FUNDAMENTAL OF MECHANICAL ENGINEERING AND MECHATRONICS

KME-101T KME-201T **3 L: 0 T: 0 P 3 Credits**

I Unit I: Introduction to Mechanics of Solid:

Normal and shear Stress, strain, Hookes' law, Poisson's ratio, elastic constants and their relationship, stress-strain diagram for ductile and brittle materials, factor of safety. Basic Numerical problems. Types of beams under various loads, Statically Determinate Beams, Shear force and bending moment in beams, Shear force and bending moment diagrams, Relationships between load, shear and bending moment. Basic Numerical problems.

Unit II: Introduction to IC Engines and RAC:

IC Engine: Basic Components, Construction and Working of Two stroke and four stroke SI & CI engine, merits and demerits, scavenging process; Introduction to electric, and hybrid electric vehicles.

Refrigeration: Its meaning and application, unit of refrigeration; Coefficient of performance, methods of refrigeration, construction and working of domestic refrigerator, concept of heat pump. Formula based
numerical problems on cooling load.

Air-Conditioning: Its meaning and application, humidity, dry bulb, wet bulb, and dew point temperatures, comfort conditions, construction and working of window air conditioner.

Unit III: Introduction to Fluid Mechanics and Applications:

Introduction: Introduction: Fluids properties, pressure, density, dynamic and kinematic viscosity, specific gravity, Newtonian and Non-Newtonian fluid, Pascal's Law, Continuity Equation, Bernaulli's Equation and its applications, Basic Numerical problems.

Working principles of hydraulic turbines & pumps and their classifications, hydraulic accumulators, hydraulic lift and their applications.

Unit IV: Measurements and Control System:

Concept of Measurement, Error in measurements, Calibration, measurements of pressure, temperature, mass flow rate, strain, force and torques; Concept of accuracy, precision and resolution, Basic Numerical problems.

System of Geometric Limit, Fit, Tolerance and gauges, Basic Numerical problems. Control System Concepts: Introduction to Control Systems, Elements of control system, Basic of open and closed loop control with example.

Unit V: Introduction to Mechatronics:

Evolution, Scope, Advantages and disadvantages of Mechatronics, Industrial applications of Mechatronics, Introduction to autotronics, bionics, and avionics and their applications. Sensors and Transducers: Types of sensors, types of transducers and their characteristics.

Overview of Mechanical Actuation System – Kinematic Chains, Cam, Train Ratchet Mechanism, Gears and its type, Belt, Bearing, Hydraulic and Pneumatic Actuation Systems: Overview: Pressure Control Valves, Cylinders, Direction Control Valves, Rotary Actuators, Accumulators, Amplifiers, and Pneumatic Sequencing Problems.

Books:

1. Basic Mechanical Engineering, G Shanmugam, S Ravindran, McGraw Hill
2. Basic Mechanical Engineering, M P Poonia and S C Sharma, Khanna Publishers
3. Mechatronics : Principles, Concepts and Applications, Nitaigour Mahalik,McGraw Hill
4. Mechatronics, As per AICTE: Integrated Mechanical Electronic Systems, K.P. Ramachandran, G.K. Vijayaraghavan, M.S.Balasundaram, Wiley India
5. Mechanical Measurements & Control, Dr. D. S. Kumar. Metropolitan Book Company
6. Fluid Mechanics and Hydraulic Machines, Mahesh Kumar, Pearson India

Program Outcome	
PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specific needs with appropriate considerations for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practices.
PO7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norm of the engineering practices.
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communications:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life learning in the broadest context of technological change.

Course Outcomes (KME101T / KME201T)

After studying the course contents, students will be able to :

CO-1	Understand the concept of stress, strain, factor of safety and beams
CO-2	Understand the basic component and working of internal combustion engines, electric and hybrid vehicles, refrigerator and heat pump, air conditioning.
CO-3	Understand fluid properties, conservation laws, hydraulic machinery used in real life.
CO-4	Understand the working principle of different measuring instrument with the knowledge of accuracy, error and calibration, limit, fit, tolerance and control system.
CO-5	Understand concept of mechatronics with their advantages, scope and Industrial application, the different types of mechanical actuation system, the different types of hydraulic and pneumatic systems.

UNIT-1 MECHANICS of SOLID & BEAM

LECTURE: 01

Body:

Particle: A particle is an object that has infinite small volume (occupies negligible space) but has a mass which can be considered to be concentrated at a point.

Body: A body has a definite shape and consists of number of particles.

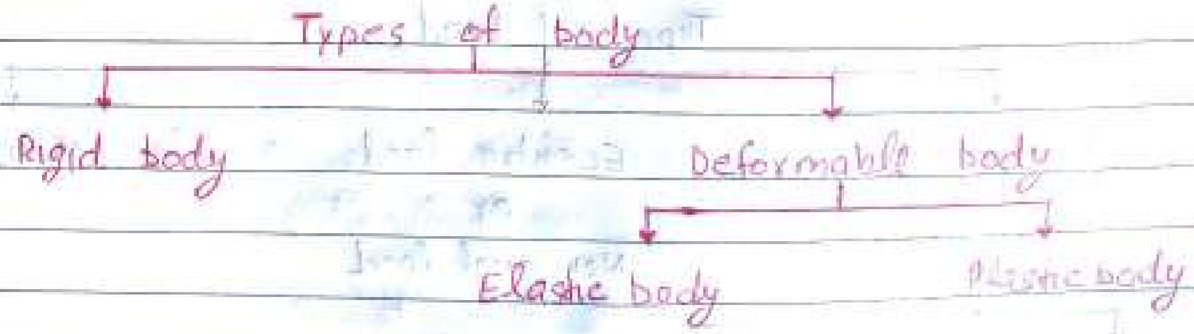
Rigid body: A body which does not undergo any change in its dimensions under the action of external load is called a rigid body.

Practically, no body is perfectly rigid but assumed to be rigid for engineering application.

Elastic body: A body regains its original dimensions when the external load acting on it is complettly removed is called as elastic body.

Ex- Mild steel, copper, aluminium, brass etc.

Plastic body: A body which gets permanent deformed under the action of load and not coming back to its original dimensions on removal of load is called as plastic body.



FORCE: It is define as an external agency which tends to change the speed or direction of a system.

Force is a vector quantity and S.I unit of force is Newton (N).

Characteristics of force:

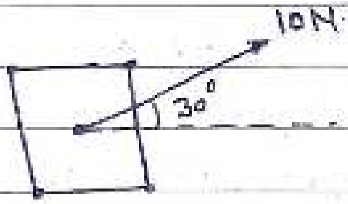
Force is characterized by following properties

(i) Magnitude: This represent the value of force ie 10N, 20N.

(ii) Direction: It is represented by line of action and the angle it forms with some fixed axis.

(iii) Nature: Nature of force is represented by arrowhead. Generally it termed as push or pull.

(iv) Point of application: The point at which the force acts is known as point of application.



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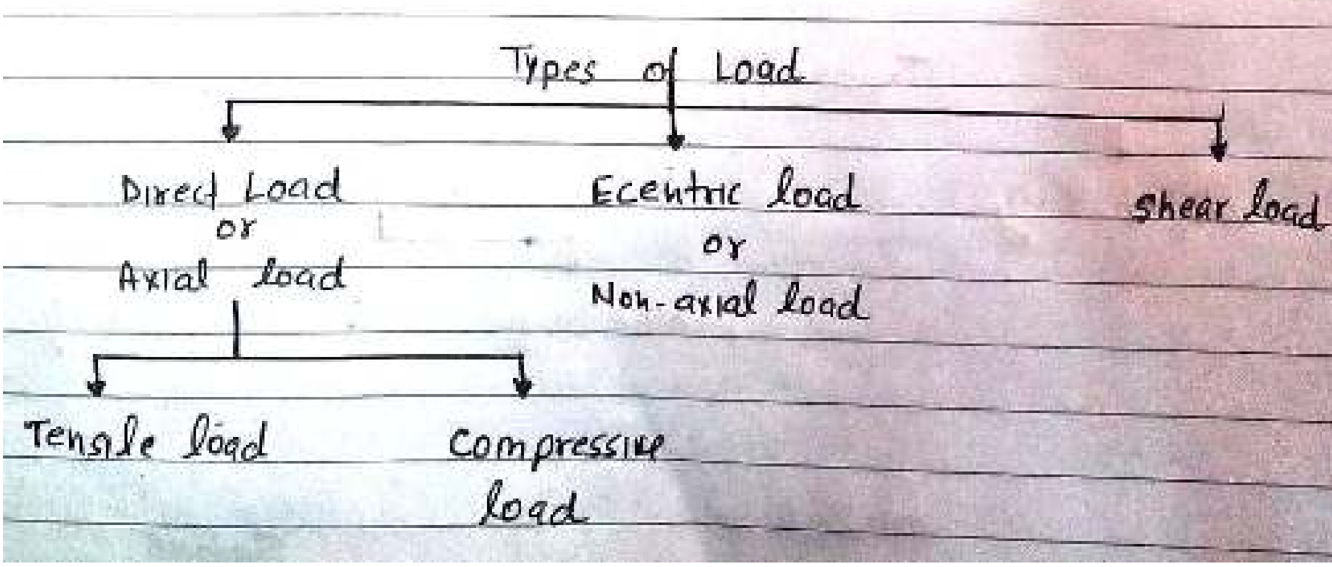
Magnitude: 10 N.

Direction. 30° from x axis

Nature: Pull (Tensile) outwards to the centre (+ve)

Point of application: Centre of body.



1- Direct load or axial load:

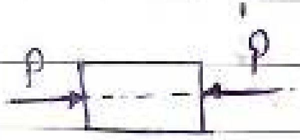
· When a load whose line of axis coincides with the axis of a body, then it is called as direct load or axial load.

Direct load always acts at the centroid of a member.

It is of two types.

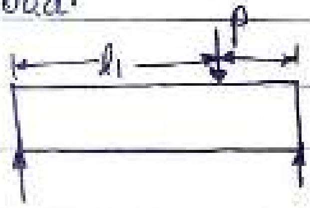
(i) Tensile force: When two equal and opposite pull is axially applied on a body then it is called as tensile force.

(ii) Compressive force: When two equal and opposite push is axially applied on a body, then it is called as compressive force.



2- Ecentric load:

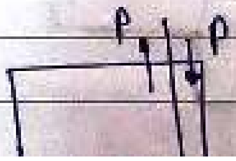
When a load whose line of action do not coincide with the axis of the body then it is called as an ecentric load.



3- Shear force:

A force which acts tangential to the plane under consideration, is called shear force.

When a force acts along the plane or area of a body.

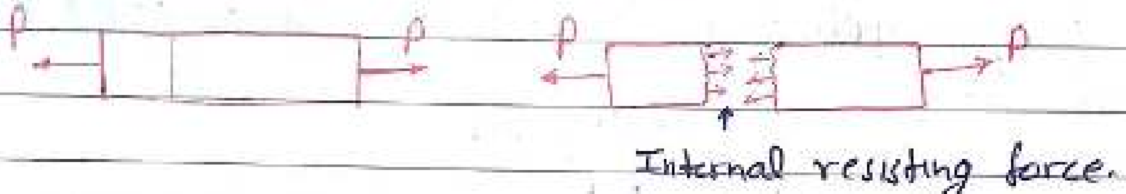


STRESS:

The internal resisting force developed per unit cross section area is defined as stress. It is also called as normal stress.

It is represented by "σ". and unit of stress is N/mm^2.

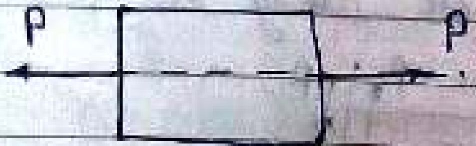
$$\boxed{\text{stress} = \frac{\text{Internal resisting force}}{\text{Cross section area}} = \frac{P}{A}}$$



$$\boxed{1\,MPa = 1\,N/mm^2}$$

Types of stress
- Direct stress or Normal stress
  - Tensile stress
  - Compressive stress
- Shear stress
- Bending stress

1- Direct Stress: stress which acts normal to the plane on which the force acts axially are called as direct stress or normal stress (σ).



It is of two types

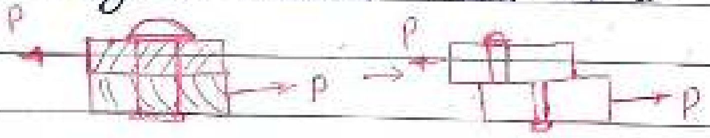
(a) Tensile stress: When two equal and opposite pull is applied on the member, then member is subjected to tension and stress is so developed into the body is called as tensile stress.

$\boxed{\sigma_t = \frac{P}{A}}$ N/mm^2

(b) Compressive Stress: When two equal and opposite push is applied on the body then body is subjected to compression & stress is so developed into the body is called as compressive stress.

$\boxed{\sigma_c = \frac{P}{A}}$ N/mm^2

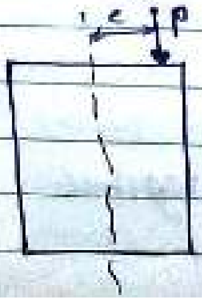
2- Shear stress: When equal and opposite force acts tengentially on a body across the resisting section then the body tends to shear off. In such case the stress is so developed in the body is called shear stress.



$\boxed{\tau = \frac{P}{A}}$ N/mm^2

3- Bending stress: When an ecentric load acts on a body then stress is so developed is called as bending stress.

In case of beam, when the load acts on transverse section, then resistance offered by the internal stress to bending is called as bending stress.



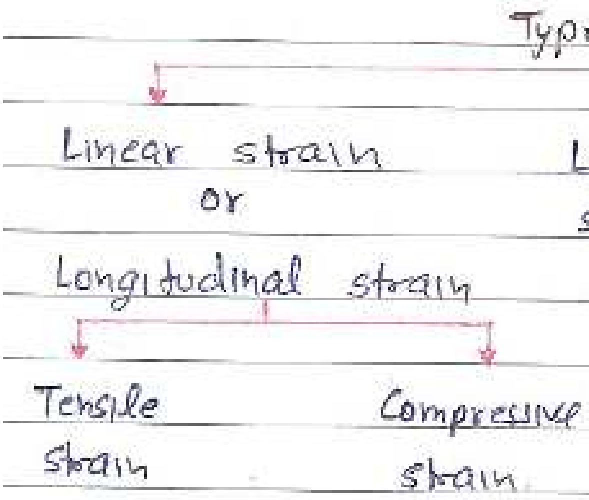
$\boxed{\sigma_b = \frac{P}{A}}$ N/mm^2

STRAIN:

When a body of elastic material is acted upon by an axial force, it undergoes change in dimensions. This change in dimension per original dimension is called as strain. It is denoted by "e" or "ε".

It has no unit.

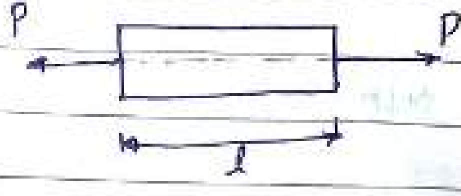
$$\boxed{\text{strain} = \frac{\text{change in dimension}}{\text{original dimension}}}$$



1- Linear Strain: Change in length in the direction of applied load per original length is called as linear strain. It is denoted by 'e' or 'ε'.

If the applied load is tensile then strain is called tensile strain.

If the applied load is compressive then strain is called compressive strain.



$$\boxed{e = \frac{\delta L}{L}}$$

Tensile is positive and compressive is negative.

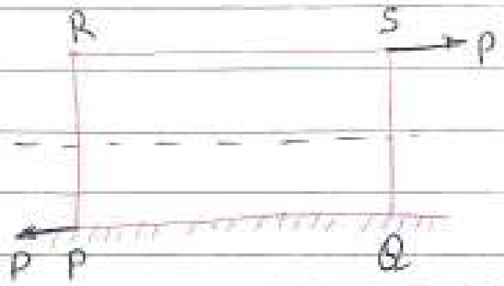
2- Lateral strain: The change in lateral dimensions (width, thickness) (perpendicular to the applied force) to the original lateral dimensions is called lateral strain or secondary strain.

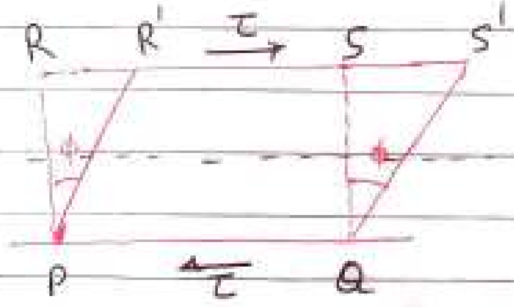
$$\boxed{e = \frac{\delta d}{d} = \frac{\delta t}{t}}$$

3- Volumetric strain: The change in volume due to external force per original volume is called as volumetric strain. It is denoted by ev.

$$\boxed{e_v = \frac{\delta V}{V}}$$

4- Shear strain: It is defined as the change in right angle. It is denoted by ϕ.





$$\boxed{\phi = \frac{SS'}{SQ}}$$

NOTE: (i) Strain is the ratio of two similar quantities, hence it has no unit.

(ii) Longitudional strain is also called linear strain, Primary strain or simple strain.

vii) Lateral strain is called secondary strain.

(iv) Volumetric strain is the algebraic sum of all linear strain.

LECTURE-02

Poisson's ratio :

It is define as the ratio of lateral strain to longitudinal strain. It is denoted by μ or $\frac{1}{m}$.

$$\boxed{\mu = \frac{\text{Lateral strain}}{\text{linear strain}} = \frac{\delta d/d}{\delta l/l}}$$

Value of poisson's ratio generally varies from 0.25 to 0.5 for different material.

HOOKE'S LAW:

It state that stress is directly proportional to strain within elastic limit for homogenius and isotropic material for one dimensional loading.

Mathematically,

$$\boxed{\sigma \propto \varepsilon}$$

$$\sigma = E\,\varepsilon \qquad \text{where } E \text{ is elastic constant}$$

$$\because \quad \sigma = \frac{P}{A} \quad \& \quad \varepsilon = \frac{\delta L}{L}$$

$$\text{so} \quad \frac{P}{A} = E.\frac{\delta L}{L} \Rightarrow \boxed{\delta L = \frac{PL}{AE}}$$

Elastic constant: There are three elastic constant namely modulus of elasticity or Young's modulus (E), modulus of rigidity or shear modulus (η or C) and bulk modulus (K).

~~These~~

Relation between E, η, K

$$\boxed{E = \frac{9K\eta}{3K+\eta}}$$

1- Young's Modulus: It is defined as the ratio of normal stress to the normal strain.

It is denoted by 'E'. & its unit is N/mm².

$$\boxed{E = \frac{\sigma}{E}}$$

2- Modulus of rigidity: It is defined as the ratio of shear stress to shear strain.

It is denoted by 'G' or 'C'. & its unit is N/mm².

$$\boxed{G = \frac{\tau}{\phi}}$$

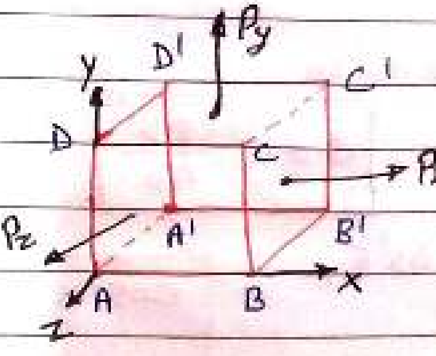
3- Bulk modulus: It is defined as the ratio of direct stress to the volumetric strain.

It is denoted by 'K' & its unit is N/mm².

$$\boxed{K = \frac{\sigma}{e_v}}$$

Relation between E and K:

When three forces are applied on mutually perpendicular planes then stresses induced in the system is called as tri-axial stress system.



Strain in x-direction $e_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} - \mu\frac{\sigma_z}{E}$

Strain in y-direction $e_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E} - \mu\frac{\sigma_z}{E}$

Strain in z-direction $e_z = \frac{\sigma_z}{E} - \mu\frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E}$

Total volumetric strain $e_v = \frac{\delta V}{V} = e_x + e_y + e_z$

$$e_v = \frac{\sigma_x+\sigma_y+\sigma_z}{E}(1-2\mu)$$

If triaxial stress system consists of equal like stress

i.e. $\sigma_x = \sigma_y = \sigma_z = \sigma$

then

$$e_v = \frac{3\sigma}{E}(1-2\mu)$$

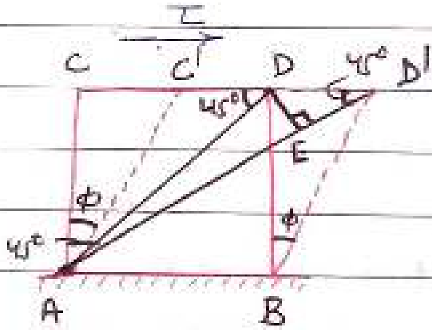
But,

Bulk modulus $K = \frac{\sigma}{e_v}$

$$K = \frac{\sigma}{\frac{3\sigma}{E}(1-2\mu)} \rightarrow K = \frac{E}{3(1-2\mu)}$$

$$\boxed{E = 3K(1-2\mu)}$$

Relation between E and G:



Consider a square block ABCD and apply a shear stress τ.

Strain in diagonal AD

$$\boxed{e = \frac{ED'}{AD}} \quad -(i) \qquad \because AE \cong AD$$

Δ DD'E,

$$\cos 45 = \frac{ED'}{DD'} \Rightarrow \boxed{ED' = \frac{DD'}{\sqrt{2}}} \quad -(ii)$$

Δ ADC,

$$\cos 45 = \frac{CD}{AD} \Rightarrow \boxed{AD = \sqrt{2}\,CD} \quad -(iii)$$

Now from eq. ①

$$e = \frac{DD'}{\sqrt{2}\cdot\sqrt{2}\,CD} \Rightarrow e = \frac{DD'}{2CD}$$

$$\boxed{e = \frac{DD'}{2BD}} \quad -(iv) \qquad \because CD = BD$$

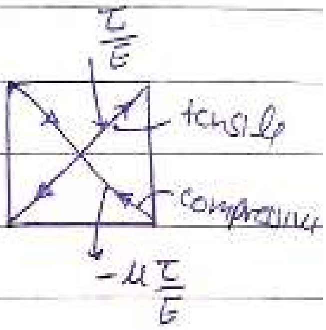
But from the geometry $\frac{DD'}{BD}$ = Shear strain (ϕ)

So $\frac{DD'}{BD} = \phi$

Now from eq. (IV)

$$\boxed{e = \frac{\phi}{2}} \quad - (V)$$

Shear strain along the diagonal AD



$$e = \frac{\tau}{E} - \left(-\mu\frac{\tau}{E}\right) = \frac{\tau}{E}(1+\mu)$$

$$\boxed{e = \frac{\tau}{E}(1+\mu)} \quad - (VI)$$

Now from eq. (V) & (VI)

$$\frac{\phi}{2} = \frac{\tau}{E}(1+\mu)$$

$$\boxed{E = 2\left(\frac{\tau}{\phi}\right)(1+\mu)}$$

But modulus of rigidity $G = \frac{\tau}{\phi}$

So

$$\boxed{E = 2G(1+\mu)}$$

Relation between E, G and K:

from the relation E and K

$$E = 3K(1-2\mu) \Rightarrow E = 3K - 6K\mu$$

$$\boxed{\mu = \frac{3K-E}{6K}} \quad -(i)$$

from the relation E and G.

$$E = 2G(1+\mu) \Rightarrow E = 2G + 2G\mu$$

$$\boxed{\mu = \frac{E-2G}{2G}} \quad --(ii)$$

Compair eq. (i) & eq. (ii)

$$\frac{3K-E}{6K} = \frac{E-2G}{2G}$$

$$3KG - EG = 3KE - 6KG$$

$$3KE + GE = 9KG$$

$$E[3K+G] = 9KG$$

$$\boxed{E = \frac{9KG}{3K+G}}$$

And

$$\boxed{G = \frac{3EK}{9K-E}}$$

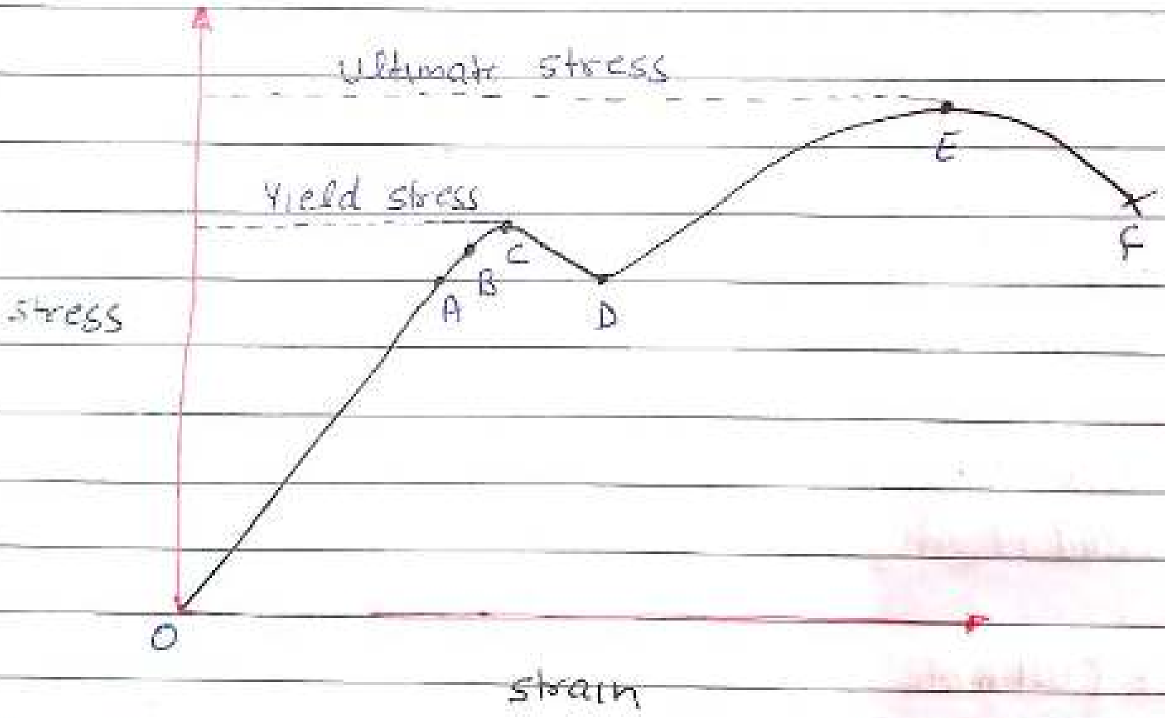
$$\boxed{K = \frac{EG}{3(3G-E)}}$$

LECTURE - 03

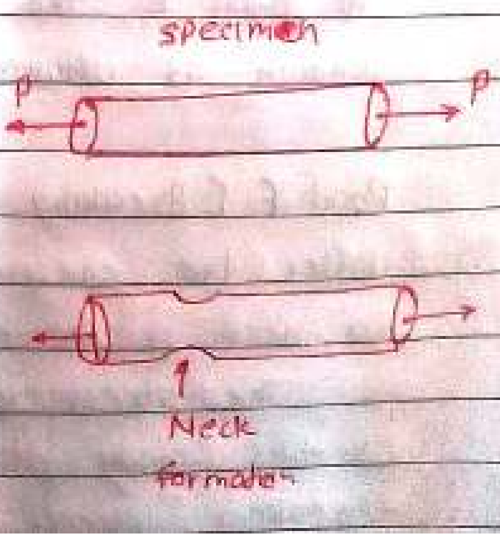
Tensile test diagram for ductile material OR stress- strain diagram for ductile material (mild steel):

This test consist of gradually applied tensile force on a ductile material (ex. mild steel) speciman and noting the corresponding values of load and elongation until specimen fractures. This test is generally conducted on universal testing machine (UTM).

Stress - strain diagram is graphical representation of stress and strain due to tensile load.



A → Proportional limit
B → Elastic limit
C → Upper yield point
D → lower yield point
E → Ultimate load point
F → Breaking point



Point-A (Proportional limit):

From point O to A is a straight line, which represent that the stress is directly proportional to strain.

Beyond point A the curve slightly deviates from the straight line.

Point B [Elastic limit]:

Material has elastic properties upto point B. This point is known as elastic limit.

Thus it is defined as the stress developed in the material without any permanent deformation.

Point C and Point D [Yield point]:

The point at which strain goes on increasing rapidly without further increase of stress is called as yield points.

If the material is stressed beyond point 'B', the plastic stage will reach i.e permanent deformation.

Point 'C' is called upper yield point and point 'D' is called lower yield point.

Point E [Ultimate stress]:

At point 'E', the stress, attains its maximum value known as ultimate stress. After 'E' stress is decreses.

Point F [Breaking stress]:

After the specimen has reached the ultimate stress a neck is formed which decrease the cross section area.

The stress is therefore reduced until the specimen breaks away at point F. The stress at F is known as breaking stress.

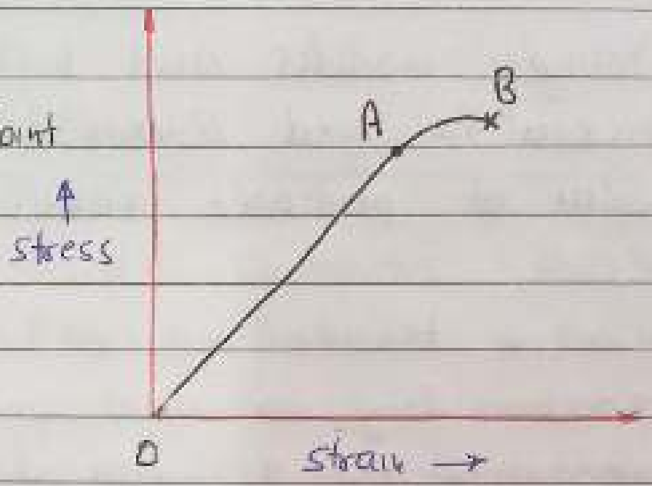
Stress - strain diagram for brittle material [Cast Iron]:

Material that fail in tension at relatively two value of strain are classified as brittle material.

Brittle materials are good for compressive stress.

Ex- Concrete, glass, ceramic material, cast iron etc.

A → Proportional limit
B → Breaking or fracture Point



Point A [Proportional limit]:

From point O to A is a straight line which represent that stress is directly proportional to strain.

Beyond point 'A', the curve slightly deviates from the straight line.

Point B [Fracture stress]:

The material fails with only little elongation after the proportional limit is exceeded. The fracture stress is some as ultimate stress.

Factor of safety [FOS]:

It is defined as the ratio of maximum stress to the working stress. It is denoted by 'FOS' or 'N'. It has no unit.

$$\boxed{FOS = \frac{\text{maximum stress}}{\text{working stress}}}$$

$$\boxed{FOS = \frac{\text{yield point stress}}{\text{working stress}}}$$

$$\boxed{FOS = \frac{\text{Ultimate stress}}{\text{working stress}}}$$

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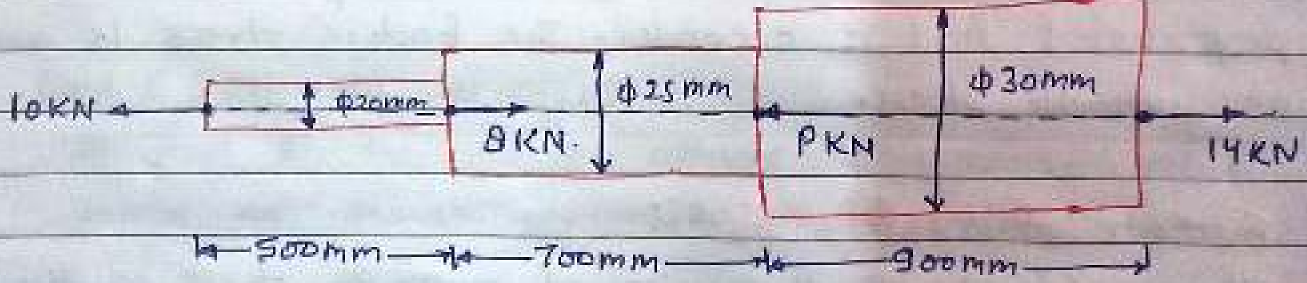
Ques1: A rectangular block of size 200 mm x 300 mm x 500 mm is subjected to stresses of 500 N/mm² (Tensile), 600 N/mm² tensile and 700 N/mm² (compressive) in x, y, and z direction respectively. Calculate change in volume of the block.

Ques2. Young's modulus and bulk modulus of steel are 2.1×10^{11} Pa and 8.4×10^{10} Pa respectively. Determine the value of poisson's ratio.

Ques.3. In a tensile test on certain specimen 20 mm dia, 200 mm long, an axial pull of 100 KN produce an alongation of 0.32 mm and reduction in diameter is observed to be 0.0085 mm. Find the value of poisson's ratio and the three modulii.

Ques4. Determine the magnitude of 'P' for equilibrium and the total elongation of the bar. Also calculate min stress induced. Take E = 210 GPa.



Ques.5 A 80m long wire of 5 mm diameter is made of steel with E = 200 GPa and an ultimate tensile strength of 400 MPa. If factor of safety of 3.2 is desired determine:

(a) the largest allowable tension in the wire

(b) Corresponding elongation of the wire.

BEAM:

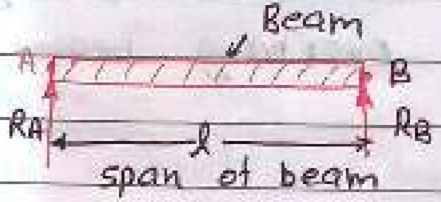
Any member of a machine or structure whose one dimension[length] is very large as compared to the other two dimensions[width & thickness] and which can carry lateral or transverse loads in the axial plane is called a beam.

Types of beam

- Simply supported Beam
- Cantilever Beam
- Fixed Beam
- Continuous Beam
- Overhanging Beam

1- Simply supported beam:

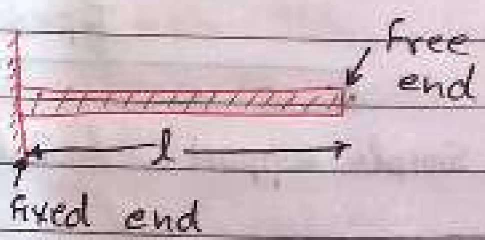
When a beam is rest on the support at the end of a beam then it is called as simply supported beam.



RA → Reaction at support A, vertically
RB → Reaction at support B, vertically.

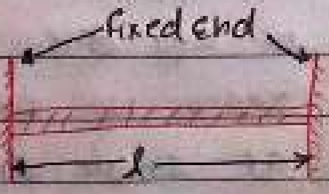
2- Cantilever beam:

When a beam is fixed at one end and free at the other end, then a beam is called as cantilever beam.

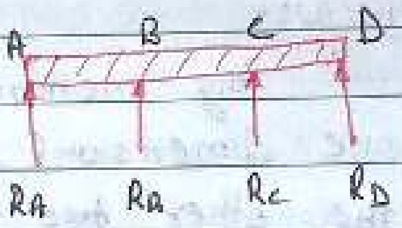


3- fixed beam:

When a beam is fixed at both the ends then it is called as fixed beam.



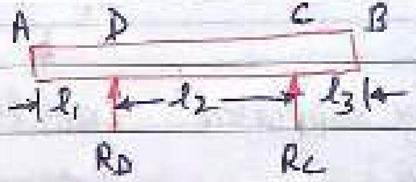
4- Continuous beam:



A statically indeterminate multi span beam supported on hinges is known as continuous beam.

These beams are supported by two or more supports.

5- Over hanging beam:



A beam in which some portion of the beam is extended beyond the support is called as overhang beam.

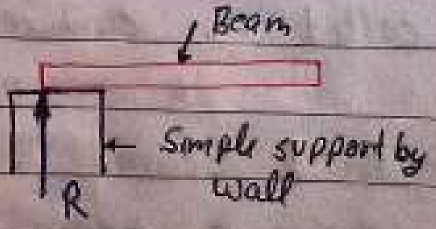
Supports for beam:

A support is an element which bears the weight of a beam & keeps it upright.

Types of support

- Simple support
- Roller support
- Hinge support
- Fixed support

1- Simple support:

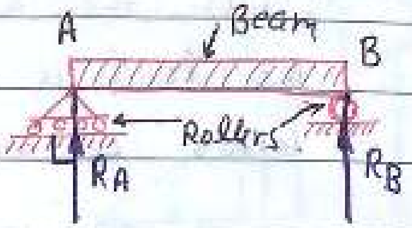


A support like wall, pillar or any othe structure on which beam is simply kept is called as simple support.

The reaction offered by the simple support are always vertical.

2- Roller support:

When the beam is supported on rollers then in such case the support is called as roller support.

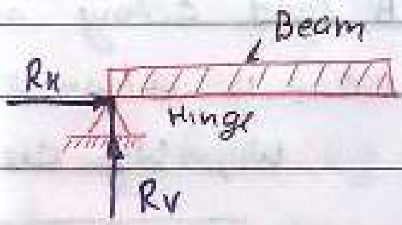


Reaction is always perpendicular to the plane of roller support.

Roller support allows the translational motion but never allows rotational motion.

3- Hinge or pin support:

When the beam is hinged to the support, then in such case, the support is called as hinged support or pin support.

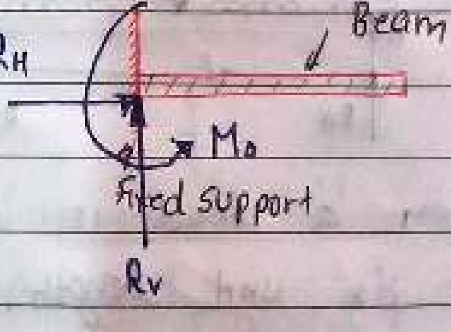


Hinged allowed rotational motion.

Reaction at the hinge support is vertical and horizontal depending upon the type of loadings acting on beam.

4- Fixed support:

When the end of the beam is firmly fixed into the support like wall, pillar, or any other structure, then in such case the support is called as fixed support.



Reaction at the fixed support is vertical, horizontal and fixing moment.

Loads for beam:

The load is applied to the beam result in reaction forces at the beam's support points.

Types of Load

Point load

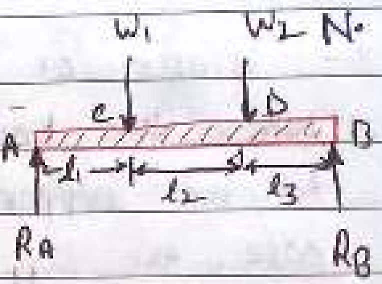
Uniformly distributed load

Uniformly varying load

1- Point load or concentraded load:

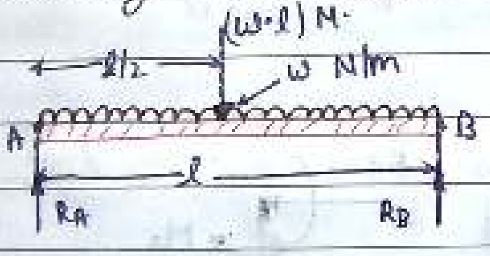
A load acting at a point on a beam is known as point load.

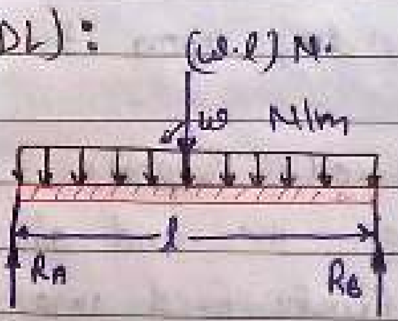
w₁, w₂ are point load.



$$\boxed{\begin{aligned} F &= W \quad N. \\ M &= w \cdot x \quad N\text{-}m \end{aligned}}$$

2- Uniformly distributed load (UDL):





when a load is uniformly spread over a beam for its unit length, then it is known as UDL.

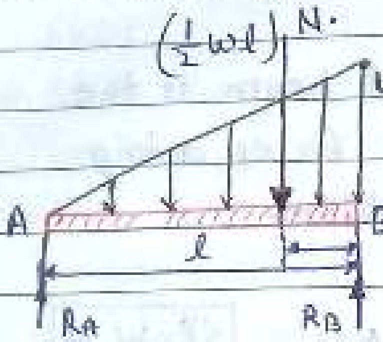
UDL is always in N/m.

