KEMENTERIAN PENGAJIAN TINGGI

ENGINEERING DESIGN VOL.1

BY MARIYATI MAT SOAD

MECHANICAL ENGINEERING

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Writer:
Mariyati binti Mat So'ad
Tn. Hj. Md Teni b. Bakar
Mohd. Zamri bin Hamid

Designer:
Mohammad Sabri b. Desa

Mechanical Engineering Dept, PTSB [09000 Kulim Kedah]

mariyati@ptsb.edu.my

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Mariyati bt Mat Soad

Mechanical Engineering Department

Politeknik Tuanku Sultanah Bahiyah

Kulim Kedah

ABSTRACT

Design is a process of rational decision-making, the creation of a plan or convention and innovative and highly iterative process . Considering any problems that to rise, find solutions as possible and then try to choose the best solution in accordance with the scope required. In the design, the problem is viewed from different aspects and solutions , made in various ways such as using mathematical analysis, the existing experience of past problem solving, using the results of research or trial either by the designer himself or others. The stress analysis is to ensure safety. Accomplishing this requires that the stress produced in the material of the member being analyzed is below a certain safe level that will described later. Understanding the meaning of stress in a load-carrying member is the upmost importance in studying design engineering.

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ENGINEERING DESIGN

1. INTRODUCTION TO ENGINEERING DESIGN

Understand the engineering design.

1.1.1 Define the meaning of design

`The man has needs that must be met. They use creative ability (creativity) to exploit natural resources to improve their lives. '

Engineering design (concrete) is an art that uses scientific concepts as a foundation.

Design is a process of rational decision-making, consider any problems that arise, find solutions as possible and then try to choose the best solution in accordance with the scope required. In the design, the problem is viewed from different aspects and solutions made in various ways such as using mathematical analysis, the existing experience of past problem solving, using the results of research or trial either by the designer himself or others.

Design is the creation of a plan or convention for the construction of an object or a system for satisfaction of a specified need or to solve a problem in engineering. If the plan results in the creation of something having a physical reality, then the product must be functional, safe, reliable, competitive, usable, manufacturable and marketable.

Design is an innovative and highly iterative process. It is also a decision-making process. Decisions sometimes have to be made with too little information, occasionally with just the right amount of information, or with an excess of partially contradictory information. Decisions are sometimes made tentatively, with the right reserved to adjust as more become known. The point is that the engineering designer has to be personally comfortable with a decision-making, problem-solving role.

1.1.2 Describe the types of design

At this time there is confusion about the meaning of the term design. To the public, design thinking is understood as the ability to make a technical invention (invention). Invention of this type require materials and tools such as sheet metal, plastic, saws, drills, machines and so on.

The two types of design:

a) Design of concrete that produce real objects such as cars, fighter jets, submarines and the like.
b) Design produces abstract concept of strategy, tactics, procedures, regulations,

However, there are so many design disciplines nowadays as shown in Table 1.1 below;

Table 1.1 : Design Disciplines

Design disciplines [edit]

- Applied arts
- Architecture
- Automotive design
- Biological design
- Cartographic or map design
- Configuration design
- Communication design
- Costume design
- Design management
- Engineering design
- Experience design
- Fashion design
- Floral design
- Game design
- Graphic design
- Information architecture
- Information design
- Industrial design
- Instructional design
- Interaction design
- Interior design
- Landscape architecture
- Lighting design
- Modular design
- Motion graphic design
- Organization design
- Process design
- Product design
- Production design
- Property design
- Scenic design
- Service design
- Social design
- Software design
- Sound design
- Spatial design
- Strategic design
- Systems architecture
- Systems design
- Systems modeling
- Urban design
- User experience design
- User interface design
- Vexillography
- Web design

Credit to https://en.wikipedia.org/wiki/Design

1.2 Understand the designing process

What is the design process? How does it begin? Does the engineer simply sit down at a desk with a blank sheet of paper and jot down some ideas? What happen next? What factor influence or control the decisions that have to be made? Finally how does the design process end?

The process begin with an identification of a need and a decision to do something about it. After many iterations, the process ends with the presentation of the plans for satisfying the need. Depending on the nature of the design task, several design phases may be repeated throughout the life of the product from inception to termination. In the next several subsections, we shall examine these steps in the process in detail.

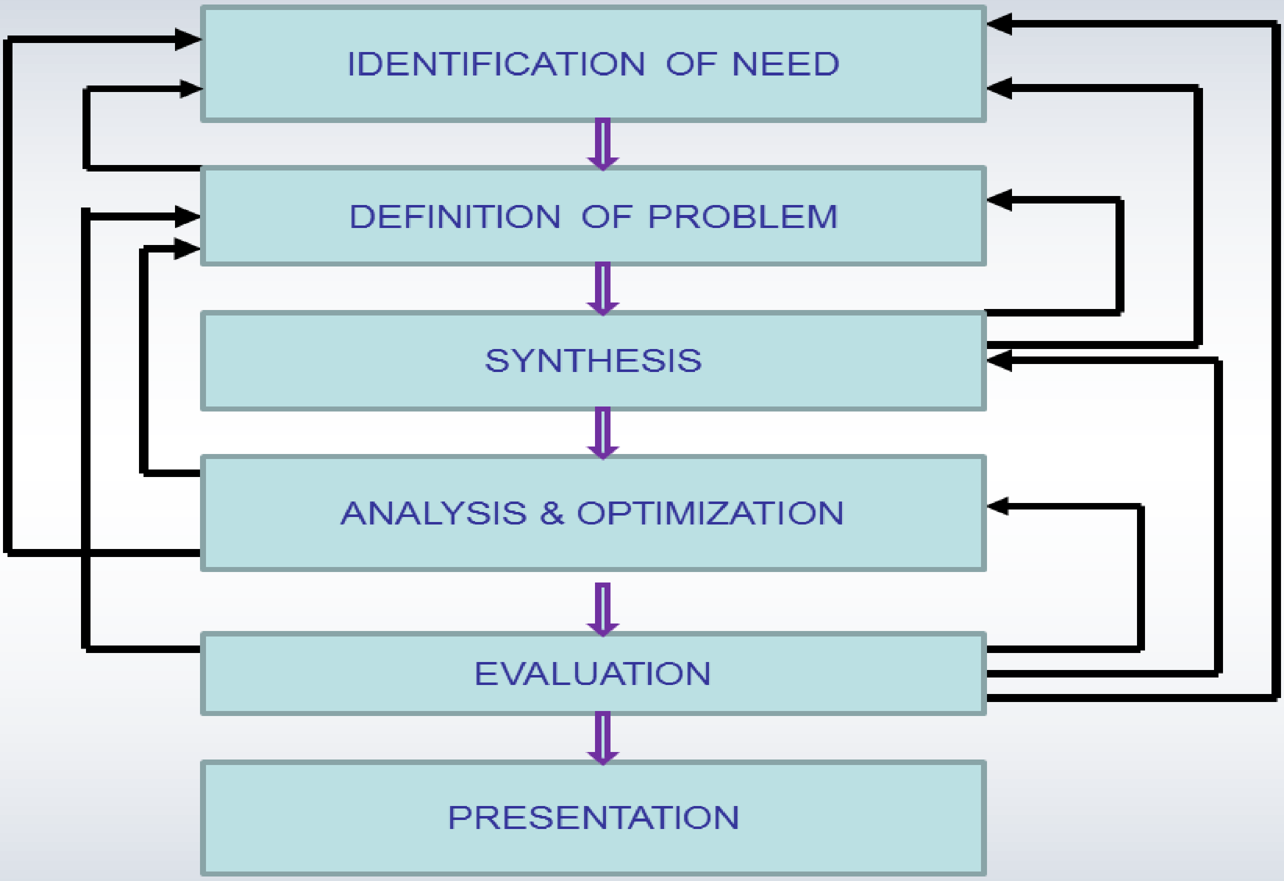


Figure 1.1 : The phases in design process

Engineering design process is an iterative process (iterative) and quite complex. This means that the design process is not a one-way process that can be easily described in our minds. For this stage it is sufficient and generally simplified design process will follow the same direction although in a somewhat later stage eventually produce quite different.

