LECTURE NOTE ON

SUB:DESIGN OF MACHINE ELEMENTS

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1.1 Introduction to Machine Design :-

Machine design in general is concerned with development of Power sources and functional mechanism. They may concentrate on such areas as design of engines or turbines or the functional portions of automobiles, machine tools, or automation equipment.

Classification of Machine Design :-

The machine design may be classied as follows.

(i) Adaptive Design :- In this the designer's work is concerned with adaptation of existing designs. The designer only makes minor alternation or modification in the existing designs of the product.

(ii) Development Design :-> This type of design needs scientific training and design ability in order to modify the existing designs into a new idea by adopting a new material.

(iii) New Design :-> This type of design needs lot of research, technical ability and creative thinking.

(iv) Rational Design :-> This type of design depends upon mathemetical formulae of principle of mechanics.

(v) Empirical Design :-> This type of design depends upon empirical formulae based on the practice and past experience.

(vi) Industrial Design :-> This type of design depends upon the production aspects to manufacture any machine component in the industry.

(vii) Optimum Design :-> It is the best design for the given objective function under the constraints.

(viii) System Design :-> It is the design of any complex mechanical system like a motor car.

(ix) Element Design :-> It is the design of any element of the mechanical system like piston, crankshaft, connecting rod, etc.

(x) Computer Aided Design :-> This type of design depends upon the use of computer systems to assist in the creation, modification, analysis and optimization of a design.

1.2 Different mechanical engineering materials used in design with their uses and their mechanical & Physical Properties :-

Introduction :-> Knowledge of materials and their properties is very important for designers. Mechanical elements should be made of materials with suitable properties depending on the operating conditions. Additionally, designers need to know how manufacturing processes and heat treatment affects material properties.

Engineering Materials :-> Engineering materials refer to a group of materials used in the construction of man-made structures and components. The main function of engineering materials is to withstand the applied load without failure. Carbon steel, Aluminum, cast iron, stainless steel, copper alloys, plastics, composites, Nickel alloys etc. are examples of engineering materials.

Mechanical Properties of Engineering Materials

• The mechanical properties of a material are those which affect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties of a meterial include :-

-> Strength
-> Toughness
-> Hardness
-> Hardenability
-> Brittleness
-> Malleability
-> Ductility
-> Creep and slip
-> Resilience
-> Fatigue.

<u>Strength</u> :-> It is the property of a meterial which opposes the deformation of material in presence of external forces or load.

<u>Toughness</u> :-> It is the ability of a material to absorb the energy and gets plastically deformed without fracturing. ~~Its numerical value is determined by the amount of~~
For example -> Brittle materials,

<u>Hardness</u> :-> It is the ability of a material to resist to permanent shape change due to external stress.

Hardenability :-> It is the ability of a material to attain the hardness by heat treatment processing. It is determined by the depth up to which the material becomes hard.

Brittleness :-> Brittleness of a material indicates that how easily it gets fractured when it is subjected to a force or load.

Malleability :-> Malleability is a property of solid materials which indicates that how easily a material gets deformed under compressive stress.

Ductility :-> Ductility is a property of a solid material which indicates that how easily a material gets deformed under tensile stress.

Creep and slip :-> Creep is the property of a material which indicates the tendency of material to move slowly and deform permanently under the influence of external mechanical stress.

Resilience :-> Resilience is the ability of material to absorb the energy when it is deformed elastically by applying stress and release the energy when stress is removed.

Fatigue :-> Fatigue is the weakening of material caused by the repeated loading of the material. When a material is subjected to cyclic loading, and loading greater than certain threshold value but much below the strength of material

1.3 Define working Stress, yield Stress, ultimate stress & Factor of safety and Stress-Strain Curve, for M.S & C.I.

Define Working Stress :-> The Stress that is capable of preventing failure is called working stress.