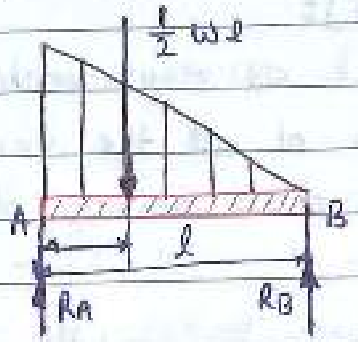
UDL is assumed as an equivalent point load of (w×l) N. acting at the c.g. (centre of gravity) of the load

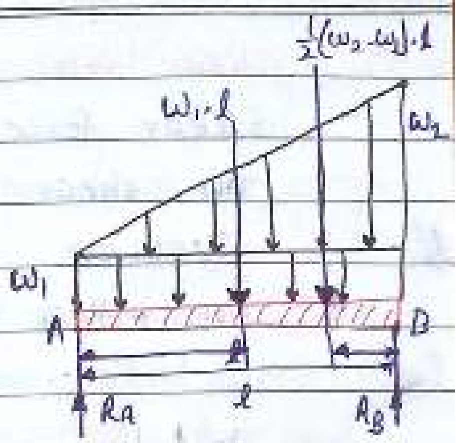
Equivalent point load is assumed to be act at centre of UDL.

$$\boxed{\begin{aligned} F &= w \times l \\ M &= w \cdot x \cdot \frac{x}{2} = \frac{wx^2}{2} \end{aligned}}$$

3- Uniformly varying load (UVL):







A load whose intensity is linearly varying between two points on the beam is known as UVL.

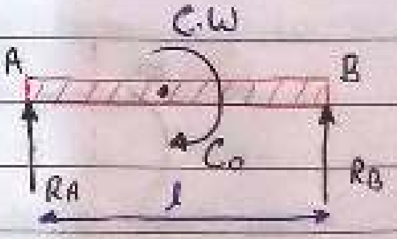
UVL is always in N/m.

UVL is assumed as an equivalent to point load of $(\frac{1}{2}w.l)$ N. acting at the distance $\frac{l}{3}$ from big end or $\frac{2l}{3}$ from the zero load end.

$$\boxed{\begin{aligned} F &= \frac{1}{2}w.l \\ M &= \frac{1}{2}w.x.\frac{x}{3} \end{aligned}}$$ from max load end

Couple:

When a combination of two equal opposite, parallel and non-collinear forces acts on a body, it is forms a couple and body starts rotating about its axis of rotation.



$$\boxed{\begin{aligned} F &= 0 \\ M &= C_0 \end{aligned}}$$

- Statically determinate beam:

A beam is said to be statically determinate if it is possible to determine the reaction for the given loading by using the equations of static equilibrium only.

Ex. SSB, Cantilever beam etc.

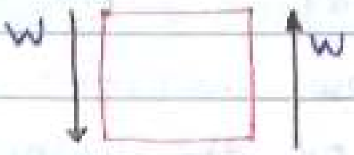
LECTURE-05

Shear force and bending moment in beams:

Shear force (SF):

The shear force at any section of beam is the algebraic sum of all the vertical forces acting on either side of a section of a beam.

+ve S.F.



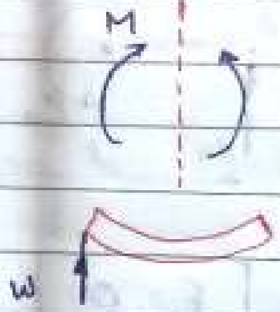
-ve S.F.

$$\boxed{SF = W\ N.}$$

SF is positive if the net resultant force to the left of the section is upward and negative if it is downward.

Bending Moment (B.M.):

B.M. at any section of the beam is the algebraic sum of moments of all the vertical force acting on either side of a section.



Sagging (+ve BM)

Hogging (-ve BM)

$$\boxed{M = W \cdot x\ N\text{-}m}$$

A bending moment is considered positive if it is produced compression on the top fibres of the beam [sagging] and negative if it is produces tension on the top fibres of the beam [hogging].

Shear force diagram [SFD] and Bending moment diagram [B.M.D]

SFD:

→ It is the graphical representation of shear force at every section of beam.

→ The point where SF is zero is called as point of zero shear and at this point B.M. is maximum. [Point of contra-shear]

→ Normally positive SF is plotted above the base line and that of negative SF below the base line.

→ Variation of SF is a horizontal line for vertical loads (Point load) and it is inclined straight line for uniformly distributed loads between the sections.

→ If there is a point load or vertical reaction at any section, the SF at that section will suddenly increase or decrease depending on the direction of load.

BMD:

→ It is the graphical representation of B.M. at all section of the beam.

→ The point at which B.M change its sign (from +ve to -ve or -ve to +ve) with respect to base line is called as point of contraflexure and at this point B.M. is zero.

→ Normally positive B.M is plotted above base line and that of negative B.M below the base line.

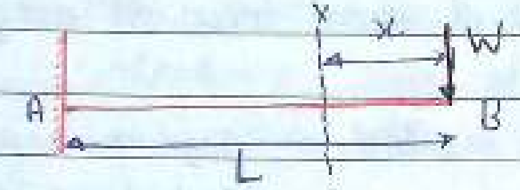
→ Variation of B.M is inclined straight line ~~for point~~ between any section having point load and it is parabolic for uniformly distributed load.

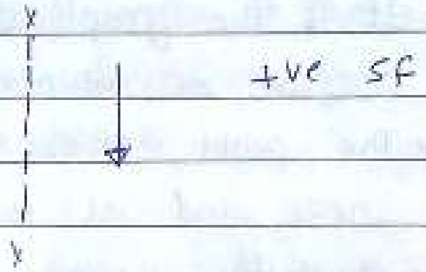
→ B.M at two supports of SSB is zero

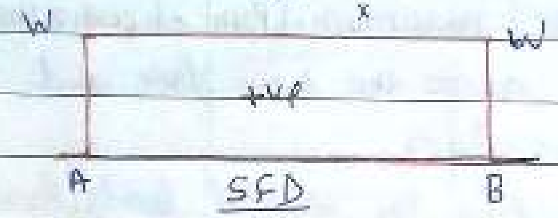
→ B.M at free end of cantilever is zero

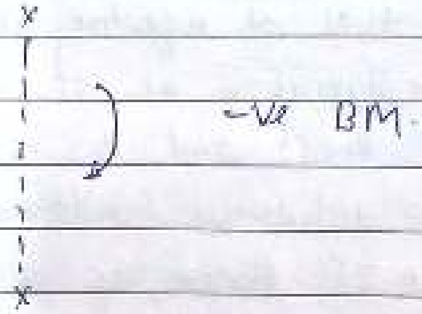
LECTURE-06

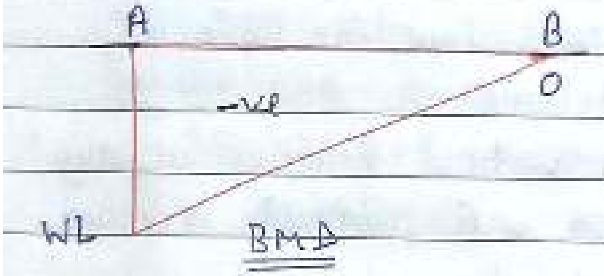
SFD and BMD for cantilever beam of span 'L' subjected to a point load 'W' at its free end:











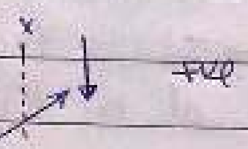
Consider a section x-x at a distance of x from the free end ie where point load acts.

SF calculation:

$$(SF)_{xx} = +W$$ [Downward load at right of the section] → so positive

$(SF)_B = +W$

$(SF)_A = +W$



shear force remains constant equal to +W on the entire span.

B.M. Calculation:

$$(B.M)_{xx} = -W \cdot x$$

$(B.M)_B = 0$

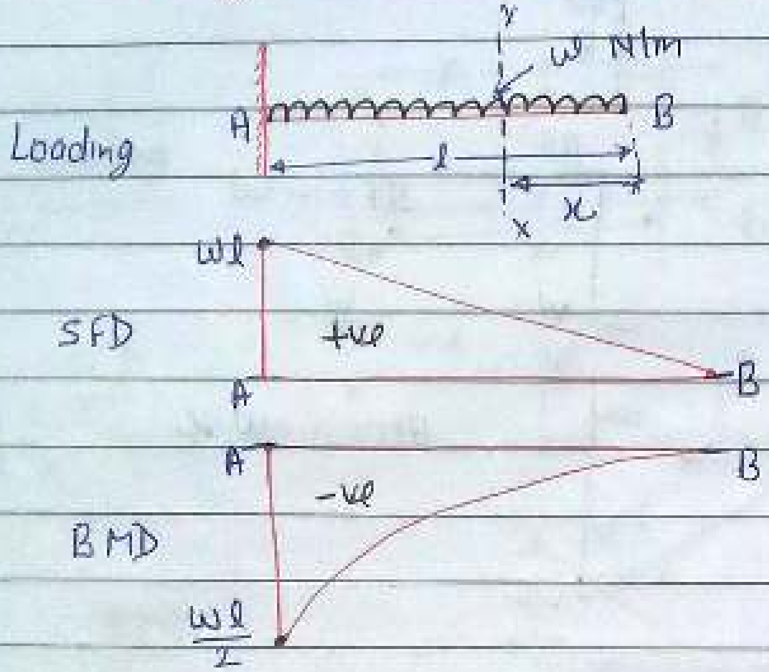
$(BM)_A = -W \cdot L$

B.M. increases as x increases and it is maximum at the fixed end where $x = L$.

B.M is -ve & its variation is linear.

SFD and BMD for a cantilever beam of span 'L' carrying uniformly distributed load over entire span:

Loading



Consider a section x-x at a distance of x from free end.

SF Calculation:

$$(SF)_{xx} = +(w \cdot x) \text{ N.}$$

$(SF_B)_{x=0} = 0$

$(SF_A)_{x=L} = +w \cdot L$

Variation of SF is linear from B to A and positive.

B.M calculation:

$$(BM)_{xx} = -(w \cdot x) \cdot \frac{x}{2} = -\frac{wx^2}{2} \text{ N-m}$$

$(BM_B)_{x=0} = 0$

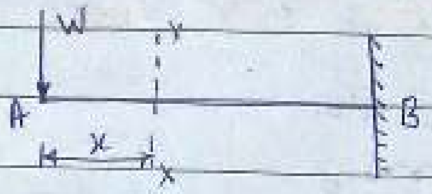
$(BM_A)_{x=L} = -\frac{wL^2}{2}$

Variation of BM is parabolic from B to A and it is negative due to hogging.

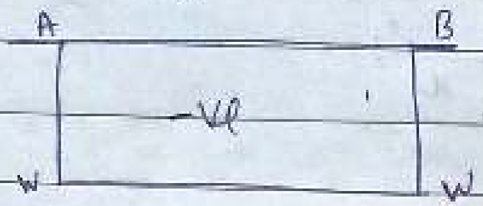
SFD and BMD for Cantilever [If fixed end at right]:

Point load

Loading

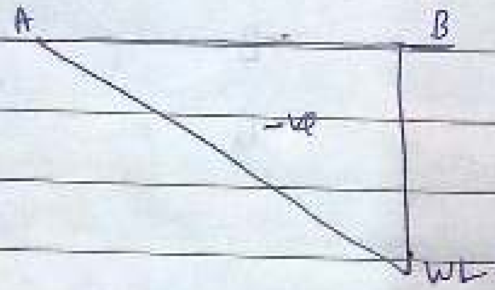


SFD



SF = -W

BMD



BM = -W.x

UDL

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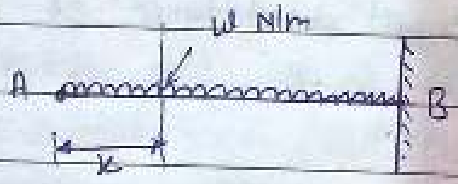
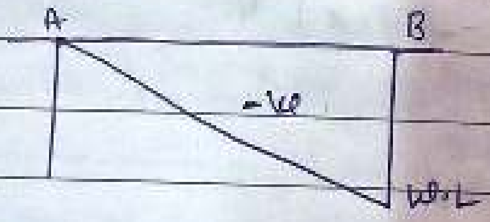
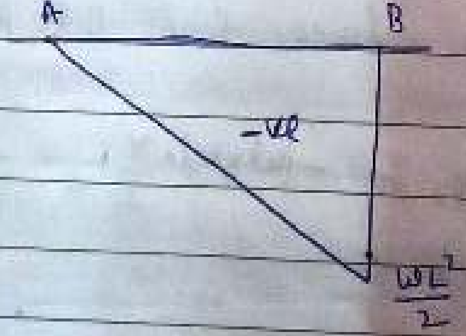


SFD



SF = -w.x

BMD



$BM = -\frac{wx^2}{2}$

LECTURE-07 Date...................

SFD and BMD for simply supported beam of span 'L' subjected to point load 'W' at mid span:

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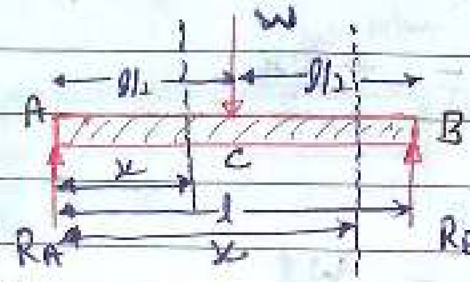
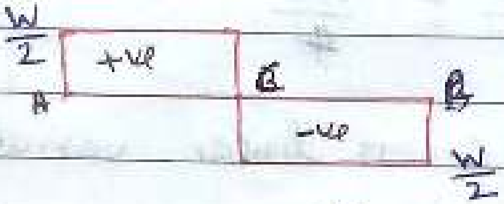
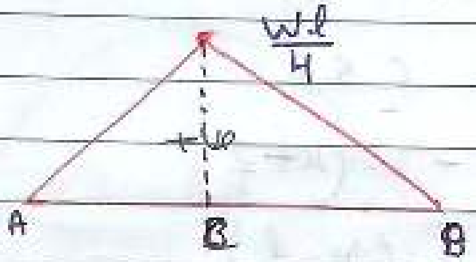


$\boxed{\begin{array}{l}\Sigma F_x = 0\\ \Sigma F_y = 0\\ \Sigma M = 0\end{array}}$

SFD



BMD.



Calculate the support reaction at point A & B using

$\boxed{R_A + R_B = W}$ – ①

taking moment about point B,

$R_a \times l = W \times \frac{l}{2} \rightarrow \boxed{R_A = \frac{W}{2}}$

Now from eq. ① $R_B = W - \frac{W}{2} \rightarrow \boxed{R_B = \frac{W}{2}}$

SFD: Consider a section x-x at a distance od x from point A between A & C.

$SF = +R_A = +\frac{W}{2}$ constant from A to C.

Now consider another section x-x at a distance od x from point A between C & B.

$SF = +R_A - W = +\frac{W}{2} - W = -\frac{W}{2}$

constant from C to B.

BMD :

for section between A & C:

$$BM_x = +R_A \cdot x = +\frac{Wx}{2}$$

$$(BM_A)_{x=0} = 0$$

$$(BM_C)_{x=\frac{l}{2}} = \frac{W \cdot l/2}{2} = \frac{Wl}{4}$$

B.M from A to C is linear variation $\left[0 \text{ to } \frac{Wl}{4}\right]$

for section between C & B.

$$BM_x = +R_A \cdot x - W \cdot \left(x \cancel{+} \frac{l}{2}\right)$$

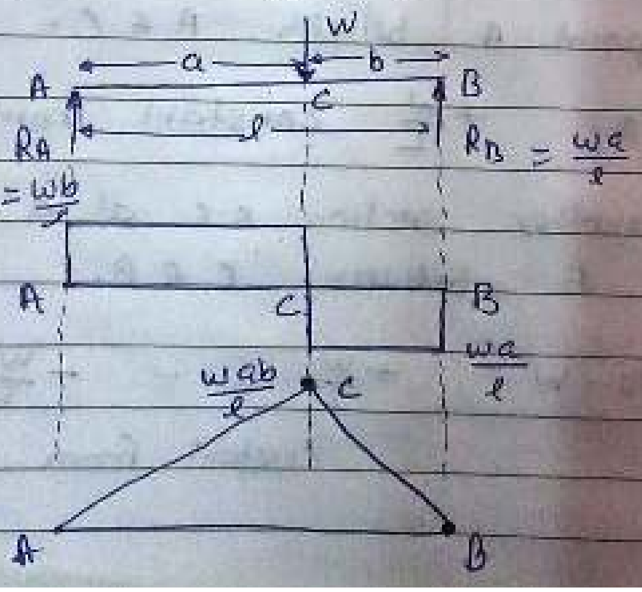
$$= \frac{Wx}{2} - W\left(x - \frac{l}{2}\right)$$

$$(BM_C)_{x=\frac{l}{2}} = \frac{W \cdot l/2}{2} - W\left(\frac{l}{2} - \frac{l}{2}\right) = \frac{Wl}{4}$$

$$(BM_B)_{x=l} = \frac{Wl}{2} - W\left(l - \frac{l}{2}\right) = 0$$

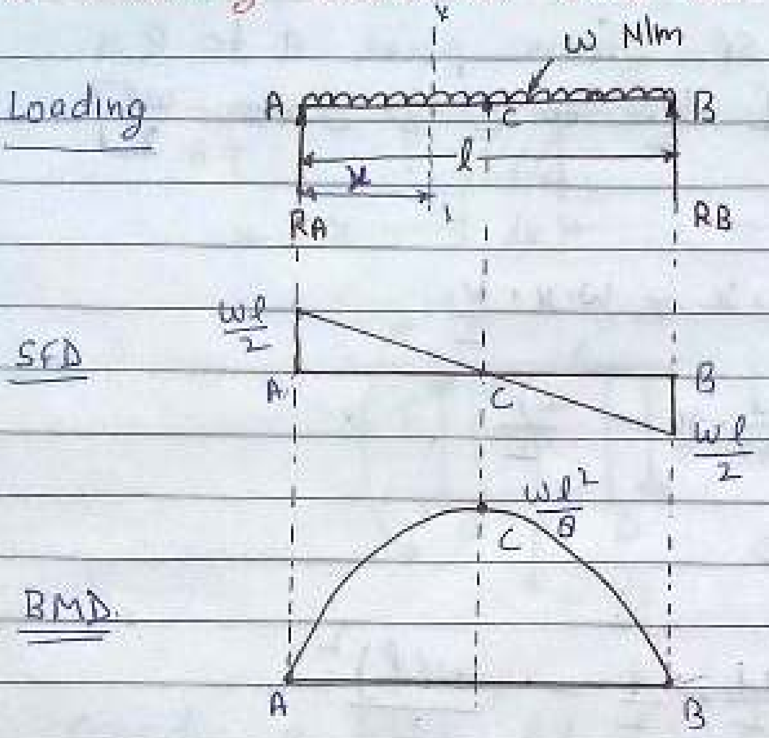
B.M from C to B is linear variation $\left[\frac{Wl}{2} \text{ to } 0\right]$

In case the beam carrying point load at a distance 'a' from end support 'A':



LECTURE-08

SFD and BMD for Simply supported beam of span 'L' Subjected to uniformly distributed load over entire span:



Calculate the reaction at point A and B using

$$\boxed{R_A + R_B = w \cdot l} \quad - ①$$

Taking moment about one end A [at support]

$$R_B \times l = (w \cdot l) \cdot \frac{l}{2} \Rightarrow \boxed{R_B = \frac{wl}{2}}$$

Now from eq. ①

$$R_A = wl - \frac{wl}{2} \Rightarrow \boxed{R_A = \frac{wl}{2}}$$

SFD: Consider a section x-x at a distance of x from one end 'A'.

$$SF_x = R_A - w \cdot x = \frac{wl}{2} - wx$$

$$(SF_A)_{x=0} = \frac{wl}{2}$$

$$(SF_C)_{x=\frac{l}{2}} = \frac{wl}{2} - w \cdot \frac{l}{2} = 0$$

$$(SF_B)_{x=l} = \frac{wl}{2} - w \cdot l = -\frac{wl}{2}$$

So variation of SF from point A to B is linear variation $\left[\frac{wl}{2} \text{ to } 0 \; \& \; 0 \text{ to } -\frac{wl}{2} \right]$

BMD:

$$BM_x = R_A \cdot x - w \cdot x \cdot \frac{x}{2}$$

$$= \frac{wl}{2} \cdot x - \frac{wx^2}{2}$$

$$(B.M_A)_{x=0} = 0$$

$$(BM_C)_{x=\frac{l}{2}} = \frac{wl}{2} \cdot \frac{l}{2} - \frac{w\left(\frac{l}{2}\right)^2}{2}$$

$$= \frac{wl^2}{4} - \frac{wl^2}{8} =$$

$$= \frac{wl^2}{8}$$

$$(BM_B)_{x=l} = \frac{wl}{2} \cdot l - \frac{wl^2}{2}$$

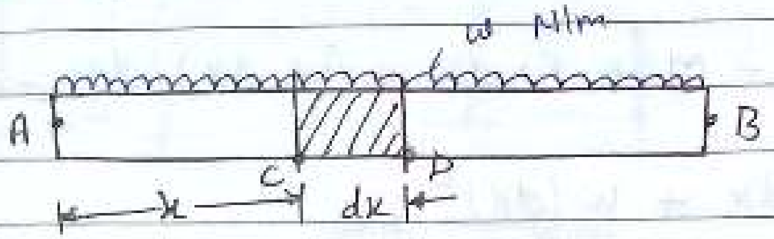
$$= 0$$

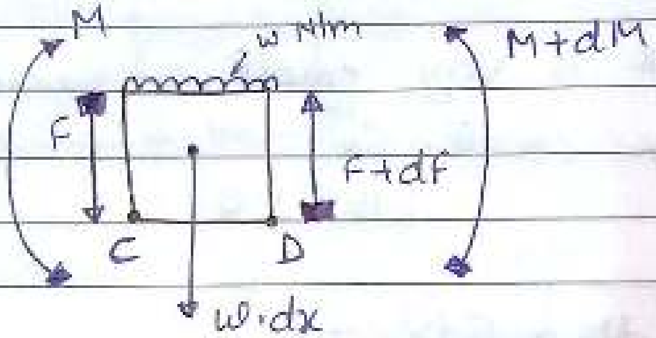
Variation of BM from point A to B is parabolic variation.

$SF_{max} = \frac{wl}{2}$ at support

$BM_{max} = \frac{wl^2}{8}$ at mid span

Relation between Load Intensity (w), Shear force (F) and Bending moment (M):





Consider a beam AB subjected to UDL of w N/m An element of length dx at a distance of x from left end A.

Now draw its free body diagram

The element is subjected to SF 'F' at its left side and F+dF at its right side. and the BM 'M' acts on left side and M+dM on right side. Weight of the element act at its centre(w.dx)

Applying the force equilibrium condition

$$\Sigma F_y = 0$$

$$(F + dF) - F - w \cdot dx = 0$$

$$dF - w \cdot dx = 0$$

$$\boxed{\frac{dF}{dx} = w}$$

ie

intensity of loading is equal to rate of change of SF with respect to x.

Taking moment about point D on the right side.

$\Sigma M_D = 0$

$$(M+dM) - M + F \cdot dx + (w \cdot dx) \cdot \frac{dx}{2} = 0$$

$$dM + Fdx + w\frac{(dx)^2}{2} = 0$$

$\because$ dx is very small so square of dx is very very small. So

$$(dx)^2 \simeq 0$$

Now $dM + Fdx = 0$

$$\boxed{\frac{dM}{dx} = -F}$$

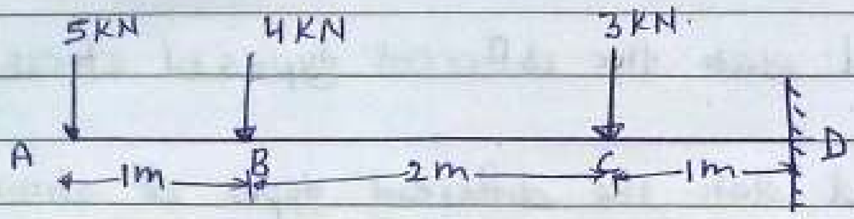
Thus the shear force is equal to the rate of change of BM with respect to x.

So,

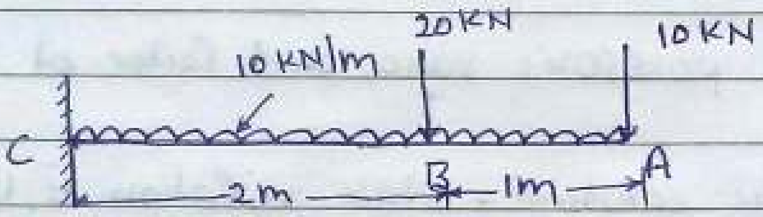
$$\boxed{\begin{gathered} w = \frac{dF}{dx} \\ -F = \frac{dM}{dx} \end{gathered}}$$

Ques 1 Draw SFD and BMD for the given beams.

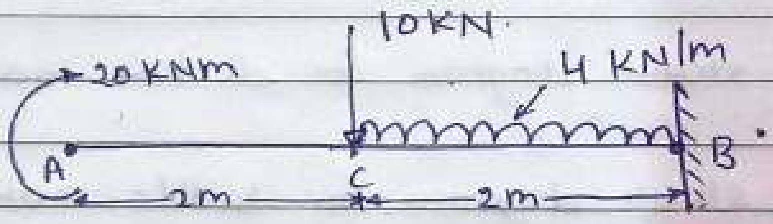
(a)



(b)

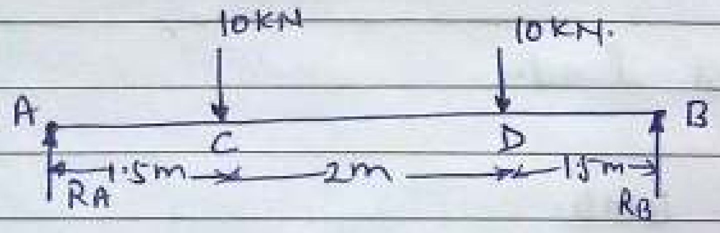


(c)

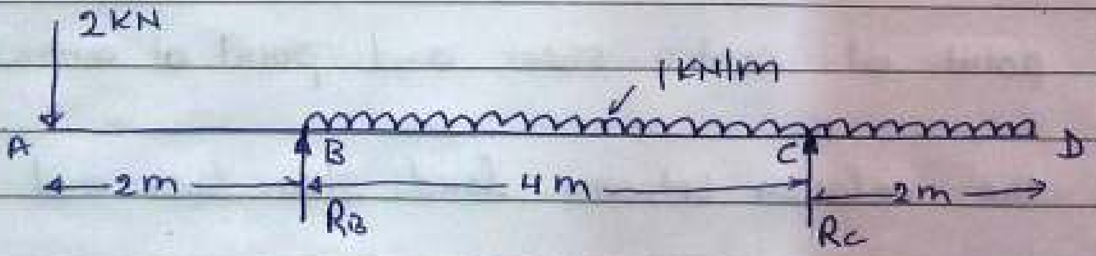


Ques. 2. Construct SFD and BMD for the given SSB:

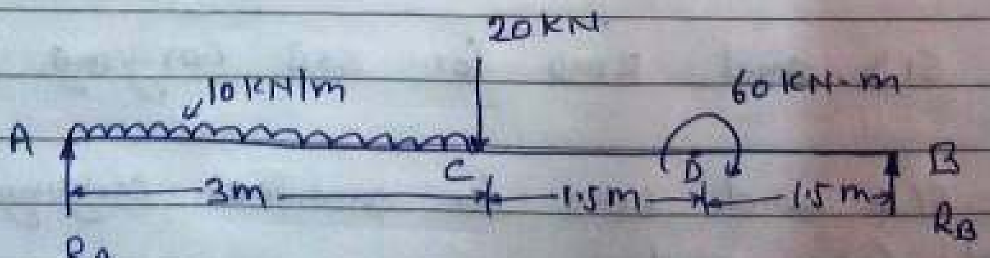
(a)



(b)



(C)



Date..........................

Q.1 State the types of load related to stress & strain.

Q.2. Define stress and state the different types of stress.

Q.3 Define strain and state the different types of strain.

Q.4 State Hooke's law, poisson's ratio, and factor of safety.

Q.5 Define three elastic constant. state relation E, G & K.

Q.6. Draw stress- strain diagram for ductile material.

Q.7 Draw stress - strain diagram for brittle material.

Q.8. Define beam. what are the various types of beam?

Q.9 State the types of load.

Q.10 Explain SFD and BMD.

Q.11 Define point of contra - shear and point of contraflexure.

Q.12 what is the relation between load, shear force and B.M.

Q.13 Construct SFD and BMD for SSB carrying point load.

Q.14 Construct SFD and BMD for SSB carrying UDL.

Q.15 Construct SFD and BMD for cantilever carrying point load at free end.

Q.16 Construct SFD and BMD for cantilever carrying UDL.

UNIT-2 IC ENGINE, REFRIGERATION & AIR CONDITIONING

Date.........................

LECTURE -10

HEAT:

Heat is a form of energy that can transmit from one body to another body as a result of difference in temperature. Heat flow takes place from hotter body to colder.

Heat neigther be created nor be distroyed, it can only transmit from one body to another.

Engine:

An engine is a device which transforms one form of energy into another form. The efficiency of conversion play an important role.

Heat Engine:

Heat engine is a device which transform the chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform usefull work. Thus thermal energy is converted into mechanical energy.

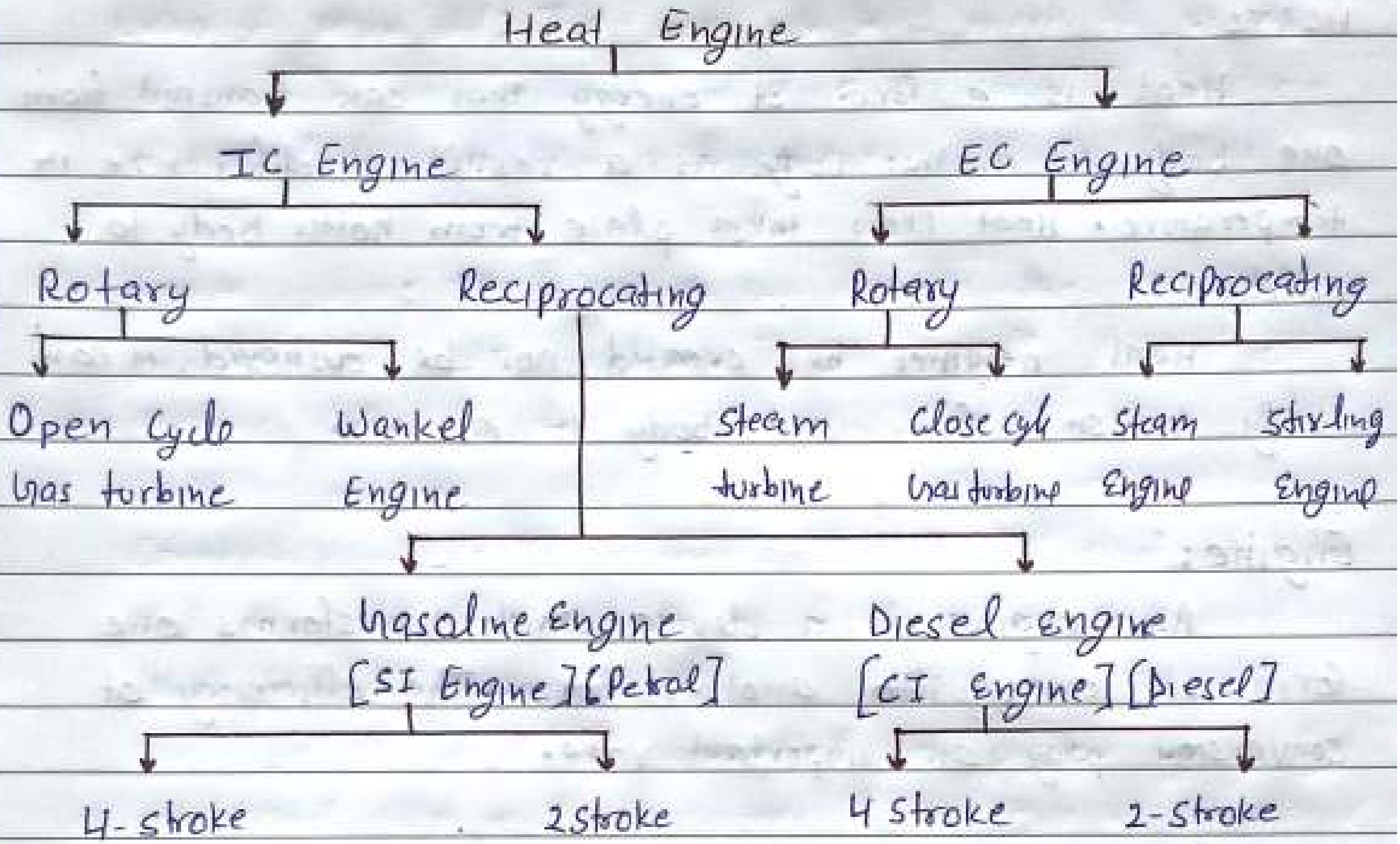
Heat engine can be broadly classified into two categories:

(i) Internal combustion engine [IC Engine]:

An IC engine is a heat engine in which the combustion of fuel occurs in a combustion chamber i.e. within the engine. Ex SI Engine, CI Engine

(ii) External combustion engine [EC Engine]:

An EC Engine is a heat engine in which the combustion of fuel takes place outside the engine. Ex. steam turbine.



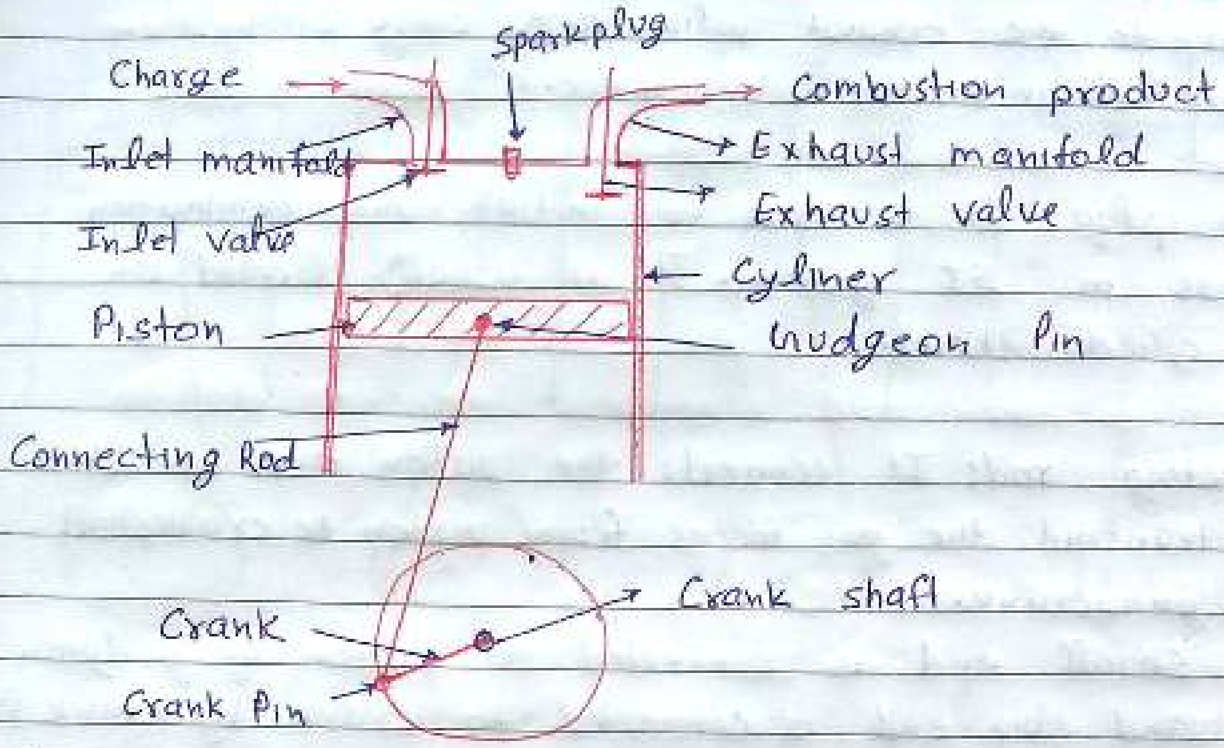
In this topic we will discuss

⇒ 4 stroke SI Engine
⇒ 4 stroke CI Engine
⇒ 2 stroke SI Engine
⇒ 2 stroke CI Engine.

→ 4 stroke and 2-stroke engine
→ SI and CI engine

SI → Spark Ignition. [Air-fuel mixture]
CI → Compression Ignition [fuel]

Basic Engine component and Nomenclature:



Cylinder: Cylinder is a vessel in which the piston makes reciprocating motion.

Piston: Piston is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system.

Piston Rings: These are fitted into the slots around the piston and provide a tight seal between the piston and the cylinder wall thus preventing leakage.

Combustion Chamber: The space between the cylinder head and the piston top during the combustion process is known as Combustion chamber (CC).

Inlet manifold: The pipe which connects the intake system to the inlet value of engine and through which charge is drawn into the cylinder is called inlet manifold.

Exhaust Manifold: The pipe which connect the exhaust system to the exhaust value and carry combustion of product into the atmosphere.

Spark plug: It is used to initiate the combustion process in SI system. It is usually located on the cylinder head.

Connecting rod: It connects the piston and crankshaft and transmit the gas forces from piston to crankshaft through crank.

Small end is connected to piston by gudgeon pin and big end is connected to crank by crank pin.

Crank shaft: It convert the reciprocating motion of piston into rotary motion of output shaft with the help of connecting road.

Nomenclature:

Cylinder bore: Inner diameter of cylinder (d)

Stroke: The distance through which piston moves from TDC to BDC or BDC to TDC. or IDC to ODC or ODC to IDC.

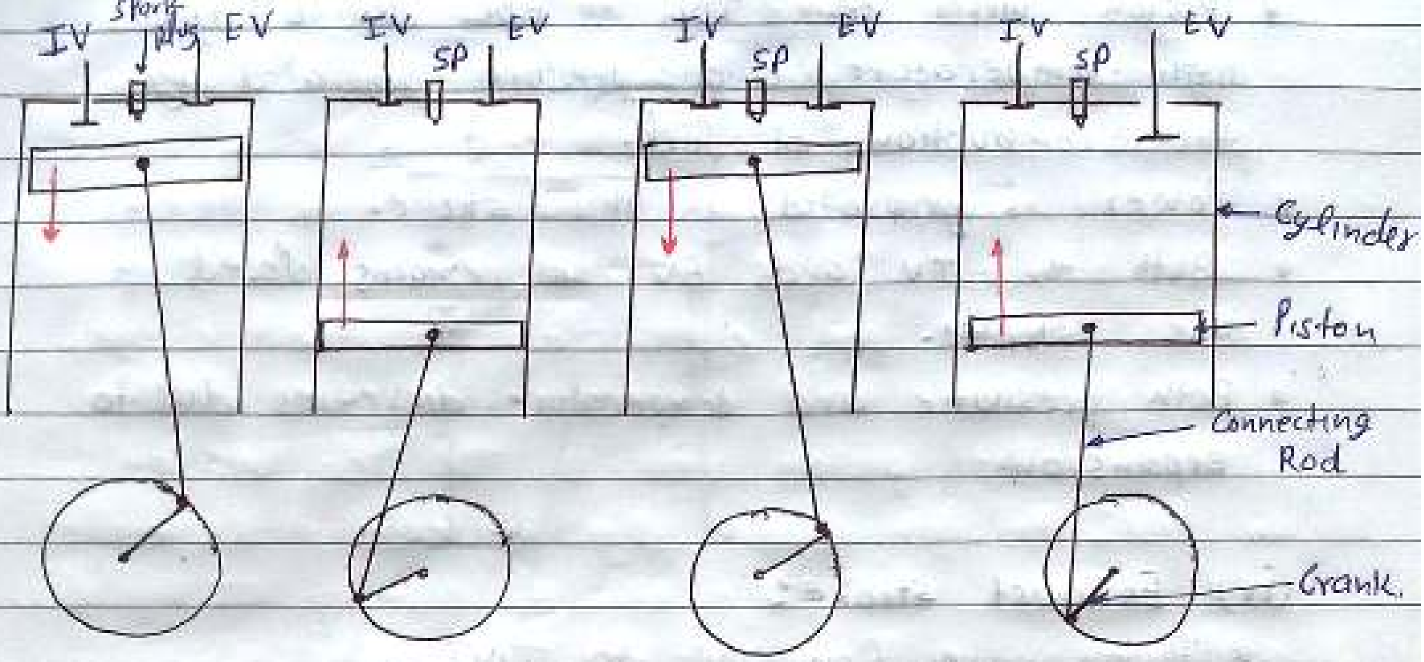
Swept volume: Volume swept by the piston in one stroke. $\boxed{V_s = \frac{\pi}{4} D^2 L}$

Clearence volume: Volume of CC above the piston when piston is at TDC.

