DESIGN OF MACHINE ELEMENT

DESIGN INTRODUCTION

- Design is essentially a decision-making process.
- Design is to formulate a plan to satisfy a particular need and to create something with a physical reality.
- Consider for an example, design of a chair. A number of factors need be considered first:

(a) The purpose for which the chair is to be designed such as whether it is to be used as an easy chair, an office chair or to accompany a dining table.

(b) Whether the chair is to be designed for a grown up person or a child.

(c) Material for the chair, its strength and cost need to be determined.

(d) Finally, the aesthetics of the designed chair.

Topic of Discussion

- Fundamentals of Machine Design – Design philosophy, Various considerations in machine design.
- Design Procedure, Common engineering materials, I.S.I. specification on steels.
- Stresses in machine elements: Types of Simple stresses , Stress strain relationship, Factor of safety.
- Design for Strength : Design for static loading, Theories of failures, Stress Concentration Factors
- Fasteners : Types of fasteners, Design of Cotter and knuckle joint, Design of Key, Coupling
- Types ,use, Design procedure, working principle of rigid and flexible rubber-bushed couplings.
- Design of Permanent Joints: Rivets, Types and use of rivet joint , Types and efficiency, design procedure, Welded joint. Bolted Joint.

Topic of Discussion

- Power Screws: Power Screw, drives and their efficiency, Design of power screws
- Design of Shaft :shaft and its design based on strength, Design of shaft for variable load and based on stiffness, Combined bending and Twisting moment.
- Springs: Introduction to Design of Helical Springs, Design of Leaf Springs

Basic concept of machine design

- Decision making comes in every stage of design.
- Consider two cars of different makes.
  - They may both be reasonable cars and serve the same purpose
  - but the designs are different.
  - The designers consider different factors and come to certain conclusions leading to an optimum design.
  - market survey gives an indication of what people want.
  - Existing norms play an important role. Once a critical decision is made, the rest of the design features follow.
  - Bad design leads to bad products
  - Design may be for different products and with the present specialization and knowledge bank,
    - we have a long list of design disciplines e.g. ship design, building design, process design, bridge design, clothing or fashion design and so on.

Types of Design

- **Adaptive design**
  - This is based on existing design,
    - for example, standard products or systems adopted for a new application.
    - Conveyor belts, control system of machines and mechanisms are some of the examples where existing design systems are adapted for a particular use.

Types of Design

- **Developmental design**
  - Here we start with an existing design but finally a modified design is obtained.
  - A new model of a car is a typical example of a developmental design .

Types of Design

- **New design**
  - This type of design is an entirely new one but based on existing scientific principles.
  - No scientific invention is involved but requires creative thinking to solve a problem.
  - Examples of this type of design may include designing a small vehicle for transportation of men and material on board a ship or in a desert. Some research activity may be necessary.

Types of Design (Based on Methods)

Rational design

- This is based on determining the stresses and strains of components and thereby deciding their dimensions.

Types of Design (Based on Methods)

Empirical design

- This is based on empirical formulae which in turn is based on experience and experiments.
- For example, when we tighten a nut on a bolt the force exerted or the stresses induced cannot be determined exactly
- but experience shows that the tightening force may be given by P=2840 d N. where, d is the bolt diameter in mm and P is the applied force in N.
- There is no mathematical backing of this equation but it is based on observations and experience.

Types of Design (Based on Methods)

Industrial design

- These are based on industrial considerations and norms viz. market survey, external look, production facilities, low cost, use of existing standard products.

Optimum Design

- Best design for the given objective function under given constraints.
- It minimizes undesirable effects.

System design

- Design of complex mechanical systems like car, ship, etc.

Element Design

- Design of any element of a mechanical system like piston, crank shaft, connecting rod.

Computer Aided Design

- Use of computer to assist in creation, modification, analysis & optimisation of a design.

Factors to be considered in machine design

- To attack design problem

(a) What device or mechanism to be used? This would decide the relative arrangement of the constituent elements.
(b) Material
(c) Forces on the elements
(d) Size, shape and space requirements. The final weight of the product is also a major concern.
(e) The method of manufacturing the components and their assembly.
(f) How will it operate?
(g) Reliability and safety aspects
(h) Inspectibility
(i) Maintenance, cost and aesthetics of the designed product.

Factors to be considered in machine design

- **What device or mechanism to be used**
  - This is best judged by understanding the problem thoroughly.
  - Sometimes a particular function can be achieved by a number of means or by using different mechanisms and the designer has to decide which one is most effective under the circumstances.
  - A rough design or layout diagram may be made to crystallize the thoughts regarding the relative arrangement of the elements.

Factors to be considered in machine design

Material-

- A wrong choice of material may lead to failure, over or undersized product or expensive items.
- The choice of materials is thus dependent on suitable properties of the material for each component.
- their suitability of fabrication or manufacture and the cost.

