Lecture Machine Design

- Step 5: Preparation of Drawings The last stage in a design process is to prepare drawings of the assembly and the individual components. On these drawings, the material of the component, its dimensions, tolerances, surface fi nish grades and machining symbols are specifi ed. The designer prepares two separate lists of components—standard components to be purchased directly from the market and special components to be machined in the factory. In many cases, a prototype model is prepared for the product and thoroughly tested before fi nalising the assembly drawings.

- BASIC REQUIREMENTS OF MACHINE ELEMENTS
- A machine consists of machine elements. Each part of a machine, which has motion with respect to some other part, is called a machine element. It is important to note that each machine element may consist of several parts, which are manufactured separately. For example, a rolling contact bearing is a machine element and it consists of an inner race, outer race, The broad objective of designing a machine element is to ensure that it preserves its operating capacity during the stipulated service life with minimum manufacturing and operating costs. In order to achieve this objective, the machine element should satisfy the following basic requirements:
- (i) Strength: A machine part should not fail under the effect of the forces that act on it. It should have suffi cient strength to avoid failure either due to fracture or due to general yielding.
- (ii) Rigidity: A machine component should be rigid, that is, it should not defl ect or bend too much due to forces or moments that act on it. A transmission shaft in many times designed on the basis of lateral and torsional rigidities. In these cases, maximum permissible defl ection and permissible angle of twist are the criteria for design
- (iii) Wear Resistance: Wear is the main reason for putting the machine part out of order. It reduces useful life of the component. Wear also leads to the loss of accuracy of machine tools. There are different types of wear such as abrasive wear, corrosive wear and pitting. Surface hardening can increase the wear resistance of the machine components, such as gears and cams.
- (iv) Minimum Dimensions and Weight: A machine part should be suffi ciently strong, rigid and wearresistant and at the same time, with minimum possible dimensions and weight. This will result in minimum material cost.
- (v) Manufacturability: Manufacturability is the ease of fabrication and assembly. The shape and material of the machine part should be selected in such a way that it can be produced with minimum labour cost.
- (vi) Safety: The shape and dimensions of the machine parts should ensure safety to the operator of the machine. The designer should assume the worst possible conditions and apply 'fail-safe' or 'redundancy' principles in such cases.
- (vii) Conformance to Standards: A machine part should conform to the national or international standard covering its profi le, dimensions, grade and material.
- (viii) Reliability: Reliability is the probability that a machine part will perform its intended functions under desired operating conditions over a specifi ed period of time. A machine part should be reliable, that is, it should perform its function satisfactorily over its lifetime

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- (ix) Maintainability: A machine part should be maintainable. Maintainability is the ease with which a machine part can be serviced or repaired.
- (x) Minimum: Life-cycle Cost: Life-cycle cost of the machine part is the total cost to be paid by the purchaser for purchasing the part and operating and maintaining it over its life span. It will be observed that the above mentioned requirements serve as the basis for design projects in many cases

- DESIGN OF MACHINE ELEMENTS
- Design of machine elements is the most important step in the complete procedure of machine design. In order to ensure the basic requirements of machine elements, calculations are carried out to fi nd out the dimensions of the machine elements. These calculations form an integral part of the design of machine elements. The basic procedure of the design of machine elements is illustrated in Fig. . It consists of the following steps:

