Preface to the Second Edition...

It is indeed with great pleasure that we bring out the Second edition of the Book Design and Engineering.

The book is a bird's eye-view to the world of Design and its associated aspects in Engineering. It serves to uncover the know-how that an amateur designer needs to start with designing. The contents have been covered as per the syllabus the subjects 'Design & Engineering' of APJ Abdul Kalam Technological University syllabus.

The process of Design can never be compartmentalised, but it is the collaborative work of different disciplines simultaneously. Systems or Products in today's world have evolved a great deal in testimony to this. The day to day consumer products that we see have gone a great deal in making our lives more simple, productive and all the above comfortable.

The close collaboration between the Medical and Engineering domain in today's world is worth mentioning and the role of Engineering Design in improving the treatment procedures are really notable. Latest equipments and implants designed, ensures better success rates for patients.

The book does not go in detail to design any product but serves the purpose of understanding some of the general principles governing the art of Engineering Design.

The first three chapters of the book focuses on the processes involved in design and how a proper methodology can be evolved to design any product. Care must be taken to customize these processes to the corresponding concerns.

The fourth and fifth chapter speaks on solid modelling and prototyping. Entrepreneurs who would like to develop new products and market them need to have a good understanding of these two before doing so. The sixth chapter is on how production can be managed in a large scale in a factory or an industry.

The seventh chapter DF'X' techniques are part of detail design and are ideal approaches to improve life-cycle cost, quality, increased design flexibility, and increased efficiency and productivity using the concurrent design concepts.

The eighth chapter is on the different attributes or qualities needed when a product is put to use. The nineth chapter is on modular design, optimization and Intellectual Property rights.

The last chapter says about the transition involved when a designer is interested in becoming an entreprenuer.

Questions paper questions are worked out and are given at the end. Also different case studies will help students to practice the theory.

The readers are expected to practice the art of designing and the course would never be complete without practice or hands on experience. The exercises given at the end of the chapters are set with such a view in the mind.

This book would not have been complete without the direct and indirect inputs from many.

The authors would like to thank Mr. Sreerag V, Assistant Professor, AmalJyothi College of Engineering, Kanjirappally for the sincere effort that he has put in to compile this work to the present form.

We also would like to thank the authors and publishers whose works have been referred to while preparing the book.

We are immensely thankful to Pentex Publishers, Kollam for bringing out the book in the present form. The authors would like to thank their family members for all their support in bringing out this book.

The readers might notice some short comings during the course of adoption of this book. They are requested to bring the same to the knowledge of the authors.

Subin P George

Arun K Varghese

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Chapter 1

Introduction to Design

1.1 Introduction to Design - History

From the very beginning of mankind, man always was in pursuit for shaping the objects around him in order to solve his day to day problems. The conversion of objects around him to suit his need was indeed a very slow process that took time. Man slowly evolved simple solutions like potter's wheel for making vessels that he could use to store food .He then discovered that the same wheel can be used for transportation purpose using animals. He learned that the trees around him can be cut down and the wood can be fashioned to make furniture, houses and many other utensils. He also discovered the immense potential behind the usage of metals in making objects of day to day use. The metal when heated gave rise to many utensils of different application. When coming to the twentieth and twenty first century much great advancement were made in all the fields that made the life of men more easy and trouble free. Ever since, people have attempted to create bigger and better structures and products to improve their lives. It is a wonder to see the Egyptians built the Pyramids and the Romans the Coliseum and Forum with the tools they had at hand. Even in the past century, it is amazing to those of us whose lives are centered on computers to envision building structures such as the Golden Gate Bridge (United States) and the Empire State Building (United States) or designing hybrid automobiles and supersonic aircraft without the tools we have become accustomed to. The architectural wonders in India like Taj Mahal, Qutb Minar, the ancient temples, churches and mosques that were built centuries earlier speak of the skill that man developed even without modern tools.

Throughout the history of mankind design, as an art had a great place in shaping man's destiny and well-being. Design process encompasses a wide range of activities that can vary from making objects of day to day use to formulating procedures to execute a task.

The last century has seen an explosion of development in the fields of automobile, airplane, electronics, space technology, Imaging, internet, Agricultural Mechanization, computers, telephone, House hold appliances and many other domains. Design had a major role in shaping materials and equipments to a product that suits the need of the customer or user.

The evolution of design process is never ending and continues for ever as the materials and processes evolve.

1.2 Design in Engineering Perspective

If you take a moment to observe your surroundings, you will see examples of technological creativity. The physical objects you see, whether they are telephones, automobiles, bicycles, or electric appliances, all came into being through the creative application of technology. These everyday inventions did not miraculously appear but originated in the minds of human beings and took time to develop. Engineering is the creative process of turning abstract ideas into physical representations (products or systems). What distinguishes engineers from painters, poets, or sculptors is that engineers apply their creative energies to producing products or systems that meet human needs. This creative act is called **design.**

1.3 Engineering Design

Most engineering designs can be grouped as inventions-devices or systems that are created by human effort and did not exist before or are improvements over existing devices or systems. Inventions, or designs, do not suddenly appear from nowhere. They are the result of bringing together technologies to meet human needs or to solve problems. Sometimes a design is the result of someone trying to do a task more quickly or efficiently. Design activity occurs over a period of time and requires a step-by-step methodology.

We described engineers primarily as problem solvers. What distinguishes design from other types of problem solving is the nature of both the problem and the solution. Design problems are open ended in nature, which means they have more than one correct solution. The result or solution to a design problem is a system that possesses specified properties.

Design problems are usually more vaguely defined than analysis problems. Suppose that you are asked to determine the maximum height of a snowball given an initial velocity and release height (Pahl et al. 1984). This is an analysis problem because it has only one answer. If you change the problem statement to read, "Design a device to launch a 1-pound snowball to a height of at least 160 feet", this analysis problem becomes a design problem. The solution to the design problem is a system having specified properties (able to launch a snowball 160 feet), whereas the solution to the analysis problem consisted of the properties of a given system (the height of the snowball). The solution to a design problem is therefore open ended, since there are many possible devices that can launch a snowball to a given height. The original problem had a single solution: the maximum height of the snowball, determined from the specified initial conditions.

Solving design problems is often an iterative process: As the solution to a design problem evolves, you find yourself continually refining the design. While implementing the solution to a design problem, you may discover that the solution you've developed is unsafe, too expensive, or will not work. You then "go back to the drawing board" and modify the solution until it meets your requirements. For example, the Wright brothers airplane did not fly perfectly the first time. They began a program for building an airplane by first conducting tests with kites and then gliders. Before attempting powered flight, they solved the essential problems of controlling a plane's motion in rising, descending, and turning. They didn't construct a powered plane until after making more than 700 successful glider flights. Design activity is therefore cyclic or iterative in nature, whereas analysis problem solving is primarily sequential.

The solution to a design problem does not suddenly appear in a vacuum. A good solution requires a methodology or process. There are probably as many processes of design as there are engineers.

1.3.1 Objectives

Objectives (or goals) are expressions of the desired attributes and behaviors that the client wants to see in the product or process or methodology.

Objectives are qualities the object should have. Clients tend to speak in terms of objectives.

A three step procedure can be evolved for objective preparation:

1. Prepare a list of design objectives
2. Order the list into sets of higher-level and lower-level objectives
3. Draw a tree of objectives, showing hierarchical relationships and interconnections

The objective list can be collected from the customer through an interview or interaction. The value or cost of the design process depends upon the quality and number of objectives. The collected crude objectives are then ordered based upon their priority. For example some deign processes may depend upon the outcome of some other, in which case the out coming processes should be placed after their parent processes.

From the previous steps, we have a clustered set of objectives

- Notice that some of the objectives within a cluster may be more specific than others
- This implies a hierarchical nature to the objectives
- The hierarchy (general to more specific) can be represented in a graphical structure known as an *objectives tree*)

Consider the example objectives list and resulting tree for the design of a Super ladder. A super ladder is a consumer product that is used for multipurpose needs. The main two objectives from customer point of view are given in bold letters i.e. it should be safe and it should be marketable. These objectives have to be converted to the language of the engineer or product designer. For example the objective that the ladder should be reasonably stiff is an objective that that the designer has to take in. The stiffness of a body depends upon material geometry and material property. The designer has to play with geometry and material properties to produce a good ladder.

Objective List

The ladder should be safe

- The ladder should be stable
  - Stable on floors and smooth surfaces
    - Stable on relatively level ground
  - Should stand safely without a support
- The ladder should be reasonably stiff

The ladder should be marketable

- The ladder should be useful
  - Useful indoors
    - Useful for electrical work

Useful for maintenance work

Useful outdoors

Useful for car washing

Useful for cutting tree branches

Be useful at the right height

The ladder should be relatively inexpensive

The ladder should be portable

Be light weight

Be small when ready for transport

The ladder should be durable

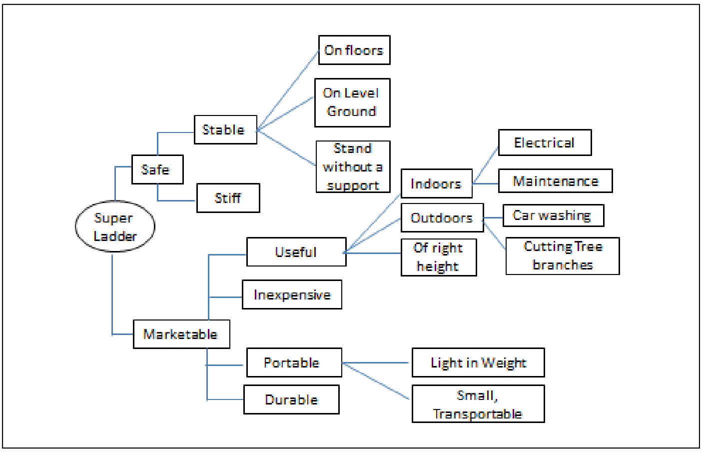

Figure 1.1: Objective tree for designing a super ladder

The objectives connected with a design plan will always be associated with limitations. For example when an automobile designer designs a car with ample performance he can increase the volume of IC engine, or number of cylinders inside the vehicle. But there is a limit to which he can increase the volume or cc of a given vehicle in a particular segment because more volume will lead to more fuel consumption thus hitting the economy of the user.

Another example is associated with the design of structures for taking load. The strength of the structure can be increased by increasing the size of the structure, but there is a limit to which the size can be increased as more is the size more money is needed to build them.

These limitations in design are rightly called constraints. So constraints are parameters that give a check to the objectives. A design problem can be mathematically expressed as an optimization problem.

The *standard form* of a (continuous) optimization problem is

$$\begin{aligned} minimize \quad & f(x) \\ subject\,to\, g_i(x) \quad & \leq 0 \quad , i = 1, \ldots.., m \\ h_j(x) \quad & = 0 \quad , i = 1, \ldots.., p \end{aligned}$$

Where

$f(x) : R^n \rightarrow R\, is\, the\, objective\, function\, to\, be\, minimized$ $over\, the\, variable\, x$

$g_i(x) \leq 0\, are\, called\, inequality\, constraints$

$h_j(x) = 0\, are\, called\, equality\, constraints$

Here there are i inequality constraints and j equality constraints. By convention, the standard form defines a **minimization problem**

1.4 Functional, Form and Strength Design

Functions are behaviors that is expected from the design. Every design is intended to perform some tasks in a specified manner. The user lays down the rules governing the product in his detailing.

Some designers (Pahl et al. 1984) describe function on the basis of inputs and outputs, where inputs and outputs can be materials, energy or signals. Function is defined as the general Input/output relationship of a system whose purpose it is to perform a task. Examples include "increase pressure", "transfer torque", and “reduce speed" etc. A design problem is described in terms of an overall function. Design solutions, in conceptual design for instance, are represented as solution principles, which are partial structural descriptions in action.

Similar is the case with Hubka's (Hubka V. 1982) conceptual solutions, and it is noticeable that this description contains both functional and structural (or form) descriptions of the solution. Problem to solution transition in conceptual design is prescribed to be done, based on the Morphological Approach (Zwicky F. 1948), in the following steps:

- Find the overall function of the problem
- Find sub-functions
- Find physical effects to each sub-function
- Find corresponding physical principles
- Combine these, to produce solution principles for the overall function.
- Evaluate these principles to select the promising ones for detailing.

For example a wall bracket is designed to hold a body and transfer the weight to the wall.

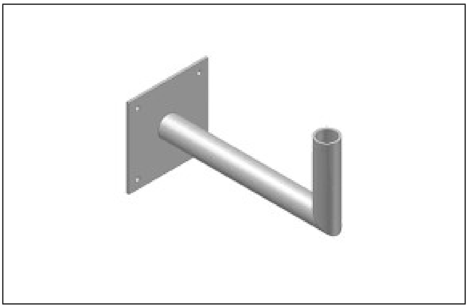

Figure 1.2: Wall Bracket

The expected functionalities of the wall bracket are:

- Carry a maximum weight of certain kg at the tip.
- Ability to hold on to the wall permanently after fixation.

The form, in simple language is shape of the product. It is connected to the geometry of the product or equipment that is involved. The form should blend with the user as well as the environment in which the product is put to use .The form design has seen an evolution since man has invented the products .Usually the initial product design is primarily intended to serve the functionality or purpose . The product then undergoes a form evolution to suit the need of the customer and environment in a better way.

Taking a simple instance, when mobile phones came to the market as a revolution Nokia® 1100 and 3310 were the most available models in the market. But we very well know how today's android phones have captured and settled in the market over the years .The same is the example in automobile sector .Initially when industrial revolution came the most popular Car was ' Model T' by Ford. The user had only one choice for buying the vehicle. Then came other automobile giants like Toyota, General Motors, Renault, BMW with different shape and appearance. The form or shape is associated with the aspirations of a user or customer now.

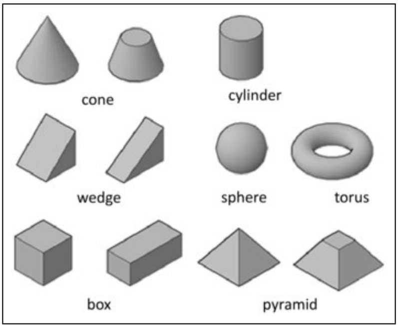

Figure 1.3: Solid Primitives

The majority of industrial or consumer products are composed of a number of elements of simple geometrical form. Every well-designed product is characterized by a number of form elements, which together make up the final outer form. These form elements help give the product its final appearance. The form elements encountered most frequently are the cube, the cylinder, the sphere, the pyramid, the cone and the ellipsoid or parts of these. The box and the cylinder are the most frequently used shapes. The majority of products consist of lines and planes at right angles to each other. Several reasons for the orthogonal shape of objects may be stated. These basic shapes are also called as Solid primitives in Solid modeling. Basic shapes are shown in Fig 1.3.

Engineering design process boils down to a problem solving activity where design problem and its solutions co-evolve. A designer starts with functional descriptions of the problem (i.e., what the intended product should deliver), and undergoes a reasoning process aimed at eventually producing a solution in terms of its form (structural) descriptions from which the solution can be realized. Reasoning about design problems and solutions in terms of their functionality, termed here as functional reasoning, is central to designing. Therefore, problem, solution, function and form are important concepts in design, and devising ways for supporting functional reasoning is important.

The important points connected with function and form are:

- There are multiple meanings and representations of function, ranging from purposes through effects to material properties, and even cost and spatial constraints.
- There are multiple representations of form (shape).
- There are multiple meanings and representations of design problems and solutions; some of these overlap.
- These views are goal - specific, i.e., serve specific purposes in design.
- Design solutions are represented in various blends of functional and structural (form) descriptions.
- All these can be at varying levels of abstraction. Function and behavior are interchangeably used.
- There are different views about form-function relations. They rely on the existing knowledge which are available at various degrees of formalism (including design guidelines)

- There are different ways of problem-to-solution transition. Problems and solutions cannot necessarily be described in terms of functions and form respectively.

In order to prevent failure,the strength of a member has to be greater than the induced stress in the member.However, a member with excessive strength wastes material. Engineers usually use a term factor of safety while designing structures or products. It is the additional tolerance that is given to the product to prevent failure due to any unforeseen event. As far as possible, the safety factor should be kept uniform throughout each machine element for a balanced design. The component of a machine that is weak is the critical element.

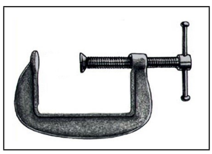

Figure 1.4: C-Clamp

In a C-clamp the curved portion is the critical element as it is subjected to bending moment and has highest bending stress. Doubling or tripling the strength at the jaws or anvils will not improve the clamp as a whole. The key lies in strengthening the curved portion by adding more material. Design for strength is a key aspect in the design of structures that carry loads. The designer has to take into consideration all the failure modes that the subject can undergo and if possible any unforeseen event too.

1.5 Role of Science, Engineering and Technology

Science, Engineering, and Technology are often confused with each other. All three are closely related but mean different things. Let's start with a quote by Theodore von Kármán that brings out the difference between Science & Engineering:

"Scientists study the world as it is; engineers create the world that has never been." As per the quote, we can observe that science is a study of the natural world while Engineering is creating new things based on that study.

"Science is the study of the natural world as it is; engineering is creating new tools, devices, and processes based on scientific knowledge; technology is the sum total of all the engineered tools, devices and processes available".

In the above quote, we can clearly see the difference as well as the interconnection between science, engineering, and technology. This can be explained using the figure 1.5 .

The connection between science, engineering and technology are very important in the case of designing. For example, scientists use the technologies that engineers create (such as microscopes, monitors, and meters) to conduct their research. And when engineers start to design a new technology, they call on the knowledge of the natural world developed by scientists (for example, the law of gravity or how fluid flows). Engineering, science, and technology connect to and influence each other.

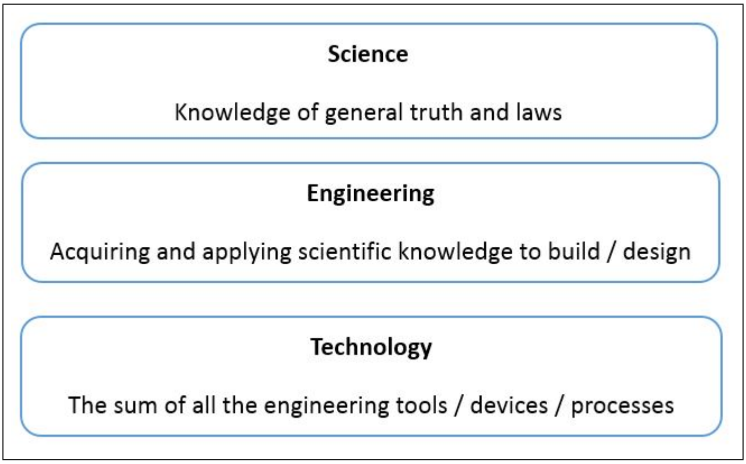

Figure 1.5: Science, Engineering and Technology

Engineering, science, and technology also influence our society. Our human values, needs, or problems often determine what questions scientists investigate and what problems engineers tackle. Meanwhile the technologies that are the products of science and engineering influence society and change human culture (just think of the impacts of cars and cell phones).

Exercise

Explain the saying “Form follows function” using example of a product.

The principle is that the shape of the product or object should be primarily based upon its intended function or purpose.

Take the example of a hoverboard or a self balancing scooter that has become popular now a days.A self-balancing scooter or self-balancing two-wheeled board, commonly referred to as a "hoverboard", is a type of portable, rechargeable battery-powered scooter. They typically consist of two wheels arranged side-by-side, with two small platforms between the wheels, on which the rider stands. The device is controlled by the rider’s feet, standing on the built-in gyroscopic, sensored pads.

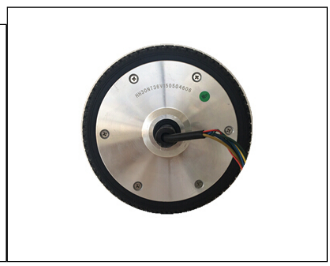

Figure 1.6: Self Balancing Scooterdriven by BLDC motor

Its parts are hub motor with wheels ,Li ion battery,Pressure sensores,Driver circuits,Gyroscope for balancing.The design is so compact that it easily fits below the feet of a person.

The hub motor is a kind of Brush Less DC motor that is fiited into the hub of the tyre or wheel for the smooth operation.This design is far superior than connecting the motor and axle of the wheel through gears as it consumes very less space and minimizes transmission losses.The Li ion battery inside the device is very compact to an extend that in order to drive a 700 W device it occupies only a weight of less than 2 kg. So the over all design can be stated by the saying "Form follows function".This product is designed in such a way that its form is best suited and adapted to its function of locomotion.

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Chapter 2

General Steps

2.1 Designing a Product for Daily Use

We see a range of products around us that performs good enough to meet our needs. Some are of daily or frequent use, but some are of occasional use. They have a key role in making our lives simpler and trouble free. A common example is the products in kitchen. Maxi, grinder, cooking utensils Refrigerator, vegetable cutter, Coconut scraper, LPG Stove, Microwave oven and the list goes on. All these product have significant importance in cooking and keeping food. Each of these individual products can be identified with its form as well as functionality.

The general steps in design process are Need identification, Problem Statement, Market survey - customer requirements, Design attributes and objectives, Idealization, Brain storming approaches, arriving at solutions, Closing on to the Design needs. Depending upon the domain in which design is done the steps can vary, but by and large the general steps remain essentially the same.

Need identification is the first step in design process. There has to be a motivation behind the product development. In simple terms any product designed and developed has to solve one or more than one problem of man.

The need can be expressed by an individual or even an organization or a group of people. The people who express their needs are rightly called customers and it is for them the design happens .The customers need not know the technical language to express their needs but they express it through common language that has to get converted to a technical language by the product designer. For example a customer who is a home maker may say that she needs a small refrigerator to keep few things cool. The designer has to decide on how 'small' the fridge is. The exact dimension of the refrigerator has to be calculated by him. Also the temperature inside the refrigerator, the refrigerant used, its power requirements and all has to be properly fixed by the product developer. So we see a transition from crude objectives to refined objectives.

The next step is to develop a proper **Problem statement**. The final objectives and attributes have to evolve from this problem statement. The problem statement should be a concise description of the design problem and its context. Be sure to include only the functional requirements of the device and not components of the solution. The aim of problem definition is to clearly define the problem for the team involved to focus on and to publicize what the team is working on. The problem definition should be measurable and observable.

Constraints have to be properly set. These are essentially restrictions or limitations on a behavior, a value, or some other aspect of performance. They have to be stated as clearly defined limits. They are often the result of guidelines and standards. Proper functionalities should be expressed. This typically involve output based on input.

Market survey is essential to find out the taste and thinking patterns of the customer. It is needed to calculate the quantity of products needed to be manufactured. It also helps to design the products according to the need of the customer. A common methodology used in IT companies today is called Agile methodology. This is different from the waterfall model that was used earlier, in which the requirement of the products are given at once and there after no interaction with the customer and the designer happens. The project is delivered to the customer at the end.

Agile management, or agile process management, or simply agile refer to an iterative, incremental method of managing the design and build activities for engineering, information technology, and other business areas that aims to provide new product or service development in a highly flexible and interactive manner; an example is its application in Scrum, an original form of agile software development. It requires capable individuals from the relevant business, openness to consistent customer input, and management openness to non-hierarchical forms of leadership.

Market survey is a valuable tool to help minimize risks and increase the probability of success. However, that doesn't mean it is a sure-shot way to eliminate risk and guarantee complete success. You should undertake market assessment with a survey before you finalize marketing plans for your product or service. Markets are changing rapidly, becoming complex and competitive. It is difficult to keep pace with the rapidly changing demand and supply patterns as an entrepreneur is unable to respond quickly to a new environment. He needs better market understanding and a market survey puts him in contact with the market. A systematic use of this tool can reduce risks in decision-making.

The design attributes and objectives are then evolved from the problem statement .The objective should be clearly and precisely listed down.

For instance ,the following objectives are that for designing a patient transfer system:

Design a patient transfer device that can transfer fragile or weak patients from bed to trolley.

With the following conditions:

- *The transfer system should be mechanically operated.*
- *It should carry a maximum load of 150 Kg.*
- *The weight of the structure should not exceed 25 Kg*
- *It should be stable and safe.*
- *The patient should not feel any jerk while transfer.*
- *The maximum cost of the device should not be more than Rs 3000.*

After finishing with the problem definition section we move on to the solution part where initially ideas are generated through discussions or literature surveys to solve the problem.

Brain storming is the first ever technique of idea generation. Brainstorming is an individual or group idea generation technique to find a solution for a particular problem by generating multiple solutions. In fact, importance is attached to the quantity of ideas and not quality at the generation stage. Even strange ideas are welcome in a brainstorming session. Frequently, far-fetched ideas become practical ones with slight modification. Ideas may be blended to create a single great idea as implied by the motto "1+1=3." Structured brainstorming that proceeds in the right manner utilizes the human brain's abilities of free association and lateral thinking.

The brainstorming has to be conducted in a comfortable environment so that you can get the best output from the participants. Devote some time to deciding who should be called to participate in the session. A simple rule to apply here would be to choose the people who would have the answers to the question you intend to put forth.

It is important that the problem for which brainstorming is to be done, be stated clearly. A good way to ensure this would be to write the problem lucidly at the head of the board. Everyone should comprehend the objective of the session. With the topic in full view all through the session, there is a greater likelihood of the session staying focused. Also remember that the participants should be given the necessary background information before the brainstorming. State the time limit at the very beginning. 5 or 10 minutes may do but sometimes more time may be required.

Allow everyone to pen down their ideas prior to the start of the session so that there is no time lost in talking about just one or a few ideas. This would help us to bring in a little argument into the discussion whenever it is possible.

Select the best ideas after short-listing the ones that meet the pre-determined criteria. One way to make things easier is to score each of the ideas a number from 0 to 5 depending on the degree to which it satisfies each of the pre-determined criterions. Once that's done, add up the scores. The one with the highest score can be taken as the best idea. However, if this best idea is not practical, in spite of the scores, you can look for the second best one.

The above mentioned method is a suggestion. There are many other ways of doing it innovatively.

After getting the **best idea** it has to be worked out either on a drafting board or on the computer.

For example if the brain storming was about the design of a toy, the toy design that evolved as an output has to be drawn with details. The drafted design has to be properly simulated for its working. There are simulation soft wares that are available that can check the working. After rectifying the mistakes in the simulation a small scaled down prototype can be built to physically see how the system is functioning in the environment. Even here the designer can improvise, optimize, or rectify the design. This continues as an iterative process until the final design is evolved .

The design is always checked with its objectives and attribute. The **final design** is then drafted and then send to make the final product. When the order is given to the manufacturing unit it has to include the detailed views, tolerancing and bill of materials.

Exercise:

Take a simple design problem. Go through the steps mentioned here to finalize on the design model of the same.

Examples

1. A hand tool with GPS that helps amateur forest ex-

pediters to navigate through the forest

2. A ceiling fan.

   A possible set of design objectives for a ceiling fan is given below.

   (a) The functionality of the product is to supply air at a certain speed to improve human comfort. Another functionality is that it should hang safely on the ceiling.
   (b) Coming to the form, it should be such that it circulates air in the room. From these needs we need to fix the specific design objectives.
   (c) Power rating of the fan
   (d) Maximum and minimum air circulation needed in m/s.
   (e) The maximum space the fan can occupy
   (f) The weight of the fan.
   (g) The aesthetics of the fan
   (h) The number of speeds the fan can run
   (i) The minimum voltage needed for the fan to run.
   (j) The maximum swing height of the fan

Chapter 3

Design Process

Morris Asimow was among the first to give a detailed description of the complete design process in what he called the morphology of design. His seven phases of design are described below, with slight changes of terminology to conform to current practice. These phases of design activities are a widely accepted representation of the basic design process.

3.1 Different Phases in Design By Morris Asimow

3.1.1 Conceptual Design (Phase I)

Conceptual design is the process by which the design is initiated, carried to the point of creating a number of possible solutions, and narrowed down to a single best concept. It is sometimes called the feasibility study. Conceptual design is the phase that requires the greatest creativity, involves the most uncertainty, and requires coordination among many functions in the business organization. The following are the discrete activities that we consider under conceptual design.