Factors to be considered in machine design

Load-

- The external loads cause internal stresses in the elements and these stresses must be determined accurately since these will be used in determining the component size. Loading may be due to:
  - i) Energy transmission by a machine member.
  - ii) Dead weight.
  - iii) Inertial forces.
  - iv) Thermal effects.
  - v) Frictional forces.

- In other ways loads may be classified as:
  - i) Static load- Does not change in magnitude and direction and normally increases gradually to a steady value.
  - ii) Dynamic load
    - a) changes in magnitude- for e.g. traffic of varying weight passing a bridge.
    - b) changes in direction- for e.g. load on piston rod of a double acting cylinder.

Factors to be considered in machine design

- **Size, shape, space requirements and weight**
  - Preliminary analysis would give an approximate size but if a standard element is to be chosen, the next larger size must be taken.
  - Shapes of standard elements are known but for non-standard element, shapes and space requirements must depend on available space in a particular machine assembly.
  - A scale layout drawing is often useful to arrive at an initial shape and size.
  - Weight is important depending on application. For example, an aircraft must always be made light. This means that the material chosen must have the required strength yet it must be light.

Factors to be considered in machine design

- **Manufacture**

  Care must always be taken to ensure that the designed elements may be manufactured with ease, within the available facilities and at low cost.
- **How will it operate**

  In the final stage of the design a designer must ensure that the machine may be operated with ease. In many power operated machines it is simply a matter of pressing a knob or switch to start the machine.

  eg. Bikes with self starter.

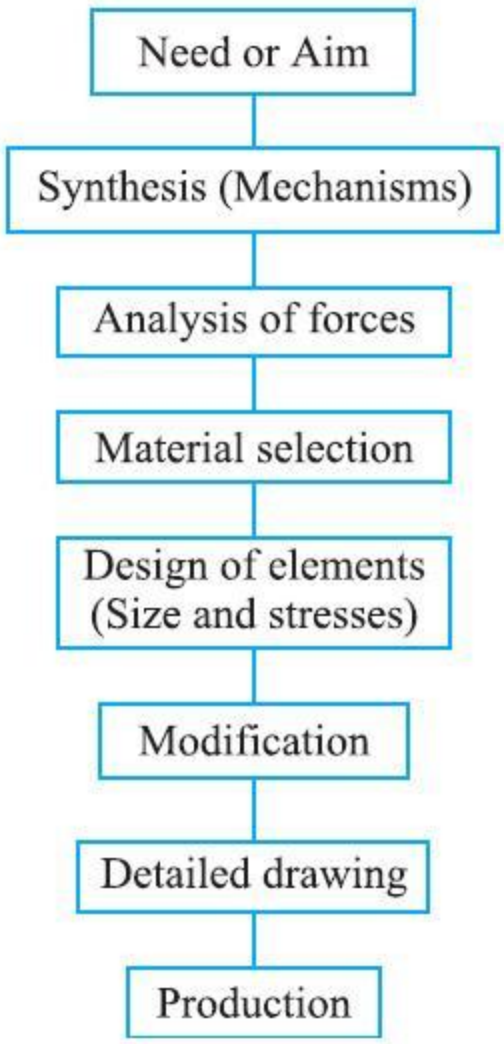
Factors to be considered in machine design

- **Reliability and safety**
- Reliability is an important factor in any design. A designed machine should work effectively and reliably.

Factors to be considered in machine design

- **Maintenance, cost and aesthetics**
- Maintenance and safety are often interlinked.
- Good maintenance ensures good running condition of machinery.
- Should have provision for easy maintenance
- Cost and aesthetics are essential considerations for product design.

General Procedure in MD



Make complete statement of problem indicating Need, aim, purpose for which the m/c to be designed

Select possible mechanism which gives desired motion

Analysis the forces acting on each member and energy Transmitted by each member.

Select best material for each member

Find size of machine element by considering forces acting On each member, permissible stresses.

Modify the design by considering the past experience for Easy manufacturing and to reduce manufacturing cost.

Draw detailed drawing with specs, dimension & assembly for manufacturing.

Component as per drawing will be manufactured.

