Lecture Notes

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Sub : Design of Machine Elements

-: INTRODUCTION :-

- A machine is a combination of several machine elements arranged to work together as a whole to accomplish specific purposes.

- Machine design involves designing the element and arranging them optimaly to obtain some useful work.

CLASSIFICATION OF MACHINE DESIGN

ADAPTIVE DESIGN :-

It is based on existing design adapted for a new system or application.
Ex:- Design of a new model of passanger car, Conveyor belts, Control system of machines.

DEVELOPMENT DESIGN :-

Here we start with an existing design but finally a modify design is obtained.
Ex:- A new model of a car

OR

- This type of design needs considerable scientific training and design ability in order to modify the existing design into a new idea by adapting a new material of different method of manufacture.

- In this case though the design are starts from the existing design but finally product may defer from original product.

NEW DESIGN:-

This type of design is an entirely new one but based on existing system scientific principle.

- No scientific invension is involved but requires creative thinking to solve a problem.

Ex:- Designing a small vehicle for transportation of people and material (goods) on boat a ship or in a desert.

TYPES OF DESIGN BASED ON METHODS

RATIONAL DESIGN :-

This is based on determining

- the stresses and strains of components and their by deciding their dimensions.

EMPIRICAL DESIGN :-

- This types of design upon empirical formula based on the practice & past experiences.

Ex:- When we tight a nut & bolt force enter or stress induced can be determined but experience so, that the tightening force may be given their is no mathematically tacking of this equation but it is based on observation & experience.

INDUSTRIAL DESIGN :-

- These are based on their industrial consideration & normal market survey, external look for production facility, low cost, use of existing standard product.

OPTIMOM DESIGN :-

- ~~It is given for~~ It is based on the design for the given objective function under the specified Constraint. It May be achieved by minimizing the undesirable effects.

SYSTEM DESIGN :-

It is the design of any complex mechanical system.

Ex:- Bike, Car, Piston, Pinion Rod.

ELEMENT DESIGN :-

It is the design of any elements of the mechanical system.

Ex:- Crank Shaft, Cam & Follower, Connecting rod.

CAD (COMPUTER ADDED DESIGN)

This type of design depends upon use of computer system to assist in the creation, modification, Analysis & Optimization of a machine.

ENGINEERING MATERIAL & THEIR PROPERTIES

The machine elements should be made of up such a material which properties are suitable for the conditions of operation.

CLASSIFICATION OF ENGINEERING MATERIAL

- Metals & Their alloys such of irons, steels, copper, zinc etc.
- Non-metal such as glass, rubber, Plastics etc.

The metal may be further classified as :-

FERROUS METAL :-

Which have the iron as their main constituent.

Ex:- Cast iron, Wrought iron, Steel.

NON-FERROUS METAL :-

Which have a metal other than iron as their main constituent.

Ex:- Copper, Aluminium, Brass etc.

SPECIFICATION OF MATERIAL FOR ENGINEERING MATERIAL

- Availability of material
- Suitability of material for working condition in service.

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PHYSICAL PROPERTIES OF METALS

The physical properties of metals include luster, Column, Size & shape, Density, Electric, Thermal conductivity and Melting Point.

MECHANICAL PROPERTIES OF METALS

The mechanical properties of metal includes strength, stiffness, Elasticity, Plasticity, Elasticity, Ductility, Malleability, Brittleness, Hardness, Toughness, Resillience, Creep, Fatigue.

STRENGTH :-

It is the ability of material to resist deformation under stresses.

STIFFNESS :-

It is the ability of material to sustain external load without excessive change of its geometry (Deformation).

ELASTICITY :-

It is the property of material which regain its original shape after deformation when the external force are removed.

PLASTICITY :-

Plasticity is that property of material by virtue of which it may be permanently deformed when it has been subjected to an externally applied force great enough to exceed the elastic limit.

DUCTILITY :-

Ductility refers to the capacity of a material to undergo deformation under tension without rupture.

MALLEABILITY :-

Malleability is the capacity of a material to withstand deformation under compression without rupture as for example in forging and rolling operations.

BRITTLENESS :-

Brittleness is defined as a tendency to fracture without appreciable deformation and is therefore the opposite of ductility or Malleability.

