<u>Advantages</u>:

1. Imposes no load on the shaft hence no power loss.
2. Non-contact type hence, no attachments needed.
3. Convenient to use for spot checks on machinery speeds and laboratory work.

<u>Disadvantages</u>:

1. The variable frequency oscillator circuit cannot be stabilized to give a fixed frequency hence less accurate than digital meters.
2. Cannot be used where ambient light is above a certain level.
3. Requires well defined lighting conditions for efficient operations
4. Errors are caused due to slight variation in the frequency.

Pickups: There are electric tachometer consists of a transducer which converts rotational speed into an electrical signal coupled to an indicator. The transducer produces an electrical signal in proportion to speed. The signal may be in the analog form or in the form of pulses. Tachometer or pickups of this type produce pulses form a rotating shaft without being mechanically connected to it. As the energy produced by these devices is not sufficient to actual an indicator directly, amplifiers of sufficient sensitivity are employed. The various types of non-contact pick-ups are optical pickups or photoelectric or photoconductive cell.

- Inductive pick up
- Capacitive pick up

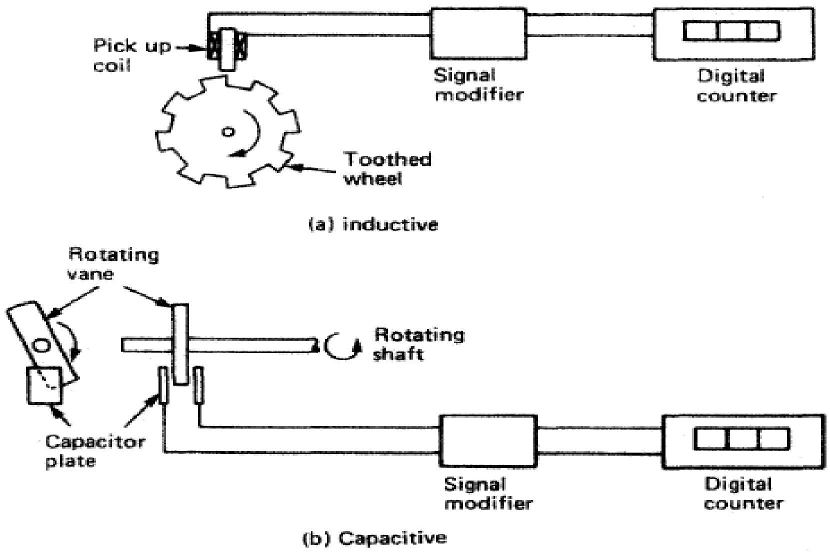

Figure Pick-up tachometers, (a) inductive; (b) capacitive

Here we will measure the speed by optical pick up. As they don"t have moving parts so speed up to 3 million rpm. These are available in a variety of designs using the principle of shaft rotation to interrupt a beam of light falling on a photoelectric or photo conductive cell. The pulse thus obtained are first amplified & then either fed to an electric counter, or shaped to an along signal and connected to the indicator. A bright white spot is made on the rotating shaft. A beam of light originating from the tachometer case hits the white spot & the reflected light falls on photoconductive cell inside the case, producing pulse in transistorized amplifier, which is turn, causes the indicator to deflect which is measure of speed of the shaft.

Procedure:

1. Connect the circuit & CRO with the required apparatus & switch on the supply.
2. Adjust the speed of the DC motor by the knob and wait for some time till the motor attains the maximum speed at corresponding knob position.
3. Measure the frequency (f) from output wave on CRO.
4. Find the speed of the motor by the given formula.

Observation Table:

S. No	RPM Sensor	Display reading
1		
2		
3		

Sample Calculations: - At knob position (A)

$$Speed \text{ (rpm) of DC Motor} = \frac{frequency \text{ (from CRO)} \square Diameter \text{ of disk}}{No. \text{ of Segments}}$$

$$\square N \text{ (rpm)} = \frac{f \square d}{S}$$

Where f = 1/tWhere

t = time period of one cycle of output wave &t = 1.8 x 2 ms = 3.6 x 10^{-3} s [on CRO] and

$$\square f \square 1/t \square \frac{1}{3.6 \square 10^{\square 3}} \square 2.78 \square 10^{2} s^{\square 1}$$

d = 56.5mm.

Therefore, R.P.M = 2.78 x 10^{2} x 56.5/ 60 = 262 rpm

Conclusion: Hence the Speed of position „A" = 262 rpm

Experiment No: 7

Aim: To measure the stress & strain using strain gauges mounted on cantilever beam.

Apparatus used: Strain gauge Kit, cantilever beam weights, multimeter.

Theory:

When external forces are applied to a stationary object, stress and strain are the result. Stress is defined as the object's internal resisting forces, and strain is defined as the displacement and deformation that occur. For a uniform distribution of internal resisting forces, stress can be calculated by dividing the force (F) applied by the unit area (A). **Strain** is defined as the amount of deformation per unit length of an object when a load is applied. Strain is calculated by dividing the total deformation of the original length by the original length (L).

