I- Mid Term Solution
Sub.- Mechatronics

Q.1 What do you mean by FMS and explain it.

Ans. FMS means Flexible Manufacturing System. It is a manufacturing system in which there is some amount of flexibility that allows the system to react in case of changes.

There are to categories of flexibility :.

1. Machine flexibility
2. Routing flexibility

1. Machine flexibility :. It covers the system's ability to be change to produce new product types, and ability to change the order of operations executed on a part.

2. Routing flexibility :- It consist of the ability to use multiple machine to perform the same operation on a part, as well as system's ability to absorb large-scale changes, such as in volume, capacity or capability.

FMS Component : Most FMS system comprise of three main system:

1. Work machine that perform series of operation.
2. An Integrated material transport system and a computer that controls flow of materials, tools and information through out the system.
3. Auxiliary work station for loading and unloading cleaning inspection etc.

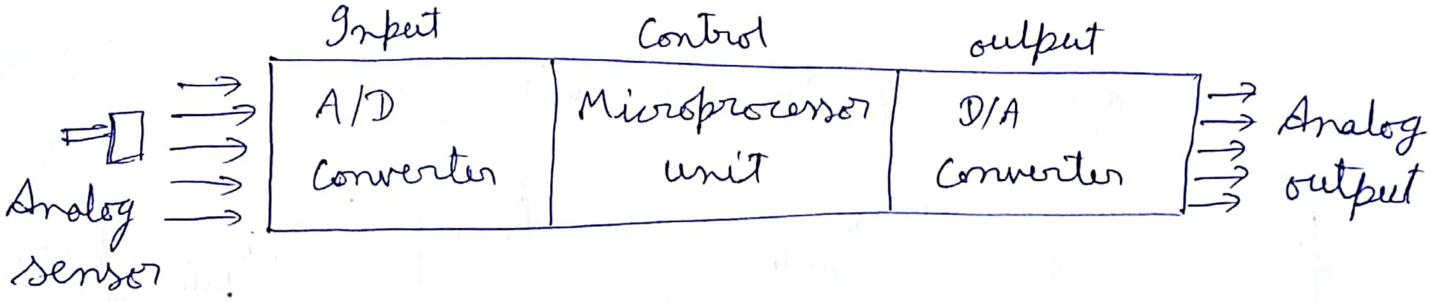
FMS Goal

1. Reduction in manufacturing cost by lowering direct labour cost and minimize scrap, rework and material wastage.
2. Less skilled labour & required.
3. Reduction in work in process inventory by eliminating the need for batch processing.

Q.2 Describe the working of microprocessor based control.

Ans In early 1960 computer based controllers were used. They were having one main frame computer and all control action was dependent on it moreover they were costly. But with the advent of microprocessor cost of controlling the

the plant decreased very less. In actual a microprocessor is a computer on a chip, and high density memory reduced costs and package size dramatically and increased application flexibility. These controller's measure signal from sensors, perform control routines in software programs, and take corrective action in the form of output signals to actuators.

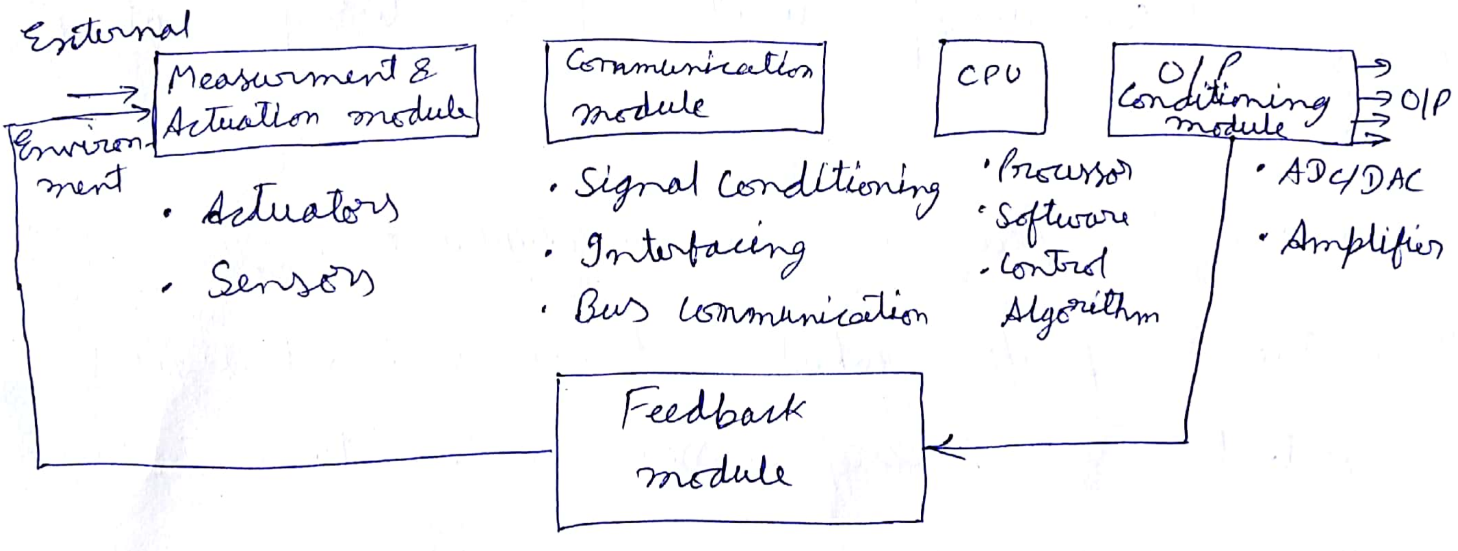


Since the programs are in digital form, the controllers perform what is known a direct digital control (DDC). Microprocessor can directly control the plant digitally. A direct digital control can be defined as controller which update the process as function of measured output variable and input provided. As the output world talks in analog from so for control digitally it has to be converted to digital form. For this A/D and D/A converters are used.

Q.3 Explain mechatronics system with suitable example.

Ans Mechatronics is combination of sensors, actuators, signal conditioning, power electronics, decision, control algorithms and computer hardware and software to manage complexity and communication in engineering system.

Block diagram of Mechatronics system



1. Measurement and Actuation module

It receive signal from external environment and feedback signal. This module uses several actuators and sensors such as solenoid.

switches, temp. / pressure / photo sensors. These sensors can be adjusted mannually.

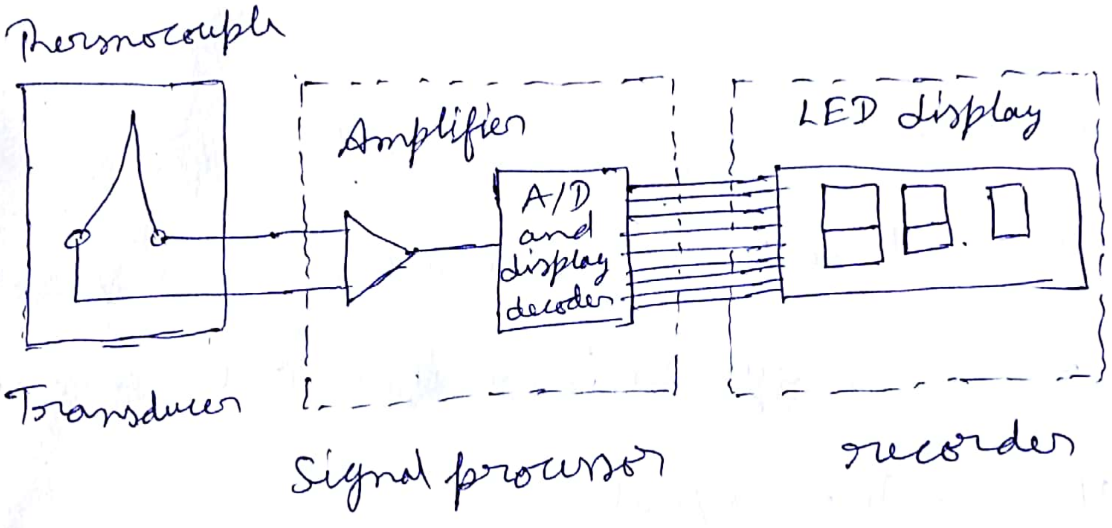
2. Communication Module : The position of sensor and the relative position of actuator are measured and corresponding signals are generated. These signal are feed to CPU through a communication module. The communication module includes signal conditioning circuit interfacing circuits and bus communication.

3. Central Processing Unit : It performs the logical and airthmetic operations by a processor and necessary software then CPU generats suitable control signal.

