LECTURE NOTES ON
DESIGN OF MACHINE ELEMENTS

5TH SEMESTER
MECHANICAL ENGINEERING

PREPARED BY:-
Ms. SHARMILA SABAR
LECTURER
GOVT. POLYTECHNIC, KORAPUT

MACHINE DESIGN

WHAT IS A MACHINE?

A machine is the assembly of resistant bodies or links which is used to transmit available energy to do useful work.

MACHINE DESIGN:

- Machine design is defined as the use of scientific principles, engineering techniques and imagination to create a machine or machine element economically.
- Machine Design focuses on the basic principles of following three areas for creation of new machines and improving the existing.
  a) Mechanical behavior of material.
  b) Mechanical parts or machine element.
  c) Life cycle analysis.

CLASIFFICATION OF MACHINE DESIGN

1. **Adaptive design:-**

   Here designers work is concerned with adaptation of existing designs. This type design needs no special knowledge or skill .The designer only makes minor modification in the existing designs of the product.

2. **Development design:-**

   This type of design needs scientific training and design ability in order to modify the exiting design into a new idea by adopting a new material or different method of manufacturing. In this case, though the designer starts from the existing design, but the final product will be quite different from the original product.

3. **New design:-**

   This type of design needs lo of research, technical ability and creative thinking. From this design completely new product will be found.

The designs, depending upon the methods used, may be classified as follows:

- Rational design:-This type of design depends upon mathematical formulae of principal of mechanics.
- Industrial design:-This type of design depends upon the production aspects to manufacture any machine component in the industry.
- System design:-It is the design of any complex mechanical system like a motor car.

- Element design:-It is the design of any element of the mechanical system like piston, crankshaft, connecting rod, etc.
- Computer aided design:-In this of design, creation, modification & analysis of a design is done by using computer system.

DIFFERENT MECHANICAL ENGG. MATERIALS USED IN DESIGN

- Commonly used ferrous alloys are carbon steel, Low-alloy steel, Tool steel, Stainless steel and cast iron.
- Non ferrous alloys are Aluminum alloys, Nickel alloys, Titanium alloys.

Properties of Material:

Properties of material are the characteristics of matter which differentiate one material from the other.

The major properties of material to be studied for selection of material in engineering field are:

1. Physical properties
2. Chemical properties
3. Mechanical properties

Physical Properties:

A materials physical properties denote the physical state of material. Physical properties include

1. Density
2. Specific Heat
3. Thermal Expansion
4. Conductivity
5. Melting Point
6. Porosity
7. Crystal Structure
8. Appearance

Mechanical properties of Materials:

1. Strength	7. Malleability
2. Stiffness	8. Toughness
3. Elasticity	9. Hardness
4. Plasticity	10. Machinability
5. Ductility	11. Creep
6. Brittleness	12. Fatigue

Strength:

- It is the ability of a material to resist the externally applied forces without breaking.
- The internal resistance offered by a part to an externally applied force is called stress.

Stiffness:

It is the ability of materials to resist deformation under the action of load.

Mathematically:

$$\text{Stiffness (K)} = \frac{\text{Load (W)}}{\text{Deflection } (\delta)}$$

Unit: KN / mm or N / mm

This property is considered during selection of material for spring manufacturing.

Elasticity:

It is a property by virtue of which a material regains its original dimension after removal of load. Elasticity is measured by Young's Modulus or Modulus of Elasticity.
Unit – N / mm^2

Plasticity:

- It is the property by virtue of which the material does not regain its original shape after removal of load . I retains its deformed shape permanently.
- This property of the material is necessary for forging & rolling process.

Ductility:

- It is a property by which materials can be drawn into wires with the application of a tensile force.
- Ductile materials have the ability to flow or elongate under load. Example : Cupper , Aluminum , mild steel , nickel, zinc, tin & lead.
- The ductility of a material is commonly measured by means of percentage elongation and percentage reduction in area in a tensile test.

Brittleness:

It is the ability of a material by which it can develop crack under load or it can break suddenly.
Example : Wood , Concrete , Cast iron.