Compression ratio: $r = \frac{V_T}{V_c} = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c}$

LECTURE-11

Construction and working of four stoke SI Engine:



In a four stroke engine, the cycle of operations is complited in four strokes of piston or two revalutions [720°] of crankshaft.

(i) Suction or Intake stroke:

* Piston moves from TDC to BDC.
* Inlet value (IV) opens. & Exhaust valve (EV) closed.
* Air-fuel mixture enters the cylinder through IV.

(ii) Compression stroke:

* Piston moves from BDC to TDC.
* Both IV and EV are closed.
* Air-fuel mixture compresses due to decreasing volume.
* Pressure and temperature of air-fuel mixture rises due to compression.
* At the end of compression when the piston at TDC spark initiated through spark plug.
* Combustion initiated at constant volume.

(iii) Expansion or Power stroke:

- * Piston moves from TDC to BDC due to the high temperature and pressure generated by the combustion of fuel.
- * Power is generated in this stroke.
- * Both the IV and EV ~~are~~ remains closed in this stroke.
- * Both pressure and temperature decreases due to expansion.

(iv) Exhaust stroke:

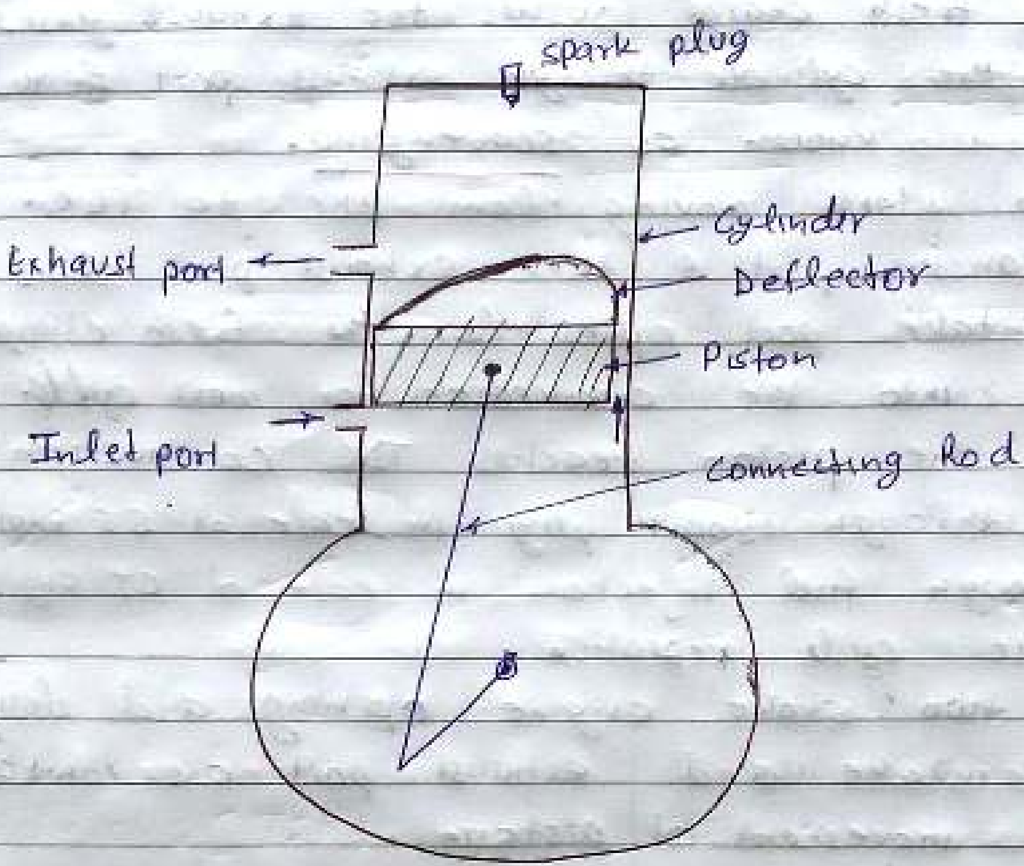
- * Piston moves from BDC to TDC.
- * IV closed & EV opens.
- * Pressure dicreses due to opening of EV & exhaust gases are swept by the piston to escape from the cylinder.

Construction and working of four stroke CI Engine:

- * four stroke CI Engine is similar to the four stroke SI Engine but it operates at a much highter compression ratio.
- * In the CI engine during suction stroke, air, instead of air-fuel mixture, is inducted.
- * Combustion is self initiated due to higher compression ratio.
- * fuel is injected at the end of compression stroke through a fuel injector placed at the cylinder head in place of spark plug.
- * fuel gets auto ignite due to high temperature and pressure.

LECTURE -12

Construction and working of two stroke SI Engine:



In two stroke engine the cycle is completed in one revolution (360°) of the crank shaft. The main difference between two stroke and four stroke engine is in the method of filling the fress charge and removing the burnt gases from the cylinder.

In two stroke engine ports are there in place of values as in four stroke engine.

Charge enters through inlet port and goes to crankcase. When combustion initiated piston moves from TDC to BDC due to high temp. & pressure generated by the combustion. When the piston moves from TDC to BDC, first exhaust port opens and exhaust gases starts scaping from the cylinder.

When the piston moves down transfer port opens & charge start entering in the cylinder from the crank case. ~~Thr~~

This fresh charge pushes the exhaust gases out of the cylinder through exhaust port & this process is known as scavenging.

Piston starts moving from BDC to TDC. first transfer port & then exhaust port closes and intake port opens for the fresh charge coming into the crankcase for next cycle.

When the piston reaches TDC combustion initiated(through spark plug in case of SI engine and through fuel injection in case of CI engine) and the cycle repeates.

In two stroke engine opening and closing of the intake and exhaust port are controled by the movement of piston.

Date.........................

Comparison of SI and CI Engine:

SI	CI
Works on otto cycle	Works on diesel cycle
Gasoline is used as a fuel	Diesel is used as a fuel
Air-fuel mixture is induced during the suction stroke	Only air is induced during suction stroke
Pressure range: 6 to 12 bar temp range: 250°c to 350°c	Pressure range: 35 to 40 bar temp range: 600°c to 700°c
Spark plug is used to ignite the fuel	Self ignition occurs due to high temp.
It is fitted with carburettor and spark plug.	It is fitted with fuel injection pump and injector
High speed engine	Low speed engine
Lower thermal efficiency	Higher thermal efficiency.
Light in weight.	Heavy in weight
The burning of fuel takes place at constant volume	The burning of fuel takes place at constant pressure.
widly used in automobile	Used in heavy vehicle ie buses, trucks etc

Comparison of two stroke and four stroke engines

Four stroke engine	Two stroke Engine
Cycle is completed in four stroke of piston or two revolution of crank shaft	Cycle is completed in two stroke of piston or one revolution of crank shaft.
Power is developed in two revolution of crank shaft	Power is developed in one revolution of crank shaft.
Heavy fly wheel is required	lighter flywheel is required
It have valves	It have port.
for the same power the engine is heavier	Engine is lighter and more compact.
Lesser cooling and lubrication required	Greater cooling and lubrication required.
Lower rate of wear & tear	Higher rate of wear and tear
Initial cost of the engine more	Initial cost is less.
Highter volumetric efficiency	lower volumetric efficiency
Thermal efficiency is higher part load efficiency is better	Thermal effeciency is lower, part load efficiency is poor.
Used where efficiency is important. Ex. Car, bus, truck	Used where low cost, compactness and light weight are important. Ex scooters,

Refrigeration:

Refrigeration may be defined as the process of removing heat from a substance under controlled condition.

It includes the process of reducing and maintaining the temp. of body below its surrounding temp.

Method of refrigerations:

1- By using ice or snow
2- Evaporative cooling process or adiabatic cooling process
3- Air refrigeration system
4- Simple vapour compression refrigeration system
5- Compound vapour compression refrigeration system
6- Vapour absorption refrigeration system.

Application of refrigeration:

It can be classified into six categories:

1- Domestic application
2- Commercial application
3- Industrial application
4- Marine
5- Air conditioning
6- Food preservation

Unit of refrigeration:

Unit of refrigeration is express as "Tonn" (TR).
One tonn of refrigeration is defined as amount of refrigeration effect produced by the melting of 1 tonne (1000kg) of ice from and at 0°C in 24 Hours.

$$1TR = \frac{1000 \times 335}{24} = 13958.3 \text{ KJ/hr}$$

$$= 232.6 \text{ KJ/min} = 3.877 \text{ KJ/sec}$$

Practically $\boxed{1TR = 210 \text{ KJ/min} = 3.5 \text{ KJ/sec} = 3.5 \text{ KW.}}$

Coefficient of performance of a Refrigerator:

Coefficient of performance [COP] is the ratio of heat extracted in the refrigerator to the work done on the refrigerator.

It is also known as theoretical COP.

Mathematically,

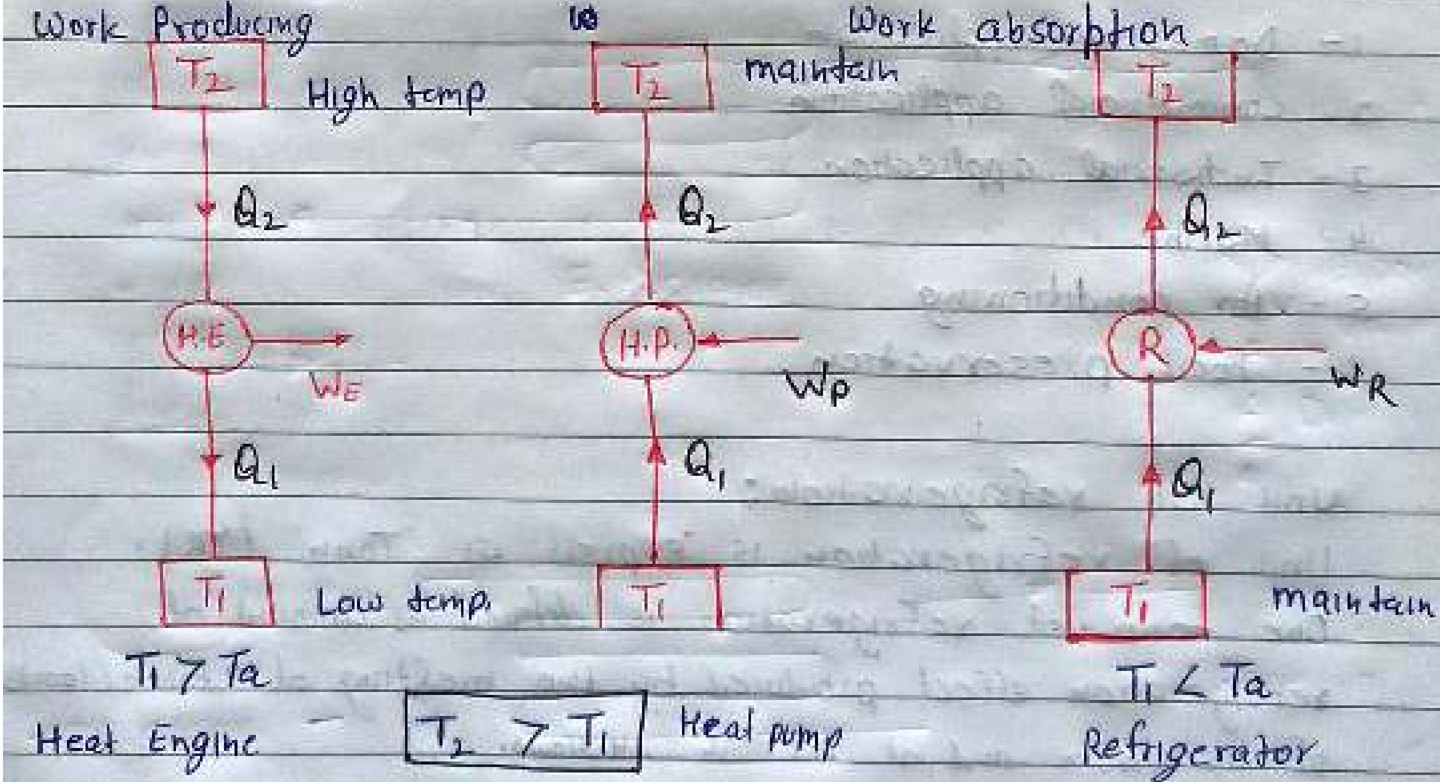
$$\boxed{COP = \frac{Q}{W}}$$

where,

Q → Amount of heat extracted in the refrigerator OR amount of refrigeration effect produced OR capacity of refrigerator.

W → Amount of work done.

Difference between a Heat engine, Refrigerator and Heat pump:



$$\boxed{W_E = W_R = W_P = Q_2 - Q_1}$$

Heat Engine: The heat supplied to the engine is converted into useful work.

Efficiency of an engine is given by

$$\eta_E = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{W_E}{Q_2} = \frac{Q_2 - Q_1}{Q_2}$$

$$\boxed{\eta_E = 1 - \frac{Q_1}{Q_2}}$$

Heat pump: Heat pump operates between hot body temp $(T_2]$ and atmospheric temp $(T_1 = T_a]$.

It extracts heat from a cold body (atmosphere) & delivers it to a hot body.

Heat pump is used for heating in winter.

$$(COP)_P = \frac{\text{Desire effect}}{\text{wok done}} = \frac{Q_2}{W_P} = \frac{Q_2}{Q_2 - Q_1}$$

$$\boxed{(COP)_P = \frac{Q_2}{Q_2 - Q_1}}$$

Refrigerator: Refrigerator operates between cold body temperature (T_1) and the atmospheric temp $(T_a = T_2]$.

It extracts the heat from cold body and delevering it to a hot body [atmosphere].

It is used for cooling in summer.

$$(COP)_R = \frac{\text{Desire effect}}{\text{Work done}} = \frac{Q_1}{W_R} = \frac{Q_1}{Q_2 - Q_1}$$

$$\boxed{(COP)_R = \frac{Q_1}{Q_2 - Q_1}}$$

$$(COP)_P = \frac{Q_2}{Q_2 - Q_1} = \frac{Q_2 - Q_1 + Q_1}{Q_2 - Q_1} = \underbrace{\frac{Q_2 - Q_1}{Q_2 - Q_1}} + \underbrace{\frac{Q_1}{Q_2 - Q_1}}$$

$$\boxed{(COP)_P = 1 + (COP)_R}$$

LECTURE -15

Construction & working of Domestic Refrigerator:

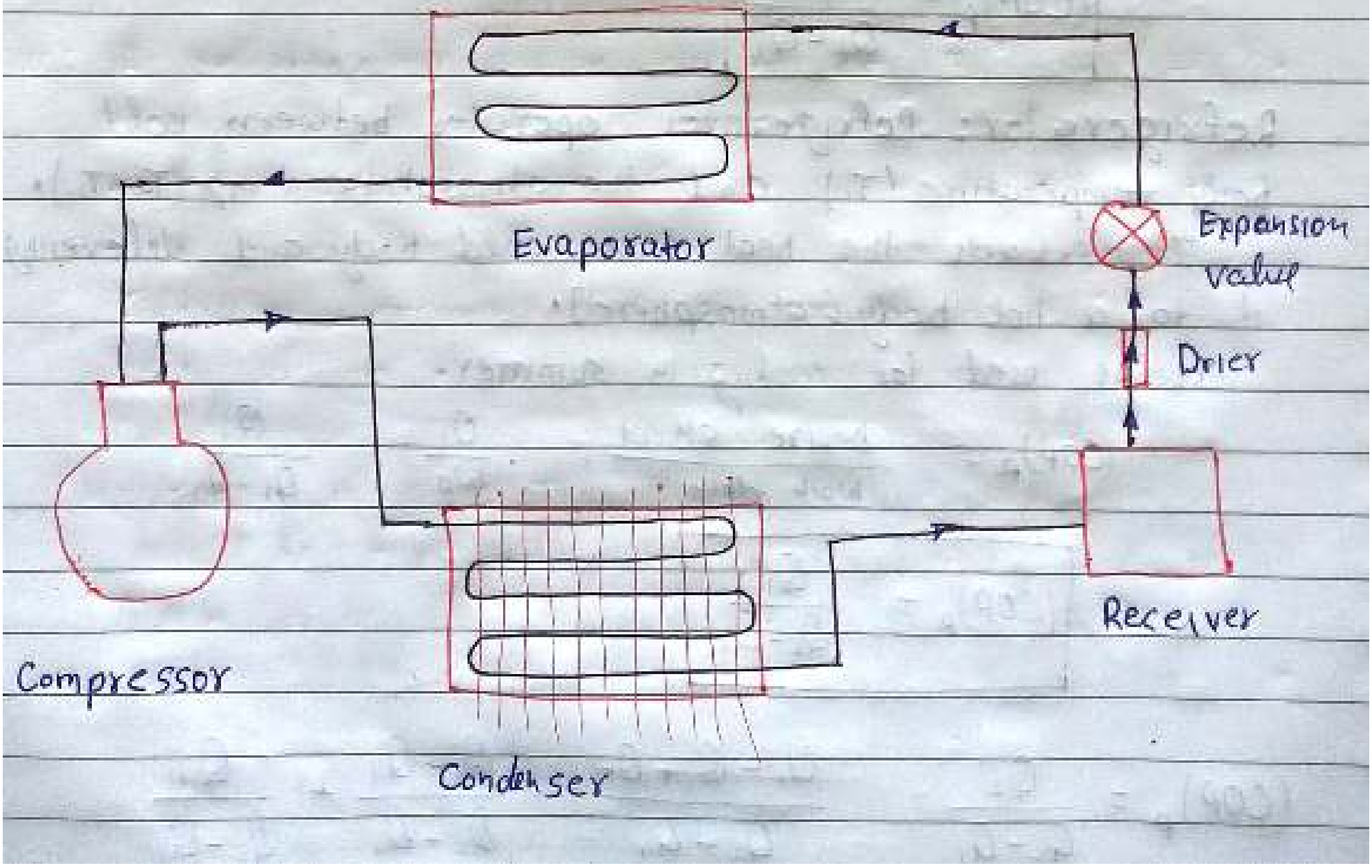
Domestic refrigerator is used for the preservation of food and formation of ice cubes.

Refrigerators are divided into two saperate compartments, one for general items and other for storage of frozen foods.

A storage temp. of 0°c to 4°c is satisfactory for the preservation of fresh food and the temp. in the freezer upto -15°c.

The freezers are generally provided at the top portion of the refrigerator space. In some refrigrators freezers are provided at bottom.

The refrigerators may be single door, double door top freezer, double door bottom breezer, and side by side door freezer. The double door refrigerators are very commonly used.



Working:

Domestic refrigerator works on vapour compression refrigeration system. The refrigerants used are generally R-12 or R-22.

Compressor: High temp, High Pr. vapour refrigerant.

The compressor is mounted at the bottom of refrigerator frame. The power of compressor can vary according to size of refrigerator.

Low pressure and low temp vapour refrigerent from evaporator drawn into the compresure, where it is compressed to a high pressure and temp vapour refrigerent & then discharge into condenser.

Condenser: High Pr., high temp liquid refrigrent.

Condenser is put at the back about 40 to 60 mm away from the cabinet. The condenser may be either chassis type or tube and wire type.

The high pressure and temp vapour refrigerant is cooled and condensed. The refrigerant give up its latent heat to the surrounding.

Expansion valve: The capillary tube is kept in contact with the evaporator inlet. A drier is connected between reciever & Evap.

The high pressure, high temp liquid refrigerant passes through capillary tube is converted into low pressure low temp liquid refrigerant.

Evaporator: The evaporator coil is wrapped arround the freezer. The cooling of lower space is accomplished by free convection (due to density dradient).

The low temp, low pressure liquid refrigerent is converted int low temp and low presure vapour refrigerent.

The refrigerator body is provided with good quality insulation in order to prevent heat transfer into the system.

Ques: Find the COP of a refrigeration system if the work input is 80KJ/kg and refrigeration effect produced is 160KJ/kg of refrigerant flowing.

Ques: A machine working on a carnot cycle operates between 305K and 260K. Determine COP. when it is operates as: 1- A refrigerator
2- A heat pump 3- A heat engine.

Ques A refrigeration cycle absorbs heat at 270K and rejects it at 300K. Calculate:
1- COP ; 2- If the cycle is absorbing 1130 KJ/min at 270K, how many KJ of work is required per second?
3- If refrigerator works as heat pump then find COP?
4- How many KJ/min will the heat pump deliver at 300K if it absorbs 1130 KJ/min at 270 K.

Ques: A refrigerating system operates at 35°C and -15°C. the capacity is to be 12 tonnes. Determine:
1- COP , 2- Heat reject from the system per hour 3- Power

LECTURE-16

Date.........................

Air Conditioning System:

This deals with the study of conditioning of air i.e. supplying and maintaining disirable internal atmospheric conditions for human comfort, irrespective of external condition.

The system which effectively controls temp of air, humidity of air, purity and motion of air to produce the desired effects upon the occupants of the space is known as an air "conditioning system".

Equipments used in an Air conditioning system:

1- Circulation fan
2- Air conditioning unit
3- Supply duct
4- Supply outlets
5- Return out lets
6- filters

Application of air conditioning system:

Air conditioning has numerous applications in industry. Air conditioning is required for provide comforts to the workers, preserve food during storage and transportation, drying of products, necessary low temp conditions required for manufacturing of certain products.

Some industrial applications are:

1- Textile industry
2- Photographic industry
3- Printing industry
4- food industry

Comfort conditions [Human comfort][comfort air conditioning]:
Human confort depend upon physiological and phychological condition. Thus it is difficult to define the term human confort:

According to ASHRAE [American Society of Heating Refrigeration and Air conditioning Engineers] "Human comfort is that condition of mind, which expresses satisfection with the thermal environment".
four important factors for comfort air conditioning are as below:

1- Temperature of air: It may be noted that human being feels comfortable when the air temp. is 21°c to 30°c.

2- Humidity of air: The control of humidity means the decreasing or increasing of moisture contents of air.

In general, for summer air conditioning the relative humidity should not be less than 60% whereas for winter air conditioning it should not be more than 40%.

3- Purity of air: It is thus obvious that proper filtration, cleaning and purification of air is essential to keep it free from dust and other impurities.

4- Motion of air: It is necessary that there should be equi- distribution of air through out the space to be air conditioned.

Psychrometry:

The psychrometry is that branch of engineering science which deals with the study of moist air i.e. dry air mixed with water vapour or humidity.

Dry air: The pure dry air is a mixture of a number of gases such as nitrogen, oxygen, hydrogen, argon etc.

Moist air: It is a mixture of dry air and water vapour.

Saturated air: It is a mixture of dry air and water vapour when the air has diffused the maximum amount of water vapour into it.

Humidity: It is the mass of water vapour present in 1kg of dry air, expressed in terms of "gm/kg of dry air". It is also called "specific humidity" or "humidity ratio".

$$\boxed{W = m_v / m_a}$$

Absolute humidity: It is the mass of water vapour present in 1 m^3 of dry air, expressed in terms of "gm/ m^3 of dry air".

Relative humidity: It is the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temp. and pressure. It is written as RH.

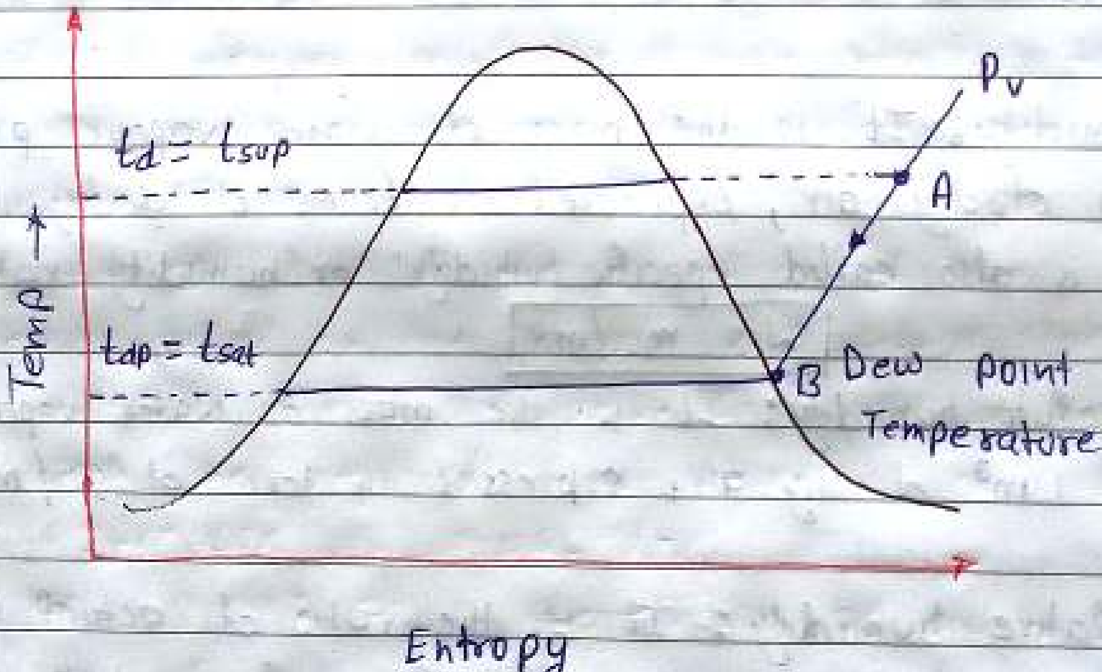
$$\boxed{\phi = \frac{m_v}{m_s} = \frac{p_v}{p_s}}$$

Dry bulb temperature: It is the temp of air recorded by a thermometer, when it is not affected by the moisture present in the air; briefly written as DBT & denoted by t_d or t_{db}.

Wet bulb temperature: It is the temperature of air recorded by a thermometer when its bulb is surrounded by a wet cloth exposed to air, briefly written as 'WBT' & denoted by t_w or t_{wb}.

Dew point temperature: It is the temp. of air recorded by a thermometer, when the moisture (water vapour) present in it begains to condense. It is denoted by t_{dp}.

NOTE: For saturated air, the dry bulb temp, wet bulb temp and dew point temp is same.



Psychrometer: Psychrometer is used to measure dry bulb temperature and wet bulb temperature. It consist of a dry bulb thermometer and wet bulb temperature thermometer side by side.

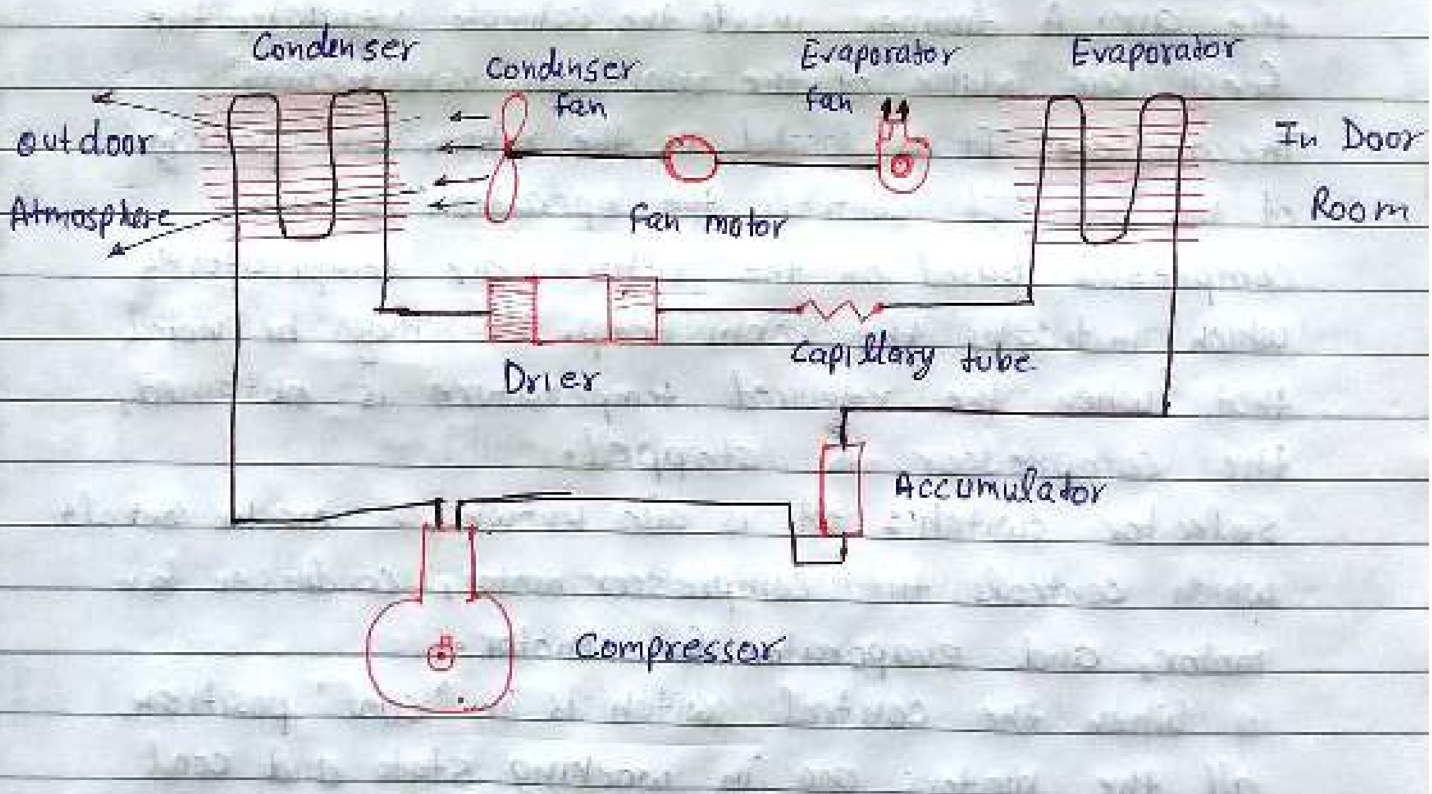
LECTURE-18

Construction and working of room air conditioner:

A room air conditioner is a compoct, self contained air conditioning unit which is normally installed in a window or wall opening.

A complete unit of a room air conditioner consists of a refrigeration system, the contoal system (thermostate and selector switch), electrical protection system (motor overload switches and winding protection thermostate on the compressor motor), air circulation system (fan motor, centrifugal evaporator blower), ventilation (fresh air damper) and exhaust system.

Its working on vapour compression cycle. The refrigerant used is R-12 and R-22.



Compressure: Air conditioner system consists of a hermetic type compressor, a winding thermostate is embedded in the compressor motor windings. It puts off the compressor if the winding temp. exceeds the safe limit, thus protecting the winding against high temperature.

Condenser: A condenser is a continuous coil made of copper tubing with aluminium fins attached to it to increase the heat transfer rate [rejecting heat to atmosphere]. A propeller type fan provides the necessary air to cool the refrigerent and also exhausts air from the air-conditioned space when exhaust damper is opened.

Evaporator: The evaporator is a cooling coil also made of copper with aluminium fins attached to it to increase the heat transfer rate (taking in heat from the room air). Evaporator faces the room.

A filter is installed on the fresh air entering side of the evaporator to remove any dirt from the air. A damper inside the cabinate regulates the fresh air intake of the room air conditioner.

Thermostate: It is located in the return air passage of the unit. It contrals the operation of the compressor based on the return air temperatore, which indicates the room temp. It may be noted that when the required temperature is obtained, the compressor is stopped.

Selector switch: It is also known as master contral, which controls the compressor motor, condenser fan motor, and evaporator fan motor.

When the contral switch is in "cool" position, all the motors are in working state and cool air is supplied to the room.

When the contral switch is in "ventilate" position, only evaporator blower motor operates.

Q.1. Define heat engine. State types of heat engine.

Q.2. Explain basic components of engine.

Q.3 Construction and working of four stroke SI Engine.

Ques.4 Difference between 4-stroke and 2-stroke engine.

Q.5 Difference between SI and CI Engine.

Q.6 Define scavenging process.

Q.7 Explain electric and hybrid electric vehicle.

Q.8 Define the terms: refrigeration, unit of refrigeration, & COP.

Q.9. Difference between heat engine, refrigerator and heat pump.

Q.10 Explain construction and working of domestic refrigerator.

Q.11 Define air conditioner and human comfort condition.

Q.12. Define the terms: humidity, absolute humidity & relative humidity.

Q.13. Define dry bulb temp, wet bulb temp and dew point temp.

Q.14 Explain construction and working of window air conditioning.

Q.15 Explain construction and working of two stroke engine.

UNIT-3 FLUID MECHANICS & FLUID MACHINERY

LECTURE-19

Date...................

Fluid Mechanics:

It is that branch of science which deals with the behaviour of fluid (liquid or gas) at rest as well as in motion.

Properties of fluid:

1- Density or mass density:

It is defined as the ratio of the mass of a fluid to its volume.

It is denoted by ρ.

Its unit is kg/m^3.

Mathematically $\boxed{\rho = \frac{m}{V}}$ mass per unit volume.

$\Rightarrow \rho = 1000\ kg/m^3$ for water.

2- Specific weight or weight density:

It is the ratio of the weight of a fluid to its volume.

It is denoted by 'w'.

Its unit is N/m^3.

Mathematically, $w = \frac{W}{V} = \frac{m \cdot g}{V} = \rho \cdot g$

$$\boxed{w = \rho \cdot g}$$

3- Specific volume: It is defined as the volume of a fluid occupied by a unit mass.

It is the reciprocal of mass density. It is expressed as m^3/kg.

$$\text{specific volume} = \frac{V}{m} = \frac{1}{m/V} = \frac{1}{\rho}$$

4- Specific gravity: It is defined as the ratio of weight density (density) of a fluid to the weight density (density) of a standard fluid.

for liquid: Standard fluid is water.

for gases: Standard fluid is air.

→ It is also called relative density.

→ It is denoted by S.

→ It is dimensionless quantity.

NOTE: 1 litre = 10^{-3} m^3

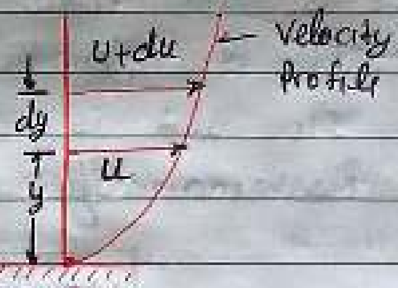
Density of water = 1000 kg/m^3

Viscosity: It is defined as the property of a fluid which offers resistance to the movement of one layer of fluid to another adjacent layer of the fluid.

It is of two types:

1- Dynamic viscosity:

when two layers of fluid, a distance 'dy' apart, move one over the other at different velocities, say u and u+du,



The viscosity together with relative velocity causes a shear stress acting between the fluid layers.

This shear stress is proportional to the rate of change of velocity with respect to y. It is denoted by 'τ'.

Mathematically $\tau \propto \frac{du}{dy}$

$$\boxed{\tau = \mu \frac{du}{dy}}$$

The constant of proportionality (μ) is known as coefficient of dynamic viscosity or simply viscosity.

So,

$$\boxed{\mu = \frac{\tau}{du/dy}}$$

Dynamic viscosity is defined as the shear stress required to produce unit rate of shear strain.

It unit is N.s/m^2. [SI unit]

Another unit of viscosity is Poise. [CGS unit]

$$\boxed{1 \text{ Poise} = \frac{1}{10} \text{ N-s}/m^2}$$

Kinematic viscosity: It is defined as the ratio of dynamic viscosity to density of fluid.

It is denoted by 'ν'.

Its unit is m^2/s in SI and stoke in CGS.

$$\boxed{1 \text{ stoke} = 10^{-4} \ m^2/s.}$$

mathematically, $\boxed{\nu = \frac{\mu}{\rho}}$

Newton's law of viscosity:

It state that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain. The constant of proportionality is called the coefficient of viscosity.

$$\tau \propto \frac{du}{dy}$$

$$\boxed{\tau = \mu \frac{du}{dy}}$$

LECTURE: 20

Types of fluid:

Fluid may be classifed into the following types.

1- Ideal fluid:

A fluid which is incompressible and is having no viscosity, is known as ideal fluid.

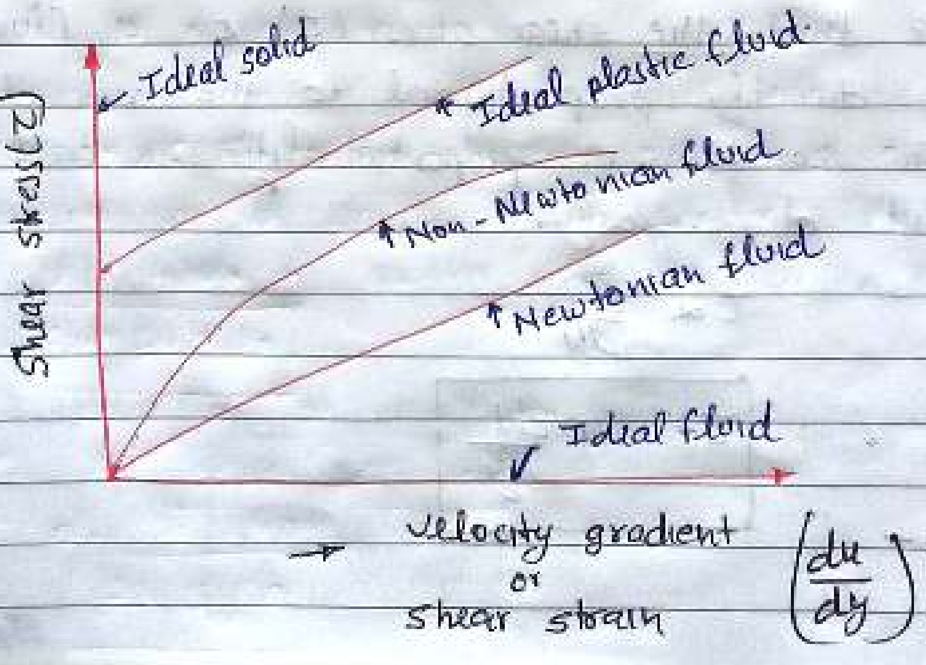
Ideal fluid is only an imaginary fluid as all the fluid which exist, have some viscosity.

2- Real fluid: A fluid which possesses viscosity, is known as real fluid.

All the fluid in actual practice are real fluid.

3- Newtonian fluid: A real fluid, in which the shear stress is directly proportional to rate of shear stain. i.e. fluids which obey Newton's law of viscosity, are known as newtonian fluid.

4- Non Newtonian fluid: A fluid, in which the shear stress is not directly proportional to rate of shear strain i.e. fluid which do not obey newton's law of viscosity, is known as non-newtonian fluid.



Fluid pressure at a point:

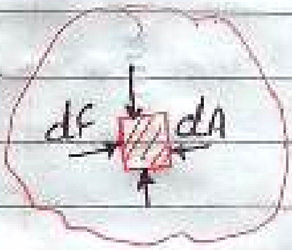
Consider a small area 'dA' in large mass of fluid, then the force exerted 'df', by the surrounding fluid on 'dA' will always perpendicular to the surface dA.

