Under Graduate Course

on

Machine Design

Design of Machine Elements

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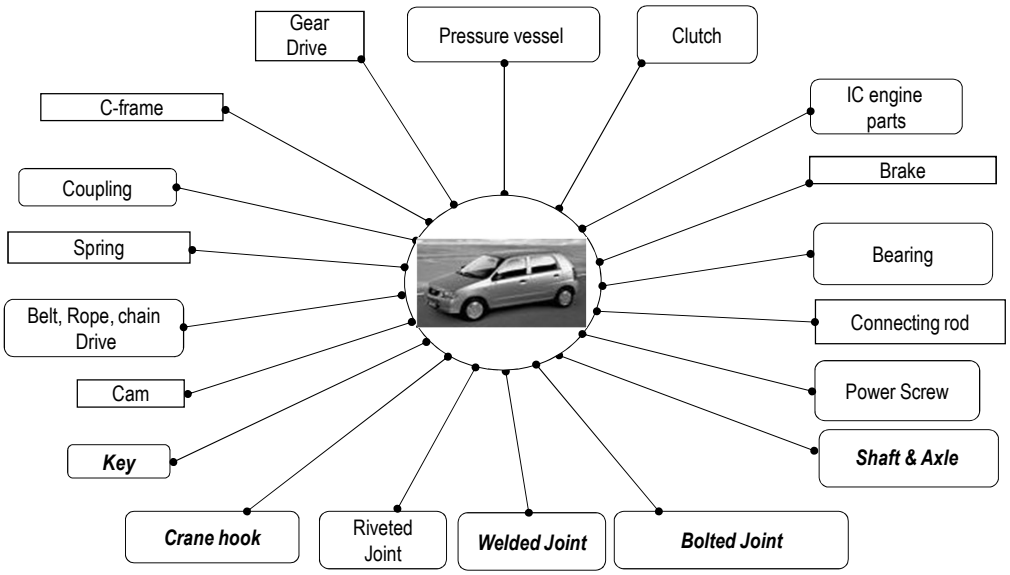
Reference Books

1. V.B. Bhandari, "***Design of Machine Elements*** ", <*Third edition*>, Tata McGraw Hill.
2. J.E. Shigley, C.R. Mischke, "***Mechanical Engineering Design***", Tata McGraw Hill.
3. M.F. Spotts & T.E. Shoup, "Design of Machine Elements", Pearson Education.

Machine Design Handbook

1. "Design Data", Compiled by Faculty of Mechanical Engineering, PSG College, Coimbatore
2. "CMTI Hand Book", Compiled by Scientists of Central Manufacturing technology Institute, Bangalore

Design of Machine Element



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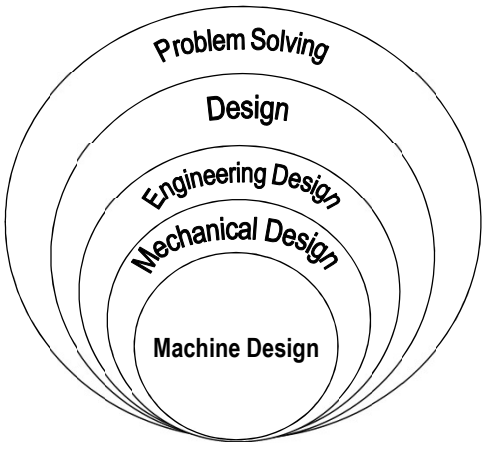
Introduction



- Design is the process of problem solving
- Design is a decision making process
- Design is an iterative process
- Design is an innovative or creative process

In Mechanical Engineering

Objective of a Designer is to design & develop a product (devices, machinery, mechanical system) or process that is *functional, safe, reliable, usable, manufacturable, competitive & marketable* by using different engineering tools [*like Mathematics, CAD-CAE etc.*]

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Mechanical Design

Mechanical Engineering Systems → **Energy Stem**, **Structures & Motion Stem**

Energy Stem in Mechanical Engineering

- Design of heat exchangers
- Design of IC engines
- Design of boilers
- Design of air compressors, gas turbine etc…

*They rely on the use of technical materials from **thermodynamics, heat transfer, combustion etc.***

Structures & Motion Stem in mechanical Engineering

- Design of gear box
- Design of belt drive, chain drive system
- Design of suspension systems
- Design of machine structure etc…

*They draw on technical materials from **solid mechanics, kinematics, dynamics etc.***

Mechanical design applies to design in mechanical engineering systems where both stems can be involved

Machine Design is a sub-set of mechanical design where the focus is on Structures & Motion stem only

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Mechanical Engineering Design/ Machine Design

the use of scientific principles, technical information, skill & imagination in the description of configuration of a mechanical system/ machine to perform specific functions with maximum economy & efficiency

Designer

- uses principles of basic engineering sciences
- has technical information of basic elements of machine like fasteners, gear, belt drive, bearing etc.