4. Feedback Module : It generates proportionate signal to the output signal which is given to the measurement and actuation moudule. The measurement and actuation module compares

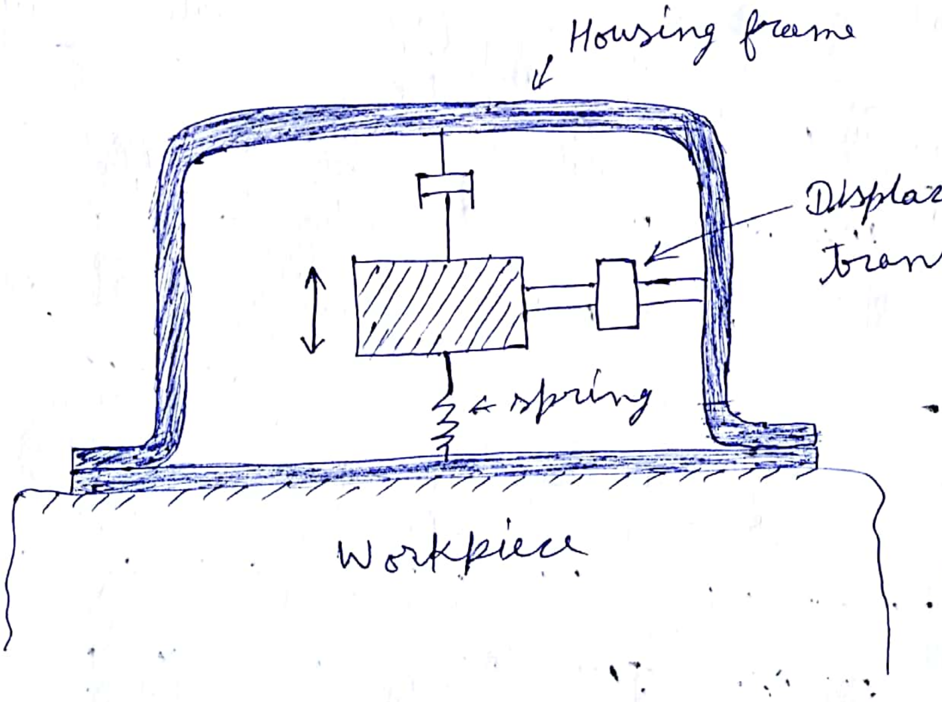
the external environment and feedback signal.

Example Digital Thermometer. The block diagram shows an example of a mesurement system. The thermocouple is a transducer that converts temp. to small voltage; the amplifier increase the magnitude of voltage; the A/D (analog to digital) converter is device that changes the analog signal to a coded digital signal; and the LED (light emitting diodes) displays the value of temperature.



Q.4 Describe the working and construction of Seismic acceleration sensor.

Ans. In a Seismic (displament sensing) accelerometer, the displacement of mass resulting from an applied force is measured and correlated to the acceleration. A Schematic diagram of this accelerometer is shown below figure. The mass is connected through the parallel spring and damper arrangement to the housing frame. The housing frame is connected to the source of vibrations whose characteristic are to be measured. The mass has tendency to remain fixed in its spatial position so that vibrational motion is registered as a relative displacement between mass and housing frame. This displacement is sensed and indicated by an appropriate transducer.

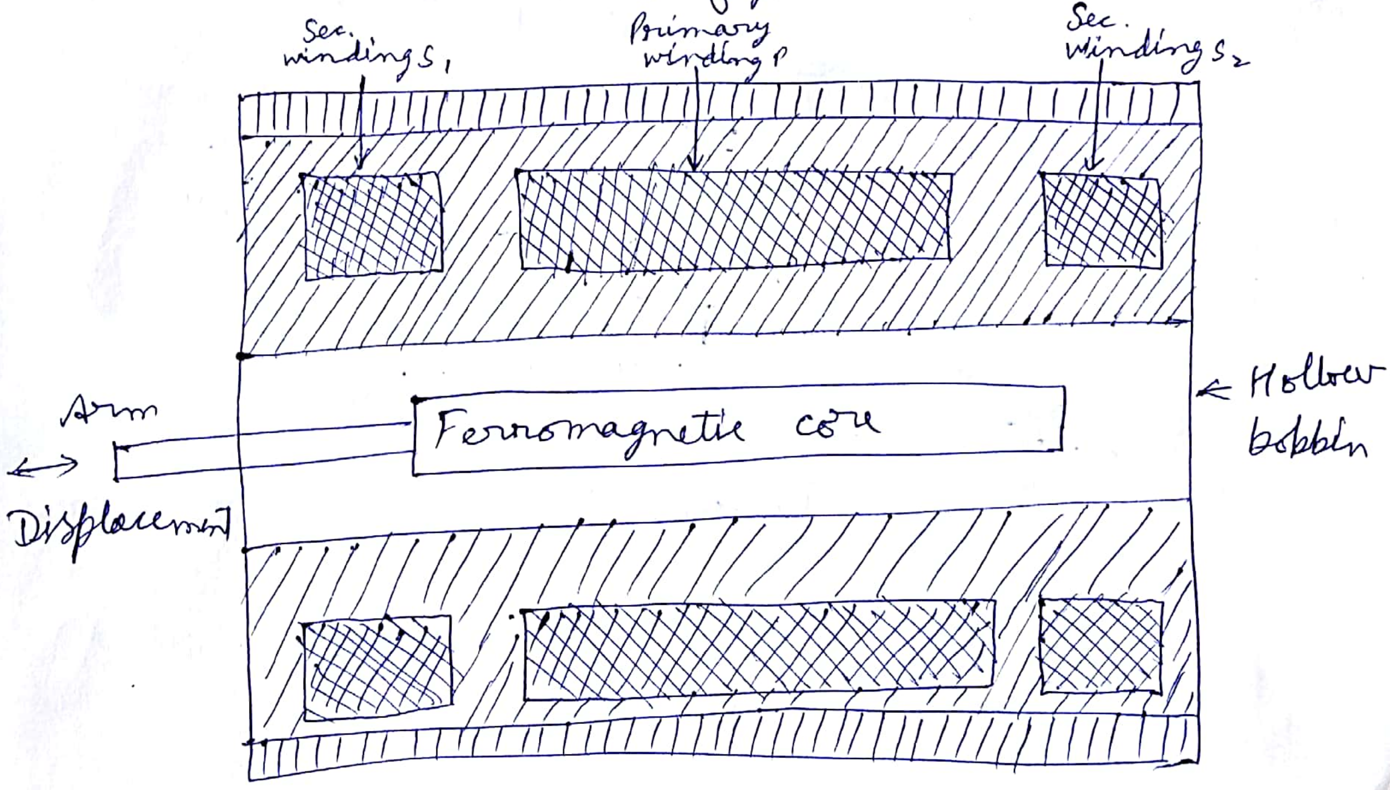


Seismic Transducer

Q.5 Explain the working construction of LVDT.

Ans. The linear variable differential transformer (LVDT) is used to translate the linear displacement in to the electrical signal. So this is also known as the displacement type transducer.

Construction of LVDT A linear variable differential transformer consist of one primary winding and two secondary windings. The windings are arranged concentrically and next to each other. They are wound over a hollow bobbin which is usually of a non-magnetic and insulating material as shown in fig.



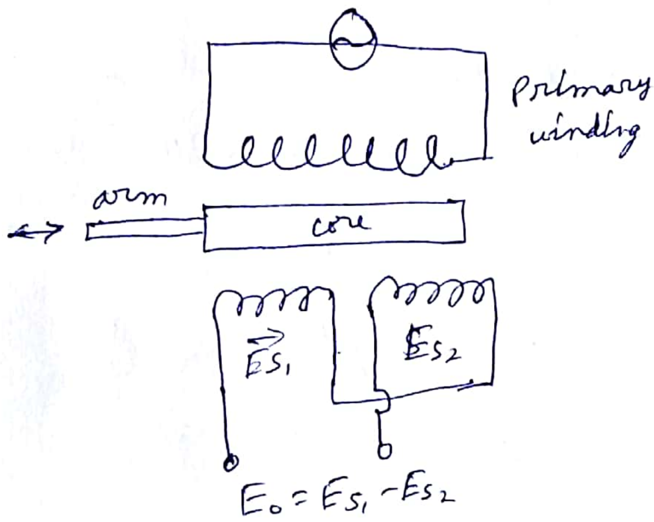
A ferromagnetic core (armature) in the shape of a rod or a cylinder is attached to the transducer sensing shaft. The core slides freely within the follow portion of the bobbin. An excitation is applied across the primary winding and movable core varies the coupling between it and the two secondary windings. When the core is in the centre position the coupling to secondary becomes move away from the centre position, the coupling to secondary coil is equal. Hence its output voltage increases, while the coupling and output voltage of other secondary winding is decreases.

