

ME2205PC: INSTRUMENTATION AND CONTROL SYSTEMS

Topic: Measurement and Measurement Systems

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Measurement Systems and Principles

Detailed Overview and Examples

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Definition and Basic Principles

- Definition: Measurement is the process of determining the magnitude, quantity, or capacity of a parameter by comparing it with a standard.
- Basic Principles:
 - - Accuracy and precision
 - - Sensitivity and resolution
 - - Repeatability and reproducibility
 - - Calibration and traceability

Measurement Systems

- Generalized Configuration:
 - - Input stage: Sensor/Transducer
 - - Signal processing: Amplification, filtering
 - - Output stage: Display/Recording system

- Functional Description:
 - - Conversion of a physical parameter to a measurable signal
 - - Processing and presenting the signal
 - - Ensuring stability and accuracy

Performance Characteristics

- Static Characteristics:
 - - Accuracy, precision, resolution
 - - Sensitivity, linearity, hysteresis

- Dynamic Characteristics:
 - - Response time, frequency response
 - - Damping, overshoot, rise time

Sources and Classification of Errors

- Sources of Errors:
 - - Environmental: Temperature, humidity, vibration
 - - Instrumental: Calibration, drift, noise
 - - Human: Observation, handling

- Classification of Errors:
 - - Systematic Errors: Predictable and correctable
 - - Random Errors: Unpredictable and vary

- Elimination of Errors:
 - - Regular calibration
 - - Environmental control
 - - Repeated measurements

Measurement of Displacement

- Displacement Transducers:
 - - Piezoelectric: Converts mechanical stress to electric charge
 - - Inductive: Measures change in inductance due to displacement
 - - Capacitive: Uses changes in capacitance
 - - Resistive: Potentiometers and strain gauges
 - - Ionization: Measures ionization due to displacement
 - - Photoelectric: Uses light to measure displacement

Calibration Procedures

- Steps in Calibration:
 - 1. Select a standard reference
 - 2. Compare the instrument with the standard
 - 3. Adjust the instrument to minimize error
 - 4. Document calibration results
- Importance of Calibration:
 - - Ensures accuracy and reliability
 - - Maintains consistency and traceability
 - - Reduces measurement errors

Examples of Measurement Applications

- - Engineering: Stress analysis, motion tracking
- - Medicine: Patient monitoring, diagnostics
- - Manufacturing: Quality control, automation
- - Research: Experimental studies, data collection

Conclusion

- Measurement systems and principles are fundamental in science and technology. Understanding their characteristics, sources of errors, and calibration procedures ensures precision and reliability in diverse applications.

Measurement of Temperature and Pressure

Principles, Classification, and Examples

Measurement of Temperature - Principles

- Principles of Temperature Measurement:
 - - Expansion: Physical expansion with temperature change
 - - Electrical Resistance: Change in resistance with temperature
 - - Radiation: Emission of radiant energy
 - - Phase Change: Change in chemical phase with temperature

Temperature Measurement - Classification

- 1. Expansion Type:
 - - Bimetallic Strip: Uses two metals with different expansion rates
 - - Liquid-in-Glass Thermometer: Measures thermal expansion of liquids
- 2. Electrical Resistance Type:
 - - Thermistor: Temperature-sensitive resistors
 - - RTD: Resistance Temperature Detectors
 - - Thermocouple: Voltage generated due to temperature difference
- 3. Radiation Pyrometry:
 - - Optical Pyrometer: Measures radiant energy from hot objects
- 4. Phase Change:
 - - Fusible Indicators: Melting points indicate temperature
 - - Liquid Crystals: Change color with temperature

Measurement of Pressure - Principles

- Principles of Pressure Measurement:
 - - Force per unit area applied on a surface
 - - Balancing against known forces or displacements
 - - Sensing deflection of elastic elements

Pressure Measurement - Classification

- 1. Manometers:
 - - Measure pressure via liquid columns
- 2. Dead Weight Pressure Gauge Tester:
 - - Balances pressure using calibrated weights (Piston Gauge)
- 3. Elastic Elements:
 - - Bourdon Pressure Gauges: Curved tube straightens under pressure
 - - Bellows and Diaphragm Gauges: Measure deflection of elastic components
 - - Bulk Modulus Pressure Gauges: Measure bulk modulus of fluids

Low-Pressure Measurement

- 1. Thermal Conductivity Gauges:
 - - Measure changes in heat transfer properties

- 2. Ionization Pressure Gauges:
 - - Ionize gas molecules and measure ion current

- 3. McLeod Pressure Gauge:
 - - Measures low pressures using compressed gas volume

Examples of Instruments

- - Temperature: Thermocouples, Optical Pyrometers, RTDs
- - Pressure: Bourdon Gauges, Diaphragm Gauges, McLeod Gauges
- - Applications: Industrial processes, scientific research, HVAC systems

Conclusion

- Temperature and pressure measurement systems utilize diverse principles and instruments. Proper selection ensures accurate and reliable measurements in various applications.

Measurement of Level and Flow Measurement

Direct and Indirect Methods of Measurement

Measurement of Level: Overview

- 1. Direct Methods
 - - Visual Indicators
 - - Dipsticks
- 2. Indirect Methods
 - - Capacitive Sensors
 - - Radioactive Level Indicators
 - - Ultrasonic Sensors
 - - Magnetic Sensors
 - - Cryogenic Fuel Level Indicators
 - - Bubbler Level Indicators

Direct vs Indirect Methods

- Direct Methods:
 - - Simple visual tools like gauges, float rods, and dipsticks.
- Indirect Methods:
 - - Advanced techniques using sensors (capacitive, ultrasonic, etc.) for higher precision and automation.

