The International Association of Certified Practicing Engineers is providing the introduction to the Training Module for your review.

We believe you should consider joining our Association and becoming a Certified Practicing Engineer. This would be a great option for engineering improvement, certification and networking.

This would help your career by

1. Providing a standard of professional competence in the practicing engineering and management field
2. Identify and recognize those individuals who, by studying and passing an examination, meets the standards of the organization
3. Encourage practicing engineers and management professionals to participate in a continuing program of personal and professional development

www.IACPE.com

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

INTRODUCTION

Scope

This Training Module provides an overview one of the basic fundamentals of engineering. The knowledge of the types of engineering materials and the strength of those materials is essential to construct safe process equipment. This module will help develop the basics of material choices, and their underlying strength.

A wealth of information can be established by looking at the structures of a material. Engineering Materials is the study of information about materials that in general have been used in many industrial application such as Irons, Carbon Steels, Alloy Steels, Stainless Steel, Non – Ferrous Metals, Plastics, Composites, and Ceramics. The strengths and weakeness, corrosion, and when to ustilize these material is very important.

Design Considerations

Material Standards and Specifications

A standard is a document, definition, or reference artifact intended for general use by as large a body as possible, a specifications, which involves similar technical content and similar format, usually is limited in both its intended applicability and its users.

Standards have been a part of technology since building began. Standarization minimizes diversity, assures acceptability of products, and facilitates technical communication. There are many attributes of materials that are subject to standarization in example : Composition, Physical Properties, Mechanical Properties and etc.

However, a specification is defined as ‘a document intended primarily for use in procurement which clearly and accurately describes the essential technical requirements for items, materials, or services inculding the procedures by which it will be determined that the requirements have been met’. A second definition defines a specification as ‘a source statement of a set of requirements to be satisfied by product, a material or a process indicating whenever appropriate, the procedure by means of which it may be determined whether the requirements given are satisfied.

Noted that :

(1) A specification may be standard, a part of standard, or independent of a standard,

(2) As far as practicable, it is desired that the requirements are expressesd numerically in terms of appropriate units, together with their limits.’.

The objectives of standarization are;

1. Economy of production by way of economies of scale in output, optimization of varieties in input material,
2. Improved managerial control, assurance of quality,
3. Improvement of interchangeability,
4. Facilitation of technical communication,
5. Enchancement of innovation and technological progres
6. Promotions of the safety persons, goods, and the environment.

Material specifications may be classified as to whether they are applied to the material, the process by which it is made, or the performance or use that is expected of it.

Mechanical Principles

Stress

In the design process, one of an important problem is to ensure that the strength of the mechanical element to be designed always exceeds the stress due to any load exerted on it.. A stress is an assumption that is frequently considered in the process design. Depending upon the way the force is applied to a mechanical element, the result is often called pure tension (compression) or pure shear.

Such an example of a tension load P applied to the ends of bar. It the bar is cut at a section remote from the ends and removed one piece, the effect of the removed part could replaced by applying a uniformly distributed force of magnitude σ . A to the cut end, where σ is the normal stress and A the cross sectional area of the bar. The stress σ is given by

$$\sigma = \frac{P}{A}$$

The engineering tensile stress-strain curve (Figure 1) is obtained by static loading of a standard specimen, that is applying the load slowly enough that all parts of the specimen are in equilibrium at any instant. ASTM Standards require a loading rate not exceeding 100,000 lb/in^2. An alternate method of obtaining the curve is to specify the strain rate as the indenpedent variable, in which case the loading rate is continuously adjusted to maintain the required strain rate.