1.2.1 Identification of need.

Generally starts in the design process. Recognition of the need and phrasing the need often constitute a highly creative act, because the need may be only a vague discontent, a feeling of uneasiness, or a sensing that something is not right. The need is often not evidence at all.

For example:

- Customers difficult to find the location of your store because no direction signs.
- You have no place to store pens and pencils, causing it to lose or break when you need it.

1.2.2 The definition of problem

More specific and must include all the specifications for the object that is to be designed. The specifications are the input and output quantities, the characteristics and dimensions of the space the object must occupy, and all the limitations on these quantities. Specified characteristics can include speeds, feeds, temperature limitations, maximum range, expected variations in the variable, dimensional and weight limitations.

Specification outlines the basic requirements, conditions of service and economic limits on the products that will be produced. This specification is an important stage and a specification created by carefully will help determine the success of the design.
Basic issues considered are:

- Are the specifications outlined sufficient?
- Does the problem presented is the real problem?
- Are the requirements expressed a fundamental requirement is that is actually required?
- Are users/customers will encounter problems in using the results of this de sign?
- There are many other questions that need to be considered to ensure that the design of superior results.
- Identify (analyze) the problem is generally more focused on the collection and processing of information in the end is to define the problem in detail. Next, it will be able to provide the best solution.

1.2.3 The syntesis

Synthesis is sometimes called the invention of the concept or concept design. This is the first and most important step in the synthesis task. Various schemes must be proposed, investigated and quantified in terms of established metrics. As the fleshing out of the scheme progresses, analyses must be performed to assess whether the system performance is satisfactory or better, and it satisfactory, just how well it will perform.

1.2.4 Analysis and optimization

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

For example, the design of a system to transmit power requires attention to the design and selection of individual components e.g gears, bearing and shaft. However as is often the case in design, these components are not independent. In order to design the shaft for stress and deflection, it is necessary to know the applied forces. If the forc-es are transmitted through gears, it is necessary to know the gear specifications in order to determine the forces that will transmitted to the shaft. But stock gears come with certain bore sizes, requiring knowledge of the necessary shaft diameter.

All the solutions obtained researched, evaluated, compared, for consideration for choosing a most suitable solution.

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

1.2.5 Comparison & Evaluation

Communicating the design to others is the final, vital presentation step in the design process. Many great designs, inventions and creative works have been lost to posterity simply because the originators were unable or unwilling to explain their accomplishment to others. Its a significant phase of the total design process. Evaluation is the final proof of a successful design and usually involves the testing of a prototype in the laboratary. Here we wish to discover if the design:

- Really satisfies the needs
- Is it reliable
- Will it compete successfully with similar product?
- Is it economical to manufacture and to use?
- Is it easily maintained and adjusted?
- Can a profit be made from its sale or use?
- Or likely is it to result in product-liability lawsuits?
- Is insurance easily and cheaply obtained?
- Is it likely that recalls will be needed to replace defective parts of systems?

1.2.6 Presentation

Presentation is a selling job. Communicating the design to others is the final, vital presentation step in the design process. The engineer, when presenting a new solution to administrative, management, or supervisory persons, is attempting to sell or to prove to them that this solution is a better one. Unless this can be done successfully, the time and effort spent on obtaining the solution have been largely wasted. When designer sell a new idea, they also sell themselves. If they are repeatedly successful in selling ideas, designs and new solution to management, they begin to receive salary increases and promotions; in fact, this is how anyone succeeds in his of her profession.