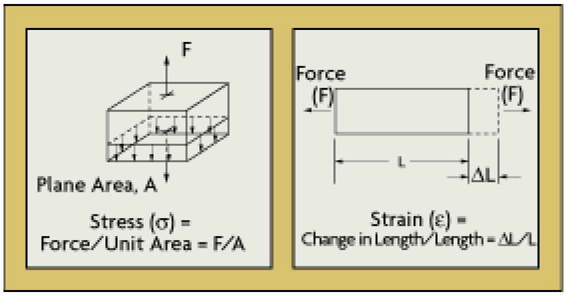

Fig: Stress - Strain Concept

Fundamentally, all **strain gauges** are designed to convert mechanical motion into an electronic signal. A change in capacitance, inductance, or resistance is proportional to the strain experienced by the sensor. If a wire is held under tension, it gets slightly longer and its cross-sectional area is reduced. This changes its resistance (R) in proportion to the strain sensitivity (S) of the wire's resistance. When a strain is introduced, the strain sensitivity, which is also called the gauge factor (GF), is given by:

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

There are many types of strain gauges. Among them, a universal strain gauge has a structure such that a grid-shaped sensing element of thin metallic resistive foil (3 to 6µm thick) is put on a base of thin plastic film (15 to 16µm thick) and is laminated with a thin film.

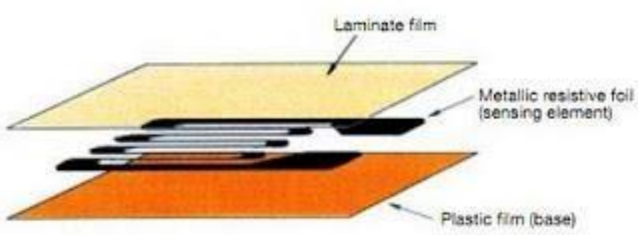

Fig: Strain Gauge

The strain gauge is tightly bonded to a measuring object so that the sensing element (metallic resistive foil) may elongate or contract according to the strain borne by the measuring object. When bearing mechanical elongation or contraction, most metals undergo a change in electric resistance. The strain gauge applies this principle to strain measurement through the resistance change. Generally, the sensing element of the strain gauge is made of a copper-nickel alloy foil. The alloy foil has a rate of resistancechange proportional to strain with a certain constant.

Procedure:

1. Arrange the cantilever beam, ammeter and voltmeter as shown in figure.
2. After this, put the weight on the rod of cantilever beam.
3. Measure the digital display reading for a particular weight.
4. Measure the value of ammeter (along) and voltmeter reading (micro-volt)
5. Increase the strength of weight.
6. Repeat the steps for increased weight.
7. Measure all dimensions of scale of cantilever.
8. Plot a graph between $\frac{\Delta R}{R_0}$ and strain (ε).
9. Find Gauge Factor (GF) by finding the inverse of the slope i.e. $\left(\frac{\varepsilon}{\Delta R/R}\right)^{-1}$..
10. Mark $\frac{\Delta R}{R_0}$ on the graph and use Gauge Factor to find strain.

Observations & Calculations:

S. No.	Load (gms)	Resistance			$\frac{\Delta R}{R_0}$	Strain (ε)
		Ro	R_f	$\Delta R = R_f - R_0$		
1						
2						
3						
4						
5						
6						
7	Unknown					-

Strain $= \varepsilon_{theoretical} = \frac{\delta l}{l} = \frac{6PL}{Ebt^2}$ for cantilever type Elastic Member exp *erimental* R/R_0

Gauge Factor (GF)

Modulus of Elasticity E *Stress Strain*

 Stress E *Strain* E e

Depending upon the beam used in apparatus force stress and strain values varies accordingly with simplysupported or cantilever beam terminology.

Conclusion: Stress and Strain induced in cantilever are_______N/mm^2 and ___________ respectively.

Experiment No: 8

Aim: To measure static/dynamic pressure of fluid in pipe/tube using pressure transducer/pressure cell.

Apparatus used: Pressure transducer Kit, multimeter etc.

Theory:

Pressure is defined as force per unit area that a fluid exerts on its surroundings. A pressure measurement can be described as either static or dynamic. The pressure in cases where no motion is occurring is referred to as static pressure. Examples of static pressure include the pressure of the air inside a balloon or water inside a basin. Often times, the motion of a fluid changes the force applied to its surroundings. Such a pressure measurement is known as dynamic pressure measurement. For example, the pressure inside a balloon or at the bottom of a water basin would change as air is let out of the balloon or as water is pouredout of the basin.

Because of the great variety of conditions, ranges, and materials for which pressure must be measured, there are many different types of pressure sensor designs. Often pressure can be converted to some intermediate form, such as displacement. The sensor then converts this displacement into an electrical output such as voltage or current. The three most universal types of pressure transducers of this form are the strain gage, variable capacitance, and piezoelectric.

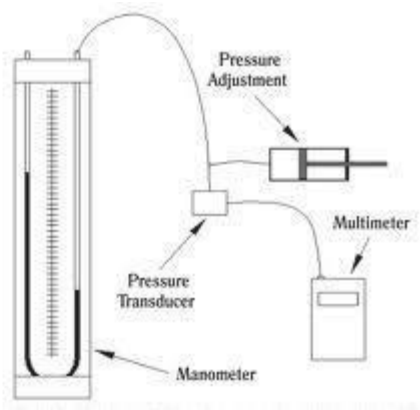

Fig: Pressure Transducer

Procedure:

1. Firstly arrange the pressure transducer, Multimeter, Voltmeter.
2. After that increase the pressure in the pressure transducer.
3. Set the readings of pressure transducer on a particular reading.
4. Now note the display reading on Kit.
5. Also note the voltmeter & ammeter readings.
6. Repeat the numbers of reading with different pressure on transducer.
7. Compare the value of pressure applied on transducer & display readings.

Observations & Calculations:

Theoretically,
$P=\rho g\Delta H$ Where,
ρ=density of water in pipe g=acceleration due to gravity
ΔH=change in head

Conclusion: Hence the pressure of the fluid in pipe is________.