Malleability:

It is the property by virtue of which the material is able to be converted in to thin sheets.
Materials which are more elastic are also more malleable.
Example : Steel , Copper, Al, Brass, Bronze etc.

Toughness:

- It is the property by virtue of which a material is able to resist shock or impact loading.
- Impact loading means applied load fall from a height.
- The amount of energy absorbed per unit volume within elastic limit is know as Resilience.
- In the deign of springs toughness or resilience of material is considered.

Hardness:

- It is the property by which the material is able to resist scratches, marks or wear & tear.
- It also measures the ability of a material to cut another metal.
- Harness is independent of the weight of a material.

Brittle materials are more hard example: Glass, cast iron , concrete.

Machinability:

- It is the property of a material which refers to the ease with which a material can be cut.
- Machinability of a material can be measured by measuring the energy required to remove a unit volume of the material, keeping all machining parameters constant.
- It may be noted that brass can be easily machined than steel.

Creep:

- When a part is subjected to a constant stress at high temperature for a long period of time , it will undergo a slow and permanent deformation called creep.
- This property is considered in designing internal combustion engines, boilers and turbines.
- Super alloys resist creep failure as they can with stand high temperature for a prolonged period without developing stress.

Fatigue:

Fatigue is the property of mater by virtue of which the material fails under stress less than yield stress due to cyclic nature of stress.

Fatigue failure is responsible for 90% of mechanical failure.

Different type of stress:-

When external load is applied on an abject resist distortion due to the applied force for which internal forces developed in the object hose magnitude is equal to externally applied force.

Stress can be defined as the internal resting force acting on unit cross sectional area of the object.

Mathematically,

$$\text{Stress}(\sigma) = \frac{\text{Load}(F)}{\text{c/s area}}$$

Unit is N/mm^2

Before discussing types of stress we will discuss about types of load.

LOAD:

It is defined as any external force acting upon a machine part. The following four types of the load are:-

1. **Dead or stead load:-**
   A load is said to be a dead or stead load, When it does not change in magnitude or direction.

2. **Live or variable load:-**
   A load is said to be a live or variable load, when it changes continually.

3. **Suddenly applied or shock loads:-**
   A load is said to be a suddenly applied or shock load, when it is suddenly applied or removed.

4. **Impact load:-**
   A load is said to be an impact load, when it is applied from certain height with some initial velocity.

Different types of Stresses

- Yield stress:-
  It is defined as the maximum stress at which increase in elongation occurs without increase in load. After yield point on removal of the load the material will not be able to recover its original shape and size. Stress corresponding to yield point is known as yield point stress.

- Ultimate stress:-
  The stress, which attains its maximum value is known as ultimate stress. It I obtained by dividing the largest value of the load reached in a test to the original cross-sectional area of the test piece.

- Working Stress :-
  When designing machine parts, it is desirable to keep the stress lower than the maximum or ultimate stress at which failure of the material takes place. This stress is known as the working stress or design stress. It is also known as safe or allowable stress.

(**Note**: By failure it is no meant actual breaking of the material. Some machine parts are said to fail when they have plastic deformation set in them, and they no more perform their function satisfactorily)

Factor of Safety:

