HO CHI MINH CITY UNIVERSITY OF TECHNICAL AND EDUCATION

MECHANICAL ENGINEERING FACULLTY

MACHINE DESIGN

Design of Mechanical Elements

Chapter Introduction

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1. Purpose

- We will explore the topics of kinematics and dynamics of machinery in respect to the synthesis of mechanisms in order to accomplish desired motions or tasks, and also the analysis of mechanisms in order to determine their rigid-body dynamic behavior.
- On the premise that we cannot analyze anything until it has been synthesized into existence.
- We will first explore the topic of synthesis of mechanisms. Then we will investigate techniques of analysis of mechanisms.
- All this will be directed toward developing your ability to design viable mechanism solutions to real, unstructured engineering problems by using a design process.

2. Definition

- The subject Machine Design is the creation of new and better machines and improving the existing ones.
- A new or better machine is one which is more economical in the overall cost of production and operation.
- The idea is then studied keeping in mind its commercial success and given shape and form in the form of drawings.
- In designing a machine component, it is necessary to have a good knowledge of many subjects such as Mathematics, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing.

3. Classifications of Machine Design

- The machine design may be classified as follows :

1. ***Adaptive design.*** In most cases, the designer's work is concerned with adaptation of existing designs. This type of design needs no special knowledge or skill and can be attempted by designers of ordinary technical training. The designer only makes minor alternation or modification in the existing designs of the product.

2. ***Development design.*** This type of design needs considerable scientific training and design ability in order to modify the existing designs into a new idea by adopting a new material or different method of manufacture. In this case, though the designer starts from the existing design, but the final product may differ quite markedly from the original product.

3. ***New design.*** This type of design needs lot of research, technical ability and creative thinking. Only those designers who have personal qualities of a sufficiently high order can take up the work of a new design.

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

(*a*) ***Rational design.*** This type of design depends upon mathematical formulae of principle of mechanics.

(*b*) ***Empirical design.*** This type of design depends upon empirical formulae based on the practice and past experience.

(*c*) ***Industrial design.*** This type of design depends upon the production aspects to manufacture any machine component in the industry.

(*d*) ***Optimum design.*** It is the best design for the given objective function under the specified constraints. It may be achieved by minimising the undesirable effects.

(*e*) ***System design.*** It is the design of any complex mechanical system like a motor car.

(*f*) ***Element design.*** It is the design of any element of the mechanical system like piston, crankshaft, connecting rod, etc.

g) Computer aided design. This type of design depends upon the use of computer systems to assist in the creation, modification, analysis and optimisation of a design.

4. General Considerations in Machine Design

Following are the general considerations in designing a machine component:

1. ***Type of load and stresses caused by the load.*** The load, on a machine component, may act in several ways due to which the internal stresses are set up.
2. ***Motion of the parts or kinematics of the machine.*** The successful operation of any machine depends largely upon the simplest arrangement of the parts which will give the motion required.

The motion of the parts may be :

(*a*) Rectilinear motion which includes unidirectional and reciprocating motions.

(*b*) Curvilinear motion which includes rotary, oscillatory and simple harmonic.

(*c*) Constant velocity.

(*d*) Constant or variable acceleration.

3. ***Selection of materials.*** It is essential that a designer should have a thorough knowledge of the properties of the materials and their behaviour under working conditions. Some of the important characteristics of materials are : strength, durability, flexibility, weight, resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity, etc.

4. ***Form and size of the parts.*** The form and size are based on judgement.

5. ***Frictional resistance and lubrication.*** There is always a loss of power due to frictional resistance and it should be noted that the friction of starting is higher than that of running friction.

6. ***Convenient and economical features.*** In designing, the operating features of the machine should be carefully studied.

7. ***Use of standard parts.*** The use of standard parts is closely related to cost, because the cost of standard or stock parts is only a fraction of the cost of similar parts made to order.

8. ***Safety of operation.*** Some machines are dangerous to operate, especially those which are speeded up to insure production at a maximum rate.

9. ***Workshop facilities.*** A design engineer should be familiar with the limitations of his employer's workshop, in order to avoid the necessity of having work done in some other workshop.

10. ***Number of machines to be manufactured.*** The number of articles or machines to be manufactured Affects the design in a number of ways.

11. ***Cost of construction.*** The cost of construction of an article is the most important consideration involved in design. In some cases, it is quite possible that the high cost of an article may immediately bar it from further considerations.

12. ***Assembling.*** Every machine or structure must be assembled as a unit before it can function. Large units must often be assembled in the shop, tested and then taken to be transported to their place of service.

5. Design Criteria

Although the general criteria used by a designer are many, the following list addresses almost all concerns:

- Function
- Safety
- Reliability
- Cost
- Manufacturability
- Marketability

6. Design Procedure

The following procedure is representative of those found in the literature and is discussed extensively by Hill:

1. Identification of need
2. Problem statement or definition of goal
3. Research
4. Development of specifications
5. Generation of ideas
6. Creation of concepts based on the ideas
7. Analysis of alternative concepts
8. Prototype and laboratory testing
9. Selection and specification of best concept
10. Production
11. Marketing
12. Usage (maintenance and repair)

7. Force

It is an important factor in the field of Engineering science, which may be defined as an agent, which produces or tends to produce, destroy or tends to destroy motion.

In S.I. system of units, the unit of force is called **newton** (briefly written as N).

$$F = m.a = \text{Mass} \times \text{Acceleration}$$

$$1\text{N} = 1\text{kg} \times 1\ \text{m/s2} = 1\text{kg-m/s2}$$

8. Torque

It may be defined as the product of force and the perpendicular distance of its line of action from the given point or axis.

A little consideration will show that the torque is equivalent to a couple acting upon a body.

The Newton's second law of motion when applied to rotating bodies states, the ***torque is directly proportional to the rate of change of angular momentum.***

Mathematically,

$$T = Fxd/2$$

9. Moment of Force

It is the turning effect produced by a force, on the body, on which it acts. The moment of a force is equal to the product of the force and the perpendicular distance of the point, about which the moment is required, and the line of action of the force. Mathematically,

$$\text{Moment of a force (M)} = F \times l$$

where F = Force acting on the body, and l = Perpendicular distance of the point and the line of action of the force (F)

10. Power

It may be defined as the rate of doing work or work done per unit time. Mathematically, Power, P = Work done/ Time taken

In S.I system of units, the unit of power is watt (briefly written as W) which is equal to 1 J/s or 1N-m/s. Thus, the power developed by a force of F (in newtons) moving with a velocity v m/s is $F. V$ watt. Generally, a igger unit of power called kilowatt (briefly written as kW) is used which is equal to 1000 W.