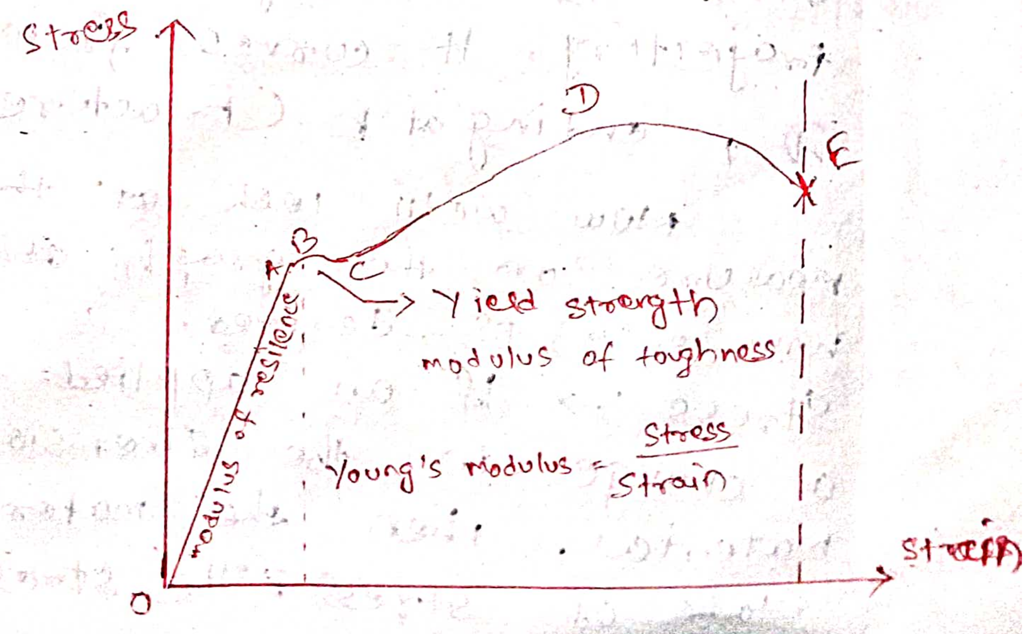
Yield Stress :-> Yield stress is the minimum stress at which a solid will undergo permanent deformation or plastic flow without a significant increase in the load or external force.

Ultimate Stress :-> Ultimate tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking.

Factor Of Safety :-> It is defined as the ratio of Maximum stress to the working or Design stress.

$$\text{Factor of Safety} = \frac{\text{Maximum Stress}}{\text{working or Design Stress}}$$

Stress-Strain Curve for M.S :->



When steel is curved, it is important to keep the stress-strain curve ratio for M.S in mind. If tensile force applied to a steel bar, it will have some elongation. If the force is small enough, the ratio of stress and strain will remain proportional. This can be seen on the graph as a straight line between zero and point A - also called the limit of proportionality. If the force is greater, the material will experience elastic deformation, but the ratio of stress & strain will no be proportional. This is between points A & B, known as the elastic limit.

Beyond the elastic limit, the mild steel will experience plastic deformation. This starts the yield point - or the rolling point - which is point B or the upper yield point. As seen in the graph, from this point on the correlation between the stress and strain is no longer an a straight trajectory. It curves from point C to D, ending at E (Fracture stress).

Now we'll look at ~~th~~ each individual measure on the graph above and explain how each is derived.

Stress :-> If an applied force causes a change in the dimension of the material, then the material is in the state of stress. The stress = F/A

Strain → Strain is the ratio of change in the dimension to the original dimension.

$$\varepsilon = \frac{\delta l}{l}$$

Elasticity → It is the property of the material which enables the material to return to its original form after the external force is removed.

Plasticity → It is a property that allows the material to remain deformed without fracture even after removal of a load.

Hooke's Law → within the proportional limit (straight line between zero & A), strain is proportionate to stress.

Young's Modulus of Elasticity → within the proportional limit, stress = E × strain. E is a proportionality constant known as the modulus of Elasticity.

Modulus of Resilience → The area under the curve ~~which is marked by the yellow area~~. It is the energy absorbed per volume unit up to elastic limit. The formula for the modulus of resilience is 1/2 × σ × ε

$\varepsilon = 0.5 \times (FL \times AE)$

Modulus of Toughness → This is the area of the whole curve (point zero to E) Energy absorbed at unit volume up to breaking point.

