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PHILOSOPHY OF DESIGN RELIABILITY ENGINEERING

Introduction

Design is essentially a decision-making process. If we have a problem, we need to design a solution. In other words, to 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.

Almost everyone is involved in design, in one way or the other, in our daily lives because problems are posed and they need to be solved.

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. For example, once we decide the engine capacity, the shape and size, then the subsequent course of the design would follow. A bad decision leads to a bad design and a bad product.

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.

Here we are concerned with machine design. We now define a machine as a combination of resisting bodies with successfully constrained relative motions which is used to transform other forms of energy into mechanical energy or transmit and modify available energy to do some useful work. If it converts heat into mechanical energy we then call it a heat engine.

In many cases however, the machines receive mechanical energy and modify it so that a specific task is carried out, for example a hoist, a bicycle or a hand-winch. This modification or transformation of energy requires a number of machine elements, some small and some large. Machine design involves primarily designing these elements so that they may transmit the forces safely and perform their task successfully. Consider the following simple mechanisms:

(a) Hand winch (b) Small press operated by a power screw.

In each one of these mechanisms some useful work is being obtained with certain combinations of a number of machine parts. Designing these mechanisms would involve firstly designing these elements and then assembling them in order.

Types of design There may be several types of design such as:

1. 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 or haulage systems are some of the examples where existing design systems are adapted for a particular use.

2. 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.

3. 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

1. Rational design

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

2. Empirical design

This is based on empirical formulae which in turn are 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=284d where, d is the bolt diameter in mm and P is the applied force in kg. There is no mathematical backing of this equation but it is based on observations and experience.

3. Industrial design

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

Factors to be considered in machine design There are many factors to be considered while attacking a design problem. In many cases these are a common sense approach to solving a problem. Some of these factors are as follows:

(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.

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.

Material- This is a very important aspect of any design. 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.

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. I

ii) 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.

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. Similar arguments apply to choice of material for ships and there too light materials are to be chosen. Portable equipment must be made light.

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. However in many other cases, a sequence of operations is to be specified. This sequence must not be complicated and the operations should not require excessive force. Consider the starting, accelerating and stopping a scooter or a car. With time tested design considerations, the sequences have been made user-friendly and as in any other product, these products too go through continuous innovation and development.

Reliability and safety

Reliability is an important factor in any design. A designed machine should work effectively and reliably. The probability that an element or a machine will not fail in use is called reliability. Reliability lies between $0 \leq R < 1$. To ensure this, every detail should be examined. Possible overloading, wear of elements, excessive heat generation and other such detrimental factors must be avoided. There is no single answer for this but an overall safe design approach and care at every stage of design would result in a reliable machine. Safety has become a matter of paramount importance these days in design. Machines must be designed to serve mankind, not to harm it. Industrial regulations ensure that the manufacturer is liable for any damage or harm arising out of a defective product. Use of a factor of safety only in design does not ensure its overall reliability.

Maintenance, cost and aesthetics

Maintenance and safety are often interlinked. Good maintenance ensures good running condition of machinery. Often a regular maintenance schedule is maintained and a thorough check up of moving and loaded parts is carried out to avoid catastrophic failures. Low friction and wear is maintained by proper lubrication. This is a major aspect of design since wherever there are moving parts, friction and wear are inevitable. High friction leads to increased loss of energy.

Wear of machine parts leads to loss of material and premature failure . Cost and aesthetics are essential considerations for product design. Cost is essentially related to the choice of materials which in turn depends on the stresses developed in a given condition. Although in many cases aesthetic considerations are not essential aspects of machine design, ergonomic aspects must be taken into considerations.