  - Relative advantages & disadvantages of basic elements & their suitability in different applications.

- uses skill & imagination to produce a configuration, which is a combination of basic elements.

  - *Intellectual part* of constructing a proper configuration is *creative* in nature

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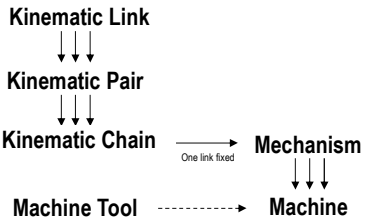
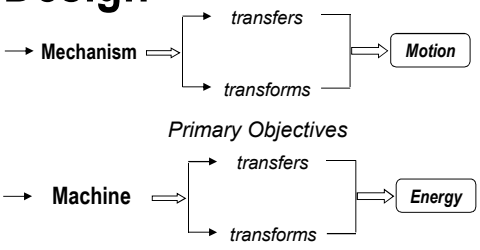
Machine Design





All Machines are Mechanism but all Mechanisms are not Machine

All Machine Tools are Machine but all Machines are not Machine Tool

Mechanism - assemblage of resistant bodies, connected by joints, to form a kinematic chain with one link fixed & having the purpose of transmitting & transforming motion.

Machine
- Combination of resisting bodies having definite motions & capable of performing useful work.
- Combination of resistant bodies with successfully constrained relative motions which is used to transform, transmit & modify available energy to do some useful work

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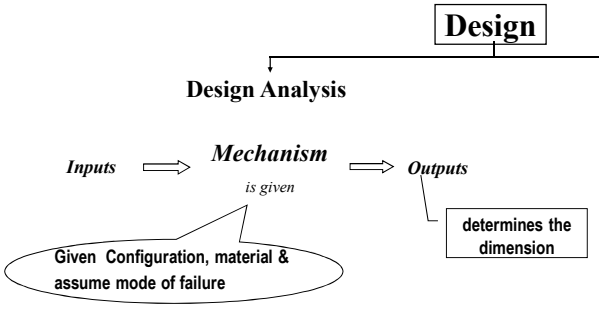
Machine Design



- decision –making process
- process of creating new configuration/ mechanism
- Selecting optimum/best configuration from no. of existing mechanism
- Selecting materials from no. of alternative materials
- Determination of optimum shape & dimensions of the component on the basis of design analysis

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Type of Design

Adaptive Design

- This is based on existing design.
- Existing standard product or systems with/ without minor modification, are adapted for a new application.

Developmental Design

- Starts with an existing design, but the final product may differ quite markedly from the original product.
- A new model of a car

New Design

- This is an entirely new one but based on existing scientific principles.
- Needs lot of research, technical ability & creative thinking.

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Type of Design
based on Methods

Rational Design

- This depends upon mathematical formulae of mechanics.
- This is based on determining the stresses and strains of components and thereby deciding their dimensions.

Empirical Design

- This is based on empirical formulae which in turn is based on experience and experiments.

Industrial Design

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

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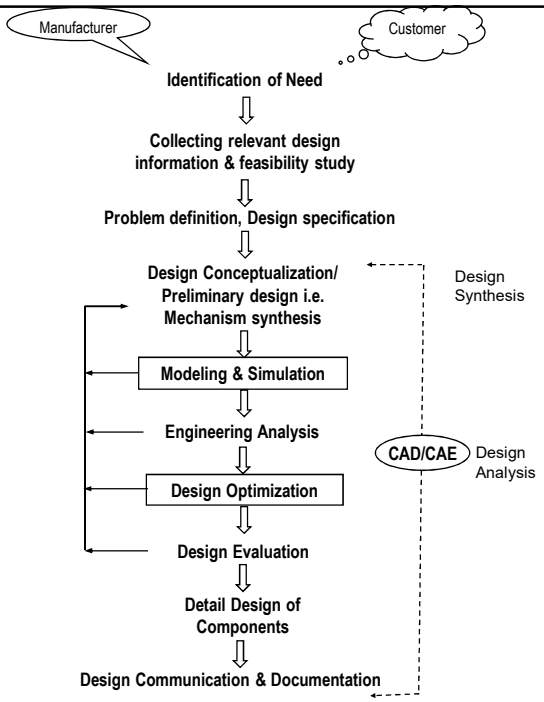
General Procedure in Machine Design