1.2.7 Another engineering design process for a given task

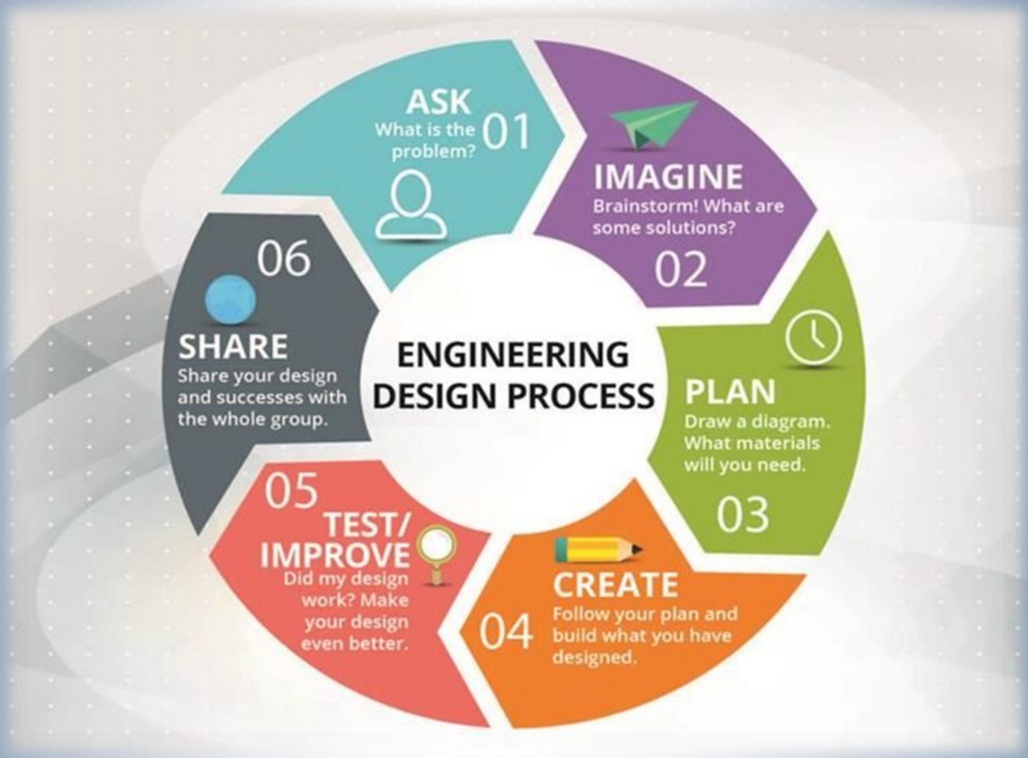


Figure 1.2: Engineering Design Process

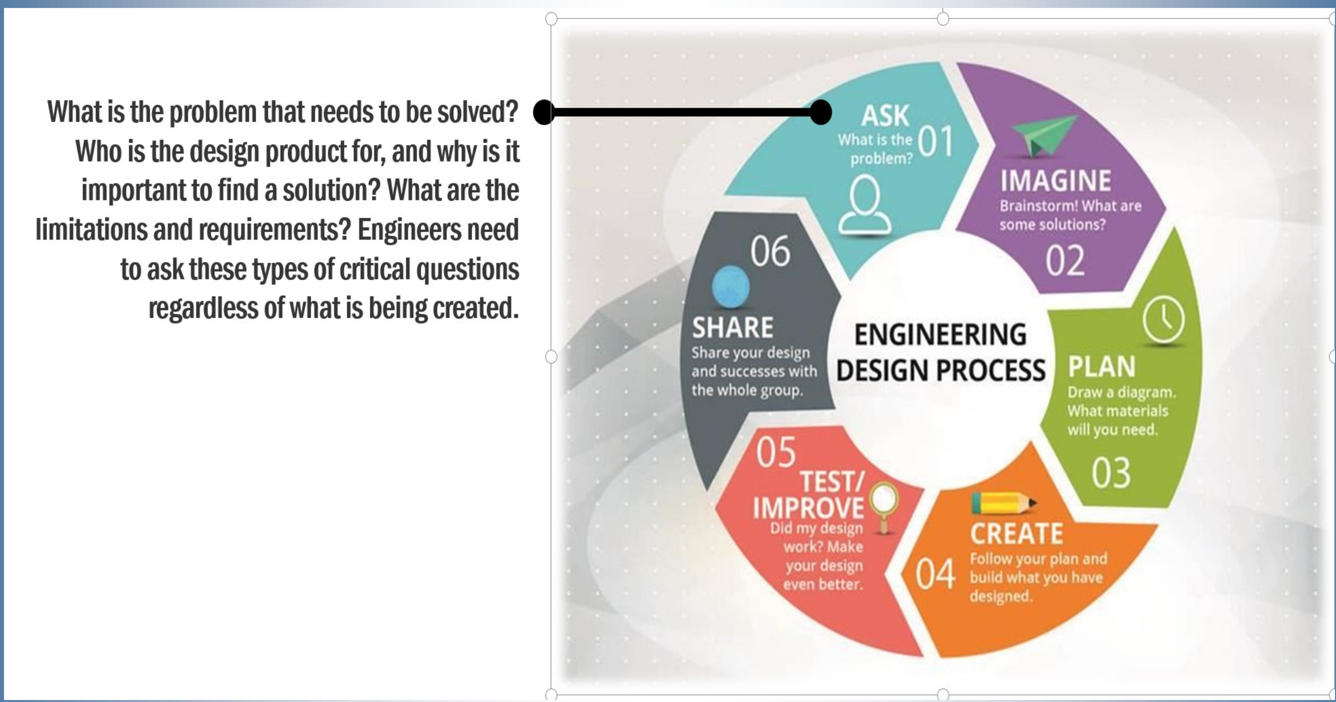
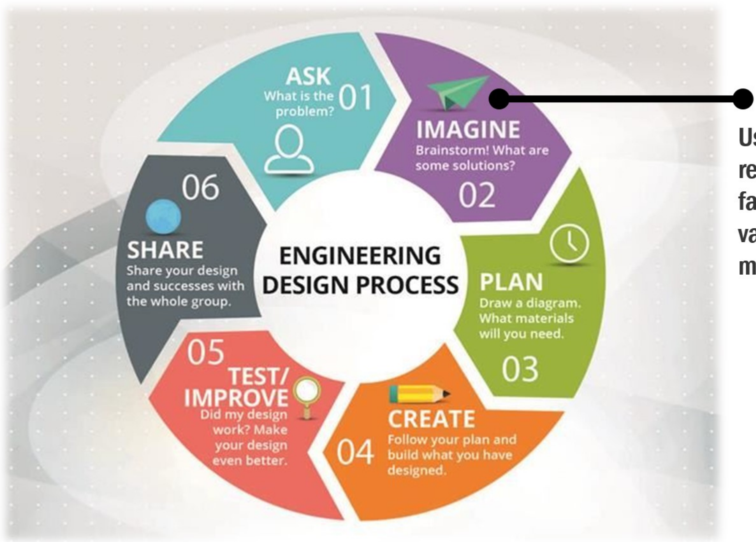
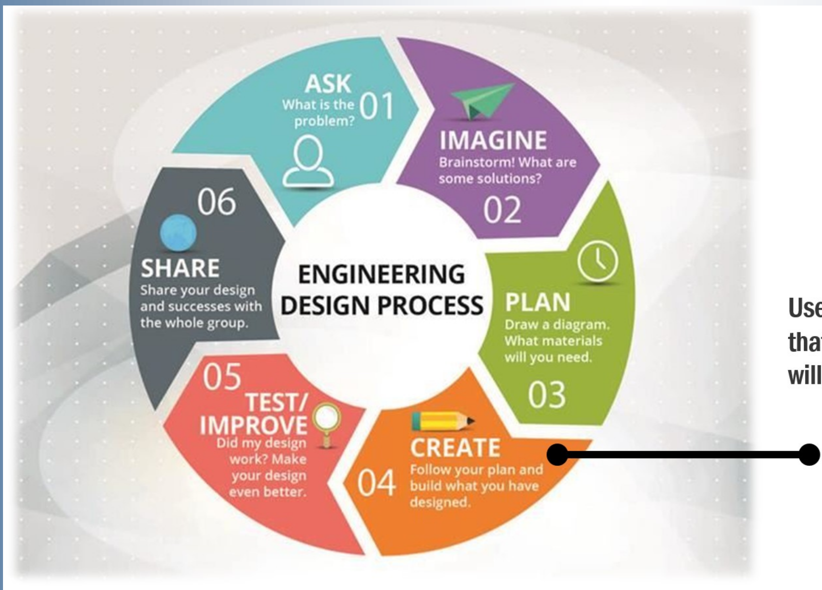


Figure 1.3: What is the problem



Use the experience of others to explore possibilities. By researching past projects you can avoid the problems faced by others. You should speak to people from various backgrounds, including users or customers. You may find some solutions that you had not considered.

Figure 1.4: Brainstorming the solution



Use your design proposal to make a prototype that will allow you to test how the final product will perform