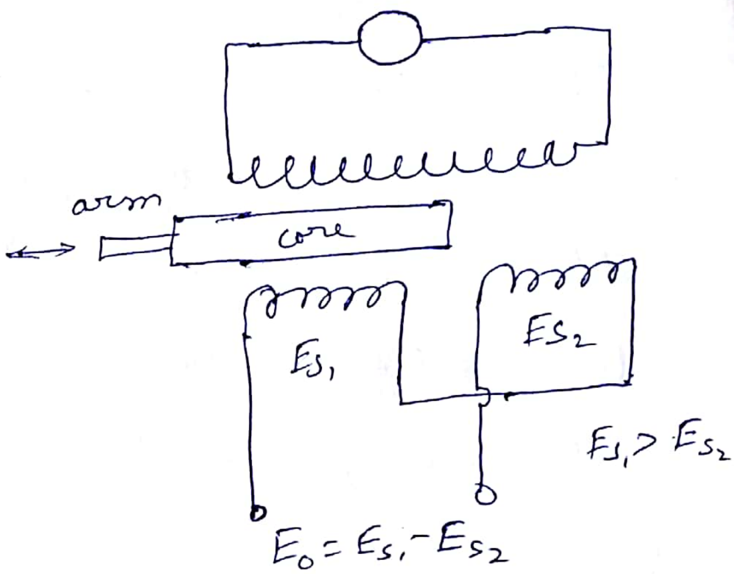
Working of LVDT The LVDT works upon the principle of transformer i.e. mutual induction principle. This principle states that when an AC current is flown through the primary winding. In the LVDT, there are three possibilities of motion of the core.

Case I: When the core is at its normal (Null) position, the flux linking with both secondary winding is equal ($\phi_{S_1} = \phi_{S_2}$) and hence EMF are

are induced in both secondary ($E_{s_1} = E_{s_2}$) Thus $E_0 = E_{s_1} - E_{s_2} = 0$

Case II :- When the core is moved to left of the Null position, more flux links with winding S_1 and less with winding S_2 ($\phi_{s_1} > \phi_{s_2}$) from which $E_{s_1} > E_{s_2}$. The magnitude of output voltage $E_0 = E_{s_1} - E_{s_2}$





Case III :- When the core is moved to the right of the null position, the flux linking with winding S_2 becomes begar than that linking with winding S_1 ($\phi_{s_1} > \phi_s$), In this case $E_0 = E_{s_2} - E_{s_1}$.

Solution of NDT

Q1. What are the merits of non-destructive testing methods over the conventional testing methods?

Sol:- NDT plays an important role not only in the quality control of the finished product but also during various stages of manufacturing. NDT is also used for condition monitoring of various items during operation to predict and assess the remaining life of the component while retaining its structural integrity.

Merits of Non-Destructive testing over conventional testing

(i) Tests are made directly on the object. 100% testing on actual components is possible.

(ii) Many NDT methods can be applied on the same part and hence many or all properties of interest can be measured.

(iii) Inservice testing is possible.

(iv) Repeated checks over a period of time are possible.

(v) Very little preparation is sufficient.

(vi) Most test methods are rapid.

Q2. What are the requirement of penetrant testing methods?

Sol:- A Typical penetrant testing involves use of a variety of materials for cleaning and developing as well as the penetrant material itself.

(i) Penetrants:- The penetrant material consists of the indicating dye plus the carrier fluid.

The indicating dye may give a colour contrast with respect to the surroundings, as is the case for visible dye penetrant methods.

(ii) Cleaners and Emulsifiers:- A cleaning fluid must act as a solvent for the material that is to be removed. For water-based penetrants, a simple water wash or rinse is suitable for the cleaning step. For petroleum-based penetrants, there are two alternate methods for cleaning the test piece.

(iii) Developers:- The developer material is used to enhance the conspicuity of the indication. For fluorescent penetrant, the developer background should appear black when illuminated by the ultraviolet light. The penetrant material concentrated around the defect will appear brighter and appear distinct from the black background of the developer.

(iv) Special Requirements:- When using various chemicals or water penetrant materials on austenitic stainless steels, titanium, nickel-base or other high temperature alloys, it is needed to restrict the impurities such as sulphur, halogen, and alkali materials since these impurities may cause embrittlement or corrosion.

Q3. Mention the criteria involved in the selection of an NDT method for the analysis of defects.

Sol:- During the non-destructive testing of materials and components, one has to deal with a variety of data generated during testing and calibration. To extract the information contained in the data, statistical methods are needed to organize, analyze and interpret it. The data may be related to the manufacturing process, material property, structural integrity, size and distribution of defects or the adequacy of NDE tools.

The criteria involved are:

→ Assessment of data distribution

→ Study of the scatter and determination of the relationship between variables.

→ Assessment of the significance of the data and the level of confidence in the system.

→ Instruments and accessories used.

→ Conditions of inspection (e.g indoor or outdoor testing, accessibility, skill of the operator and availability of reliable data for correct interpretation)

→ Type of material / component under test.

This makes the detection of defects and the repeated reproducibility of results highly probabilistic in nature.

The probability of detecting a defect diminishes as its size decreases. The defect could be due to such factors as design, materials, manufacturing processes, assembly, poor maintenance or error of individuals.

Q4. Write the steps involved in radiographic technique for testing.

Sol: Radiography is essentially a technique of projecting a three-dimensional object on a plane, utilizing a few of the properties of X-rays, gamma rays or any other penetration radiation. The properties used are:

→ Rectilinear propagation
→ Differential absorption
→ Photographic or fluorescence effects.

The projected image of the object is called a "radiograph" and the process of obtaining the radiographic image and evaluating its contents is called "radiography".

The essential requirements for producing a radiograph are;

→ A source of radiation
→ Object to be examined.
→ Recording medium
→ Processing chemicals.

In this section, the radiographic process using X-rays, and gamma rays as the source of radiation and films as the recording medium is discussed.

Irrespective of the type of component to be radiographed, the following steps are followed during radiography:

→ Surface preparation
→ Selection ~~of~~ and processing of film.
→ Keeping image unsharpness to as low ~~as~~ a value as possible
→ Optimizing exposure parameters and usage of exposure charts.
→ Ensuring appropriate radiographic sensitivity by using image quality indicators (IQI).

Q5. What do you mean by X-rays? What are the effect of tube voltage and current on intensity of X-rays?

Sol. X-rays are produced when high-speed electrons strike a metal target in a highly evacuated glass enclosure (vacuum ≃ $10^{-9 \text{ to } -13}$ mm/Hg). A metal filament is sealed inside the enclosure, which is heated by a current of a few amperes to produce electrons at its surface.

The wavelength of the emitted X-rays is given by

$$\lambda = \frac{hc}{e(V-V')}$$

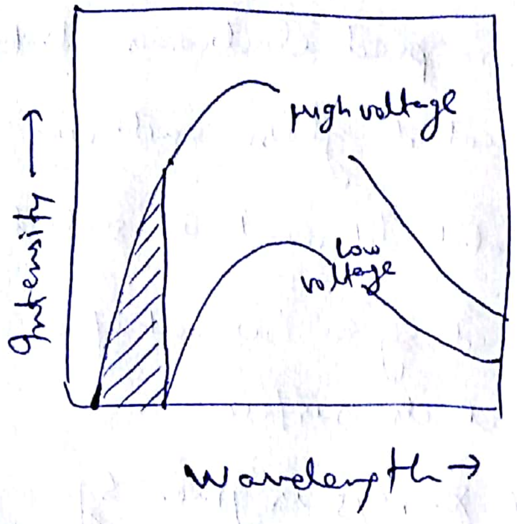
Effect of tube voltage and current on intensity of X-rays

The X-ray spectrum is significantly influenced by change in voltage between electrodes of the X-ray tube. Increased voltage leads to increase in generation of shorter wavelength compared to those that were present at low voltage. Also the intensity of the X-ray beam increases significantly and is given by the relation:

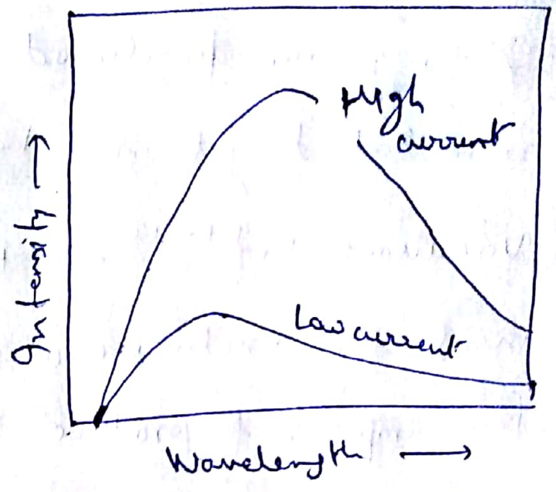
$$I = KV^2$$

where, K is a constant.

The intensity also increases as the tube current increases. (Tube current is the current that flows between the cathode and the anode and should not be confused with filament current, which heats the filament to produce electrons at its surface).



Effect of change in voltage



Effect of change in current

NMM

Q1. Justify the need of advance machining process in today's industries.