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Basic Procedure of Design of Machine Element

Specify functions of element

⇩

Determine loads acting on element

⇩

Select suitable material for element

⇩

Determine failure mode (s) of element

⇩

Determine geometric dimensions of element based on above failure mode

⇩

Check & modify dimensions for assembly & manufacture

⇩

Check design at critical cross-sections

⇩

Prepare detail engineering drawing of element

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Basic Requirements of Machine Elements

Broad objective of designing a machine element is to ensure that it preserves its operating capacity during the stipulated service life with minimum manufacturing & operating costs.

In order to achieve these objectives, the machine element should satisfy following basic requirements.

Strength - should have sufficient strength to avoid failure (fracture/ general yielding) due to force.

Rigidity - should not deflect or bend beyond permissible limit due to forces/moments.

Wear Resistance - Machine components like gear, cam should have sufficient wear resistance. Wear leads to the loss of accuracy, puts the part out of order.

Minimum Dimensions & Weight - Machine part should be sufficiently strong, rigid & wear resistant & at the same time, with minimum possible dimensions & weight.

Manufacturability
- ease of fabrication & assembly.
- shape & material of the m/c part should be selected in such a way that it can be produced with minimum manufacturing cost

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Basic Requirements of Machine Elements

Safety - shapes & dimensions of the machine parts should ensure safety to the user/operator.

Reliability
- is probability that a machine part will perform its intended functions under desired operating conditions over a specified period of time.
- machine part should be reliable i.e. it should perform its function satisfactorily over its lifetime.

Maintainability
- ease with which a machine part can be serviced or repaired.
- machine part should be maintainable

Conformance to Standards - machine part should confirm to the National or International standard.

Minimum Life Cycle cost - Total cost to be paid by the purchaser for purchasing the part and operating & maintaining it over its life span.

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"*Standards*" in Machine Design

Standardization

Standardization is defined as obligatory norms, to which various characteristics of a product should conform.

The characteristics include materials, dimensions and shape of the component, method of testing and method of marking, packing and storing of the product.

Standard

Standard is defined as a set of specifications for parts, materials or processes

Purpose of Standard — ***to reduce the variety & limit the no. of items to a reasonable level***

Code

Code is defined as a set of specifications for the analysis, design, manufacture, testing and erection of the product

Purpose of Code — ***to achieve a specified level of safety***

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"*Standards*" in Machine Design

Advantages of Standardization

- ✓ The reduction in types & dimensions of identical components, to a rational number, makes it possible to manufacture the standard component on mass scale in a centralized process.
- ✓ Standard parts are easy to replace when worn out due to interchangeability.
- ✓ The application of standard machine elements & especially the standard units reduce the time & effort needed to design a new machine.

  Standardization results in substantial saving in Designer's effort
- ✓ The standards of specifications & testing procedures of machine elements improve their quality & reliability.

In designing, the aim is to use as many standard components as possible for a given machine

Types of Standards

- Company Standards
- National Standards
- International Standards

I.S / *B.I.S*	**India**
B.S	**UK**
A.I.S.I / *S.A.E*	**USA**
D.I.N	**German**

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"*Standards*" in Machine Design

Indian Standards in Mechanical Engineering Design

SP 46	Bureau of Indian Standards on "Engineering Drawing Practice for Schools & Colleges
I.S. 210	Seven grades of grey cast iron
I.S. 1570	Chemical composition of various grades of alloy steel
I.S. 733 : 1983	Mechanical Properties of wrought Al. & Al alloy Bars, Rods for general purposes
I.S. 736 : 1986	Mechanical Properties of wrought Al. & Al alloy Plates for general purposes
I.S. 919	Recommendations for Limits & Fits for Engineering
I.S. 2709	Guide for selection of fits
I.S. 8000	Geometrical tolerancing on technical drawings
I.S. 4218 : 1996	Designation & Dimension of screw threads, bolts & nuts

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Aesthetic Considerations in Machine Design

When there are a number of products in the market, having the same qualities of efficiency, durability and cost, the customer will naturally attracted towards the most appealing product.