Figure 1.5 : Plan and Create

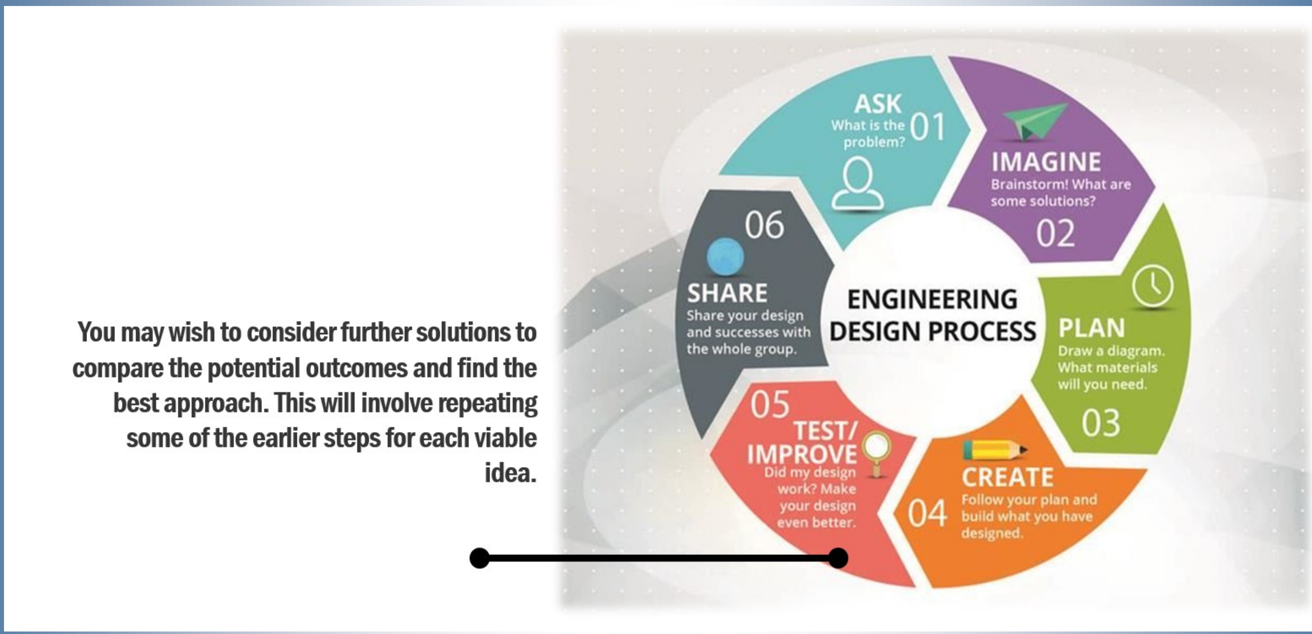


Figure 1.6 : Test and Improve

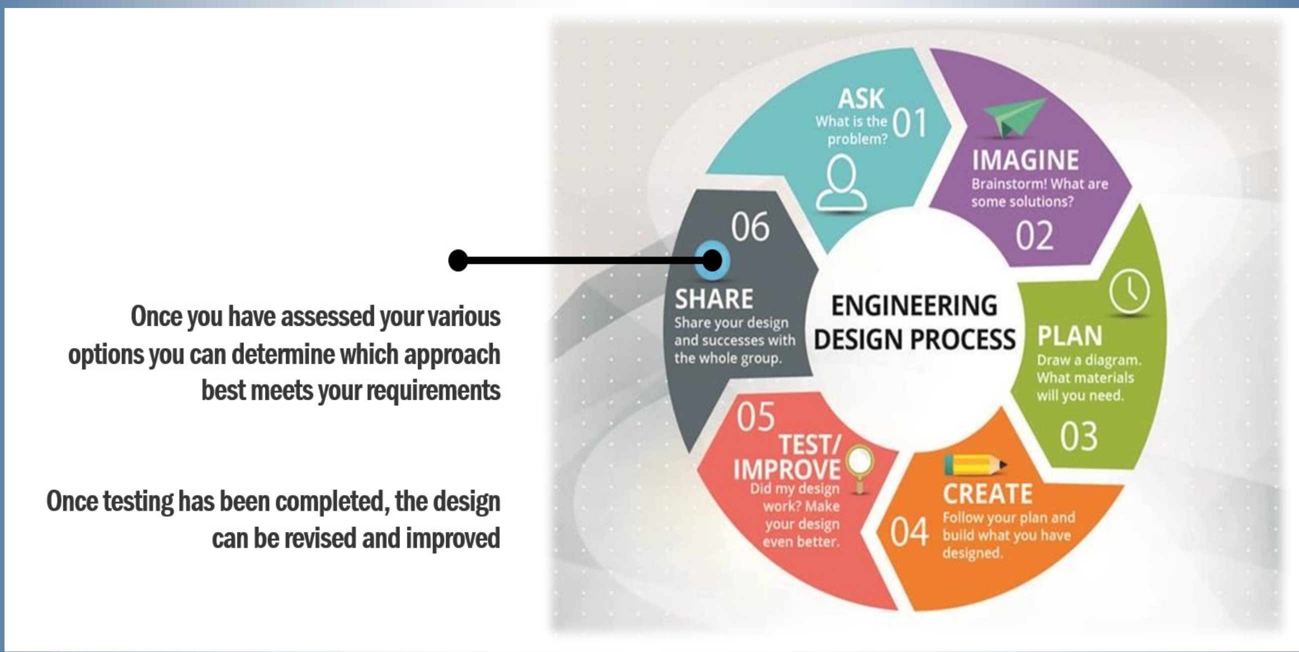


Figure 1.7 : Share or Presentation

1.3 The design consideration

There are many factors that will influence the design and most likely a mutually dependent on each other. Degree of importance of these factors depends on how the design was used.

1.3.1 Economic and production factors

a) Position within the scope of price-quality.
b) Number and date required (slow / fast).
c) Cost of capital.
d) Cost of operations / manufacturing (energy, precision, worn parts replaced).
e) Availability of raw materials.
f) Ability to use existing production operations.
g) Whether the components made / bought.
h) Ability to modifications to wider use.
i) The ability of the components exchanged with other engine parts.
j) Type of technology (working principle) required (gear drive, chain drive, rock et boosters, jet engines, power turbines and the like).
k) Expenses incurred (number either fixed or variable and its type either static/ dynamic/ shock).
l) Speed (fixed or determined by design calculation, can be either fixed or variable).
m) Life Cycles (in minutes / hours / week and so on)
n) Sources of power (mechanical / electrical / hydraulic / pneumatic, etc.)
o) Long life required
p) The degree of reliability required (without service operating life, the possibility of failure before the end of design life).

1.3.2 The codes and standards are using in design

A standard is a set of specification for parts, materials, or processes intended to achieve uniformity, efficiency, and a specified quality. One of the important purposes of a standard is to place a limit on the number of items in the specifications so as to provide a reasonable inventory of tooling, sizes, shapes and varieties.

A code is a set of specifications for the analysis, design, manufacture and construction of something. The purpose of a code is to achieve a specified degree of safety, efficiency and performance or quality.

All the organizations and societies listed below have establish specifications for standards and safety or design codes. The name of the organization provides a clue to the nature of the standard or code. Some of the standards and codes as well as addresses can be obtained in most technical libraries. ***Table 1.2*** shows the codes and standard are using in design.

Table 1.2 The Codes and Standard Using In Design

Aluminum Association (AA)	American Bearing Manufacturers Association (ABMA)
American Gear Manufacturers Association (AGMA)	British Standard Institution (BSI)
American Institute of Steel Construction (AISC)	Industrial Fasteners Institute (IFI)
American Iron and Steel Institute (AISI)	Institution of Mechanical Engineers (I. Mech. E)
American National Standard Institute (ANSI)	International Bureau of Weights and Measures (BIPM)
American Society for Metals (ASM) international.	International Standards Organization (ISO)
American Society of Mechanical Engineers (ASME)	National Institute for Standards and Technology (NIST)
American Society of Testing and Material (ASTM)	Society of Automotive Engineers (SAE)
American Welding Society (AWS)	

1.3.3 Safety and Product Liability

The strict liability concept of product liability generally prevails in the United States. This concept states that the manufacturer of an article is liable for any damage or harm that results because of a defect. And it doesn't matter whether the manufacturer knew about the defect, or even could have known about it. For example, suppose an article was manufactured, say 10 years ago. And suppose at that time the article could not have been considered defective on the basic of all technological knowledge then available. Ten years later, according to the concept, the plaintiff needs only to prove that the articles was defective and that the defect caused some damage or harm. Negligence of the manufacturer need to be proved.

The best approaches to the prevention of product liability are good engineering in analysis and design, quality control and comprehensive testing procedures. Advertising managers often make glowing promises in the warranties and sales literature for a product. These statements should be reviewed carefully by the engineering staff to eliminate excessive promises and to insert adequate warnings and instructions for use.

1.3.5 Appropriate design consideration when designing

a) Size / dimensions (length, width, height).
b) Weight (if it is important).
c) Rigidity (stifness).
d) Characteristic (interesting).
e) Ergonomics (the study of human movement and natural surroundings).
f) Security feature.
g) The factor of safety.
h) Use (easy / hard).

Design involves attempts to obtain the best solution from a set of complex relationships where compromise is needed, and this complicates the decision was made. If after all carefully considered solutions but results have yet to be made, it should be remembered that the results may not be so critical and any decision taken is better than not making any decision at all (if not worse).

The Specification in Design

The requirement of design specification

Specification outlines the basic requirements, service conditions and economic boundaries for products to be manufactured. Determining this specification is a crucial stage and one specification carefully done will help determine the success of the design.

Analyze the possible specification:

The fundamental question is commonly considered as:

> Are the specifications outlined sufficient?
> Are the problems mentioned is the real problem?
> Are the requirements set is a basic requirement is that is actually required?
> Are consumers / customers will be facing problems in using the results of this design?
> There are many other questions that need to be considered to ensure that the design of the home.

Write specification for certain design product :

For example:

A home hardware makers wishing to market a new type of washing machine. The machine is expected to perform the duties of washing and also serves as a dryer unit. The factory management had also decided that:

A home hardware makers wishing to market a new type of washing machine. The machine is expected to perform the duties of washing and also serves as a dryer unit. The factory management had also decided that:

a) The unit must not exceed 0.75 m wide, 1.0 m high and 0.75 m thick.
b) Must be operated with 240V ac 50Hz.
c) Must be approved by SIRIM.
d) The cost of production must not exceed RM400.00
e) Must be washed natural and synthetic textile materials satisfactorily.
f) Must not be damaged even if operated in the wrong.