Ans. The need of advance machining process in today's industries are :-

(1) Advanced machining processes requires according to the product. Some product have complex shapes and low tolerances.

(2) There is a limitations of conventional machining methods, so the newer or advanced machining methods for material removal are needed.

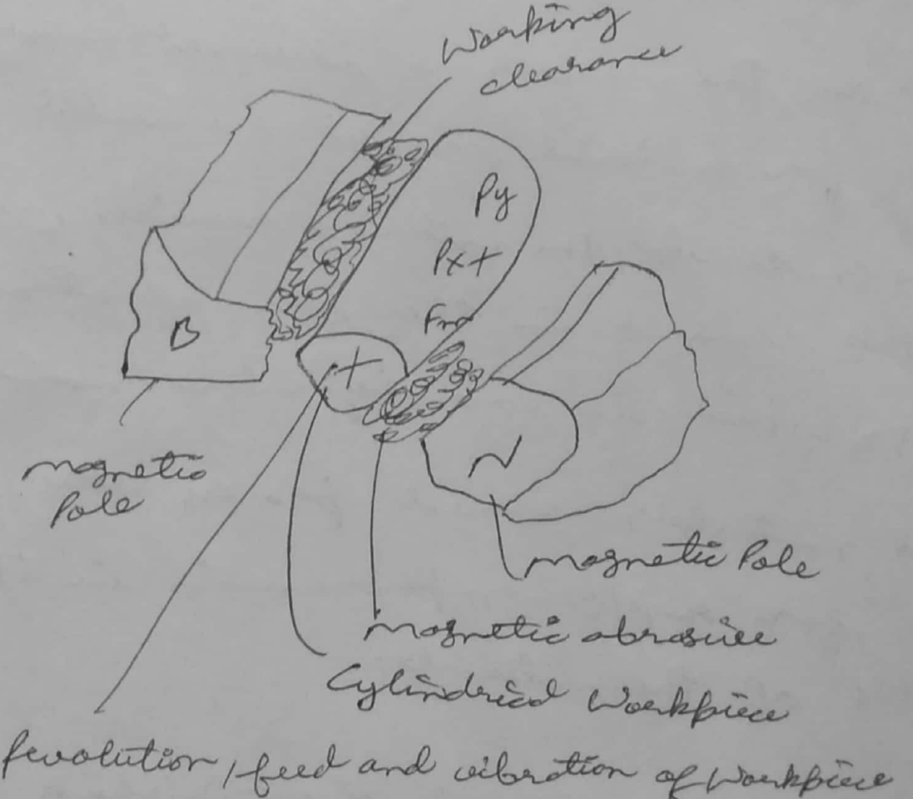
(3) For some materials, the materials requires machining or metal removal in the form of atoms or molecules, which is done by micro-machining.

(4) Advanced material removal process are needed for rapid improvements in the properties of the materials.

Q2. Explain the magnetic Abrasive Finishing Process.

Ans. Magnetic Abrasive Finishing (MAF) is one of the advanced finishing processes, which produces a high level of surface quality and is primarily controlled by a magnetic field. In MAF, the work piece is kept between the two poles of a magnet. The

Working gap between the workpiece and the magnet is filled with magnetic abrasive particles. A magnetic abrasive flexible brush (MAFB) is formed, acting as a multipoint cutting tool, due to the effect of the magnetic field in the working gap. When inserting a cylindrical work-piece in such a processing field giving revolution, feed and vibration in axial direction, surface and edge finishing are carried out by magnetic brush.



Advantages of MAF

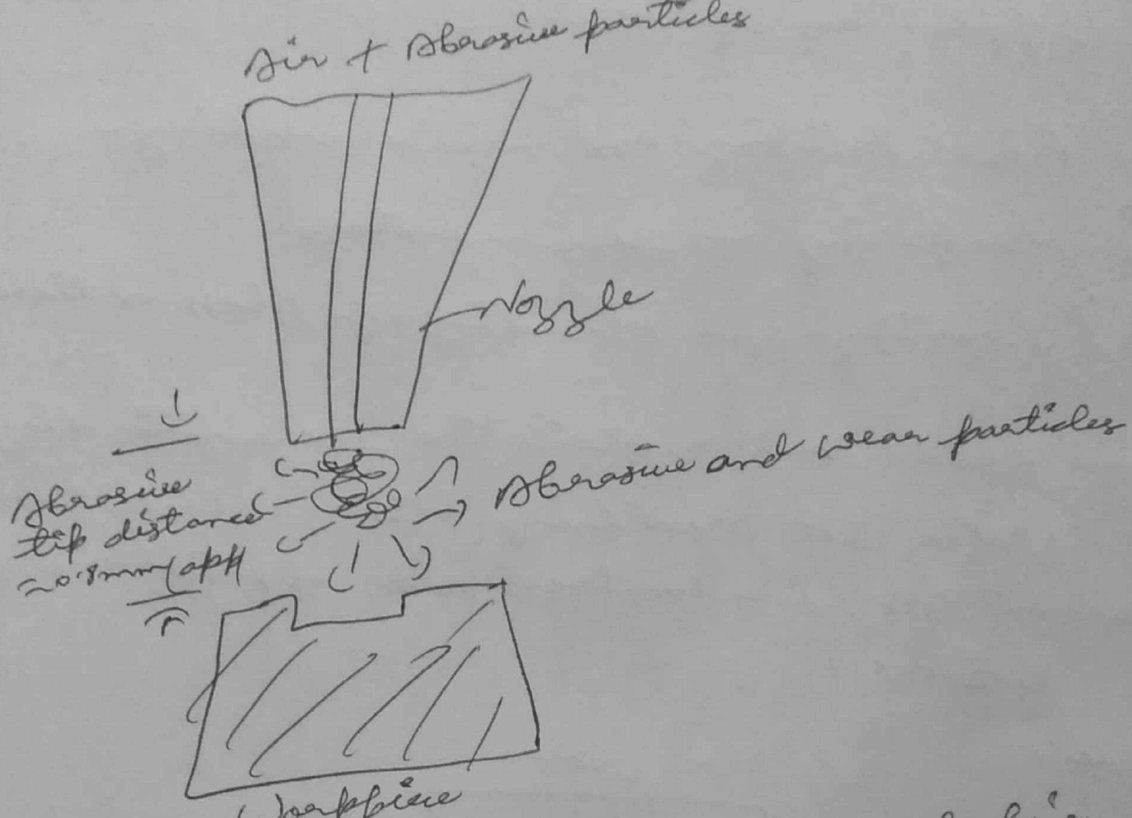
1. Capable to accessing hard to reach areas.
2. Capable of modifying roughness without altering form.

Disadvantages of MAF

1. Can be difficult to scale up to mass production operation.

(03). Sketch and explain the schematic diagram of Abrasive Jet machining (AJM). Write the advantages disadvantages and applications of AJM.

Ans. -



The process consists of directing a stream of fine abrasive grains, mixed with compressed air or some other gas at high pressure through a nozzle on to the surface of the workpiece to be machined. These particle impinge on the work surface at high speed and the erosion caused by their impact enables the removal of metal. The metal removal rate depends upon the flow rate and size of abrasive particles.

(*) Advantages of AJM: -

(1) Low capital investment required.

(2) There is no direct contact between the tool and workpiece.

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⊗ Disadvantages of ASM:—

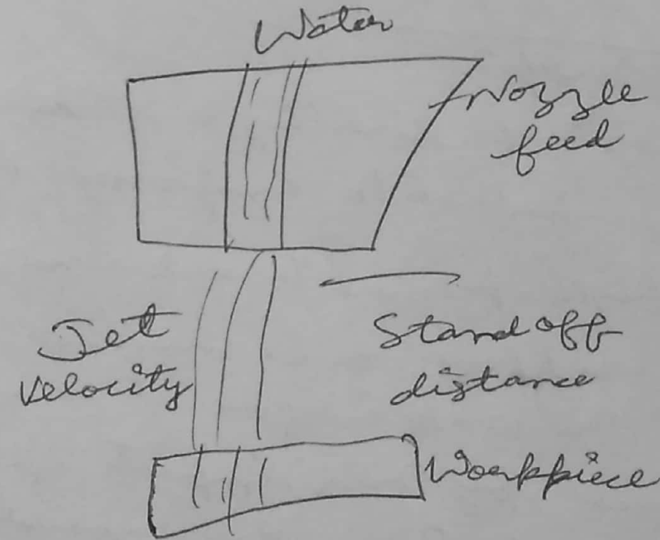
1. Low metal removal rate.
2. Machining accuracy is relatively poorer.

⊗ Applications of ASM:—

1. Fine drilling and micro-welding.
2. Machining of semiconductors.
3. Frosting and abrading of glass articles.

Q4. Sketch and explain the schematic diagram of Water Jet Machining (WJM). Write the advantages, disadvantages and applications of WJM.