The external appearance is an important feature, which not only gives grace and luster to the product but also dominates the sale in market.

Automobiles **Household Appliances** **Audio Visual Equipments**

Industrial Design

The job of an Industrial Designer is to create new forms & shapes, which are aesthetically pleasing.

The external appearance of the products is a cumulative effects of number of factors :

Form (Step, Stream, Taper, Shear, Sculpture) | Colour | Surface finish & Tolerances | Materials | Manufacturing Methods

Relationship between Functional requirement & Appearance of the Product

- In many cases, functional requirements result in shapes, which are aesthetically pleasing. The evolution of the streamlined shape of the boeing is the result of studies in aerodynamics for effortless speed.
- Chromium plating on the household appliances is for corrosion resistance rather than for pleasing appearance

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Ergonomic Considerations in Machine Design

Ergonomics is defined as the relationship between *Man* & *Machine* and the application of anatomical, physiological and psychological principles to solve the problems arising from Man-Machine relationship.

Topics of Ergonomic studies in Machine Design

- Anatomical factors in design of driver's seat.
- Layout of instrument dials & display panels for accurate perception by the operators
- Design of hand levers & hand wheels.

Ergonomists have carried out experiments to determine the best dimensions of driver's seat, the most convenient hand or foot pressure or dimensions of levers and hand wheels.

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Manufacturing Considerations in Machine Design

Design Considerations of Castings

General Principles :

- Round all external corners
- All sections in a casting should be designed of uniform thickness, as far as possible. If variation is unavoidable, it should be done gradually
- Avoid very thin section : Minimum thickness for CI component in sand casting is about 6 mm.
- The cast components should be designed in such a way that it will require a simpler pattern & its moulding is easier.
- In designing a casting, the various allowances must be provided in making a pattern.
- The casting should be designed as simple as possible, but with a good appearance.

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Design Considerations of Machined Components

- Machining is basically secondary & finishing manufacturing process.

Dimensional Accuracy	Dimensional Tolerance
Geometric / Form Accuracy	Geometric Tolerance
Surface finish	Surface roughness

General Principles :

- Avoid sharp corners
- Avoid too many shoulders & undercuts
- Avoid hard materials.

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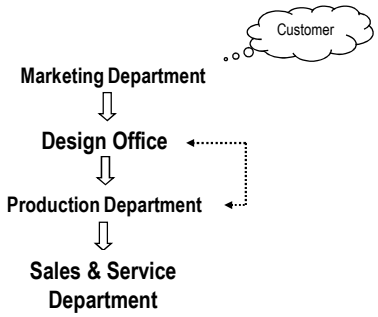
Sequential Engineering Approach Vs. Concurrent Engineering Approach

Sequential Design Process — Prototype Development Stage



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Sequential Engineering Approach Vs. Concurrent Engineering Approach

Concurrent Engineering

Concurrent Engineering is defined as the design process/approach that brings together a wide spectrum of expert/specialist from several functional areas (like R & D, Engineering, Manufacturing, Quality control, Marketing, sales & service etc.) during the early phases of the design process in new product development.

The team reviews the design from different aspects

- design for Manufacturing & Assembly (DFx)
- quality assurance & standardization
- aesthetics & ergonomics
- maintenance
- reliability & safety
- process, facility, capacity planning
- tool design
- functional / performance testing
- cost

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Sequential Engineering Approach Vs. Concurrent Engineering Approach

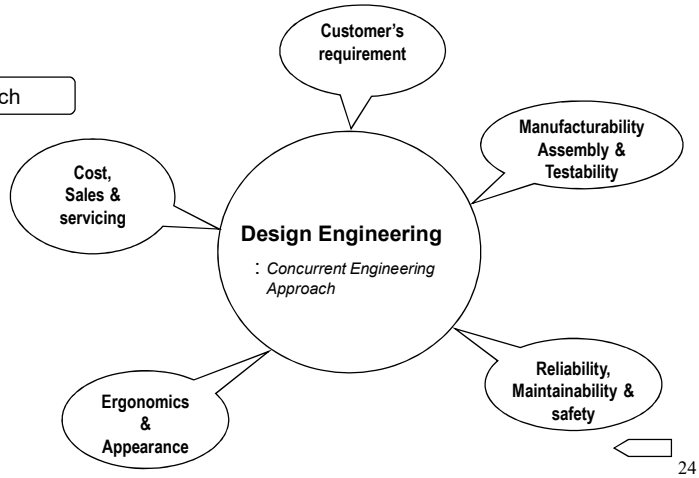
Concurrent Engineering

Any possible bottleneck/mistake is thoroughly studied & rectified. This results in small nos. of modification in the design at a later stage & reduce time interval from conceptual stage to marketing stage.