Selection of Materials

Based on Mechanical Properties and application, the materials can be choosen

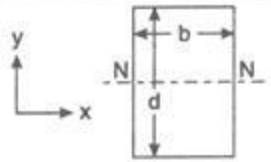
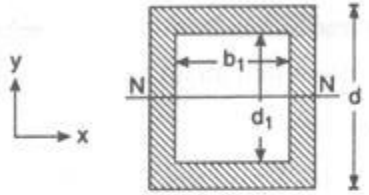
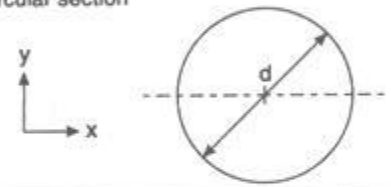
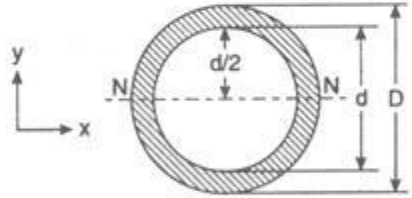
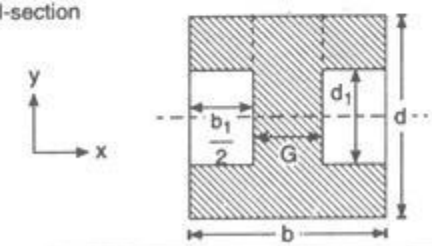
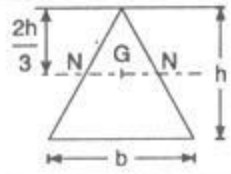
- Strength : Ability to bear applied load with out failure
- Hardness : ability to resist abrasion, indentation.
- Toughness: ability to withstand shock loads
- Ductility : Property which enables it to draw into thin wires
- Malleability : property which enables it to draw into thin sheets.

- Elasticity : ability to regain its original shape after deformation when ext load is removed

- Plasticity : ability to retains plast def when the load is removed.
- Stiffness : ability to resist deformation under stress.
- Brittleness : ability of material to fail with no of micro plastic deformation only.
- Machinability : Relative case with which the matl can be cut
- Fatigue: when matl is subjected to repeated stresses, the matl fails at a stress much lower than yield point stress. Such failure is known as fatigue.

- Creep : Slow and permanent deformation under constant stress at high temperature

- Resilence : Property of material to absorb energy and to resist shock and impact loads. Ammt of energy absorbed per unit volume with in the elastic limit

Type of section	Moment of Inertia	y_{max}	Section modulas (Z)
Rectangle or paralleogram 	$I_{xx} = \frac{bd^3}{12}$ $I_{yy} = \frac{db^3}{12}$	$\frac{d}{2}$ $\frac{b}{2}$	$Z_{xx} = \frac{bd^2}{6}$ $Z_{yy} = \frac{db^2}{6}$
Hollow rectangular section 	$I_{xx} = \frac{bd^3}{12} - \frac{b_1d_1^3}{12}$ $I_{yy} = \frac{db^3}{12} - \frac{d_1b_1^3}{12}$	$\frac{d}{2}$ $\frac{b}{2}$	$Z_{xx} = \frac{1}{6d}(bd^3 - b_1d_1^3)$ $Z_{yy} = \frac{1}{6b}(db^3 - d_1b_1^3)$
Circular section 	$I_{xx} = \frac{p}{64}d^4$ $I_{yy} = \frac{p}{64}d^4$	$\frac{d}{2}$ $\frac{d}{2}$	$Z_{xx} = \frac{p}{32}d^3$ $Z_{yy} = \frac{p}{32}d^3$
Hollow curcular section 	$I_{xx} = I_{yy} = I$ $I_{yy} = \frac{p}{64}(D^4 - d^4)$	$\frac{D}{2}$	$Z_{xx} = Z_{yy} = Z$ $Z = \frac{p}{32D}(D^4 - d^4)$
I-section 	$I_{xx} = \frac{bd^3}{12} - \frac{b_1d_1^3}{12}$ $I_{yy} = \frac{db^3}{12} - \frac{d_1b_1^3}{12}$	$\frac{d}{2}$ $\frac{b}{2}$	$Z_{xx} = \frac{1}{6d}(bd^3 - b_1d_1^3)$ $Z_{yy} = \frac{1}{6b}(db^3 - d_1b_1^3)$
Triangle 	$I_G = \frac{bh^3}{36}$	$\frac{2}{3}h$	$Z_G = \frac{bh^2}{24}$

Tutorial Problem-1

- A press working operation blanks out discs of 35 mm diameter and 1.6 mm thick. If the ultimate strength of the material is 200 N/mm^2. Assume shear strength = 0.5 UTS. The press ram can exert a maximum force of 150 kN. Can you blank out 5 disc simultaneously.

Tutorial Problem - 2

- A cantilever beam of span 500 mm carries a vertical downward load of 6 kN at the free end. Assume yield value of 350 Mpa, FOS = 3. Find the economical section for cantilever beam having I section of depth 7t and flange width 5t, where t is the thickness. Specify the dimension and the cross sectional area.

Tutorial Problem - 3

- A shaft transmitting 100 kW at 160 rpm. Find a suitable diameter for the shaft, if the maximum torque transmitted exceeds mean by 25%. Take maximum allowable shear stress as 70 MPa.