Then the ratio of 'df/dA' is known as intensity of pressure or simply pressure.

It is denoted by 'p'.

Mathematically,

$$\boxed{p = \frac{df}{dA}}$$



If force (F) is uniformally distributed over the area(A) then

$$\boxed{p = \frac{F}{A}}$$

Unit of pressure is N/m^2 or Pascal (Pa)

$$\boxed{\begin{array}{l} 1 Pa = 1 N/m^2 \\ \hline 1 MPa = 1 N/mm^2 \end{array}}$$

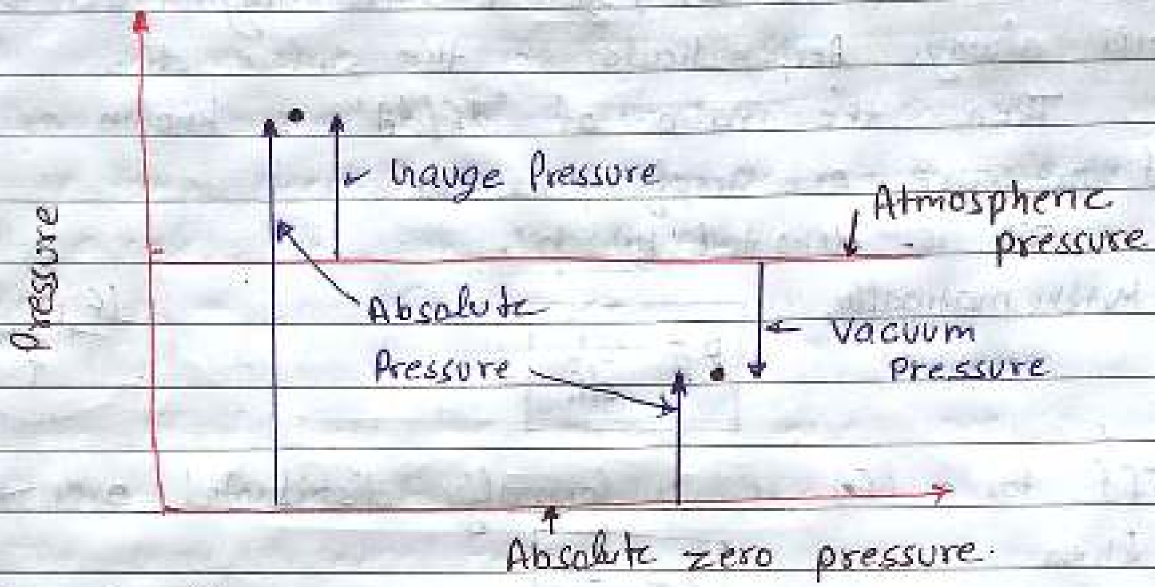
Measurement of Pressure [Absolute, Gauge, Atmospheric and vaccuum pressure]:

The pressure on a fluid is measured in two different systems. In one system, it is measured below atmospheric pressure (Vaccuum) & other is above atmosphoric pressure.

1- Absolute pressure: It is defined as the pressure which is measured with reference to absolute vacuum pressure.

2- Gauge pressure: It is defined as the pressure which is measured with the help of a pressure meaning instrument in which the atmospheric pressure is taken as datum. The atmp pressure on the scale is marked as zero.

3- Vacuum pressure: It is defined as the pressure below the atmospheric pressure.



Mathematically,

Absolute pressure = Atmospheric pressure + Gauge Pressure

$$\boxed{P_{abs} = P_{atm} + P_{gauge}}$$

Vacuum pressure = Atmospheric pressure − Absolute pressure

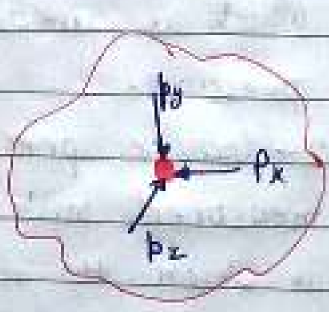
$$\boxed{P_{vac} = P_{atm} - P_{abs}}$$

→ Atmospheric pressure is taken as 101.3 KN/m^2 or $1.013 \times 10^5 \text{ N/m}^2$ or 1.013×10^5 Pa or 10.13 N/cm^2.

→ Atmospheric pressure ~~head~~ is 760 mm of Hg or 10.33 m of water.

Pascal's Law: It state that the pressure or intensity of pressure at a point in a static fluid is equal in all direction.

$$\boxed{p_x = p_y = p_z}$$



Pressure at any point 'A' at a height of 'h' from free surface

$$\boxed{p = \rho g h}$$

LECTURE: 21

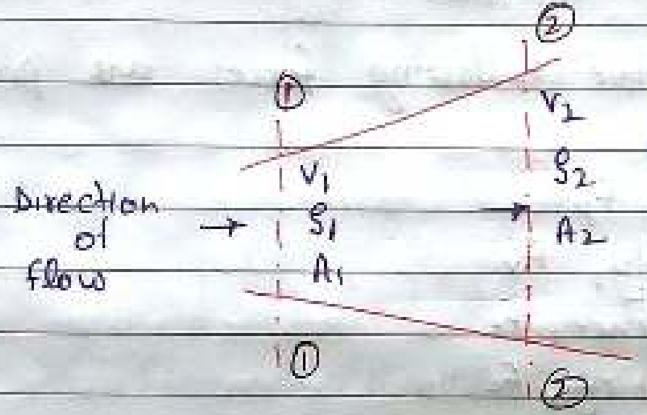
Date.......................

Continuity Equation:

Continuity equation is derived for kinematics of flow, which deals with motion of particles without considering the forces causing the motion. ($\overset{\text{study}}{S}$, V, and a only)

The equation based on the principle of conservation of mass is called continuity equation.

Thus for a fluid flowing through the pipe at all the cross section, the quantity of fluid per second is constant.



Fluid kinematics
- → Lagrangian approach
  (Video) Obserb motion of each partcl wrt time from original Position. $\vec{s} = f(x_0, y_0, z_0, t)$
- → Eulerian approach
  (Picture) (Instantanious behaviour of fluid)

Consider two cross sections of a pipe as shown in fig

Let V_1 → Average velocity at cross section 1-1

ρ_1 → Density at section 1-1

A_1 → Area at section 1-1

and V_2, ρ_2, A_2 are corresponding values at section 2-2

Then rate of flow at section 1-1 $= \rho_1 A_1 V_1$

& rate of flow at section 2-2 $= \rho_2 A_2 V_2$

According to law of conservation of mass

Rate of flow at section 1-1 = Rate of flow at section 2-2

$$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2}$$

This equation is applicable to the compressible as well as incompressible fluids & is called continuity equation.

If fluid is incompressible then $\rho_1 = \rho_2$, So

$$\boxed{A_1 V_1 = A_2 V_2}$$

LECTURE: 22

Dynamics of fluid flow:

It is the study of fluid motion with the forces causing flow. The fluid is assumed to be incompressible and non-viscous.

Dynamic behaviour of fluid flow is analysed by the newton's second law of motion, which relates the acceleration with the forces.

$$\boxed{F_x = m a_x}$$

In the fluid flow, the fallowing forces are present.

(1) Gravity force, F_g

(2) The pressure force, F_p

(3) Force due to viscosity, F_v

(4) Force due to turbulence, F_t

(5) Force due to compressibility, F_c

Thus the net force.

$$\boxed{F_x = F_g + F_p + F_v + F_t + F_c}$$

<u>NOTE:</u> (A) If F_c, is negligible then resultant equations of motion are known as Reynold's equation of motion.

$$\boxed{F_x = F_g + F_p + F_v + F_t}$$

(B) If F_t is negligible then resultant equations of motion are known as Navier-stokes Equation.

$$\boxed{F_x = F_g + F_p + F_v}$$

(C) If the flow is assumed to be Ideal, F_v is zero then resultant equations of motion are known as Euler's equation of motion.

$$\boxed{F_x = F_g + F_p}$$

Differential form of Euler's eq. → $\frac{dP}{\rho} + g\,dz + V\,dV = 0$

Bernoulli's equation:

Assumptions

(i) The fluid is ideal ie viscosity is zero

(ii) The flow is steady

(iii) The flow is incompressible

(iv) The flow is irrotational

Bernoulli equation is drived using Euler's equation of motion. ie

$$\boxed{\frac{\delta P}{\rho} + gdz + vdv = 0}$$ Euler's equation.

Bernoulli's equation is obtain by integrating Euler's eq.

$$\int \frac{\delta P}{\rho} + \int gdz + \int vdv = \text{constant}$$

If flow is incompressible, ρ is constant then.

$$\frac{P}{\rho} + gz + \frac{v^2}{2} = \text{constant}$$

$$\boxed{\frac{P}{\rho g} + \frac{v^2}{2g} + z = \text{constant}}$$

This is called ~~Euler's~~ Bernoulli's equation of motion. in which

$\frac{P}{\rho g}$ → Pressure energy per unit weight of fluid
OR pressure head
work required to maintain the flow/weight

$\frac{v^2}{2g}$ → Kinetic energy per unit weight or kinetic head

z → Potential energy per unit weight or potential head.

So $\boxed{\text{Pressure head + Kinetic head + potential head = constant}}$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

Bernoulli's equation for real fluid:

The Bernoulli equation for real fluid between point 1 and 2 is given as

$$\boxed{\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_L}$$

where

h_L → loss of energy between point 1 and 2.

Practical applications of Bernoulli's equation:

Bernoulli equation is applied in all problems of incompressible fluid flow where energy considerations are involved.

Its practical application to the following measuring devices.

1- Venturimeter
2- Orifice meter
3- Pitot tube.

Cd, Cc and Cv are the coefficient of venturimeter, contraction or orifice meter and pitot tube respectively

$$(Cd)_{orific} << (Cd)_{venturi}$$

$$E_1 = E_2 + E_L$$

$$\frac{E_1}{\rho g} = \frac{E_2}{\rho g} + h_L$$

i.e. $$\boxed{h_L = \frac{E_{in} - E_{out}}{\rho g}}$$

Ques.1: Calculate specific weight, density and specific gravity of one litre of a liquid which weights 7 N.

Ques.2: A flat plate of area 1.5×10^6 mm^2 is pulled with a speed of 0.4 m/s relative to another plate located at a distance of 0.15 mm from it. Find the force and power required to maintain this speed, if the fluid separating them is having viscosity as 1 Poise.

Ques.3 Calculate the pressure due to a column of 0.3m for

(a) water, take density of water $\rho = 1000$ kg/m^3

(b) an oil of specific gravity 0.8.

(c) mercury of specific gravity 13.6.

Ques.4. What are the gauge pressure and absolute pressure at a point 3m below the free surface of a liquid having a density of 1.53×10^3 kg/m^3. If the atmospheric pressure is equivalent to 750 mm of mercury? The specific gravity of mercury is 13.6 and density of water is 1000 kg/m^3.

Ques.5 A 30Cm diameter pipe, conveying water, branches into two pipes of diameters 20Cm and 15Cm respectively. If the average velocity in the 30Cm diameter pipe is 2.5 m/s. find the discharge in this pipe. Also determine the velocity in 15Cm pipe if the average velocity in 20Cm diameter is 2 m/s.

Ques.6. The water is flowing through a pipe having diameters 20Cm and 10Cm at sections 1 and 2 respectively. The rate of flow through pipe is 35 liters/s. The section 1 is 6m above datum and section 2 is 4m above datum. If the pressure at section 1 is 39.24 N/cm^2, find the intensity of pressure at section 2.

LECTURE:23

Hydraulic Machine:

Hydraulic machine are defined as those machines which converts either hydraulic energy (energy possed by water) into mechanical energy (which is further converted into electrical energy) or mechanical energy into hydraulic energy.

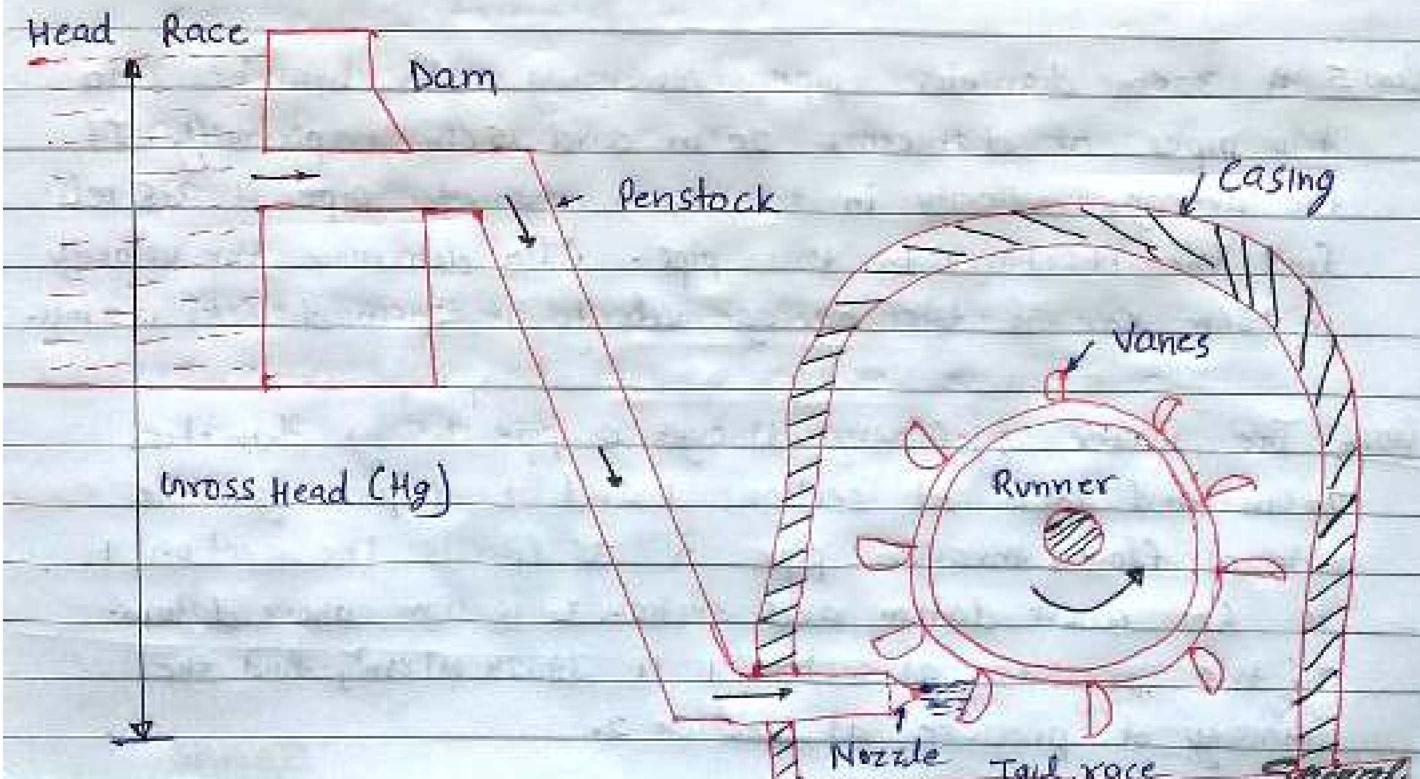
Turbines converts hydraulic energy into mechanical energy.

Pumps converts mechanical energy into hydraulic energy.

Turbines: Turbines are defined as the hydraulic machines which convert hydraulic energy into mechanical energy which is further converted into electrical energy.

The electric power which is obtained from the hydraulic energy (energy of water) is known as Hydro-electric power.

- Construction & working principle of turbine:



Hydro-electric power plant consists of

(i) A dam constructed across a river to store water.

(ii) Pipes of large diameter called pen stocks, which carry water under pressure from the storage reservoir to the turbines.

(iii) Turbines having different types of vanes fitted to the wheels.

(iv) Tail race, which is a channel carries water away from the turbines after the water has worked on the turbines.

Working Principle:

The liquid comes out in the form of a jet from the outlet of a nozzle through penstock, which is fitted to the dam through which the liquid is flowing under pressure. ~~Nozzle is fitted at the~~ vanes of the wheel are placed in the path of the jet, a force is exerted by the jet on the plate. This force is obtained from Newton's second law of motion or from Impulse-momentum equation.

If the vanes or wheel is stationary then work done by the jet is zero ie no work done on the vanes.

If wheel is moving then the work done on the wheel rotate it which is coupled with shaft. Thus hydraulic energy is converted into mechanical energy.

The force exerted by the jet on the vanes.

F = Rate of change of momentum in the direction of force

$$\boxed{F = \rho A V^2}$$

Work done per second by the jet on the vanes

$$\boxed{W = \rho A V^2 \cdot u}$$

Classification of Hydraulic turbines:

The following are the important classification of the turbines:

1- According to type of energy at inlet:

(a) Impulse turbine: Only kinetic energy available at the inlet of the turbine. Ex- Pelton wheel.

(b) Reaction turbine: If kinetic energy as well as pressure energy available at the inlet of the turbine. Ex - francis turbine, kaplan turbine

2- According to the direction of flow through runner:

(a) Tangential flow turbine: Water is flowing along the tangent of the runner.

(b) Radial flow turbine: If the water flows in the radial direction through the runner.
If the water is flows from outwards to inwards radially, the turbine is known as inward radial flow turbine. Ex: francis turbine.
If the water is flows radially inwards to outwards, the turbine is known as outward radial flow turbine.

(c) Axial flow turbine: If the water flow through the runner along the direction parallel to the axis of rotation of the runner. Ex: Kaplan turbine.

3- According to the head at the inlet of turbine:

(a) High head turbine: Above 250m. Ex: Pelton

(b) Medium head turbine: 60m - 250m. Ex: Francis

(c) Low head turbine: Below 60m. Ex: Kaplan

4- According to the specific speed of the turbine:

(a) Low specific speed turbine: Below 50, Ex - Pelton

(b) Medium specific speed turbine: 50 - 300, Ex- Francis

(c) High specific speed turbine: Above 300, Ex - Kaplan.

Efficiency:

Turbine converts hydraulic energy into mechanical energy.

Power supplied at inlet [Hydraulic power or water power]
(W.P.)

↓ → Hydraulic efficiency $\boxed{(\eta_h) = \frac{R.P.}{W.P.}}$

Power delivered to runner [Runner power]
(R.P.)

↓ → Mechanical efficiency $\boxed{(\eta_m) = \frac{S.P.}{R.P.}}$

Power at the shaft of the turbine [Shaft power]
(S.P.)

↓

$$\boxed{\eta_o = \eta_m \times \eta_h = \frac{S.P.}{W.P.}}$$

Electric power

LECTURE:25

Pumps:

The hydraulic machines which convert the mechanical energy into hydraulic energy [Pressure energy] are called pumps.

Pumps converts mechanical energy [shaft power] into impeller power, this impeller power is converted into manometric head ie water power.

Power is decreases from shaft of the pump to impeller and then to the water.

$$\text{E.P.} \longrightarrow \text{S.P.} \underset{\downarrow \atop \text{mechanical efficiency}(\eta_m)}{\longrightarrow} \text{I.P.} \underset{\downarrow \atop \text{Manometric efficiency }(\eta_{man})}{\longrightarrow} \text{W.P. (Head)}$$

$$\boxed{\eta_{man} = \frac{W.P.}{I.P.}}$$

$$\boxed{\eta_m = \frac{I.P.}{S.P.}}$$

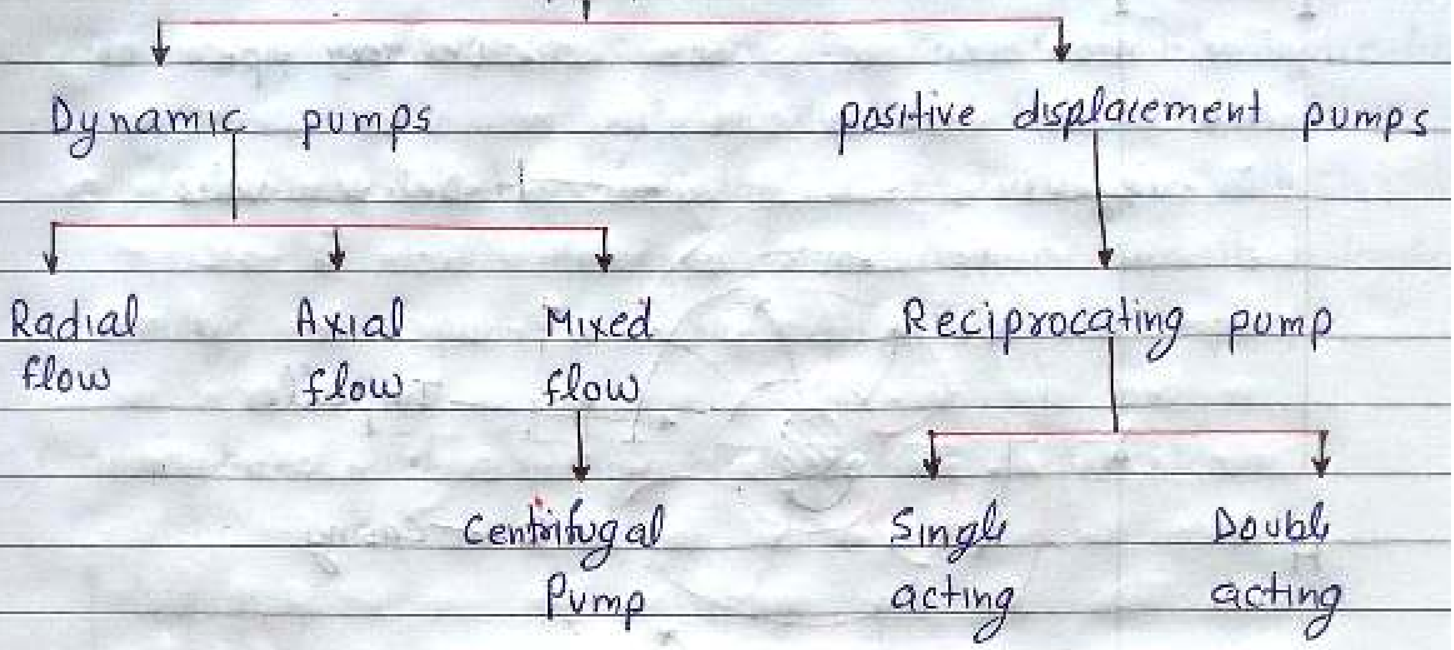
$$\boxed{\eta_o = \frac{W.P.}{S.P.}}$$

NOTE:

(i) For high head pumps are connected in series.

(ii) For obtaining high discharge the pump should be connected in parallel.

Classification of pumps:



Here we discuss in detail construction and working principle of centrifugal pump and reciprocating pump.

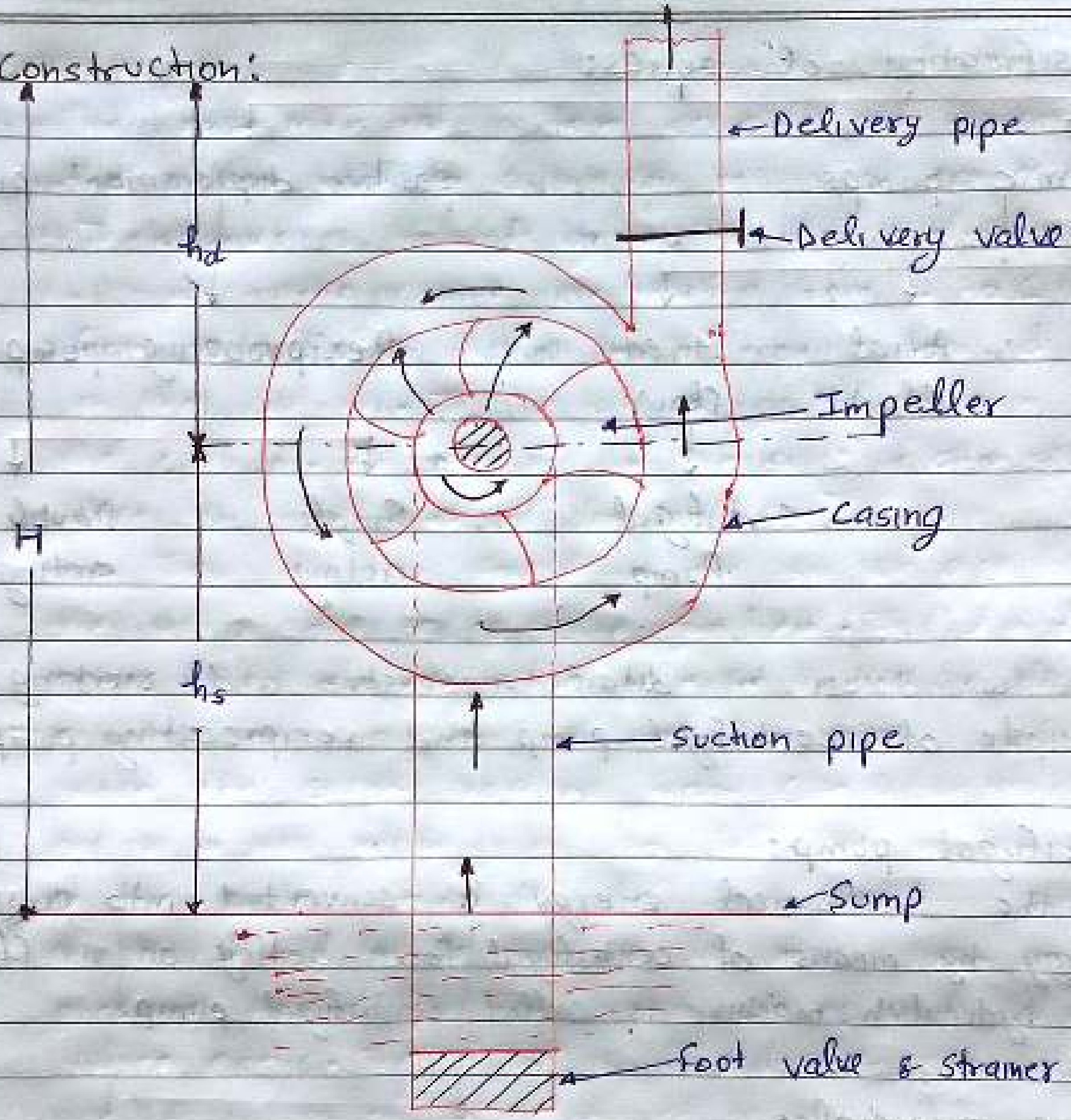
Centrifugal pump:

If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulich machine is called centrifugal pump.

Working principle:

Centrifugal pump acts as a reverse of inward flow reaction turbine. The centrifugal pump works on principle of forced vortex flow which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place. The rise in pressure head at any point of the rotating liquid is proportional to the square of tangential velocity of the liquid at that point i.e. rise in pressure head = $\frac{V^2}{2g}$ or $\frac{r^2\omega^2}{2g}$.

Construction:



The main part of a centrifugal pump are:

1- Impeller: It is the rotating part which consists of a series of curved vanes.

2- Casing: It is an air tight passage surrounding the impeller & designed in such a way that kinetic energy is converted into pressure energy.

3- Suction pipe with a foot valve and a strainer: Suction pipe is connect inlet of the pump to water sump. A foot valve opens only in the upward direction (one way valve)

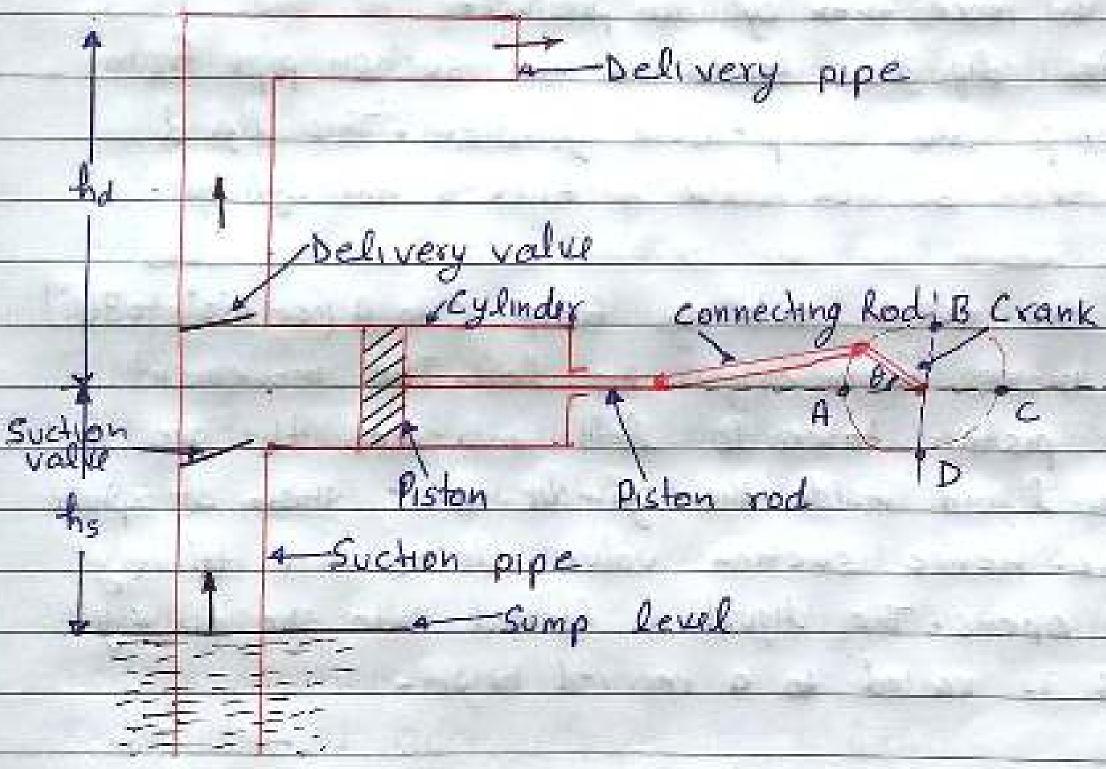
4- Delivery pipe: One end is connected to the outlet of the pump and other end delivers the water at a required height

LECTURE:26

Reciprocating pump:

If the mechanical energy is converted into hydraulic energy [pressure energy] by sucking the liquid into a cylinder in which a piston is reciprocating, which exerts the thrust on the liquid and increase its hydraulic energy, the pump is known as reciprocating pump.

Constouction and working of Reciprocating pump:



Main parts of the reciprocating pump

1- A cylinder with a piston, piston rod, connecting rod and a crank.
2- Suction pipe: Connected between sump to cylinder.
3- Dileivery pipe: Conected between cylinder & delivery point.
4- Suction valve: fitted in suction pipe
5- Delivery valve: fitted in delivery pipe

valves are one way valve which allowed water only upward direction.

Sairal

Working:

The movement of piston is obtained by connecting the piston rod to crank by means of connecting rod. The crank is rotated by means of an electric motor.

When the crank is rotating from A to C (ie from 0 to 180°), the piston is moving toward right in the cylinder. This creates a partial vacuum in the cylinder. But pressure in the sump is atmospheric which is more than cylinder pressure.

Thus liquid is forced in the suction pipe from the sump due to pressure gradient. This liquid opens the suction valve & enters the cylinder.

When the crank rotating from C to A (ie 180° to 360°) piston moves from right to left. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valves opens. The liquid is forced into the delivery pipe & is raised to a required height.

Weight of the water delivered per second

$$W = \rho g Q = \frac{\rho g A L N}{60}$$

Work done per second $= \frac{\rho g A L N}{60} \times (h_s + h_d)$

Power required to drive the pump in kW

$$\boxed{P = \frac{\rho g A L N (h_s + h_d)}{60 \times 1000} \text{ kW}}$$

Sonal

LECTURE: 27

Date..................

Fluid System:

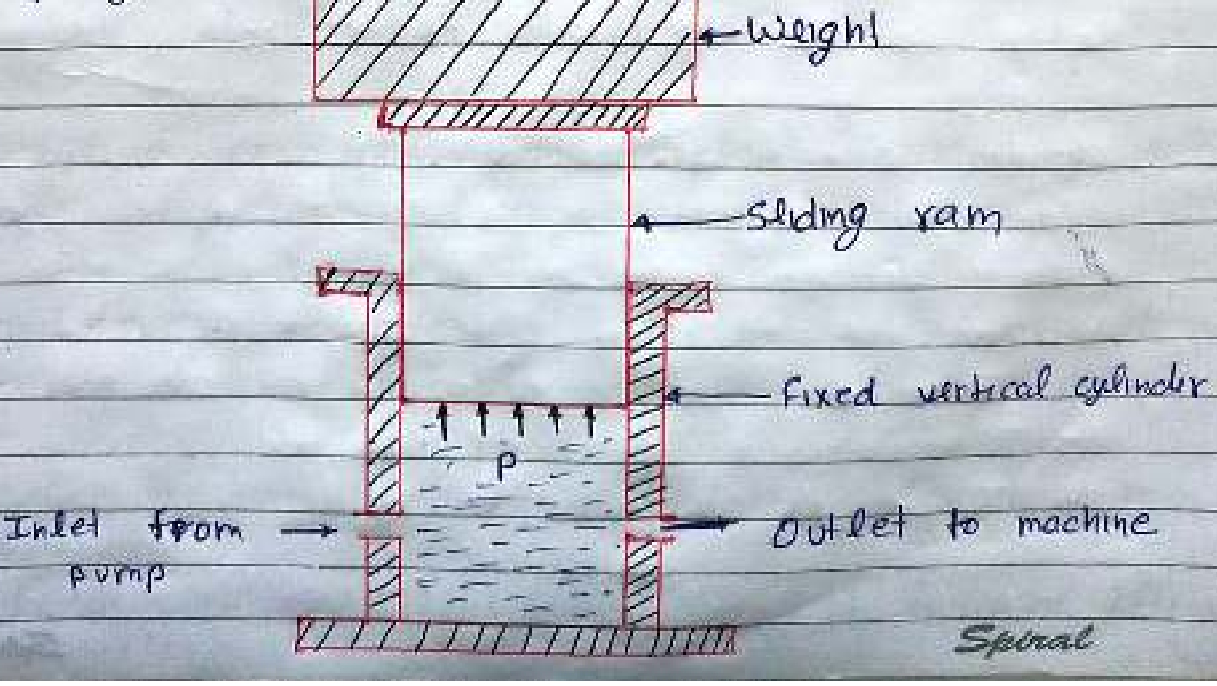
Fluid system is defined as the device in which power is transmitted with the help of a fluid [liquid or gas] under pressure. These devices are based on the principles of fluid statics and fluid kinematics.

Hydraulic accumulator: It is a device used for storing the energy of a liquid in the form of pressure energy which may be supplied for any sudden or intermittent requirement. Ex for hydraulic lift and hydraulic crane.

It consists of a fixed vertical cylinder containing a sliding ram. A heavy weigh is placed on the ram. The inlet of the cylinder is connected to the pump, which continuously supply fluid under pressure to the cylinder. The outlet of the cylinder is connected to the machine (lift or crane).

If the fluid under pressure is not required by the machine, the energy will be stored in the cylinder. When the machine required a large amount of energy, the hydraulic accumulator with supply this energy and ram will move in the downward direction.

Capacity of accumulator = p×A×L



Hydraulic lift: It is a device used for carrying passenger or goods from one floor to another in multistoreyed building.

Hydraulic lifts are of two types:

1- Direct acting hydraulic lift
2- Suspended hydraulic lift.

Direct acting hydraulic lift consists of a ram, sliding in fixed cylinder. At the top of the sliding ram, a cage [on which the persons may stand or goods may be placed] is fitted. The liquid under pressure flows into the fixed cylinder. This liquid exerts force on the sliding ram, which moves vertically up & thus raises the cage to the required height.

The cage is moved downward direction, by removing the liquid from the fixed cylinder.

Q.1 Define the fallowing fluid properties:
Density, weight density & specific gravity of a fluid

Q.2 Explain the terms: Dynamic viscosity and kinematic viscosity. Give their dimension.

Q.3 Define Newtonian and non-Newtonian fluid.

Q.4 Define pressure. State the pascal's law.

Q.5 Define the equation of continuity. Also derive its expression.

Q.6 What is Euler's equation of motion? How will you obtain Bernoulli's equation from it?

Q.7 Define the terms: Hydraulic machines, turbines and pumps.

Q.8 How will you classify the turbines.

Q.9 Explain construction and working of turbine (Pelton turbine)

Q.10 Explain classification of pumps.

Q.11 Define a centrifugal pump. Explain the working of a single acting centrifugal pump with sketch.

Q.12 What is a reciprocating pump? Describe the principle and working of a reciprocating pump with a neat sketch.

Q.13 Define the term hydraulic accumulator. Explain its working.

Q.14 Explain with neat sketch, the working of hydraulic lift.

LECTURE-34

Concept of Measurement, Error in Measurement, Calibration

Introduction

Dairy processing unit operations mainly involve heating, cooling, separating, drying or freezing of the products. These unit operations are carried out under varying conditions of temperatures, pressures, flows and physical compositions. The measurement and control of these variable factors at the various stages of processing call for the accurate and efficient instruments, in addition to the dependence upon human skills. With the advent of large scale milk handling plants the automatic operation and control through efficient instrumentation and automation has become even more necessary. Utilities such as steam, water, electricity air, fuel etc. have to be measured and controlled at appropriate points in the plant. Automatic control instruments are employed to measure and control the temperature, pressure, flow and level of these utilities. The overall aim of the instrumentation/ automation is to improve the product quality and enhance the plant efficiency for better economic returns.

Measurement

When we decide to study a variable we need to devise some way to measure it. Some variables are easy to measure and others are very difficult. The values of variables are made meaningful by quantifying them into specific units. For example, instead of saying that a particular fluid is hot, we can specify a measurement and specify that the fluid is having a temperature of 80C. Measurement is collection of quantitative data. A measurement is made by comparing a quantity with a standard unit. An example of measurement means the use of a ruler to determine the length of a piece of paper.

Measurement is thus essentially an act or the result of comparison between the quantity (whose magnitude is unknown) and a predefined standard. Since both the quantities are compared, the result is expressed in numerical values. In the physical sciences, quality assurance, and engineering, measurement is the activity of obtaining and comparing physical quantities of real-world objects and events. Established standard objects and events are used as units, and the process of measurement gives a number relating the item under study and the referenced unit of measurement.

There are two essential requirements of the measurements, in order to make the results meaningful;

(i) The standard used for comparison purposes must be accurately defined and should be commonly accepted.

(ii) The apparatus used and the method adopted must be provable.

Significance of Measurements

Science is based on objective observation of the changes in variables. The greater our precision of measurement the greater can be our confidence in our observations. Also, measurements are always less than perfect, i.e., there are errors in them. The more we know about the sources of errors in our measurements the less likely we will be to draw erroneous conclusions. With the progress in science and technology, new phenomena and relationships are constantly being discovered and these advancements require newer developments in measurement systems. Any invention is not of any practical utility unless it is backed by actual measurements. The measurements thus confirm the validity of a given hypothesis and also add to its understanding. This is a continuous chain that leads to new discoveries with new and more sophisticated measurement techniques. While elementary measurements require only ordinary methods of measurement, the advanced measurements are associated with sophisticated methods of measurement. The advancement of Science and Technology is therefore dependent upon a parallel progress in measurement techniques. It can be said that, the progress in Science and Technology of any country could be assessed by the way in which the data is acquired by measurements and is processed.

Error in Measurement

Static Error

Measurements done with an instrument always involve errors. No measurement is free from errors. If the precision of the equipment is adequate, no matter what its accuracy is, a discrepancy will always be observed between two measured results. Since the accuracy of an instrument is measured in terms of its error, an understanding and evaluation of the errors is thus essential.

Static error is defined as the difference between the best measured value and the true value of the quantity. Then:

$$Es = Am - At$$

Where, Es = error,

Am = measured value of quantity, and

At = true value of quantity.