1.4 The ergonomic factors inside design

Ergonomics is the human factor in engineering. Derived from two Greek words, "Nomoi" meaning natural laws and "Ergon" meaning work. Hence, ergonomists study human capabilities in relationship to work demands

1.4.1 Define the ergonomic in relationship between human and machine

It is the study of how people interact with machines. Most products have to work with people in some manner. People occupy a space in or around the design, and they may provide a source of power or control or act as a sensor for the design. For example, people sense if an automobile air-conditioning system is maintaining a comfortable temperature inside the car. These factors form the basis for human factors, or ergonomics, of a design.

A design solution can be considered successful if the design fits the people using it. The handle of a power tool must fit the hand of everybody using it. The tool must not be too heavy or cumbersome to be manipulated by all sizes of people using the tool. The geometric properties of people-their weight, height, reach, circumference, and so on-are called anthropometric data. The difficulty in designing for ergonomics is the abundance of anthropometric data.

As early as 18th century doctors noted that workers who required to maintain body positions for long periods of time developed musculoskeletal problems. Within last 20 years research has clearly established connections between certain job tasks and Repetitive Strain Injury or Musculoskeletal Disorder.

1.4.2 The relationship of basic ergonomic between human and machine in the display element.

Static work: musculoskeletal effort required to hold a certain position, even a comfortable one.

Example: sit & work at computers; keeping head and torso upright requires small or great amounts of static work depending on the efficiency of the body positions we chose. Force: amount of tension our muscles generate. Example: tilting your head forward or backward from a neutral, vertical position quadruples the amount of force acting on your lower neck vertebrae.

Increased force is due to increase in muscular tension needed to support head in a tilted position. The facts is;

- Overexertion, falls & Repetitive Motion Injury are the most common cause of workplace injury
- An average of 125,000 back injuries due to improper lifting each year.
- Muscles overuse results in tiny tears in the muscles and scarring; these contribute to inflammation and muscle stiffness

How to prevent ?

- Warm up & stretch before activities that are repetitive, static or prolonged
- Take frequent breaks from ANY sustained posture every 20-30 minutes
- Respect pain- positions or stop painful activity
- Recognize early signs of inflammatory process
- Avoid bending neck forward for prolonged periods of time (*remember quadruple the force); use a copy holder

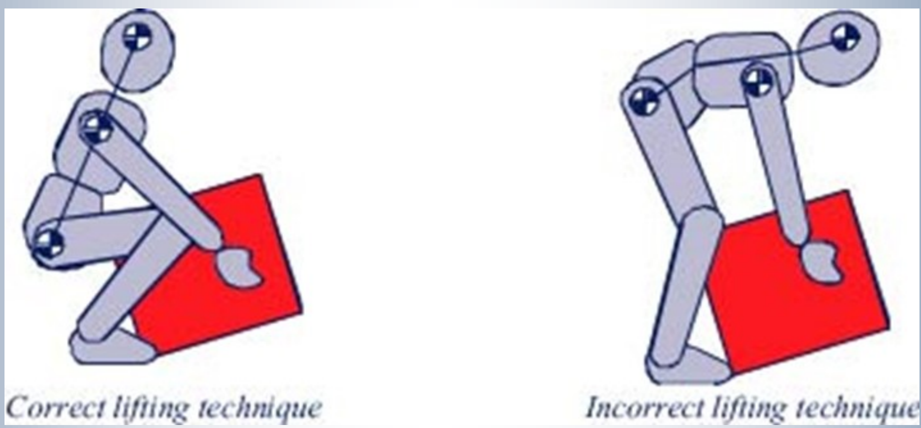


Figure 1.8 The correct and incorrect technique to lifting the box.

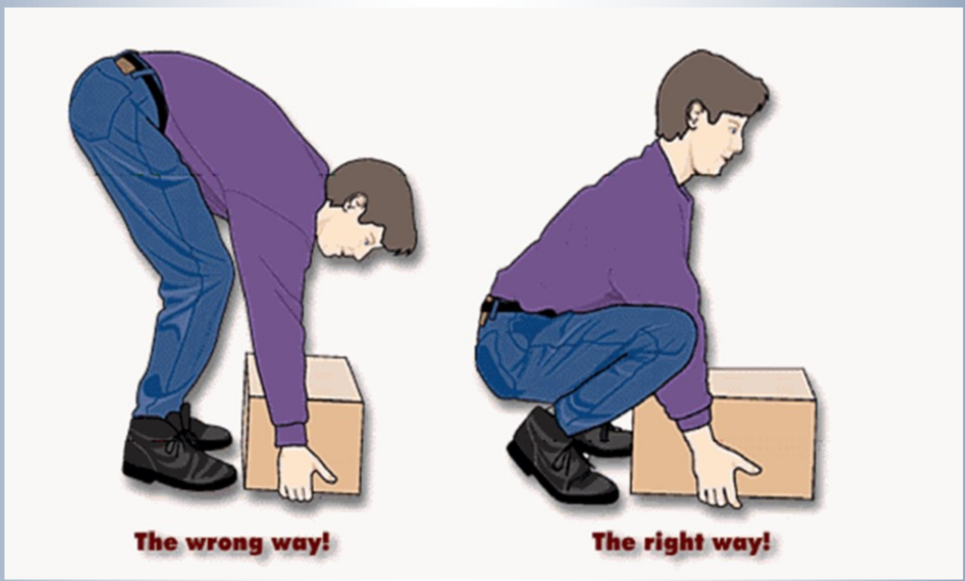


Figure 1.9 The correct and incorrect technique to lifting the box.

1.4.3 The target users of our design.

a) Design for Body and Human Movement

> Ergomik factors to be considered are:
> Size (hands and fingers)
> Movement (comfort reach equipment)
> Vision (easily visible, color)
> sound
> touch
> odor
> taste
> temperature

b) Design for safety

Sharp edges, stability, fire, electricity, guard, materials (toxic?)

c) Design for growth and design for increasing age

Childhood, youth and old people

d) Design for the needs of disabled and elderly

Mental disability, physical and emotional

e) Design for vision, color and lighting

1.4.4 Evaluate ergonomic factors used on simple equipment

A) Micrometer

•Ergonomic anti-slip frame cover and front panel for more comfortable hand-held measurements

•Ratchet thimble provides better operability for one-handed operation

Figure 1.10 Ergonomic Values in Micrometer Design.

b. Microscope

Stereomicroscopes approach substitutes a lenticular array-driven screen that is positioned on top of the microscope body to allow the operator wide latitude in viewing angle and distance

Figure 1.11 Ergonomic Values in Microscope Design.

1.5 Materials Selection in Design

For a perfect and smart design, designers must understand the nature and properties of materials suitable for use in the invention. The choice of material depends on many factors such as stress experienced by component, hardcore, high temperature, chemical action and performance materials when manufacturing processes (casting, forging, machining, etc.). Selection is made by the designer will affect the strength, weight, shape, manufacturing pro cess and cost. Price also is the last factor that determines whether an invention was success ful marketable. There are three groups of substances:

- Iron-based metal is used when the power is needed, cheap, readily available and high machinability. Iron can be made of steel which has good mechanical properties and is widely used when blended / alloy with other metals.

- Nonferrous metals have properties such as light weight, shape, electrical properties, high thermal conductivity, the ratio of strength / weight high but the price is quite

1.5.1 The material properties

- **Aluminum** is widely used for structural and mechanical applications. Chief among its attractive properties are light weight, good corrosion resistance, relative ease of forming and machining and pleasing appearance.

- **A zinc alloy** is typically contained aluminum and a small amount of magnesium. Some alloy include copper or nickel. Zinc is the most commonly used metal in the world.