Ans:



Water Jet machining is a mechanical energy based non traditional machining process used to cut and machine soft and non metallic materials. It involves the use of high velocity water jet to smoothly cut a soft workpiece and water from the reservoir is pumped to the intensifier using a hydraulic pump and when the water jet strikes the workpiece, stresses are induced and these stresses are used to remove material from the workpiece.

* Advantages of WJM:-

1. It does not produce any hazardous gas.
2. It is eco-friendly.

* Disadvantages of WJM:-

1. only soft materials can be machined.
2. very thick materials cannot be easily machined.

* Applications of WJM:-

1. cutting of rocks.
2. Drilling
3. Deburring
4. cutting of printed circuit board

05. Write the difference between AJM and USM process.

Ans:

	AJM	USM
1	Abrasive Jet machining (AJM) does not use ultrasonic wave	Ultrasonic machining (USM) process use ultrasonic wave.
2	AJM process use steam of abrasive particles as cutting edge.	USM process use abrasive slurry cutting edge.

(3) AJM process heat generated	USM process does not any heat generation.
(4) AJM required nozzle to flow air abrasive particles.	USM process does not require any nozzle to flow abrasive slurry.
(5) AJM process machining brittle and fragile materials.	USM process machining brittle and hard materials.

Solution of Midterm I[st] SE Paper (6MESA)

Q1: What is steam generator and on what parameter it is classified?

Steam generator:-

Ans:- A combination of apparatus for producing, furnishing or recovery heat together with the apparatus for transforming the heat so made available to water which could be heated, vapourised and superheated to steam form.

The function of steam generator is to generate steam at a desired pressure and temperature by transferring heat produced by burning fuel in a furnace to water to change it into steam.

Steam generators are used both in fossil-fuel and nuclear-fuel electric generating stations.

Classification:- Steam boilers are classified on the following basis:-

(A) Based on the contents of tubes:- On this basis, boilers are classified as below

(i) Fire tube boilers: The hot gases pass through the tubes and water surrounds them. The products of combustion leaving the furnace pass through fire tubes which are surrounded by water. Heat is transferred from hot flue gases to water which is converted into steam. The spent flue gases are then discharged to atmosphere through the chimney.

Examples:- Cochran, Lancashire, Cornish and Locomotive boilers.

(ii) Water-tube boilers:- In this type water flows inside the tubes and hot flue gases flow outside the tubes. A bank of water tube containing water is connected with a steam-drum by means of two sets of headers. The hot flue gases from the furnace pass over the tubes and discharged through the chimney. The water thus absorbs heat from the hot gases and evaporates in the steam form. This steam gets accumulated in the steam space of drum from where it may be taken into superheater to superheat steam.

(B.) Based on the nature of services:-

(i) Utility boilers:- These are used by utilities for electric power generation plants. Depending upon the pressure of steam wheather it is below or above the critical pressure, they can be subcritical and super-critical units.

Subcritical boilers ⟶ water tube - drum type and operate between 130 & 180 bar steam pressure.

(ii) Industrial steam boilers:- These are used in process industries like sugar, paper, jute etc. Institutions like hospitals, commercial and residential buildings etc. They are smaller in size and can be pulverized coal fired, fluidized bed or stoker fired units with coal as well as fuel. They can also be heat recovery types which uses waste heat from various industrial processes. They operate at pressures ranging from 5 to 105 bar with steam capacities up to 125 kg/s.

iii) Marine boilers:- They are used in marine ships and ocean liners driven by steam turbines. They are usually oil-fired and produce superheated steam at about 60-65 bar and 540°c.

iv) Locomotive boilers:- They are fire-tube type and used in locomotive which are now generally not used. The evaporating capacity of 8500 Kg/hr at 14 bar and 370°C temp. and rate of firing coal was 1585 Kg/hr.

(C) Vertical & Horizontal: This classification is according to the direction of the axis of the shell. Sometimes the axis may be inclined also.

(D) Internally fired or Externally fired:- This classification is based on the location of the furnace. If the furnace is so designed that it completely inside the boiler then the boiler is known as internally fired while the furnace is completely outside from the boiler then the boiler is known as externally fired.

Ex:- Lancashire boiler is an internally fired boiler while locomotive boiler is an externally fired boiler.

(E) Solid, Liquid or Gas fired:- This classification is according to the type of fuel used by the boiler. Energy by electricity, nuclear fission etc. may be used instead of form fuels.

(F) Natural or forced Circulation:- This classification is according to the method of circulation of water. When the circulation of water is due to convection currents setup due to difference in temperature then it is called natural circulation. When the pumps are used for water circulation then it is known as forced circulation.

(G.) Pressure:- This classification is according to working pressure. Boiler upto 30 bar pressure are low pressure boilers, 30 to 60 bar medium pr. boiler and above 60-70 bar high pressure boilers. If the pressure above 220 bar then it is known as supercritical pressure once through boiler.

Q.2 Explain the fire tube boiler in detail with neat sketch.

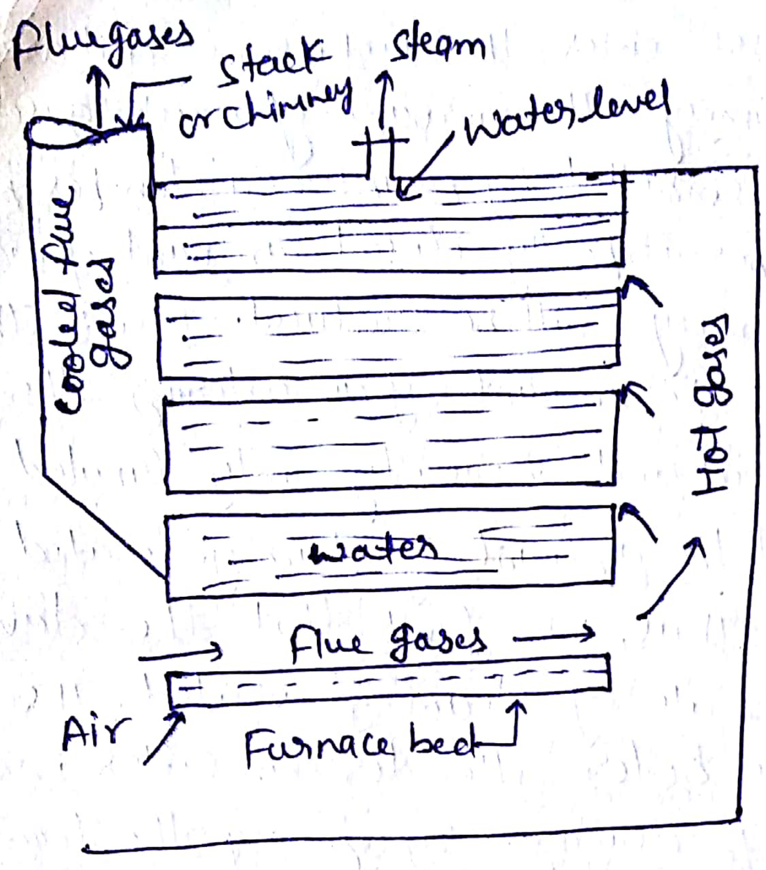
Ans:- Fire tube boilers:- In the fire-tube boilers, the hot gases (flue gases) pass through tube and water surrounds them. The production of combustion (hot gases) leaving the furnace pass through fire tubes which are surrounded by water. Heat from hot flue gases is transferred to water which is converted into steam. This spent flue gases are then discharged to atmosphere through the chimney (stack).

These boilers are now not used in utility power plants but they are used in industrial boilers, locomotive etc. They operate at pressure equal or less than 18 bar with steam capacity upto 6.5 kg/s

Fire-tube boilers are suitable for small steam requirements. The advantages are low first cost, reliability in operation, quick response to load changes, need only unskilled labour, less draught required, relatively inexpensive etc.

A fire tube boilers may be externally fired or it may internally fired

(locomotive boiler, Lancashire boiler, HRT boilers etc.)



Fire-tube boiler.

Q.3. Sketch and describe a Cochran boiler. What it's special features.

Ans:- Cochran boiler:-

This is a vertical fire-tube boiler. The fuel is feed into the grate through the fuel door and lighted. The fuel is burnt in the grate and hot gases go to the combustion chamber through a short flue tube. The combustion continues in the combustion chamber. The fire brick layer prevents the over-heating of the boiler shell. The hot gases pass through a large no. of fire tubes and heat the surrounding water and convert it into steam. Since the steam is lighter, it goes up to the steam space. The fire tube normally have 62.5mm external diameter and are 165 in number. The crown of the boiler shell and grate are both hemispherical in shape. This boiler can evaporate upto 3500kg of steam per hour, when the diameter is 3m and height is 6m.