Es is also called the absolute static error of quantity A. The absolute value of error does not indicate precisely the accuracy of measurement. For example, an error of 2 A is negligible when the current being-measured is of the order of 1000 A while the same error highly significant if the current under measurement is 10 A. Thus another term relative static error is introduced. The relative static error is the ratio of absolute static error to the true value of the quantity under measurement. Thus the relative static error Er is given by:

Percentage static error % Er = Er x 100

Static Correction

It is the difference between the true value and the measured value of the quantity, or

$$\delta C = At - Am$$

Dynamic Error

The dynamic error is the difference between the true value of the quantity changing with time and the value indicated by the instrument if no static error is assumed.

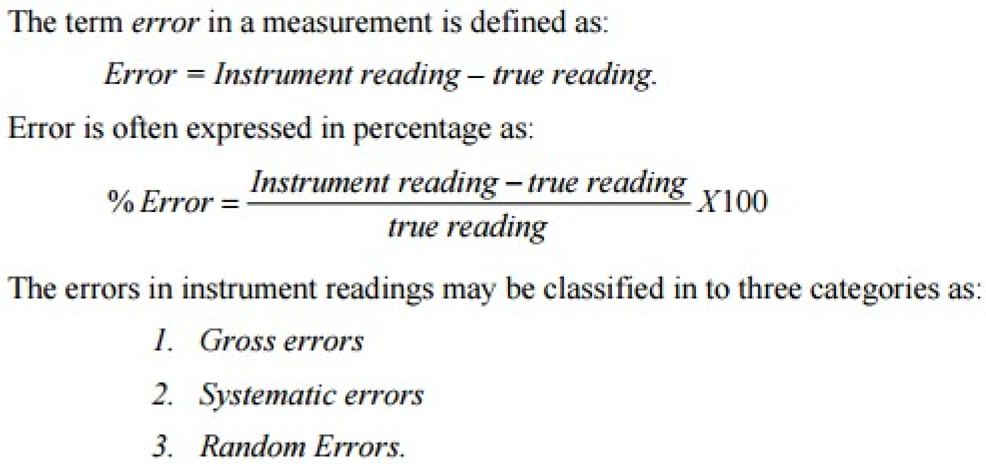
However, the total dynamic error of the instrument is the combination of its fidelity and the time lag or phase difference between input and output of the system.

Overshoot

Moving parts of instruments have mass and thus possess inertia. When an input is applied to instruments, the pointer does not immediately come to rest at its steady state (or final deflected) position but goes beyond it or in other words overshoots its steady position.

The overshoot is evaluated as the maximum amount by which moving system moves beyond the steady state position. In many instruments, especially galvanometers it is desirable to have a little overshoot but an excessive overshoot is undesirable.

Error Analysis



The term *error* in a measurement is defined as:

$$Error = Instrument\ reading - true\ reading.$$

Error is often expressed in percentage as:

$$\%\,Error = \frac{Instrument\ reading - true\ reading}{true\ reading} X100$$

The errors in instrument readings may be classified in to three categories as:

1. *Gross errors*
2. *Systematic errors*
3. *Random Errors.*

Gross errors arise due to human mistakes, such as, reading of the instrument value before it reaches steady state, mistake of recording the measured data in calculating a derived measured, etc. Parallax error in reading on an analog scale is also is also a source of gross error. Careful reading and recording of the data can reduce the gross errors to a great extent.

Systematic errors are those that affect all the readings in a particular fashion. Zero error, and bias of an instrument are examples of systematic errors. On the other hand, there are few errors, the cause of which is not clearly known, and they affect the readings in a random way. This type of errors is known as Random error. There is an important difference between the systematic errors and random errors. In most of the case, the systematic errors can be corrected by calibration, whereas the random errors can never be corrected, the can only be reduced by averaging, or error limits can be estimated.

Random Errors: It has been already mentioned that the causes of random errors are not exactly known, so they cannot be eliminated. They can only be reduced and the error ranges can be estimated by using some statistical operations. If we measure the same input variable a number of times, keeping all other factors affecting the measurement same, the same measured value would not be repeated, the consecutive reading would rather differ in a random way. But fortunately, the deviations of the readings normally follow a particular distribution (mostly normal distribution) and we may be able to reduce the error by taking a number of readings and averaging them out.

Calibration

All the static performance characteristics are obtained in one form or another by a process called static calibration. The calibration procedures involve a comparison of the particular characteristic with either a primary standard, a secondary standard with a higher accuracy than the instrument to be calibrated, or an instrument of known accuracy. It checks the instrument against a known standard and subsequently to errors in accuracy. Actually all measuring instruments must be calibrated against some reference instruments which have a higher accuracy. Thus reference instruments in turn must be calibrated against instrument of still higher grade of accuracy, or against primary standard, or against other standards of known accuracy. It is essential that any measurement made must ultimately be traceable to the relevant primary standards.

Static Characteristics

The main static characteristics include:

(i) Accuracy, (ii) Sensitivity, (iii) Reproducibility,

(iv) Drift, (v) Static error, and (vi) Dead zone

The qualities (i), (ii) and (iii) are desirable, while qualities (iv), (v) and (vi) are undesirable. The above characteristics have been defined in several different ways and the generally accepted definitions are presented here. Some more quantities have to be defined here which are essential in understanding the above characteristics.

Calibration and error reduction

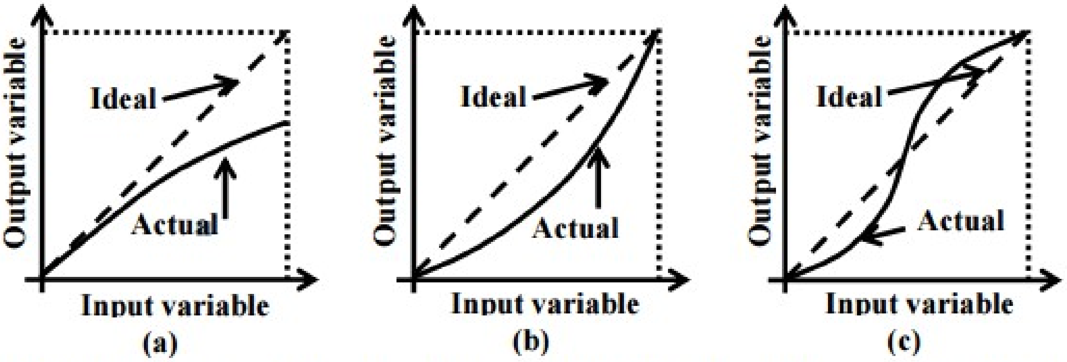
It has already been mentioned that the random errors cannot be eliminated. But by taking a number of readings under the same condition and taking the mean, we can considerably reduce the random errors. In fact, if the number of readings is very large, we can say that the mean value will approach the true value, and thus the error can be made almost zero. For finite number of readings, by using the statistical method of analysis, we can also estimate the range of the measurement error.

On the other hand, the systematic errors are well defined, the source of error can be identified easily and once identified, it is possible to eliminate the systematic error. But even for a simple instrument, the systematic errors arise due to a number of causes and it is a tedious process to identify and eliminate all the sources of errors. An attractive alternative is to calibrate the instrument for different known inputs.

Calibration is a process where a known input signal or a series of input signals are applied to the measuring system. By comparing the actual input value with the output indication of the system, the overall effect of the systematic errors can be observed. The errors at those calibrating points are then made zero by trimming few adjustable components, by using calibration charts or by using software corrections. Strictly speaking, calibration involves comparing the measured value with the standard instruments derived from comparison with the primary standards kept at Standard Laboratories. In an actual calibrating system for a pressure sensor (say), we not only require a standard pressure measuring device, but also a test-bench, where the desired pressure can be generated at different values. The calibration process of an acceleration measuring device is more difficult, since, the desired acceleration should be generated on a body, the measuring device has to be mounted on it and the actual value of the generated acceleration is measured in some indirect way.

The calibration can be done for all the points, and then for actual measurement, the true value can be obtained from a look-up table prepared and stored before hand. This type of calibration, is often referred as software calibration. Alternatively, a more popular way is to calibrate the instrument at one, two or three points of measurement and trim the instrument through independent adjustments, so that, the error at those points would be zero. It is then expected that error for the whole range of measurement would remain within a small range. These types of calibration are known as single-point, two-point and three-point calibration. Typical input-output characteristics of a measuring device under these three calibrations are shown in given figure.

The single-point calibration is often referred as offset adjustment, where the output of the system is forced to be zero under zero input condition. For electronic instruments, often it is done automatically and is the process is known as auto-zero calibration. For most of the field instruments calibration is done at two points, one at zero input and the other at full scale input. Two independent adjustments, normally provided, are known as zero and span adjustments. One important point needs to be mentioned at this juncture. The characteristics of an instrument change with time. So even it is calibrated once, the output may deviate from the calibrated points with time, temperature and other environmental conditions. So the calibration process has to be repeated at regular intervals if one wants that it should give accurate value of the measurand through out.



(a) (b) (c)

Fig. 2 (a) single point calibration, (b) two point calibration, (c) three point calibration

LECTURE-35

Measurement of Pressure, Temperature, Mass flow rate

Pressure measuring devices

Main characteristics of manometers are pressure range, accuracy, sensitivity and speed of response. Pressure range of manometers varies from almost perfect vacuum to several hundreds of atmosphere. The conventional instruments used for pressure measurement are divided into the following groups.

1) Liquid column manometers

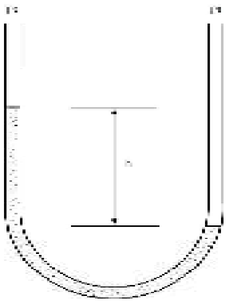
2) Pressure gauges with elastic sensing elements

3) Pressure transducers

4) Manometers for low absolute pressures

5) Manometers for very high absolute pressures

Liquid column manometers



For amplifying the deflection in a liquid column manometer, liquids with lower density could be used or one of the limbs of the manometer may be inclined. Commonly used manometric liquids are mercury, water or alcohol.

Some of the important and desirable properties of the manometric liquids are:

- High chemical stability
- Low viscosity
- Low capillary constant
- Low coefficient of thermal expansion
- Low volatility
- Low vapour pressure

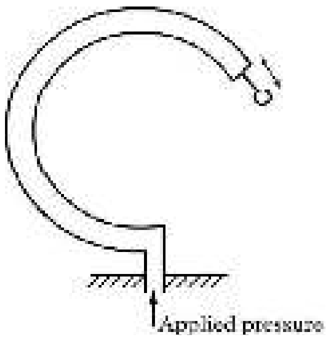
Mechanical manometers

Mechanical manometers provide faster response than liquid column manometers. In liquid column measurements, lag is due to the displacements of the liquid. In elastic sensing element type of manometers the time lag is due to the time required for equalisation of pressure to be measured with that in the sensing chamber. The deformation of elastic sensing elements is measured with the aid of kinematic, optical or electrical systems. There are three types of elastic sensing elements which are (i) Bourdon Tubes (ii) Diaphragms (flat or corrugated) (iii) Bellows

Bourdon tube

Bourdon tube is the oldest pressure sensing element .It is a length of metal tube of elliptical cross section and shaped into letter 'C'.

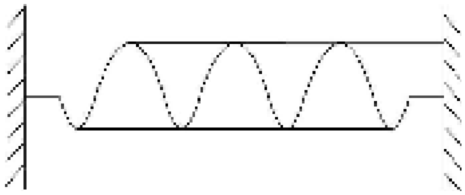
One end is left free and the other end is fixed and is open for the pressure source to be applied. A tube of elliptical cross section has a smaller volume than a circular one of the same length and perimeter. When connected to the pressure source it is made to accommodate more of the fluid. Resultant of all reactions will produce maximum displacement at the free end. Within close limits, the change in angle subtended at the centre by a tube is proportional to the change of internal pressure and within the limits of proportionality of the material; the displacement of the free end is proportional to the applied pressure. The ratio between major and minor axes decides the sensitivity of the Bourdon tube. The larger is the higher is the sensitivity. Materials of the Bourdon tube is Phosphor bronze, Beryllium bronze or Beryllium Copper.



Bourdon tube pressure gauge

Corrugated diaphragms

Corrugated diaphragms permit considerably larger deflections than flat diaphragms. Their number and depth control the response and sensitivity. The greater the number and depth, the more linear is its deflection and greater is the sensitivity.



Temperature measurement

Contact method uses three types of thermometers (temp. inst.) 1) Expansion Thermometers 2) Filled System Thermometers 3) Electrical temperature Instruments

Expansion Thermometers: In expansion thermometers bimetallic devices are used, in bimetallic devices there are two different materials whose rate of thermal expansion is also different. Therefore, in bimetallic devices there are strips of two metals which are bonded together. When heated, one side will expand more than the other, thus the resulting expansion is translated into temperature reading by a mechanical linkage to a pointer. The advantage of this type of instrument is that they are portable and they do not need a power supply. And the disadvantages of this type of instrument are that they are not as accurate as other devices and they do not readily lend themselves to temperature recording.

Filled system thermometer: It simply means that they are filled with any of the substitute. They generally come in two main classifications: the mercury type and the organic-liquid type. Since, mercury is considered an environmental hazard, so there are regulations governing the shipment of that type of devices that contain it. Now a day, there are filled system thermometers which employ gas instead of liquids. The advantages of these types of devices are that they do not require any electric power, they do not pose any explosion hazard and they are stable even after repeated cycling. And the disadvantage of these types of devices is that they do not generate data that are easily recorded or can be transmitted and they do not make spot or point measurements.

Electrical Temperature Instruments: As the name implies these types of instruments sense the temperature in the terms of electrical quantities like voltage, resistance etc. Therefore, we can say that these types of instruments are not directing indicating thermometers like mercury in glass devices. In the majority of industrial and laboratory processes the measurement point is usually far from the indicating or controlling instrument. This may be due to necessity (e.g. an adverse environment) or convenience (e.g. centralized data acquisition).Therefore; Devices are required which convert temperature in to another form of signal, usually electrical quantities.

The most common devices used in these types of temperature instruments are (a) thermocouples, (b) resistance thermometers and (c) thermistors, the similarity is, all of them require some form of contact with the body (of whose temperature is to be measured), the mode of contact could be immersed or it could be surface, depending on the construction of the sensor and the application where it is used.

Thermocouples: Thermocouples essentially comprises of a thermo element (which is a junction of two dissimilar metals) and an appropriate two wire extension lead. A thermocouple operates on the basis of the junction located in the process producing a small voltage, which increases with temperature. It does so on a reasonably stable and repeatable basis.

Resistance Thermometer: Resistance thermometer utilizes a precision resistor, the resistance (Ohms) value of which increases with temperature. RTD has had positive temperature coefficient. Such variations are very stable and precisely repeatable.

Thermistors: Thermistor is a semiconductor used as a temperature sensor. It is manufactured from a mixture of metal oxides pressed into a bead, wafer or other shape. The bead is heated under the pressure at high temperatures and then encapsulated with epoxy or glass. Beads can be very small, less than 1 mm in some cases. The result of all these is a temperature sensing devices that displays a very distinct non linear resistance versus temperature relationship. The resistance of thermistor decreases with increase in the temperature; this is called as negative temperature coefficient of thermistor. Thermistor exhibits a very large resistance changes for a small temperature change. This can be as large as 3 to 5% per °C. This makes them very sensitive to small temperature changes. They can detect temperature change as low as 0.1 °C or smaller. A thermistor element is significant smaller in size compared to RTDs. The sensitivity of thermistors to temperature change and their small size make it ideal for use in medical equipment.

Non-Contact Method: This method is used when the body (whose temperature is to be measured) and the sensor (which is measuring the temperature) are not allowed to remain in contact with each other, in other words, we can say that if the body and the sensor are not allowed to remain in contact with each other during the measurement of temperature then non contact method is used.

Most common thermometers (temperature instrument) using Non-Contact method are:

a) Infra red sensors and Pyrometers and Thermal Imagers

Infrared Sensors & Pyrometers: Infra red sensors & Pyrometer, now a day is the most common non contact temperature instrument in the industrial applications as it is easy to operate and use if the working principle is known to the user. Infra red sensor & Pyrometer measures the temperature of the object without being in the contact of the body but how is it possible? The answer is here, every object whose temperature is above absolute zero (-273.15K) emits radiation. This emission is heat radiation and its wavelength/frequency depends upon the temperature. So, this property of emission is used when the temperature is to be measured via non contact method. The term infra red radiation is also in use because the wavelength of the majority of this radiation lies in the electromagnetic spectrum above the visible red light which is in the infra red region. Similar to the radio broadcasting where emitted energy from a transmitter is captured by a receiver via an antenna and then transformed into sound waves, the emitted heat radiation of an object is received by detecting devices and transformed into electric signals, and in this way the temperature of an object is measured through non contact temperature measuring instruments.

FLOW MEASURING DEVICES, ROTAMETER

Accurate measurement of flow rate of liquids and gases is an essential requirement for maintaining the quality of industrial processes. In fact, most of the industrial control loops control the flow rates of incoming liquids or gases in order to achieve the control objective. As a result, accurate measurement of flow rate is very important. Needless to say that there could be diverse requirements of flow measurement, depending upon the situation. It could be volumetric or mass flow rate, the medium could be gas or liquid, the measurement could be intrusive or nonintrusive, and so on. As a result there are different types of flow measuring techniques that are used in industries.

The common types of flowmeters that find industrial applications can be listed as below:

(a) Obstruction type (differential pressure or variable area) (b) Inferential (turbine type), (c) Electromagnetic, (d) Positive displacement (integrating), (e) fluid dynamic (vortex shedding), (f) Anemometer, (g) ultrasonic and (h) Mass flowmeter (Coriolis). In this lesson, we would learn about the construction and principle of operation few types of flowmeters.

Obstruction type flowmeter

Obstruction or head type flowmeters are of two types: differential pressure type and variable area type. Orifice meter, Venturimeter, Pitot tube fall under the first category, while rotameter is of the second category. In all the cases, an obstruction is created in the flow passage and the pressure drop across the obstruction is related with the flow rate.

Basic Principle

It is well know that flow can be of two types: viscous and turbulent. Whether a flow is viscous or turbulent can be decided by the Reynold's number RD. If RD > 2000, the flow is turbulent. In the present case we will assume that the flow is turbulent, that is the normal case for practical situations. We consider the fluid flow through a closed channel of variable cross section.

Orifice meter

Depending on the type of obstruction, we can have different types of flow meters. Most common among them is the orifice type flowmeter, where an orifice plate is placed in the pipe line, as shown in fig.2. If d1 and d2 are the diameters of the pipe line and the orifice opening, then the flow rate can be obtained measuring the pressure difference (p1-p2).

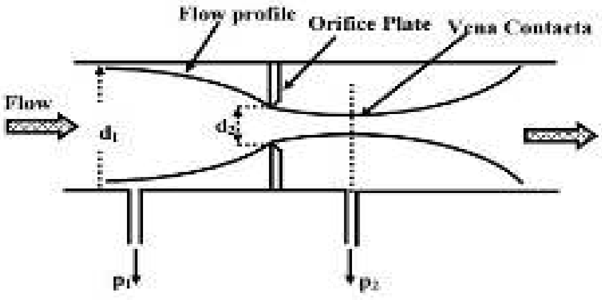


Fig. 2 Orifice type flowmeter

Orifice Plate, Venturimeter and Flow nozzle

The major advantages of orifice plate are that it is low cost device, simple in construction and easy to install in the pipeline as shown in fig.3. The orifice plate is a circular plate with a hole in the center. Pressure tappings are normally taken distances D and 0.5D upstream and downstream the orifice respectively (D is the internal diameter of the pipe). But there are many more types of pressure tappings those are in use.

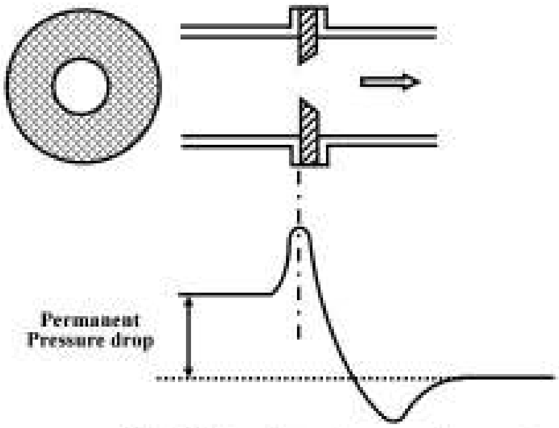


Fig. 3 Orifice plate and permanent pressure drop

The major disadvantage of using orifice plate is the permanent pressure drop that is normally experienced in the orifice plate as shown in fig.3. The pressure drops significantly after the orifice and can be recovered only partially. The magnitude of the permanent pressure drop is around 40%, which is sometimes objectionable. It requires more pressure to pump the liquid. This problem can be overcome by improving the design of the restrictions. Venturimeters and flow nozzles are two such devices.

The construction of a venturimeter is shown in fig.4. Here it is so designed that the change in the flow path is gradual. As a result, there is no permanent pressure drop in the flow path. The discharge coefficient Cd varies between 0.95 and 0.98. The construction also provides high mechanical strength for the meter. However, the major disadvantage is the high cost of the meter.

Rotameter

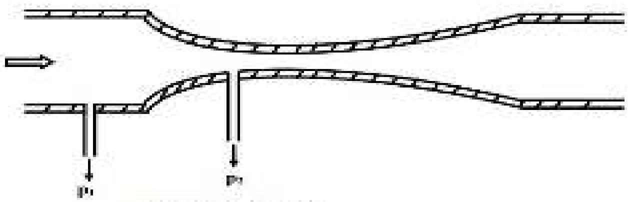


Fig. 4 Venturimeter

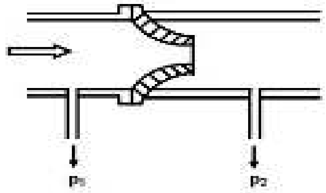


Fig. 5 Flow nozzle

The orificemeter, Venturimeter and flow nozzle work on the principle of constant area variable pressure drop. Here the area of obstruction is constant, and the pressure drop changes with flow rate. On the other hand Rotameter works as a constant pressure drop variable area meter. It can be only be used in a vertical pipeline. Its accuracy is also less (2%) compared to other types of flow meters. But the major advantages of rotameter are, it is simple in construction, ready to install and the flow rate can be directly seen on a calibrated scale, without the help of any other device, e.g. differential pressure sensor etc. Moreover, it is useful for a wide range of variation of flow rates (10:1). The basic construction of a rotameter is shown in fig. 7. It consists of a vertical pipe, tapered downward. The flow passes from the bottom to the top. There is cylindrical type metallic float inside the tube. The fluid flows upward through the gap between the tube and the float. As the float moves up or down there is a change in the gap, as a result changing the area of the orifice. In fact, the float settles down at a position, where the pressure drop across the orifice will create an upward thrust that will balance the downward force due to the gravity. The position of the float is calibrated with the flow rate.

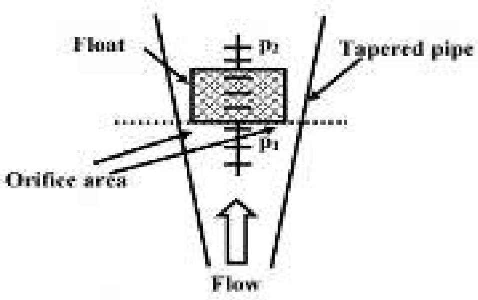


Fig. 7 Basic construction of a rotameter.

LECTURE-36

Measurement of Strain, force, and torque

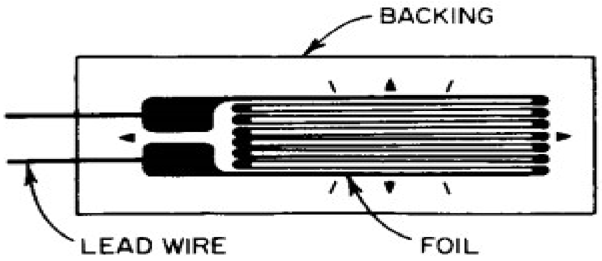
Strain and Torque Measurement

STRAIN GAUGES AND THEIR WORKING

A strain-sensitive material is one whose electrical resistance is proportional to the instantaneous strain over its surface. Such materials are of two types: metallic (i.e., foil or wire) or semiconductor. When such a material is stretched, its length increases and its cross-section decreases; consequently, there is an increase in its electrical resistance. This change in resistance is a measure of its mechanical motion. Thus, a strain gage is a device which uses change in electrical resistance to measure strain. The resistance strain gage may be employed in shock or vibration instrumentation in either of two ways. The strain gage may be the active element in a commercial or special-purpose transducer or pickup, or it may be bonded directly to a critical area on a vibrating member. Both of these applications are considered in this chapter, together with a discussion of strain-gage types and characteristics, cements and bonding techniques, circuitry for signal enhancement and temperature compensation, and related aspects of strain-gage technology. The electrical resistance strain gage discussed in this chapter is basically a piece of very thin foil or fine wire which exhibits a change in resistance proportional to the mechanical strain imposed on it. In order to handle such a delicate filament, it is either mounted on, encapsulated in, or bonded to some type of carrier material and is known as the bonded strain gage. Bonded strain gages are available in a wide range of sizes and resistances. Unbonded strain gages, where the wire is free, are rarely used because of their limited frequency range and lack of sensitivity. The strain gage is used universally by stress analysts in the experimental determination of stresses. Since strain always accompanies vibration, the strain gage or the principle by which it works is broadly applicable in the field of shock and vibration measurement. Here it serves to determine not only the magnitude of the strains produced by the shock or vibration, but also the entire time-history of the event, no matter how great the frequency of the phenomenon.

STRAIN-GAGE CONSTRUCTION

Most strain gages are of foil construction, illustrated in Fig. 17.1, although fine-wire strain gages are used for special purposes, such as at high temperatures. Foil strain gages are usually made by a printed-circuit process. Since the foil used in a strain gage must be very fine or thin to have a sufficiently high electrical resistance (usually between 60 and 350 ohms), it is difficult to handle. For example, the foil used in gages is often about 0.1 mil in thickness. Some use has been made of wire filaments in strain gages, but this type of gage is seldom used except in special or hightemperature applications. In order to handle this foil, it must be provided with a carrier medium or backing material, usually a piece of paper, plastic, or epoxy. The backing material performs another very important function in addition to providing ease of handling and simplicity of application. The cement provides so much lateral resistance to the foil that it can be shortened significantly without buckling; then compressive as well as tensile strains can be measured. Lead wires or connection terminals are often provided on foil gages, as illustrated in the typical foil gage shown in Fig. 17.1.A protective coating, recommended or supplied by the manufacturer, is usually applied over the strain gage, especially where the lead wires are attached.



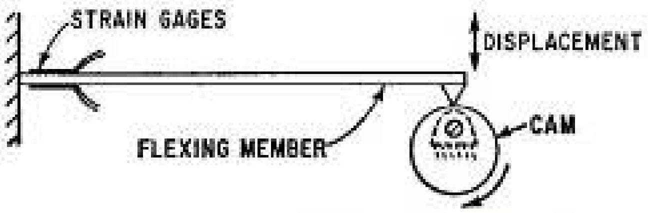
Typical construction of a foil strain gage.

STRAIN-GAGE MEASUREMENTS

The resistance strain gage,7 because of its inherent linearity, very small mass, wide frequency response (from zero to more than 100,000 Hz), general versatility, and ease of installation in a variety of applications, is an ideal sensitive component for electrical transducers for use in shock and vibration instrumentation.8 The Wheat- stone bridge circuit, described in a subsequent section, can be used to extend the versatility of the strain gage to still broader applications by performing mathematical operations on the strain-gage output signals. The combination of these two devices can be used effectively for the measurement of acceleration, displacement, force, torque, pressure, and similar mechanical variables. Other useful attributes include the capacity for separation of forces and moments, vector resolution of forces and accelerations, and cancellation of undesired vector components. The usual technique for employing a strain gage as a transducing element is to attach the gage to some form of mechanical member which is loaded or deformed in such a manner as to produce a signal in the strain gage proportional to the variable being measured. The mechanical member can be utilized in tension, compression, bending, torsion, or any combination of these. All strain-gage-actuated transducers can be considered as either force- or torque-measuring instruments.Any mechanical variable which can be predictably manifested as a force or a couple can be instrumented with strain gages. There are a number of precautions which should be observed in the design and construction of custom-made strain-gage transducers.9 First, the elastic member on which the strain gage is to be mounted should be characterized by very low mechanical hysteresis and should have a high ratio of proportional limit to modulus of elasticity (i.e., as large an elastic strain as possible). Although aluminum, bronze, and other metals are often employed for this purpose, steel is the most common material. An alloy steel such as SAE 4340, heat-treated to a hardness of RC 40, will ordinarily function very satisfactorily.

DISPLACEMENT MEASUREMENT

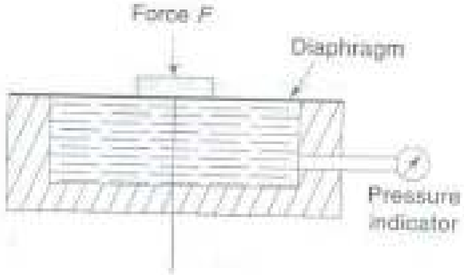
Measurement of displacement with strain gages can be accomplished by exploiting the fact that the deflection of a beam or other loaded mechanical member is ordinarily proportional to the strain at every point in the member as long as all strains are within the elastic limit. For small displacements at low frequencies, a cantilever beam arranged as shown in Fig. 17.5 can be employed. The beam should be mounted with sufficient preload on the moving surface that continuous contact at the maximum operating frequency is assured. In the case of higher-frequency applications, the beam can be held in contact with the moving surface magnetically or by a fork or yoke arrangement, as illustrated in Fig. 17.6. It is necessary to make certain that the measuring beam will not affect the displacement to be instrumented, and that no natural mode of vibration of the beam itself will be excited.



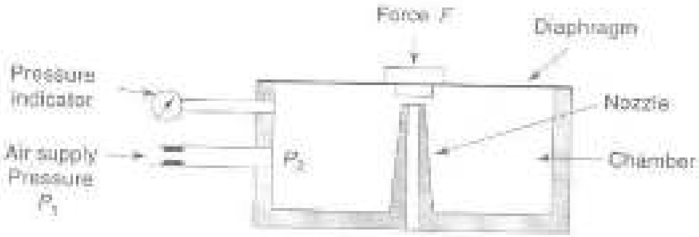
Strain gages mounted on a cantilever beam for displacement measurement produce electrical signals proportional to cam motion.

Load Measurement

HYDRAULIC LOAD CELL • Hydraulic pressure is used to indicate the force F, applied to a diaphragm • Normally oil is used. • Used to measure very large forces of the order of millions of Newtons.



PNEUMATIC LOAD CELL • For any force F, pressure P2 gives an indication • Used upto 20 kN.



LECTURE-37

Concept of accuracy, precision and resolution

True value

The true value of variable quantity being measured may be defined as the average of an infinite number of measured values when the average deviation due to the various contributing factors tends to zero. Such an ideal situation is impossible to realize the practice and hence it is not possible to determine the true value of a quantity by experimental means. The reason for this is that there are several factors such as lags, loading effects, wear or noise pick-up etc. Normally an experimenter would never know that the value or quantity being measured by experimental means is the true value of the quantity or not.

Accuracy

Accuracy is the closeness with which an instrument reading approaches the true value of the quantity being measured. Thus accuracy of a measurement means conformity to truth. The accuracy of an instrument may be expressed in many ways. The accuracy may be expressed as point accuracy, percent of true value or percent of scale range. Point accuracy is stated for one or more points in the range, for example, the scale of length may be read with in 0.2 mm. Another common way is to specify that the instrument is accurate to within x percent of instrument span at all points on the scale. Another way of expressing accuracy is based upon instrument range.

Accuracy is many a time confused with Precision. There is difference in these two terms. The term Precise means clearly or sharply defined. For example an ammeter will possesses high degree of precision by virtue of its clearly legible, finely divided, distinct scale and a knife edge pointer with mirror arrangements to remove parallax. As an example of the difference in meaning of the two terms, suppose above ammeter can read up to 1/100 of an ampere. Now if its zero adjustment is wrong, every time we take a reading, the readings taken with this ammeter are not accurate, since they do not confirm to truth on account of its faulty zero adjustment. Though the ammeter is as precise as ever and readings are consistent and clearly defined and can be down to 1/100 of an ampere. The instrument can be calibrated remove the zero error. Thus the accuracy of the instrument can be improved upon by calibration but not the precision.

Scale Readability or Precision

This indicates the closeness to with which the scale of an analog type of instrument can be read. The readability of an instrument depends upon following factors:

i) Number of graduations

ii) Spacing between the graduations

iii) Size of the pointer

iv) Discriminating power of the observer

The readability is actually the number of significant figures in the instrument scale. The higher the number of significant figures, the better would be the readability.

Repeatability and Reproducibility

Repeatability is the degree of closeness with which a given value may be repeatedly measured. It is the closeness of output readings when the same input is applied repetitively over a short period of time. The measurement is made on the same instrument, at the same location, by the same observer and under the same measurement conditions. It may be specified in terms of units for a given period of time. Reproducibility relates to the closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument location, conditions of use and time of measurement. Perfect reproducibility means that the instrument has no drift. Drift means that with a given input the measured values vary with time.

Reproducibility and Repeatability are a measure of closeness with which a given input may be measured over and over again. The two terms cause confusion. Therefore, a distinction is made between the two terms. Reproducibility is specified in terms of scale readings over a given period of time. On the other hand, Repeatability is defined as the variation of scale reading and is random in nature.

Threshold and Resolution

Threshold

Threshold of a measuring instrument is the minimum value of input signal that is required to make a change or start from zero. This is the minimum value below which no output change can be detected when the input is gradually increased from zero. In digital system, the output is displayed in incremental digits. Thus, in digital instruments the threshold is the minimum input signal which is necessary to produce at least one significant digit of output to indicate on the display.

Resolution

When an instrument is showing a particular output reading, there is a lower limit on the magnitude of the change in the input measured quantity that produces an observable change in the instrument output. That means, when the input is slowly increased from some arbitrary input value, which is non-zero, the output does not change at all until certain increment is exceeded. This increment is called resolution or discrimination of the instrument. Thus, the resolution refers to the smallest change of input for which there will be a change output.

In the analog instruments, the resolution is also determined by the observers ability to judge the position of pointer on the scale. One of the major factors influencing the resolution of an instrument is how finely its output scale is divided into subdivisions. Using a car speedometer as an example again, this has subdivisions of typically 20 km/h. This means that when the needle is between the scale markings, we cannot estimate speed more accurately than to the nearest 5 km/h.

The difference between threshold and the resolution of the measuring instrument could be understood this way.Threshold defines the smallest measureable input, while the resolution defines the smallest measureable input change. Both of these values may be expressed in terms of an actual value or as a fraction / percentage of the full scale value.

LECTURE-38

Basic numerical problems

Q: A meter reads 115.50 V and the true value of the voltage is 115.44 V. Determine the static error, and the static correction for this instrument.

Solution:

The error is: $E_s = A_m - A_t = 115.50 - 115.44 = +0.06V$

Static correction: $\delta C = A_t - A_m = -0.06V$

Q: A thermometer reads 71.5 C and the static correction given is +0.5C. Determine the true value of the temperature.

Solution:

True value of the temperature

$A_t = A_m + \delta C = 71.5 + 0.5 = 72.0C$

Q: A thermometer is calibrated for the range of 100°C to 150°C. The accuracy is specified within 0.25 percent. What is the maximum static error?

Solution:

Span of thermometer = 150 - 100 = 50°C

Maximum static error = $\frac{\pm 0.25 \times 50}{100} = \pm 0.125$°C

Q: An analogue indicating instrument with a scale range of 0 - 2.50 V shows a voltage of 1.46 V. A voltage has a true value of 1.50 V. What are the values of absolute error and correction? Express the error as a fraction of the true value and the full scale deflection.

Solution:

Absolute error = $A_m - A_t = 1.46 - 1.50 = -0.04V$

Absolute correction (δC) = δA = +0.04 V

Relative error: $\varepsilon_r = \frac{-0.04}{1.50} \times 100 = -2.66\%$

Relative error expressed as a percentage of full scale division

$$\varepsilon_r = \frac{-0.04}{2.50} \times 100 = -1.60\%$$

Q: A pressure indicator showed a reading as 22 bar on a scale range of 0-25 bar. If the true value was 21.4 bar, determine:

i) Static error

ii) Static correction

iii) Relative static error

Solution:

i) Static error = 22 - 21.4 = + 0.6 bar

ii) Static correction = - (+0.6) = - 0.6 bar

iii) Relative error = 0.6 / 21.4 = 0.028 or 2.8 %

Q: A step input of 5 A is applied to an ammeter. The pointer swings to a voltage of 5.18 A and finally comes to rest at 5.02 A. (a) Determine the overshoot of the reading in ampere and in percentage of final reading. (b) Determine the percentage error in the instrument.

Solution:

(a) Overshoot = 5.18 - 5.02 = 0.16 A

(b) % Overshoot = (0.16/5.02)*100 = 3.2%

(b) % error = [(5.02-5.0)/5.0]*100 = 0.4%

LECTURE-39

Basic numerical problems

Q: Determine the resolution of a voltmeter which has a range readout scale with 100 divisions and a full-scale reading of 100 V. If one tenth of a scale division can be read certainty, determine the resolution of the voltmeter.

Solution:

100 scale division = 100V

One scale division = 100 /100 = 1V

Resolution = 1 x 1/10

= 0.1 V

Q: A transducer measures a range of 0-200 N force with a resolution of 0.20 percent of full scale. What is the smallest change in the force which can be measured by this transducer?

Solution:

Range of force = 0-200 N

Resolution = 0.20 % of full scale

Smallest change in force which can be measured = 200 x 0.20 / 10

= 0.4 N

LECTURE-40

System of geometric limit, fit

Terminologies used in Limits and Fits

Shaft: The term shaft refers not only to the diameter of a circular shaft but also to any external dimension of a component.

Hole: The term shaft not only refers to the diameter of the circular hole but also any internal dimension of a component.

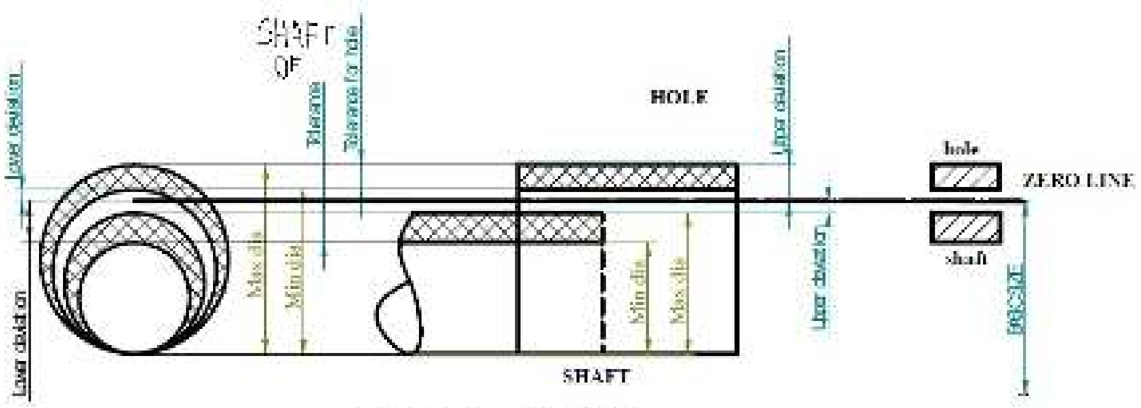


Figure: Shaft and Hole System

When an assembly is made of two parts, one is known as male-surface and the other mating part as female (enveloping) surface. The male surface is called as shaft and the female surface is called as hole.

Basic Size or Nominal Size: It is the standard size of a part in relation to which all limits of variation are determined. the basic size is same for hole and shaft.

Actual size: actual size is the dimension as measured on manufacturing part.

Zero line: it is straight line drawn horizontally to represent the basic size. In the graphical representation of limits and fits, all the deviations are shown with respect to the zero line (datum line).

The positive deviations are shown above zero line and negative deviation are shown below zero line as shown in figure.

Deviation: deviation is the algebraic difference between the size (actual, maximum, etc) and the corresponding basic size.

Upper deviation: it is the algebraic difference between the upper (maximum) limit of size and the corresponding basic size.