- **Titanium** has very good corrosion resistance and a high strength-to-weight ratio. Its stiffness and density are between those of steel and aluminum; its modulus of elasticity is approximately 110 GPa (16x106 psi) and its density 4.429kg/m3. Typical yield strengths range from 172-1210 MPa. The applications of titanium include aerospace structure and components, chemical tanks and processing equipment, fluids-handling devices, and marine hardware. Disadvantage of titanium include relatively high cost and difficult machining.

- **Copper** is widely used in its nearly pure form for electrical and plumbing applications because of its high electrical conductivity and good corrosion resistance. It is rarely used for machine parts because of its relatively low strength compared with that of its alloys, brass and bronze.

- **Brass** is a family of alloy of copper and zinc, with content of zinc ranging from 5% to 40%. Brass is often used in marine applications because of its resistance to corrosion in salt water. Many brass alloys also have excellent machinability and are used as connector, fittings and other parts made on screw machines. Yellow brass contains about 30% or more of zinc and often contains a significant amount of lead to improve machinability. Red brass contains 5% to 15% zinc.

- **Bronze** is a class of alloys of copper with several different elements, one of which is usually tin. They are useful in gears, bearings, and other applications where good strength and high wear resistance are desirable.

- **Plastics** include a wide variety of materials formed of large molecules called polymers. The thousands of different plastics are created by combining different chemicals to form long molecular chains. One method of classifying plastics is by the terms thermoplastic and thermosetting. In general, the thermoplastic materials can be formed repeatedly by heating or molding because their basic chemical structure is unchanged from its initial linear form. Thermosetting plastic do undergo some change during forming and result in a structure in which the molecules are cross-linked and form a network of interconnected molecules.

1.5.2 Material selection to minimize environment impact

From a manufacturing point of view, an increase in production is good because it reduces manufacturing cost, but in terms of environmental impact, the increase in energy consumption leads to increase in carbon dioxide emission. Sustainable production is an approach to improving environmental performance in manufacturing production. Sustainable production means that products are designed, produced, distributed, used and disposed with minimal (or none) environmental and occupational health damages, and with minimal use of resources (materials and energy), (Leo, 1993).

The environmental impact of a manufacturing process is also dependent on the selection of the material and design of a product. This is because the manufacturing of a product is directly connected to the amount of carbon emitted in consuming the electrical energy for that manufacturing process. The difference in the general properties of materials such as strength, hardness and impact will have significant effect on the power consumption of the machine used to complete the product. In addition the environmental impact can also be reduced if the proposed designs use less material.

In the study, an LCA tool called Eco-It is used. Evaluate the environmental impact caused by manufacturing simple jig. A simple jig with 4 parts was used as a case study. Two experiments were carried out. The first experiment was to study the environmental effects of different material, and the second experiment was to study the environmental impact of different design. The materials used for the jig are Aluminium and mild steel. The results showed a decrease in the rate of carbon emissions by 60% when Aluminium is use instead from mild steel, and a decrease of 26% when the-design is modified.

TUTORIAL CHAPTER 1

1. Explain the definition of Engineering Design from your understanding.
2. You are a manager of MAR Company. You are planning to produce Banana Slicer machine for IKS Industries in " Kerepek Ubi". List and explain 6 Step Process Design in producing this machine.
3. State the differences between abstract and concrete design and list an example of each.
4. Ergonomic is the scientific study of the relationship between human, the working environment and life. State FIVE (5) objectives of ergonomic in engineering design
5. Give the important of the codes and standards using in the design

CHAPTER 2:

STRESS ANALYSIS

CHAPTER 2: STRESS ANALYSIS

One of the main objectives of this course is to describe how specific machine components function and how to design or specify them so that they function safely without failing structurally. Structural strength in terms of load or stress versus strength, failure of function for structural reasons may arise from other factors such as excessive deformations or deflections. Here it is assumed that the student has completed basic courses in Statics of Rigid Bodies and Mechanics of Material and is quite familiar with the analysis of loads, the stresses and deformations associated with the basic load states of simple prismatic elements.

A designer is responsible for ensuring the safety of the components and systems that he or she designs. Many factors affect safety, but one the most critical aspects of design safety is that the level of stress to which a machine component is subjected must be safe under reasonably foreseeable conditions. This principle implies, of course, that nothing actually breaks. Safety may also be compromised if components are permitted to deflect excessively, even though nothing breaks.

You have already studied the Principle of Strength of Materials to learn the fundamentals of stress analysis. Thus, at this point, you should be competent to analyse load-carrying members for stress and deflection due to direct tensile and compressive loads, direct shear and torsion shear.

The objective of any strength analysis is to ensure safety. Accomplishing this requires that the stress produced in the material of the member being analysed is below a certain safe level that will described later. Understanding the meaning of stress in a load-carrying member is of upmost importance in studying design engineering.

2.1 Explain the direct stresses

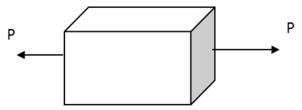
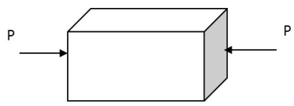
We are concerned with what happen inside a load-carrying member. We must determine the magnitude of force exerted on each unit area of the material. The concept of stress can be expressed mathematically as:

$$\boxed{stress = \frac{\text{load/force}}{\text{area}}, \qquad \sigma = \frac{P}{A}}$$

2.1.1 Differentiate between direct tension and direct compression of stresses.

In some case, as describe in the following section on Direct Normal Stress, the applied force is shared uniformly by the entire cross section of member. Direct normal stress is one of the most fundamental types of stress that exists is the normal stress, indicated by the lowercase Greek letter σ (sigma), in which the stress acts perpendicular, or normal, to the cross-section of the load carrying member. If the stress is also uniform across the resisting area, the stress is called a direct normal stress. Normal stresses can be either compressive or tensile.

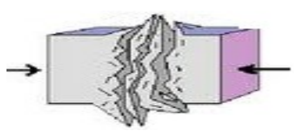
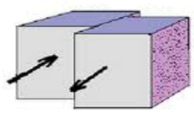
Table 2.1 : Direct tension and direct compression

Normal force, F	- This force acts perpendicular to the area. - It is developed whenever the external loads tend to push or pull on the two segments of body.	TENSION  COMPRESSION 

A compressive stress is one that tends to crush the material of the load-carrying member and to shorten the member itself.

In such cases stress can be computed by simply dividing the total force by the area of the part that resists the force. Then the level of stress will be the same at any

Table 2.2: Difference between stress

TENSIONAL STRESS	COMPRESSIVE STRESS	SHEAR STRESS
Tensional Stress, s  $= \frac{Tensional\ Force}{Area}$ $= \frac{P/F}{A} \ \frac{(N)}{(m^2)}$	Compressive stress, s  $= \frac{Compression\ Force}{Area}$ $= \frac{P/F}{A} \ \frac{(N)}{(m^2)}$	Shear Stress, t  $= \frac{Shear\ Force}{Area}$ $= \frac{V}{A} \ \frac{(N)}{(m^2)}$

2.1.2 Calculate direct stress in the round bar.

This section highlights the Direct Stress and the resilience in bars of varying cross section as well as in compound bars; made with more than one material, each having its coefficient of thermal expansion. When a force is applied to an elastic body, the body deforms. The way in which the body deforms depends upon the type of force applied to it.

2.2 Explain the deformation under direct axial loading

In each case, a force F produces a deformation x. In engineering, we usually change this force into stress and the deformation into strain and we define these as follows:

Strain is the deformation per unit of the original length. Used to measure the deformation or extension of a body that is subjected to the force or set of forces. The strain of a body is generally defined as the change of length divided the initial length.

Strain has no unit's since it is a ratio of length to length. Most engineering materials do not stretch very mush before they become damages, so strain values are very small figures. It is quite normal to change small numbers in to the exponent for 10^{-6} (micro strain).