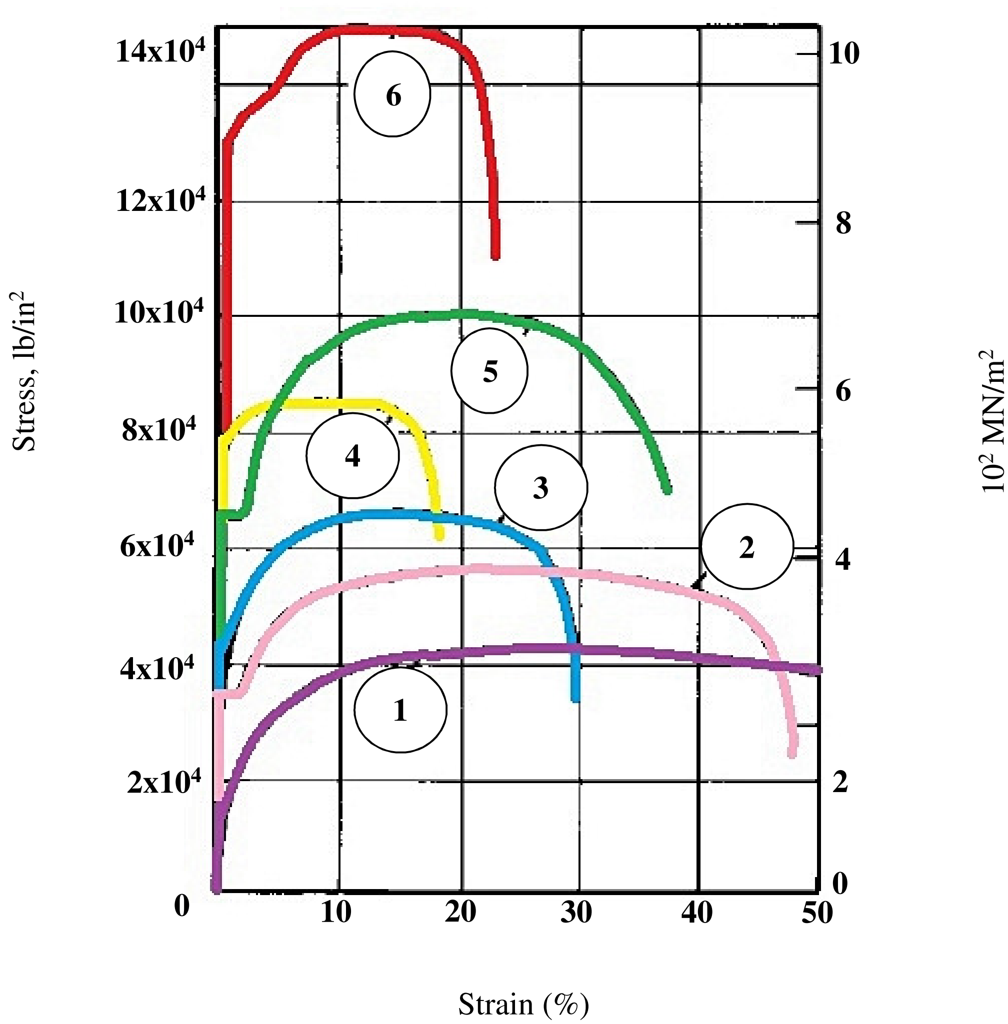

Figure 1. Stress – Strain Diagrams, (1. Soft Brass, 2. Low Carbon Steel, 3. Hard Bronze, 4. Cold rolled Steel, 5. Medium Carbon Steel, annealed, 6. Medium Carbon Steel, heat treated.)

For engineering materials applications, the curve will have an initial linear region as cited in Figure 2 in which deformation is reversible and time-independent. The slope in this region is Young's Modulus E. The proportional elastic limit (PEL) is the point where the curve starts to deviate from a straight line. The elastic limit is the point on the curve beyond which plastic deformation is present after release of the load.