1.4 Modes of Failure (By Elastic deflection, General yielding & Fracture)

Elastic Failure :-> Elastic failures are those failures which occur as a result of a low value of young's modulus, E.

General Yielding :-> General yielding is the failure mode that occurs when a material is simply loaded to beyond its ultimate tensile strength.

Fracture Failure :-> Fracture failure in the tubular off shore structures often initiates from the fatigue generated cracks at the hot-spot locations in critical joints within the structure, experiences the cyclic environmental loads including waves, currents, and winds.

1.5 Factor Governing The Design of Machine Elements :->

(i) Strength & Stiffness
(ii) Surface finish & Tolerance
(iii) Manufacturability
(iv) Ergonomics & aesthetics
(v) Working Atmosphere
(vi) Wear & Hardness Requirement.
(vii) Cooling & Lubrication
(viii) Safety & Reliability
(ix) Noise Requirement
(x) Cost

1.6 Describe Design Procedure :->

It's prominent in engineering, architecture, and manufacturing because it help companies deliver finished solutions that customers want & need.

There are 7 steps in Design Process :->

(i) Identify The Problem You want to Solve :-> whether you found a pattern in negative customer feedback or you have some R&D budget left to spend, the approach stays the same.

-> what Problem do you want to solve?
-> who has this problem?
-> Can the solution help everyone equally?
-> what are the requirements for this project?
-> what is our ultimate good?

Even if you think you have a good idea, focus on the requirements and your limitations. A lot of new projects fail before they even start.

(ii) Research the Problem in-depth :-

At this stage, you will figure out the market state, whether any competing products exist or are on their way, and what user needs competitors neglect.

-> Do current solutions exist that try to solve the problem?
-> Are these failing to meet customer needs in any way?

(ii) → How much are customers spending on similar products ?

If You are trying to solve problems for an existing product or service, starting from scratch isn't always best. You may find that developing an integration or partnering with another company is the best solution.

(iii) Ideate Possible Solution :→

Start by using how might we questions to create a list of ideas. You can also add more details if you want.

→ How might we achieve X ?
→ what is the scope and timeframe for developing the solution ?

(iv) Evaluate & select a promising Solution :→

→ Does it fit the necessary time frame ?
→ Can you complete it with budget restraints ?
→ Is the Product in itself a differentiator for your Company ?

Depending on company size, you may have an approval committee or a senior executive who gives the go-ahead on large projects.

(v) Create your Prototype :->

Spend as little time as possible to validate your idea with a prototype without rushing the process.

-> For Physical Products, use cheap materials and re-usable segments.

-> Rely on lo-fi prototypes like storyboards or partially developed products where you manually fulfill the process.

Don't underestimate the value of lo-fi prototypes. Airbnb built a billion-dollar business after renting out a single air-mattress manually on craigslist.

(vi) Test & Troubleshoot :-> It's time to put your prototype to the test and see if you made any faulty assumptions about your customers.

For example, If your Product is an AI-powered curator for cheap airline tickets based on someone's bucket list you can start with a landing page and have someone manually curate tickets using search engines.

-> Did the Prototypes solve your Problem ?

-> ~~what was~~

(vii) Make improvements & release the final Product.

2.0 DESIGN OF FASTENING ELEMENTS

2.1 Joints & Their Classifications :-

→ A screw thread is formed by cutting a continuous helical groove on cylindrical surface.

→ Screw joint are formed by bolt and nut used for joining machine parts or for fastening, adjustment, assembly, inspection, replacement.