Capacitive, Radioactive, Ultrasonic, and Magnetic Sensors

- Capacitive Sensors:
 - - Measure changes in capacitance caused by level variation.
- Radioactive Indicators:
 - - Use gamma rays to detect levels in sealed containers.
- Ultrasonic Sensors:
 - - Measure time taken by sound waves to return.
- Magnetic Sensors:
 - - Use magnetic fields to detect level changes.

Cryogenic Fuel and Bubbler Level Indicators

- Cryogenic Fuel Indicators:
 - - Specialized for very low temperatures in cryogenic liquids.

- Bubbler Level Indicators:
 - - Measure hydrostatic pressure of gas bubbles in a liquid.

Flow Measurement: Overview

- 1. Rotameter
- 2. Magnetic Flow Meters
- 3. Ultrasonic Flow Meters
- 4. Turbine Flow Meters
- 5. Hot-wire Anemometer
- 6. Laser Doppler Anemometer (LDA)

Rotameter and Magnetic Flow Meters

- Rotameter:
 - - Measures flow rate using a floating object in a tapered tube.

- Magnetic Flow Meters:
 - - Use electromagnetic fields to measure fluid velocity.

Ultrasonic and Turbine Flow Meters

- Ultrasonic Flow Meters:
 - - Measure flow using Doppler shift or transit time of ultrasonic waves.

- Turbine Flow Meters:
 - - Use rotor blades that spin at a rate proportional to fluid flow.

Hot-wire and Laser Doppler Anemometers

- Hot-wire Anemometer:
 - - Measures fluid velocity using heat transfer rates.

- Laser Doppler Anemometer (LDA):
 - - Uses laser interference to measure the velocity of particles in fluid.

Measurement of Speed, Acceleration, and Vibration

Overview of Instruments and Principles

Measurement of Speed: Overview

- 1. Mechanical Tachometers
- 2. Electrical Tachometers
- 3. Non-contact Type Stroboscope

Mechanical Tachometers

- Mechanical Tachometers:
 - - Use centrifugal force to measure rotational speed.
 - - Common types: Flywheel and governor tachometers.

Electrical Tachometers

- Electrical Tachometers:
 - - Use electrical signals (e.g., generated EMF) proportional to speed.
 - - Examples: DC tachogenerators and AC tachometers.

Non-contact Type Stroboscope

- Stroboscope:
 - - Emits flashes of light synchronized with moving objects.
 - - Measures speed by freezing motion visually.

Measurement of Acceleration and Vibration

- 1. Simple Instruments
- 2. Seismic Instruments
- 3. Vibro Meter
- 4. Accelerometer
- 5. Piezoelectric Accelerometer

Simple Instruments and Seismic Principles

- Simple Instruments:
 - - Measure acceleration and vibration using basic mechanical setups.

- Principles of Seismic Instruments:
 - - Measure motion relative to a suspended mass.
 - - Common in vibration and acceleration measurements.

Vibro Meter and Accelerometer

- Vibro Meter:
 - - Measures vibration levels using seismic principles.

- Accelerometer:
 - - Measures acceleration using a mass-spring system.

Piezoelectric Accelerometer

- Piezoelectric Accelerometer:
 - - Uses piezoelectric crystals to generate electrical charge under stress.
 - - Highly sensitive and suitable for dynamic measurements.

Stress-Strain Measurements

Overview of Techniques and Applications

Stress and Strain Measurements

- 1. Types of Stress:
 - - Tensile Stress
 - - Compressive Stress
 - - Shear Stress
- 2. Types of Strain:
 - - Tensile Strain
 - - Compressive Strain
 - - Shear Strain
- Measurement involves metallic and electrical strain gauges.

Metallic Strain Gauges

- Metallic Strain Gauges:
 - - Measure strain using a metallic conductor.
 - - Selection criteria: Sensitivity, durability, and environment.
 - - Installation: Proper bonding and alignment are critical.

Electrical Strain Gauges

- Electrical Strain Gauges:
 - - Convert strain into changes in electrical resistance.
 - - Gauge Factor (GF):
 - $GF = (\Delta R/R) / \text{Strain}$
 - - Used for precise measurements of strain.

Usage of Resistance Strain Gauge

- Applications:
 - - Bending Strain: Measure curvature effects.
 - - Compressive Strain: Detect compression forces.
 - - Tensile Strain: Measure elongation under tension.
- Installation:
 - - Ensure strong adhesion and proper positioning.

Temperature Compensation Techniques

- Challenges:
 - - Strain gauge readings affected by temperature changes.
- Techniques:
 - - Use of dummy gauges for compensation.
 - - Temperature-insensitive materials.
 - - Wheatstone bridge circuit to nullify effects.

Strain Gauges for Measuring Torque

- Torque Measurement:
 - - Strain gauges installed on shafts measure torsional strain.
 - - Applications include engines, motors, and gear systems.
 - - Ensure accurate alignment along torsional axis.

Strain Gauge Rosettes

- Strain Gauge Rosettes:
 - - Measure strain in multiple directions simultaneously.
 - - Types:
 - - Rectangular Rosette
 - - Delta Rosette
 - - Useful for determining principal strains and stresses.











































