1. **Identification of customer needs**

   The goal of this activity is to completely understand the customers' needs and to communicate them to the design team. Problem definition: The goal of this activity is to create a statement that describes what has to be accomplished to satisfy the needs of the customer. This involves analysis of competitive products, the establishment of target specifications, and the listing of constraints and trade-offs. Quality function deployment (QFD) is a valuable tool for linking customer needs with design requirements. A detailed listing of the product requirements is called a product design specification (PDS).

2. **Gathering information**

   Engineering design presents special requirements over engineering research in the need to acquire a broad spectrum of information.

3. **Conceptualization**

   Concept generation involves creating a broad set of concepts that potentially satisfy the problem statement. Team-based creativity methods, combined with efficient information gathering, are the key activities.

4. **Concept selection**

   Evaluation of the design concepts, modifying and evolving into a single preferred concept, are the activities in this step. The process usually requires several iterations.

5. **Refinement of the PDS**

   The product design specification is revisited after the concept has been selected. The design team must commit to achieving certain critical values of design parameters, usually called critical to quality (CTQ) parameters, and to living with trade-offs between cost and performance.

6. **Design review**

   Before committing funds to move to the next design phase, a design review will be held. The design review will assure that the design is physically realizable and that it is economically worthwhile. It will also look at a detailed product development schedule. This is needed to devise a strategy to minimize product cycle time and to identify the resources in people, equipment, and money needed to complete the project.

3.1.2 Embodiment Design (Phase II)

Structured development of the design concept occurs in this engineering design phase. It is the place where flesh is placed on the skeleton of the design concept. An embodiment of all the main functions that must be performed by the product must be undertaken. It is in this design phase that decisions are made on strength, material selection, size, shape, and spatial compatibility. Beyond this design phase, major changes become very expensive. This design phase is sometimes called preliminary design. Embodiment design is concerned with three major tasks. They are,

1. **Product architecture**

Product architecture is concerned with dividing the overall design system into subsystems or modules. In this step we decide how the physical components of the design are to be arranged and combined to carry out the functional duties of the design.

2. **Configuration design of parts and components**

   Parts are made up of features like holes, ribs, splines, and curves. Configuring a part means to determine what features will be present and how those features are to be arranged in space relative to each other. While modelling and simulation may be performed in this stage to check out function and spatial constraints, only approximate sizes are determined to assure that the part satisfies the PDS. Also, more specificity about materials and manufacturing is given here. The generation of a physical model of the part with rapid prototyping processes may be appropriate.

3. **Parametric design of parts**

   Parametric design starts with information on the configuration of the part and aims to establish its exact dimensions and tolerances. Final decisions on the material and manufacturing processes are also established if this has not been done previously. An important aspect of parametric design is to examine the part, assembly, and system for design robustness. Robustness refers to how consistently a component performs under variable conditions in its service environment.

3.1.3 Detail Design (Phase III)

In this phase the design is brought to the stage of a complete engineering description of a tested and producible product. Missing information is added on the arrangement, form, dimensions, tolerances, surface properties, materials, and manufacturing processes of each part. This results in a specification for each special-purpose part and for each standard part to be purchased from suppliers. In the detail design phase the following activities are completed and documents are prepared:

1. Detailed engineering drawings suitable for manufacturing. Routinely these are computer-generated drawings, and they often include three-dimensional CAD models.

2. Verification testing of prototypes is successfully completed and verification data is submitted. All critical-to quality parameters are confirmed to be under control. Usually the building and testing of several preproduction versions of the product will be accomplished.

3. Assembly drawings and assembly instructions also will be completed. The bill of materials for all assemblies will be completed.

4. A detailed product specification, updated with all the changes made since the conceptual design phase, will be prepared.

5. Decisions on whether to make each part internally or to buy from an external supplier will be made.

6. With the preceding information, a detailed cost estimate for the product will be carried out.

7. Finally, detail design concludes with a design review before the decision is made to pass the design information on to manufacturing.

Phases I, II, and III take the design from the realm of possibility to the real world of practicality. However, the design process is not finished with the delivery of a set of detailed engineering drawings and specifications to the manufacturing organization. Many other technical and business decisions must be made that are really part of the design process. A great deal of thought and planning must go into how the design will be manufactured, how it will be marketed, how it will be maintained during use, and finally, how it will be retired from service and replaced by a new, improved design. Generally these phases of design are carried out elsewhere in the organization than in the engineering department or product development department. As the project proceeds into the new phases, the expenditure of money and personnel time increases greatly.

One of the basic decisions that must be made at this point is which parts will be made by the product developing company and which will be made by an outside vendor or supplier. This often is called the “make or buy” decision. Today, one additional question must be asked: “Will the parts be made and/or assembled in the United States or in another country where labour rates are much lower?”

3.1.4 Planning for Manufacture (Phase IV)

A great deal of detailed planning must be done to provide for the production of the design. A method of manufacture must be established for each component in the system. As a usual first step, a process sheet is created; it contains a sequential list of all manufacturing operations that must be performed on the component. Also, it specifies the form and condition of the material and the tooling and production machines that will be used. The information on the process sheet makes possible the estimation of the production cost of the component. High costs may indicate the need for a change in material or a basic change in the design. Close interaction with manufacturing, industrial, materials, and mechanical engineers is important at this step.

The other important tasks performed in phase IV are the following:

1. Designing specialized tools and fixtures

2. Specifying the production plant that will be used (or designing a new plant) and laying out the production lines

3. Planning the work schedules and inventory controls (production control)

4. Planning the quality assurance system

5. Establishing the standard time and labour costs for each operation

6. Establishing the system of information flow necessary to control the manufacturing operation

All of these tasks are generally considered to fall within industrial or manufacturing engineering.

3.1.5 Planning for Distribution (Phase V)

Important technical and business decisions must be made to provide for the effective distribution to the consumer of the products that have been produced. In the strict realm of design, the shipping package may be critical. Concepts such as the shelf life of the product may also be critical and may need to be addressed in the earlier stages of the design process. A system of warehouses for distributing the product may have to be designed if none exists. The economic success of the design often depends on the skill exercised in marketing the product. If it is a consumer product, the sales effort is concentrated on advertising in print and video media, but highly technical products may require that the marketing step be a technical activity supported by specialized sales brochures, performance test data, and technically trained sales engineers.

3.1.6 Planning for Use (Phase VI)

The use of the product by the consumer is all-important, and considerations of how the consumer will react to the product pervade all steps of the design process. The following specific topics can be identified as being important user-oriented concerns in the design process: ease of maintenance, durability, reliability, product safety, convenience in use (human factors engineering), aesthetic appeal, and economy of operation. Obviously, these consumer-oriented issues must be considered in the design process at its very beginning. They are not issues to be treated as afterthoughts.

Phase VI of design is less well defined than the others, but it is becoming increasingly important with the growing concerns for consumer protection and product safety. More strict interpretation of product liability laws is having a major impact on design. An important phase VI activity is the acquisition of reliable data on failures, service lives, and consumer complaints and attitudes to provide a basis for product improvement in the next design cycle.

3.1.7 Planning for Retirement of the Product (Phase VII)

The final step in the design process is the disposal of the product when it has reached the end of its useful life. Useful life may be determined by actual deterioration and wear to the point at which the design can no longer function, or it may be determined by technological obsolescence, in which a competing design performs the product's functions either better or cheaper. In consumer products, it may come about through changes in fashion or taste.

In the past, little attention has been given in the design process to product retirement. This is rapidly changing, as people the world over are becoming concerned about environmental issues. There is concern with depletion of mineral and energy resources, and with pollution of the air, water, and land as a result of manufacturing and technology advancement. This has led to a formal area of study called industrial ecology. Design for the environment, also called green design, has become an important consideration in design. As a result, the design of a product should include a plan for either its disposal in an environmentally safe way or, better, the recycling of its materials or the re-manufacture or reuse of its components.

3.2 Quality Function Deployment (QFD)

The main objective of a manufacturing company is to bring new products to market sooner than the competition with lower cost and improved quality. The mechanism for doing this is called QFD. QFD provides a means of translating customer requirements into appropriate technical requirements for each stage of product development and production, that is, marketing strategy, planning, product design and engineering, prototype evaluation, production process development, production, and sales.

There are four phases of QFD

1. Product planning phase
2. Part deployment phase
3. Process deployment phase
4. Production deployment phase

3.2.1 Product Planning Phase

In this phase, the overall customer requirements drawn from market evaluations, comparison with competitors, and market plans are converted into specified final product control characteristics.

Product Planning Matrix

- Step 1.

  State requirements in customer terms. The primary customer requirements are expanded into secondary and tertiary requirements to obtain a more definite list.

- Step 2.

  List the final product control characteristics that should meet the customer-stated product requirements.

- Step 3.

  Develop a relationship matrix between customer requirements and final product control characteristics. A set of symbols is used to represent the relationships, such as strong, medium, and weak relationships. If the matrix shows a majority of "weak relationship" signs, it is an indication that some customer requirements are not addressed properly.

- Step 4.

  Enter market evaluations. The objective is to evaluate the strengths and weaknesses of the products vs. the competitions so that areas for improvement are clearly identifies.

- Step 5.

  Enter product control characteristic competitive evaluations and compare it with market competitive evaluations. This helps indicate inconsistencies between customer requirements and your own evaluations.

- Step 6.

  Determine selling points for new product. Based on these points, product marketing, distribution, and promotion strategies are decided.

- Step 7.

Develop measurable targets for final product control characteristics based on agreed-upon selling points, the customer importance index, and the current product strengths and weaknesses.

- Step 8.

  Select control characteristics based on customer importance, selling points, and competitive evaluations.

3.2.2 Part Deployment Phase

In this phase, the output of the product planning (i.e. final product control characteristics) is translated into critical component characteristics. This phase is the first step in materializing the customer needs. For this purpose, a document called the final product characteristic deployment matrix is used. In this matrix, the final product control characteristics are carried from the final assembly (product) level to the subsystem/component. From the customer requirements and final product control are identified.

3.2.3 Process Deployment Phase

In this phase, all the critical product and process parameters are identified and quality control checkpoints for each parameter are established. If a critical product component parameter is created or directly affected in a given step of a process, that parameter is identified as a control point. These points establish the data and strategy for the product quality control plan and are essential for achieving product characteristics that meet the high-priority customer requirements. If critical parameters, such as time, temperature, and pressure, must be monitored to ensure that the component parameters are achieved, these parameters are designed as checkpoints and become the basis for operating instructions and the process control strategy.

3.2.4 Production Deployment Phase

The output from the process development and quality control planning phase provides the critical product and process parameters. The objective of the production operating instruction phase is to identify the operations to ensure that these parameters are achieved. The operating instructions sheet is the fourth and final key QFD document. It basically defines the operator requirements as determined by the actual process requirements, the process plan chart checkpoint, and the quality control plan chart control points. What is important is that this document, which relates to the checkpoints and control points, clearly conveys the following points to the operator: What parts are involved? How many should he or she check, using what tool? How should the check be made?

Exercise

1.Detail out the steps of Morris Asimow for developing a software package for doing a student survey.

Chapter 4

Solid Modelling

4.1 Introduction

Geometric/Solid modelling is concerned with the mathematical representation of curves, surfaces, and solids necessary in the definition of complex physical or engineering objects. The objects we are concerned with in designing range from the simple mechanical parts (machine elements) to complex sculptured objects such as ships, automobiles, airplanes, turbine and propeller blades, etc. Similarly, for the description of the physical environment we need to represent objects such as the ocean bottom as well as three-dimensional scalar or vector physical properties, such as salinity, temperature, velocities, chemical concentrations (possibly as a function of time as well). Sculptured objects play a key role in engineering because the shape of such objects (e.g. for aircraft, ships and underwater vehicles) is designed in order to reduce drag or increase the thrust (e.g. for propeller blades). At the same time these objects need to satisfy other design constraints to permit them to fulfill certain design requirements (e.g. carry a certain payload, be stable in perturbations, etc.). Similarly, there are objects which have significant aesthetic requirements, e.g. Passenger vehicles, Construction equipments, Consumer products.

Typically, engineers deal with the definition of complex shapes such as engines, automobiles, aircraft, ships, submarines, underwater robots, offshore platforms, etc. The shape of these objects is usually not fully known in advance (except when a baseline design is available). Consequently, the usual design procedure is iterative, involving:

1. Shape creation based on certain design needs.
2. Analysis to evaluate the performance of the object.
3. Shape modification to improve the shape, followed by analysis until a satisfactory design is reached, which satisfies all the design requirements and minimizes a certain cost function.

Geometric modelling attempts to provide a complete, flexible, and unambiguous representation of the object, so that the shape of the object can be:

- Easily visualized (rendered)
- Easily modified (manipulated)
- Increased in complexity
- Converted to a model that can be analyzed computationally
- Manufactured and tested

Computer graphics is an important tool in this process as visualization and visual inspection of the object are fundamental parts of the design iteration. Computer graphics and geometric modelling have evolved into closely linked fields within the last 40 years, especially after the introduction of high-resolution graphics workstations, which are now pervasive in the engineering environment.

4.2 Requirements for Solid Representation

- Domain

  While no representation can describe all possible solids, a representation should be able to represent a useful set of geometric objects.

- Unambiguity

  When we see a representation of a solid, we will know what is being represented without any doubt. An unambiguous representation is usually referred to as a complete one.

- Uniqueness

  That is, there is only one way to represent a particular solid. If a representation is unique, then it is easy to determine if two solids are identical since one can just compare their representations.

- Accuracy

  A representation is said accurate if no approximation is required.

- Validness

  This means a representation should not create any invalid or impossible solids. More precisely, a representation will not represent an object that does not correspond to a solid.

- Closure

  Solids will be transformed and used with other operations such as union and intersection. "Closure" means that transforming a valid solid always yields a valid solid

- Compactness and efficiency

  A good representation should be compact enough for saving space and allow for efficient algorithms to determine desired physical characteristics.

4.3 Technical Drawing

Technical drawing, also known as drafting or draughting, is the act and discipline of composing drawings that visually communicate how something functions or is to be constructed.

Technical drawing is essential for communicating ideas in industry and engineering. To make the drawings easier to understand, people use familiar symbols, perspectives, units of measurement, notation systems, visual styles, and page layout. Together, such conventions constitute a visual language, and help to ensure that the drawing is unambiguous and relatively easy to understand. These drafting conventions are condensed into internationally accepted standards and specifications that transcend the barrier of language making technical drawings a universal means of communicating complex mechanical concepts.

This need for precise communication in the preparation of a functional document distinguishes technical drawing from the expressive drawing of the visual arts. Artistic drawings are subjectively interpreted; their meanings are multiply determined. Technical drawings are understood to have one intended meaning.

A drafter, draftsperson, or draughtsman is a person who makes a drawing (technical or expressive). A professional drafter who makes technical drawings is sometimes called a drafting technician. Professional drafting is a desirable and necessary function in the design and manufacture of complex mechanical components and machines. Professional draftspersons bridge the gap between engineers and manufacturers, and contribute experience and technical expertise to the design process.

Today, the mechanics of the drafting task have largely been automated and accelerated through the use of computer-aided drawing systems (CAD).

There are two types of computer-aided design systems used for the production of technical drawings" two dimensions ("2D") and three dimensions ("3D").

2D CAD systems such as AutoCAD® or MicroStation® replace the paper drawing discipline. The lines, circles, arcs and curves are created within the software. It is down to the technical drawing skill of the user to produce the drawing. There is still much scope for error in the drawing when producing first and third angle orthographic projections, auxiliary projections and cross sections. A 2D CAD system is merely an electronic drawing board. Its greatest strength over direct to paper technical drawing is in the making of revisions. Whereas in a conventional hand drawn technical drawing, if a mistake is found, or a modification is required, a new drawing must be made from scratch. The 2D CAD system allows a copy of the original to be modified, saving considerable time. 2D CAD systems can be used to create plans for large projects such as buildings and aircraft but provide no way to check the various components will fit together.

3D CAD systems such as Autodesk Inventor®, SolidWorks® or CATIA V5® first produce the geometry of the part, the technical drawing comes from user defined views of the part. Any orthographic, projected and section views are created by the software. There is no scope for error in the production of these views. The main scope for error comes in setting the parameter of first or third angle projection, and displaying the relevant symbol on the technical drawing. 3D CAD allows individual parts to be assembled together to represent the final product. Buildings, Aircraft, ships and cars are modelled, assembled and checked in 3D before technical drawings are released for manufacture.

Both 2D and 3D CAD systems can be used to produce technical drawings for any discipline. The various disciplines; electrical, electronic, pneumatic, hydraulic, etc., have industry recognized symbols to represent common components.

BS and ISO produce standards to show recommended practices but it is up to individuals to produce the drawings. There is no definitive standard for layout or style. The only standard across engineering workshop drawings is in the creation of orthographic projections and cross section views.

4.4 Case Studies of CAD Model

4.4.1 CAD Model of a Fluid Discharge Bottle

A fluid discharge bottle is used for discharging waste fluid collected, in different places like hospital and other health centres. The bottle is housed with a small pump at its bottom (shown in hidden lines) that can discharge low density fluid to the drainage system. It consists of a bottle with handle, a holder and a housing for a small fluid pump.

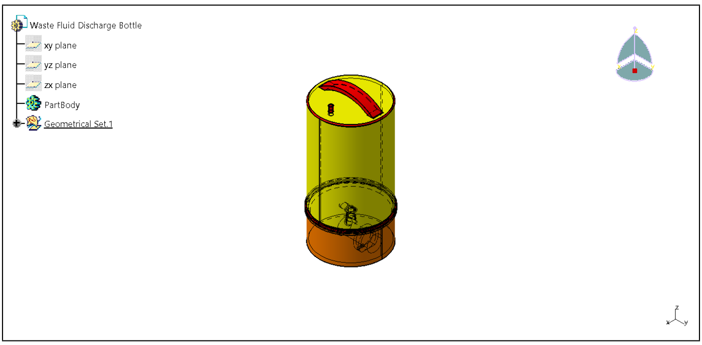
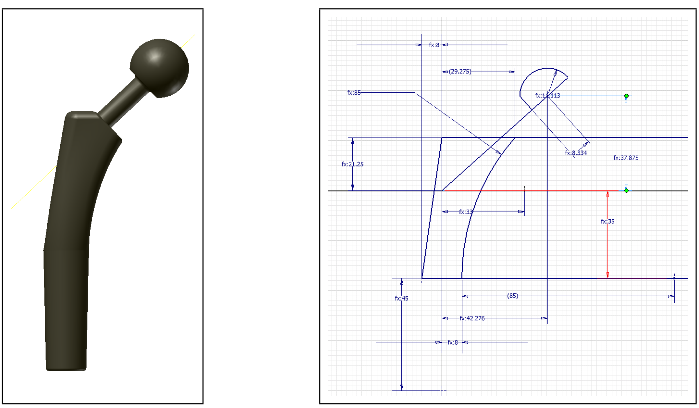


Figure 4.1: Fluid discharge bottle drawn in CATIA V5

4.4.2 Technical Drawing of a Custom Implant Used in Hip Surgery.

A hip implant is used by an orthopaedic surgeon to replace a damaged hip joint. The stem of the implant is fitted into the cavity of the bone .The 3D view of the product is as shown. The implant can be customized for different patients for better adaptability. Certain features of the hip joint are extracted to construct the custom hip implant. These features can be incorporated into the CAD model of the implant that is going for manufacturing(George & Saravana Kumar 2013).

A template prepared in a CAD package can be used to develop the custom CAD model for a specific patient. Figure 4.2b shows the parametric modelling feature in Autodesk Inventor®. Parametric modelling uses parameters to define a model (dimensions, for example). Examples of parameters are: dimensions used to create model features, material density, formulas to describe swept features, imported data (that describe a reference surface, for example). The parameter may be modified later, and the model will update to reflect the modification. Typically, there is a relationship between parts, assemblies, and drawings. A part consists of multiple features, and an assembly consists of multiple parts. Drawings can be made from either parts or assemblies.



(a) CAD Model of Custom Implant

(b) Parametric modelling of Hip Implant in Autodesk Inventor

Figure 4.2: CAD model of implant

4.4.3 Detailed 2D Drawing of Shifter Fork

The shifter fork is used to change gears in mechanisms. Figure 4.3 shows the detailed 2D drawing with sectional views for the shifter fork.

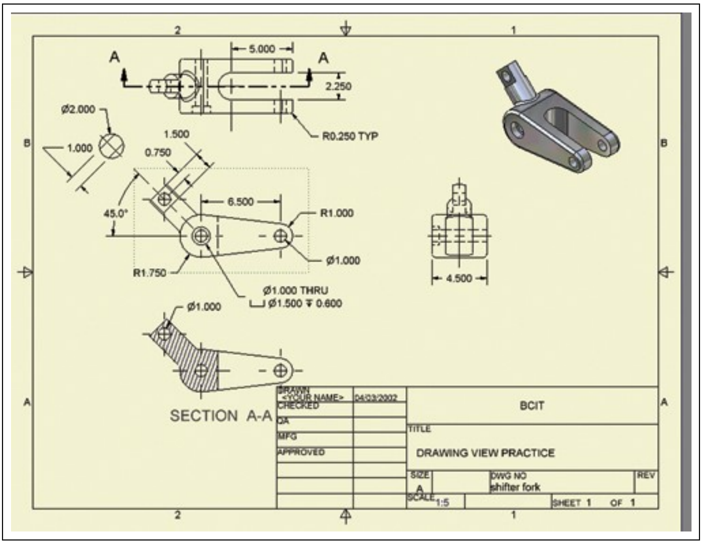


Figure 4.3: Detailed 2D drawing of a shifter fork

Detailed 2D drawings are needed to send the designed product to the factory. The manufacturer at the factory should know each and every minute details regarding the product. He should know the material with which the product is to be made. The range of variation of the dimension of the product is also expected to be known. This small variation that can happen in the product while manufacturing is called tolerance. Engineering tolerance is the permissible limit or limits of variation in a physical dimension. Dimensions, properties, or conditions may have some variation without significantly affecting functioning of systems, machines, structures, etc.

Exercise

Identify a simple product. Develop its CAD model using a free CAD modelling software (E.g.: Autodesk Inventor® or FreeCad).Develop a detailed 2D drawing so that it can be manufactured easily in a workshop or Fabrication Lab nearby.

References

George, S.P. & Saravana Kumar, G., 2013. Patient specific parametric geometric modelling and finite element analysis of cementless hip prosthesis. *Virtual and Physical Prototyping*, 8(1), pp.1–19.

Chapter 5

Prototyping to Production

A **prototype** is an early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. It is a term used in a variety of contexts, including semantics, design, electronics, and software programming. A prototype is designed to test and try a new design to enhance precision by system analysts and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one. In some work-flow models, creating a prototype (a process sometimes called **materialization**) is the step between the formalization and the evaluation of an idea.

The word *prototype* derives from the Greek *prototypon*, "primitive form".

One of the essential early steps in the inventing process is creating a prototype which, simply defined, is a three-dimensional version of your vision. Creating a prototype can also be one of the most fun and rewarding steps taken.

That's because developing a prototype gives us the opportunity to really tap into our creativity, using those skills that inspired our invention idea in the first place.

In general, prototypes will differ from the final production variant in four fundamental ways:

- **Scaled Model** - The prototypes is usually a scaled model of the final product .It can be a scaled up or scaled down model depending on the situation.
- **Materials -** Production materials may require manufacturing processes involving higher capital costs than what is practical for prototyping. Instead, engineers or prototyping specialists will attempt to substitute materials with properties that simulate the intended final material.
- **Processes -** Often expensive and time consuming unique tooling is required to fabricate a custom design. Prototypes will often compromise by using more variable processes, repeatable or controlled methods; substandard, inefficient, or substandard technology sources; or insufficient testing for technology maturity.
- **Lower fidelity -** Final production designs often require extensive effort to capture high volume manufacturing detail. Such detail is generally unwarranted for prototypes as some refinement to the design is to be expected. Often prototypes are built using very limited engineering detail as compared to final production intent, which often uses statistical process controls and rigorous testing.

A designer will make a number of prototypes before deciding on a final version of a product. There are many reasons for this and some are written below.

1. Unlike a computer model, a prototype can be physically handled by the designer, a design team and potential customers.

2. Making a scaled prototype allows the designer / manufacturer to work out the method of construction/manufacture. This cannot be done accurately when using CAD.

3. Making a prototype allows the manufacturer to determine the 'flow' of production on a production line, in a factory.

4. Design errors are often detected when making a scaled model / prototype. Often design or manufacturing problems can be solved at this stage.

5. The designer can display the prototype at meetings and there is no need to rely on an expensive computer system.

6. A prototype can be tested by potential customers and focus groups.

7. A prototype can be used as an integral part of a questionnaire. A computer model is not as effective as a real life object, as it cannot be handled.

5.1 Rapid Prototyping

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. What is commonly considered to be the first RP technique, Stereo lithography, was developed by 3D Systems of Valencia, CA, USA. The company was founded in 1986, and since then, a number of different RP techniques have become available.

Rapid Prototyping has also been referred to as solid freeform manufacturing, computer automated manufacturing, and layered manufacturing. RP has obvious use as a vehicle for visualization. In addition, RP models can be used for testing, such as when an aerofoil shape is put into a wind tunnel. RP models can be used to create male models for tooling, such as silicone rubber moulds and investment casts. In some cases, the RP part can be the final part, but typically the RP material is not strong or accurate enough. When the RP material is suitable, highly convoluted shapes (including parts nested within parts) can be produced because of the nature of RP.

The reasons of Rapid Prototyping are

1. To increase effective communication.

2. To decrease development time.

3. To decrease costly mistakes.

4. To minimize sustaining engineering changes.

5. To extend product lifetime by adding necessary features and eliminating redundant features early in the design.

Rapid Prototyping decreases development time by allowing corrections to a product to be made early in the process.

By giving engineering, manufacturing, marketing, and purchasing a look at the product early in the design process, mistakes can be corrected and changes can be made while they are still inexpensive. The trends in manufacturing industries continue to emphasize the following:

1. Increasing number of variants of products.

2. Increasing product complexity.

3. Decreasing product lifetime before obsolescence.

4. Decreasing delivery time.

Rapid Prototyping improves product development by enabling better communication in a concurrent engineering environment.

5.2 Methodology of Rapid Prototyping

The basic methodology for all current rapid prototyping techniques can be summarized as follows:

1. A CAD model is constructed, then converted to STL format. The resolution can be set to minimize stair stepping.

2. The RP machine processes the .STL file by creating sliced layers of the model.

3. The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model.

4. The model and any supports are removed. The surface of the model is then finished and cleaned.

Figure 5.1: A Fused Decomposition Modeling rapid Prototyping Machine with the created objects

5.3 Freezing the Design

Freezing the design play a major role during product development (Eger et al. 2005). Many companies use high-level stage-gateway processes for new product development, where freezes mark the finishing of a development stage: for example, “specification freeze” defines the set of requirements the entire design will be based on, and “design freeze” describes the end point of the design phase at which a technical product description is handed over to production. Stage-gateway processes usually depict a single point for design freeze. A Gateway process is often used by organizations whose business is highly dependent on projects, as a means of controlling progress from one stage of a project to the next. Thus in the petrochemicals industry, organizations use a gateway process to ensure that the exploration stage is completed to everyone’s satisfaction before moving onto the drilling stage.

However, some systems, parts, features or parameters need to be frozen prior to the official design freeze: dependencies between parameters require early definition and long lead time items need to be completed ahead of time. A design sequence, strongly influenced by freezes evolve. It allows structuring and planning of the design process and is a major benefit of freeze. An aim of freezes is also the reduction of the likelihood of further engineering changes. For example, freezes avoid cost reductions that can be implemented in the next product generation. However, other changes like safety issues, problem corrections or new customer requests may still have to be included. Changes that need to be implemented after freeze may be more costly if tooling etc. is already in place. Quality control norms like ISO 9000 require a freeze point for change control to distinguish between the design phase and change implementation afterwards.

Product parts are rarely totally fluid until they are suddenly fixed at a freeze point. Parts are often "chilled", making changes less likely and more costly until the component reaches a point where it is only modified if the integrity of the product is jeopardized. A "chill" in this context signifies that the design of a part has been completed. When changes need to be carried out in a product architecture in which some parts have already been chilled or frozen, then a preferred implementation avoids changes to these parts.