HARDNESS :-

Hardness is the resistance of material to plastic deformation usually by indentation. However, the term may refer stiffness or temper or to resistance to scratching.

TOUGHNESS :-

Toughness is the ability of material to absorb energy during ~~plastic~~ deformation up to fracture.

RESILIENCE :-

It is the capacity of a material to absorb energy when it is elastically deformed and then upon unloading, to have this energy recovered. 1

CREEP :-

Creep is the time-dependent permanent deformation that occurs under stress; for most material, it is important only at elevated temperature

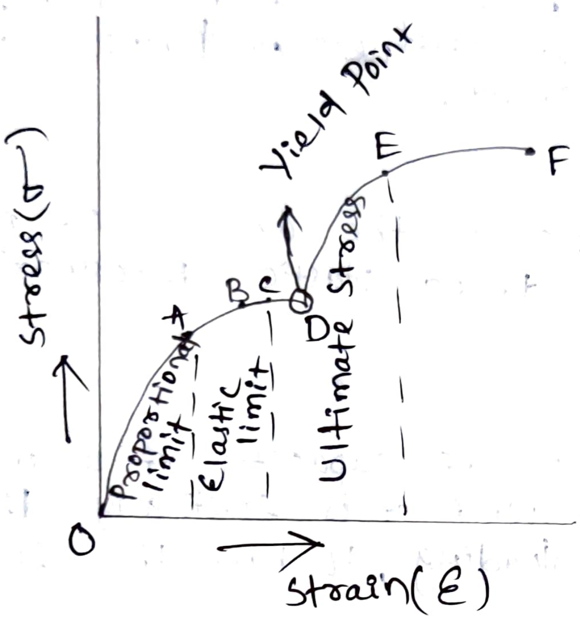
FATIGUE :-

When subjected to fluctuating or repeated loads (or stresses), materials tend to develop characteristic behaviour which is different from that (of the materials) under steady loads.

MACHINABILITY :-

Machinability is the ease with ~~with~~ which a metal can be cut permitting the removal of the material with a satisfactory finish at low cost.

STRESS STRAIN DIAGRAM



O–A ⇒ Proportional limit
A–B–C ⇒ Elastic limit
C–D ⇒ Yield Point
D–E ⇒ Ultimate stress
E–F ⇒ Breaking stress
F ⇒ Fracture Point.

PROPORTIONAL LIMIT :– It represents that stress is proportional to point A, the curve slidely deficient from the straight line that hook's law goes upto point A and it is known as proportional limit.

ELASTIC LIMIT :– If the load is increased beyond beyond point A upto point B the material will regain its shape and size when the load is removed.

YIELD POINT :-

If the material stress beyond point B, the plasticity page will reach that is on the removal of load the material will not be able to recover its original shape and size. The material its before the load and there is an appreciable strain without any increasing stress.

ULTIMATE STRESS :-

At D point specimen regain some strain at higher value of stresses are require for higher strain.

- The stress those on increasing till the point E, the gradual increase in strain of the specimen is followed with the uniform reduction of its cross-sectional area.

BREAKING STRESS / FRACTURE POINT :-

After the specimen has reached ultimate stress a making formed with decrease cross-sectional area. of specimen.

- Break away at point F the specimen is less than maximum stress.

WORKING STRESS

- When designing machine parts, it is desirable to give the stress lower than the maximum or ultimate stress at which failure of material takes place, this is known as working stress or designing stress.
- It is also known as allowable stress.

FACTOR OF STRESS

- It is defined as the ratio of maximum stress to working stress.
- Mathematically,

$$F.O.S = \frac{\text{Maximum Stress}}{\text{Working Stress}}$$

YIELD STRESS

- In case of ductile material that is mild steel where the yield point is clearly defined the factor of safety is based upon the yield point stress.