Types of Screw Fastening

- 1- Bolts
  - (i) Through Bolt
  - (ii) Tap Bolts
- 2- Cap Screw
- 3- Stud
- 4- Machine Screw
- 5- Set Screw

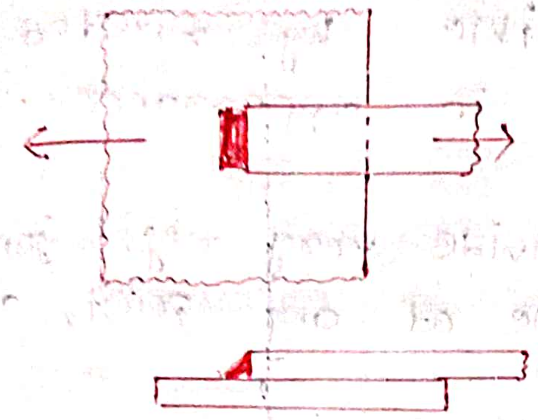
2.2 States Types OF Welded Joint :-

1- Lap Joint :- The lap joint is obtained by over lapping the plates and then welding the edge of plates.

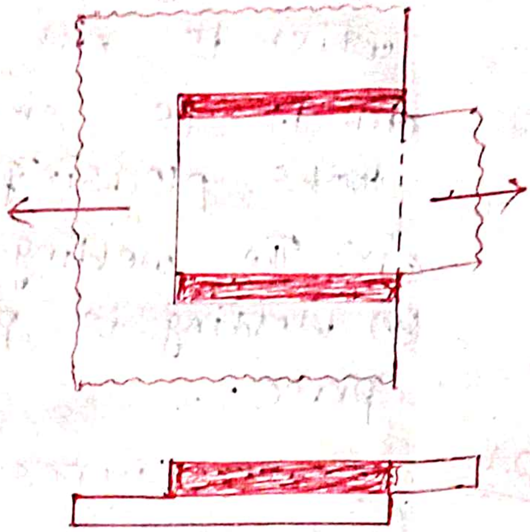
(a) single transverse

(b) Double transverse

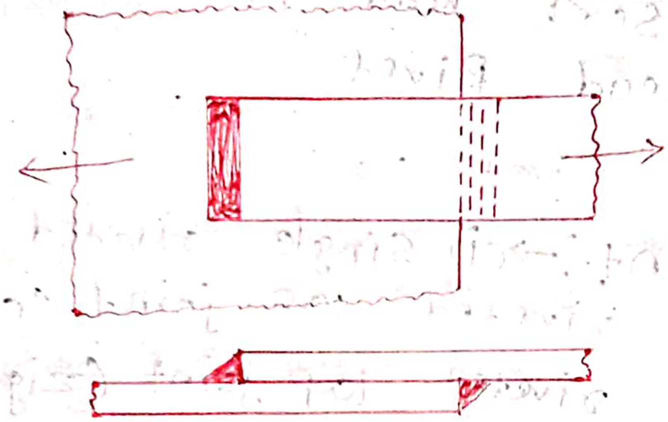
(c) Parallel fillet joints



(a) Single Transverse



(b) Parallel Fillet



(b) Double transverse

2- Butt Joints :-> It is obtained by welding the ends & edge of the two plates which approximately in the same plane.

(a) Square Butt Joint
(b) Single V-butt Joint
(c) Single U-butt Joint
(d) Double V-butt Joint &
(e) Double U-butt Joint

2.3 Advantages of Welded Joints :->

(i) The welded structure are usually lighter than riveted structure because in welding gussets and other connecting component are not used.

(ii) Weld joint provide maximum efficiency which is not possible by riveted joint.
(iii) It is smooth in appearance therefore looks pleasing.
(iv) The welding provide very rigid joints.
(v) Welding is possible at any point, any place.