Figure 5.2 shows a typical stage-gateway process that can be found in similar forms in industry. At least in theory the specifications are frozen before conceptual design begins, which in turn is frozen before detailed design starts. Before manufacturing can start the entire design needs to be frozen. However, reality is often far more fluid and processes can iterate across different stages. Freezes of the complete design or its details play a vital role throughout the entire design process, arising from within the company or coming from outside. Four freeze categories result that either address the product concept as a whole or part details in particular:

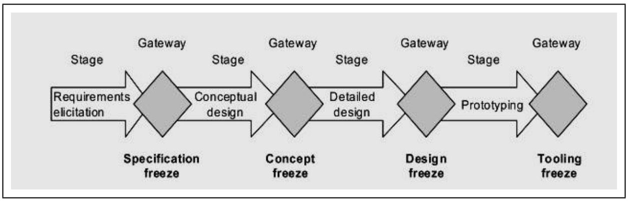


Figure 5.2: Stage-gateway process

- External conceptual freezes arise from customer requirements or tooling constraints.
- External detailed freezes include detailed customer specifications, lead times and the use of pre-defined parts like platform parts, legacy parts or standard components that need to be incorporated into the design.
- Internal conceptual freezes reflect the fundamental decisions made about the concept of the design throughout the iterative refinement of the product.
- Internal detailed freezes occur when components, features or parameters of parts are frozen at any time throughout the design process; this typically occurs as a means of structuring the design process.

In Figure 5.2, the term “design freeze” refers to one point in time at the end of the detailed design phase at which the final version of the technical drawings is signed off and released to production.

5.3.1 Freezes in The Product Hierarchy

Freezes occur on three levels of detail:

- **Product freezes :** as was indicated, the term design freeze is most commonly used in the literature to describe the definition of the whole product design at once. It is a single point in time that marks the end of the design phase.

- **Part freezes :** these refer to single parts or groups of parts that are frozen at the same time ("system freeze"). A typical freeze of a group of parts is a "style freeze" in the automotive industry. By this point in time, the interior design of a car is frozen, and the shape and the available room for all parts in the passenger cabin has been defined. Of course, such a freeze is done in conjunction with the engineers responsible for the separate parts. Individual parts are frozen at different times to allow for design continuation of dependent components. Part freezes are frequently driven by lead time. For example, in a car's interior design process, the airbag took the longest lead time and thus needed to be defined within a few months from starting work on the car, thus fixing many of the airbag's interface parameters.

- **Parameter freezes :** parts are not usually frozen at a single point in time. Instead, parameters, features and the interfaces to other parts are frozen individually before the whole part is approved. Key parameters that determine the performance, function and manufacturability of the whole part are usually set first. For example, while the material of a part may be decided early on to allow procurement, the exact part shape is only set later. Even the shape can be set in stages, as long as "metal-off" is possible, i.e. the part can be machined into its final form. Parameter freezes structure the design process. The dependency of key parameters sets a type of internal logic of the product, which governs process planning as well as decision ordering throughout the entire product. Without defining key parameters dependent decisions cannot be finalized.

5.4 Cost Analysis in Design

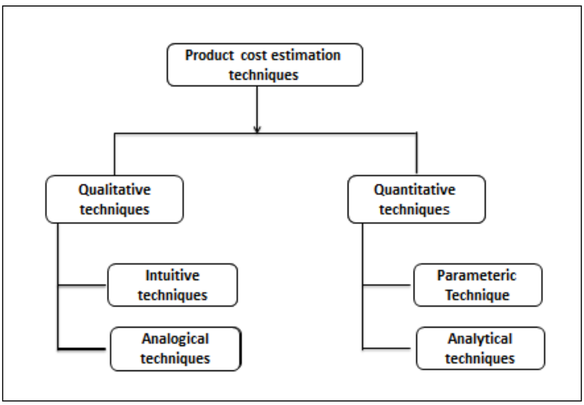


Figure 5.3: Product cost estimation technique

Cost estimation plays an important role in the product development cycle. Proper cost estimation will simplify the process to determine the profit that will be obtained, evaluation against competitors, and to simplify the investment of a new tool. There are many techniques that have been developed by researchers such as the one shown in Figure

5.3 (Niazi et al. 2006).

Qualitative cost estimation techniques are used for estimating costs by relying on the experience of the estimator (intuitive basis) or by searching for product similarity (analogy basis). On the other hand, quantitative cost estimation may be based on a detailed analysis of the product design. The latter technique consists of two kinds of approaches, i.e. parametric and analytical.

The difference between the parametric and the analytical technique lies on the level of the data completeness (Niazi et al. 2006).The analytical technique is based on a detailed analysis of the manufacturing process required.

The detailed cost data are collected from the smallest component level to an aggregate of the total product level. One of analytical techniques used is to identify high cost products through a feature-based cost estimation method. The method allows for the selection of a particular design or the form of a feature that is able to characterize the shape, geometry, tolerance, etc. which can be attributed to the manufacturing activity and its techniques. Since the feature itself plays an important role in the product design and manufacturing, it will be beneficial to use it as a basis for cost estimation. However, the cost of the product in the early stages of the design process is not easily calculated, because at this stage the final design has not been decided as yet, so a calculation of product complexity is required.

5.5 Considerations to Make Before Taking Idea from Prototype to Production

The role of the designer gets completed upon prototyping, then the product has to be taken to the customer. The product can be tangible hardware products or software applications or even procedural methodologies. When a consumer product is taken to mass production there are certain factors that needs to be taken care of, as given below.

1. **BOM (Bill of Materials).** What are the materials involved in the product? Paper or plastic? Metal or fabric? How many parts are in the product? Open market or custom fit? The factory partner involved is unlikely to share the cost breakdown, so the designer need to tap into every network available to compile this and decide if that is really worth it.

2. **MOQ (Minimum Order Quantity)**. The factory chosen gets a vote in the business. The designer will get a quote based on MOQs with volume price breaks that factor in time to set up and take down the project plus required labour and material resources with some profit margin for the factory. Sometimes MOQs are in the hundreds and negotiable.

3. **PO (Purchase Order).** To start the manufacturing factories ask for a third to half the total cost up front. When it's time to ship the goods, the rest is paid. It might be weeks or months before any sales attached to that investment is seen.

4. **Tooling.** If the design is with metals or plastics or even paper, the product might need tooling - a custom mould or fixture the factory uses to make product - that can cost anywhere from \$1,000 to \$200,000. The advantage with this is that the producer own this tooling.

5. **Quality.** The quality of the product has to be ensured when it is going from prototype to the product. It has to be kept in mind that the people doing mass production of the product need not know everything about the product like the developer or designer. Adequate care has to be taken while revealing the details of the product to the industry people. They should know whatever they need to know.

6. **Packaging**. If the product is destined for retail shelves, it will need packaging, and it should be good. It's not just what protects the product, it's the marketing pitch. Many companies spent more money for developing the packaging for their products than they do on the products. Packaging is a separate product that needs resources and time for. If product is needed to be shipped almost any distance, it needs to be protected with inside boxes.

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Chapter 6

Production Management

Industrial production constitutes the transformation of materials into a desirable output (Products). Production consists of a series of sequential operations to produce a desirable product acceptable to customer and meets the customer demand, with respect to the quality and intended function. Production is an organised activity which has got specific objectives. The efficiency of production system is stated in terms of its ability to produce the products with required quantity and specified quality at predetermined cost and pre-established time. Production planning and control is a tool available to the management to achieve the stated objectives. Thus, a production system is composed by the four factors, i.e., quantity, quality, cost and time. Production Planning starts with the analysis of the given data, i.e., demand for products, delivery schedule, etc., and on the basis of the information available, a scheme of utilisation of firms resources like machines, materials and men are worked out to obtain the target in the most economical way. Once the plan is prepared, then operations (execution of plan) are performed in line with the details given in the plan. Production control comes into action if there is any deviation between the actual and planned. The corrective action is taken so as to achieve the targets set as per plan by using control techniques. Thus production planning and control can be defined as the direction and coordination of firm's resources towards attaining the prefixed goals. Production planning and control helps to achieve uninterrupted flow of materials through production line by making available the materials at right time and required quantity.

Production planning is used in companies and in several different industries including agriculture, industry, amusement industry, etc.

Production planning is a plan for the future production, in which the facilities needed are determined and arranged. A production planning is made periodically for a specific time period, called the planning horizon. It can comprise the following activities:

- Determination of the required product combination and factory load to satisfy customer's needs.
- Matching the required level of production to the existing resources.
- Scheduling and choosing the actual work to be started in the manufacturing facility
- Setting up and delivering production orders to production facilities.
- Quality control and working on the customer feedback on goods

In order to develop production plans, the production planner or production planning department needs to work closely together with the marketing department and sales department. They can provide sales forecasts, or a listing of customer orders. The work is usually selected from a variety of product types which may require different resources and serve different customers. Therefore, the selection must optimize customer-independent performance measures such as cycle time and customer-dependent performance measures such as on-time delivery.

A critical factor in production planning is the accurate estimation of the productive capacity of available resources, yet this is one of the most difficult tasks to perform well. Production planning should always take into account material availability, resource availability and knowledge of future demand.

6.1 Production Scheduling

Scheduling is the process of arranging, controlling and optimizing work and workloads in a production process or manufacturing process. Scheduling is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials. It is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process.

In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff and on which equipment. Production scheduling aims to maximize the efficiency of the operation and reduce costs. Load charts illustrate the workload relative to the capacity of a resource. Table 6.1 shows the job schedule of different employees in a workshop against time in a day.

Table 6.1: Job Schedule in a typical workshop

<table>
<tr><th>MECHANIC</th><th>8 to 9</th><th>9 to 10</th><th>10 to 11</th><th>11 to 12</th><th>12 to 1</th><th>1 to 2</th><th>2 to 3</th><th>3 to 4</th><th>4 to 5</th></tr>
<tr><td>1</td><td colspan="3">Job A</td><td>Job G</td><td rowspan="5">Break</td><td colspan="4">Job I</td></tr>
<tr><td>2</td><td colspan="3">Job B</td><td>Job H</td><td colspan="2">Job J</td><td colspan="2">Job N</td></tr>
<tr><td>3</td><td colspan="2">Job C</td><td colspan="2">Job E</td><td colspan="2">Job K</td><td colspan="2">Job O</td></tr>
<tr><td>4</td><td colspan="2">Job D</td><td colspan="2">Job F</td><td>Job L</td><td colspan="3">Job M</td></tr>
<tr><td>5</td><td colspan="3">Job P</td><td>Job R</td><td colspan="2">Job Q</td><td colspan="2">Job S</td></tr>
</table>

6.2 Supply Chain Management

Supply chain management (SCM) is the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Interconnected or interlinked networks, channels and node businesses are involved in the provision of products and services required by end customers in a supply chain. Supply chain management has been defined as the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally.

SCM draws heavily from the areas of operations management, logistics, procurement, and information technology, and strives for an integrated approach.

6.2.1 The Supply Chain Idea

- The supply chain system contains three Elements:
  - Supply
  - Production
  - Distribution
- Supply chain includes all activities and processes to supply a product or service to a final customer.
- Any number of companies can be linked in the supply chain. Sometimes called the Value Chain.
- The total chain can have any number of supplier/customer relationships.
- The chain includes intermediaries such as wholesalers, warehouses, and retailers
- Product or services usually flow from supplier to customer and design and demand information usually flow from customer to supplier

6.2.2 Conventional Supply Chain

- Traditionally, management focused on internal operating issues, constraints and parameters. Suppliers were considered adversaries.

- Conflicts in traditional systems often appear because differing departments maximize departmental objectives without considering the impact to other parts of the system.

6.2.3 Growth of Supply Chain

- The first major change evolved through the explosive growth of Just-in-Time (JIT) concepts. Suppliers were viewed as partners

- The growth of the supply chain concept continues to be influenced by

  - The explosive growth in information technology,
  - Software applications (Enterprise Resource Planning) and the ability to link companies electronically (Internet)
  - Growth in global competition
  - Growth in Technology leads to dramatic reduction in product life cycles and the resulting design flexibility and ability to effectively communicate changes to suppliers and distributors.

6.2.4 The Present Status of Supply Chain

- Emphasis was on trust in the relationship, i.e. elimination of receiving inspection, reduction in administrative paperwork replaced with the exchange of electronic data, mutual analysis of cost reductions and shared benefits, and shared product design.

- To result an Optimal Performance, the supply chain of activities, from raw material to final customer, should be managed as an extension of the partnership. This implies three critical issues: flow of materials, flow of information electronically and fund transfers. More recently, the new trend is to manage the recovery, recycling and reuse of material.

- The need for SC Integration:

  - To manage a supply chain, efforts have to be taken to efficiently plan material and information flows to maximize cost efficiency, effectiveness, delivery, and flexibility.
  - This requires systems integration and revaluating performance measures. To maximize profit, objectives are set that provide better customer service, lowest production costs, lowest inventory investment, and lowest distribution cost.
  - Stress the need to supply customers with what they want when they want it and to keep inventories at a minimum

6.3 Inventory and Handling

Inventory or **stock** refers to the goods and materials that a business holds for the ultimate purpose of resale.

Inventory management is a science primarily about specifying the shape and percentage of stocked goods. It is required at different locations within a facility or within many locations of a supply network to precede the regular and planned course of production and stock of materials.

The scope of inventory management concerns the fine lines between replenishment lead time, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods, and demand forecasting. Balancing these competing requirements leads to optimal inventory levels, which is an on-going process as the business needs shift and react to the wider environment.

Inventory management involves a retailer seeking to acquire and maintain a proper merchandise assortment while ordering, shipping, handling, and related costs are kept in check. It also involves systems and processes that identify inventory requirements, set targets, provide replenishment techniques, report actual and projected inventory status and handle all functions related to the tracking and management of material. This would include the monitoring of material moved into and out of stockroom locations and the reconciling of the inventory balances. It also may include ABC analysis, lot tracking, cycle counting support, etc. Management of the inventories, with the primary objective of determining/controlling stock levels within the physical distribution system, functions to balance the need for product availability against the need for minimizing stock holding and handling costs.

6.3.1 Functions of Inventories

In batch manufacturing, the basic purpose of inventories is to separate supply and demand. Inventory serves as a buffer between: supply and demand, customer demand and finished goods, finished goods and component availability, requirements for an operation and the output from the preceding operation, and parts and materials to begin production and the suppliers of materials.

Anticipation inventories are built up in anticipation of future demand. Safety stock is held to cover random unpredictable fluctuations in supply and demand or lead-time. Its purpose is to prevent disruptions in manufacturing or deliveries to customers. Safety stock is also called buffer stock or reserve stock. Items purchased or manufactured in quantities greater than needed immediately create lot-size inventories, sometimes called cycle stock. It is the portion of inventory that depletes gradually as customers' orders come in and is replenished cyclically when suppliers' orders are received. Transportation inventories exist because of the time needed to move goods from one location to another such as from plant to a distribution center or a customer. They are sometimes called pipeline or movement inventories. Hedge inventory is purchased to minimize the market fluctuations of raw materials traded on the worldwide market. MRO items are used to support general operations and maintenance, but which do not become directly part of a product.

6.3.2 Objectives of Inventory Management

A firm wishing to maximize profit will have at least the following objectives: maximum customer service, low-cost plant operation, and minimum inventory investment. Inventories help to maximize customer service by protecting against uncertainty. If inventory is carried, there has to be a benefit that exceeds the costs of carrying that inventory. Someone once said that the only good reason for carrying inventory beyond current needs is if it costs less to carry it than not.

Inventories help make a manufacturing operation more productive in four ways:

1. Inventories allow operations with different rates of production of operate separately and more economically.

2. By levelling production, manufacturing can continually produce an amount equal to the average demand.

3. Inventories allow manufacturing to run longer production runs.

4. Inventories allow manufacturing to purchase in larger quantities, which results in lower ordering costs per unit and quantity discounts

Costs used for inventory management decisions are item cost (landed price), carrying costs, ordering costs, stock out costs, and capacity-associated costs

6.4 Material Handling

Raw materials/Inventory forms a critical part of manufacturing as well as service organization. In any organization, a considerable amount of material handling is done in one form or the other. This movement is either done manually or through an automated process. Throughout material, handling processes significant safety and health; challenges are presented to workers as well as management. Therefore, manual material handing is of prime concern for health and safety professional, and they must determine practical ways of reducing health risk to the workers.

Manual material handling ranges from movement of raw material, work in progress, finished goods, rejected, scraps, packing material, etc. These materials are of different shape and sizes as well as weight. Material handling is a systematic and scientific method of moving, packing and storing of material in appropriate and suitable location. The main objectives of material handling are as follows:

- It should be able determine appropriate distance to be covered.
- Facilitate the reduction in material damage as to improve quality.
- Reducing overall manufacturing time by designing efficient material movement
- Improve material flow control
- Creation and encouragement of safe and hazard-free work condition
- Improve productivity and efficiency
- Better utilization of time and equipment

It is critical for manufacturing organization to identify importance of material handling principle as the critical step in promoting the job improvement process. Manual material handling significantly increases health hazard for the workers in from lower back injuries.

In the current competitive and globalized environment, it is important to control cost and reduce time in material handling. An efficient material handling process promotes:

- Design of proper facility layout

- Promotes development of method which improves and simplifies the work process
- It improves overall production activity.
- Efficient material handling reduces total cost of production.

6.5 Manufacturing/Construction

Manufacturing is the production of merchandise for use or sale using labour and machines, tools, chemical and biological processing, or formulation. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as aircraft, household appliances or automobiles, or sold to wholesalers, who in turn sell them to retailers, who then sell them to end users and consumers.

Manufacturing takes turns under all types of economic systems. In a free market economy, manufacturing is usually directed toward the mass production of products for sale to consumers at a profit. In a collectivist economy, manufacturing is more frequently directed by the state to supply a centrally planned economy. In mixed market economies, manufacturing occurs under some degree of government regulation.

Modern manufacturing includes all intermediate processes required for the production and integration of a product's components. Some industries, such as semiconductor and steel manufacturers use the term *fabrication* instead.

The manufacturing sector is closely connected with engineering and industrial design. Examples of major manufacturers in North America include General Motors Corporation, General Electric, Procter & Gamble, General Dynamics, Boeing, Pfizer and Precision Cast parts. Examples in Europe include Volkswagen Group, Siemens and Michelin. Examples in Asia include Sony, Huawei, Lenovo, Toyota, Samsung and Bridgestone. Some of the major manufacturing companies in India are Ashok Leyland, Bajaj Auto, TVS Motors, Hero Motor Ltd., Apollo Tyres, Asian Paints, BPL Group, Videocon Group, Larsen & Toubro and Jindal Steel

Additive manufacturing is a recently evolved manufacturing technique that is very effective in making specific custom parts of complicated geometry. Additive Manufacturing (AM) is an appropriate name to describe the technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or one day.....human tissue.

Common to AM technologies is the use of a computer, 3D modelling software (Computer Aided Design or CAD), machine equipment and layering material. Once a CAD sketch is produced, the AM equipment reads in data from the CAD file and lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object. The term AM encompasses many technologies including subsets like 3D Printing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), layered manufacturing and additive fabrication.

AM application is limitless. Early use of AM in the form of Rapid Prototyping focused on preproduction visualization models. More recently, AM is being used to fabricate end-use products in aircraft, dental restorations, medical implants, automobiles, and even fashion products.

While the adding of layer-upon-layer approach is simple, there are many applications of AM technology with degrees of sophistication to meet diverse needs including:

- A visualization tool in design
- A means to create highly customized products for consumers and professionals alike
- As industrial tooling
- To produce small lots of production parts
- Production of human prosthetic implants

6.6 Storage

Industrial goods/products are stored for further use in warehouses. A warehouse is a commercial building for storage of goods. Warehouses are used by manufacturers, importers, exporters, wholesalers, transport businesses, customs, etc. They are usually large plain buildings in industrial areas of cities, towns and villages. They usually have loading docks to load and unload goods from trucks. Sometimes warehouses are designed for the loading and unloading of goods directly from railways, airports, or seaports. They often have cranes and forklifts for moving goods, which are usually placed on ISO standard pallets loaded into pallet racks. Stored goods can include any raw materials, packing materials, spare parts, components, or finished goods associated with agriculture, manufacturing and production. In Indian

English a warehouse may be referred to as a godown. In industries whose goods require a period of maturation between production and retail, such as viniculture and cheese making, warehouses can be used to store the goods in large quantities.

6.6.1 Warehousing Management

In a factory, warehouses contain raw materials, work-in-process inventory, finished goods, supplies and possibly repair parts. The objective of a warehouse is to minimize cost and maximize customer service.

The costs of operating a warehouse can be broken down into capital and operating costs. Capital costs are those of space and materials handling equipment. The major operating cost is labour, and the measure of labour productivity is the number of units that an operator can move in a day.

The efficient operation of the warehouse depends upon how well the processing activities are performed. These activities include receive goods, identify the goods, dispatch goods to storage, hold goods, pick goods, marshal the shipment, dispatch the shipment, and operate an information system .

To maximize productivity and minimize cost, warehouse management must work to maximize space utilization and to use labour and equipment effectively. The effective use of warehouses is influenced by cube utilization and accessibility, stock location, order picking and assembly, and packaging.

6.7 Physical Distribution

6.7.1 Introduction

Physical distribution is the movement of materials from the producer to the consumer. This movement of materials is divided into two functions: Physical supply is the movement and storage of goods from suppliers to manufacturing. Physical distribution is the movement and storage of finished goods from the end of production to the customer. The particular path in which the goods move – through distribution centers, wholesalers, and retailers – is called the channel of distribution.

A channel of distribution is one or more companies or individuals who participate in the flow of goods and/or services from the producer to the final user or consumer. The transaction channel is concerned with the transfer of ownership. Its function is to negotiate, sell, and contract. The distribution channel is concerned with the transfer or delivery of the goods or services.

To extend markets requires a well-run distribution system. Distribution adds place value and time value by placing goods in markets where they are available to the consumer at the time the consumer wants them. The specific way in which materials move depends upon many factors, some of which are the channels of distribution that the firm is using, the types of markets served, the characteristics of the product, and the type of transportation available to move the material.

6.7.2 Physical Control and Security

The objective of distribution management is to design and operate a distribution system that attains the required level of customer service and does so at least cost. To reach this objective, all activities involved in the movement and storage of goods must be organized into an integrated system.

In a distribution system, six interrelated activities affect customer service and cost of providing it: Transportation, Distribution inventory, Warehouses (distribution centers), Materials handling, Protective packaging and Order processing and communication.

The objective of distribution management is to provide the required level of customer service at the least total system cost. Management must treat the system as a whole and understand the relationships among the activities.

6.7.3 Interfaces

The "marketing mix" is made up of product, promotion, price, and place, and the latter is created by physical distribution. Marketing is responsible for transferring ownership. Physical distribution is responsible for giving the customer possession of the goods and does so by operating distribution centers, transportation systems, inventories, and order processing systems. Physical distribution contributes to creating demand. Prompt delivery, product availability, and accurate order filling are important competitive tools in promoting a firm's products. The distribution system is a cost, so its efficiency and effectiveness influence the company's ability to price competitively. All of these affect company profits.

Physical supply establishes the flow of material into the production process. The service level must usually be very high because the cost of interrupted production schedules caused by raw material shortage is usually enormous. Cost and availability or transportation for raw materials to the factory and the movement of finished goods to the market-place are important factors in factory site selection. Unless a firm is delivering finished goods directly to a customer, demand on the factory is created by the distribution centre orders and not directly by the final customer. This can have severe implications on the demand pattern and the efficiency at the factory.

6.7.4 Transportation

The carriers of transportation can be divided into five basic modes: Rail, Road (including trucks, buses, and automobiles), Air, Water (including ocean going, inland, and coastal ships), and Pipeline. Each mode has different cost and service characteristics.

To provide transportation service, any carrier, whatever mode, must have certain basic physical elements, ways, terminals, and vehicles. Ways are the paths over which the carrier operates. Terminals are places where carriers load and unload goods to and from vehicles and make connections between local pickup and delivery service and line-haul service. Vehicles of various types are used in all modes except pipelines. They serve as carrying and power units to move the goods over the ways.

Carriers are legally classified as public (for hire) or private (not for hire). In the latter, individuals or firms own or lease their vehicles and use them to move their own goods. Public transport, on the other hand, is in the business of hauling for others for pay. All modes of transport have public and for-hire carriers. For-hire carriers are subject to economic regulation by federal, state, or municipal governments. Economic regulation has cantered on three areas: regulation of rates, control of routes and service levels, and control of market entry and exit. Private carriers are not subject to economic regulation but, like public carriers, are regulated in such matters as public safety, license fees, and taxes. A for-hire carrier may carry goods for the public as a common carrier or under contract to a specified shipper as a contract carrier.

6.7.5 Packaging

The basic role of packaging in any industrial organization is to carry the goods safely through a distribution system to the customer. The package must do the following: identify the product, contain and protect the product and contribute to physical distribution efficiency. There are usually at least three levels of packaging required in a distribution system, primary package, shipping container, and unit load.

Unitization is the consolidation of several units into large units, called unit loads, so there is less handling. A unit load is a load made up of a number of items, or bulky material, arranged or constrained so the mass can be picked up or moved as a single unit too large for manual handling. The most common unit-load is the pallet. To get the highest cube utilization in the capacity of pallets, trucks or other vehicles, and warehouses, there should be some relationship between the dimensions of the product, the primary package, the shipping cartons, the pallet, the truck, and the warehouse space.

6.8 Marketing

The final step in the operations management process is marketing. Marketing is about communicating the value of a product, service or brand to customers or consumers for the purpose of promoting or selling that product, service, or brand. The oldest – and perhaps simplest and most natural form of marketing – is 'word of mouth' (WOM) marketing, in which consumers convey their experiences of a product, service or brand in their day-to-day communications with others. These communications can of course be either positive or negative.

In for-profit enterprise the main purpose of marketing is to increase product sales and therefore the profits of the company. In the case of non-profit marketing, the aim is to increase the take-up of the organization's services by its consumers or clients. Governments often employ social marketing to communicate messages with a social purpose, such as a public health or safety message, to citizens. In for-profit enterprise marketing often acts as a support for the sales team by propagating the message and information to the desired target audience. Marketing techniques include choosing target markets through market analysis and market segmentation, as well as understanding consumer behavior and advertising a product's value to the customer. From a societal point of view, marketing provides the link between a society's material requirements and its economic patterns of response.

Marketing satisfies these needs and wants through the development of exchange processes and the building of long-term relationships. Marketing can be considered a marriage of art and applied science (such as behavioral sciences) and makes use of information technology. Marketing is applied in enterprise and organizations via marketing management techniques.

6.9 Feed-back on Design

It is for the customers that the design is made. Due care has to be taken to understand his needs and tastes. If at the end of the design process the customer interest changes then product design and production process becomes a waste. A thorough survey of the customer needs, tastes and mood is therefore necessary not only before the product development but during as well as while marketing the product or when he is using it.

Customer surveys can be through internet services or through interaction between the sales person and the customer at the retail outlet .Business Process Outsourcing units does this work day in and day out. This data gathered goes to the designer and the manufacturer for correction or up gradation. If a mistake is caught by a customer then the product management would have to pay a heavy price as their reputation would go at stake.

6.10 Standardization

The implementation of standards in industry and commerce became highly important with the onset of the Industrial Revolution and the need for high-precision machine tools and interchangeable parts. Henry Maudslay developed the first industrially practical screw-cutting lathe in 1800, which allowed for the standardization of screw thread sizes for the first time.

Maudslay's work, as well as the contributions of other engineers, accomplished a modest amount of industry standardization; some companies' in-house standards spread a bit within their industries. Joseph Whitworth's screw thread measurements were adopted as the first (unofficial) national standard by companies around the country in 1841. It came to be known as the British Standard Whitworth, and was widely adopted in other countries.

Standardization is a process of defining and applying the conditions necessary to ensure that given range of requirements can normally be met with a minimum of variety and in a reproducible and economic manner on the basis of the best current techniques. The other two words associated with standardization are:

- Simplification - A process of reducing types of products within a definite range.
- Specialization - A process where in particular firms concentrate on the manufacture of the limited number of product types.