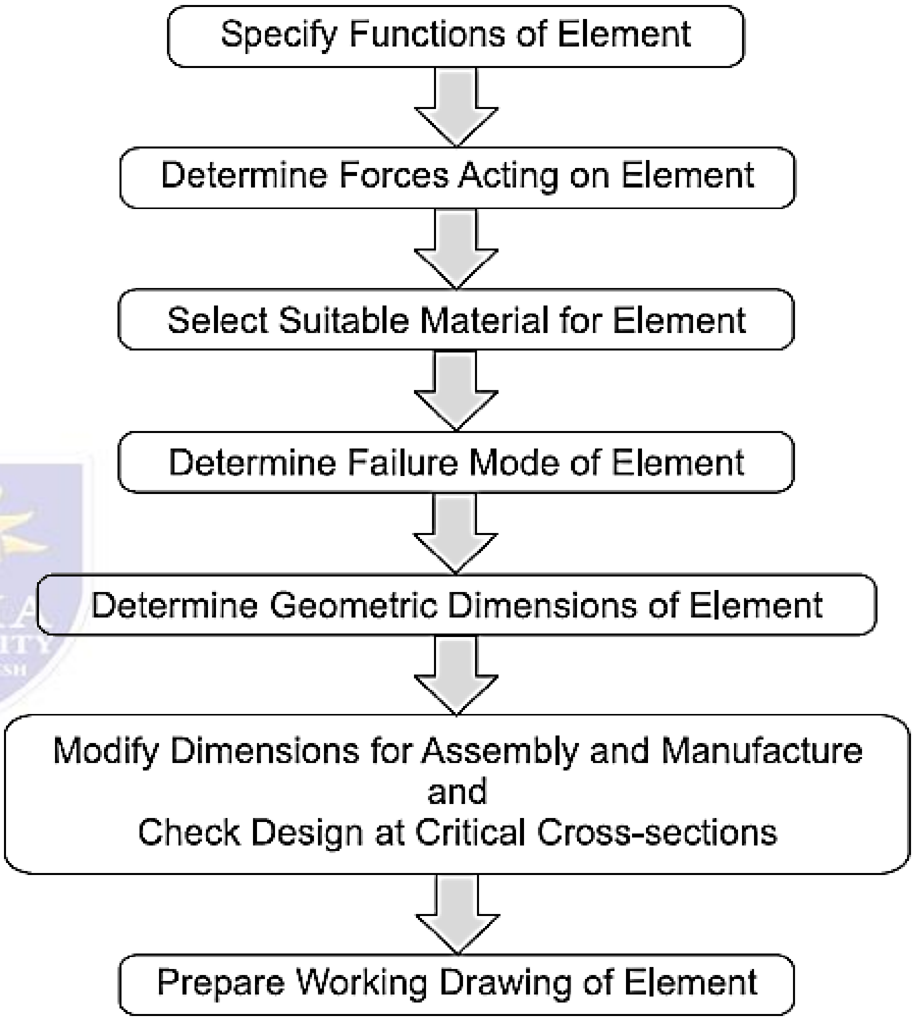

Fig. 1.2 *Basic Procedure of Design of Machine*

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- Step 1: Specifi cation of Function
- The design of machine elements begins with the specification of the functions of the element. The functions of some machine elements are as follows:
- (i) Bearing To support the rotating shaft and confine its motion
- (ii) Key To transmit the torque between the shaft and the adjoining machine part like gear, pulley or sprocket
- (iii) Spring in Clock To store and release the energy
- (iv) Spring in Spring Balance To measure the force
- (v) Screw Fastening To hold two or more machine parts together
- (vi) Power Screw To produce uniform and slow motion and to transmit the force

- Step 2: Determination of Forces In many cases, a free-body diagram of forces is constructed to determine the forces acting on different parts of the machine. The external and internal forces that act on a machine element are as follows:
- (i) The external force due to energy, power or torque transmitted by the machine part, often called 'useful' load
- (ii) Static force due to deadweight of the machine part
- (iii) Force due to frictional resistance
- (iv) Inertia force due to change in linear or angular velocity
- (v) Centrifugal force due to change in direction of velocity
- (vi) Force due to thermal gradient or variation in temperature
- (vii) Force set up during manufacturing the part resulting in residual stresses
- (viii) Force due to particular shape of the part such as stress concentration due to abrupt change in cross-section

- Step 3: Selection of Material
- Four basic factors, which are considered in selecting the material, are availability, cost, mechanical properties and manufacturing considerations.
- For example, fl ywheel, housing of gearbox or engine block have complex shapes. These components are made of cast iron because the casting process produces complicated shapes without involving machining operations.
- Transmission shafts are made of plain carbon steels, because they are available in the form of rods, besides their higher strength.
- The automobile body and hood are made of low carbon steels because their cold formability is essential to press the parts. Free cutting steels have excellent machinability due to addition of sulphur.
- They are ideally suitable for bolts and studs because of the ease with which the thread profi les can be machined.
- The crankshaft and connecting rod are subjected to fl uctuating forces and nickel–chromium steel is used for these components due to its higher fatigue strength.
- Step 4: Failure Criterion Before fi nding out the dimensions of the component, it is necessary to know the type of failure that the component may fail when put into service. The machine component is said to have 'failed' when it is unable to perform its functions satisfactorily. The three basic types of failure are as follows:
- (i) failure by elastic defl ection;
- (ii) failure by general yielding; and
- (iii) failure by fracture
- Step 5: Determination of Dimensions The shape of the machine element depends on two factors, viz., the operating conditions and the shape of the adjoining machine element.
- For example, involute profi le is used for gear teeth because it satisfi es the fundamental law of gearing. A V-belt has a trapezoidal cross-section because it results in wedge action and increases the force of friction between the surfaces of the belt and the pulley.
- On the other hand, the pulley of a V-belt should have a shape which will match with the adjoining belt. The profi le of the teeth of sprocket wheel should match the roller, bushing, inner and outer link plates of the roller chain
- Depending on the operating conditions and shape of the adjoining element, the shape of the machine element