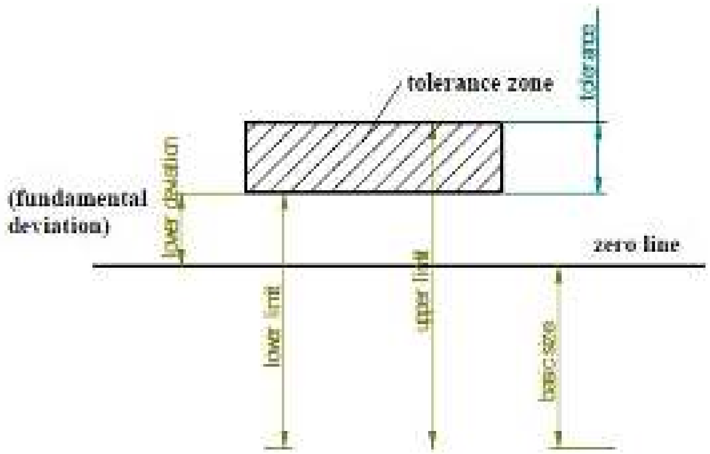
It is positive quantity when the upper limit of size is greater than the basic size and negative quantity when the upper limit of the size less than the basic size as shown in figure. It is denoted by „ES‟ for hole and „es‟ for shaft.

Lower deviation: it is it is the algebraic difference between the lower (minimum) limit of size and the corresponding basic size.

It is positive quantity when the lower limit of size is greater than the basic size and negative quantity when the lower limit of the size less than the basic size. It is denoted by „EI‟ for hole and „ei‟ for shaft.

Fundamental deviation: either the upper or lower deviation, which is the nearest one to the zero line for either a hole or a shaft.

It fixes the position of Tolerance zone in relation to the zero line.



Lower deviation as Fundamental Deviation

Types of fits:

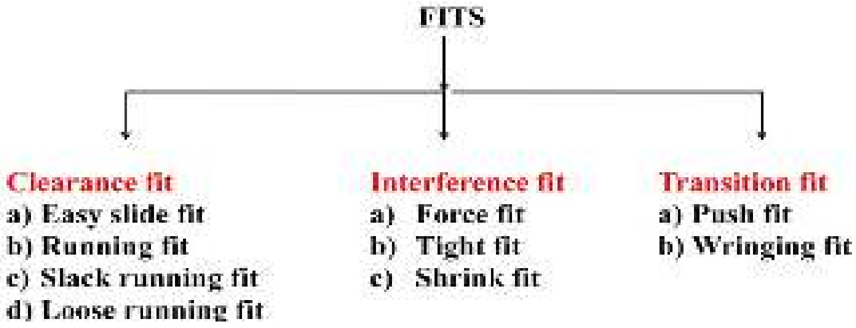
On the basis of positive, zero and negative values of clearance, there are three types of fits:

1. Clearance fit

2. Interference fit

3. Transition fit

These fits are further classified in the following manner:



Clearance fit: In this type of fit, the largest permitted shaft diameter is smaller than the diameter of the smallest hole as shown in figure. So that the shaft can rotate or slide through with different degree of freedom according to the purpose of mating part. In this type of fit shaft is always smaller than hole.

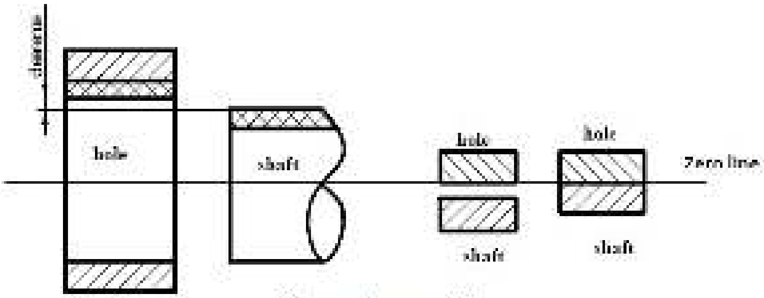


Figure: clearance fit

Interference fit: In this type of fit the minimum permissible diameter of the shaft is larger than the maximum allowable diameter of the hole. Here the shaft and hole members are intended to be attached permanently and used as a solid component.

Example: bearing bushes, steel rings on a wooden bullock cart wheel etc.

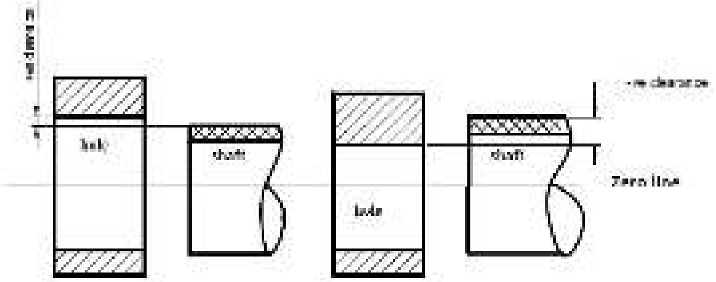


Figure: Transition fit

Transition fit: Transition fit lies mid way between clearance and interference fit. In this type of fit, the diameter of the largest allowable hole is greater than that of the smallest shaft, but the smallest hole is smaller than the largest shaft, so that a small positive and negative clearance exists between the shaft and hole as shown in figure.

Example: Spigot in mating holes, coupling rings.

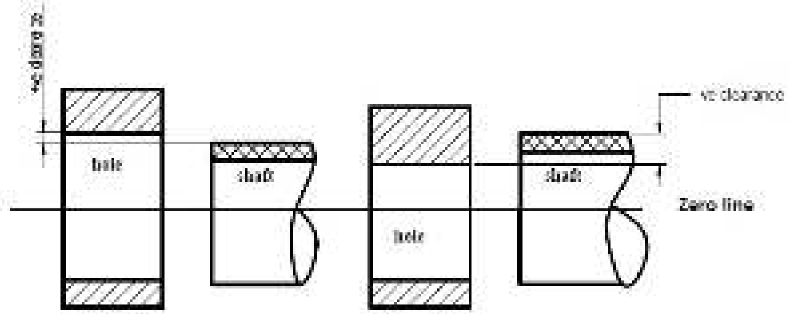


Figure: Transition fit

LECTURE-41

System of geometric tolerance and gauges

Tolerance: Tolerance can be defined as the permissible variation in size or dimension of a part or the difference between the upper limit and lower limit of a part. The word Tolerance indicated that a worker is not expected to produce the part to the exact size, but a definite small size error is permitted.

Tolerance Zone: The difference between upper limit and the lower limit of a dimension represents the margin for variation in workmanship, and is called a “Tolerance zone”.

Example: A shaft of 25 mm basic size may be written as 25 + 0.02.

Upper limit = 25 + 0.02 = 25.02 mm

Lower limit = 25 – 0.02 = 24.98 mm

Tolerance = upper limit – lower limit = 25.02 – 24.98 = 0.04 mm

System of writing Tolerance (Toleranced dimensions):

There are two systems of writing tolerance:

1. Unilateral system

2. Bilateral system

1. Unilateral system: When the two limit dimensions are only above or only below the nominal size (basic size) then the tolerances are said to be Unilateral.

Example: $25^{\substack{+0.03\\+0.02}}$, $25^{\substack{+0.01\\+0.00}}$, $25^{\substack{-0.00\\-0.01}}$, $25^{\substack{-0.01\\-0.02}}$ etc…

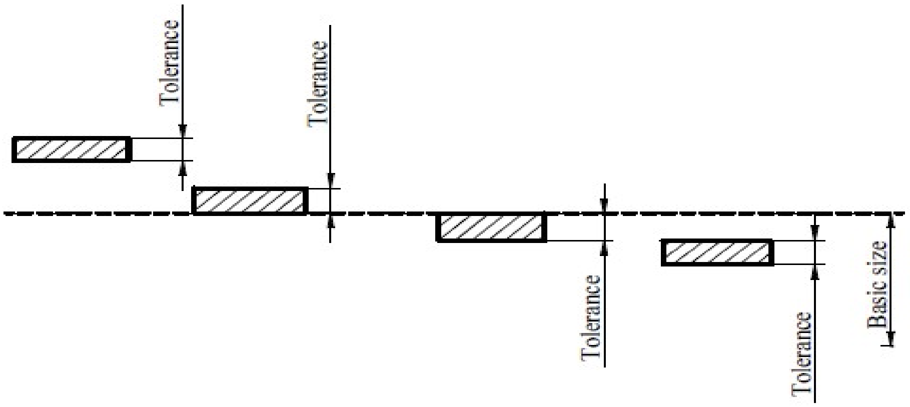


Figure: unilateral system

2. Bilateral system: When the limit dimensions are given above and below the nominal size (basic size) then the tolerances are said to be bilateral.

Example: 25+0.02 , 25 +0.00 etc…

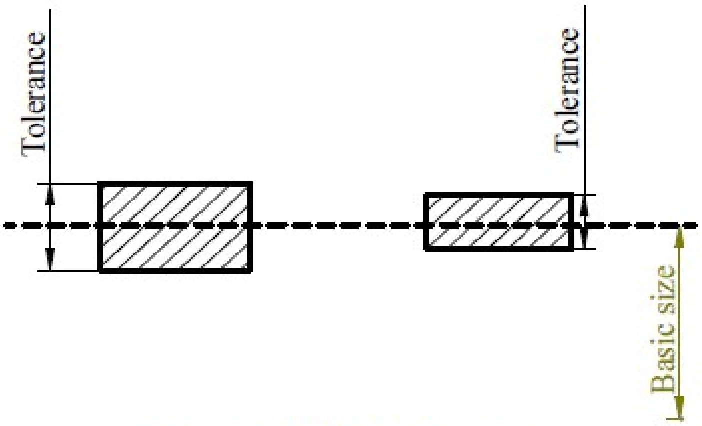


Figure: Bilateral Tolerance

GAUGE DESIGN

It states that GO gauge should check all related dimensions. Simultaneously NOGO gauge should check only one dimension at a time.

Maximum metal condition: It refers to the condition of hole or shaft when maximum material is left on i.e. high limit of shaft and low limit of hole.

Minimum metal condition: If refers to the condition of hole or shaft when minimum material is left on such as low limit of shaft and high limit of hole.

Applications of Limit Gauges

1. Thread gauges
2. Form gauges
3. Screw pitch gauges
4. Radius and fillet gauges
5. Feeler gauges
6. Plate gauge and Wire gauge

LIMIT GAUGES

- A limit gauge is not a measuring gauge. Just they are used as inspecting gauges.
- The limit gauges are used in inspection by methods of attributes.
- This gives the information about the products which may be either within the prescribed limit or not.
- By using limit gauges report, the control charts of P and C charts are drawn to control invariance of the products.

- This procedure is mostly performed by the quality control department of each and every industry.
- Limit gauge are mainly used for checking for cylindrical holes of identical components with a large numbers in mass production.

Purpose of using limit gauges

- Components are manufactured as per the specified tolerance limits, upper limit and lower limit. The dimension of each component should be within this upper and lower limit.
- If the dimensions are outside these limits, the components will be rejected.
- If we use any measuring instruments to check these dimensions, the process will consume more time. Still we are not interested in knowing the amount of error in dimensions.
- It is just enough whether the size of the component is within the prescribed limits or not. For this purpose, we can make use of gauges known as limit gauges.

LECTURE-42

Basic numerical problems

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Upper limit = 25 + 0.02 = 25.02 mm

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Tolerance = upper limit – lower limit = 25.02 – 24.98 = 0.04 mm

System of writing Tolerance (Toleranced dimensions):

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1. Unilateral system: When the two limit dimensions are only above or only below the nominal size (basic size) then the tolerances are said to be Unilateral.

Example: $25^{+0.03}_{+0.02}$, $25^{+0.01}_{-0.00}$, $25^{0.00}_{-0.01}$, $25^{-0.01}_{-0.02}$ etc

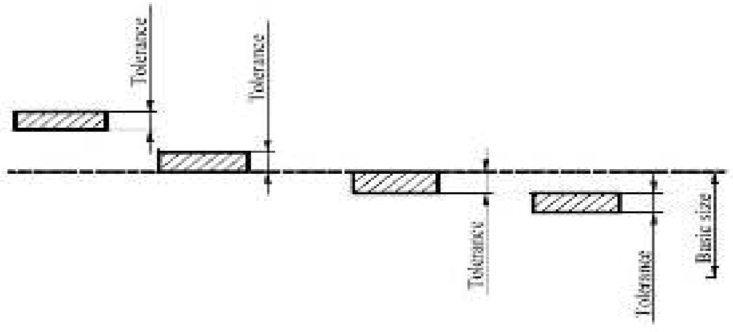


Figure: unilateral system

2. Bilateral system:

When the limit dimensions are given above and below the nominal size (basic size) then the tolerances are said to be bilateral.

Example: 25+0.02 , 25 +0.00 etc…

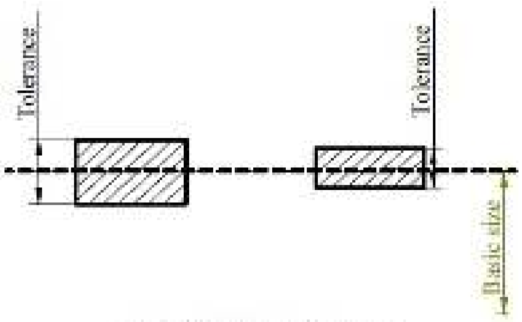


figure: Bilateral Tolerance

LECTURE-43

Introduction to control systems, elements of control system

Function of Instrumentals and Measurement Systems

The measurement systems and the instruments may be classified based upon the functions they perform. There are four main functions performed by them: indicating, signal processing, recording and control.

i). Indicating Function: This function includes supplying information concerning the variable quantity under measurement. Several types of methods could be employed in the instruments and systems for this purpose. Most of the time, this information is obtained as the deflection of a pointer of a measuring instrument.

ii). Recording Function: In many cases the instrument makes a written record, usually on paper, of the value of the quantity under measurement against time or against some other variable. This is a recording function performed by the instrument. For example, a temperature indicator / recorder in the HTST pasteurizer gives the instantaneous temperatures on a strip chart recorder.

iii). Signal Processing: This function is performed to process and modify the measured signal to facilitate recording / control.

iv). Controlling Function: This is one of the most important functions, especially in the food processing industries where the processing operations are required to be precisely controlled. In this case, the information is used by the instrument or the systems to control the original measured variable or quantity.

Thus, based on the above functions, there are three main groups of instruments. The largest group has the indicating function. Next in line is the group of instruments which have both indicating and or recording functions. The last group falls into a special category and perform all the three functions, i.e., indicating, recording and controlling.

In this lesson only those instruments would be discussed whose functions are mainly indicating and recording, especially those instruments which are used for engineering analysis purposes.

Basic Requirements of a Measurement System / Instrument in control

The following are the basic requirements of a good quality measurement system / instrument:

a) Ruggedness

b) Linearity

c) No hysteresis

d) Repeatability

e) High output signal quality

f) High reliability and stability

g) Good dynamic response

LECTURE-44

Basic of open and closed loop control with example

Different applications of the instruments and measurement systems in closed or open loops are:

i). Monitoring a process/operation

ii). Control a process/operation

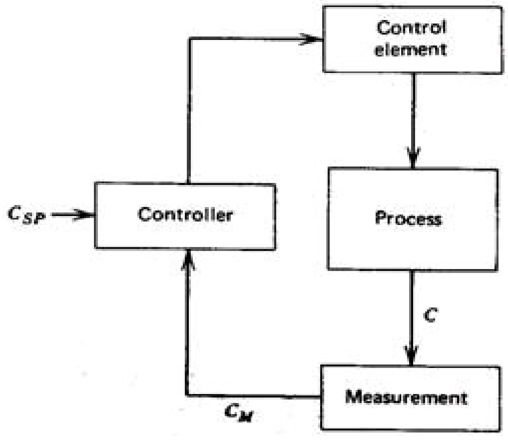
i). Monitoring a Process/Operation

There are several applications of measuring instruments that mainly have a function of monitoring a process parameter. They simply indicate the value or condition of parameter under study and these readings do not provide any control operation. For example, a speedometer in a car indicates the speed of the car at a given moment, an ammeter or a voltmeter indicates the value of current or voltage being monitored at a particular instant. Similarly, water and electric energy meters installed in homes and industries provide the information on the commodity used so that its cost could be computed and realized from the user.

ii). Control a Process/Operation in closed loop control system

Another application of instruments is in automatic control systems. Measurement of a variable and its control are closely associated. To control a process variable, e.g., temperature, pressure or humidity etc., the prerequisite is that it is accurately measured at any given instant and at the desired location. Same is true for all other process parameters such as position, level, velocity and flow, etc. and the servo-systems for these parameters.

A block diagram of a simple process close loop control system is shown in Fig.



Close loop process control system

Let us assume that the output variable to be controlled is non-electrical quantity and the control action is through electrical means. Since the output variable is a non-electrical quantity, it is converted into a corresponding electrical form by a transducer connected in the feedback loop. The input to the controller is reference which corresponds to the desired value of the process parameter. The output process variable is compared with the reference or desired value with the help of a comparator. In case the desired value and the process variable differ, there is a resultant error signal. This error signal is amplified and then fed to an actuator, which produces power to drive the controlled circuitry.

The corrective action goes on till the output is at the same level as the input which corresponds to the desired output. At this stage, there is no error signal and hence there is no input to the actuator and the control action stops.

Common examples of this application are the domestic appliances, such as, refrigerator, air conditioner or a hot air oven. All of these employ a thermostatic control. A temperature measuring device (often a bimetallic element) measures the temperature in the room, refrigerated chamber or in the oven and provides the information necessary for appropriate functioning of the control system in these appliances.

Measurement System

Scientists, engineers and other humans use a vast range of instruments to perform their measurements. These instruments may range from simple objects such as ruler scales and stopwatches to electron microscopes and particle accelerators used by scientists and engineers.

An instrument is as a device or a system which is designed to maintain a functional relationship between prescribed properties of physical variables being measured. It provides the means of communication to a human observer or the operator of a machine or equipment. The above stated functional relationship remains valid, only as long as the static calibration of system remains constant. The performance of an instrument of a measurement system is usually described in terms of a set of its static and dynamic characteristics.

Functional Elements of a Measurement System in a close and open loop system

To understand a measuring instrument/system, it is important to have a systematic organization and analysis of measurement systems. The operation of a measuring instrument or a system could be described in a generalized manner in terms of functional elements. Each functional element is made up of a component or groups of components which perform required and definite steps in the measurement. The functional elements do not provide the intricate details of the physical aspects of a specific instrument or a system. These may be taken as basic elements, whose scope is determined by their functioning rather than their construction.

The main functional elements of a measurement system are:

i) Primary sensing element

ii) Variable conversion element

iii) Variable manipulation element

iv) Signal conditioning element

v) Data transmission element

vi) Data presentation element.

Primary sensing element

The quantity or the variable which is being measured makes its first contact with the primary sensing element of a measurement system. The measurement is thus first detected by primary sensor or detector. The measurement is thenimmediately converted into an analogous electrical signal. This is done by a transducer. Though a transducer in general, is defined as a device which converts energy from one form to another. But in measurement systems, this definition is limited in scope. A transducer is defined as a device which converts a physical quantity into an electrical quantity. The output of the sensor and detector element employed for measuring a quantity could be in different analogous form. This output is then converted into an electrical signal by a transducer. This is true of most of the cases but is not true for all. In many cases, the physical quantity is directly converted into an electrical quantity by a detector transducer. The first stage of a measurement system is known as a detector transducer stage.

Variable conversion element

The output signal of the variable sensing element may be any kind. It could be a mechanical or electrical signal. It may be a deflection of elastic member or some electrical parameter, such as, voltage, frequency etc. Sometimes, the output from the sensor is not suited to the measurement system. For the instrument to perform the desired function, it may be necessary to convert this output signal from the sensor to some other suitable form while preserving the information content of the original signal. For example, suppose the output from the sensing element is in the form of very small displacement which is difficult to measure mechanically, it is converted in to corresponding electrical signal with the help of transducer called stain gauge for further processing. Also if the output at one stage is analogue form and the next stage of the system accepts input signal only in digital form. In such cases, we will have to use as Analogue /Digital converter.

In many instruments variable conversion element is not required. Some instruments/measuring systems may require more than one element.

Variable manipulation element

Variable manipulation means a change in numerical value of the signal. The function of a variable manipulation element is to manipulate the signal presented to this element while preserving the original nature of the signal. For example, a voltage amplifier acts as a variable manipulation element. The amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude. The variable manipulation element could be either placed after the variable conversion element or it may precede the variable conversion element.

Signal conditioning element

The output signal of transducers contains information which is further processed by the system. Many transducers develop usually a voltage or some other kind of electrical signal and quite often the signal developed is of very low voltages, may be of the order of mV and some even V. This signal could be contaminated by unwanted signals like noise due to an extraneous source which may interfere with the original output signal. Another problem is that the signal could also be distorted by processing equipment itself. If the signal after being sensed contains unwanted contamination or distortion, there is a need to remove the interfering noise / sources before its transmission to next stage. Otherwise we may get highly distorted results which are far from its true value.

The solution to these problems is to prevent or remove the signal contamination or distortion. The operations performed on the signal, to remove the signal contamination or distortion, is called Signal Conditioning. The term signal conditioning includes many other functions in addition to variable conversion and variable manipulation. Many signal conditioning processes may be linear, such as, amplification, attenuation, integration, differentiation, addition and subtraction. Some may be non-linear processes, such as, modulation, filtering, clipping, etc. The signal conditioning processes are performed on the signal to bring it to the desired form for further transmission to next stage in the system. The element that performs this function in any instrument or instrumentation system is known as Signal Conditioning Element.

Data transmission element

There are several situations where the elements of an instrument are actually physically separated. In such situations it becomes necessary to transmit data from one element to another. The element that performs this function is called a Data Transmission Element. For example satellites or the air planes are physically separated from the control stations at earth. For guiding the movements of satellites or the air planes control stations send the radio by a complicated telemetry systems. The signal conditioning and transmission stage is commonly known as Intermediate Stage.

Data presentation element

The function of data presentation element is to convey the information about the quantity under measurement to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. The information conveyed must be in a convenient form. In case data is to be monitored, visual display devices are needed. These devices may be analogue or digital indicating instruments like ammeters, voltmeters, etc. In case the data is to be recorded, recorders like magnetic tapes, high speed camera and T.V. equipment; storage type C.R.T., printers, analogue and digital computers may be used. For control and analysis purpose computers and the control elements are used. The final stage in a measurement system is known as terminating stage.

Figure 2.1 below presents the block diagram of functional elements of a generalized measuring system / instrument. One must understand the difference between functional elements and the physical elements of measuring system. Functional element indicates only the function to be performed. Physical elements are the actual components or parts of the system. One physical element can perform more than one function. Similarly one function could be performed by more than one physical element. This is more suitably illustrated in the example of a measuring instrument described below.

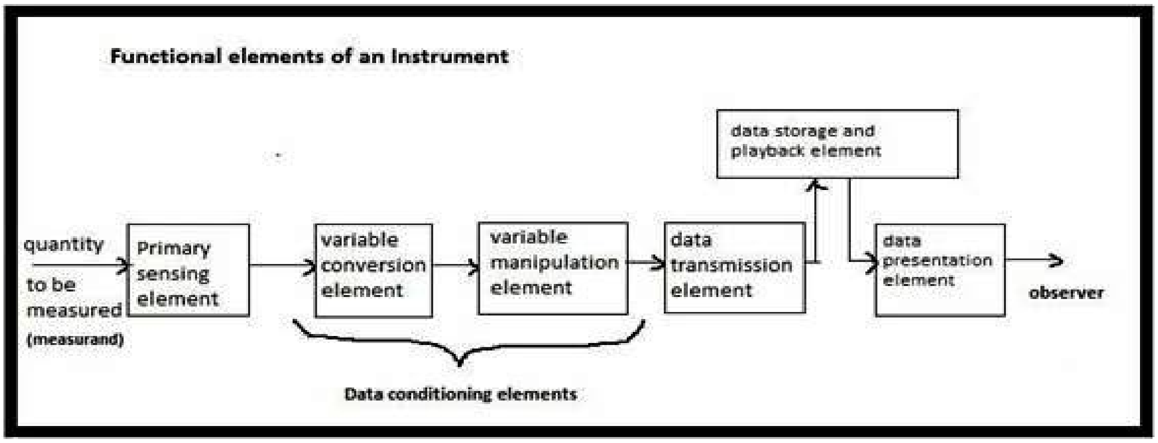


Fig. Block diagram of functional elements of a measurement system / instrument in an open loop system

Unit 5

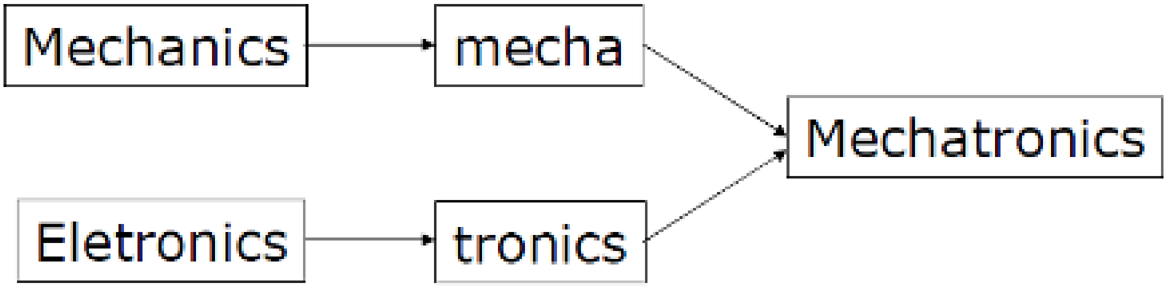
Mechatronics

Lecture 1: Introduction to Mechatronics: Evolution, Scope, Advantages and disadvantages of Mechatronics

The integration of mechanical engineering, electronics engineering and computer technology is increasingly forming a crucial part in the design, manufacture and maintenance of a wide range of engineering products and processes. As a consequence of the synergy of systems in industry, it is becoming increasingly important for engineers and technicians to adopt an interdisciplinary and integrated approach towards engineering problems. The term 'mechatronics' is used to describe this integrated approach. In the design of cars, robots, machine tools, washing machines, cameras, microwave ovens, and many other machines, an integrated and interdisciplinary approach to engineering design is increasingly being adopted.

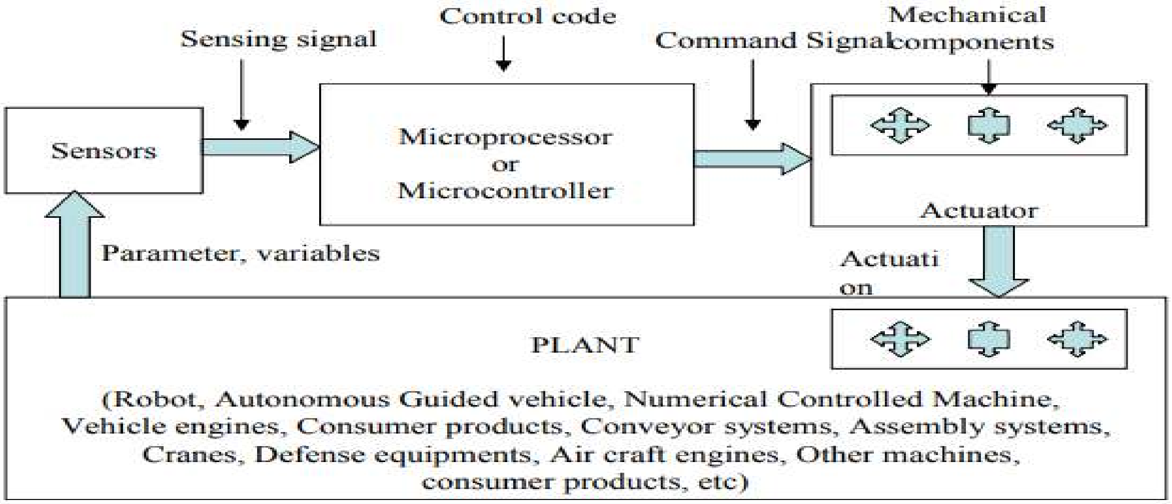
The term 'mechatronics' was first coined by the Japanese scientist Yoshikaza in 1969. The trademark was accepted in 1972. Mechatronics is a subject which includes mechanics, electronics, and informatics.

The word, mechatronics is composed of mecha from mechanics and tronics from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins.



Mechatronics basically refers to mechanical electronic systems and normally described as a synergistic combination of mechanics, electrical, electronics, computer and control which, when combined, make possible the generation of simple, more economic, and reliable systems.

Physically, a mechatronic system is composed of four prime components. They are sensors, actuators, controllers and mechanical components. Figure shows a schematic diagram of a mechatronic system integrated with all the above components.



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"Application of complex decision making to the operation of physical systems." D. M. Auslander and C. J. Kempf, Mechatronics: Mechanical System Interfacing, Prentice-Hall, 1996.

"Synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes." F. Harshama, M. Tomizuka, and T. Fukuda,

Evolution Level of Mechatronics

Primary Level Mechatronics: This level incorporates I/O devices such as sensors and actuators that integrates electrical signals with mechanical action at the basic control levels. Examples: Electrically controlled fluid valves and relays.

Secondary Level Mechatronics: This level integrates microelectronics into electrically controlled devices. Examples: Cassette players

Third Level Mechatronics: This level incorporates advanced feedback functions into control strategy thereby enhancing the quality in terms of sophistication called smart system.

The control strategy includes microelectronics, microprocessor and other ' Application Specific Integrated Circuits' (ASIC)

Example: Control of Electrical motor used to activate industrial robots, hard disk, CD drives and automatic washing machines

Fourth Level Mechatronics: This level incorporates intelligent control in mechatronics system. It introduces intelligence and fault detection and isolation (FDI) capability systems.

Evolution of Mechatronics as a Contemporary Design Paradigm

Technological advances in design, manufacturing, and operation of engineered products/devices/processes can be traced through: –

Industrial revolution-Allowed design of products and processes for energy conversion and transmission thus allowing the use of energy to do useful work

Semiconductor revolution-Led to the creation of integrated circuit (IC) technology.

Information revolution-Development of VLSI technology led to the introduction of microprocessor, microcomputer, and microcontroller

Advantages of Mechatronics

- It is cost effective and it can produce high quality products.

- Production of parts and products of international standards gives better reputation and return.
- It serves effectively for high dimensional accuracy requirements.
- It provides high degree of flexibility to modify or redesign the systems.
- It provides excellent performance characteristics.
- It Results in automation in production, assembly and quality control.
- Mechatronic systems provide the increased productivity in manufacturing organization.
- Reconfiguration feature by pre supplied programs facilitate the low volume production.
- It provides higher level of flexibility required for small product cycles.
- It provides the possibility of remote controlling as well as centralized monitoring and control. .
- It has greater extend of machine utilization.
- Higher life is expected by proper maintenance and timely diagnosis of the fault.

Disadvantages of Mechatronics

- The initial cost is high.
- Maintenance and repair may workout costly.
- Multi-disciplinary engineering background is required to design and implementation.
- It needs highly trained workers to operate.
- Techno-economic estimation has to be done carefully in the selection of mechatronic system.
- It has complexity in identification and correction of problems in the systems.

Lecture 2: Industrial applications of Mechatronics

Mechatronics has a wide range of applications, as discussed in the following subsections.

1. Design and Modelling

Design and modelling are simplified to a large extent by the use of mechatronic systems. Basically, design involves drawing, analysis, and documentation. In earlier days, the processes of design were performed manually and it took weeks or months together. Now, the computer is used to complete processes of design faster. There are many designing tools such as AUTOCAD, IDEAS, and PROENGG, through which 2D or 3D drawings can be made. There are a number of tools to edit drawings at a faster rate. Analysis of the design involves working out the stress distribution, temperature distribution, weight analysis, and animations. The virtual modelling of a manufacturing plant gives an idea of the time taken for a particular component to be manufactured and also shows virtually how the operations will be performed. The drum plotter, *x*-*y* plotter, printer, etc. give complete documentation of design drawings. Important parameters such as surface roughness and tolerance value can be incorporated in the drawing. Digitizers, plotters, CD drives, and many such devices are mechatronic systems.

2 Software Integration

Different kinds of software are used in manufacturing, design, testing, monitoring, and control of the manufacturing process. Examples of such software include computer aided design (CAD), computer aided testing (CAT), computer aided engineering (CAE), and computer aided processing planning (CAPP). The integration of the packets of software leads to computer integrated manufacturing (CIM) or just-in-time (JIT) manufacturing. Software integration is not only used for manufacturing but also for communication networks, economic analysis, etc.

3 Actuators and Sensors

Mechanical, electrical, hydraulic, and pneumatic actuators are widely used in the industry. Toggle linkage and quick return mechanics are typical examples of mechanical actuators. Switching devices, solenoid-type devices, and drives such as alternative current (ac) and direct current (dc) motors can be used as electrical actuators. Hydraulic and pneumatic drives use linear cylinders and rotary motors as actuators. The term sensor is used for an element which produces a signal relating to the quantity being measured. For example, an electrical resistance temperature device transforms the input of temperature into change in resistance. The term transducer is often used in place of sensor. Transducers are defined as devices which when subject to some physical change experience a related change. In the displacement transducer, force is not an error. Addition of extra force into the system reduces backlash and play. For example, in the dial gauge, an additional tension spring is provided on the rack so that the play between the set of gear trains is minimized. Similarly, in a force-transmitting transducer, the provision of more displacement is not an error. Reduction in the play in force transmitting devices produces a loss in power due to friction.

4 Intelligent Control

Feedback control systems are widespread not only in nature and the home but also in industry. There are many industrial processes and machines which control many variables automatically. Temperature, liquid level, fluid flow, pressure, speed, etc. are maintained constant by process controllers. Adaptive control and intelligent manufacturing are the areas where mechatronic systems are used for decision making and controlling the manufacturing environment.

5 Robotics

Robot technology uses mechanical, electronic, and computer systems. A robot is a multifunctional reprogrammable machine used to handle materials, tools, or any special items to perform a particular task. Manipulation robots are capable of performing operations, assembly, and spot welding, spray painting, etc. Service robots such as mail service robots, household servant robots, nursing robots in hospitals are being used nowadays.

6 Manufacturing

In the domain of factory automation, mechatronics has had far-reaching effects in manufacturing. Major constituents of factory automation include computer numerically controlled (CNC) machines, robots, automation systems, and computer integration of all functions of manufacturing. Low volume, more variety, higher levels of flexibility, reduced lead time in manufacture, and automation in manufacturing and assembly are likely to be the future needs of customers, and mechatronic systems will play an important role in this context.

7 Motion control

A rigid body can have a very complex motion which might seem difficult to describe. However, the motion of any rigid body can be considered to be combinations of translational and rotational motions. By considering a three dimensional space, a translational movement can be considered to be one which can be resolved into components along one or more of three axes. The rotation of a rigid body has rotating components about one or more of the axes. A complex motion may be a combination of translational and rotational motion. Motion control is important in many industrial applications such as robots, automated guided vehicles, NC machines, etc. If the robot arm cannot reach a particular location, then the movements of work piece have to be analyzed further. Anybody has six degrees of freedom, three translations and three rotations. A point has only three translations. In a machine tool, the work piece has six degrees of freedom and the tools also have six degrees of freedom. Thus, a machine tool with twelve degrees of freedom can be manufactured. Such a tool can perform a complicated machining operation.

8 Vibration and Noise Control

When a machine member is subjected to a periodic dynamic force, it will vibrate. If the vibration level ranges from a frequency of 20 Hz to 20,000 Hz, it produces noise. Vibration and noise isolation are important in industry. Vibration isolation can be achieved by passive, semi-active, or active dampers. In passive dampers the structure is mounted on damping materials with initial spring loading. In semi-active dampers, both passive and active damping elements are used. In active damping, extra energy is used to damp the structure. When a structure is subjected to a pulse input, a shock is produced. Different types of shock absorbers are used to reduce the shock amplitude. Noise isolation is equally important in industry since noise is harmful to human beings. Adaptive control techniques are used for noise isolation. In this method, the system predicts the noise level in each interval of time and noise is introduced through the speaker in phase opposition. This adaptive control system reduces the noise level.

9 Microsystems

It is fair to say that microsystems are a major step towards the ultimate miniaturization of machines and devices such as dust-size computers and needle type robots. The advancement of nanotechnology will certainly result in the realization of super miniaturized machinery. The need for miniaturization has increased manifold in recent years, and engineering systems and devices have become more and more complex and sophisticated. Pico satellites, space crafts, table-top manufacturing units, and micro electromechanical systems will become a reality in the future. The knowledge of mechatronics is very useful for microsystems.

10 Optics

All slip gauge blocks are calibrated against light wavelength as a standard. Angle gauges can be calibrated to an accuracy of 0.1 sec using a light wave standard—the angstrom unit. A combination of optical and electronic principles has led to the development of instruments such as the midarm which measures angular displacement with an accuracy of 0.05 sec. Optical angle measurement systems for inertial guidance with an accuracy of 0.02 sec have been in use since 1961. Opto-electronic systems use a lens or telescope to form an optical image of an object under study on a photocathode image detector tube. The motion of the object causes the motion of the photocathode optical image and the corresponding motion of the electron image. The optical image is obtained by a conventional videcon camera or a coupled charge device. The camera converts an array of analog signals, in 236 \ 236 pixels in a square centimetre. The analog signals are then converted into digital signals for each pixel and transmitted to an electron image grabber to produce an electron image. As the image starts deviating from the neutral position, the photo multiple layer output tends to drive back by means of a deflection coil. Thus, any main object can be brought to the aperture continuously. The application of still and motion picture photography often allows qualitative and quantitative analyses of complex motion. The photoelastic method is convenient to determine the stress distribution in a machine element. The basic phenomenon of double refraction under load is used in photoelasticity. Double refraction takes place when light travels at a different speed in a transparent material depending on the direction of travel relative to the direction of the principle stress and also depending on the magnitude of the difference between principle stresses for two-dimensional fields. Due to double refraction, light waves form an interference pattern of fringes on a photograph. The photograph is then used to determine the principal stresses. By the use of the frozen stress technique, the method can be extended to three-dimensional problems. The cathode ray tube provides display devices for computers and other entertainment devices such as the television, projector, etc. Electron guns with basic columns can be obtained in a pixel. Cathode ray tubes for picture displays usually have 256 \ 256 pixels/cm2. As the number of pixels increases per square centimetre, the clarity of the picture becomes better. Systems are available which permit each pixel in grey levels (256 levels) in a black-and-white display. Grey levels (light intensity levels) are called grey scaling. With the basic three colours 2563 colour combinations can be obtained with grey scaling. In the ordinary film, only the magnitude of intensity is recorded, which in turn gives two-dimensional images. By recording the amplitude and phase of the reflected light from an object, a hologram can be obtained. A hologram gives three-dimensional ghost images of three-dimensional objects. An optical computer with a hologram will give faster computation in future. Coding and decoding is not required as in conventional computer operation. A ghost image from the hologram gives a grey-scaled image on each voxel. 2563 voxels can be accommodated in a cubic centimetre of laser hologram. Sintering in each voxel can be obtained by packing the metal particles in the ghost image. Thus in future any complicated article can be manufactured in seconds using the laser hologram technique.

Lecture 3: Introduction to autotronics, bionics, and avionics and their applications

Autotronics: Autotronics can be defined as the combination of automobile and electronics or we can say that the use of electronics science in automobile vehicles is called autotronics. A lot of research and implementation had been done in this context to make the design of automobiles easier. The use of electronics in the automobile field makes the system safe, improved and efficient. In a vehicle almost all significant parts are featured with electronic items.

New developments are coming very frequently in this field because there no limitations in the development of new autotronics. It helps to improve overall automobile system.