Objectives of Standardization

- Interchangeability of parts, components, etc.
- Keeping the variety minimum.
- Helps to achieve a better control due to reduced variety.

Advantages

- Reduction of waste and obsolescence .
- Reduction in inventory.
- Reduced effort in book keeping and accounting.
- Standardization reduces the price because of economy of scale.
- Ease in procurement because of availability.
- Reduction in maintenance and repair costs.

The standardization can be described by the following category windows:

- Physical dimensions and tolerance of components with a definite range.
- Rating of machines and equipment (energy, speed, voltage, temperature, etc.).
- Methods of testing characteristics.
- Performance standards.
- Specification of properties of material (Physical and chemical).
- Methods of safety considerations.
- Methods of installation to comply with precautionary measures and convenience of use.

Simplification is a point of controversy between the production and marketing departments. Production department is in favour of minimum of variety as it reduces the number of set ups required, hence, utilisation of production facilities is increased and can be able to produce the component at the reduced cost compared to more variety.

Marketing argues that the higher variety helps them to sell more as it helps them to meet the needs of the larger customer groups. Thus, a balance is struck between the two in order to arrive at the optimum variety of types of products to be manufactured. The advantages of simplification (minimum variety) are:

1. Reduce inventories of materials and component parts.
2. Reduced investments in plant and machinery.
3. Reduced space requirements of storage.
4. Ease of planning and control.
5. Reduction in selling price.
6. Simplification of inspection and control.

The disadvantages are:

1. Not able to meet the needs of wide range of customer preferences.
2. Possibility of losing orders to competitors.
3. Creates a constant source of conflict between marketing and production.

Example of using standardized parts is mobile phone .Mobile phones are products that are used all over the world .The number of mobile subscribers in India is about to touch 1 billion by 2016.Therefore it is expected to have certain standard spare parts so that both the user and manufacturer are at convenience.

All mobile phones have a number of features in common, but manufacturers also try to differentiate their own products by implementing additional functions to make them more attractive to consumers. This has led to great innovation in mobile phone development over the past 20 years.

The common components found on all phones are:

- A battery, providing the power source for the phone functions.
- An input mechanism to allow the user to interact with the phone. The most common input mechanism is a keypad, but touch screens are common now
- Basic mobile phone services to allow users to make calls and send text messages.
- All GSM phones use a SIM card to allow an account to be swapped among devices. Some CDMA devices also have a similar card called an R-UIM.
- Individual GSM, WCDMA, iDEN and some satellite phone devices are uniquely identified by an International Mobile Equipment Identity (IMEI) number.
- All mobile phones are designed to work on cellular networks and contain a standard set of services that allow phones of different types and in different countries to communicate with each other.

However, they can also support other features added by various manufacturers over the years:

- Roaming which permits the same phone to be used in multiple countries, providing that the operators of both countries have a roaming agreement.

- Send and receive data and faxes (if a computer is attached), access WAP services, and provide full Internet access using technologies such as GPRS.

- Applications like a clock, alarm, calendar and calculator and a few games.

- Sending and receiving pictures and videos (by without internet) through MMS, and for short distances with e.g. Bluetooth.

- In Multimedia phones Bluetooth is commonly but important Feature.

- GPS receivers integrated or connected (i.e. using Bluetooth) to cell phones, primarily to aid in dispatching emergency responders and road tow truck services.

- Push to talk, available on some mobile phones, is a feature that allows the user to be heard only while the talk button is held, similar to a walkie-talkie.

Irrespective of the manufacturers a phone has got these features and some, even more.

A very common standardized unit in a phone is the SIM card. GSM mobile phones require a small microchip called a Subscriber Identity Module or SIM card, to function. The SIM card is approximately the size of a small postage stamp and is usually placed underneath the battery in the rear of the unit. The SIM securely stores the service-subscriber key

(IMSI) used to identify a subscriber on mobile telephony devices (such as mobile phones and computers). The SIM card allows users to change phones by simply removing the SIM card from one mobile phone and inserting it into another mobile phone or broadband telephony device.

A SIM card contains its unique serial number, internationally unique number of the mobile user (IMSI), security authentication and ciphering information, temporary information related to the local network, a list of the services the user has access to and two passwords (PIN for usual use and PUK for unlocking). The standardization achieved in SIM is a very good example of how systems manufactured at different places can be used on a common network of different service providers.

Exercise:

Prepare a list of standard items used in any engineering specialization. Develop any design with over 50% standard items as parts.

[Hint: Think of a simple consumer product of daily use. It could be a food processing unit to make a particular food item. Develop a hand sketch of the product. Think about what all parts can be standardized.]

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Chapter 7

Design for 'X'

7.1 Introduction to Design for 'X'

DF'X' techniques are part of detail design and are ideal approaches to improve life-cycle cost, quality, increased design flexibility, and increased efficiency and productivity using the concurrent design concepts. Benefits are usually pinned as competitiveness measures, improved decision-making, and enhanced operational efficiency. The letter "X" in DFX is made up of two parts: life-cycle processes x and performance measure (ability).

The DF'X' family is one of the most effective approaches to implement concurrent engineering. DF'X' focuses on vital business elements of concurrent engineering, maximizing the use of the limited resources available to the team.

1. Design for manufacture / construction

2. Design for assembly

3. Design for quality

4. Design for maintenance

5. Design for safety
6. Design for handling
7. Design for logistics
8. Design for reliability
9. Design for dis-assembly
10. Design for recycling
11. Design for re-engineering

7.2 Design for Manufacturing /Construction (DFM)

For decades engineers have seen a large amount of effort devoted to the integration of design and manufacture, for reducing manufacturing cost and improving product quality. The processes and procedures that have been developed have become known as design for manufacture or design for manufacturability (DFM). Associated with this is the closely related area of design for assembly (DFA). The field is often simply described by the abbreviation DFM/DFA or DFMA. DFMA methods should be applied during the embodiment stage of design. Design for manufacture represents an awareness of the importance of design as the time for thoughtful consideration of all steps of production. To achieve the goals of DFM requires a concurrent engineering team approach in which appropriate representatives from manufacturing, including outside suppliers, are members of the design team from the start.

7.2.1 DFM Guidelines

DFM guidelines are statements of good design practice that have been empirically derived from years of experience. These guidelines helps to narrow the range of possibilities so that the mass of detail that must be considered is within the capability of the designer.

1. **Minimize total number of parts**

   Eliminating parts results in great savings. A part that is eliminated costs nothing to make, assemble, move, store, clean, inspect, rework, or service. A part is a good candidate for elimination if there is no need for relative motion, no need for subsequent adjustment between parts, and no need for materials to be different. However, part reduction should not go so far that it adds cost because the remaining parts become too heavy or complex. The best way to eliminate parts is to make minimum part count a requirement of the design at the conceptual stage of design. Combining two or more parts into integral design architecture is another approach. Plastic parts are particularly well suited for integral design. Fasteners are often prime targets for part reduction. Another advantage of making parts from plastics is the opportunity to use snap-fits instead of screws.

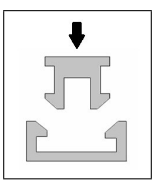


Figure 7.1: Snap Fit

2. **Standardize components:**

   Costs are minimized and quality is enhanced when standard commercially available components are used in design. The benefits also occur when a company standardizes on a minimum number of part designs (sizes, materials, processes) that are produced internally in its factories. The life and reliability of standard components may have already been established, so cost reduction comes through quantity discounts, elimination of design effort, avoidance of equipment and tooling costs, and better inventory control.

3. **Use common parts across product lines:**

   It is good business sense to use parts in more than one product. Specify the same materials, parts, and sub-assemblies in each product as much as possible. This provides economies of scale that drive down unit cost and simplify operator training and process control. Product data management (PDM) systems can be used to facilitate retrieval of similar designs.

4. **Standardize design features:**

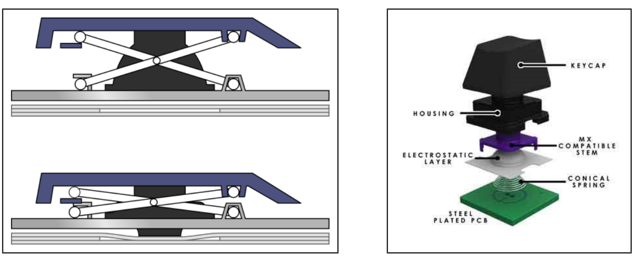
   Standardizing on design features like drilled hole sizes, screw thread types, and bend radii minimizes the number of tools that must be maintained in the tool room. This reduces manufacturing cost.

5. **Aim to keep designs functional and simple:**

   Achieving functionality is paramount, but don't specify more performance than is needed. It is not good engineering to specify a heat-treated alloy steel when plain carbon steel will achieve the performance with a little bit more careful analysis. When we add features to the design of a component, have a firm reason for the need. The product with the fewest parts, the least intricate shapes, the fewer precision adjustments, and the lowest number of manufacturing steps will be the least costly to manufacture. Also, the simplest design will usually be the most reliable and the easiest to maintain.

Figure 7.2: Apple I pod - An example of functional and simple designs

6. **Design parts to be multifunctional:**



(a) Switch eliminated coil spring by structure

(b) Switch with conical spring

Figure 7.3: New Computer keypad

A good way to minimize part count is to design such that parts can fulfill more than one function, leading to integral architecture. For example, a part might serve as both a structural member and a spring; the part might be designed to provide a guiding, aligning, or self-fixturing feature in assembly.

7. **Design parts for ease of fabrication:**

   The least costly material that satisfies the functional requirements should be chosen. It is often the case that materials with higher strength have poorer workability .Thus, one pays more for a higher-strength material, and it also costs more to process it into the required shape. Since machining to shape tends to be costly, manufacturing processes that produce the part to near net shape are preferred whenever possible so as to eliminate or minimize machining. It is important to be able to visualize the steps that a machine operator will use to make a part so that you can minimize the manufacturing operations needed to make the part. For example, clamping a part before machining is a time consuming activity, so design to minimize the number of times the operator will be required to reorient the part in the machine to complete the machining task. Re-clamping also is a major source of geometric errors. Consider the needs for the use of fixtures and provide large solid mounting surfaces and parallel clamping surfaces.

8. **Avoid excessively tight tolerances:**

   Tolerances must be set with great care. Specifying tolerances that are tighter than needed will increase the cost. These come about from the need for secondary finishing operations like grinding, honing, and lapping, from the cost of building extra precision into the tooling, from longer operating cycles because the operator is taking finer cuts, and from the need for more skilled workers. Before selecting a manufacturing process, be sure that it is capable of producing the needed tolerance and surface finish. As a designer, it is important to maintain your credibility with manufacturing concerning tolerances. If in doubt that a tolerance can be achieved in production, always communicate with manufacturing experts. Never give a verbal agreement to manufacturing that they can loosen a tolerance without documentation and making the change on the part drawing. Also, be careful about how the statement for blanket tolerances on the drawing is worded and might be misinterpreted by manufacturing.

9. **Minimize secondary and finishing operations:**

   Minimize secondary operations such as heat treatment, machining, and joining and avoid finishing operations such as deburring, painting, plating, and polishing. Use only when there is a functional reason for doing so. Machine a surface only when the functionality requires it or if it is needed for aesthetic purposes.

10. **Utilize the special characteristics of processes:**

    Be alert to the special design features that many processes provide. For example, moulded polymers can be provided with colours can replace metals that needed to be painted or plated. Aluminium extrusions can be made in intricate cross sections that can then be cut to short lengths to provide parts. Powder-metal parts can be made with controlled porosity that provides self-lubricating bearings.

7.3 Design for Assembly (DFA)

Once parts are manufactured, they need to be assembled into sub-assemblies and products. The assembly process consists of two operations, handling, which involves grasping, orienting, and positioning, followed by insertion and fastening. There are three types of assembly, classified by the level of automation. In manual assembly a human operator at a workstation reaches and grasps a part from a tray, and then moves, orients, and pre-positions the part for insertion. The operator then places the parts together and fastens them, often with a power tool. In automatic assembly, handling is accomplished with a parts feeder, like a vibratory bowl, that feeds the correctly oriented parts for insertion to an automatic work-head, which in turn inserts the part. In robotic assembly, the handling and insertion of the part is done by a robot arm under computer control.

The cost of assembly is determined by the number of parts in the assembly and the ease with which the parts can be handled, inserted, and fastened. Design can have a strong influence in both areas. Reduction in the number of parts can be achieved by elimination of parts (e.g., replacing screws and washers with snap or press fits, and by combining several parts into a single component).

Ease of handling and insertion is achieved by designing so that the parts cannot become tangled or nested in each other, and by designing with symmetry in mind. Parts that do not require end-to-end orientation prior to insertion, as a screw does, should be used if possible. Parts with complete rotational symmetry around the axis of insertion, like a washer, are best.

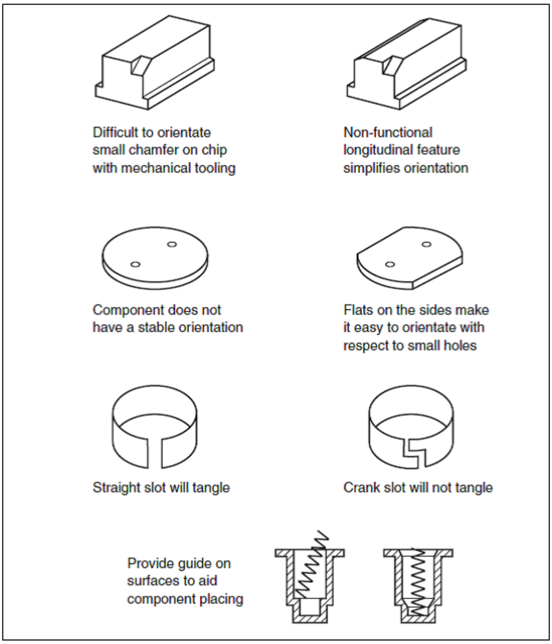


Figure 7.4: Few examples that improves DFA

When using automatic handling it is better to make a part highly asymmetric if it cannot be made symmetrical. For ease of insertion, a part should be made with chamfers or recesses for ease of alignment, and clearances should be generous to reduce the resistance to assembly. Self-locating features are important, as is providing unobstructed vision and room for hand access. Some examples have shown in figure 7.4.

7.3.1 DFA Guidelines

1. **Minimize the total number of parts:**

   A part that is not required by the design is a part that does not need to be assembled. Go through the list of parts in the assembly and identify those parts that are essential for the proper functioning of the product. All others are candidates for elimination. The criteria for an essential part, also called a theoretical part, are:

   (a) The part must exhibit motion relative to another part that is declared essential.

   (b) There is a fundamental reason that the part be made from a material different from all other parts.

   (c) It would not be possible to assemble or disassemble the other parts unless this part is separate that is it is an essential connection between parts.

   (d) Maintenance of the product may require dis-assembly and replacement of a part.

   (e) Parts used only for fastening or connecting other parts are prime candidates for elimination.

   Designs can be evaluated for efficiency of assembly with equation shown below, where the time taken to assemble a "theoretical" part is taken as 3 seconds.

$$Design\, assembly\, efficiency = \frac{3 \times N}{T}$$

   where,

   $N = theoretical\ minimum\ number\ of\ parts$

$T = Total\, assembly\, time$

A theoretical part is one that cannot be eliminated from the design because it is needed for functionality. Typical first designs have assembly efficiencies of 5 to 10 percent, while after DFA analysis it is typically around 20 to 30 percent.

2. **Minimize the assembly surfaces:**

   Simplify the design so that fewer surfaces need to be prepared in assembly, and all work on one surface is completed before moving to the next one.

3. **Use sub-assemblies:**

   Sub-assemblies can provide economies in assembly since there are fewer interfaces in final assembly. Sub-assemblies can also be built and tested elsewhere and brought to the final assembly area. When sub-assemblies are purchased they should be delivered fully assembled and tested. Products made from sub-assemblies are easier to repair by replacing the defective sub-assembly.

4. **Mistake-proof the design and assembly:**

   An important goal in design for assembly is to ensure that the assembly process is unambiguous so that the operators cannot make mistakes in assembling the components. Components should be designed so that they can only be assembled one way. The way to orient the part in grasping it should be obvious. It should not be capable of being assembled in the reverse direction. Orientation notches, asymmetrical holes, and stops in assembly fixtures are common ways to mistake-proof the assembly process.

7.3.2 Guidelines for Handling

1. **Avoid separate fasteners or minimize fastener costs:**

   Fasteners may amount to only 5 percent of the material cost of a product, but the labour they require for proper handling in assembly can reach 75 percent of the assembly costs. The use of screws in assembly is expensive. Snap fits should be used whenever possible. When the design permits, use fewer large fasteners rather than several small ones. Costs associated with fasteners can be minimized by standardizing on a few types and sizes of fasteners, fastener tools, and fastener torque settings. When a product is assembled with a single type of screw fastener it is possible to use auto-feed power screwdrivers.

2. **Minimize handling in assembly:**

   Parts should be designed to make the required position for insertion or joining easy to achieve. Since the number of positions required in assembly equates to increased equipment expense and greater risk of defects, quality parts should be made as symmetrical as their function will allow. Orientation can be assisted by design features that help to guide and locate parts in the proper position. Parts that are to be handled by robots should have a flat, smooth top surface for vacuum grippers, or an inner hole for spearing, or a cylindrical outer surface for gripper pickup.

7.3.3 Guidelines for Insertion

1. **Minimize assembly direction:**

   All products should be designed so that they can be assembled from one direction. Rotation of an assembly requires extra time and motion and may require additional transfer stations and fixtures. The best situation in assembly is when parts are added in a top-down manner to create a z-axis stack.

2. **Provide unobstructed access for parts and tools:**

   Not only must the part be designed to fit in its prescribed location, but there must be an adequate assembly path for the part to be moved to this location. This also includes room for the operator's arm and tools, which in addition to screwdrivers, could include wrenches or welding torches. If a worker has to go through contortions to perform an assembly operation, productivity and possibly product quality will suffer after a few hours of work.

3. **Maximize compliance in assembly:**

   Excessive assembly force may be required when parts are not identical or perfectly made. Allowance for this should be made in the product design. Designed-in compliance features include the use of generous tapers, chamfers, and radii. If possible, one of the components of the product can be designed as the part to which other parts are added (part base) and as the assembly fixture. This may require design features that are not needed for the product function.

7.4 Design for Quality (DFQ)

Quality is the most effective factor a company can use in the battle for customers. To be competitive, we must satisfy the customer. In order to be more competitive, we must delight the customer. Quality is defined here as the measure of customer satisfaction. Note that customer satisfaction is a region on the scale of customer satisfaction. To satisfy the customer, we must design for quality.

Figure 7.5: DFQ Strategy

Design for quality (DFQ) is a modern, scientific approach that formalizes product design, automates manual testing, and streamlines troubleshooting. It uses a systematic approach to ensure quality by developing a thorough understanding of the compatibility of a finished product to all of the components and processes involved in manufacturing that product. Instead of relying on finished product testing alone, DFQ provides insights upstream throughout the development process. As a result, a quality issue can be efficiently analyzed and its root cause quickly identified. DFQ requires identification of all critical formulation attributes and process parameters as well as determining the extent to which any variation can impact the quality of the finished product. The more information generated on the impact – or lacks of impact – of a component or process on a product's quality, safety or efficacy, the more business flexibility Quality by Design provides.

7.4.1 Checklist for DFQ

1. Correctness of Drawing
2. Drawings complete with Respect to Functional Tolerance
3. Process Capability been incorporated while selecting Tolerances
4. Assembly Build Criteria been defined
5. Interference Analysis been performed
6. Identify the Critical dimensions for assembly
7. Tolerances been maximized for required Assembly
8. Tolerances been optimized for least cost
9. PPM Estimate meeting our Business Profitability Objective
10. Provide dimensional verification plan

7.5 Design for Maintenance

Design for Maintenance is an approach to influence the maintenance activities through the design of the equipment. This set of guidelines serves as a tool to apply Design for Maintenance in practice. The guidelines describe various ways how these future maintenance activities can be influenced. Applying the guidelines can help to reduce the number of maintenance activities, to make them easier to execute or to decrease the logistic support time that is required for them.

7.5.1 Guidelines to Enhance Maintainability

1. Use materials that do not prolong maintenance activities avoid non-corrosion resistant materials in moist environments.

2. Use standard, universally applicable components they are widely understood, what makes it likely that they are easy to maintain or that technicians know how to maintain them.

3. Use fasteners that accelerate maintenance activities in the ideal situation, no tools are required to open or remove components.

4. Ensure that the operators of installations are also able to maintain them.

5. Provide sufficient space around the maintenance points Maintenance personnel should be able to execute maintenance with good posture

6. Design equipment in such a way that it can only be maintained in the right way an unambiguous design induces that no mistakes can be made when executing maintenance.

7. Components that are regularly replaced need to be easy to handle Standard size and weight, no sharp edges and easy to transport.

8. Guarantee safety by the design itself Instead of using warning labels and colour codes.

9. Design modular systems Modular systems enable complete replacement of a broken module to repair it at a different place.

10. Use standard interfaces To enable quick connection between modules and sub-systems

11. Design the weakest link every system has a weakest link, which should be a relatively cheap and easily replaceable component.

12. Position components that often need to be maintained at an easily accessible place Location of components could be based on the number of times they need to be maintained Position the maintenance points close to each other. The maintenance location is known beforehand.

7.6 Design for Safety

Designers can make decisions that significantly reduce the risks to safety and health during the development stage and during subsequent use and maintenance. They are therefore a key contributor to construction health and safety. As a designer can directly influence safety. Designers must take account of the General Principles of Prevention when preparing designs. The Principles of Prevention are a hierarchy or risk elimination and reduction. The concept supports the view that along with quality, programme and cost; safety is determined during the design stage.

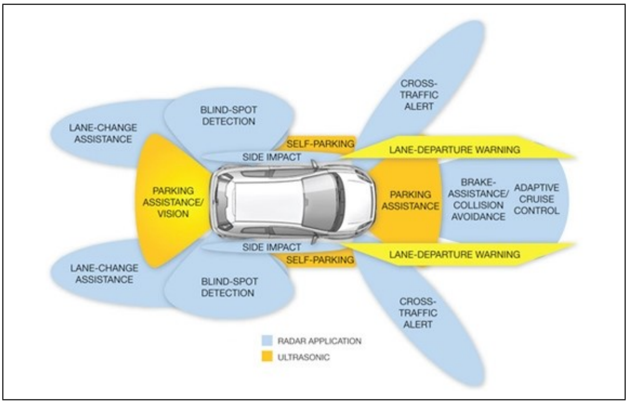


Figure 7.6: Safety systems in a latest car

7.6.1 The General Principles of Prevention

The General Principles of Prevention are set out in descending order of preference as follows:

1. Avoid risks.
2. Evaluate unavoidable risks.
3. Combat risks at source.
4. Adapt work to the individual, especially the design of places of work
5. Adapt the place of work to technical progress.
6. Replace dangerous articles, substances, or systems of work by non-dangerous or less dangerous articles, substances, or systems

7. Use collective protective measures over individual measures
8. Develop an adequate prevention policy
9. Give appropriate training and instruction to employees.

7.7 Design for Handling

Design for handing is integral to the design of most production systems since the efficient flow of material between the activities of a production system is heavily dependent on the arrangement (or layout) of the activities. If two activities are adjacent to each other, then material might easily be handed from one activity to another. If activities are in sequence, a conveyor can move the material at low cost. If activities are separated, more expensive industrial trucks or overhead conveyors are required for transport. The high cost of using an industrial truck for material transport is due to both the labour costs of the operator and the negative impact on the performance of a production system (e.g., increased work in process) when multiple units of material are combined into a single transfer batch in order to reduce the number of trips required for transport.

7.7.1 The Unit Load Concept

A unit load is either a single unit of an item, or multiple units so arranged or restricted that they can be handled as a single unit and maintain their integrity. Although granular, liquid, and gaseous materials can be transported in bulk, they can also be contained into unit loads using bags, drums, and cylinders. Advantages of unit loads are that more items can be handled at the same time (thereby reducing the number of trips required and, potentially, reducing handling costs, loading and unloading times, and product damage) and that it enables the use of standardized material handling equipment. Disadvantages of unit loads include the negative impact of batching on production system performance, the time spent forming and breaking down the unit load, the cost of containers/pallets and other load restraining materials used in the unit load, and the cost of returning empty containers/pallets to their point of origin.

7.7.2 In-process Handling

Unit loads can be used both for in-process handling and for distribution (receiving, storing, and shipping).Unit load design involves determining the type, size, weight, and configuration of the load; the equipment and method used to handle the load; and the methods of forming (or building) and breaking down the load. For in-process handling, unit loads should not be larger than the production batch size of parts in process. Large production batches (used to increase the utilization of bottleneck activities) can be split into smaller transfer batches for handling purposes, where each transfer batch contains one or more unit loads, and small unit loads can be combined into a larger transfer batch to allow more efficient transport.

7.7.3 Distribution

Selecting a unit load size for distribution can be difficult because containers/pallets are usually available only in standard sizes and configurations; truck trailers, rail boxcars, and airplane cargo bays are limited in width, length, and height; and the number of feasible container/pallet sizes for a load may be limited due to the existing warehouse layout and storage rack configurations and customer package/carton size and retail store shelf restrictions. Also, the practical size of a unit load may be limited by the equipment and aisle space available and the need for safe material handling.

7.8 Design for Logistics

Design for logistics is a series of concepts in the field of supply chain management involving product and design approaches that help to control logistics costs and increase customer service levels. Design for Logistics uses product design to address logistics costs.

7.8.1 Key Concepts of Design for Logistics

1. **Economic packaging and transportation**

    (a) Design products so that they can be efficiently packed and stored

    (b) Design packaging so that products can be consolidated at cross docking points

    (c) Design products to efficiently utilize retail space

2. **Concurrent/Parallel Processing**

   (a) Objective is to minimize lead times
   (b) Achieved by redesigning products so that several manufacturing steps can take place in parallel
   (c) Modularity/Decoupling is key to implementation
   (d) Enables different inventory levels for different parts

3. **Mass Customization**
   (a) Predictability of Demand
   (b) Predictability of Operations
   (c) Inventory levels
   (d) Equipment capacity requirements
   (e) Increase in the number of components and hence in the number of suppliers

7.9 Design for Reliability (DFR)

Design for Reliability (DFR) is not a new concept, but it has begun to receive a great deal of attention in recent years. All reliability professionals are familiar with the terms "Weibull Analysis and/or Life Data Analysis". In fact, for many, these analysis techniques have become almost synonymous with reliability and achieving high reliability. The reality, though, is that although life data analysis is an important, performing just this type of analysis is not enough to achieve reliable products. Rather, there are a variety of activities involved in an effective reliability program and in arriving at reliable products. Achieving the organization's reliability goals requires strategic vision, proper planning, sufficient organizational resource allocation and the integration and institutionalization of reliability practices into development projects.

Design for Reliability, however, is more specific than these general ideas. It is actually a process. Specifically, DFR describes the entire set of tools that support product and process design (typically from early in the concept stage all the way through to product obsolescence) to ensure that customer expectations for reliability are fully met throughout the life of the product with low overall life-cycle costs. In other words, DFR is a systematic, streamlined, concurrent engineering program in which reliability engineering is weaved into the total development cycle. It relies on an array of reliability engineering tools along with a proper understanding of when and how to use these tools throughout the design cycle. This process encompasses a variety of tools and practices and describes the overall order of deployment that an organization needs to follow in order to design reliability into its products.

Three important statements summarize the best practice reliability philosophy of successful companies:

1. Reliability must be designed into products and processes using the best available science-based methods.

2. Knowing how to calculate reliability is important, but knowing how to achieve reliability is equally, if not more, important.

3. Reliability practices must begin early in the design process and must be well integrated into the overall product development cycle.

Understanding when, what and where to use the wide variety of reliability engineering tools available will help to achieve the reliability mission of an organization. And this is becoming more and more important with the increasing complexity of systems as well as the complexity of the methods available for determining their reliability. System interactions, interfaces, complex usage and stress profiles need to be addressed and accounted for. With such increasing complexity in all aspects of product development, it becomes a necessity to have a well defined process for incorporating reliability activities into the design cycle. Without such a process, trying to implement all of the different reliability activities involved in product development can become a chaotic situation, where different reliability tools are deployed too late, randomly, or not at all, resulting in the waste of time and resources as well as the occurrence of problems in the field.