Strain represented by the Greek letter or symbol ;

$$Strain = \varepsilon = \frac{x}{L}$$

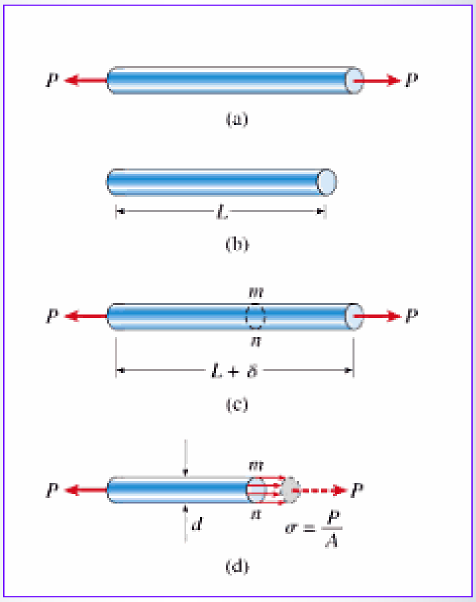


Figure 2.1 : The deformation in the round bar

2.2.1 Solve problem regarding strain due to a direct axial tensile load or due to a direct axial compressive load.

<u>MODULUS OF ELASTICITY (E)</u>

Elastic materials always spring back into shape when released. They also obey HOOKE's LAW.

This is the law of spring which states that deformation is directly proportional to the force. F/x = stiffness = kN/m

The stiffness is different for the different material and different sizes of the material. We may eliminate the size by using stress and strain instead of force and deformation:

If F and x is refer to the direct stress and strain , then

$F = \sigma A$ and $x = \varepsilon L$ hence

$$\frac{F}{x} = \frac{\sigma A}{\varepsilon L}$$

And $$\frac{FL}{Ax} = \frac{\sigma}{\varepsilon}$$

The stiffness is now in terms of stress and strain only and this constant is called the MODULUS of ELASTICITY (E);

$$E = \frac{FL}{Ax} = \frac{\sigma}{\varepsilon}$$

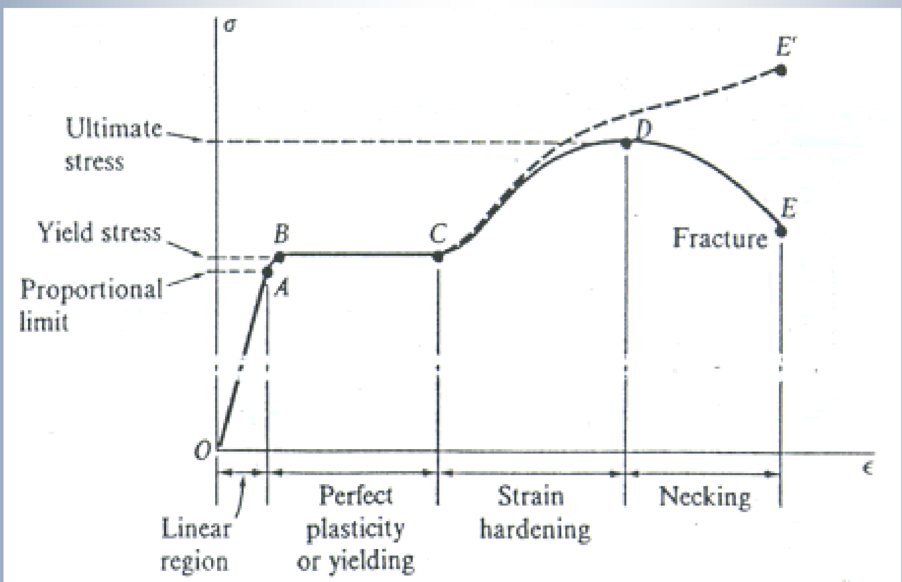


Figure 2.2 : Stress vs Strain Graph

Elastic behaviour

- The curve is straight line trough out most of the region
- Stress is proportional with strain
- Material to be linearly elastic
- Proportional limit
    - The upper limit to linear line
    - The material still respond elastically
    - The curve tend to bend and flatten out
- Elastic limit
    - Upon reaching this point, if load is remove, the specimen still return to original shape

Yielding

- A Slight increase in stress above the elastic limit will result in breakdown of the material and cause it to deform permanently.
- This behaviour is called yielding
- The stress that cause = YIELD STRESS@YIELD POINT
- Plastic deformation
- Once yield point is reached, the specimen will elongate (Strain) without any increase in load
- Material in this state = perfectly plastic

Strain Hardening

- When yielding has ended, further load applied, resulting in a curve that rises continuously
- Become flat when reached ULTIMATE STRESS
- The rise in the curve = STRAIN HARDENING
- While specimen is elongating, its cross sectional will decrease
- The decrease is fairly uniform

Necking

WORKED EXAMPLE No.1

A metal wire is 2.5 mm diameter and 2 m long. A force of 12 N is applied to it and it stretches 0.3 mm. Assume the material is elastic. Determine the following.

i. The stress in the wire σ.
ii. The strain in the wire ε.

SOLUTION

$$A = \frac{\pi d^2}{4} = \frac{\pi \times 2.5^2}{4} = 4.909 \text{ mm}^2$$

$$\sigma = \frac{F}{A} = \frac{12}{4.909} = 2.44 \text{ N/mm}^2$$

Answer (i) is hence 2.44 MPa

$$\varepsilon = \frac{x}{L} = \frac{0.3 \text{ mm}}{2000} = 0.00015 \text{ or } 150\ \mu\varepsilon$$

WORKED EXAMPLE No.2

A steel tensile test specimen has a cross sectional area of 100 mm^2 and a gauge length of 50 mm, the gradient of the elastic section is 410 x 10^3 N/mm. Determine the modulus of elasticity.

SOLUTION

The gradient gives the ratio F/A = and this may be used to find E.

$$E = \frac{\sigma}{\varepsilon} = \frac{F}{x} \times \frac{L}{A} = 410 \times 10^3 \times \frac{50}{100} = 205\,000 \text{ N/mm}^2 \text{ or } 205\,000 \text{ MPa or } 205 \text{ GPa}$$

WORKED EXAMPLE No.3

A Steel column is 3 m long and 0.4 m diameter. It carries a load of 50 MN. Given that the modulus of elasticity is 200 GPa, calculate the compressive stress and strain and determine how much the column is compressed.

SOLUTION

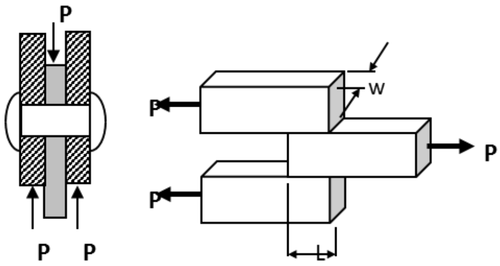
$$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.4^2}{4} = 0.126 \text{ m}^2$$

$$\sigma = \frac{F}{A} = \frac{50 \times 10^6}{0.126} = 397.9 \times 10^6 \text{ Pa}$$

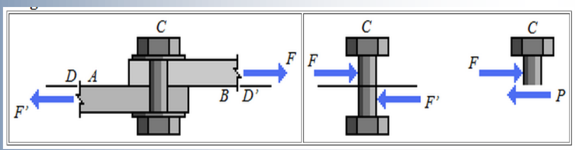
$$E = \frac{\sigma}{\varepsilon} \quad \text{so} \quad \varepsilon = \frac{\sigma}{E} = \frac{397.9 \times 10^6}{200 \times 10^9} = 0.001989$$

$$\varepsilon = \frac{x}{L} \quad \text{so} \quad x = \varepsilon L = 0.001989 \times 3000 \text{ mm} = 5.97 \text{ mm}$$

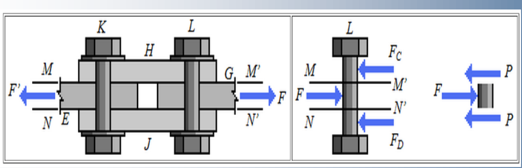
2.3 Apply the shear stress

Shear force, V	- Shear force lies in the plane of the area and is developed whenever the external loads tend to cause the two segments of the body slide over one another.	