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

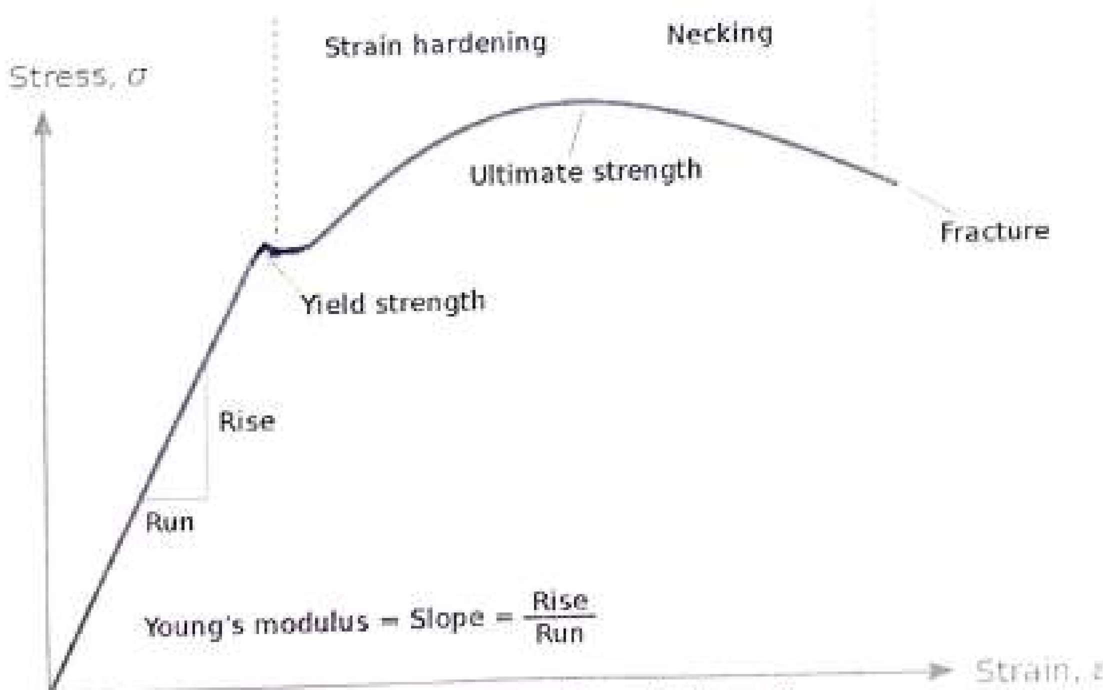
$$\text{Factor of safety} = \frac{(\text{Maximum Stress})}{(\text{Working or design stress})}$$

In case of ductile material example mild steel, where the yield point is clearly defined, the factor of safety is based upon the yield point stress.
In such cases,

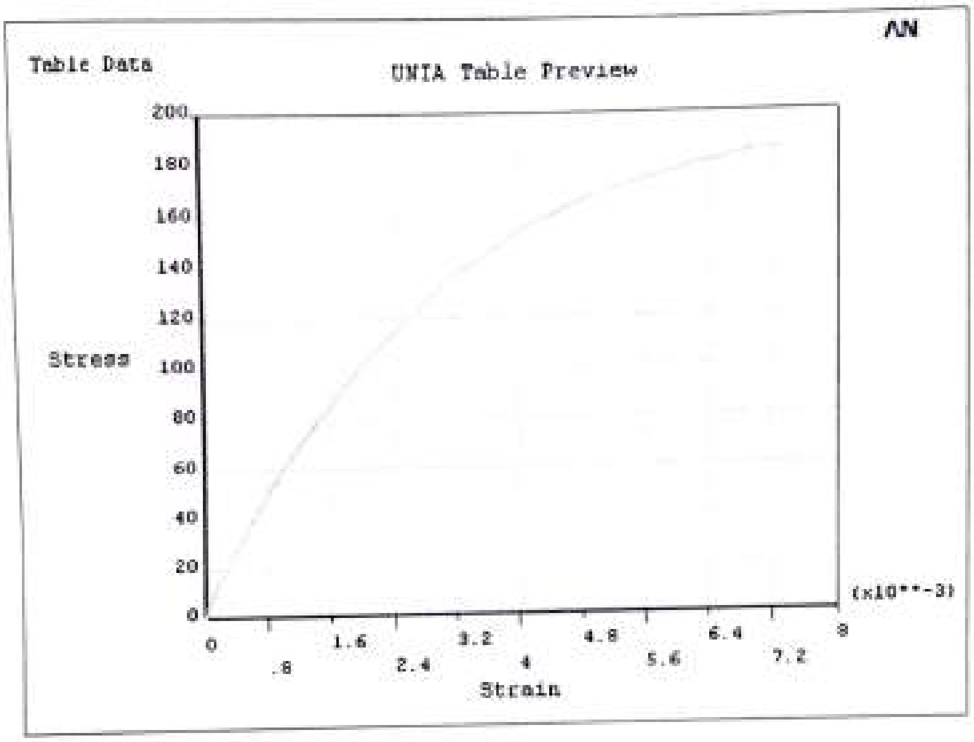
$$\text{Factor of safety} = \frac{(\text{Yield point stress})}{(\text{Working or design stress})}$$