7.9.1 Guidelines to Enhance Reliability

1. Design-out moving parts Unnecessary movements need to be avoided

2. Avoid unnecessary components Limit the number of components by eliminating the non-essential ones

3. Avoid non-rigid parts / avoid rigid parts Use tubes instead of hoses / use hoses instead of tubes

4. Design for under stressed use in normal situations, the system is used at less than full capacity

5. Provide redundancy Standby systems or components can take over the operation when necessary

6. Over-design components Dimension critical components larger than minimally required

7. Choose materials that can withstand environmental influences The equipment should withstand the environmental conditions in which it is used
8. Do not use coated, painted or plated components They need to be maintained to keep them in good condition
9. Use components and materials with verified reliability Proven technology minimises the chance of unexpected system behaviour
10. Design robust interfaces between components The interaction between components has a strong influence on the reliability of the system
11. Use parallel subsystems and components Systems containing parallel subsystems, each with the same function, are less likely to fail completely
12. Distribute workload equally over parallel subsystems or components Wear, and therefore behaviour, of both systems or components will be the same

7.10 Design For Dis-assembly and Recycling (DFD & DFR)

Design for Dis-assembly (DFD) is the process of designing products so that they can easily, cost-effectively and rapidly take apart at the end of the product's life so that components can be reused and/or recycled.

When designing products with dis-assembly in mind, there are three important factors which must be considered by the designer:

1. The selection and use of materials
2. The design of components and product architecture
3. The selection and use of fasteners

In addition to this, the choice of recycling/recovery methods used at the product's end of life can partly determine the recyclability of the product. The resources used in packaging the product can sometimes be factored in.

7.10.1 Material Selection

Studies into vehicle recyclability suggest that the limiting factor in the economic recycling of complex assemblies found in vehicles (e.g. instrument panels, headlight clusters) is the separation into pure material streams – either manually or mechanically. For manual separation to be carried out there must be a significant value retained in the recycled product in order for the separation to be economically feasible. This scenario is applicable to most other products constructed from sub-assemblies consisting of a variety of materials. Different guidelines apply, depending on whether manual or mechanical separation is carried out.

Reduced separation times for dis-assembly can be achieved through the careful selection of materials. Indeed some parts may not require dis-assembly at all if they are made from the same or similar materials. It can be seen that having materials which are compatible with compatible fixings/attachments greatly increases the product's recyclability, while incompatible materials, non-dismountable surface attachments and factors reducing recycling performance increase the steps required for recycling, making it both costly and resourceintensive. In some cases it is just not economically feasible to carry out recycling as the resources required to carry this out far exceed the actual material value of the product. In an ideal situation, the assembly would be constructed from a single material, although this is rarely case. The shortest "path" towards material recycling is the next best target, and this will largely depend on the material compatibility.

7.10.2 Guidelines for Dis-assembling and Recycling

1. Unplated metals are more recyclable than plated ones.

2. Low alloy metals are more recyclable than high alloy ones.

3. Most cast irons are easily recycled.

4. Aluminium alloys, steel, and magnesium alloys are readily separated and recycled from automotive shredder output.

5. Contamination of iron or steel with copper, tin, zinc, lead, or aluminium reduces recyclability.

6. Contamination of aluminium with iron, steel, chromium, zinc, lead, copper or magnesium reduces recyclability.

7. Contamination of zinc with iron, steel, lead, tin, or cadmium reduces recyclability.

The selection of materials should in no way compromise the structural requirements of the design. If the properties of a specific material meet the requirements for the design better than others, then it would be an obvious choice (not taking cost into account). However, analogous reasoning should allow the designer to find a material that is widely used in a different context (and is therefore relatively easy to store, recycle and transport) and apply it to the design problem in question.

Regulated/restricted materials often have legislation stating that they MUST be recycled, or at least separated/removed from host assemblies before disposal. It is far easier and more economical to avoid these materials where possible, especially those which pose a safety or environmental risk.

Materials should be marked according to standards (e.g. ISO 1043) for identification purposes. Markings which are moulded into the part are preferable because no additional manufacturing processes are required, although they should not create a stress concentration on the part.

If more than one material is used within an assembly, they should be made from a similar material or at least be easily separable so that they can be recycled individually. Laminates are usually difficult to separate and should ideally be made from recycling-compatible materials.

The use of materials with different properties can be beneficial during the separation/sorting process; the use of magnetic and non-magnetic materials within an assembly, for example, takes advantage of large-scale robotic dis-assembly machinery. Separation by density is common for plastics – it is recommended that a 0.03 specific gravity difference between polymers is maintained. It is down to the designer's ingenuity to select appropriate materials for this.

7.10.3 Component Design & Product Architecture

Design for Dis-assembly through component design and product architecture shares many of the principles used in design for assembly. Designers should:

1. Minimize the number of components used in an assembly, either by integrating parts or through system re-design

2. Minimize the number of material types used in an assembly

3. Separate working components into modular sub-assemblies

4. Construct sub-assemblies in planes which do not affect the function of the components

5. Avoid using laminates which require separation prior to re-use

6. Avoid painting parts as only a small percentage of paint can contaminate and prevent an entire batch of plastic from being recycled.

7.10.4 Use of Fasteners

Fasteners play an integral part in the joining of components and sub-assemblies. Designers should:

1. Minimize the number of fasteners used within an assembly.

2. Minimize the types of fastener used within an assembly.

3. Standardize the fasteners used.

4. Not compromise the structural qualities of the assembly by using too few or inadequate fasteners.

5. Use snap-fits where possible to eliminate the need for a fastener

6. Consider work-hardening, fracture, fatigue failure and general wear when designing snap-fits.

7. Consider the use of destructive fasteners or those incorporating ADSM technology.

7.10.5 Checklist of DFD

1. Choose recycling-compatible materials (as far as possible).

2. Avoid using materials which require separating before recycling (re-use is OK, subject to performance testing).

3. Use as few components and component types as possible (without compromising the structural integrity or function of the product).

4. Integrate components (which relate to the same function) where possible.

5. Standardize the use of fasteners – use commonly available parts and maintain consistency within the design.

6. Make components easily separable.

7. Apply non-contaminating markings (e.g. through etching or moulding) to materials for ease of sorting.

8. Maintain good access to components and fasteners. Consider making the plane of access to components the same for all components.

9. Do not paint plastic parts or other coatings which may contaminate other plastics when recycled.

10. Consider the use of ADSM technology for non-temperature-critical products.

7.11 Design for Re-engineering

Business process re-engineering (BPR) is a business management strategy, originally pioneered in the early 1990s, focusing on the analysis and design of work-flows and business processes within an organization. BPR aimed to help organizations fundamentally rethink how they do their work in order to dramatically improve customer service, cut operational costs, and become world-class competitors. In the mid-1990s, as many as 60% of the Fortune 500 companies claimed to either have initiated re-engineering efforts, or to have plans to do so.

BPR seeks to help companies radically restructure their organizations by focusing on the ground-up design of their business processes. According to Davenport (1990) a business process is a set of logically related tasks performed to achieve a defined business outcome. Re-engineering emphasized a holistic focus on business objectives and how processes related to them, encouraging full-scale recreation of processes rather than iterative optimization of sub processes.

Exercise

Explain the design of a bicycle with reference to modularity,safety & reliability.

Solution

A bicycle is defined as a two-wheeled vehicle having a rear drive wheel solely human-powered; or a two-or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts (1 h.p.), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 pounds, is less than 20 mph.

DESIGN FOR SAFETY

- A bicycle may not have unfinished sheared metaledges or other sharp parts that may cut a rider'shands or legs. Sheared metal edges must berolled or finished to remove burrs or feathering

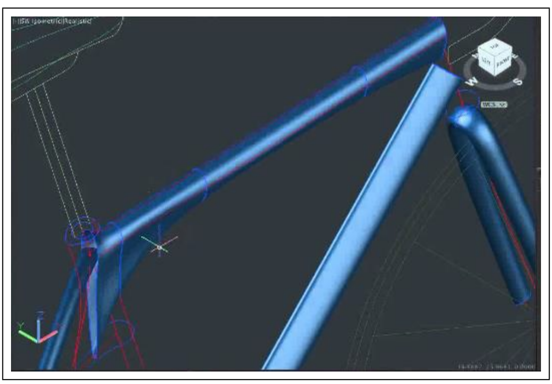


Figure 7.7: Bicycle with no sharp edges

- When the bicycle is tested for brakingor road performanceneither the frame, nor anysteering part, wheel, pedal, crank, or brakingsystem part may show a visible break.
- Screws, bolts, and nuts used to fasten parts maynot loosen, break, or fail
- Control cables must be routed so that they do notfray from contact with fixed parts of a bicycle orwith the ends of the cable sheaths. The ends ofcontrol cables must be capped or treated so that they do not unravel.

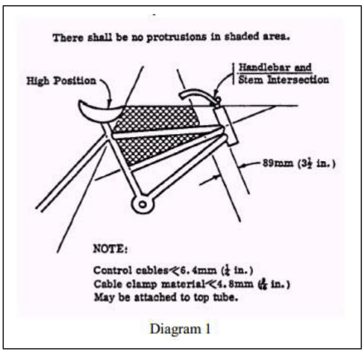


Figure 7.8: No protrusions

- The seat post must have a permanent mark orcircle showing the minimum depth that the postmust be inserted into the bicycle frame.
- Each wheel must have a positive locking devicethat fastens it to the frame.
- The ends of the handlebars must be capped orcovered.
- Foot brake/ hand brake combinations:thecycle should have a disc brake system ,the foot brake lever should

be there on the inclined bar on the bicycle.Ifone break system fails the other can be used to stop the bicycle

- To make sure that motorists can see bicycleriders at night, bicycles (other than sidewalkbicycles) must have a combination of reflectors.

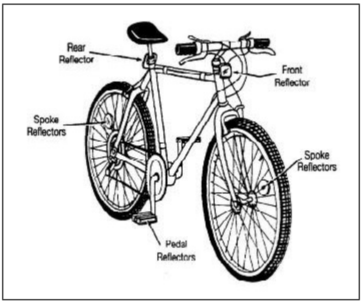


Figure 7.9: Reflectors needed

- Foot brake/ hand brake combinations:Thecycle should have a disc brake system ,the foot brake lever should be there on the inclined bar on the bicycle.If one break system fails the other can be used to stop the bicycle.

Figure 7.10: Need of brakes

- The bicycle should have shock absorber so that the rider do not feel jerk while riding

Figure 7.11: Shock Absorbers needed

DESIGN FOR MODULARITY

Modular design, or "modularity in design", is a design approach that subdivides a system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces. Besides reduction in cost (due to less customization, and shorter learning time), and flexibility in design, modularity offers other benefits such as augmentation (adding new solution by merely plugging in a new module), and exclusion.

Some of the modular design of components are:

- Frame

  The rods of the frame can made telescopic.

  Spherical balls with projections aligned at desired angles are given at each joints.

  The helical threads inside the balls and that of the connections are given unique colours for easy identification.

Figure 7.12: Modular frame

- Handles

Figure 7.13: Modular frame

- Pedals:The pedals are also attached to the main frame by simple screw mechanism.
- The **seats** as well as is attached by screwing mechanism.
- The **rim** of a cycle is made into different small blocks which when assembled, forms the required shape. A small inner projection is given inside.

Figure 7.14: Modular Rim

- The **bells** are attached near the handles by some simple sliding mechanism. A 'T' shaped cavity is given on the handles and an ' -'shaped structure is given at the bottom of the bell. Then the bell is just locked by inserting the bell into the top portion of the cavity and sliding it downwards.

Figure 7.15: Modular bell

- The **mud guard** can be attached to the main frame by some snap fit mechanism.

Figure 7.16: Modular mud guard

- The **brakes** are attached safely to the frame by using simple and proper joints.

Figure 7.17: Modular brakes

Concluding, modularity helps the common man in repairing bicycle, as the modular parts can be suitably replaced at apropriate physical location.

DESIGN FOR RELIABILITY

Reliability of bicycle covers the following areas:

- Unnecessary movements need to be avoided.
- Limit the number of components by eliminating non-essential ones
- . Avoid non-rigid parts.
- Design for under stressed use in normal situations; the bicycle is used at less than full capacity.
- Critical components should be designed larger than minimal requirement.
- The components should withstand environmental conditions in which it is used.
- Use of components and materials with verified reliability.

- Proven technologies minimize the chance of system failure.
- Design robust interfaces between components.
- The interaction between components has strong influence on reliability.
- Distribution of workload equally over the components ensuring same behavior from all the components.

Tubeless Tyres

The accident due to sudden air leakage in case of puncture is the main problem dealt with tyres. Actually the tyre is not affected but the tube inside the tyre is torn off and causes air leakage. To eliminate this scenario tubeless tyres are introduced. It is light weight, more durable and air leakage is prevented. If possible filling of nitrogen gas instead of compressed air provides cooling for the tyre and easy movement

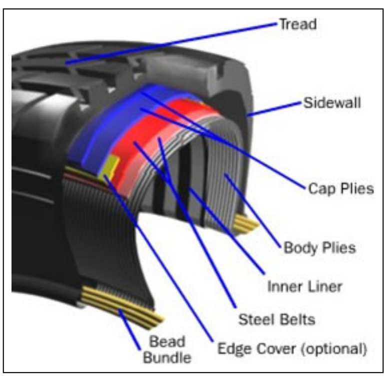


Figure 7.18: Tubeless tyre

Chainless Arrangement

One of the main problems during cycling is slipping of chain. Most of the cycle accidents are caused by this reason. This crucial problem can be resolved by introducing chainless gear mechanism. In the gear mechanism a small gear is attached to the center shaft of the back tyre. There is a gear connected to pedal such that when we rotate the pedal the gear also rotates. There is another big gear placed in between them. When we rotate the pedal the gear attached to the pedal will also rotate, it leads to the rotation of big gear and it leads to the rotation of gear that attached to the wheel. This help in the rotation of bicycle wheel.

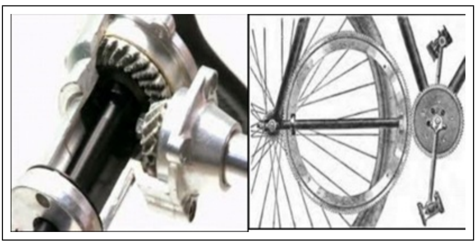


Figure 7.19: Gear instead of chain

High Strength Low Weight Body

CARBON FIBRE- Carbon fiber, a composite material is an increasingly popular non-metallic material commonly used for bicycle frames. It is light weight, corrosion resistant and strong and can be formed into almost any shape desired. The result is a frame that can be fine-tuned for specific strength where it is needed while allowing flexibility in other frame section. Many racing bicycle built for individual time trial races and traditional employee composite construction because the frame can be shaped with a aerodynamic profile not possible with cylindrical tubes .Other materials besides carbon fiber such as metallic boron, can be added to the matrix to enhance stiffness. Some carbon fiber frames use cylindrical tubes that are joined with adhesive and lugs, in a method somewhat analogous to a lugged steel frames. It has also been suggested that these materials are vulnerable to fatigue failure, a process which occur with use over a long period of time.

Figure 7.20: C fibre frame

Chapter 8

Product Attributes

The product development styles can be broadly divided into two realms, namely Product Centered Design and User Centered Design (UCD)

8.1 Product Centred Design

A product centric organization is one that is focused on the products it brings to market rather than the customers that buy those products.

It looks to develop new products by leveraging technology or specialized skills that exist in the company. It starts by looking internally at its capabilities rather than externally at what needs are not being met.

In large complex organizations a product focus provides management with direct line of site into which products are selling well, at what profit and clear product owner accountability. While it does simplify the management of a firm it does come at a cost. It tends to create concealed or siloed organizations that compete for customers and often lacks a coordinated approach. In fact many of the poor customer experiences happen as a result of this internal/product focus. The other downside is a myopic vision of the market that blindsides companies to key changes.

Product focused companies define themselves by their products. For example Kodak® originally defined itself as being in the photo processing business. This definition impacted the culture of the company because when the shift to digital came, Kodak resisted this because of the impact on its products – photo processing.

8.2 User Centred Design

User-centred design (UCD) is a framework of processes (not restricted to interfaces or technologies) in which the needs, wants, and limitations of end users of a product, service or process are given extensive attention at each stage of the design process. User-centred design can be characterized as a multi-stage problem solving process that not only requires designers to analyse and foresee how users are likely to use a product, but also to test the validity of their assumptions with regard to user behaviour in real world tests with actual users at each stage of the process from requirements, concepts, pre-production models, mid production and post-production creating a circle of proof back to and confirming or modifying the original requirements. Such testing is necessary as it is often very difficult for the designers of a product to understand intuitively what a first-time user of their design experiences, and what each user's learning curve may look like.

The chief difference from other product design philosophies is that user-centred design tries to optimize the product around how users can, want, or need to use the product, rather than forcing the users to change their behaviour to accommodate the product.

8.2.1 UCD Models and Approaches

For instance, the user-centred design process can help software designers to fulfill the goal of a product engineered for their users. User requirements are considered right from the beginning and included into the whole product cycle. These requirements are noted and refined through investigative methods including: ethnographic study, contextual inquiry, prototype testing, usability testing and other methods. Generative methods may also be used including: card sorting, affinity diagramming and participatory design sessions. In addition, user requirements can be inferred by careful analysis of usable products similar to the product being designed.

The ISO standard describes 6 key principles that will ensure a design is user centred:

- The design is based upon an explicit understanding of users, tasks and environments.
- Users are involved throughout design and development.
- The design is driven and refined by user-centered evaluation.
- The process is iterative.
- The design addresses the whole user experience.

- The design team includes multidisciplinary skills and perspectives.

8.2.2 Benefits of User-Centred Design

8.2.2.1 Customer Experience

A customer experience is the holistic experience that customers perceive as they interact with every facet of a product or service. Individual experiences add up to form a concept, which becomes the product's "brand." If a user experiences poor technical support, or a sales person was rude, the user is likely to develop a negative perception of that product's brand. In turn, the customer will likely tell his or her friends and family about his or her experience to discourage them from purchasing the product and having a similar negative experience. The same chain reaction happens with positive customer experiences. People love to share positive experiences with brands to convince friends and family to try a new product or service.

8.2.2.2 Employee Productivity

When re-designing the customer experience, it is a good idea to also evaluate how the change may affect employees of the organization. Conduct user research on employees from a variety of departments – not only the employees who have direct interactions with customers – as any change to the customer experience has the potential to impact all employees in an organization.

The level of employee productivity, with respect to a specific task or set of tasks, is often based on the tools that employees use to perform job-related tasks. In many cases, a software application or website is one of those tools. As employees use these tools to do their job, they develop a perception of each tool's user experience and level of usability. For instance, as an employee looks up customer records or creates a sales transaction, the experience will have an impact on how they feel about their job, the company they work for, i.e., the brand they perceive, and ultimately, this will influence the way they treat other people, including co-workers, managers, and customers. Table 6.1 shows the comparison between a product centric and market centric approach(Shah et al. 2006).

Table 8.1: Comparison between a product centric and market centric approach

Strategic Questions	Product - Centric Approach	Customer - Centric Approach
What is the underlying philosophy?	Sell products; sell to whoever will buy	Serve customers; all decisions based on customer level opportunities.
What is the business approach?	Transaction oriented.	Relationship oriented.
How should the product be positioned?	Highlight product features and advantages.	Highlight product's benefits in terms of meeting individual customer needs

How is the organization structured?	Product based profit centres, managers, sales team.	Customer –based segment centres, segment sales team, customer relationship managers.
What is the strategic focus?	Internally focused, new product development, new account development, market share growth; customer relations addressed by marketing department.	Externally focused, customer relationship development, profitability through customer loyalty; employees are customer advocates
How is performance measured?	Number of new products, profitability per product, market share by product/sub-brands.	Share of Wallet (SOW) of customers, customer satisfaction, CLV, customer equity.
What is the management criteria?	Portfolio of products.	Portfolio of customers.

How is selling approached?	How many customers can we sell this product to?	How many products can we sell to this customer?
Source: Adapted from Den'sh Shah, et al., "The Path to Customer Centricity", Journal of Service Research 9(2): 113-124.		

8.3 Bridging the Two Approaches

The future for companies is to balance this product focus with a customer focus so that customers feed directly into decision making and are not an afterthought. The right balance between product and customer centric marketing comes from an understanding of the buyer experience. When we know how the buyers/customers think at every stage of their interaction with the organization, we can easily determine how to market to them.

While many organizations default to product-centric approaches because they don't have the marketing resources to spin up market leadership through big ideas, many others make it so hard for potential buyers to figure out what they do that they end up disappearing before they become prospects. The marketing approach should focus on marketing the right product features to the audience that will understand the benefits. Our marketing intelligence determines how well we can target prospects, and will make or break our entire marketing approach.

A very popular device where product centred design has transferred into user centred design is the smart phone. Smartphones are designed so that the user can use the phone like a PC. He /She can personalize it according to tastes. The same device lets us call people, send text messages, browse the net , edit documents ,set remainders, take pictures, send and share the photos, use as a torch, watch movies and many other utilities.

Initially when mobile phones were launched in the market it could only be used for making calls and sending text messages. But later as technology developed more and more features based on the use of customers came into being. Android is the most popular platform for the Operating System of Smart Phones. Android is a mobile operating system (OS) currently developed by Google, based on the Linux kernel and designed primarily for touchscreen mobile devices such as smartphones and tablets. Android's user interface is mainly based on direct manipulation, using touch gestures that loosely correspond to real-world actions, such as swiping, tapping and pinching, to manipulate on-screen objects, along with a virtual keyboard for text input. Current Smart Phones are very user friendly and have become a must-own device for everyone.

8.4 Aesthetics and Ergonomics

Aesthetics is concerned with how things look. This can be influenced by an object's appearance and its style. The appearance of an object is the feature that people notice first. In some ways appearance can be very personal and is influenced by things like the materials from which the object is made and the type of finish applied to its surface. It is important that products have visual appeal. In a world where many new products function in a similar way, it is often the appearance which sells the product. Aesthetics is a pan of design which is difficult to analyse and describe in words. However there are aspects of appearance which can be considered separately.

There are many different things that contribute to the overall perception of a product, and to the opinion as to whether it is aesthetically pleasing to the observer.

Table 8.2: Elements of Aesthetics

Vision	Hearing	Touch	Taste	Smell
Colour	Loudness	Texture	Strength	Strength
Shape	Pitch	Shape	Sweetness	Sweetness
Pattern	Beat	Weight	Sourness	Pleasantness
Line	Repetition	Comfort	Texture	
Texture	Melody	Temperature		
Visual weight	Pattern	Vibration		
Balance	Noise	Sharpness		
Scale		Ease of use		
Movement				

The opinion about a product may also be influenced by certain associations that are important to the person, such as:

- How fashionable it is?
- Whether it is a novelty, or an old favourite?
- Whether it is a symbol of wealth or love?
- How much danger or risk is involved?

- If it provides a link with your past?

8.4.1 Consideration of Aesthetics in Design

There are four different 'pleasure types' to consider:

- Physio-pleasure

  Pleasure derived from the senses from touch, smell, sensual pleasure etc. For example the smoothness of a curve in a hand-held product or the smell of a new car.

- Socio-pleasure

  Pleasure gained from interaction with others. This may be a 'talking point' product like a special ornament or painting, or the product may be the focus of a social gathering such as a vending machine or coffee machine. This pleasure can also come from a product that represents a social grouping, for example, a particular style of clothing that gives you a social identity.

- Psycho-pleasure

  Pleasure from the satisfaction felt when a task is successfully completed. Pleasure also comes from the extent to which the product makes the task more pleasurable, such as the interface of an ATM cash machine that is quick and simple to use. It is closely related to product usability.

- Ideo-pleasure

  Pleasure derived from entities such as books, art and music. This is the most abstract pleasure. In terms of products, it is the values that a product embodies, such as a product that is made of eco-friendly materials, and processes that convey a sense of environmental responsibility to the user.

8.4.2 Visual Aesthetics

Visual aesthetics is made up of two words visual and aesthetics. According to the Oxford English Dictionary (OED) 2, visual pertains to vision or that which proceeds from sight, while aesthetics is defined as the philosophy of theory of taste, or the perception of the beautiful in nature or art. Therefore, visual aesthetics refers to the perception of beauty, or taste that is motivated by sight. Some of the fields where the study of visual aesthetics or aesthetics (as used in a more general context to represent the study of beauty for various forms of art, including music, dance, poetry and nature) has been central include Philosophy, Arts, Psychology, History, Communication/Media, and more recently, Human-Computer Interaction. Early work in aesthetics reveals an overwhelming overlap across disciplines, especially in dated fields of Philosophy, Art, Psychology and History making clear cut demarcations between fields less obvious. The quest for a discipline which most appropriately accommodates aesthetics and its various theories has been a long standing problem.

While aestheticians who are philosophers have been concerned with reasoning about aesthetic theories and attempting to establish facts about the characteristics of beauty and works of art, artists have been more concerned with the production and study of the aesthetics of various pieces of art such as paintings, literature, poetry, and music. Psychologists who study aesthetics have been more interested in the response of mind to aesthetic objects, and have therefore sought to understand the mental realm of people.

Figure 8.1: An aesthetically designed chair by Guido Lanari and Jesica Vicente of Glid Studio(Geneva, Switzerland).

8.4.3 Definition of Ergonomics

- Ergonomics or human factors are the scientific discipline concerned with the understanding of interactions among humans and other elements of a system.
- It deals with the scientific study of relationship between the humans and its environment.

An ergonomically designed toothbrush has a broad handle for easy grip, a bent neck for easier access to back teeth, and a bristle head shaped for better tooth surface contact. Ergonomic design has dramatically changed the interior appearance of automobiles. The steering wheel once a solid awkward disc is now larger and padded for an easier, more comfortable grip. Its center is removed to improve the view of the instruments on the dashboard. Larger, contoured seats, adjustable to suit a variety of body sizes and posture preferences, have replaced the small, upright seats of the early automobiles. Equipped with seat belts and airbags that prevent the face and neck from snapping backwards in the event of a collision, modern automobiles are not only comfortable but they are also safer. Virtually, all automotive and component manufacturers already recognize ergonomics as an important part of the vehicle design process.

The role ergonomics plays in improving productivity and quality has been well documented although generally not well recognized. In most cases, ergonomics interventions have been reactive, i.e. initiated only after an injury has occurred and after losses have been sustained to both the organization and the worker(s). The opportunities for profitability that present themselves at the start of a manufacturing program production line, however, have been less apparent. The proactive evaluation of a new product and manufacturing process at the design stage, i.e. before losses occur, is of paramount importance. Ideally, these activities should occur with a fundamental need to support the productivity and profitability goals of the organization.

8.4.4 Case Study: Ergonomics for Computer Workstation

Ergonomics for computer workstation can generally be split into two parts. The first part is learning about good work posture and habits which involves applying ergonomic principles. The second part of computer workstation ergonomics is either adjusting the workplace equipment such as the monitor, chair, desk, lighting to make it more 'ergonomic' or considering the purchase of ergonomic computer furniture.

Obviously when designing products for people you must take into account their physical size, weight, reach and movement. In order to do this you will need data relating to human dimensions.

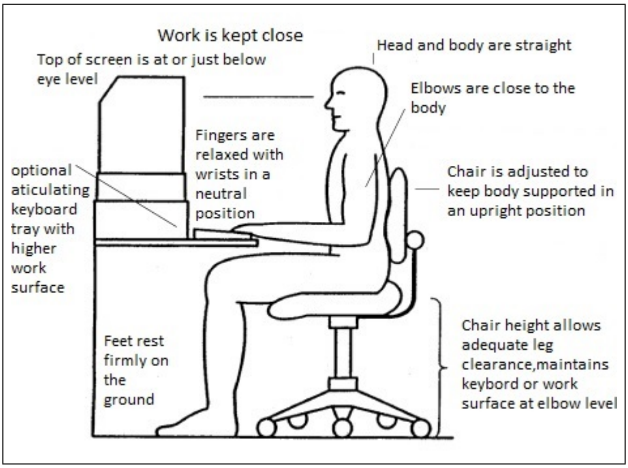


Figure 8.2: Ergonomically designed computer table

Anthropometry: Data on human dimensions can be found in tables of anthropometric data. Anthropometric data is available on all aspects of human dimension e.g. height, arm length and distance between the eyes. This data is available for men and women and for different age groups. As people are all different sizes it is necessary to select data which is appropriate to the design situation. For example consider the height of a doorway. Obviously to find this dimension we must consider the height of people.