At present, in the new generation automobiles almost 75%-85% of automobile parts are embedded with electronics system. The main areas of automobiles using autotronics are engine controlling system, airbags, antilock braking system, lightening interiors, GPS, music systems etc. The application area of autotronics is very vast, brakes, steering system, engine controlling unit, transmission and suspension in the vehicles are the main phases where autotronics are used.The use of these technologies has given a phenomenal revolution in the automobile industry from past few decades. The gradual improvements in systems causes the new features in reduced cost.In the autotronic systems the use of control units like sensors, motors and digital equipment establishes a communication between the various essential system and components of the vehicle.The various systems are given below

1. Autotronic braking system/Electronic braking system

The braking system in such a system is denoted s EBS (electronic braking system). A braking system is defined by its stopping distance. The system with shortest stopping distance is considered the best braking system. So the development phase in the braking system is to minimize the stopping distance of vehicle but without compromising the safety. The ECB solve these purposes with an advance control system. The anti-lock braking system and traction control system are the essential components of ECB.

ABS is responsible for maneuver control by deciding the braking pressure and wheel rotation control.

Traction means providing movement or acceleration to a vehicle. So, to control the acceleration the control on traction system should be applied. This system controls the movement of wheel and its steadiness.

2. Control of steering system

In the vehicle the power steering system is used. Which maintains the communication between pressure applied by steering system on the hydraulic pump and the speed of the automobile. The EPS (electric power steering) uses sensors and motors, which controls the maneuver. Motor controls the steering motions and sensors gives signal to the wheels by analyzing the speed and torque.

3. Suspension system

Suspension system makes the ride on vehicle shock free, comfortable and safe. There are three types of suspension system 1. Passive, 2. Semi active, and 3. Active suspension system. The important task of the system is to dissipate the heat produced in the system due to friction. The conventional method of suspension is called passive suspension and when we add electronic sensors and hydraulic system then its performance increases and it is called active suspension system.

4. Transmission control

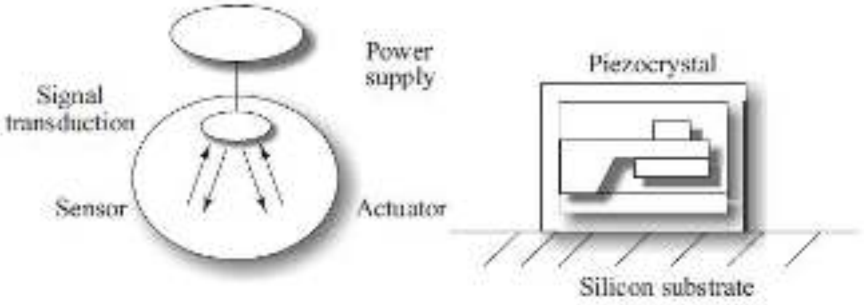
The transmission of gearing system controls the shifting of gears. Using the electronic gear transmission improves the shifting operation and increases the fuel efficiency by reducing the losses.

5. Electronic control of fuel intake in engine

The electronic system used to analyze the amount of fuel to supply to the cylinder of engine so that the maximum efficiency can be achieved with minimum loss of energy.

6. Air Bag Deployment System

A sensor and an actuator embedded in a microsystem are used to operate the air bag deployment system in an automobile. The impact of the car in a serious collision is felt by a micro-inertia sensor built on the principle of micro-accelerometer. The sensor generates an appropriate signal to actuate the deployment of an air bag to protect the driver and passengers from serious injuries due to the impact of collision. Figure shows a micro-inertia sensor employed for rapid deployment of an air bag. The sensor contains two micro-accelerometers mounted onto the chassis of the car. The accelerometer on the left measures the deceleration in the horizontal direction and the accelerometer on the right measures the deceleration in the transverse direction. Both these accelerometers are mounted on the same integrated circuit chip along with a signal transducer and processing unit.



7. Antilock or Antiskid Device

A vehicle stops more quickly when the brakes are applied just hard enough to get maximum static friction between the tyres and the road. If the brakes are applied harder than this, the tyres will skid or slide on the road and lesser kinetic friction will result. In this situation, applying brakes is less effective. Several devices have been developed to prevent a vehicle from skidding and thus provide maximum effective braking. Skid control is employed generally for the rear wheel only. As long as the wheels are turning/rotating, the antiskid device permits normal application of the brakes. But if the brakes are applied so hard that wheels stop turning, skid starts to develop. At this point, the antiskid device starts operating and partially releases the brakes so that the wheels continue to turn/rotate. However, intermittent braking continues, but it is held to just below the point where a skid would start. The result is maximum braking effect. The distance in which a vehicle can be brought to rest from a steady speed depends upon the following factors:

Σ Braking efficiency

Σ Condition and inflation pressure of tyres

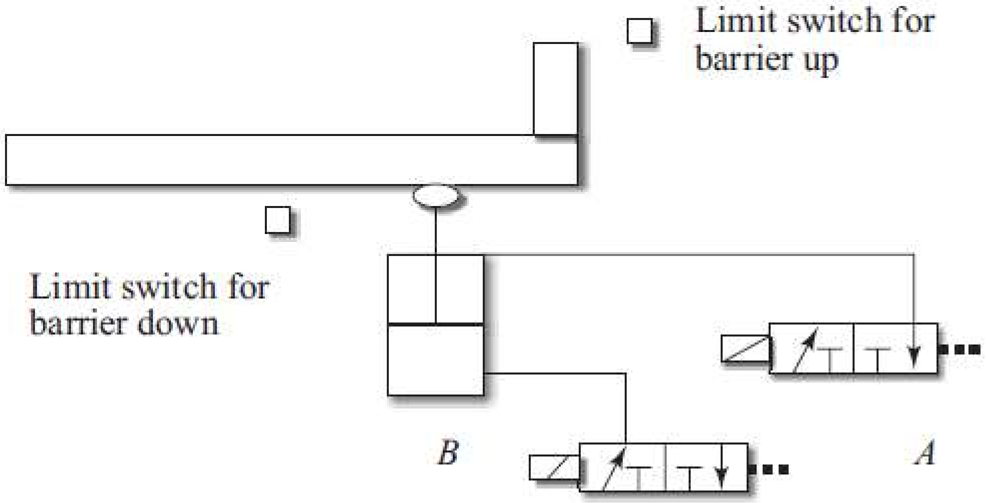
Σ Nature of road surface

Σ Air resistance encountered by the vehicle

Braking causes a retarding force on the vehicle, which in turn gives rise to deceleration. Braking efficiency is measured in terms of the rate at which it will bring the vehicle to a stationary position from a given speed. It is expressed in terms of the ratio of the deceleration rate to the acceleration rate due to gravity.

9. Car Park Barrier

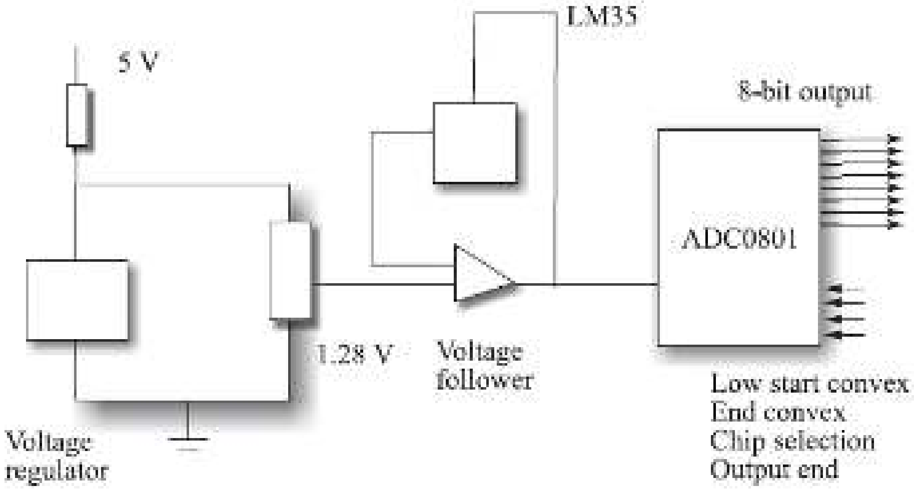
Consider the cam-operated barrier for a car park. The barrier opens and allows a car in when the correct money is inserted into the collection box. The barrier opens again to allow the car out on its detection on the park side of the barrier. Figure shows the type of the wall system that can be used to lift and lower the pivoted barrier. When a current flows through the solenoid of valve *A*, the piston in the cylinder moves upwards and causes the barrier to rotate about its pivot and raise to let a car through. When the current through the solenoid of valve *A* ceases, the return spring of the valve results in the valve position changing back to its original position. When the current flows through the solenoid of valve *B*, pressure is applied to the lower barrier. Limit switches are used to detect whether the barrier is in down or up position.



10. Engine Temperature Measurement

Consider the requirement for a temperature measurement system for measuring temperature in the range 0–100oC, which is the case of the body temperature of the engine of an automobile. The system gives an 8-bit binary output with a change in 1 bit corresponding to the temperature change of 1oC. The output is intended for inputting to a microprocessor as part of a temperature indicating system. Thermistor LM35 can be used since a linear temperature sensor is required. LM35 gives an output of 10 mV/oC when fed with a supply voltage of 5 V. If one supplies from LM35 with an 8-bit analog to digital converter (ADC), then a digital output can be obtained. The resolution of the ADC should be 10 mV so that each strip of 10 mV can generate a change in the output of 1 bit. If one uses a successive approximation ADC, ADC0801, then it requires an input of the response voltage, which when subdivided into 256 bits gives 10 mV per bit.

This reference voltage input to the ADC0801 has to be *V*ref /2 and so an accurate input voltage of 1.28 V is required. Such a voltage can be obtained by using a potentiometer circuit across the 5-V supply with a voltage follower to avoid loading problems. Because the voltage has to be steady at 1.25 V even if the 5-V supply voltage fluctuates, a voltage regulator is likely to be used for a 2.54-V supply, ZN458/B. Such a circuit is shown in Fig.



BIONICS

Bionics is a common term for bio-inspired information technology, typically including three types of systems, namely:

- Bio-morphic (eg neuromorphic) and bio-inspired electronic/optical devices,
- Autonomous artificial sensor-processor-activator prostheses and various devices built into the human body, and
- Living-artificial interactive symbioses, e.g. brain-controlled devices or robot

Bionics is poised to have significant stake in mechatronic sensors market in the near future. Biomedical sensors are mainly used for diagnostic analyses. Because of its miniature size, a biomedical sensor requires less amount of sample and can produce results significantly faster. These sensors can be produced in batches, thus resulting low unit cost of the sensor. Another cost cutting factor is that most of these sensors are disposable, thus manual labour involving cleaning and proper treatment for reuse is saved. Biosensors are extensively used in analytical chemistry and biomedical care as well as genetic engineering. These sensors usually involve biological molecules such as antibodies or enzymes, which interact with analytes that are to be detected. Major advantages of the use of mechatronic systems in biomedicine are as follows:

1. Functionality for biomedical operators
2. Adaptability to existing instruments and equipment
3. Compatibility with biological systems
4. Controllability, mobility, and easy navigation facilities for operators
5. Possibility of the fabrication of mechatronic structures with a high aspect ratio

(The ratio of the depth dimension to the surface dimension of the structure)

Application

Glucose Detection and DNA Sensing

Detection of glucose levels in human body is a classic case of bio sensing. Diabetic patients cannot control their insulin level if the level of blood glucose fluctuates tremendously. If the level gets either too high or too low, their condition can be life threatening. Currently such patients must actually draw blood on a daily basis or even more often to monitor the blood glucose level. Sensing the blood glucose level can be done in many ways, using optical, conduction, or molecular recognition methods. None of these have yet been shown to be compatible with an implantable simple device that could automatically show or continuously sense the glucose level in the blood. This remains one of the major challenges in chemical sensing and Nano scale structures. The DNA sensing is potentially an enormous area in which the application of Nano science can prove to be path breaking. One can sense the structure with the sequence GEGEAAG by using a strand GCGCAAG. This means that a single strand of, say, six bases can contain 4096 different combinations. Consequently, a particular biological target such as botulism or strap or scarlet always has a unique DNA sequence. It is possible to target a short sector of the DNA sequence, say, a section of 10–15 bases. It can be uniquely sensed without any error. The most important application of DNA sensing will probably come in the generalization of a laboratory on a chip concept. By using the powerful analytic capability of such dense micro-laboratories, it will be possible to include several screening sensors on a chip. This chip can be used to recognize a viral or bacterial DNA associated with several different diseases found in the body. This chip could also be used to sense the presence of toxic species, either natural or artificial. Since the entire human genome is known, a biochip can be used to sense either a particular DNA signature or a particular protein signature known to be characteristic of a disease. It is also possible to create a sensor that takes advantage of the DNA recognition technique. The simplest DNA recognition sensor works by introducing a strand of DNA complimentary to the analyte into a solution to be tested. If the analyte is present, it will hybridize with the test DNA and form a double strand. Hybridization confirms that the analyte is present, or finding out that hybridization has occurred is trivial. One cannot see the double strands without very sophisticated instruments. Therefore, one of the great challenges in DNA sensing is to amplify the effect of hybridization so that it is easy for measurement. One way to provide amplification is to change the optical properties of gold or silver nanodots that are attached to the DNA. The change in the colour of gold upon changing the size of the gold cluster and the molecular recognition is called quantum optical effect. The colour change is measured by a device called calorimetric sensor, which can be read by simply looking at it. Nanosphere lithography is used to prepare the tiny gold dots on a surface. A sensor is designed to recognize a particular portion of the analyte appearing in the solution. If one wants to construct an explosive detection sensor, the problem is much more complex. Nitrates, which are common to most explosives, are common in household items including fertilizers. If one detects them to an accuracy of a single molecule, then even fertilizers are carrying a bomb. A great deal of research is underway in this direction.

Drug Delivery

The size of the human body is very large compared to the size of a molecule. It is important for the thermofusion effectiveness that drug molecules find/reach the place in the body where they are needed/effective. Bio-availability refers to the presence of drug molecules where they are needed in the body and where they will do the most good. The issue of drug delivery aims at maximizing bio-availability both over a period of time and at the specific place in the body. Increasing the bioavailability is seldom as simple as increasing the amount of drug used. The drugs used in chemotherapy are actually somewhat toxic and need to be target-specific to avoid damage to the normal/healthy tissue. It is necessary to keep the drug doses to a minimum, otherwise the amount used can adversely affect or even kill a patient. Taking these issues into account, drug delivery assumes a lot of significance. Nanotechnology and Nano science are very useful in developing entirely new ways for increasing bio-availability and improving the drug delivery. Magnetic nanoparticles used for computer memory can be used for drug delivery also. For drug delivery, the molecular recognition method is used to bind a Nano magnet to the drug to be delivered. External control is exercised over the magnetic field created by magnetic nanoparticles to improve local bio-availability of the drug. Effectively, a doctor can drag drug molecules through the body in the same way as you drag an iron filing across a table with a hand magnet. One interesting combination of smart materials and drug delivery is the triggered response. This consists of placing drug molecules within the body in an inactive form that works upon encountering a particular signal. A simple example is antacid implored in a coating of a polymer that dissolves in a highly acidic spot. The antacid is released only when the outer polymer coat encounters a highly acidic spot in the digestive track.

Photodynamic Therapy

In photodynamic therapy, a particle is placed within the patient’s body. This particle is illuminated with a light source from outside of the body. The light may come from outside from a laser or light bulb. The light is absorbed by the particle, after which several things might happen. If the particle is simply a metal nanodot, the energy from the light will heat the dot, which, in turn, will heat any tissue within its neighborhood. With the same particular molecular dot, light can also be used to produce highly energetic oxygen molecules. Such oxygen molecules are very reactive and will chemically react with (and, therefore, destroy) many organic molecules that are next to them. The photodynamic therapy is attractive for many reasons. One reason is that, unlike the traditional chemotherapy, it is directed at the damaged/diseased cell. The chemically reactive excited oxygen or quantum data is released only where such cells are present and where the light is illuminated.

This ensures that, unlike the traditional chemotherapy, the photodynamic therapy does not leave a fixed trail of highly aggressive and reactive molecules throughout the body.

Neuro-electronic Interface

The neuro-electronic interface involves the idea of constructing nano devices that can permit computers to be joined and linked to the neuro system. The construction of a neuro-electronic interface system requires the building of a molecular structure that will permit control and detection of nerve impulses by an external computer. The real challenge is to combine computational technology and bio-nanotechnology. The nerves in the human body convey messages by permitting electrical current to flow between the brain and nerve centre throughout the body. The most important ions for signals are sodium and potassium ions. These ions move along sheets and channels that have evolved specially to permit special, controllable, rapid ion motion. This is the mechanism that allows you to feel sensation. For example, when you put your foot in hot water, a signal is transmitted by the local nerve through the nervous system to the brain. The brain interprets the transmitted signal and processes it for a suitable reaction. Often this process results in a response being filtered into the muscular system. The aim of the neuro-electronic interface technology is to permit the registration and interpretation of these signals as well as response to them to be handled by a computer. The sensor must be able to sense ionic currents and cause current to flow backward so that the muscular system can be instructed to perform a desired motion. The most obvious structure will be a molecular conductor or molecule whose own conduction process, ions, or electrons can link with the ionic motion in a nerve fibre.

Biotechnology

Mechatronics plays an important role in biotechnology even though it is a small subdomain of biotechnology. Biotechnology includes all techniques that use living organisms or substances obtained from them to make or modify a product. It involves improvement of microbe, plant, and animal species. Genes and gene products are the basic tools in biotechnology. Biotechnology aims at harnessing the genetic diversity in the living organisms for the benefit of the humankind. Understanding of genes and the possibility to manipulate them are the very bases of modern biotechnology. Classical genes and manipulation of the genes at cellular level have played a major role in enhancing the productivity of crops, plants, and animals. Molecular manipulation of genes to obtain better products requires input from specialists in many different areas of biology, besides from specialist in other branches of science, especially mechatronics. The splendors of biotechnology are so much that it almost seems to be the science of wish fulfillment. Bigger fruits, bright flowers, higher yields, super cattle, exotic colours and flavours, cheaper medicines, and more efficient vaccines are the products of biotechnology.

Avionics

Considerable effort and progress have been made in recent years in the development of mechatronic systems in the aerospace industry. Numerous and complex mechatronic systems are used in advanced commercial and military aircrafts. With the ever-increasing emphasis on robustness and safety, there is a trend towards using more mechatronic systems in aerospace industry. This has given rise to a new area of mechatronics in the form of avionics. The major applications of mechatronic systems in aerospace industry can be classified as follows:

- Cockpit instrumentation
- Safety devices
- Wind tunnel instrumentation
- Sensors for fuel efficiency and safety
- Microgyroscope for navigation and stability
- Microsatellites

Cockpit Instrumentation

Air-data systems vary in complexity from a light airplane to advanced commercial or military aircrafts. However, all air-data computations are based upon four sensed parameters, namely, static pressure, total pressure, temperature, and the angle of attack. Pressure and temperature of the atmosphere are functions of the altitude above the sea level, latitude, season, and time of day. Static pressure can be easily and accurately measured because the actual altitude for a given pressure varies only slowly with respect to time and distance. A Pitot tube is a pressure measuring instrument used to measure fluid flow velocity and, more specifically, to determine the airspeed of an aircraft The opening on the smooth side of the Pitot-static tube provides a source of the atmospheric pressure, termed static pressure. The open end of the Pitot-static tube is headed into the stream and provides a source of the total pressure resulting from the impact of a body travelling through the atmosphere. The difference between the total pressure and the static pressure gives the dynamic force, which contains the velocity term. The speed of the aircraft can thus be determined. Most of the Pitot-static tubes are electrically heated to melt off any ice that might form. Otherwise, ice might partly or completely seal off the opening and the instrument will give erroneous results. Air-speed indicators work on the principle that the difference between the total pressure and the static pressure is the measure of the indicated air speed. The indicated air speed at which a given aircraft with a given load stalls is a constant over a wide range of pressure and temperature The angle of attack transducer measures the acute angle between the velocity vector of the aircraft through the surrounding air and some reference such as the force-opt axis of the aircraft or the chord of an aircraft. The lift developed by an aircraft wing increases as a function of the angle of attack and the airplane velocity. The air-data computers centralize the computation of air data from a number of inputs, e.g., static pressure, total pressure, air stagnation temperature, and angle of attack. This information is used to ascertain the true air speed, temperature, Mach number, air density, and rate of climb. The information is then transmitted to indicators and displays and is used by various aircraft subsystems such as the flight control system, fire control system, and navigation system.

Alarms and Safety Devices

An alarm is a protective device for maintaining critical points in a system under constant surveillance. In basic principles, alarm differs little from other forms of indication and control instruments. Strong emphasis is placed on reliable performance of alarms. Such devices must remain operable over long periods of inactivity and need periodic, scheduled check, because the equipment does not function except in case of emergency. Most alarm installations are of audiovisual type, with illuminated name plates or bull-eye lights. There is a means to silence the alarm and switch the light to steady state. Another push button usually is provided for testing other components of the system. Micro-accelerometers or micro-inertial sensors are used to eject the pilot seat from the aircraft, especially in military airplanes. The use of the seat eject system protects the pilot in the event of an emergency. The sensor opens the latch where the seat is loaded with a spring, which throws the seat along with the pilot a distance away from the aircraft. When it is detached from the aircraft, a parachute automatically opens to ensure safe landing of the pilot.

Aircraft Guidance and Control

To guide and control an aerospace vehicle successfully is a matter of measuring position, determining path errors, and controlling to correct the path. These three functions usually are called navigation, guidance, steering, and control. Navigation determines the position, guidance determines the error from the indicated path, steering is used to select a proper series of changes in the path, and control changes the forces on the vehicle to adjust them with the direct path changes. Initial guidance predicts the ballistic path. The aircraft guiding system measures accelerator and recalls the reference angle, computes velocity and position, predicts the destination, determines a preferred path to correct the error and controls the forces to change the path from steering instructions, all can be automated. Aerospace vehicle systems have many degrees of automation. Almost all aerospace vehicle systems use combinations of all or many of automatic, manual, remote, self-contained, and preprogrammed corrections. Aerospace vehicles may be piloted by a human being or an automatic flight control system. Gyroscope instruments are among the most important elements of the flight instrumentation and control systems whether for assisting a human pilot or for providing input to a fully automatic flight control system. A wide variety of gyroscope instruments are used in aircrafts. The rate gyroscope is a device designed to measure the instantaneous angular velocity component of a body with respect to the inertial space. Its typical applications include autopilot damping, rate of turn indicator, limiting antenna stabilization, and telemetry instrumentation. The rate integrating gyroscope or floated gyroscope can be designed as either a single- or two-axis device. It is designed so that the fluid damping between gimbals and housing is the predominant torque, which balances the input rate precessional torque.

Air Traffic Control

Position reporting by the pilot to the air traffic controller over a voice radio link is the basic source of air traffic control position data. The ground controller can ascertain the aircraft location independently using the following methods.

***Method* 1** It can use the primary radar, which operates on the reflection by the aircraft of the pulse signals that the radar transmits.

***Method* 2** It can use the secondary radar, which operates on replies from pulsed radio and is verified by the secondary radar pulses. Some airports are equipped for precision approach radius. There are primary radars that use two very narrow beams to scan a relatively narrow section aligned with the approach course to a particular runway. One beam is broad in the vertical dimension and narrow in the horizontal dimension. It scans at a relatively high rate in the horizontal dimension. The controller watching the cathoderay- tube display is able to tell the pilot whether the pilot is to the right or left of the true approach course.

Aircraft Engine Control

The extent and sophistication of engine instrumentation vary widely with the type of the aircraft and intended use. In a small-engine plane, most instruments are simple and a mechanically connected throttle suffices. It is highly desirable to keep fuel and oil under pressure out of the cockpit. Thus most engine parameters are remotely indicated in the cockpit from a transmitter mounted near or on the engine. Instrumentation for a typical jet engine will provide for controlling and monitoring of the following:

1. Low-pressure rotor speed
2. High-compressor rotor speed
3. Fuel flow
4. Exhaust gas temperature
5. Engine pressure
6. Engine inlet air pressure
7. Engine inlet air temperature
8. Fuel pump inlet temperature
9. Fuel decreasing air shut off valve position
10. Fuel pump inlet pressure
11. Fuel filter pressure difference warning
12. Engine oil pressure
13. Engine oil and inlet temperature
14. Engine radial vibration

Lecture 4: Sensors and Transducers: Types of sensors, and their characteristics

Sensor: A sensor is defined as an element which when subjected to some physical change experiences a relative change. A sensor in which the output energy is supplied entirely or almost entirely by its input signals is called a passive element. An active element has an uxiliary source of power that supplies a major part of the output power. There may or may not be a conversion of energy from one form to another.

Sensors are used in mechatronics for the following purposes:

1. To provide position, velocity, and acceleration information of the measuring element in a system which provides feedback information
2. To act as protective mechanism for a system

3. To help eliminate mechanically complex and expensive feeding and sorting devices
4. To provide identification and indication of the presence of different components
5. To provide real time information concerning the nature of the task being performed.

Types of Sensor:

Vision and Imaging Sensors

Vision and Imaging Sensors/Detectors are electronic devices that detect the presence of objects or colors within their fields of view and convert this information into a visual image for display. Key specifications include sensor type and intended application, along with any particular transducer features.

Temperature Sensors

Temperature Sensors/Detectors/Transducers are electronic devices that detect thermal parameters and provide signals to the inputs of control and display devices. A temperature sensor typically relies on an RTD or thermistor to measure temperature and convert it to an output voltage. Key specifications include sensor/detector type, maximum and minimum measurable temperatures, as well as the dimensions of diameter and length. Temperature sensors are used to measure the thermal characteristics of gases, liquids, and solids in many process industries and are configured for both general- and special-purpose uses.

Radiation Sensors

Radiation Sensors/Detectors are electronic devices that sense the presence of alpha, beta, or gamma particles and provide signals to counters and display devices. Key specifications include sensor type and minimum and maximum detectable energies. Radiation detectors are used for surveys and sample counting.

Proximity Sensors

Proximity Sensors are electronic devices used to detect the presence of nearby objects through non-contacting means. A proximity sensor can detect the presence of objects usually within a range of up to several millimeters, and, doing so, produce a usually dc output signal to a controller. Proximity sensors are used in countless manufacturing operations to detect the presence of parts and machine components. Key specifications include sensor type, maximum sensing distance, minimum & maximum operating temperatures, along with dimensions of diameter and length. Proximity sensors are generally short-range devices but are available too in designs that can detect objects up to several inches away. One commonly used type of proximity sensor is known as a capacitive proximity sensor. This device uses the change in capacitance resulting from a reduction in the separation distance between the plates of a capacitor, one plate of which is attached to the object being observed, as a means of determining motion and position of the object from the sensor.

Pressure Sensors

Pressure Sensors/Detectors/Transducers are electro-mechanical devices that detect forces per unit area in gases or liquids and provide signals to the inputs of control and display devices. A pressure sensor/transducer typically uses a diaphragm and strain gage bridge to detect and measure the force exerted against a unit area. Key specifications include sensor function, minimum and maximum working pressures, full-scale accuracy, along with any features particular to the device. Pressure sensors are used wherever information about the pressure of a gas or liquid is needed for control or measurement.

Position Sensors

Position Sensors/Detectors/Transducers are electronic devices used to sense the positions of valves, doors, throttles, etc. and supply signals to the inputs of control or display devices. Key specifications include sensor type, sensor function, measurement range, and features that are specific to the sensor type. Position sensors are used wherever positional information is needed in a myriad of control applications. A common position transducer is a so-called string-pot, or string potentiometer

Photoelectric Sensors

Photoelectric sensors are electrical devices that sense objects passing within their field of detection, although they are also capable of detecting color, cleanliness, and location if needed. These sensors rely on measuring changes in the light they emit using an emitter and a receiver. They are common in manufacturing and material handling automation for purposes such as counting, robotic picking, and automatic doors and gates.

Particle Sensors

Particle Sensors/Detectors are electronic devices used to sense dust and other airborne particulates and supply signals to the inputs of control or display devices. Particle sensors are common in bin and baghouse monitoring. Key specifications include transducer type, minimum detectable particle size, operating temperature range, sample volume, and response time. Particle detectors used in nuclear engineering are referred to as radiation detectors

Motion Sensors

Motion Sensors/Detectors/Transducers are electronic devices that can sense the movement or stoppage of parts, people, etc. and supply signals to the inputs of control or display devices. Typical applications of motion detection are detecting the stalling of conveyors or the seizing of bearings. Key specifications include the intended application, sensor type, sensor function, and minimum and maximum speeds.

Metal Sensors

Metal Detectors are electronic or electro-mechanical devices used to sense the presence of metal in a variety of situations ranging from packages to people. Metal detectors can be permanent or portable and rely on a number of sensor technologies with electromagnetics being popular. Key specifications include the intended application, maximum sensing distance, and certain feature choices like handheld and fixed systems. Metal detectors can be tailored to explicitly detect metal in specific manufacturing operations such as sawmilling or injection molding..

Level Sensors

Level Sensors/Detectors are electronic or electro-mechanical devices used for determining the height of gases, liquids, or solids in tanks or bins and providing signals to the inputs of control or display devices. Typical level sensors use ultrasonic, capacitance, vibratory, or mechanical means to determine product height. Key specifications include sensor type, sensor function, and maximum sensing distance. Level sensors/detectors can be of the contacting or non-contacting type.

Leak Sensors

Leak Sensors/Detectors are electronic devices used for identifying or monitoring the unwanted discharge of liquids or gases. Some leak detectors rely on ultrasonic means to detect air leaks, for example. Other leak detectors rely on simple foaming agents to measure the soundness of pipe joints. Still, other leak detectors are used to measure the effectiveness of the seals in vacuum packages

Humidity Sensors

Humidity Sensors/Detectors/Transducers are electronic devices that measure the amount of water in the air and convert these measurements into signals that can be used as inputs to control or display devices. Key specifications include maximum response time and minimum and maximum operating temperatures.

Gas and Chemical Sensors

Gas and Chemical Sensors/Detectors are fixed or portable electronic devices used to sense the presence and properties of various gases or chemicals and relay signals to the inputs of controllers or visual displays. Key specifications include the intended application, sensor/detector type, measurement range, and features. Gas and chemical sensors/detectors are used for confined space monitoring, leak detection, analytical instrumentation, etc. and are often designed with the capability of detecting multiple gases and chemicals.

Force Sensors

Force Sensors/Transducers are electronic devices that measure various parameters related to forces such as weight, torque, load, etc. and provide signals to the inputs of control or display devices. A force sensor typically relies on a load cell, a piezoelectric device whose resistance changes under deforming loads. Other methods exist for measuring torque and strain. Key specifications include sensor function, number of axes, minimum and maximum loads (or torques), minimum and maximum operating temperature, as well as the dimensions of the sensor itself. Force sensors are used in load measuring applications of all kinds, from truck scales to bolt tensioning devices.

Flow Sensors

Flow Sensors/Detectors are electronic or electro-mechanical devices used to sense the movement of gases, liquids, or solids and provide signals to the inputs of control or display devices. A flow sensor can be all electronic—using ultrasonic detection from outside a pipeline, say—or partially mechanical—a paddlewheel, for instance, that sits and spins directly in the flow stream itself. Key specifications include sensor/detector type, sensor function, maximum flowrate, maximum working pressure, and minimum and maximum operating temperatures. Flow sensors are used extensively in the processing industries. Some designs for panel mounting allow quick indication of flow conditions to process operators

Flaw Sensors

Flaw Sensors/Detectors are electronic devices used in a variety of manufacturing processes to uncover inconsistencies on surfaces or in underlying materials such as welds. Flaw detectors use ultrasonic, acoustic, or other means to identify defects in materials and can be portable or fixed installations. Key specifications include sensor type, detectable defect or thickness range, and intended application.

Flame Sensors

Flame Detectors are optoelectronic devices used to sense the presence and quality of fire and provide signals to the inputs of control devices. A flame detector typically relies on ultraviolet or infrared detection of the presence of flame and finds use in many combustion control applications such as burners. A key specification is detector type. Flame detectors find applications in safety settings too, such as in under-the-hood fire suppression systems

Electrical Sensors

Electrical Sensors/Detectors/Transducers are electronic devices that sense current, voltage, etc. and provide signals to the inputs of control devices or visual displays. Electrical sensors often rely on hall effect detection but other methods are used as well. Key specifications include sensor type, sensor function, minimum and maximum measurement ranges, and operating temperature range.

Electrical sensors are used wherever information on the state of an electrical system is needed and are employed in everything from railway systems to fan, pump, and heater monitoring.

Contact Sensors

Contact sensors refer to any type of sensing device that functions to detect a condition by relying on physical touch or contact between the sensor and the object being observed or monitored. A simple type of contact sensor is used in alarm systems to monitor doors, windows, and other access points. When the door or window is closed, a magnetic switch provides an indication to the alarm control unit so that the status of that entry point is known. Similarly, when a door or window is opened, the contact sensor alerts the alarm controller of the state of that access point and may trigger an action such as engaging an audible siren. There are many uses of contact sensors such as temperature monitoring and as proximity sensors in robotics applications and automated machinery.

Non-Contact Sensors

In contrast to contact sensors, non-contact sensors are devices that do not require a physical touch between the sensor and the object being monitored in order to function. A familiar example of this type of sensor is the motion detector used in security lights. Detection of objects within the range of a motion detector is accomplished using non-mechanical or non-physical means, such as via detection of passive infrared energy, microwave energy, ultrasonic waves, etc. Radar guns used by law enforcement to monitor the speed of vehicles is another example of a form of non-contact sensor. Other types of devices that fall under the category of non-contact sensors include Hall-effect sensors, inductive sensors, LVDTs (linear variable differential transformers), RVDTs (rotary variable differential transformers), and Eddy current sensors, to name a few.

Characteristics of Sensors

To choose an appropriate sensor for a particular need, we have to consider a number of different characteristics.

•These characteristics determine the performance, economy, ease of application, and applicability of the sensor.

•In certain situations, different types of sensors may be available for the same purpose.

•Therefore, the following may be considered before a sensor is chosen:

1. Cost: The cost of a sensor is an important consideration, especially when many sensors are needed for one machine. However, the cost must be balanced with other requirements of the design such as reliability importance of the data they provide accuracy, life, and so on.

2. Size: Depending on the application of the sensor, the size may be of primary importance. For example, the joint displacement sensors have to be adapted into the design of the joints and move with the robot's body elements. The available space around the joint may be limited. Therefore, it is important to ensure that enough room exists for the joint sensors.

3. Weight:

Since robots are dynamic machine, the weight of a sensor is very important. A heavy sensor adds to the inertia of the arm and reduces its overall payload.

4. Type of output (digital or analog):

The output of a sensor may be digital or analog and depending on the application, this output may be used directly or have to be converted.

For example, the output of a potentiometer is analog, whereas that of an encoder is digital.

If an encoder is used in conjunction with a microprocessor, the output may be directly routed to the input port of the processor, while the output of a potentiometer has to be converted to digital signal with an analog-to-digital converter (ADC).

The appropriateness of the type of output must be balanced with other requirements.

5. Interfacing: Sensors must be interfaced with other devices such as microprocessors and controllers. The interfacing between the sensor and the device can become an important issue if they do not match or if other add-on components and circuits become necessary (including resistors, transistor switches, power source, and length of wires involved).

6. Resolution**:** Resolution is the minimum step size within the range of measurement of the sensor

7. Sensitivity: Sensitivity is the ratio of a change in output in response to a change in input. Highly sensitive sensors will show larger fluctuations in output as a result of fluctuations in input, including noise.

8. Linearity. Linearity represents the relationship between input variations and output variations. This means that in a sensor with linear output, the same change in input at any level within the range will produce a similar change in output. Almost all devices in nature are somewhat nonlinear, with varying degrees of nonlinearity.

9. **Range:** Range is the difference between the smallest and the largest outputs the sensor can produce, or the difference between the smallest and largest inputs with which it can operate properly.

10. **Response rime:** Response time is the time that a sensor's output requires to reach a certain percentage of the total change. It is usually expressed in percentage of total change, such as 95%. It is also defined as the time required to observe the change in output as a result of a change in input. For example, the response time of a simple mercury thermometer is long, whereas a digital thermometers response time, which measures temperature based on radiated heat, is short.

11. Frequency response: Suppose you attach a very high-quality radio tuner to a small, cheap speaker. Although the speaker will reproduce the sound, its quality will be very low, whereas a high-quality speaker system with a woofer and tweeter *will reproduce the same signal with much better quality. This is because the frequency response of the two-speaker system is very different from the single, cheap speaker.*

12. Reliability:

Reliability is the ratio of how many times a system operates properly, divided by how many times it is used. For continuous, satisfactory operation it is necessary to choose reliable sensors that last a long time while considering the cost and other requirements.

13. Accuracy:

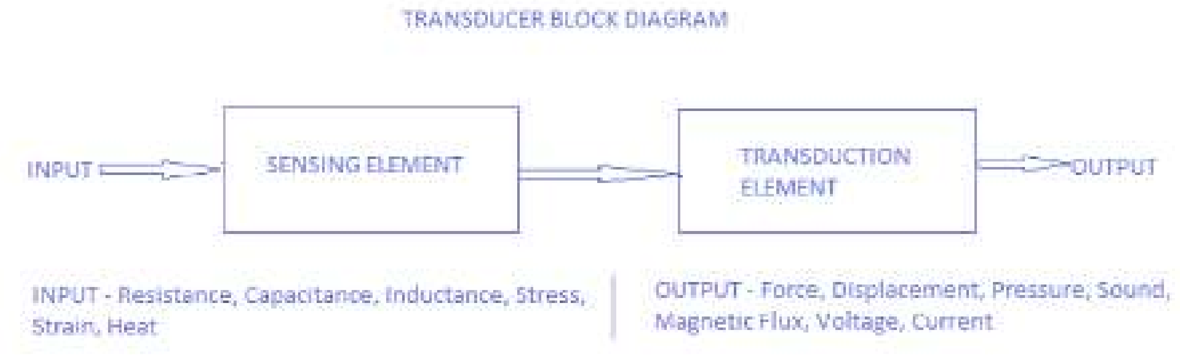
Accuracy is defined as how close the output of the sensor is to the expected value. If for a given input, the output is expected to be a certain value, accuracy is related to how close the sensor's output is to this value.

14. Repeatability:

If the sensor's output is measured a number of times in response to the same input, the output may be different each time. Repeatability is a measure of how varied the different outputs are relative to each other.

Lecture 5: Types of transducers and their characteristics

Transducer: A device that converts variations in a physical quantity, such as pressure or brightness, into an electrical signal, or vice versa. Transducer is a device which converts one form of energy into another form. It is also defined as a device that converts a non electrical quantity into proportional electrical quantity.



For example –

1. An electric generator converts mechanical energy into equivalent electrical energy.
2. A solar cell used in calculators converts light energy into equivalent electrical energy.
3. A pencil cell converts chemical energy into equivalent electrical energy.

Classifications of transducers – broadly the transducers are classified into two main types: Active trans ducers and passive transducers. The active transducer generates its own electrical voltage during conversion. Thus it does not require any battery supply for conversion (e.g. solar cell, thermocouple etc.). In passive transducer, it requires *external*battery supply. It only changes its parameter during conversion like change in resistance or capacitance etc. (e.g. LDR, thermistor etc.)

Active transducers –

Definition – an active transducer is defined as a transducer which generates its own electrical voltage during conversion. It does *not* require any external battery supply for its working.

Examples –

1. **Solar cell –** when it is exposed to strong sunlight or any other light, it converts light energy into proportional *DC voltage*.
2. **Piezo electric crystal –** when it is subjected to *changing pressure* it produces proportional *AC voltage*.

Passive transducers –

Definition – passive transducer is defined as the transducer which requires *external*battery voltage to operate. Also it only changes its parameter like change in resistance or capacitance during conversion.

Examples –

1. **LDR (Light Dependent Resistor)** – when LDR is exposed to light, its resistance decreases *(less than 10W)* proportionally & when it is dark its resistance is very high*(several MW)*.
2. **Thermistor** – when thermistor is exposed to heat its resistance decreases and when it is cooled its resistance increases.

According to working principle of transducers they are classified into four main types –

1. **Mechanical transducers** – for example strain gauge, LVDT etc.
2. **Thermal transducers** – for example thermistor, thermocouple etc.
3. **Magnetic transducers** – for example search coil etc.
4. **Radiation transducers** – for example solar cell, photo diode etc.

