Fundamentals of Mechanical Design

Mechanical design means the design of things and systems of a mechanical nature—machines, products, structures, devices, and instruments. For the most part mechanical design utilizes mathematics, the materials sciences, and the engineering-mechanics sciences.

The total design process is of interest to us. How does it begin? Does the engineer simply sit down at his desk with a blank sheet of paper? And, as he jots down some ideas, what happens next? What factors influence or control the decisions which have to be made? Finally, then, how does this design process end?

Sometimes, but not always, design begins when an engineer recognizes a need and decides to do something about it. Recognition of the need and phrasing it in so many words often constitute a highly creative act because the need may be only a vague discontent, a feeling of uneasiness, or a sensing that something is not right.

The need is usually not evident at all. For example, the need to do something about a food-packaging machine may be indicated by the noise level, by the variation in package weight, and by slight but perceptible variations in the quality of the packaging or wrap.

There is a distinct difference between the statement of the need and the identification of the problem which follows this statement. The problem is more specific. If the end is for cleaner air, the problem might be that of reducing the dust discharge from power-plant stacks, or reducing the quantity of irritants from automotive exhausts.

Definition of the problem must include all the specifications for the thing

that is to be designed. The specifications are the input and output quantities, the characteristics and dimensions of the space the thing must occupy and all the limitations on these quantities. In this case we must specify the inputs and outputs of the box together with their characteristics and limitations. The specifications define the cost, the number to be manufactured, the expected life, the range, the operating temperature, and t he reliability.

There are many implied specifications which result either from the designer's particular environment or from the nature of the problem itself. The manufacturing processes which are available, together with the facilities of a certain plant, constitute restrictions on a designer's freedom, and hence are a part of the implied specifications. A small plant, for instance, may not own cold-working machinery. Knowing this, the designer selects other metal-processing methods which can be performed in the plant. The labor skills available and the competitive situation also constitute implied specifications.

After the problem has been defined and a set of written and implied specifications has been obtained, the next step in design is the synthesis of an optimum solution. Now synthesis cannot take place without both analysis and optimization because the system under design must be analyzed to determine whether the performance complies with the specifications.

The design is an iterative process in which we proceed through several steps, evaluate the results, and then return to an earlier phase of the procedure. Thus we may synthesize several components of a system, analyze and optimize them, and return to synthesis to see what effect this has on the remaining

parts of the system. Both analysis and optimization require that we construct or devise abstract of the system which will admit some form of mathematical analysis. We call these models mathematical models. In creating them it is our hope that we can find one which will simulate the physical system very well.

Evaluation is a significant phase of the total design process. Evaluation is the final proof of a successful design, which usually involves the testing of a prototype in the laboratory. Here we wish to discover if the design really satisfies the need or needs. Is it reliable? Will it compete successfully with similar products? Is it economical to manufacture and to use? Is it easily maintained and abjusted? Can a profit be made from its sale or use?

Communicating the design to others if the final, vital step in the design process. Undoubtedly many great designs, inventions, and creative works have been lost to mankind simply because the originators were unable or unwilling to explain their accomplishments to others. Presentation is a selling job. The engineer, when presenting a new solution to administrative, management, or supervisory persons, is attempting to sell or to prove to them that this solution is a better one. Unless this can be done successfully, the time and effort spent on obtaining the solution have been largely wasted.

Basically, there are only t here means of communication available to us. These are the written, the oral, and the graphical forms. Therefore the successful engineer will be technically competent and versatile in all three forms of communication. A technically competent person who lacks ability in any one of these forms is severely handicapped. If ability in all three

forms is lacking, on one will ever know how competent that person is!

The competent engineer should not be afraid of the possibility of not succeeding in a presentation. In fact, occasional failure should be expected because failure or criticism seems to accompany every really creative idea. There is a great deal to be learned from a failure, and the greatest gains are obtained by those willing to risk defeat. In the final analysis, the real failure would lie in deciding not to make the presentation at all.

Machine design is the application of science and technology to devise new or improved products for the purpose of satisfying human needs. It is a vast field of engineering technology which not only concerns itself with the original conception of the product in terms of terms of its size, shape and construction details, but also considers the various factors involved in the manufacture, marketing and use of the product.

People who perform the various functions of machine design are typically called designers, or design engineers. Machine design is basically a creative activity. However, in addition to being innovative, a design engineer must also have a soild background in the areas of mechanical drawing, kinematics, dynamics, materials engineering, strength of materials and manufacturing processes.

As stated previously, the purpose of machine design is to produce a product which will serve a need for man. Inventions, discoveries and scientific knowledge by themselves do not necessarily benefit people; only if they are incorporated into a designed product will a benefit be derived. It should be recognized, therefore, that a human need must be identified before a particular product is designed.

Good designs require trying new ideas and being willing to take a certain amount of risk, knowing that if the new idea does not work the existing method can be reinstated. Thus a designer must have patience, since there is no assurance of success for the time and effort expended. Creating a completely new design generally requires that many old and well-established methods be thrust aside. This is not easy since many people cling to familiar ideas, techniques and attitudes. A design engineer should constantly search for ways to improve an existing product and must decide what old, proven concepts should be used and what mew, untried ideas should be incorporated.

New designs generally have“bugs”or unforeseen problems which must be worked out before the superior characteristics of the new designs can be enjoyed. Thus there is a chance for a superior product, but only at higher risk. It should be emphasized that, if a design does not warrant radical new methods, such methods should not be applied merely for the sake of change.

During the beginning stages of design, creativity should be allowed to flourish without a great number of constraints. Even though many impractical ideas may arise, it is usually easy to eliminate them in the early stages of design before firm details are required by manufacturing. In this way, innovative ideas are not inhibited. Quite often, more than one design is developed, up to the point where they can be compared against each other. It is entirely possible that the design which is ultimately accepted will use ideas existing in one of the rejected designs that did not show as much overall promise.

Psychologists frequently talk about trying to fit people to the machines they operate. It is essentially the responsibility of the design engineer

to strive to fit machines to people. This is not an easy task, since there is really no average person for which certain operating dimensions and procedures are optimum.

Another important point which should be recognized is that a design engineer must be able to communicate ideas to other people if they are to be incorporated. Initially, the designer must communicate a preliminary design to get management approval. This is usually done by verbal discussions in conjunction with drawing layouts and written material. To communicate effectively, the following questions must be answered:

Does the design really serve a human need?

Will it be competitive with existing products of rival companies?

Is it economical to produce?

Can it be readily maintained?

Will it sell and make a profit?

Only time will provide the true answers to the preceding questions, but the product should be designed, manufactured and marketed only with initial affirmative answers. The design engineer also must communicate the finalized design to manufacturing through the use of detail and assembly drawings.

Quite often, a problem will occur during the manufacturing cycle. It may be that a change is required in the dimensioning or telegramming of a part so that is can be more readily produced. This falls in the category of engineering changes which must be approved by the design engineer so that the product function will not be adversely affected. In other cases, a deficiency in the design may appear during assembly or testing just prior

to shipping. These realities simply bear out the fact that design is a living process. There is always a better way to do if and the designer should constantly strive towards finding that better way.