Single Shear Stress	Double Shear Stress
If plates *A* and *B* are connected by bolt *C*, shear will take place in bolt *C* in plane *DD′*. The bolt is in single shear. To determine the average shearing stress in the plane, free-body diagrams of bolt *C* and of the portion of the bolt located above the plane is drawn. Observing that the shear *P* = *F*, it can be concluded that the average shearing stress is:	If splice plates *H* and *J* are used to connect plates *E* and *G*, shear will take place in bolts *K* and *L* in each of the two planes *MM′* and *NN′*. The bolts are in double shear. To determine the average shearing stress in each plane, free-body diagrams of bolt *L* and of the portion of the bolt located between the two planes is drawn. Observing that the shear *P* in each of the sections is *P* = *F*/2, it can be concluded that the



$$\tau_{ave} = \frac{P}{A} = \frac{F}{A}$$



$$\tau_{ave} = \frac{P}{A} = \frac{F/2}{A} = \frac{F}{2A}$$

WORKED EXAMPLE No.4

Calculate the force needed to guillotine a sheet of metal 5 mm thick and 0.8 m wide given that the ultimate shear stress is 50 MPa.

SOLUTION

The area to be cut is a rectangle 800 mm x 5 mm

$A = 800 \text{ x } 5 = 4000 \text{ mm}^2$ The ultimate shear stress is 50 N/mm^2

$$\tau = \frac{F}{A} \quad \text{so} \quad F = \tau \text{ x } A = 50 \text{ x } 4000 = 200\ 000 \text{ N or } 200 \text{ kN}$$

WORKED EXAMPLE No.5

Calculate the force needed to punch a hole 30 mm diameter in a sheet of metal 3 mm thick given that the ultimate shear stress is 60 MPa.

SOLUTION

The area to be cut is the circumference x thickness = πd x t

$A = \pi \text{ x } 30 \text{ x } 3 = 282.7 \text{ mm}^2$ The ultimate shear stress is 60 N/mm^2

$$\tau = \frac{F}{A} \quad \text{so} \quad F = \tau \text{ x } A = 60 \text{ x } 282.7 = 16965 \text{ N or } 16.965 \text{ kN}$$

WORKED EXAMPLE No.6

Calculate the force needed to shear a pin 8 mm diameter given that the ultimate shear stress is 60 MPa.

SOLUTION

The area to be sheared is the circular area $A = \frac{\pi d}{4}$

$A = \frac{\pi \text{ x } 8^2}{4} = 50.26 \text{mm}^2$ The ultimate shear stress is 60 N/mm^2

$$\tau = \frac{F}{A} \quad \text{so} \quad F = \tau \text{ x } A = 60 \text{ x } 50.26 = 3016 \text{ N or } 3.016 \text{ kN}$$

WORKED EXAMPLE No.7

A pin is used to attach a clevis to a rope. The force in the rope will be a maximum of 60 kN. The maximum shear stress allowed in the pin is 40 MPa. Calculate the diameter of a suitable pin.

SOLUTION

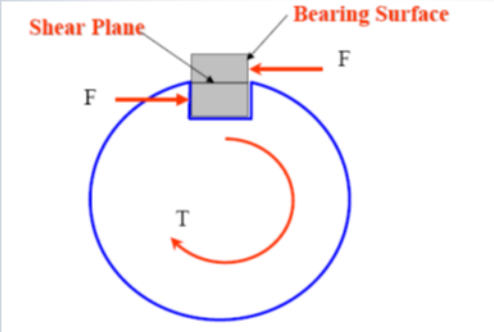
The pin is in double shear so the shear sress is $\tau = \frac{F}{2A}$

$$A = \frac{F}{2\tau} = \frac{60000}{2 \times 40 \times 10^{6}} = 750 \times 10^{-6}\ \mathrm{m}^2$$

$$A = 750\ \mathrm{mm}^2 = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4 \times 750}{\pi}} = 30.9\ \mathrm{mm}$$

2.3.1 Determine direct shear stresses on a key.

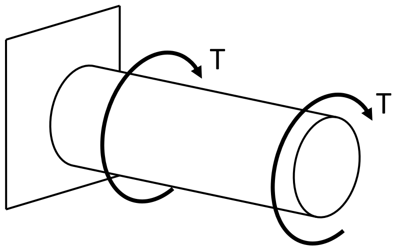


A key has two failure mechanisms:

> it can be sheared off, and

> it can be crushed due to the compressive bearing forces

2.3.2 Determine the torsional shear stress formula on a shaft.

Torsion moment or Torque, T	- This effect is developed when the external load that tend to twist one segment of the body with respect to the other	

When a shaft is subjected to a torque or twisting, a shearing stress is produced in the shaft. The shear stress varies from zero in the axis to a maximum at the outside surface of the shaft.

The shear stress in a solid circular shaft in a given position can be expressed as:

$t = T r / J$ (1)

where

t = shear stress (N/m^2, MPa, psi)

T = twisting moment (Nmm, in lb)

r = distance from center to stressed surface in the given position (mm, in)

J = Polar Moment of Inertia of an Area (mm^4, in^4)

Note

•the "Polar Moment of Inertia of an Area" is a measure of a beam's ability to resist torsion. The "Polar Moment of Inertia" is defined with respect to an axis perpendicular to the area considered. It is analogous to the "Area Moment of Inertia" - which characterizes a beam's ability to resist bending - required to predict deflection and stress in a beam.

2.3.3 Solve problem regarding relationship among torque, power and rotational speed.

The relationship among the power (P), the rotational speed (ω) and the torque in the shaft is described by the equation;

$$T = P / \omega$$

Exercise 7:

Compute the amount of torque in a shaft transmitting 750 W of a power while rotating at 183 rad/s.

Calculate the torque in the shaft.

Answer:

T = 4.10 N.m/rad

** In such calculation, the unir N.m/rad is dimensionally correct, and some advocate in use. Most however, consider the radian to be dimensionless, and thus torque is expressed in N.m or other familiar units of force times distance.

- A shaft is a rotation member usually with cylindrical shape which is used to transmit torque, power and motion between various elements such as electric or combustion motors and gear sets, wheels, cams, flywheels, pulleys, or turbines and electric generators. Shafts can be solid or hollow. During power transmission, shafts twist and stresses and deformations are taking place.
- Torsion is twisting of an object due to an applied torque. When a shaft twists, one end rotates relative to the other and shear stresses are produced on any cross section.
- uShear stress is zero on the axis passing through the center of a shaft and maximum at the outside surface of a shaft. On an element where shear stress is maximum, normal stress is 0.
- uThis element where maximum shear stress occurs is oriented in such a way that its faces are either parallel or perpendicular to the axis of the shaft as shown in the figure.

Exercise 8 :

Relationship between key and Rotational Shaft.

u 15 kW, 960 rpm motor has a mild steel shaft of 40 mm diameter and the extension being 75 mm. The permissible shear and crushing stresses for the mild steel key are 56 MPa and 112 MPa

respectively. Design the keyway in the motor shaft extension. Check the shear strength of the key

u**Solution :**

Given P = 15 kW = 15 x 10^3 W; N = 960 rpm; d = 40 mm;

l = 75 mm; t = 56 MPa = 56 N/mm2; σ_c = 112 MPa = 112 N/mm2.

We know that the torque transmitted by the motor,

$$T = \frac{P \times 60}{2\pi N}$$

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