Simultaneous Engineering

Cross Functional Team Approach

Parallel Engineering



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Motivation

Requirements

Most Economic

Most Productive

Improved Quality

Successful entry of a product into the market can best occur if it can complete the above cycle in the *shortest possible time* & at the *lowest cost* while maintaining very *high product quality* & reliability

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
VP & VR	Virtual Prototyping & Virtual Reality

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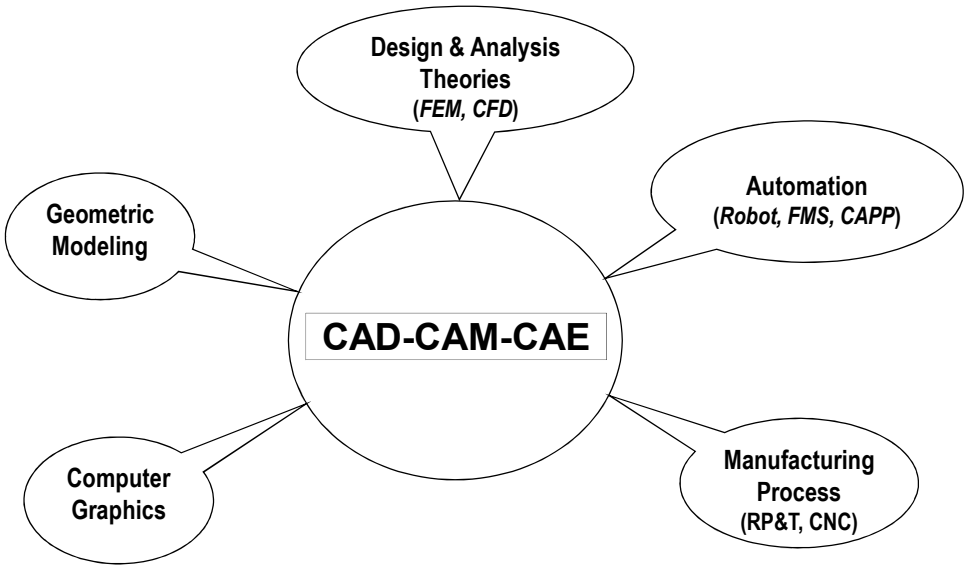
Scope of CAD-CAM-CAE



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CAD-CAM-CAE Software

CAD/CAM/CAE software	*Purpose*
CATIA *(CATIA PLM Express)*	3-D modeling, Analysis & Simulation etc.
NX *(Siemens PLM)*	
PRO-ENGINEER	
SOLID WORKS	
SOLID EDGE	
INVENTOR	
Mechanical DESKTOP	
MasterCAM	3-D modeling & Manufacturing Simulation
SolidCAM	
SmartCAM	

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CAD-CAE Software

CAE software	*Purpose*
ADAMS	*Multi-body dynamic analysis & simulation*
SimDESIGNER Motion with CATIA	*Multi-body dynamic analysis & simulation*
Working Model	*Multi-body dynamic analysis & simulation*
ANSYS	*Finite Element Analysis*
NASTRAN	*Finite Element Analysis*
ABAQUS	*Finite Element Analysis*
LS-DYNA	*Finite Element Analysis, Crash simulation*
DEFORM	*Finite Element Analysis, Crash simulation*
PAMCRASH	*Finite Element Analysis, Crash simulation*
FLUENT	*Computational Fluid Dynamics*
Altair Hyper Mesh	*Meshing for Finite Element Analysis*

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Computational Tools

Software	*Purpose*
MATLAB	*Design calculation, dynamic analysis & simulation, design optimization, control*
Mathematica	*Design calculation*
MathCAD	
Maple	
TK Solver	
Excel	

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Assignment # 1

1. Explain with example, the different steps involved in machine design process & in design of machine elements? What are the basic requirements of machine elements?
2. Distinguish between design synthesis and design analysis.
3. What is Standardization & what are the advantages of standardization? Give examples of Indian standards for commonly used engineering materials.
4. What is an industrial design? What is the relationship between functional requirement and external appearance of the product.
5. Define ergonomics. What is the scope of ergonomics in machine design?
6. Distinguish between sequential design and concurrent engineering.