Mathematically,

Yield Point stress = Factor of safety x working stress

$$F.O.S = \frac{\text{Yield Point Stress}}{\text{Working stress}}$$

ULTIMATE STRESS

- In case of brittle material that is cast iron, the yield point is not well defined as per ductile material. Therefore the factor of safety for brittle material is based on ultimate stress.

$$F.O.S = \frac{\text{Ultimate stress}}{\text{Working stress}}$$

SELECTION OF FACTOR OF SAFETY

- The reliability takes result an accuracy of application of these result to actual machine part.
- The reliability of applied load.
- Shortening as to exact mode of failure.
- The extend of simplifies assumption.
- The extend of localised stresses.
- The extend of initial stresses set-up
- The extend during manufacturing.
- The extend of loss of life if failure occurs.
- The extend of lass of property if failure occurs.
-

Q. Describe design procedures ?

Ans:- The basic procedures are mentioned below for the process of machine design :-

Identifying the Need.
↓
Selecting the possible mechanisms
↓
Analysis of forces
↓
Selection of materials
↓
Design of elements
↓
Modification
↓
Detail Drawings
↓
Production
↓
Quality checking.

1. IDENTIFYING THE NEED

- Recognising the solution for a problem by giving a complete statement of the problem by identifying the aim and purpose of why the machine is needed to be designed.

2. SELECTING THE POSSIBLE MECHANISMS

- Synthesise the different mechanism and choose the best mechanism for the required motions among the different mechanisms.

3. ANALYSIS OF FORCES

- Analyse the different system of forces in the motion of the machine members and power transmissions among the different machine elements.

4. SELECTION OF MATERIALS

- Select the best-suited materials for the different components in the machine and we should keep on eye on the availability of the materials as well.

5. DESIGN OF ELEMENTS

- We should design a machine that should accept the operations conditions as well as it should withstand for a longer life.
- For that, we need to analyse the size and stresses acting in different element in the machine by considering the forces acting on the machine elements. We should check these stresses with the permissible stress of each material we have used in the making of machine elements.

6. MODIFICATION

- To reduce the overall cost of the productions and due to the availability of the resources, we should make some considerations to accomodate the changes. We should modify the size or any other modification needs to happen. This is the case we need to be ready to be modification in the design.

7. DETAILED DRAWINGS

- We can say this is the final stage for determining what kind of machine we are going to build. Once we have done with the detailing of each and ~~every~~ components and assemby and subassemblies drawings, we should proceed with the manufacturing.

8. PRODUCTION

- As per the drawing, the components will be manufactured in the manufacturing units and assembled as per the detailed drawings Everything will be produced and sent them to the next step quality checking. If any difference is there then it should come back for the reproduction.

9. QUALITY CHECKING

- This is the final step to determine whether the production of each machine element is as per the detailed drawings we have provided.

DESIGNING OF FASTENING ELEMENTS

JOINTS & THEIR CLASSIFICATION :

JOINTS OR FASTENER :-

It is a mechanical joints which is used to be fixed or attached to something or holds something in place.

TYPES OF JOINTS

- Joints
  - Permanent
    - Welded
    - Riveted
  - Temporary
    - 1. Thread joint
      - (a) Bolted joint
      - (b) Screw joint
    - 2. Keys
    - 3. Coupling joint
    - 4. Pins joint
      - (a) Cutter joint
      - ~~(b) Pins joint~~
      - (b) Knuckle joint
    - 5. Pipe joint

PERMANENT JOINT

Permanent fastening are those fastening which can not be this assembled without destroying the connecting component.

TEMPORARY JOINT OR DEATTACHABLE JOINT

Temporary fastening are those fastening which can be assembled without the destroying the connecting component.

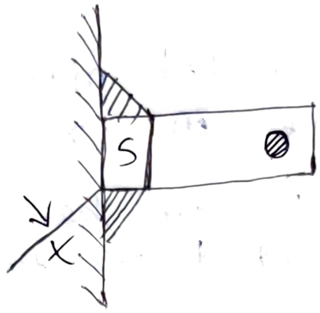
ADVANTAGES OF WELDED JOINT OVER RIVETED JOINT

- The welded structure are usually lighter than riveted structure. This is due to welding is used for connecting other components.
- The welded joint provided maximum efficiency which is not possible in riveted joint.
- Ulternation and addition can be easily made in existing structure. As the welded structure is smooth in appearance.
- In welded connection the tension member are not weakend as in the case of riveted joint.
- Welded joints are a grade strength.
- Sometimes the members are of such a shape that they afford difficulty for riveting they can be easily welded.
- The welding provides very rigid joints.
- It is possible to weld any part of structure at any point but requires enough clearance.
- The process of welding takes less time than the riveting.