The graph (figure 8.3) shows the range of heights of men and the number of men at each height. It is seen that few men are very small i.e. 1.5 m. few men are very tall i.e. 2 m. However there are large numbers of men who are around average height i.e. 1.75 m.

A first hand thought may tell us that choosing the height of the doorway is from the size of the tallest man but this is not the case. The chances of the largest person in the world using the doorway are so slim that it is not practical to use this size for a door. In fact when designers require upper dimensions as in the case of the doorway they ignore the upper 5%. The dimension chosen is called the 95th percentile (Figure 8.3). Similarly if the designer requires to consider small individuals they ignore the smallest 5%. The dimension used is called the 5^{th} percentile (Figure 8.3).

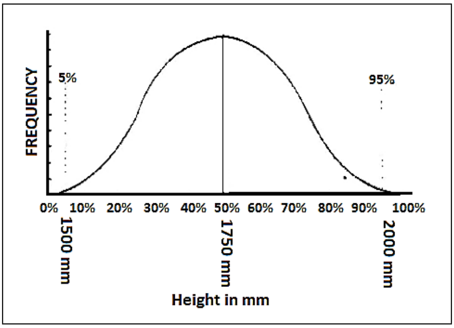


Figure 8.3: Height distribution of people

When selecting anthropometric data remember:-

- Strive to accommodate as many people as possible.
- Design for a range of users, not just the average, as this will often exclude half of the users.
- Data such as body size cannot be used without thought to the activities to be carried out. E.g. To design a ski stick handle the designer must consider that the user will be wearing a glove.

8.5 Ecological Design

Ecological design is defined by Sim Van der Ryn and Stuart Cowan as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes”. Ecological design is an integrative ecologically responsible design discipline. It helps connect scattered efforts in green architecture, sustainable agriculture, ecological engineering, ecological restoration and other fields. By including life cycle models through energy and materials flow, ecological design was related to the new interdisciplinary subject of industrial ecology. Industrial ecology meant a conceptual tool emulating models derived from natural ecosystem and a frame work for conceptualizing environmental and technical issues. Living organisms exist in various systems of balanced symbiotic relationships. The ecological movement of the late twentieth-century is based on understanding that disruptions in these relationships has led to serious breakdown of natural ecosystems. In human history, technological means have resulted in growth of human populations through fire, implements and weapons. This dramatic increase in explosive population contributed the introduction of mechanical energies in machine production and there have been improvements in mechanized agriculture, manufactured chemical fertilizers and general health measures.

Four main issues addressed in design for environment are:

1. **Design for environmental processing and manufacturing:** This ensures that raw material extraction (mining, drilling, etc.), processing (processing reusable materials, metal melting, etc.) and manufacturing are done using materials and processes which are not dan-

gerous to the environment or the employees working on said processes. This includes the minimization of waste and hazardous by-products, air pollution, energy expenditure and other factors.

2. **Design for environmental packaging:** This ensures that the materials used in packaging are environmentally friendly, which can be achieved through the reuse of shipping products, elimination of unnecessary paper and packaging products, efficient use of materials and space, use of recycled and/or recyclable materials.

(a) Disposable Areca Plates

(b) Jute Bag

Figure 8.4: Ecological Design

3. **Design for disposal or reuse:** The end-of-life of a product is very important, because some products emit dangerous chemicals into the air, ground and water after they are disposed of in a landfill. Planning for the reuse or refurbishing of a product will change the types of materials that would be used, how they could later be disassembled and reused, and the environmental impacts such materials have.

4. **Design for energy efficiency:** The design of products to reduce overall energy consumption throughout the product's life.

8.6 Value Engineering

8.6.1 Historical Development

Value engineering is based on a methodology developed by Lawrence Miles, who worked for the General Electric Company in the USA during the Second World War. Because of the war, there were shortages of materials and certain finished products. However, manufacturing industry was running at maximum capacity, and ideas where needed to further expand production. Miles was responsible for purchasing raw materials for the General Electric Company. He came up with the idea that if he was unable to obtain one particular material, then it was necessary to obtain a replacement material which performed the same function. This 'value engineering' began with a creative, team-based approach which allowed the generation of many alternatives to the existing solution. Because the General Electric Company were manufacturers, the term 'engineering' was seen as being more appropriate at that time, than 'management'.

Later in the 20^{th} century, value engineering started to spread cross the world. But because of the differences between the mentality and the behaviour of American companies compared to European companies, value engineering, as developed in the USA had to undergo some modification.

Consequently, the European Community's SPRINT programme (Strategic Programme for Innovation and Technology) adopted the term ‘value management’ as the official term. It described the same philosophical concept but in terms that were more in keeping with European management styles. The term ’value management’ was also applied as a broad, high-order description which encompassed all value techniques, whether applied at a strategic or tactical level.

Execution: Value engineering is often done by systematically following a multi-stage job plan. Lawrence Miles original system was a six-step procedure which he called the "value analysis job plan." Others have varied the job plan to fit their constraints. Depending on the application, there may be four, five, six, or more stages. One modern version has the following eight steps:

1. Preparation
2. Information
3. Analysis
4. Creation
5. Evaluation
6. Development
7. Presentation
8. Follow-up

Four basic steps in the job plan are:

1. **Information gathering -** This asks what the requirements are for the object. Function analysis, an important technique in value engineering, is usually done in this initial stage. It tries to determine what functions

or performance characteristics are important. It asks questions like;

(a) What does the object do?

(b) What must it do?

(c) What should it do?

(d) What could it do?

(e) What must it not do?

2. **Alternative generation (creation)** - In this stage value engineers ask;

   (a) What are the various alternative ways of meeting requirements?

   (b) What else will perform the desired function?

3. **Evaluation** - In this stage all the alternatives are assessed by evaluating how well they meet the required functions and how great the cost savings will be.

4. **Presentation** - In the final stage, the best alternative will be chosen and presented to the client for final decision.

8.7 Concurrent Engineering

Another philosophy encountered in product design methodology is **Concurrent engineering.**

Concurrent engineering is a work methodology based on the parallelization of tasks (i.e. performing tasks concurrently). It refers to an approach used in product development in which functions of design engineering, manufacturing engineering and other functions are integrated to reduce the elapsed time required to bring a new product to the market.

A publication in 2008(Ma et al. 2008) described the concurrent engineering method as a relatively new design management system that has had the opportunity to mature in recent years to become a well-defined systems approach towards optimizing engineering design cycles. Because of this, concurrent engineering has been implemented in a number of companies, organizations and universities, most notably in the aerospace industry. Beginning in the early 1990s, CE was also adapted for use in the information and content automation field, providing a basis for organization and management of projects outside the physical product development sector for which it was originally designed.

The basic premise for concurrent engineering revolves around two concepts. The first is the idea that all elements of a product's life-cycle, from functionality, producibility, assembly, testability, maintenance issues, environmental impact and finally disposal and recycling, should be taken into careful consideration in the early design phases.

The second concept is that the preceding design activities should all be occurring at the same time, i.e., concurrently. The idea is that the concurrent nature of these processes significantly increases productivity and product quality. This way, errors and redesigns can be discovered early in the design process when the project is still flexible. By locating and fixing these issues early, the design team can avoid what often become costly errors as the project moves to more complicated computational models and eventually into the actual manufacturing of hardware.

As mentioned above, part of the design process is to ensure that the entire product's life cycle is taken into consideration. This includes establishing user requirements, propagating early conceptual designs, running computational models, creating physical prototypes and eventually manufacturing the product. Included in the process is taking into full account funding, work force capability and time.

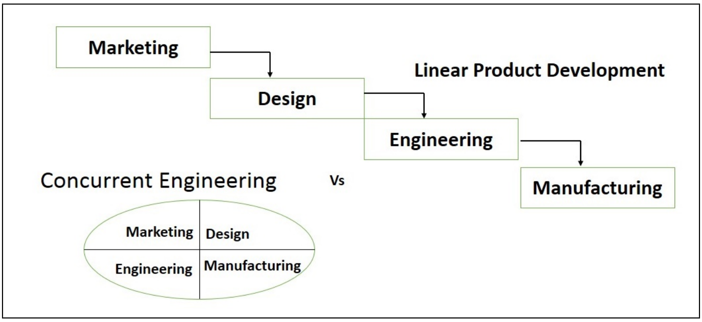


Figure 8.5: Concurrent engineering

Concurrent engineering replaces the more traditional sequential design flow, or 'Waterfall Model'. In concurrent engineering an iterative or integrated development method is used instead. The difference between these two methods is that the 'Waterfall' method moves in a linear fashion by starting with user requirements and sequentially moving forward to design, implementation and additional steps until you have a finished product. In this design system, a design team would not look backwards or forwards from the step it is on to fix possible problems. In the case that something does go wrong, the design usually must be scrapped or heavily altered. On the other hand, the iterative design process is more cyclic in that, all aspects of the life cycle of the product are taken into account, allowing for a more evolutionary approach to design. The difference between the two design processes can be seen graphically in Figure 8.5.

A significant part of the concurrent design method is that the individual engineer is given much more say in the overall design process due to the collaborative nature of concurrent engineering. Giving the designer ownership is claimed to improve the productivity of the employee and quality of the product that is being produced, based on the assumption that people who are given a sense of gratification and ownership over their work tend to work harder and design a more robust product, as opposed to an employee that is assigned a task with little say in the general process.

8.8 Reverse engineering in design

There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part/ product without any technical details, such as drawings, bills-of-material, or without engineering data. The process of duplicating an existing part, sub-assembly, or product, without drawings, documentation, or a computer model is known as reverse engineering. Reverse engineering is also defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/ digitizing existing parts/products. The process of digitally capturing the physical entities of a component, referred to as reverse engineering (RE), is often defined by researchers with respect to their specific task. Abella et al. (Abella et al. 1994) described RE as, “the basic concept of producing a part based on an original or physical model without the use of an engineering drawing". Reverse engineering is now widely used in numerous applications, such as manufacturing, industrial design, and jewellery design and reproduction For example, when a new car is launched on the market, competing manufacturers may buy one and disassemble it to learn how it was built and how it works. In software engineering, good source code is often a variation of other good source code. In some situations, such as automotive styling, designers give shape to their ideas by using clay, plaster, wood, or foam rubber, but a CAD model is needed to manufacture the part. As products become more organic in shape, designing in CAD becomes more challenging and there is no guarantee that the CAD representation will replicate the sculpted model exactly. Reverse engineering provides a solution to this problem because the physical model is the source of information for the CAD model. This is also referred to as the physical-to-digital process. Another reason for reverse engineering is to compress product development cycle times. In the intensely competitive global market, manufacturers are constantly seeking new ways to shorten lead times to market a new product. Rapid product development (RPD) refers to recently developed technologies and techniques that assist manufacturers and designers in meeting the demands of shortened product development time. For example, injection-moulding companies need to shorten tool and die. By using reverse engineering, a three-dimensional physical product or clay mock-up can be quickly captured in the digital form, remodelled, and exported for rapid prototyping/tooling or rapid manufacturing using multi-axis CNC machining techniques.

A recent advancement in the medical field has come up with the help of reverse engineering. Scanning of human internal body details are necessary in order to understand the problems associated with a patient. X –Ray, Computed tomography and Magnetic Resonance Imaging are the common visualization tools available with the doctor. But none of these tools can give a 3 D visualization of the internal details of a patient with accuracy. Sometimes it is needed for performing a complicated operation like fitting a prosthetic, repairing a bone fracture or even some transplant. Reverse engineering has made a big leap in this field .Now there are commercial medical image processing tools like Amira®, Mimics® ,3D Doctor® and many others, that can read a CT or MRI image and convert it to 3D CAD models or stl files which can be viewed or 3D printed for better understanding.

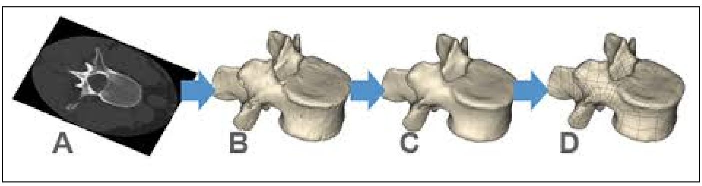


Figure 8.6: Stages of image processing a vertebra to a CAD model

Figure 8.6 shows the stages of 3d modelling a human vertebra. ‘A’ is the CT scanned image which is read by the application. It is then segmented based on the intensity of the image. The segmented region (B in Figure 8.6) is then fitted with surface using surface generation application. The surface is created using tessellated triangles. The surface is then smoothened using robust algorithms(C in the Figure 8.6). The generated surface can be converted to a volume or a stl file for 3D Printing.

8.9 Culture Based Design

Globalisation has led to international cooperation among product manufacturers, spanning not only production and assembly but also product development(Gautam & Blessing 2007). By becoming active worldwide, companies try to gain benefits from local markets, both in the sense of work force as well as customers. In such cooperation's, engineering designers from different cultural background participate in one design process to develop or adapt products under contribution of local engineering designers. As far as culture is addressed, the focus is on the desired properties of a product for use in different cultures.

Cambridge English Dictionary states that culture is, "*the way of life, especially the general customs and beliefs, of a particular group of people at a particular time*".

Empirical studies on culture have revealed many dimensions, some of which can be related to the characteristics of individual approaches and some are interesting in the context of a design process in general. Nisbett and Kühnen (Nisbett 2005) showed in their study that in different cultures there are basic differences in viewing things - in western cultures by dissecting objects into components (i.e. Westerners pay more attention to the objects and see the environment in terms of unconnected entities) and in Asian cultures viewing objects in holistic terms (i.e. Asians focus on the relationships of the objects and see the environment in terms of inter-connected entities). Time is also conceived differently in different cultures and as a result, the sequence of carrying out activities is also different. Another cultural characteristic observed by Nisbett and also by Kühnen is informational context. Depending on the culture, information is considered and processed independent from the context in which it has appeared or information is considered and processed in the context, in which it has appeared.

The American washing machine Company WhirlPool® had come up with a global/local approach to product development on the basis of product concepts adaptable to different countries. With a lightweight 'world washer' it could accommodate 18 foot long saris without tangling in India. It also added a soak cycle for Brazil to cater for their belief that only pre-soaking can yield a really clean wash(Heskett 2005).

The shaving blade company Gillete® was right when they found out that cultural differences have little effect on shaving. So they treats all the market places to be the same(Heskett 2005).

Interior lighting pattern design is an area where the culture has got a role to play. It was recognized in research studies that cultural background influences consumers' perceptions of pleasure, attractiveness, and approachability in a retail setting. Jewellery, furniture and crockery are other areas where the influence of culture can be seen.

8.10 Motifs and Cultural Background

In art and iconography, a motif is an element of an image. A motif may be repeated in a pattern or design, often many times, or may just occur once in a work. A motif may be an element in the iconography of a particular subject or type of subject that is seen in other works, or may form the main subject, as the Master of Animals motif in ancient art typically does. The related motif of confronted animals is often seen alone, but may also be repeated, for example in Byzantine silk and other ancient textiles.

Ornamental or decorative art can usually be analysed into a number of different elements, which can be called motifs. These may often, as in textile art, be repeated many times in a pattern. Important examples in Western art include acanthus, egg and dart, and various types of scrollwork.

Many designs in mosques in Islamic culture are motifs, including those of the sun, moon, animals such as horses and lions, flowers, and landscapes. Motifs can have emotional effects and be used for propaganda.

Motif is the most basic unit with the help of which a design or a composition is made. Motifs are often inspired from nature and are also closely linked to natural, cultural, religious and socio-economic factors prevailing in any society. A motif is the most basic unit or the smallest unit of pattern. Motifs are repeated in different ways to create patterns and these patterns are repeated to create a design. Motif has a distinct identity of its own in a pattern or design. Each motif is generally developed from a geometrical shape or a combination of different geometrical shapes.

The motifs or units of a textile design may be classified as :

- Geometric
- Realistic or Natural
- Stylized

- Abstract

8.10.1 Geometric Motifs

These motifs include lines in various forms, such as vertical, horizontal, diagonal and curved. They form fabric designs, such as stripes, plaids, checks and circles and their associated designs. Geometric designs lead the eye in the design or pattern that is created by them.

Geometrical motifs may be created during the weaving or knitting fabric construction process. If motifs are applied as prints after the fabric is constructed, ensuring that lines are straight with the yarns of the fabric is important; otherwise the finished garment will be unsightly. A distinctive geometric design may dictate the garment styling and limit the possibilities for using the fabric.

Geometric designs may require additional fabric in order to match the motifs during the layout and construction.

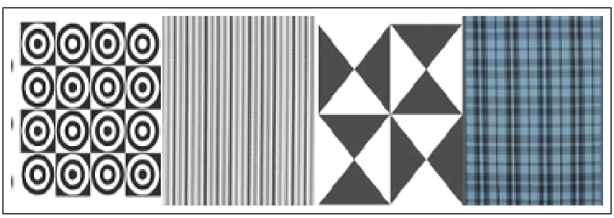


Figure 8.7: Geometric Motifs

8.10.2 Realistic or Natural Motifs

Natural motifs portray as direct replica of things as they exist in nature, Such as flowers on trees, animals in jungle, human figure and other natural things. They also called novelty patterns. As these motifs lack a designer's creativity and require three-dimensional platform to copy reality, they do not find wide acceptance in apparel designing.

Examples of Realistic Motifs are animals, animal skins, fruit, games, toys, mythological designs, vegetables, shells and jungle etc. are all form the natural or realistic designs.

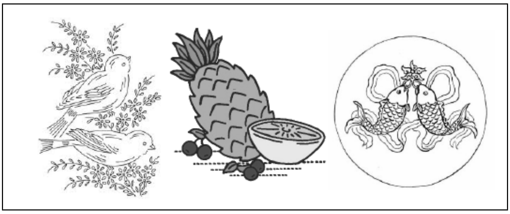


Figure 8.8: Realistic Motifs

8.10.3 Stylized Motifs

These are simplified variations of natural or man-made objects that are no longer recognizable. These motifs are full of creativity, as they are the result of a designer's interpretation of naturally existing things. Stylized motifs are obtained by rearranging the real objects either by simplifying or exaggerating them to achieve the purpose of the design.

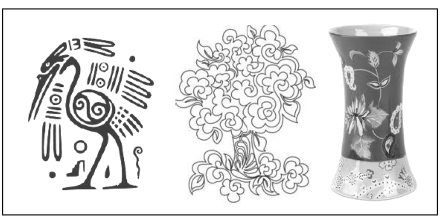


Figure 8.9: Stylized Motifs

Examples of stylized Motifs are flower spilling out of basket, flowerpots, vases, bouquets and all that coming out the designer's imaginary ideas form the stylized designs.

8.10.4 Abstract Motifs

These are combinations of colour, size, and shape without relationship to natural or man-made objects. They are full of colour and interest to the fabric. Abstract implies an element of impression and a greater freedom than is found in most geometric designs. This type of design is used in modern art.

Examples of Abstract Motifs are realistic, stylized, and abstract motifs may be easier or more difficult to use depending on the size of the motif, the contrast between the motif and the background, and whether or not the design is multiple-direction or one-way. Smaller size motifs, softened shadings, and multiple direction designs are easier to sew and wear.

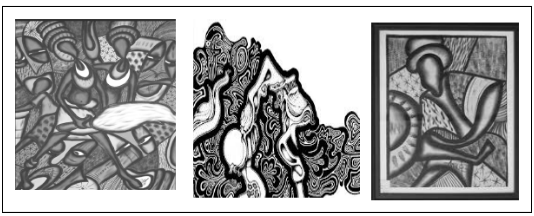


Figure 8.10: Abstract Motifs

8.11 Motifs of India– Styles and Colour Combinations

Traditional motifs can be described as the motifs which are being used in Indian textiles since ancient times and are handed over from one generation to the other. Our traditional motifs are deeply influenced by religious belief, culture, environment, activities of day to day life, architecture, history, rulers etc. The artisans have modified motifs based on the whims and fancies of the kings who invaded and ruled India for several years. For creating the variety of motifs and designs, weavers and designers had also taken inspiration from their environment. Indian artisans have created varied motifs and patterns which are exclusive in their styles and colour combinations like creeping vines and floral patterns, which remind us of Mughal history and the Islamic portrayals. Motifs like lotus, conch shells, fish, elephant and horse etc. which represent the philosophy of Hinduism and the concept of bring good-luck, health and prosperity are typically found in the textiles worn in the occasional ceremonies

8.12 Role of Colours in Design

Colour may be the most influential factor in the decision to buy, or not to buy. In Malcolm Gladwell's book, Blink: The Power of Thinking Without Thinking, he suggests that when presented with a choice, the subconscious mind makes a decision within just a few seconds. Even before one rationalizes and investigates the choices, through rapid cognition the mind has already been made up. In relation to industrial design, that critical decision is the purchasing decision. Within those first few seconds the majority of the information that is available is visual information and one of the most dominant aspects of that visual information is colour. So, considering this, the application of colour and finish in design becomes much more important than one first thought.

The Power of Colour (Morris 2006): Colour can dominate all other factors of a product designs success. One might not buy or drive a Porsche automobile if it were a hideous colour, despite the quality of manufacture and engineering, prestige of the name, or the high performance. The same is true with home appliances, consumer electronics, soft goods, sports equipment, shoes, and practically every area of industrial design. A poor choice of colour and finish can make or break the success of a product. Colours chosen for a design can be meaningful, purposeful, and even functional. The impact of colour in different realms of design are given below.

1. **Colour as association:**

   Colour can have high emotional and symbolic associations. It can be applied in design to conjure up soothing emotions or vivid memories to the user. These associations vary by culture, geography, and generation. These emotions seem to come from general associations the mind makes with that colour, though long-term memories. These memories were developed throughout our lifetime through repetition or specific indelible events For instance, when asked to describe what they like about the Apple iPod, most people say that it looks clean. Why is this a common description? Consider the material, finish and colours. It is glossy white and polished stainless metal. For most people in America, every morning of every day of their lives they spend time cleaning themselves in a room that is usually made of white porcelain with polished metal fixtures. The bathroom is a place of cleaning and cleanliness, and this association is engrained deeply into the mind.

2. **Colour as user interface**

   Colour can give cues as to how to operate a machine or an appliance. Even without understanding of the function of a form, a contrasting coloured feature indicates how and what to do. A green button usually indicates "go" or "start," a red button may indicate, "stop" or on a trigger may mean, "Fire". Our traffic lights use green, yellow and red to direct drivers with its colour cues. The white stripes of a crosswalk on the street direct the pedestrians where to safely cross and warn drivers. The controls of an X-Box game controller are coloured differently. Grey is used for the controls that are ordinary and commonly used and colours are used for the special functions. With a series of controls, only the most important and critical ones are usually coloured.

   This application should be used carefully and with consideration. Liberal use of colour on many buttons or controls dilutes the power and influence of the colours. Contrasting colours can be applied to those controls that are critical and most important, even though they may be rarely used.

Figure 8.11: User interface cues on the X-Box video game controller

3. **Colour as fashion**

   Fashion announces a fresh new palette of trendy colours every season. Application of these colours in design can attract buyers who are, consciously or not, affected by today's hot palette. These colours change depending on the target market, the geographic region, the season of the year, the culture and the design. Because of these factors of variability, considerable research must be done to select an appropriate palette.

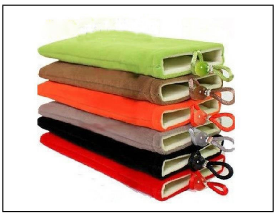


Figure 8.12: Mobile phone cover in different colours

4. **Colour as identity**

   Colour can be used to identify the object with a person, a company, or a group. The use of colour for a corporation becomes critical for those with strong brand recognition. Even a sports team is identified through its application of colour on helmets and uniforms. Colour can also identify a user or efficiently organize items.

Figure 8.13: Kensington Smart Sockets designed by Astro

Astro, a product design firm based in San Francisco, changed the power-strip market through a simple yet ingenious use of colour. On the Smart Sockets for Kensington(Figure 8.13), each plug outlet on the strip is coloured with a ring, which matches a tab on the corresponding cord, identifying which piece of equipment with its plug.

5. **Colour as form emphasis**

   Colour can be used to emphasize the physical form, and to enhance the surface variation or three-dimensionality. This application is not dependent upon culture, but rather is based on how our minds process visual information. Our eyes equate value variation with surface variation. When this variation is pronounced through colour its three-dimensional form is enhanced.

6. **Colour as form alteration**

   This application of colour alters the three-dimensional form by concealment or disguise. An extreme example is camouflage on a military vehicle. The purpose is to break up the form visually and to change its visual boundary, thereby causing the mind to not recognize its true form. The changes of value in the colour are contrary to the change of surface. This application may be used in design to hide or conceal a feature of an object, or to de-emphasize a form. The example below (Figure 8.14) utilizes high contrast colour graphic treatment to obliterate the perception of its three dimensional form.

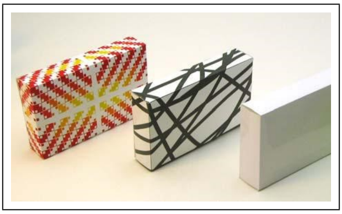


Figure 8.14: Using graphic colour treatment to obliterate a form

7. **Colour as harmony**

   Colour can be used to make a design visually compatible with its environment. A white kitchen appliance, for instance, is made to blend into and match the kitchen environment. This application of colour can be used to achieve a quiet, neutral, harmonious environment and reduce visual chaos. It is also used when a particular colour and finish is prevalent with other items in the environment. A Band-Aid bandage, for example, is coloured to match the majority of skin colours. In the 1980's beige computer housings and monitors were meant to blend into the conventional office environment of the era. The beige box era was prevalent in all desktop computers, printers, accessories, office furniture, and even walls and carpet. This had the intention of matching all items in the office environment, making it visually cohesive and harmonious.

8. **Colour as contrast**

   In order to stand out and contrast with its environment, colour can be critical. Whether it's an orange traffic cone or a yellow taxicab, colour is a powerful differentiator. Distinction from environment can happen

> through contrasting hue, saturation, or value. This application is important when safety is a concern. On tools with cutting or rotating parts, a contrasting colour can be used to focus the operator's attention where it needs to be directed. A garden tool may be coloured a contrasting colour to its predominately green environment in order to avoid being lost or stepped on.

Colour also an element of visual language that people process before they are consciously aware of it. It 'pops out' at viewers in the early stages of vision. The solitary use of colour to convey information leaves many visually impaired persons without the information they require. To keep designs inclusive, use redundant attributes, such as icons, labels or patterns to ensure everyone can perceive the information that colour conveys.

8.13 Rounded Corners for Aesthetic Needs

Designers use rounded corners so much today that they're more of an industry standard than a design trend. Not only are they found on software user interfaces, but hardware product designs as well. So what is it about rounded corners that make them so popular? Indeed they look appealing, but there's more to it than that.

Anyone can appreciate the aesthetic beauty of rounded corners, but not everyone can explain where exactly that beauty comes from. The answer to that is literally in your eye. Some experts say that rectangles with rounded corners are easier on the eyes than a rectangle with sharp edges because they take less cognitive effort to visually process. Processing edges involve more "neuronal image tools" in the brain. Thus, rectangles with rounded corners are easier process because they look closer to a circle than a regular rectangle.

Another explanation on why we have an eye for rounded corners is because they're more organic to how we use everyday objects in the physical world. Rounded corners are everywhere. And as children, we quickly learn that sharp corners hurt and that rounded corners are safer. That's why when a child plays with a ball, most parents aren't alarmed. But if a child were to play with a fork, the parents would take the fork away for the fear of the child hurting itself. This provokes what neuroscience calls an "avoidance response" with sharp edges. Thus, we tend to "avoid sharp edges because in nature, they can present a threat". In a workshop the rounding off operation is performed by grinding.

8.14 Case Studies

Design a small table that can be used by people who want to sit on a floor or bed .The height should not be more than 1 feet and the apperance should be good.Also comment on the manufacturibility of the same .