The waste gases enter the smoke box and are released through the chimney. The amount of waste gases leaving the chimney is controlled by means of a damper manually. When the damper is partly closed, amount of waste gases leaving the chimney will be reduced. Due to this action of the damper, the amount of air entering the grate will also be reduced and obviously, only limited fuel can be burnt and the amount of steam generated also will be reduced. Thus, we find that the damper controls the rate of steam generated. Through the manhole, the boiler attender can enter inside the boiler shell for cleaning. By opening the door in the smoke box, the fire tubes and the smoke box can be cleaned with a wire brush.

The diameter of the boilers varies from 1-3 m. The height of the boiler varies from 2-6 m. The evaporative capacity of the boiler ranges from 20-3000 kg/hr. The boiler is fitted with various mountings.

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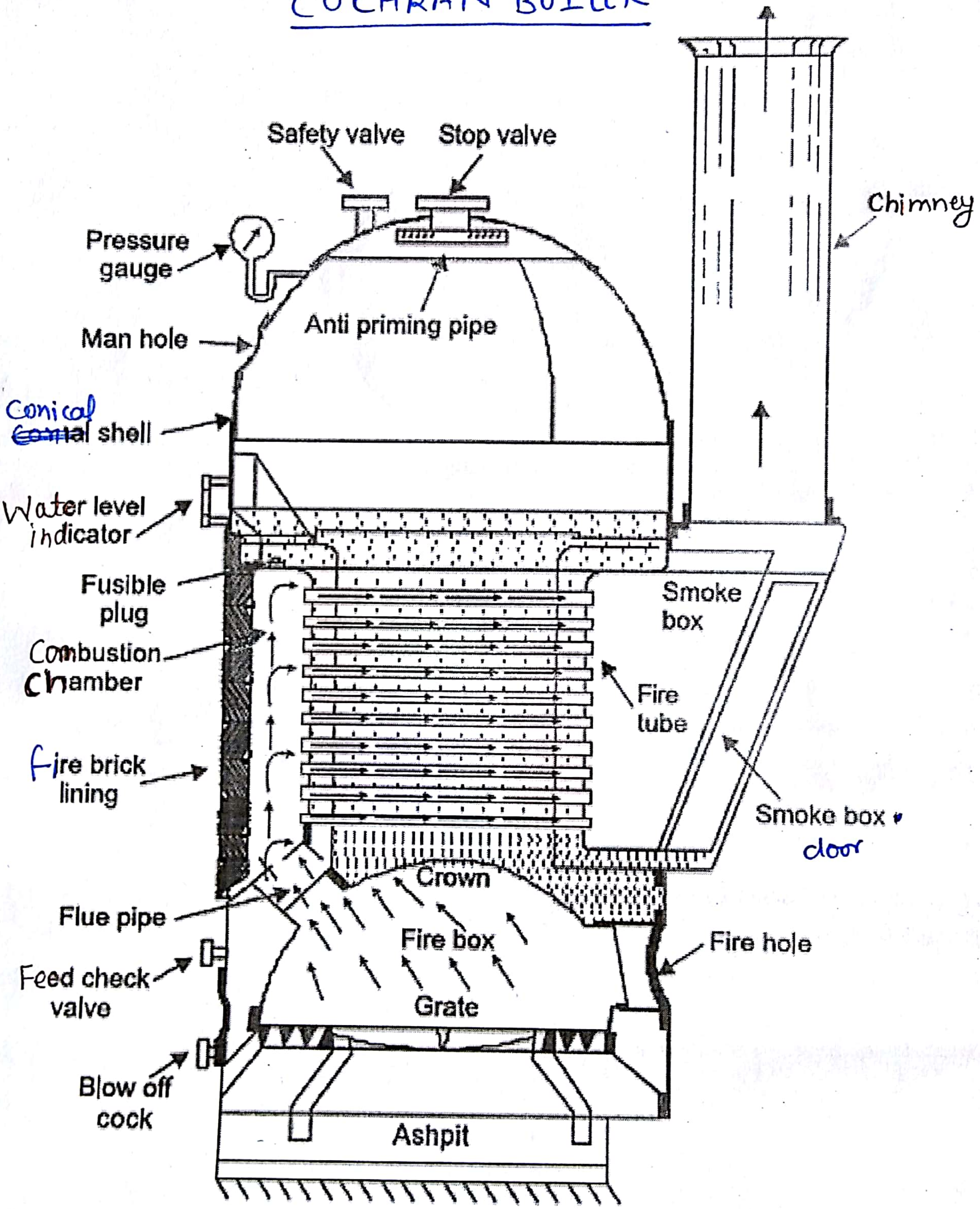
COCHRAN BOILER



Q4. Explain the lancashire boiler with neat sketch:-

Ans:- This is a fire tube, internally fired, horizontal, natural draft and natural circulation type of boiler.

Construction:-

(i) The boiler has a cylindrical horizontal shell made to suitable dimensions by several rings of steel plates which are either welded or riveted. The shell is provided with two parallel flues which run throughout the entire length of the shell. The diameter of the tubes is about 0.4 times the diameter of the shell.

(ii) The flue tubes built in short lengths are flanged. further to reduce the amount of internal mechanical bracing, the flue tubes are sometimes corrugated. To accomodate a grate of sufficient area and minimum length, the flue tubes are larger in diameter at the front of the shell.

(iii) Each of the flue tube has its own furnace with grate of about 2 m length arranged at the front end of the shell. Through the fire door, the coal is fed to the grates where its combustion takes place. The fire bridge provided at the back of the grate prevents the fuel from falling over the end of the furnace and also restricts the space through which hot gases have to pass. This space restriction is necessary to produce proper mixture of air and gases and to give perfect combustion.

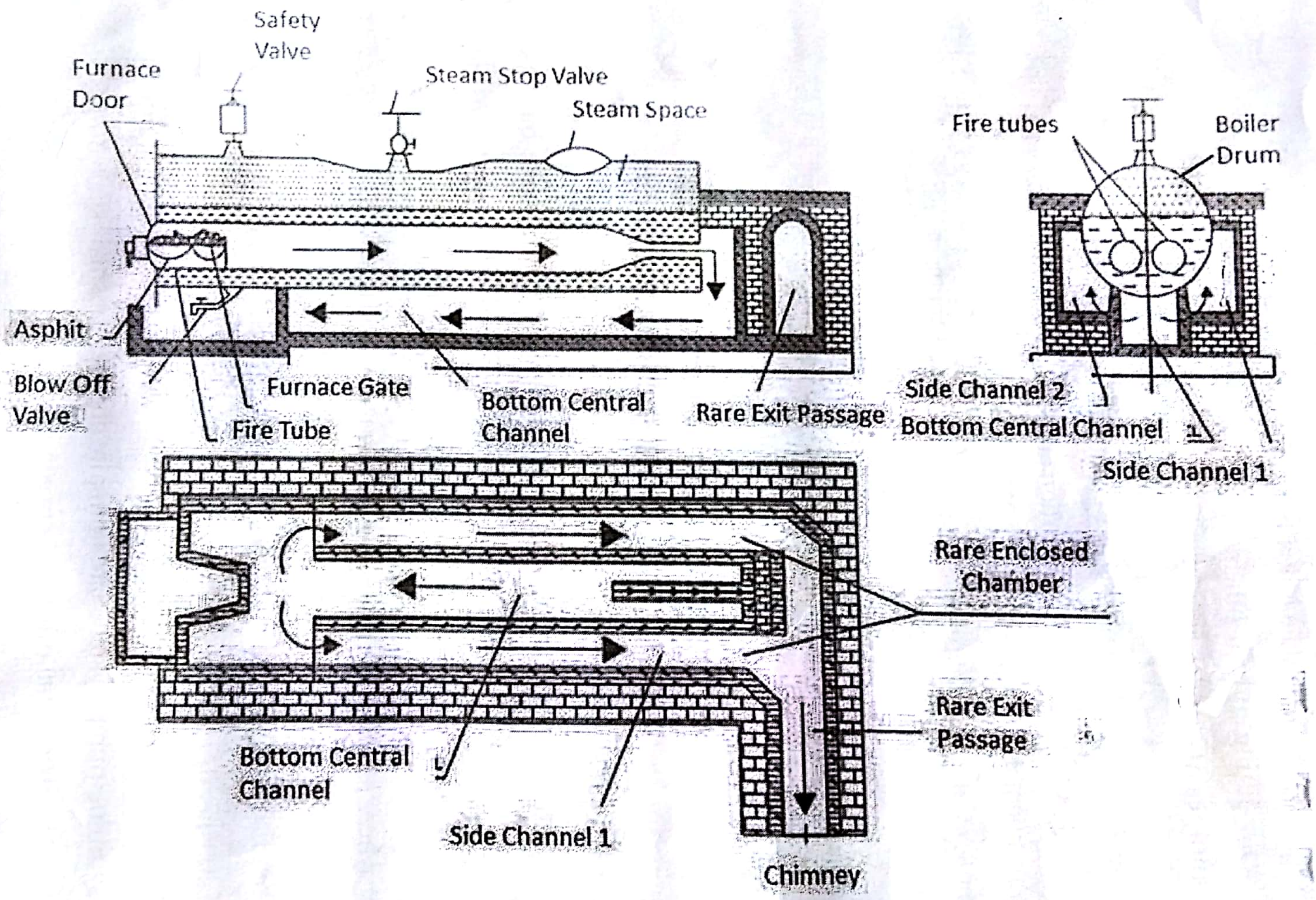
(iv) To regulate the gas flow and to control the amount of air entering the grate, there are dampers placed in the path of the flue gases. These dampers are operated by means of chains passing over pulleys from the front of the boiler.