2.4 States Types of Riveted Joint :-
(a) Snap or button head Rivet
(b) Pan head rivet
(c) Countersunk head rivet
(d) Flat head Rivet

Types of Rivets :-
(a) Lap Joint :- (i) Single riveted Lap joint
(ii) Double riveted lap joint (chain Pattern)
(iii) Double riveted lap joint (zig-zag Pattern)

(b) Butt Joint :-
(i) Single-riveted single strap Butt joint
(ii) Single-riveted double-strap Butt joint
(iii) Double-riveted double-strap butt joint (chain pattern)
(iv) Double riveted double strap butt joint (zig zag Pattern)

2.5 Describe Failure of Riveted Joints :→

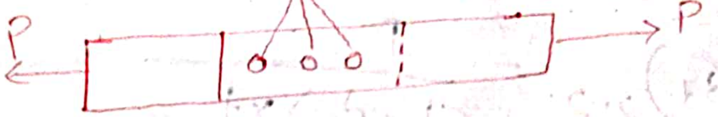
There are 4 types of stresses occur at riveted joints. Therefore, the failure is possible in four locations as follows.

(i) Shearing stress failure in rivets
(ii) Tension stress failure in plate
(iii) Bearing stress failure between plate & Rivet.
(iv) Shearing Stress failure in plate.

Shearing Stress Failure in Rivets :→

All rivets are of same Dia.

Case 1 :-



plan

$$F_{rivet} = \frac{P}{3}$$

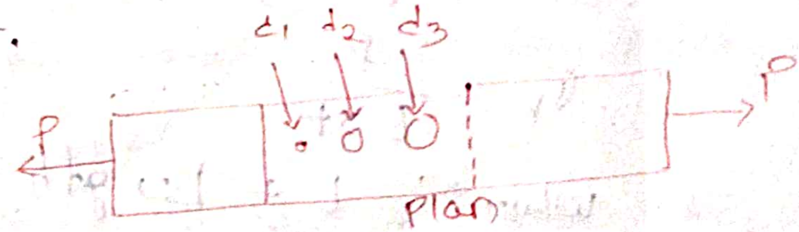
$$\tau_{rivet} = \frac{P/3}{\pi d^2/4}$$

Section

$$F_{rivet} = \frac{P}{4}$$

$$\tau_{rivet} = \frac{P/4}{\pi d^2/4}$$

Case-2 :→ According to the assumption, the shear stress must be equal in the three rivets. Therefore, the shear force must be different.



plan

Section

$$\tau_{rivet} = \frac{P}{\frac{\pi}{4}(d_1^2 + d_2^2 + d_3^2)}$$

$$F_1 = \tau_{rivet} \times \frac{\pi}{4} d_1^2$$

$$F_2 = \tau_{rivet} \times \frac{\pi}{4} d_2^2$$

$$F_3 = \tau_{rivet} \times \frac{\pi}{4} d_3^2$$

Tension Stress Failure In Plate

$$\sigma_t)_{1-1} = \frac{P}{b \times t}$$

$$\sigma_t)_{2-2} = \frac{P}{(b - d_h) \times t}$$

where : t = thickness of plate,
d_h = dia of hole
d_h = d_{rivet} + 3 mm

$$\sigma_{2-2} > \sigma_{1-1}$$

Bearing Stress Between the Plate & Rivet :-

$$\sigma_b = \frac{P}{d \times t}$$

Shearing Stress Failure In Plate :-

$$\sigma_b = \frac{P}{L \times t}$$

where: L = Length of the tearing Line

2.6 Determine Strength & Effeciency of Riveted Joints :->

Strength of a Riveted Joints :->

The strength of a joints may be defined as the maximum force, which it can transmit, without causing it to fail. A little consideration will show that if we go on increasing the pull on a riveted joint, it will fail when the least of 3 pulls is reached, because a higher value of other pulls will never reach since the joint has failed, either by tearing off the plate, shearing of the rivet.

Effeciency of a Riveted Joints :->

The effeciency of a riveted joints is defined as the strength of riveted joint to the strength of the un-riveted or solid plate.

We have already discussed that strength of the riveted joint,

$$= \text{Least of } P_t, P_s, \& P_c$$

Strength of the un-riveted per pitch length, $P = p \times t \times \sigma_t$

$\therefore$ Effeciency of the Riveted joint,

$$\eta = \frac{\text{Least of } P_t, P_s \& P_c}{p \times t \times \sigma_t}$$

where,

p = Pitch of rivets

t = Thickness of the plate

σ_t = Permissible tensile stress of plate