Solution.

- It can be made with PVC pipes , connectors, rivets and a mica board as shown.The pipes are connected by means of connectors.The board is riveted to the pipe frame .The handle on the top helps the user to grip the table firmly.It can easily be disassembled for packing and transferring.

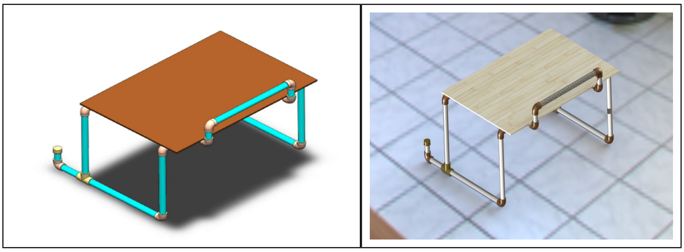


Figure 8.15: Mini Table with pipe frame

- It can be made with plastic as shown in the image .The arrangement consists of 3 pieces that can be easily dismantled or assembled. The parts can be made by plastic injection moulding process.It is also light weight.The slot in the board helps for carrying the table.

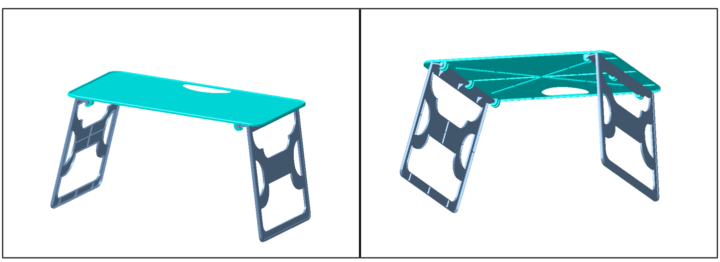


Figure 8.16: Mini Table in plastic

List out the key elements in the design of a website with due importance on aesthetics and ergonomics.

Answer

1.Appearance:

A site must be visually appealing, polished and professional. It's reflecting the company, the products and services. The website may be the first, and only, impression a potential customer receives of a company.

An attractive site is far more likely to generate a positive impression and keep visitors on your site once they arrive. As businesses large and small continue to populate the web, the challenge is to attract and keep users' attention. Some guidelines are given below.

Guidelines:

- Good use of color: an appropriate color scheme will contain 2 or 3 primary colors that blend well and create a proper mood or tone for your business. Don't overdo the color, as it can distract from the written content.

- Text that is easily read: The most easily read combination is black text on a white background, but many other color combinations are acceptable if the contrast is within an appropriate range. Use fonts that are easy to read and are found on most of today's computer systems depending on the audience. Keep font size for paragraph text between 10 and 12 pts.

- Meaningful graphics: Graphics are important, as they lend visual variety and appeal to an otherwise boring page of text. However, don't over-use them, and make sure that add meaning or context to your written content. Don't overload any one page with more than 3 or 4 images.

- Quality photography: A simple way to increase visual appeal is to use high quality photography. High quality product images are especially important for online retailers.
- Simplicity: Keep it simple and allow for adequate white space. Uncluttered layouts allow viewers to focus on your message. Do not overload the site with overly complex design, animation, or other effects just to impress the viewers.

2.Content

Along with style, the site must have substance. Ther audience is looking for information that will help them make a decision, so it should be informative and relevant. Use this opportunity to increase visitor confidence in the company's/service's knowledge and competence.

Guidelines

- Short and organized copy: Clearly label topics and break your text up into small paragraphs.
- Update the content regularly: No one likes to read the same thing over and over again. Dead or static content will not bring visitors back to the site!
- Speak to the visitors: Use the word you as much as possible. Minimize the use of I, we and us.

2.Usability

A critical, but often overlooked component of a successful website is its degree of usability. Your site must be easy to read, navigate, and understand. Some key usability elements include:

- Simplicity: The best way to keep visitors glued to your site is through valuable content, good organization and attractive design. Keep your site simple and well organized.
- Fast-loading pages: A page should load in 20 seconds or less via dial-up; at more than that, you'll lose more than half of your potential visitors.
- Minimal scroll: This is particularly important on the first page. Create links from the main page to read more about a particular topic.
- Consistent layout: Site layout is extremely important for usability. Use a consistent layout and repeat certain elements throughout the site
- Prominent, logical navigation: Place your menu items at the top of your site, or above the fold on either side. Limit your menu items to 10 or fewer. Remember, your visitors are in a hurry -- don't make them hunt for information.
- Descriptive link text: Usability testing shows that long link text makes it much easier for visitors to find their way around a site. Long, descriptive link text is favored by Search Engines, too. Back links are important to

give users a sense of direction and to keep them from feeling lost.

- Screen Resolution: Screen resolution for the typical computer monitor continues to increase. Today, the average web surfer uses a resolution of 1024 x 768 pixels. However, you need to make sure that what looks good at this setting will also work nicely for other resolutions

Exercise

Examine the possibility of value addition for an existing product.

[Hint: Take a simple product with few functionalities. Think of what all replacements can be done to attain the same functionality.

E.g.: Take a traditional rubber roller that is used to make rubber sheets. Can an alternative be thought of, to replace the heavy metallic rollers with something that is less bulky and cheap?

Or can this operation of pressing rubber sheets be performed with some other process.]

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Chapter 9

Modular Design

Modular design, or "modularity in design", is a design approach that subdivides a system into smaller parts called modules or skids, which can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces. Besides reduction in cost (due to less customization, and shorter learning time), and flexibility in design, modularity offers other benefits such as augmentation (adding new solution by merely plugging in a new module), and exclusion. Examples of modular systems are cars, computers, process systems, solar panels and wind turbines, elevators and modular buildings.

Modular design provides better diagnosis and remedy of failures, easier repair and replacement and simplification of manufacturing and assembly.

For example we have practiced programming in the small; programming in the large requires modular design. Characteristics of large programs are size more than 100,000 lines of code, efforts of many teams of programmers and large time spent for program maintenance and evolution. Modular design of programs aims to control the complexity of a program by dividing it into modules. A typical example of a module is a library of functions. Another example is CNC part programming.

9.1 Benefits and Disadvantages

9.1.1 Product Cost

Cost can be partitioned into development cost and production cost.

If the partitioning of the design into modules has already been done and the development consists of simply refining existing and assembling existing modules development cost is lower for modular design.

If however the design has to be partitioned into modules and the interfaces between modules defined, the development cost tend to be higher. This is particularly the case if the modules are designed to be reusable and the needs of products other than that being currently designed have to be taken into account.

Some form of modular design is a necessity, in order for us to make sense of complex modern products. Development cost is more when we try to make modules that can be re used in other efforts.

For hardware, increased interconnects between different modules can add significantly to product cost. However if one can use modules in mass production cost is significantly reduced. This is the reason why we see so many power modules being currently sold, especially for the popular 7805 physical form factor.

Software development cost is higher or lower using modular design. If pre-designed modules are already available in the form of libraries, the cost of design is lower. However if modular libraries are being developed as a part of the development effort the development cost and time are higher.

This increased development cost and time can be recouped in future if the libraries generated are used for other purposes.

9.1.2 Development Time

The development time is often lower because once the design is split up into modules, design teams can work in parallel on the different modules.

9.1.3 Performance

For software the increasing capability of modern machines has papered over the increasing hardware requirements of running software designed in a modular fashion.

For hardware the interconnection between different modules as subsystems often act as limits for overall performance. For example if we examine the personal computer, its performance is often limited by the amounts of data we can transfer over the different buses on the system.

9.1.4 Reliability

The interfaces between different modules are often common causes of failure.

9.2 Design Optimization

Design optimization is a technique that seeks to determine an optimum design. It mean meeting all specified requirements or needs with a minimum expense of factors such as weight, surface area, volume, stress, cost, etc. We can say the optimum design "as effective as possible".

9.2.1 Design Optimization Techniques

9.2.1.1 Classical Optimization Techniques

The classical optimization techniques are useful in finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions. These are analytical methods and make use of differential calculus in locating the optimum solution. The classical methods have limited scope in practical applications as some of them involve objective functions which are not continuous and/or differentiable. Yet, the study of these classical techniques of optimization form a basis for developing most of the numerical techniques that have evolved into advanced techniques more suitable to today's practical problems. These methods assume that the function is differentiable twice with respect to the design variables and the derivatives are continuous.

Three main types of problems can be handled by the classical optimization techniques:

1. Single variable functions

2. Multivariable functions with no constraints

3. Multivariable functions with both equality and inequality constraints. In problems with equality constraints

the Lagrange multiplier method can be used. If the problem has inequality constraints, the Kuhn-Tucker conditions can be used to identify the optimum solution.

These methods lead to a set of nonlinear simultaneous equations that may be difficult to solve.

9.2.1.2 Numerical Methods of Optimization

1. **Linear programming** studies the case in which the objective function f is linear and the set A is specified using only linear equalities and inequalities. (A is the design variable space).

2. **Integer programming** studies linear programs in which some or all variables are constrained to take on integer values.

3. **Quadratic programming** allows the objective function to have quadratic terms, while the set A must be specified with linear equalities and inequalities.

4. **Nonlinear programming** studies the general case in which the objective function or the constraints or both contain nonlinear parts.

5. **Stochastic programming** studies the case in which some of the constraints depend on random variables.

6. **Dynamic programming** studies the case in which the optimization strategy is based on splitting the problem into smaller sub-problems.

7. **Combinatorial optimization** is concerned with problems where the set of feasible solutions is discrete or can be reduced to a discrete one.

8. **Infinite-dimensional optimization** studies the case when the set of feasible solutions is a subset of an infinite-dimensional space, such as a space of functions.

9. **Constraint satisfaction** studies the case in which the objective function f is constant (this is used in artificial intelligence, particularly in automated reasoning).

9.2.1.3 Advanced Optimization Techniques

1. **Hill climbing:** It is a graph search algorithm where the current path is extended with a successor node which is closer to the solution than the end of the current path. In simple hill climbing, the first closer node is chosen whereas in steepest ascent hill climbing all successors are compared and the closest to the solution is chosen. Both forms fail if there is no closer node. This may happen if there are local maxima in the search space which are not solutions. Hill climbing is used widely in artificial intelligence fields, for reaching a goal state from a starting node. Choice of next node/ starting node can be varied to give a number of related algorithms.

2. **Simulated annealing:** The name and inspiration come from annealing process in metallurgy, a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects. In the simulated annealing method, each point of

the search space is compared to a state of some physical system, and the function to be minimized is interpreted as the internal energy of the system in that state. Therefore the goal is to bring the system, from an arbitrary initial state, to a state with the minimum possible energy.

3. **Genetic algorithms:** A genetic algorithm (GA) is a local search technique used to find approximate solutions to optimization and search problems. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). Genetic algorithms are typically implemented as a computer simulation, in which a population of abstract representations (called chromosomes) of candidate solutions (called individuals) to an optimization problem evolves toward better solutions. The evolution starts from a population of completely random individuals and occurs in generations. In each generation, the fitness of the whole population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (mutated or recombined) to form a new population. The new population is then used in the next iteration of the algorithm.

9.2.1.4 Ant Colony Optimization

In the real world, ants (initially) wander randomly, and upon finding food return to their colony while laying down pheromone trails. If other ants find such a path, they are likely not to keep travelling at random, but instead follow the trail laid by earlier ants, returning and reinforcing it if they eventually find food. Over time, however, the pheromone trail starts to evaporate, thus reducing its attractive strength. The more time it takes for an ant to travel down the path and back again, the more time the pheromones have to evaporate. A short path, by comparison, gets marched over faster, and thus the pheromone density remains high. Pheromone evaporation has also the advantage of avoiding the convergence to a locally optimal solution. If there were no evaporation at all, the paths chosen by the first ants would tend to be excessively attractive to the following ones. In that case, the exploration of the solution space would be constrained. Thus, when one ant finds a good (short) path from the colony to a food source, other ants are more likely to follow that path, and such positive feedback eventually leaves all the ants following a single path. The idea of the ant colony algorithm is to mimic this behaviour with "simulated ants" walking around the search space representing the problem to be solved. Ant colony optimization algorithms have been used to produce near-optimal solutions to the travelling salesman problem. They have an advantage over simulated annealing and genetic algorithm approaches when the graph may change dynamically. The ant colony algorithm can be run continuously and can adapt to changes in real time. This is of interest in network routing and urban transportation systems.

9.3 Intelligent and Autonomous Products

Smart, connected products are products, assets and other things embedded with processors, sensors, software and connectivity that allow data to be exchanged between the product and its environment, manufacturer, operator/user, and other products and systems. Connectivity also enables some capabilities of the product to exist outside the physical device, in what is known as the product cloud. The data collected from these products can be then analyzed to inform decision-making, enable operational efficiencies and continuously improve the performance of the product.

Smart, connected products have three primary components; physical, smart, and connectivity.

- **Physical** – made up of the product's mechanical and electrical parts.
- **Smart** – made up of sensors, microprocessors, data storage, controls, software, and an embedded operating system with enhanced user interface.
- **Connectivity** – made up of ports, antennae, and protocols enabling wired/wireless connections that serve two purposes, it allows data to be exchanged with the product and enables some functions of the product to exist outside the physical device.

Each component expands the capabilities of one another resulting in, "a virtuous cycle of value improvement." First, the smart components of a product amplify the value and capabilities of the physical components. Then, connectivity amplifies the value and capabilities of the smart components. These improvements include:

- **Monitoring** of the product's conditions, its external environment, and its operations and usage.
- **Control** of various product functions to better respond to changes in its environment, as well as to personalize the user experience.
- **Optimization** of the product's overall operations based on actual performance data, and reduction of downtimes through predictive maintenance and remote service.
- **Autonomous product** operation, including learning from their environment, adapting to users' preferences and self-diagnosing and service.

Examples of smart, connected products:

- Philips Lightning Hue Light Bulbs and Bridge –provides users with a Connected Devices for home automation. Users have the ability to customize their interaction though a Smartphone, as well as connects their system to the wider world. With it a user can control their lights remotely or link them up to the rest of the web, newsfeeds, or even their inbox.
- Tesla Motors Automobiles – are a smart products with an Intelligent Maintenance Systems that periodically monitors itself and can autonomously alert Tesla, to issues so that they can be resolved quickly and easily. Many issues can be resolved remotely with a corrective software download.

9.4 User Interfaces

The user interface, in the industrial design field of human–machine interaction, is the space where interactions between humans and machines occur. The goal of this interaction is to allow effective operation and control of the machine from the human end, whilst the machine simultaneously feeds back information that aids the operators' decision making process. Examples of this broad concept of user interfaces include the interactive aspects of computer operating systems, hand tools, heavy machinery operator controls, and process controls. The design considerations applicable when creating user interfaces are related to or involve such disciplines as ergonomics and psychology.

Generally, the goal of user interface design is to produce a user interface which makes it easy (self explanatory), efficient, and enjoyable (user friendly) to operate a machine in the way which produces the desired result. This generally means that the operator needs to provide minimal input to achieve the desired output, and also that the machine minimizes undesired outputs to the human.

With the increased use of personal computers and the relative decline in societal awareness of heavy machinery, the term user interface is generally assumed to mean the graphical user interface, while industrial control panel and machinery control design discussions more commonly refer to human-machine interfaces

9.5 Communication Between Products

9.5.1 RFID

A radio-frequency identification system uses tags, or labels attached to the objects to be identified. Two-way radio transmitter-receivers called interrogators or readers send a signal to the tag and read its response. The readers generally transmit their observations to a computer system running RFID software or RFID middleware.

RFID tags can be either passive, active or battery assisted passive. An active tag has an on-board battery and periodically transmits its ID signal. A battery assisted passive (BAP) has a small battery on board and is activated when in the presence of a RFID reader.

Frequency: 120–150 kHz (LF), 13.56 MHz (HF), 433 MHz (UHF), 865-868 MHz (Europe), 902-928 MHz (North America) UHF, 2450-5800 MHz (microwave), 3.1–10 GHz (microwave)

Range: 10cm to 200m

Examples: Road tolls, Building Access, Inventory

9.5.2 EnOcean

The EnOcean technology is an energy harvesting wireless technology used primarily in building automation systems; but is also applied to other applications in industry, transportation, logistics and smart homes.

Modules based on EnOcean technology combine micro energy converters with ultra low power electronics and enable wireless communications between battery less wireless sensors, switches, controllers and gateways.

Frequency: 315 MHz, 868 MHz, 902 MHz

Range: 300m Outdoor, 30m Indoors

Examples: Wireless switches, sensors and controls

9.5.3 NFC

NFC is a set of short-range wireless technologies, typically requiring a distance of 10 cm or less. NFC operates at 13.56 MHz on ISO/IEC 18000-3 air interface and at rates ranging from 106 kbps to 424 kbps.

NFC always involves an initiator and a target; the initiator actively generates an RF field that can power a passive target. This enables NFC targets to take very simple form factors such as tags, stickers, key fobs, or cards that do not require batteries. NFC peer-to-peer communication is possible, provided both devices are powered.

Frequency: 13.56 MHz

Range: < 0.2 m

Examples: Smart Wallets/Cards, Action Tags, Access Control

9.5.4 Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength radio transmissions in the ISM band from 2400–2480 MHz) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security.

Frequency: 2.4GHz

Range: 1-100m

Examples: Hands-free headsets, key dongles, fitness trackers

9.5.5 Wi-Fi

Wi-Fi is a technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high-speed Internet connections. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards. - 802.11a/b/g/n/af, Wi-Fi Direct, WPS

Frequency: 2.4 GHz, 3.6 GHz and 4.9/5.0 GHz bands.

Range: Common range is up to 100m but can be extended.

Applications: Routers, Tablets, etc

9.5.6 GSM

GSM (Global System for Mobile communications) is an open, digital cellular technology used for transmitting mobile voice and data services.

Terrestrial GSM networks now cover more than 90% of the world's population. GSM satellite roaming has also extended service access to areas where terrestrial coverage is not available.

Frequency: Europe: 900MHz & 1.8GHz, US: 1.9GHz & 850MHz, Full List can be found here.

Data Rate: 9.6 kbps

Examples: Cell phones, M2M, smart meter, asset tracking

Additional: 3G/4G LTE, ANT, Dash7, Ethernet, GPRS, PLC/Powerline, QR Codes, EPC, WiMax, X-10, 802.15.4, Z-Wave, Zigbee.

9.6 Internet of Things

The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. The Internet of Things allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit; when IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020. Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications. The interconnection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields, while also enabling advanced applications like a Smart Grid, and expanding to the areas such as smart cities. "Things," in the IoT sense, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, electric clams in coastal waters, automobiles with built-in sensors, DNA analysis devices for environmental/food/pathogen monitoring or field operation devices that assist fire-fighters in search and rescue operations. These devices collect useful data with the help of various existing technologies and then autonomously flow the data between other devices. Current market examples include smart thermostat systems and washer/dryers that use Wi-Fi for remote monitoring.

9.6.1 Applications

Media, Environmental monitoring, Infrastructure management, Manufacturing, Energy management, Medical and healthcare systems, Building and home automation, Transportation, Large scale deployments.

9.7 Human Psychology and the Advanced Products

Human factors and ergonomics, also known as comfort design, functional design, and user-friendly systems, is the practice of designing products, systems, or processes to take proper account of the interaction between them and the people who use them. The field has seen contributions from numerous disciplines, such as psychology, engineering, biomechanics, industrial design, physiology, and anthropometry. In essence, it is the study of designing equipment and devices that fit the human body and its cognitive abilities. The two terms "human factors" and "ergonomics" are essentially synonymous.

Human factors and engineering psychologists study how people interact with machines and technology. They use psychological science to guide the design of products, systems and devices we use every day. They often focus on performance and safety.

Human factors and engineering psychologists strive to make these interactions easier, more comfortable, less frustrating and, when necessary, safer. But their purview extends beyond the everyday gadgets we need to function; they also apply the science of psychology to improve life-critical products, such as medical equipment and airline computer systems.

These professionals apply what they know about human behaviour to help businesses design products, systems and devices. They combine technology and psychology to improve our interactions with the systems and equipment we use daily.

Some products seem to work better than others. The best products are thought out and tested with people trying them out in real-life situations. Better designs mean happy customers, fewer costly redesigns and less likelihood of accidents or injuries. Because of this, businesses and organizations need the expertise of human factors and engineering psychologists, who study how people behave and use that knowledge to create better processes and products.

These psychologists work in many different areas, including business, government and academia. And they can work on a range of designs — from the ordinary things that touch all of our lives, such as better can openers and safer cars, to the highly specialized, such as instruments that allow pilots to land jumbo jets safely.

9.8 Design as a Marketing Tool

Visual marketing is the discipline studying the relationship between an object, the context it is placed in and its relevant image. Representing a disciplinary link between economy, visual perception laws and cognitive psychology, the subject mainly applies to businesses such as fashion and design.

As a key component of modern marketing, visual marketing focuses on the studying and analysing how images can be used to make objects the centre of visual communication. The product and its visual communication become therefore inseparable and their fusion is what reaches out to people, engages them and defines their choices (a marketing mechanism is known as persuasion). Not to be confused with visual merchandising, that is one of its facets and more about retail spaces; here, Marketing gets customers in the door. Once inside, merchandising takes over—affecting placement of products, signage, display materials, ambiance and employee staffing.

Harnessing the power of images and visuals makes a marketing plan more powerful and more memorable. Images — when done deftly – can turn concepts and intangible things into something concrete. That helps people envision a brand and its message in their mind's eye — and remember it when it comes time to buy.

Visual Marketing can be a part of every aspect of the Communication Mix. Marketing persuades consumer's buying behaviour and Visual Marketing enhances that by factors of recall, memory and identity.

Growing Trends in the usage of Picture Based Websites and social networking platforms like Pinterest, Instagram, Tumblr, Timeline feature of Facebook justifies the fact that people want to believe what they see, and therefore, need for Visual Marketing.

Visual Marketing includes all visual cues like logo, signage, sales tools, vehicles, uniforms, and right to your Advertisements, Brochures, Informational DVDs, websites, everything that meets the Public Eye.

9.9 Intellectual Property Rights

Intellectual property (IP) is a term referring to creations of the intellect for which a monopoly is assigned to designated owners by law. Some common types of intellectual property rights (IPR) are copyright, patents, and industrial design rights; and the rights that protect trademarks, trade dress, and in some jurisdictions trade secrets: all these cover music, literature, and other artistic works; discoveries and inventions; and words, phrases, symbols, and designs. While intellectual property law has evolved over centuries, it was not until the 19th century that the term intellectual property began to be used, and not until the late 20th century that it became commonplace in the majority of the world.

9.9.1 Trade secret

A trade secret is a formula, practice, process, design, instrument, pattern, or compilation of information which is not generally known or reasonably ascertainable, by which a business can obtain an economic advantage over competitors or customers.

9.9.2 Patent

A patent is a form of right granted by the government to an inventor, giving the owner the right to exclude others from making, using, selling, offering to sell, and importing an invention for a limited period of time, in exchange for the public disclosure of the invention. An invention is a solution to a specific technological problem, which may be a product or a process and generally has to fulfill three main requirements: it has to be new, not obvious and there needs to be an industrial applicability.

9.9.3 Copy-Right

A copyright gives the creator of an original work exclusive right to it, usually for a limited time. Copyright may apply to a wide range of creative, intellectual, or artistic forms, or works. Copyright does not cover ideas and information themselves, only the form or manner in which they are expressed.

9.9.4 Trademarks

A trademark is a recognizable sign, design or expression which distinguishes products or services of a particular trader from the similar products or services of other traders.

9.9.5 Product Liability

Product liability is the area of law in which manufacturers, distributors, suppliers, retailers, and others who make products available to the public are held responsible for the injuries those products cause. Although the word "product" has broad connotations, product liability as an area of law is traditionally limited to products in the form of tangible personal property.

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Chapter 10

Designer to Entreprenuer

10.1 Introduction

Design skills and entreprenuership are very closely related to each other.Somebody who makes a creative product or a system or a service idea woul also have the enthusiasm to market and deliver it to people at large for economic as well as societal gains.But entreprenuership needs to be adressed as such to be successful. There are many successful enttreprenuers who have made their way into the world facing many challenges and successfully overcoming them. Pursuing this art is very much needed for the development of a country and most of the government agencies have schemes to support them. Many people try to become an entreeprenuer but very few actaully come up to the strata of a successful one.Hence having an overall idea bout this is highly recommeded .

10.1.1 Who is an entreprenuer

Entrepreneur is an Economic Agent who plays a vital role in the economic development of a country. Economic development of a country refers steady growth in the income levels. This growth mainly depends on its entrepreneurs. An Entrepreneur is an individual with knowledge, skills, initiative, drive and spirit of innovation who aims at achieving goals. An entrepreneur identifies opportunities and seizes opportunities for economic benefits. Entrepreneurship is a dynamic activity which helps the entrepreneur to bring changes in the process of production, innovation in production, new usage of materials, creator of market etc. It is a mental attitude to foresee risk and uncertainty with a view to achieve certain strong motive. It also means doing something in a new and effective manner.

The word "Entrepreneur" is derived from the French verb 'entrepredre'. It means 'to undertake'. In the early 16th century the Frenchmen who organized and led military expeditions were referred as 'Entrepreneurs'. In the early 18th century French economist Richard Cantillon used the term entrepreneur to business. Since that time the word entrepreneur means one who takes the risk of starting a new organization or introducing a new idea, product or service to society. According to J.B. Say, “An Entrepreneur is the economic agent who unites all means of production; land of one, the labour of another and the capital of yet another and thus produces a product. By selling the product in the market the pays rent of land, wages to labour, interest on capital and what remains is his profit". Thus an Entrepreneur is an organizer who combines various factors of production to produce a socially viable product. An entrepreneur can be regarded as a person who has the initiative skill and motivation to set up a business or enterprise of his own and who always looks for high achievements. He is the catalyst for social change and works for the common good. They look for opportunities, identify them and seize them mainly for economic gains. An action oriented entrepreneur is a highly calculative individual who is always willing to undertake risks in order to achieve their goals. According to Joseph Schumepeter, "An entrepreneur in an advanced economy is an individual who introduces something new in the economy, a method of production not yet tested by experience in the branch of manufacture concerned, a product with which consumers are not yet familiar, a new source of raw material or of new market and the like". According to Cantillon "An entrepreneur is the agent who buys factors of production at certain prices in order to combine them into a product with a view to selling it at uncertain prices in future". To conclude an entrepreneur is the person who bears risk, unites various factors of production, to exploit the perceived opportunities in order to evoke demand, create wealth and employment.

In the 2000s, the definition of "entrepreneurship" has been expanded to explain how and why some individuals (or teams) identify opportunities, evaluate them as viable, and then decide to exploit them, whereas others do not, and, in turn, how entrepreneurs use these opportunities to develop new products or services, launch new firms or even new industries and create wealth.Conventionally,an entrepreneur has been defined as "a person who organizes and manages any enterprise, especially a business, usually with considerable initiative and risk". "Rather than working as an employee, an entrepreneur runs a small business and assumes all the risk and reward of a given business venture, idea, or good or service offered for sale. The entrepreneur is commonly seen as a business leader and innovator of new ideas and business processes. Entrepreneurs tend to be good at perceiving new business opportunities and they often exhibit positive biases in their perception (i.e., a bias towards finding new possibilities and seeing unmet market needs) and a pro-risk-taking attitude that makes them more likely to exploit the opportunity.

"Entrepreneurial spirit is characterized by innovation and risk-taking."While entrepreneurship is often associated with new, small, for-profit start-ups, entrepreneurial behavior can be seen in small-, medium- and large-sized firms, new and established firms and in for-profit and not-for-profit organizations, including voluntary sector groups, charitable organizations and government.For example, in the 2000s, the field of social entrepreneurship has been identified, in which entrepreneurs combine business activities with humanitarian, environmental or community goals.