(v) Openings are made in the boiler for inspection, steam exit and for necessary mountings and accessories.

Working :- The flue gases rising from the furnace pass over the fire bridge and traverse along the horizontal path. At the rear end, the gases enter the bottom common flue, travel backward to near the front of the boiler where they bifurcate and pass into the two sides and are finally discharged to the atmosphere through chimney. The feed water is supplied uniformly to the shell by a ~~perforated~~ perforated feed pipe controlled by a feed valve. When the boiler is strongly heated, the steam generated carries a large quantity of water in the steam space. To remove these water ~~pipes~~ particles, the steam is passed through an antipriming pipe before it is taken out through the stop valve and supplied to the engine when required.

Capacity & Utility :- Lancashire boilers are made to withstand working pressure upto 20 bar and have evaporative capacity upto 8000 kg/hr. The ratio of heating surface to grate area varies from 24 to 30. The size of the shell ranges from 2m dia. X 6m length to 3m dia. X 10m length.

These boilers are widely used in sugar mills and chemical industries. The boiler is also commonly employed where we need large reservoir of water and steam.



Lancashire Boiler

Q5 Explain the difference between a fire tube and water tube boiler. State which type of boiler is used for power generation and why?

Ans' Difference between fire tube boiler and water tube boiler.

Fire tube boiler	Water tube boiler.
1) In fire tube boiler hot flue gases pass through tubes and water surrounds them.	1) In water-tube boilers water passes through tubes and hot flue gases surround them.
2) They operated at low pressure upto 20 bar	2) Operated at high pressure upto 250 bar.
3) Rate of steam generation and quality of steam are very low, therefore not suitable for power generation	3) Rate of steam generation and quality of steam are better and suitable for power generation
4) Load fluctuations can not be handled.	4) It requires less floor area for a given output.
5) Requires more floor area for a given output	5) requires less floor area for a given output
6) Bulky and difficult to transport	6) light in weight and easy to transport
7) overall efficiency is 75%.	7) Overall efficiency with an economizer is upto 90%.
8) Water doesn't circulate in a definite direction	8) water circulate in a definite direction.
9) Drum is large and damage due to bursting is large.	9) any water tube is damaged, it can be easily replaced or repaired.

10.) Simple in design, easy to erect and low maintenance cost	10.) Complex design, difficult to erect and high maintenance cost
11.) less skill operator required to operate	11.) Skilled operators are required for operations.
12) Treatment of feed water is not very essential, as overheating due to scale formation cannot burst thick shell.	12.) Treatment of feed water is very essential as small scale deposits inside the tubes can cause overheating and bursting.
13.) Used in process Industry	13.) Used in large power plants.

Rate of steam generation and quality of steam are very good in ~~fire~~ Water tube boilers so it is suitable for power generation.

JNIT JAIPUR

Sub: Vibration Engineering
Sub Code: 6ME4A

Q.1 What is the major source of the noise and describe the industrial noise pollution.

Ans:→ Major causes / Sources of Noise Pollution are'

(i) Industrial Sources

(ii) Transport Vehicles

(iii) Household.

(IV) Public Address system

(V) Agricultural machines

(VI) Defence Equipment.

(VII) Miscellaneous source.

Industrial Noise Pollution ⇒ The Progress in technology (industrialization) has resulted in creating noise pollution. Textile mills, printing presses, engineering establishments and metal work etc. contribute heavily towards noise pollution. In industrial cities like Kolkata, Ludhiana etc. The industrial zones are not separated from the residential zones of the city especially in the case of small scale industries.

These operate from workshops located on the ground floors of the residential area and cause annoyance discomfort and irritation to the residents exposed to the noise that is inevitably produced.

Q.2. What is the response of single degree of freedom system with viscous damping when it is: (any one)

(a) Underdamped ($\zeta < 1$)

(b) critically damped ($\zeta = 1$)

(c) over damped ($\zeta > 1$)

Ans ⇒ Free vibration with viscous damping :-

In the study of vibrations the process of energy dissipation is generally referred to as damping. The most common type of energy dissipating element is the viscous damper, also called the dashpot.

Viscous damping force is proportional to the velocity '$\dot{x}$' of the mass and acts in the direction opposite to the velocity of the mass.

$$F = c\dot{x}$$

c = Damping constant or coefficient of viscous damping.

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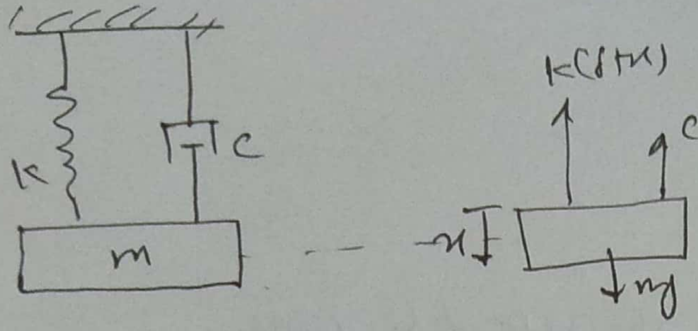


Applying Newton's second law

$$m\ddot{x} = -k(\delta + x) + mg - c\dot{x} \quad \text{--- (1)}$$

Since the damper exerts no force at equilibrium the equilibrium condition $mg = k\delta$ --- (2)

$$m\ddot{x} = -kx - c\dot{x}$$

$$m\ddot{x} + kx + c\dot{x} = 0$$

$$\ddot{x} + \frac{c\dot{x}}{m} + \frac{k}{m}x = 0$$

let $x(t) = Ce^{st}$

$$s^2 + \frac{c}{m}s + \frac{k}{m} = 0$$

$$s_{1,2} = \frac{1}{2}\left[-\frac{c}{m} \pm \sqrt{\left(\frac{c}{m}\right)^2 - 4\frac{k}{m}}\right]$$

$$s_{1,2} = \frac{-c}{2m} \pm \sqrt{\left(\frac{c}{2m}\right)^2 - \frac{k}{m}} \quad \text{--- (3)}$$

The solution given by eqn (3) takes one of three forms depending on whether the quantity $\left[\left(\frac{c}{2m}\right)^2 - \frac{k}{m}\right]$ is zero, positive or negative.

Critical Damping ~~constant (ζ=1)~~

$$\frac{c}{2m} = \sqrt{\frac{k}{m}} = \omega_n$$

$$c = 2m\omega_n$$

in which case we have the repeated roots

$$s_1 = s_2 = \frac{-c}{2m}$$

$$x(t) = (A + Bt)e^{-\left(\frac{c}{2m}\right)t} \quad \text{———} \quad (4)$$

As the case in which repeated roots occur has special significance we shall refer to the corresponding value of the damping constant as the critical damping constant

$$\boxed{C_c = 2m\omega_n}$$

$$S_{1,2} = \frac{-c}{C_c}\omega_n \pm \omega_n\sqrt{\left(\frac{c}{C_c}\right)^2 - 1}$$

$$\boxed{s_{1,2} = \left(\zeta \pm \sqrt{\zeta^2 - 1}\;\omega_n\right)} \quad \text{———} \quad (5)$$

Damping Factor $= \zeta = \dfrac{c}{C_c}$

$$\boxed{\zeta = \frac{c}{C_c} = \frac{c}{2m\omega_n}}$$

Case-1 Underdamped system ($\zeta < 1$)

If $\zeta < 1$ both the roots of eqn '5' are imaginary

$$S_{1,2} = (-\zeta \pm i\sqrt{1-\zeta^2})\omega_n$$

$i = \sqrt{-1}$ the solution for the motion

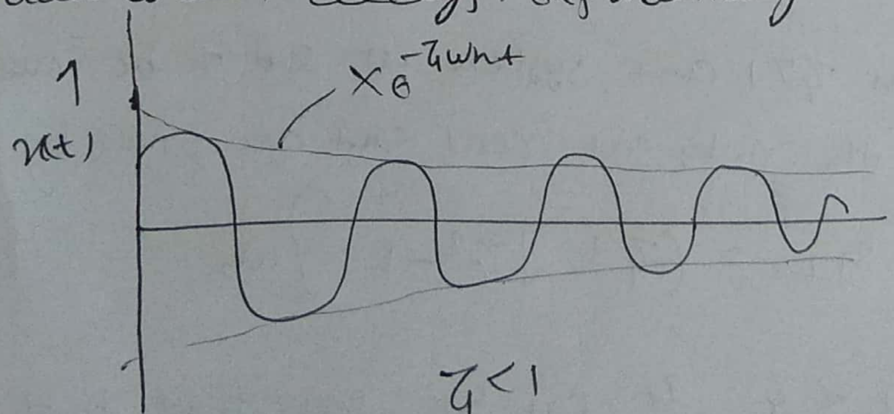
$$x(t) = e^{-\zeta \omega_n t}\left[A \cos\sqrt{1-\zeta^2}\,\omega_n t + B \sin\sqrt{1-\zeta^2}\,\omega_n t\right]$$

$$x(t) = X e^{-\zeta \omega_n t} \sin(\omega_d t + \phi)$$

$$\boxed{\omega_d = \sqrt{1-\zeta^2}\,\omega_n}$$ is called damped circular frequency.