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

$$\therefore \text{Factor of safety} = \frac{(\text{Ultimate stress})}{(\text{Working or design stress})}$$



(Stress-strain curve for mild steel)



(Stres-strain curve for cast iron)

Mode of Failure to be considered in Machine design

1. By Elastic deflection:

- In the transmission system, the shaft which support gears are subjected to load which causes deflection of shaft.
- The maximum force which can be applied on the shaft is limited by the permissible elastic deflection.
- Lateral or torsional rigidity is the criteria for designing such components.
- Most effective method of decreasing the defection of a member is by changing its shape or c/s dimension.

2. **Yielding:**

- Mechanical component made of ductile material loses its engineering usefulness due to a large amount of plastic deformation or yielding of a considerable portion of the member.
- To avoid failure due to yielding working stress for ductile material is always less than they yield stress.

3. **Failure by fracture:**

- Sudden fracture of brittle materials.
- Fracture of cracked or flawed members.
- Progressive fracture due to cyclic load (fatigue) and due to low temperature.

4. **By Fracture:**

- Fracture occurs at much below stress than yield stress if the component has to work under cyclic load.
- Brittle materials cease to function suddenly due to fracture without any plastic deformation.

State the factors governing the design of machine elements:

1. **Strength:**

A machine part shouldn't fail under the effect of forces acting on it. It should have sufficient strength to avoid failure due to fracture or yielding.

2. **Rigidity:**

Machine component should be rigid enough, so that it will not deflect or bend due to forces or moment acting on it. A transmission shaft is designed on the basis of lateral rigidity & torsional rigidity.

3. **Wear resistance :**

A machine component should be wear resistant because wear reduces accuracy of machine tool along with its life cycle. Surface hardening will increase the wear resistance of the machine component.

4. **Safety:**

The shape and dimension of the machine part should ensure safety to the operator of the machine.

5. **Minimum dimension and weight :**

A machine should have minimum possible dimension & weight which will reduce the material cost.

6. **Conformance to the standard:**

Machine part should conform to the national & international standards covering the dimension , profile & material.

7. **Minimum life cycle cost:**

Total cost i.e to be paid for purchasing the parts, operating & maintaining it for its life span should be minimum.

<u>Describe design procedure:</u>

The general procedure to solve a design problem is as follows:

1. **Recognisation of need :**

   First of all the need, aim or purpose for which the machine is to be designed should be recognized.

2. **Mechanism:**

   Select the possible mechanism or group of mechanisms which will give the desired motion.

3. **Analysis of forces:**

   Find the forces acting on each member of the machine and the energy transmitted by each member.

4. **Material selection:**

   Select the material best suited for each member of the machine.

5. **Design of elements:**

   Find the size of each member of the machine by considering the force acting on the member and the permissible stresses for the material used . it should be kept in mind that each member should not deflect or deform more than the permissible limit.

6. **Modification:**

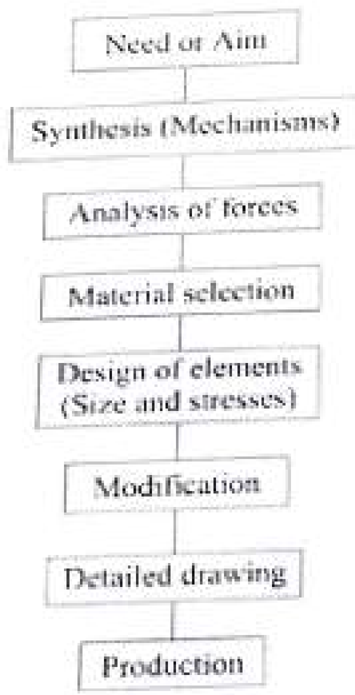
Modify the size of the member to reduce overall cost.

7. **Detailed drawing:**

Draw the detailed drawing of each component and the assembly of the machine with complete specification for the manufacturing processes.

The detailed drawing along with material of each component.

The flow chart for the general procedure in machine design is shown in fig.



General procedure in Machine Design