Characteristics of Transducer

Following factors must be considered while selecting transducer for a particular work or system –

1. Physical quantity to be measured must be considered for –
2. The type of physical quantity whether it is electrical quantity *(AC or DC)* or nonelectrical quantity *(pressure, intensity, displacement, speed, heat etc.)*
3. Range of quantity like pressure *(0–10N)*, intensity *(0–250L)*, temperature *(–10°C to 200° C)* etc.
4. The principle of transducer must be considered for –
5. The system and transducer must be compatible i.e. the output characteristics of transducer and input characteristics of the system and must match.

1. This means that principle of maximum power transfer theorem must be satisfied.
2. The measurement accuracy of the transducer must be considered which depends on
3. Type and range of quantity under measurement.
4. Physical conditions like mechanical and electrical connections, mounting style of transducer.
5. Surrounding conditions like nonlinearity effect and frequency response etc.
6. Environmental conditions like temperature effects, shocks or vibrations etc.
7. Compatibility of some associated equipment’s like zero balancing provision, sensitivity tolerance, impedance matching etc.

Types of transducers

· **Temperature transducers** – this transducer converts heat energy into its equivalent electrical energy. They are of two types –

Active temperature transducers – thermo-couple which converts heat energy into equivalent electrical voltage.

Passive temperature transducers – thermistor or resistance thermometer is a passive transducer. It only changes its resistance due to change in temperature.

Pressure transducers – these are of two types: the stress and strain types. When either stress or strain is applied, they produce a proportional electrical voltage.

Active pressure transducers – piezo electric crystal is a good example of active pressure transducer. It produces proportional electrical voltage when pressure is applied on it.

Passive pressure transducers – strain gauge, capacitive transducer. When either stress or strain is applied, their passive parameter like resistance or capacitance proportionally changes.

Light transducers – it converts light energy into equivalent electrical energy. There are two types of light transducers –

Active light transducers – in this photo–voltaic cell, photo multiplier tubes (made up within vacuum tubes) and solar cells (made up of semiconductor material) are used. They convert light into electrical energy.

Passive light transducer – this contains LDR – light dependent resistor. Its resistance changes as light on it changes.

Sound transducers – it converts sound energy into equivalent electrical energy and vice versa.

Active sound transducer – carbon microphone is good examples of active transducer. It converts sound into proportional AC voltage. This happens because carbon granules in it vibrate and produce proportional voltage across two dissimilar metal plates.

Passive sound transducers – capacitive microphone is passive transducer. Its capacity (C) changes proportionally due to change in sound intensity.

Transducer Applications

The applications of transducers based on the electric parameter used and the principle involved is given below.

1. Passive Type Transducers

a. Resistance Variation Type

Resistance Strain Gauge – The change in value of resistance of metal semi-conductor due to elongation or compression is known by the measurement of torque, displacement or force.

Resistance Thermometer – The change in resistance of metal wire due to the change in temperature known by the measurement of temperature.

Resistance Hygrometer – The change in the resistance of conductive strip due to the change of moisture content is known by the value of its corresponding humidity.

Hot Wire Meter – The change in resistance of a heating element due to convection cooling of a flow of gas is known by its corresponding gas flow or pressure. Displacement transducer

Photoconductive Cell – The change in resistance of a cell due to a corresponding change in light flux is known by its corresponding light intensity.

Thermistor – The change in resistance of a semi-conductor that has a negative co-efficient of resistance is known by its corresponding measure of temperature.

Potentiometer Type – The change in resistance of a potentiometer reading due to the movement of the slider as a part of an external force applied is known by its corresponding pressure or displacement.

b. Capacitance Variation Type

Variable Capacitance Pressure Gauge – The change in capacitance due to the change of distance between two parallel plates caused by an external force is known by its corresponding displacement or pressure.

Dielectric Gauge – The change in capacitance due to a change in the dielectric is known by its corresponding liquid level or thickness.

Capacitor Microphone – The change in capacitance due to the variation in sound pressure on a movable diagram is known by its corresponding sound.

c. Inductance Variation Type

Eddy Current Transducer – The change in inductance of a coil due to the proximity of an eddy current plate is known by its corresponding displacement or thickness.

Variable Reluctance Type – The variation in reluctance of a magnetic circuit that occurs due to the change in position of the iron core or coil is known by its corresponding displacement or pressure.

Proximity Inductance Type – The inductance change of an alternating current excited coil due to the change in the magnetic circuit is known by its corresponding pressure or displacement.

Differential Transformer – The change in differential voltage of 2 secondary windings of a transformer because of the change in position of the magnetic core is known by its corresponding force, pressure or displacement.

Magnetostrictive Transducer – The change in magnetic properties due to change in pressure and stress is known by its corresponding sound value, pressure or force.

d. Voltage and Current Type

Photo-emissive Cell – Electron emission due to light incidence on photo-emissive surface is known by its corresponding light flux value.

Hall Effect – The voltage generated due to magnetic flux across a semi-conductor plate with a movement of current through it is known by its corresponding value of magnetic flux or current.

Ionisation Chamber – The electron flow variation due to the ionisation of gas caused by radio-active radiation is known by its corresponding radiation value.

2. Active Type

Photo-voltaic Cell – The voltage change that occurs across the p-n junction due to light radiation is known by its corresponding solar cell value or light intensity.

Thermopile – The voltage change developed across a junction of two dissimilar metals is known by its corresponding value of temperature, heat or flow.

Piezoelectric Type – When an external force is applied on to a quartz crystal, there will be a change in the voltage generated across the surface. This change is measured by its corresponding value of sound or vibration.

Moving Coil Type – The change in voltage generated in a magnetic field can be measured using its corresponding value of vibration or velocity.

Lecture 6: Overview of Mechanical Actuation System

Kinematic Chains: When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (i.e. completely or successfully constrained motion), it is called a kinematic chain.

In other words, a kinematic chain may be defined as a combination of kinematic pairs, joined in such a way that each link forms a part of two pairs and the relative motion between the links or elements is completely or successfully constrained. For example, the crank- shaft of an engine forms a kinematic pair with the bearings which are fixed in a pair, the connecting rod with the crank forms a second kinematic pair, the piston with the connecting rod forms a third pair and the piston with the cylinder forms a fourth pair. The total combination of these links is a kinematic chain. If each link is assumed to form two pairs with two adjacent links, then the relation between the number of pairs (p) forming a kinematic chain and the number of links (l) may be expressed in the form of an equation :

$$l = 2p - 4$$

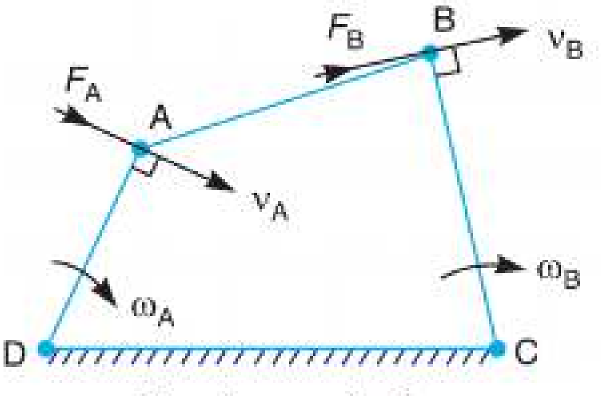
Another relation between the number of links (l) and the number of joints (j) which constitute a kinematic chain is given by the expression

$$j = \frac{3}{2} l - 2$$

Types of Kinematic Chains: The most important kinematic chains are those which consist of four lower pairs, each pair being a sliding pair or a turning pair. The following three types of kinematic chains with four lower pairs are important from the subject point of view

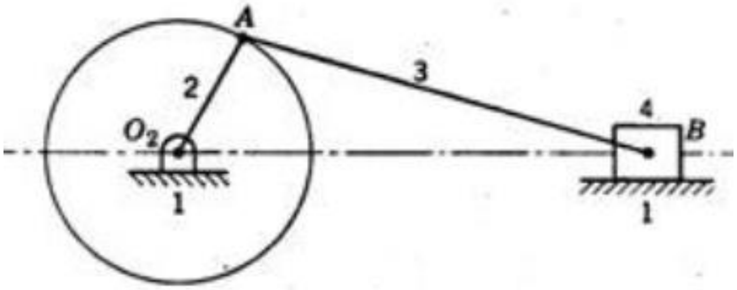
1. Four bar chain or quadric cyclic chain,
2. Single slider crank chain,
3. Double slider crank chain

Four bar chain or quadric cyclic chain: The kinematic chain is a combination of four or more kinematic pairs, such that the relative motion between the links or elements is completely constrained. The simplest and the basic kinematic chain is a four bar chain or quadric cycle chain. It consists of four links, each of them forms a turning pair at A, B, C and D. The four links may be of different lengths. According to Grashof 's law for a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths if there is to be continuous relative motion between the two links. A very important consideration in designing a mechanism is to ensure that the input crank makes a complete revolution relative to the other links. The mechanism in which no link makes a complete revolution will not be useful. In a four bar chain, one of the links, in particular the shortest link, will make a complete revolution relative to the other three links, if it satisfies the Grashof 's law. Such a link is known as crank or driver. A D (link 4) is a crank. The link BC (link 2) which makes a partial rotation or oscillates is known as lever or rocker or follower and the link CD (link 3) which connects the crank and lever is called connecting rod or coupler. The fixed link A B (link 1) is known as frame of the mechanism. When the crank (link 4) is the driver, the mechanism is transforming rotary motion into oscillating motion.

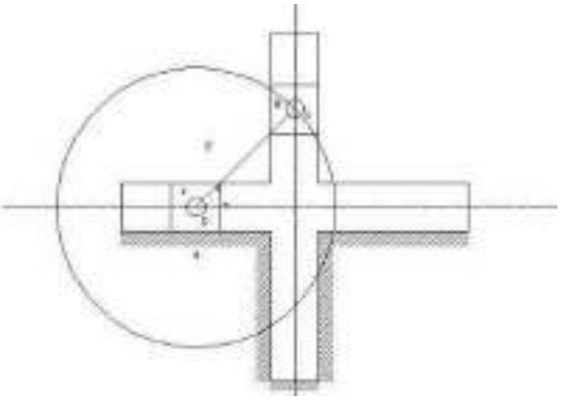


Four bar mechanism.

Single slider crank chain: A single slider crank chain is a modification of the basic four bar chain. It consist of one sliding pair and three turning pairs. It is, usually, found in reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating motion and vice versa. In a single slider crank chain, as shown the links 1 and 2, links 2 and 3, and links 3 and 4 form three turning pairs while the links 4 and 1 form a sliding pair. The link 1 corresponds to the frame of the engine, which is fixed. The link 2 corresponds to the crank; link 3 corresponds to the connecting rod and link 4 corresponds to cross-head. As the crank rotates, the cross-head reciprocates in the guides and thus the piston reciprocates in the cylinder.

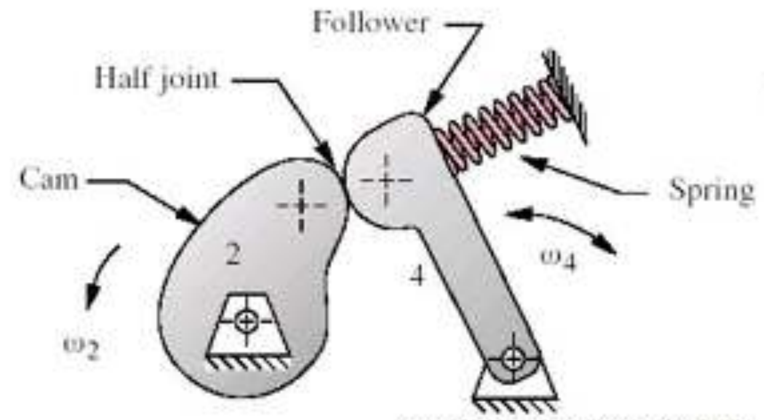


Double Slider Crank Chain: A kinematic chain which consists of two turning pairs and two sliding pairs is known as double slider crank chain. We see that the link 2 and link 1 form one turning pair and link 2 and link 3 form the second turning pair. The link 3 and link 4 form one sliding pair and link 1 and link 4 form the second sliding pair.



CAM: In machines, particularly in typical textile and automatic machines, many parts need to be imparted different types of motion in a particular direction. This is accomplished by conversion of the available motion into the type of motion required. Change of circular motion to translatory (linear) motion of simple harmonic type and vice-versa and can be done by slider-crank mechanism as discussed previously. But now the question arises, what to do when circular or rotary motion is to be changed into linear motion of complex nature or into oscillatory motion. This job is well accomplished by a machine part of a mechanical member, known as cam.

A **cam** may be defined as a rotating, reciprocating or oscillating machine part, designed to impart reciprocating and oscillating motion to another mechanical part, called a follower. A cam and follower have, usually, a line contact between them and as such they constitute a higher pair. The contact between them is maintained by an external force which is generally, provided by a spring or sometimes by the sufficient weight of the follower itself.



Source: Norton, Design of Machinery

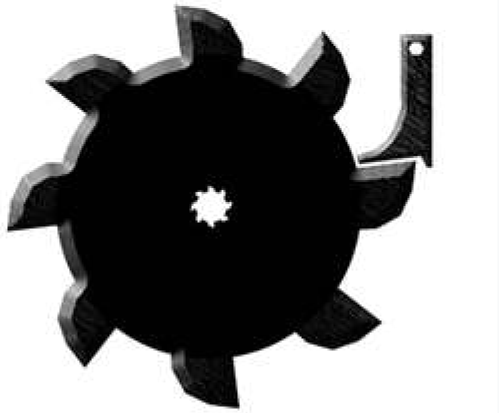
Cams are Used For

- Valve actuation in IC engines
- Motion control in machinery
- Force generation
- Precise positioning
- Event timing

Train Ratchet Mechanism

A **ratchet** is a mechanical device that allows continuous linear or rotary motion in only one direction while preventing motion in the opposite direction. Ratchets are widely used in machinery and tools. The word *ratchet* is also used informally to refer to a ratcheting socket wrench.

Theory of operation



A ratchet moving in its "forward" direction

A ratchet consists of a round gear or a linear rack with teeth, and a pivoting, spring-loaded finger called a *pawl* (or *click*, in clocks and watches) that engages the teeth. The teeth are uniform but asymmetrical, with each tooth having a moderate slope on one edge and a much steeper slope on the other edge.

When the teeth are moving in the unrestricted (i.e. forward) direction, the pawl easily slides up and over the gently sloped edges of the teeth, with a spring forcing it (often with an audible 'click') into the depression between the teeth as it passes the tip of each tooth. When the teeth move in the opposite (backward) direction, however, the pawl will catch against the steeply sloped edge of the first tooth it encounters, thereby locking it against the tooth and preventing any further motion in that direction.

Because the ratchet can only stop backward motion at discrete points (i.e., at tooth boundaries), a ratchet does allow a limited amount of backward motion. This backward motion—which is limited to a maximum distance equal to the spacing between the teeth—is called backlash. In cases where backlash must be minimized, a smooth, toothless ratchet with a high friction surface such as rubber is sometimes used. The pawl bears against the surface at an angle so that any backward motion will cause the pawl to jam against the surface and thus prevent any further backward motion. Since the backward travel distance is primarily a function of the compressibility of the high friction surface, this mechanism can result in significantly reduced backlash.

Uses

Ratchet mechanisms are used in a wide variety of applications, including these:

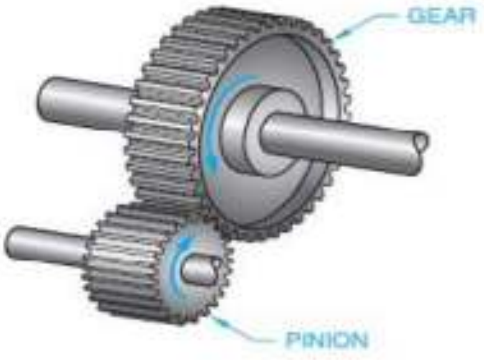
- Cable ties
- Capstans
- Caulking guns
- Clocks
- Freewheel (overrunning clutch)
- Grease guns
- Handcuffs
- Jacks
- Anti-rollback devices used in roller coasters
- Looms
- Slack lines
- Tie down straps
- Turnstiles
- Typewriters

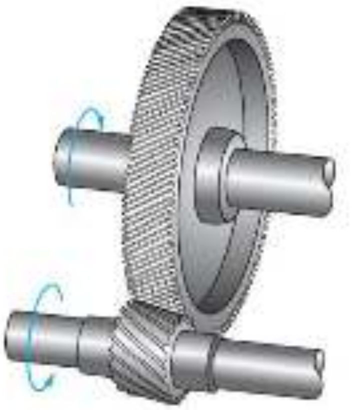
Lecture 7 Gears and its type, Belt, Bearing

Gears: Gears are machine elements that transmit motion by means of successively engaging teeth. The gear teeth act like small levers. Gears are mechanisms that mesh together via teeth and are used to transmit rotary motion from one shaft to another. Gears are defined by two important items:

radius and number of teeth. They are typically mounted, or connected to other parts, via a shaft or base.

Spur gears have teeth parallel to the axis of rotation and are used to transmit motion from one shaft to another, parallel, shaft.





Helical gears have teeth inclined to the axis of rotation. Helical gears are not as noisy, because of the more gradual engagement of the teeth during meshing.

Bevel gears have teeth formed on conical surfaces and are used mostly for transmitting motion between intersecting shafts.

Worms and worm gears The worm resembles a screw. The direction of rotation of the worm gear, also called the worm wheel, depends upon the direction of rotation of the worm and upon whether the worm teeth are cut right-hand or left-hand.

Application:

Gears are devices used throughout industry for a variety of mechanical machines and systems. Several types of gears are available and employed in a wide range of residential, commercial, and industrial applications, including:

- Aircrafts
- Automobiles
- Clocks
- Marine systems
- Material handling equipment
- Measuring instrumentation
- Power plants
- Pumps

Type of Gear	**Common Industries and Applications**
Spur	• Clocks • Pumps • Watering systems • Household appliances • Clothes washing and drying machines • Power plants • Material handling systems • Aerospace and aircrafts • Railways and trains
Helical	• Same as spur gears but with greater loads and higher speeds (see above) • Automobiles (transmission systems)
Bevel	• Pumps • Power plants • Material handling systems • Aerospace and aircrafts • Railways and trains • Automobiles
Worm	• Instruments • Lifts and elevators • Material handling systems • Automobiles (steering systems)
Rack and Pinion	• Weighing scales • Material handling and transfer systems • Railways and trains • Automobiles (steering systems)

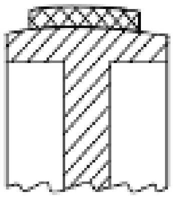
Belt: A **belt** is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts may be used as a source of motion, to transmit power efficiently or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, and the shafts need not be parallel.

In a two pulley system, the belt can either drive the pulleys normally in one direction (the same if on parallel shafts), or the belt may be crossed, so that the direction of the driven shaft is reversed (the opposite direction to the driver if on parallel shafts). As a source of motion, a conveyor belt is one application where the belt is adapted to carry a load continuously between two points. The belt drive can also be used to change the speed of rotation, either up or down, by using different sized pulleys.

In case of belts, friction between the belt and pulley is used to transmit power. In practice, there is always some amount of slip between belt and pulleys, therefore, exact velocity ratio cannot be obtained. That is why, belt drive is not a positive drive. Therefore, the belt drive is used where exact velocity ratio is not required.

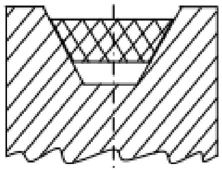
Types of Belt:

Flat belt: The flat belt is rectangular in cross-section as shown in Figure (a). The pulley for this belt is slightly crowned to prevent slip of the belt to one side. It utilizes the friction between the flat surface of the belt and pulley.



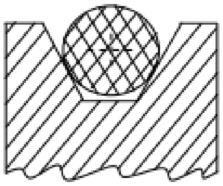
(a) Flat Belt and Pulley

V-belt: The V-belt is trapezoidal in section as shown in Figure (b). It utilizes the force of friction between the inclined sides of the belt and pulley. They are preferred when distance is comparative shorter. Several V-belts can also be used together if power transmitted is more.



(b) V-belt and Pulley

Circular belt or rope: The circular belt or rope is circular in section as shown in Figure (c). Several ropes also can be used together to transmit more power.



(c) Circular Belt or Rope Pulley

Application

1.Drives to beaters on conventional blow rooms. crossed flat-belt transmits drives from cylinder to flat on old cards.

2.Drives in high production cards such as the drive from motor to lickerin and cylinder; drive to cleaner roller at the delivery side; drive from motor to flat-stripper roller and crossed-flat-belt drive from cylinder to a pulley from where further drive proceeds through double stage speed reduction using worm and worm gears and a mechanical clutch to the driving-shaft of flat.

3.Drive to drafting rollers and other rolling elements on a single delivery drawing machine.

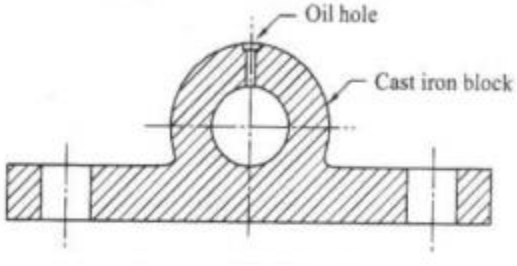
4.Drives to opening rollers, friction drums and take-off rollers on friction spinning machine.

5.Drive to rotor on rotor-spinning machine.

6.Main drive on draw-texturing machine.

7.Drive to creel-rollers of a high speed drawing machine.

Bearings: A bearing is machine part, which support a moving element and confines its motion. The supporting member is usually designated as bearing and the supporting member may be journal. Since there is a relative motion between the bearing and the moving element, a certain amount of power must be absorbed in overcoming friction, and if the surface actually touches, there will be a rapid wear.



Classification: Bearings are classified as follows:

1. Depending upon the nature of contact between the working surfaces:

a) Sliding contact bearings

b) Rolling contact bearings.

a) SLIDING BEARINGS:

- Hydro dynamically lubricated bearings
- Bearings with boundary lubrication
- Bearings with Extreme boundary lubrication.
- Bearings with Hydrostatic lubrication.

b) ROLLING ELEMENT BEARINGS:

♣ Ball bearings

♣ Roller bearings

♣ Needle roller bearings

2. Based on the nature of the load supported:

- Radial bearings - Journal bearings

- Thrust bearings

- Plane thrust bearings

- Thrust bearings with fixed shoes

- Thrust bearings with Pivoted shoes

- Bearings for combined Axial and Radial loads.

Lecture 8: Hydraulic and Pneumatic Actuation Systems: Overview

Actuators: are structures that transmit and support load. A joint is a connection between two or more links at their nodes and allows some motion between the connected links. Levers, cranks, connecting rods, pistons, sliders, pulleys, belts, and shafts are all examples of links. A sequence of joints and links is known as a *kinematics chain*. For a kinematics chain to transmit motion, one link must be fixed. The movement of one link produces predictable relative movement of other links in the chain. For mechatronics system actuation, one can use hydraulic, pneumatic, or electrical drives with kinematic chains.

Hydraulic and Pneumatic Actuators

The hydraulic actuation is powered by fluids. Fluids usually are pressurized oils. The operation of hydraulic actuators is generally similar, except in their ability to contain the pressure of the fluid. Hydraulic systems operate in a pressure range between 60 bars and 200 bars. The main constituents of a hydraulic system are the power supply unit, hydraulic fluid, direction control valve, linear and rotary actuators, and interaction components. The power supply unit is the most important component in a hydraulic pump. The pump drives the hydraulic fluid from a reservoir (tank) and delivers it through a system of lines in the hydraulic installation against the offering resistance.

Pressure should not build up in the flowing liquid which encounters a resistance. An oil filtration unit is also often contained in the power supply section. Impurities are often introduced into a system as a result of mechanical wear. For this reason, filters are installed in the hydraulic circuit to remove impurities in the form of dirt particles from the hydraulic fluids. Water and gases in oil can also act as disrupting factors, so special measures must be taken to remove them. Heaters and coolers are installed for conditioning the hydraulic fluids. The hydraulic fluid is the working medium that transfers the generated energy from the power supply unit to the drive section. Hydraulic fluids have a wide range of characteristics. Therefore, care needs to take to choose a fluid with characteristics that suit the application. Hydraulic fluids on a mineral oil base are generally used. Such fluids are called hydraulic oils.

Valves are the devices for controlling the energy flow. They can control and regulate the direction, pressure, and rate of the hydraulic fluid flow. Four types of valves are commonly used: direction control valves, pressure valves, flow control valves, and non-return valves. Direction control valves control the direction of flow of hydraulic fluid and thus the direction of motion and the positioning of the working components. Direction control valves may be actuated manually, mechanically, electrically pneumatically, or hydraulically. They convert and amplify signals and form an interface between the power control section and the signal control section. When labelling direction control valves, it is necessary to specify the number of ports, followed by the number of switching position. Direction control (DC) valves have at least two switching positions and two ports. Such a valve is designated as a 2/2 way valve. Pressure valves are used to influence the pressure in the complete hydraulic system.

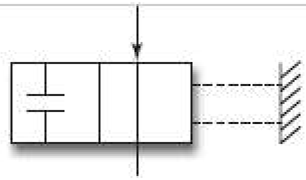
There are three main types of pressure control valves:

(1) Pressure regulating valves used to maintain a constant operating pressure in a circuit.

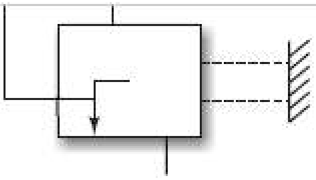
(2) Pressure sequence valves used to sense the pressure of an external line and give a signal when it reaches some preset value.

(3) Pressure limiting valves used as safety devices to limit the pressure in a circuit to below some safe value.

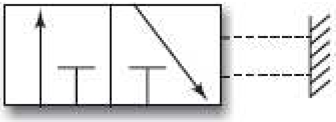
The flow control valve interacts with pressure valves to control the flow rate. They both make it possible to control or regulate the speed of motion of the power components. If the flow rate is constant, the division of flow must take place. This is generally achieved through the interaction of the flow control valve with the pressure valve. Non-return valves block the flow in one direction and permit free flow in the other direction. As there must not be any leakage from the closed direction, these valves always have a poppet design. In the case of a non-return valve, a distinction is made between ordinary non-return valves and piloted non-return valves. In the case of piloted non-return valves, flow in the blocked direction can be released by a signal. Figure shows schematic diagrams of various control valves.



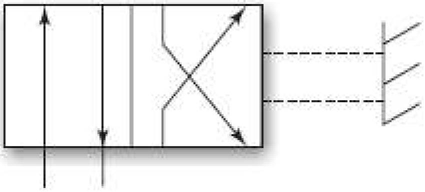
(a) 2/2 way valve



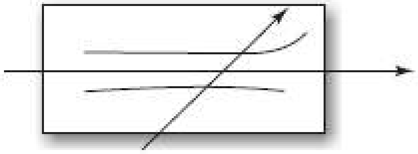
(b) Adjustable pressure valve



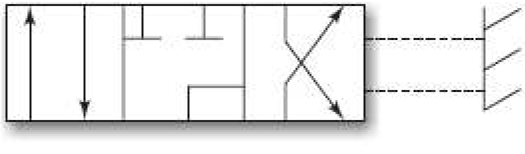
(c) 3/2 way valve



(d) 4/2 way valve



(e) Adjustable flow valves



(f) 4\3 way valve

Some advantages of hydraulic systems are as follows:

1. High load-carrying capacity
2. Low actuator inertia

3. Simple field design of system
4. High flexibility
5. Indefinite stocking capacity
6. High speed at high load
7. Very good strength

Some disadvantages of hydraulic system are as follows:

1. High cost of servo system
2. Need for high resolution feedback
3. Effect of oil temperature on performance
4. Non-availability of small actuators
5. Leakage
6. Low sensitivity
7. Difficulties in maintenance
8. Requirement of skilled workers to connect the system
9. Less natural frequency when actuator is in full value

Pneumatic Actuators: Pneumatic systems have been used for some considerable time for carrying out simplest mechanical tasks. In more recent times, such systems have played an important role in the development of pneumatic technology for automation through mechatronic systems. A pneumatic system can be broken down into a number of levels representing hardware and signal flow. Except the energy supply system, all other levels can be represented as in a hydraulic system. The air supply for a particular pneumatic application should be sufficient and of adequate quality. The air is compressed to 1/7th of its volume with the help of an air compressor and is delivered to an air distribution system in factory. To ensure proper quality of the air, air service equipment is utilized to prepare the air before it is applied to a control system. As a rule, all pneumatic components are designed for a maximum operating pressure of 8–10 bars. But it is recommended to operate the same between 5 and 6 bars for economic use. An air receiver is fitted to reduce pressure fluctuations. In normal operations, a compressor is fitted with the receiver when required, and the receiver is available as a reserve at all the times. This helps reduce the switching cycle of the compressor. If oil is required for a pneumatic system, then there should be a separate oil meter using air service unit. An air service unit is a combination of compressed-air filter, regulator, and lubricator. The compressed-air filter performs the job of filtering all contamination from the compressed air flowing through it as well as water which has already condensed. The purpose of the regulator is to keep the operating pressure virtually constant regardless of any fluctuation in line pressure and air consumption. Different types of sequence operations can be designed using sequence circuits associated with hydraulic systems. Pneumatic actuators are very useful and have the following advantages:

1. Compressed air is readily available in most factories.
2. Compressed air can be stored and conveyed easily to larger distances.
3. Compressed air need not be returned to sump.
4. Compressed air is clean.
5. Operation is fast and offers high load-carrying capacity.
6. Digital and logical switches can be prepared using fluidic circuits.
7. Pneumatic elements are simple and reliable.

Lecture 9: Pressure Control Valves

Pressure-control valves are used in hydraulic systems to control actuator force (force = pressure × area) and to determine and select pressure levels at which certain machine operations must occur. Pressure controls are mainly used to perform the following system functions:

- Limiting maximum system pressure at a safe level.
- Regulating/reducing pressure in certain portions of the circuit.
- Unloading system pressure.
- Assisting sequential operation of actuators in a circuit with pressure control.
- Any other pressure-related function by virtue of pressure control.
- Reducing or stepping down pressure levels from the main circuit to a lower pressure in a sub-circuit.

Pressure-control valves are often difficult to identify mainly because of the many descriptive names given to them. The function of the valve in the circuit usually becomes the basis for its name. The valves used for accomplishing the above-mentioned system functions are therefore given the following names:

- Pressure-relief valve.
- Pressure-reducing valve.
- Unloading valve
- Counterbalance valve.
- Pressure-sequence valve.
- Brake valve

Pressure-Relief Valves: Pressure-relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a preset level. All fixed-volume pump circuits require a relief valve to protect the system from excess pressure. Fixed-volume pumps must move fluid when they turn. When a pump unloads through an open-center circuit or actuators are in motion, fluid movement is not a problem. A relief valve is essential when the actuators stall with the directional valve still in shifted position.

Unloading Valves: Unloading valves are pressure-control devices that are used to dump excess fluid to the tank at little or no pressure. A common application is in high-low pump circuits where two pumps move an actuator at a high speed and low pressure. The circuit then shifts to a single pump providing a high pressure to perform work. Another application is sending excess flow from the cap end of an oversize-rod cylinder to the tank as the cylinder retracts. This makes it possible to use a smaller, less-expensive directional control valve while keeping pressure drop low.

Directional control valves: Directional control valves are essentially used for distribution of energy in a fluid power system. They establish the path through which a fluid traverses a given circuit. For example they control the direction of motion of a hydraulic cylinder or motor. These valves are used to control the start, stop and change in direction of flow of pressurized fluid.

As the name implies directional control valves are used to control the direction of flow in a hydraulic circuit. They are used to extend, retract, position or reciprocate hydraulic cylinder and other components for linear motion. Valves contains ports that are external openings for fluid to enter and leave via connecting pipelines, The number of ports on a directional control valve (DCV

) is usually identified by the term " way". For example, a valve with four ports is named as four-way valve.

Directional control valves can be classified in a number of ways:

1. According to type of construction :
   - Poppet valves
   - Spool valves
2. According to number of working ports:
   - Two- way valves
   - Three – way valves
   - Four- way valves
3. According to number of Switching position:
   - Two – position
   - Three - position
4. According to Actuating mechanism:
   - Manual actuation
   - Mechanical actuation
   - Solenoid (Electrical) actuation
   - Hydraulic (Pilot) actuation
   - Pneumatic actuation
   - Indirect actuation

Cylinders:

Lecture 10: Rotary Actuators, Accumulators

Rotary Actuators: A rotary actuator is an actuator that produces a rotary motion or torque.

The simplest actuator is purely mechanical, where linear motion in one direction gives rise to rotation. The most common actuators are electrically powered; others may be powered pneumatically or hydraulically, or use energy stored in springs.

The motion produced by an actuator may be either continuous rotation, as for an electric motor, or movement to a fixed angular position as for servomotors and stepper motors. A further form, the torque motor, does not necessarily produce any rotation but merely generates a precise torque which then either causes rotation or is balanced by some opposing torque.

Electric actuators

Stepper motors are a form of electric motor that has the ability to move in discrete steps of a fixed size. This can be used either to produce continuous rotation at a controlled speed or to move by a controlled angular amount. If the stepper is combined with either a position encoder or at least a single datum sensor at the zero position, it is possible to move the motor to any angular position and so to act as a rotary actuator.

Servomotors

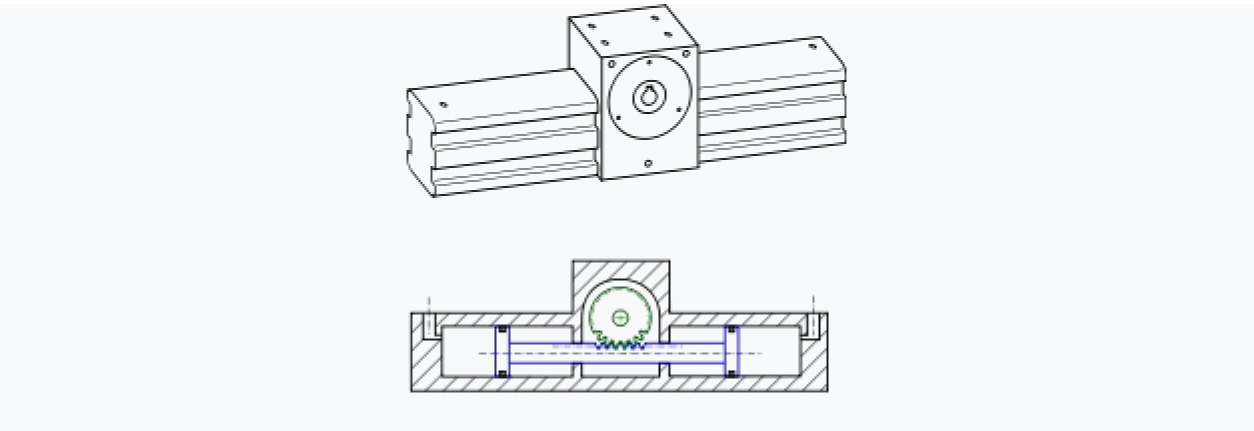
A servomotor is a packaged combination of several components: a motor (usually electric, although fluid power motors may also be used), a gear train to reduce the many rotations of the motor to a higher torque rotation, a position encoder that identifies the position of the output shaft and an inbuilt control system. The input control signal to the servo indicates the desired output position. Any difference between the position commanded and the position of the encoder gives rise to an error signal that causes the motor and geartrain to rotate until the encoder reflects a position matching that commanded.

A simple low-cost servo of this type is widely used for radio-controlled models.

Other types

A recent, and novel, form of ultra-lightweight actuator uses memory wire. As a current is applied, the wire is heated above its transition temperature and so changes shape, applying a torque to the output shaft. When power is removed, the wire cools and returns to its earlier shape.[1]

Fluid power actuator



Both hydraulic and pneumatic power may be used to drive an actuator, usually the larger and more powerful types. As their internal construction is generally similar (in principle, if not in size) they are often considered together as fluid power actuators.[2] Fluid power actuators are of two common forms: those where a linear piston and cylinder mechanism is geared to produce rotation (illustrated), and those where a rotating asymmetrical vane swings through a cylinder of two different radii. The differential pressure between the two sides of the vane gives rise to an unbalanced force and thus a torque on the output shaft.[2] Vane actuators require a number of sliding seals and the joints between these seals have tended to cause more problems with leakage than for the piston and cylinder type.

Vacuum actuators

Where a supply of vacuum is available, but not pneumatic power, rotary actuators have even been made to work from vacuum power. The only common instance of these was for early automatic windscreen wipers on cars up until around 1960. These used the manifold vacuum of a petrol engine to work a quarter-turn oscillating vane actuator. Such windscreen wipers worked adequately when the engine was running under light load, but they were notorious that when working hard at top speed or climbing a hill, the manifold vacuum was reduced and the wipers slowed to a crawl.[3]

Applications

Rotary actuators are used in a vast range of applications. These require actuators of all sizes, power and operating speed. These can range from zero power actuators that are only used as display devices, such as air core gauges. Others include valve actuators that operate pipeline and process valves in the petrochemical industry, through to actuators for large civil engineering projects such as sluice gates and dams. Examples are... Car wiper

Accumulators: Accumulators make it possible to store useable volumes of almost non-compressible hydraulic fluid under pressure. A hydraulic accumulator is a pressure storage reservoir in which an incompressible hydraulic fluid is held under pressure that is applied by an external source of mechanical energy. The external source can be an engine, a spring, a raised weight, or a compressed gas. An accumulator enables a hydraulic system to cope with extremes of demand using a less powerful pump, to respond more quickly to a temporary demand, and to smooth out pulsations. It is a type of energy storage device.

Accumulator types

No separator: Some original accumulators were high-pressure containers with a sight glass to show fluid level. They were filled approximately half with oil and half with nitrogen gas -- with no separation barrier between them. Before stopping the pump, a shut off valve at the accumulator discharge port was closed to prevent fluid and gas from escaping. This type of accumulator is not used on new circuits today, but there still are many in service.

Gas-charged bladder: Many accumulators now use a rubber bladder to separate the gas and liquid. A poppet valve in the discharge port keeps the bladder from extruding when the pump is off. The original design was the bottom-repair style, shown on the left in Figure 16-1. It is still offered by most manufacturers. The top-repair style on the right is now available and makes bladder replacement simple and fast.

Gas-charged piston: The gas-charged piston accumulator has a free-floating piston with seals to separate the liquid and gas. It operates and performs similarly to the bladder type, but has some advantages in certain applications. A gas-charged piston accumulator can cost twice as much as an equal-sized bladder type.

Spring-loaded piston: A spring-loaded piston accumulator is identical to a gas-charged unit, except that a spring forces the piston against the liquid. Its main advantage is that there is no gas to leak. A main disadvantage is that this design is not good for high pressure and large volume.

Weight loaded: All gas-charged accumulators lose pressure as fluid discharges. This is because the nitrogen gas was compressed by incoming fluid from the pump and the gas must expand to push fluid out. The weight-loaded accumulator in Figure 16-1 does not lose pressure until the ram bottoms out. Thus 100% of the fluid is useful at full system pressure. The major drawback to weight-loaded accumulators is their physical size. They take up a lot of space and are very heavy if much volume is required. They work well in central hydraulic systems because there usually is room for them in the power unit area. However, central hydraulic systems are falling out of favor, so only a few facilities use weight-loaded accumulators. (Rolling mills are one application where space to place large items is not a problem.) Note that there is often a long dwell time to fill these monsters.

Diaphragm accumulators: There are also diaphragm accumulators with resilient or metal diaphragms. They are used where the stored volume is small.

Why are accumulators used?

To supplement pump flow: The most common use for accumulators is to supplement pump flow. Some circuits require high-volume flow for a short time and then use little or no fluid for an extended period. Generally speaking, when half or more of the machine cycle is not using pump flow, the application is a likely candidate for an accumulator circuit.