ϕ = phase angle of the damped oscillation.

The displacement is a harmonic function having an amplitude which decays exponentially with time.



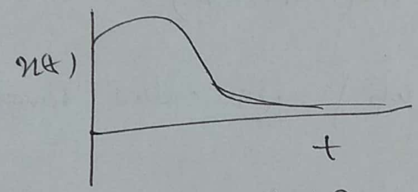
$\zeta < 1$

Underdamping

Case-2 Critically damped system ($\zeta = 1$)

$$x(t) = (A + Bt)\, e^{-\omega_n t}$$

The solution to the above equation is the product of a linear function of time and decaying exponential. Depending on the values of 'A' and B, many forms of motion are possible, but each form is characterized by the amplitude which decays without oscillation.



Critical Damping

Case-3 Over Damping System ($\zeta > 1$)

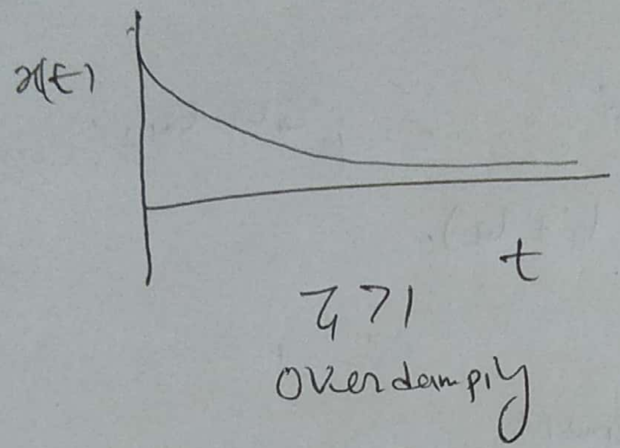
In this case $\zeta > 1$ and system is said to be overdamped here both the roots are real and are given by

$$s_{1,2} = \left(-\zeta \pm \sqrt{\zeta^2 - 1}\right)\omega_n$$

Since $\sqrt{\zeta^2 - 1} < \zeta$ it can be seen that both s_1 and s_2 are negative so that the displacement is the sum of the two decaying exponential given by

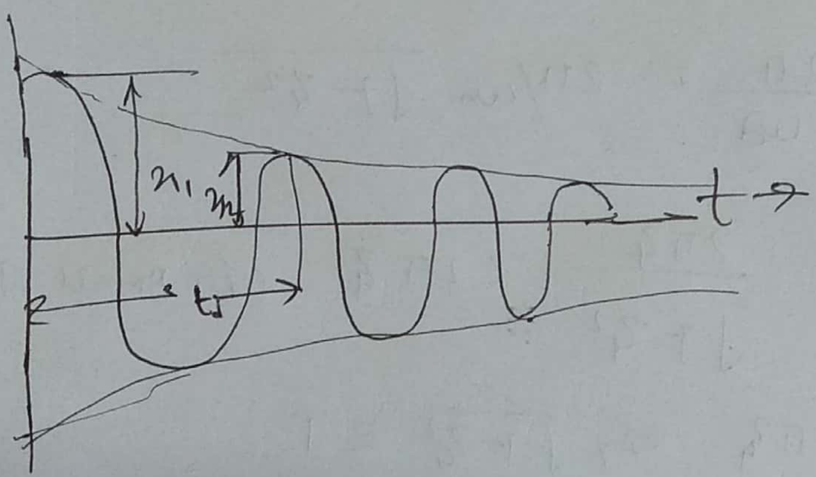
$$x(t) = \left\{ C_1 e^{(-\zeta + \sqrt{\zeta^2 - 1})\omega_n t} + C_2 e^{(\zeta - \sqrt{\zeta^2 - 1})\omega_n t} \right\}$$

The motion will be non oscillatory and will be similar to that



Q.3 Explain the logarithmic decrement of a single degree of freedom viscous damping system.

Ans ⇒



$$x_i = X e^{-\zeta \omega_n t_i}$$

The logarithmic decrement represent the rate at which the amplitude of a free damped vibration decrease. It is defined as the natural logarithm of the ratio of any two successive amplitude.

$$x_i = X e^{-\zeta \omega_n t_i}$$

$$x_{i+1} = X e^{-\zeta \omega_n (t_i + t_d)}$$

$$\delta = \frac{x_i}{x_{i+1}} = \frac{X e^{-\zeta \omega_n t_i}}{X e^{-\zeta \omega_n (t_i + t_d)}} = e^{\zeta \omega_n t_d} = \text{Constant.}$$

δ = logarithmic decrement

$$\delta = \ln \frac{x_i}{x_{i+1}} = \ln e^{\zeta \omega_n t_d} = \zeta \omega_n t_d$$

$$t_d = \frac{2\pi}{\omega_d} = 2\pi / \omega_n \sqrt{1 - \zeta^2}$$

$$\delta = \frac{2\pi \zeta}{\sqrt{1 - \zeta^2}} = 2\pi \zeta \quad \text{(for small Damping)}$$

$$\zeta \simeq 2\pi \zeta \quad \text{as } \sqrt{1 - \zeta^2} \simeq 1$$

$$\zeta = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}}$$

$$\& \ \zeta = \frac{\delta}{2\pi}$$

of n cycles the

$$\frac{x_0}{x_n} = \frac{x_0}{x_1} \cdot \frac{x_1}{x_2} \cdot \frac{x_2}{x_3} - - \frac{x_{n-1}}{x_n}$$

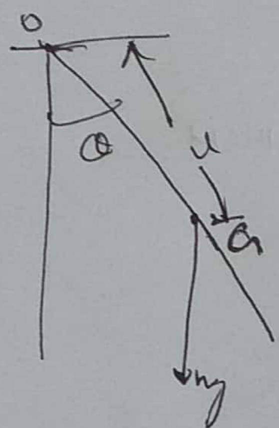
$$= \left(\frac{x_j}{x_{j+1}} \right)^n$$

The natural log of this is $\ln\left(\frac{x_0}{x_n}\right) = n \ln\left(\frac{x_i}{x_{i+1}}\right) = n\delta$

$$\delta = \frac{1}{n} \ln\left(\frac{x_0}{x_n}\right)$$

Q.4 = Find the time period of vibration of a compound pendulum.

Ans ⇒



Newton's second law of motion

$$J_0 \ddot{\theta} = -mgd\theta$$

J_0 = mass moment of inertia of the body about 'O'

$$J_0 = (J_G + md^2)$$

J_G = mass moment of inertia of the body about its centre of gravity 'G'.

~~J_G mg~~ $(J_G + md^2)\ddot{\theta} + mgd\theta = 0$

$$\omega_n = \sqrt{\frac{mgd}{J_G + md^2}}$$

$$t = 2\pi \sqrt{\frac{J_G + md^2}{mgd}}$$ ⇒ ~~t~~ 2π

$J_G = mr^2$

r = Radius of gyration

$$t = 2\pi \sqrt{\frac{r^2 + d^2}{g d}}$$

Q.5 A single degree of freedom viscous damping system make five complete oscillation per second. Its amplitude diminishes to 15 percent in 60 cycle. Determine

(a) The logarithmic decrement

(b) The Damping Ratio.

Soln (a) Given $f = 5$

$t_d = 0.2$ but $t_d = \frac{2\pi}{\omega_d}$

$\omega_d = 31.416$ rad/sec

$$\delta = \frac{1}{n} \ln\left(\frac{x_0}{x_n}\right)$$ Ans

(a) $\delta = \frac{1}{60} \ln 0.15 = 0.0457$

(b) $\xi_4 = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}} = \frac{0.0457}{\sqrt{(2\pi)^2 + (0.0457)^2}}$

$\xi_4 = = 0.007177$ Ans