DISADVANTAGES OF WELDED JOINTS

- Since there is an heating & cooling during fabrication therefore the members may get resorted or addition stress may developed.
- It requires a highly skilled labour & super vision.
- Since no provision is kept for expansion & contraction in the frame, therefore there is a possibility of cracks developing in it.
- The inspection of welding work is more difficult than riveting work.

DESIGN OF WELDED JOINTS FOR ECENTRIC LOADS



An ecentric load may be imposed on welded joint in many ways:-

(i) The stresses induced on the joint may be of same nature or different nature.

(ii) The induced stresses are combined depending upon the nature of stresses when the shear and bending stress are simultaneously present in a joint then the maximum stresses are :-

Maximum normal stress :-

$$\sigma_{max} = \frac{\sigma_b}{2} + \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau^2}$$

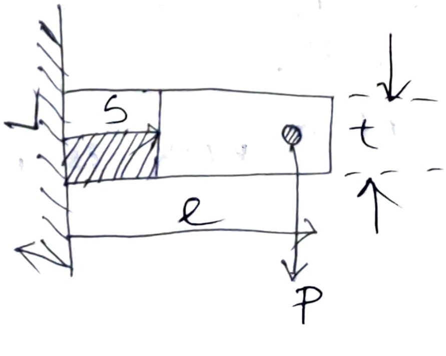
Maximum normal stress

$$\tau_{max} = \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau^2}$$

Where, σ_b = Bending stress

τ = Shear stress

CASE -1



Where, S = Size of weld
L = Length of weld
t = Throat thickness
P = Load

- Consider a 'T' joint fixed at one end and subjected to an ecentric load 'P' at a distance 'e'.

- The joint may be subjected to :-

(i) Direct shear stress due to the shear force 'P' acting at the welds.

(ii) Bending stress due to bending moment (P.e)

- Area at the throat = Throat thickness × Length of weld.

mathematically,

$$\boxed{A = t \times 2L}$$

(For double fillet welding)

$$P = S\cos 45^\circ$$

$$A = S\cos 45^\circ \times 2 \times l$$

$$\Rightarrow A = 1.414\, S \times l$$

$$\tau = \frac{P}{A} = \frac{P}{1.414 \cdot S \times l}$$

$$= \frac{0.707\, P}{S \times l}$$

- Selection modulus of the weld metal to the throat

$$Z = \frac{t + e^2}{6} \times 2$$

(For both side weld)

Bending moment :-

$$M = P \times e$$

Bending stress

$$\sigma_b = \frac{M}{Z}$$

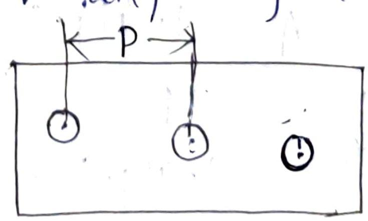
We know for maximum bending

$$\sigma_{max} = \frac{\sigma_b}{2} + \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau^2}$$

PITCH

- It is the distance between the centers of the adjacent rivets in the same row.
- It is denoted by 'P' and may taken as 3d (d → Diameter)

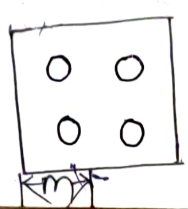
$$P = 3d$$



MARGIN

- It is the distance from the edge of the plate to the center of the nearest rivet.

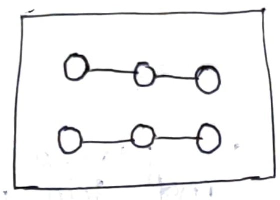
$$m = 1.5d$$



- It is denoted by 'm'.

CHAIN RIVETING

- The rivets are used along a number of rows such that the rivets in the adjacent row are placed directly opposite to each other. It is known as chain riveting.
- $P_r = 0.8P$



ZIG ZAG RIVETING

- In a multi row riveting, if the rivets in the adjacent rows are staggered and are placed in between rows of the adjacent row. It is known as zig zag riveting.
- $P_r = 0.6\,P$

ROW PITCH (TRANSVERSE PITCH)

- It is the distance between the two adjacent rivets.
- It is denoted by 'P_r'.
- $P_r = 0.6P$.

DIAGONAL PITCH

- This term is associated with zigzag riveting and it is denoted by 'P_d'.
- It is the distance between the center of ~~the~~ a rivet in a row, to the next rivet in the adjacent row.