10.2 Major Functions of Entreprenuer

An entrepreneur is an opportunity seeker. He is also the organizer and coordinator of the agents of production. He has to execute many a good functions while establishing a small scale enterprise. He not only perceives the business opportunities but also mobilizes the other resources like 5 Ms-man, money, machine, materials and methods. However, the main functions of the entrepreneurs are discussed further;

1. Idea generation: This is the most important function

of the entrepreneur. Idea generation can be possible through the vision, insight, observation, experience, education, training and exposure of the entrepreneur. Idea generation precisely implies product selection and project identification. Ideas can be generated through environmental scanning and market survey. It is the function of the entrepreneurs to generate as many ideas as he can for the purpose of selecting the best business opportunities which can subsequently be taken up by him as a commercially-viable business venture.

2. Determination of objectives: The next function of the entrepreneur is to determine and lay down the objectives of the business, which should be spelt out on clear terms. In other words, entrepreneur should be very much clear about the following things: (i) The nature of business (ii) The type of business This implies whether the enterprise belongs to the category of a manufacturing concern or a service -oriented unit or a trading business, so that the entrepreneurs can very well carry on the venture in accordance with the objectives determined by him.

3. Raising of funds: Fund raising is the most important function of an entrepreneur. All the activities of a business depend upon the finance and its proper management. It is the responsibility of the entrepreneur to raise funds internally as well as externally. In this matter, he should be aware of the different sources of funds and the formalities to raise funds. He should have the full knowledge of different government sponsored schemes by which he can get Government assistance in

the form of seed capital, fixed and working capital for his business.

4. Procurement of raw materials: Another important function of the entrepreneur is to procure raw materials. Entrepreneur has to identify the cheap and regular sources of supply of raw materials, which will help him to reduce the cost of production and face the competition boldly.

5. Procurement of machinery: The next function of the entrepreneurs is to procure the machineries and equipments for establishment of the venture. While procuring the machineries, he should specify the following details:

   (a) The details of technology.
   (b) Installed capacity of the machines.
   (c) Names of the manufacturers and suppliers.
   (d) Whether the machines are indigenously made or foreign made.
   (e) After-sales service facilities.
   (f) Warranty period of the machineries.
   (g) All these details are to be minutely observed by the entrepreneurs.

6. Market research: The next important function of the entrepreneur is market research and product analysis. Market research is the systematic collection of data regarding the product which the entrepreneur wants to manufacture. Entrepreneur has to undertake market research persistently in order to know the details of

the intending product, i.e. the demand for the product, the supply of the product, the price of the product, the size of the customers, etc. while starting an enterprise.

7. Determination of form of enterprise: The function of an entrepreneur in determining the form of enterprise is also important. Entrepreneur has to decide the form of enterprise based upon the nature of the product, volume of investment, nature of activities, types of product, quality of product, quality of human resources, etc. The chief forms of ownership organizations are sole proprietorship, partnership, Joint Stock Company and cooperative society. Determination of ownership right is essential on the part of the entrepreneur to acquire legal title to assets.

8. Recruitment of manpower: Entrepreneur has to perform the following activities while undertaking this function: (a) Estimating manpower need of the organization. (b) Laying down of selection procedure. (c) Devising scheme of compensation. (d) Laying down the rules of training and development.

9. Implementation of the project: Entrepreneur has to work on the implementation schedule or the action plan of the project. The identified project is to be implemented in a time-bound manner. All the activities from the conception stage to the commissioning stage are to be accomplished by him in accordance with the implementation schedule to avoid cost and time overrun, as well as competition. Thus, implementation of the project is an important function of the entrepreneur. To conclude with, all these functions of the en-

trepreneur can precisely be put into the following categories:

- Innovation.
- Risk bearing.
- Organization.
- Management.

10.3 The Fundamentals of Design Entrepreneurship

The conceptualization, production and marketing of a design idea are a critical case for a company's growth and survival. Simultaneously design is a key strategic activity in many firms because new products contribute incessantly destroying the old one and define new competencies and qualifications in the market place. In other words, reutilization of innovation frequently embodies as a practice of new product design yet design include the discovery and creation of new kinds of consumer goods that covers creative thinking, planning and also brand, identity, packaging, color, finish and materiality, form, and user experience; in sum values for consumers. The amount of contribution of designer in value creation process has been a controversial issue for a long time; on the other hand, there is a very large pool of empirical studies promoting design and its result as added value in the literature.

Design entrepreneurship is about creating business and new opportunities by the help of design. It is a natural outgrowth of the typical design practice yet it is not limited by creating viable concepts but marketing their intellectual rights.It means that to motivate industrial design activity to be more entrepreneurial for to take a product from concept to market which require giving the designers crucial and extra insights about the total product development process.

Already entrepreneurship is not a foreign concept to the design area. Both are working to shape the future by the new one as well as denying the past. According to Simon "Everyone designs who devise courses of action aimed at changing existing situations into preferred ones (Simon, 1996, MIT Press)". From this state, entrepreneurship seems to be one of the indispensable action or condition of design practice. However, the design entrepreneurship does not see the value it deserves. Because many designers think that the talent and creativity at design work is sufficient for success. Yet talent and creativity required creating only viable concepts.On the other hand, marketing the viable concepts requires entrepreneurship skills. Most designer candidate seem to be confused in their future practice if they settle for set of activities such as concept development and CAD work as required skill set.

Nevermore the perception of design entrepreneurship is limited under the establishment a design firm or sometimes designs automation. But the establishment of a firm does not mean entrepreneurship. As the most entrepreneurial ventures somehow involve a firm; the clear link between the establishment of a design firm and fulfill the requirements of being entrepreneur seems logical at the preliminary stage, on the other hand, firms serves just mechanisms for individuals to expose their entrepreneurial spirits and opportunities.

Based on all of these discourses, we should set out clearly what the design entrepreneurship is.Design entrepreneurship is the collection of correct skills and abilities to develop the right ideas and market them as the successful design products. These skills are not limited with conventional ones as idea generation or CAD drawing but skill for today's modern entrepreneurial and knowledge-based economy like high level of executive responsibility, business planning and management for creative and marketing issues and so on.

10.4 Entrepreneurship Education

The issue of teaching and developing entrepreneurial skills and mindsets are essential for students to create new jobs in future and to become major drivers of economic growth through creativity and innovation. Some researches indicate that people who have received entrepreneurship education perform better at running their own business. So, entrepreneurship education should be embedded in to the curriculums for all levels; specifically in design schools curriculums to build designer candidates ability to turn product ideas (concepts) into the action as intellectual property rights.

The aim of university education maybe to train a person for a job or to create perfect human beings and to build knowledge based society or to prepare individuals various situations that life offers. But, as a result, in all mentioned conditions there will be a gap between what students learn at school and what they are required to do in practice after graduation. One of these gaps is adequacy on entrepreneurship skills. The development of entrepreneurial skills requires process knowledge and experience. Universities can contribute to entrepreneurship both indirectly, through education of future innovator candidates,and directly by commercialization of research within the university and by being the seed-bed for new ventures .However, for the creation of the basics of entrepreneurship, entrepreneurship education should be given or the entire curriculum should be established on the practice of entrepreneurship skills. Yet, most of the empirical studies indicate that entrepreneurship skills can be taught or at least encouraged . According to Solomon, Duffy and Tarabishy (2002)entrepreneurial education must include skill building courses in negotiation, leadership, new product development, creative thinking and exposure to technological innovation.

It can easily be understood that, the two concepts; new product development and entrepreneurship are common in essence. As one of the foundations of entrepreneurship is to create a new one, it shares same roots with new product development. So entrepreneurship orientation will helps firms to take personal control and thereby promote great improvement in New Product Development(NPD) activities and entrepreneurship orientation positively affects product design activities and performance.

Definitions of design have changed due to the sophisticated production and distribution of design tools. This has increased the scope of the capabilities of designers and the way that build their partnerships. As a result of these developments, design entrepreneurship is quickly expanding as a part of design business. But the increase in the capabilities does not guarantee the emergence of entrepreneurship an entrepreneurial perspective should be developed beginning from design education.

Entrepreneurship based design education is a crucial foundation for creativity and innovation driven economic development. It is about developing awareness of entrepreneurship and seeks to provide design students with the managerial, economic and strategic thinking knowledge, as well as design skills and motivation to encourage entrepreneurial success. It should also provide role models, mentorship and expertise (mainly success stories at local, national and international level) to encourage young candidates to pursue their creative potential and should be conduct with a cross disciplinary approach to introduce new way of thinking, frameworks and to build critical links and new interactions through teams.

The main motivation of design entrepreneurship education is raising students' awareness of self employment as a career option and develops attitudes, behaviors and capacities at individual level to establish growth oriented ventures.

To create high-growth-oriented ventures a sample and stages of design entrepreneurship education should cover the following issues:

- Basics: Basics of economics, introduction to microeconomics, concepts of economic thought and consumption and consumer culture.

- Competency Awareness: The nature of competition, market economies, the importance of strategic innovation and design thinking, decision making and economic environment, entrepreneurs, practicing entrepreneurial skills, designer as an entrepreneur, social and cultural aspects of entrepreneurship, future role of industrial design.

- Creative Application: Enabling students to be self-employed and self-reliant, learn how to create highgrowth-oriented design ventures, clarifying the confusion exists between entrepreneurship and small business training, networking as a basic driver

- Business Models: State of art competitive models as Blue Ocean Strategy, Disruptive Innovation Theory, Co-creation Value, Design Driven Innovation, Karaoke Capitalism, New Economy, Funky Business, Spaghetti Organization, Everyone is Designer,IKEA Effect, Trophy Effect and I Design Myself.

10.5 Milestones

Stages of design entrepreneurship education should cover first basics of economics, introduction to microeconomics, concepts of economic thought and consumption and consumer culture for gaining knowledge on business ecosystem and to become familiar with the concepts of scarcity, choice and opportunity cost; demand, supply and price; profit-maximizing objective of a firm; cost and output of a firm; depreciation and cost and so on. It should also emphasis on the nature of competition, market economies, the importance of strategic innovation and design thinking, decision making and economic environment, entrepreneurs, practicing entrepreneurial skills, designer as an entrepreneur, social and cultural aspects of entrepreneurship, future role of industrial design to get proper knowledge on the fundamental concepts of analyzing the mass production and mass consumption opportunity in the market place. The design entrepreneurship education should also introduce creative applications and hands on projects to practice on entrepreneurial skills and state of art business models that depends on innovation based competition. To sum up, designers are natural entrepreneurs due to working to shape the future by the new one as well as destroying the past. From this state, entrepreneurship is an indispensable action or condition of design practice. So designers should be educated or at least encouraged on entrepreneurial skills to establish high-growth-oriented ventures and to be self-employed and practiced on the management of all New Product Development processes to produce viable concepts and marketing their intellectual properties.

Solved Questions

Second Semester B Tech Degree Examination,May/June 2016

BE 102 Design and Engineering

Instructions:Answer all questions:this is an open book examination and the students are permitted to use text books,class notes,own notes,earlier assignments but access to mobile phone and internet is not allowed.

Part A (5 Marks)

1.In an ordinary bicycle name at least 6 parts that are not made of metal.

Sketch any one of these parts.

Solution

Seat , tyre,reflectors, handle cover,pedal,valve tube.

Figure 10.1: Bicycle Tyre

2.How modular design is realized in 1) Umbrella 2) Ink Pen ? Draw the different modules involved in each of these products.

Solution

Umbrella : The different modules are handle(6) ,shaft with springs(4) , umbrella fabric(2),ribs with top & tip (1,5,3)

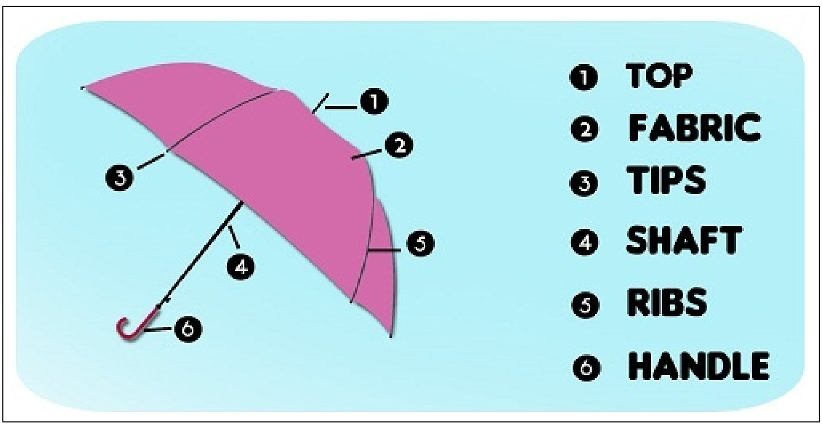

Figure 10.2: Modules of umbrella

Ink Pen: Cap,barrel,nib-feed system,section converter system for holding the ink.

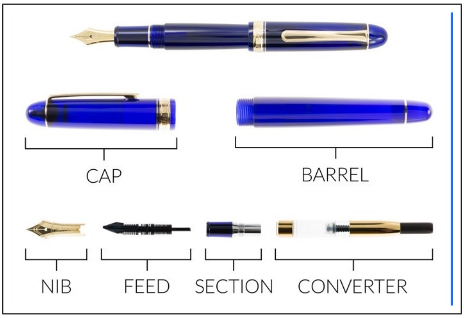

Figure 10.3: Modules of a fountain Pen

3.Design a chair with steel tube as shown. The seat and back rest are made of wood and are screwed onto the steel frame. Identify the interesting aspect of this design and list the different number of parts used for the chair.

Figure 10.4: Chair

The chair has got minimum number of parts in the assembly.There are two steel frames and a seat and back rest each made of wood.The chair can be easily disassembled and then the spare can be packed easily and shipped.Since steel tubes are used ,the weight is less and no compromise on strength is made.

Solution

4.Evolve a questionnaire for user centered design of an automobile.

Solution

The following are the topics on which questions can be prepared.

- .Height of the passenger .
- Weight of the passenger.
- What do you prefer more mileage or luxury.
- How big is your family or with how many people do you often travel together
- What are the Road conditions.
- Is it hlly or a rough terrain.

5.Considering the principle of value engineering ,design a suitable product for easy cleaning of dust from windows fans and lamp shades.

Solution

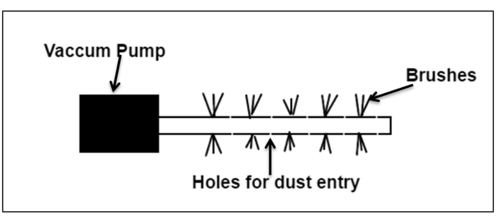

Figure 10.5: Dust cleaning brush

The design consist of a vaccum pump that is operated by compact Lithium ion batteries and the dust is sucked through the holes between the brushes.

6.Sketches of a screw driver and a normal screw head are given. This screw could be loosened or tightened using the screw driver. Now design the head of such a screw that could only be tightened but not loosened by this screw driver.

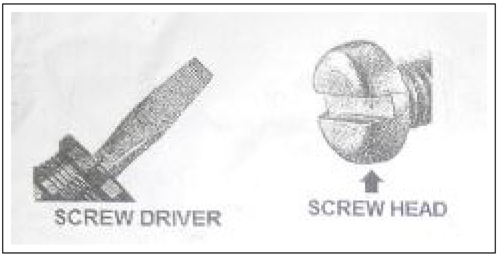

Figure 10.6: Screw driver

Solution

The screw can be designed as shown. The semicircular cut ensure that the screws are tightened in one direction and not loosened in the other .

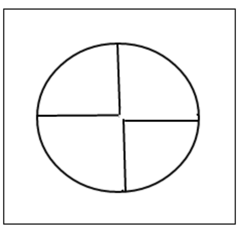

Figure 10.7: unidirectional screw

Part B

(Each question carries 10 marks)

7.Without using an air conditioner , blower or exhaust fan, design a natural system of heat removal from the rooms of a building and simultaneous inflow of fresh air from outside into the room. Prepare the necessary sketches and justify your answer.

Solution

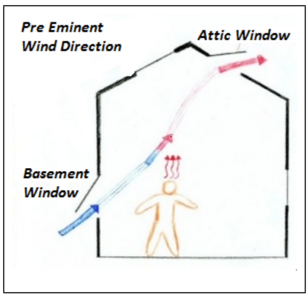

Figure 10.8: Natural Air Conditioning system

As it is shown in the figure,the cold air as it is light weight enters through the bottom window of the house and as it heats up becomes lighter and rises up and escapes through the attic window.This creates a vaccum in the house and the cycle further continues.

8.Develop and sketch anyone design concept of a mechanical system to drive a generator for energy harvesting by exploiting heavy traffic.

Solution

- Power generation from speed breaker
- Here the reciprocating motion of the speed-breaker is converted into rotary motion using the rack and pinion arrangement.
- The axis of the pinion is coupled with the sprocket arrangement.
- The sprocket ensures the unidirectional rotation of the shaft which is connected to the generator.
- Finally the generator generates electricity and is stored or used.

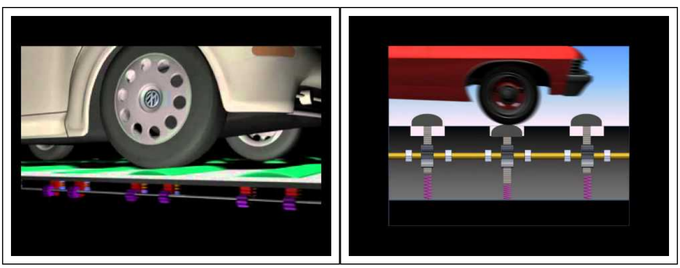

Figure 10.9: Energy from Traffic

Internal Exam Questions

1. List out the considerations needed when designing a frying pan stirrer. What all materials could be used for the same. Design with form.

Solution

- The stirrer should not have sharp edges that may tamper the teflon on the pan
- It should be made with thermally resistant material that do not melt at high temperature .
- Should be provided with a long handle that do not conduct heat.
- Metal stirrers should not be considered , instead soft materials like teflon mixed with styrene can be used .

Figure 10.10: Wooden frying pan stirrer

The figure 10.10 shows wooden frying pan stirrer with slots for good stirring .

2. Develop a design solution for avoiding tangling (twist together into a confused mass) of earphones. Sketch it out.

Solution

The credit card provided a solution. Punching five holes into the credit card, and making the sides curvy. One master hole at the top lets the extension of the ear buds into the Tangle so that you can quickly roll the wire. The sequentially placed four holes below the master hole are used to keep the remaining wire and the tip of the earphone in a stitching pattern.

Figure 10.11: Earphone Tangling Solution

3. Why Product freezing is essential in an industry. Explain with an example showing what will happen if freezing is not done in different stages of design and Production.

Solution

Product freezing in design process is essential as it fixes the different stages in design and thus brings out clarity and cost reduction in the entire design process.Refer Chapter 5, Freezing the design.

Take the example of a plastic bucket.After fixing the dimensions of the design it has to be frozen. Then later the metal mould is made using CNC machining process . This is a costly process . If the design dimensions are not frozen before the making of the mould ,then changes can become costly as the mould has to be made all over again.

4. Why tanker trucks are having cylindrical tanks, not cubical? Sketch any possible modification.

Solution

Pressure vessels are cylindrical, or better still, spherical in shape because these shapes are better at distributing stress. A box shape, although pretty strong, tends to concentrate stress where the sides meet and at the corners.A spherical shape also can be given to pressure vessel as this shape is also good at distributing stress , but it is difficult to manufacture.

Solution

5. Comment on the value engineering behind making the handle of a water bucket with plastic instead of metal.

Solution

Figure 10.12: Bucket with plastic bucket handle

The handle made of plastic is good in two ways.

- Since it has more cross sectional area it is good at reducing the pressure on the hand of the person taking the loaded bucket.
- The plastic handle made out of Injection moulding is

very cheap in mass production compared to the conventional metal handle .

Due to these two reasons the plastic handle adds more value to the product.

6. Design the interface of a website to be used by the public . The aim of the website is to save the environment by planting trees .Anyone can plant a tree and it will be looked after for a certain time for a certain amount.They also can get the GPS coordinates of the planted tree also.

Solution

Figure 10.13: User interface of website for planting tree

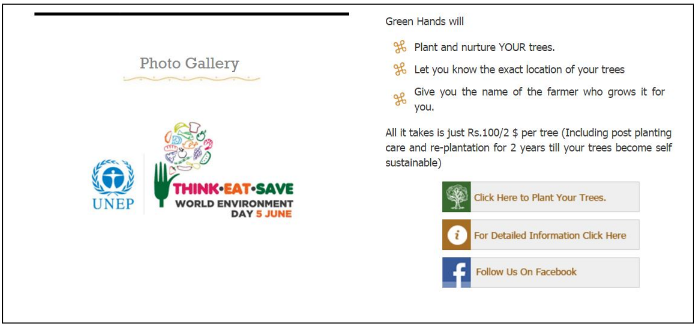

Figure 10.14: Interface for tree plantation details

The interfaces of the website are given(http://www.ishafoundation.org/) takes 100 INR for planting a tree and looking after it.The user interface is self explanatory.

7.During summer season while parking cars under intense sunlight, the car cabin get over heated. Develop an optimal solution to overcome this problem.

A water sparyer powered by a mini solar pump can be fitted on the top of the car that sprays atomized water droplets on to the roof and windshield of the car. The water evaporates and carries away the heat from the car.

8.A round glass of 600 mm diameter and 6 mm thick is available. This is to be designed as a table supported at three points by a steel tube bent in any convenient way. The height of the table is to be 300 mm and the total length of the tube used should not exceed 1.8 m. The tube should not be cut or joined. Design the bent tube for supporting the table.

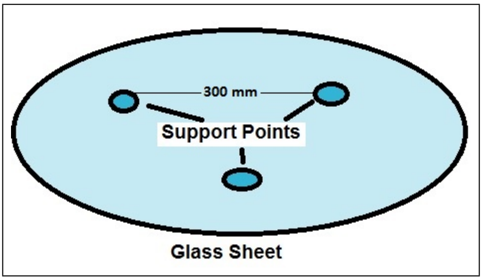

Figure 10.15: User interface of website for planting tree

Solution

The tube , as shown in the figure is bent in 5 different locations leaving 300 mm between each bent.

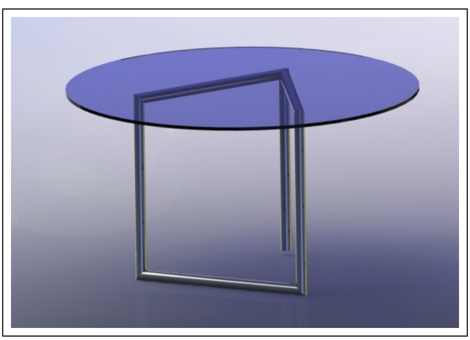

Figure 10.16: Table top made of Glass

Model Question Paper for Design and Engineering

BE 102 Design and Engineering

Open Book Examination

Students can use class notes, own notes, earlier assignments and any of the text or reference books in this examination. However access to internet and mobile phones is NOT permitted. Use simple sketches to explain the design. Written details should be limited to less than 20 lines

1.Think of any two design changes for an ordinary soap box that can add value to it.(5 marks)

Solution

- Make it fluoroscent by adding a glow material like Zinc Sulfide and Strontium Aluminate.Thus soap can be seen even at night.
- It can be given a vaccum hook with which it can be fitted on to the wall of the bathroom

2. Normal dice has six sides as shown in the figure.Design an eight sided dice. (Only sketch the design)(5 Marks)

Solution

Figure 10.17: Eight Sided Dice

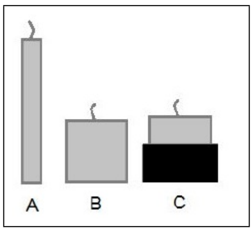

Figure 10.18: Candle Shapes

3.Three different designs of candles are given below. A: is a long and slender one; B: is short and big; C: is short and big with an aluminium cover at the bottom (darker shade) Give the advantages and limitations of these three designs in the following way:(5 Marks)

Solution

Candles	A	B	C
Design Advantages	Light covers larger area	Short and hence burns slowly	Wax gets deposited in container
			Short and hence burns slowly
Design Limitations	Finishes faster	Light covers smaller area	Light covers smaller area
	Wax get deposited at bottom	Wax get deposited at bottom	

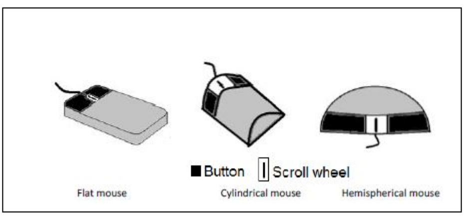

Figure 10.19: Different shapes of mouse

4.Computer mouse has certain features (two press buttons and the scrolling wheel) that can be given any shape. It can be a flat one, a cylindrical one or a hemispherical one. But the common mouse design is different from the above shapes. Why is this so?(5 Marks)

Solution

The design of mouse is different from all these because it has to match the average profile of the palm of a person using it.

5.Why pencils are designed to have longer lengths than pens or a ball point pens?(5 Marks)

Solution

Pencils have graphite lead inside them for writing purpose. As lead gets depleted the pencil is sharpened to expose the fresh lead. Thus to use the load for longer time , a pencil is given longer length.But this is not the case with a pen which writes through liquid ink.

6.Trees shed their leaves annually. These leaves are fairly large - 6 to 20 cm average size. Municipality would like to collect them for later use. Design a system for the following constraints. It should be done manually; The surface on which the leaves fall could be smooth, uneven or rocky; The leaves are dry; Can use electricity if needed; Give your design options and make a rough sketch of the design you have chosen giving reasons for your choice, within 15 lines.(10 marks)

Solution

A vaccum pump can be used for sucking the tree leaves from the surfaces. This can be operated by electricity.The collected dry leaves can be made to pass through a plastic screw feed and then it can be compacted and stored for later use .

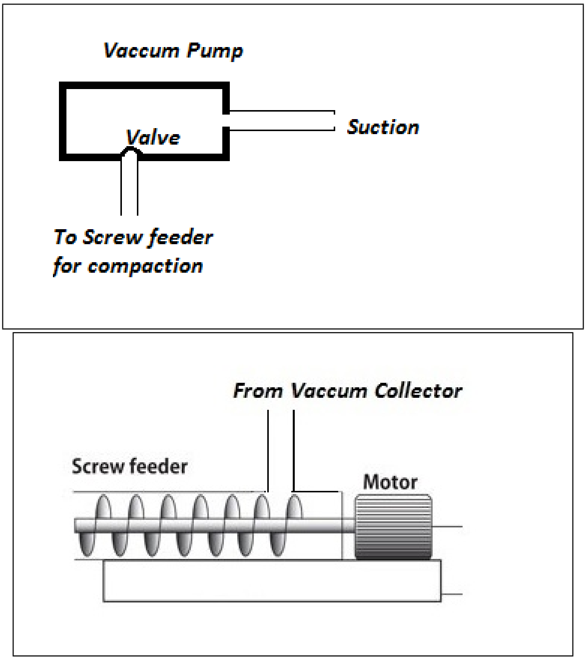

Figure 10.20: Dry Leaves Collector

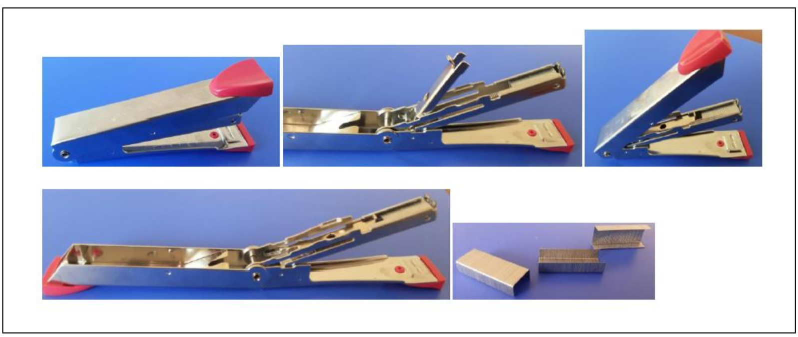

Figure 10.21: Stapler

7.The picture of a stapler is given below.The user has the complaint that he does not know how much of stapler pins are left in the stapler. His need is

to know whether there are enough stapler pins in the stapler before he uses it. Can this be solved through any design modification to the stapler? If so, what design modification to the stapler can be done to achieve this? Sketch the solution and explain it briefly (ten lines only).

Solution

The stapler casing that covers the stapler pin can be made transparent and thus the user can directly count how many pins are left in the device .

Another method is that the stopper that is spring loaded can be given an extension outside that will tell as to how many pins are left in the device.

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