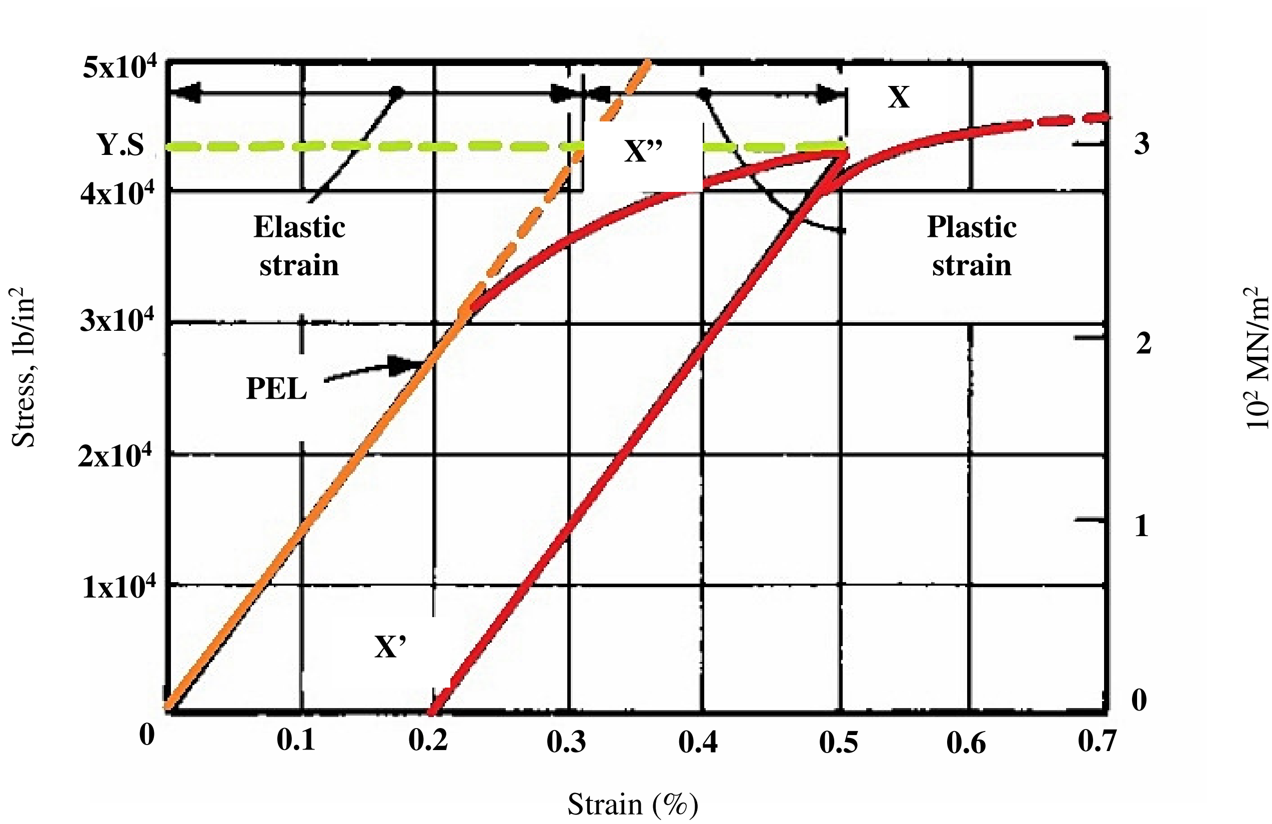

Figure 2. General stress-strain diagram

The Ultimate Tensile Strength (UTS) is the maximum load sustained by the specimen divided by the original specimen cross-sectional area. The percent elongation at failure is the plastic extension of the specimen at failure expressed as divided by the original gage length. Methods of constructing the true stress-strain curve are described in technical literature. In the range between initial yielding and the neighborhood of the maximum load point the relationship between plastic strain εp and true stress often approximates as :

$$\sigma = k.\varepsilon_p^n$$

Where,

k : the strength coefficient
n : the work-hardening exponent

Combined Stresses refers to the situation in which stresses are present on each of the faces of a cubic element of the material. For a given cube orientation the applied stresses may include shear stresses over the cube faces as well as stresses normal to them.

Elastic Strain

If a tensile load is applied to a straight bar, it becomes longer. The amount of elongation is called total strain. The elongation per unit length of the bar (ϵ) is called strain. The equation for strain is given by :

$$\epsilon = \frac{\delta}{l}$$

Where,

δ : Total elongation (total strain)
l : length of bar

Shear strain (γ) is the change in a right angle of an element subjected to pure shear stresses. Elasticity is a property of materials that allows them to regain their original geometry when the load is removed. The elasticity of a material could be defined in terms of Hooke's Law, which states that, within certain limits, the stress in a material is proportional to the strain which produce it. Hence, Hooke's law could be cited as :

$$\sigma = E\,.\,\epsilon$$

And

$$\tau = G\,.\,\gamma$$

Where

E : Modulus Elasticity
G : Shear Modulus Elasticity / Modulus of Rigidity

Subtituting σ = P / A and ϵ = δ / l into both equation above and manipulating them will result the new expression for the total deformation (δ) of a bar loaded in axial tension or compression as follows :

$$\delta = \frac{F\,.\,l}{A.\,E}$$

When a tension load is applied to a body, not only does an axial strain occur, but also a lateral one. If the material obeys Hooke's law, it has been demonstrated that the two strains are proportional to each other. This proportionality constans is called a Poisson' ratio give as :

$$v = \frac{lateral\ strain}{axial\ strain}$$

It could be proved that the elastic constants are related by the formulation below :

$$E = 2G(1 + v)$$

The stress state at a point could be calculated if the relationship between stress and strain is known and the state of strain has already measured. The principal strains are defined as the strain in the direction of the principal stresses.

Torsion

A torque vector is a moment vector collinear with an axis of a mechanical element, causing the element to twist about that axis. A torque $\mathbf{T_x} = T.\mathbf{i}$ applied to a solid round bar. The torque vectors are the arrows shown on the x axis. The angle of twist given by the relationship :

$$\theta = \frac{T.l}{G.J}$$

Where,

T : Torque
l : Length
G : Modulus of rigidity
J : The polar second moment of area

Fatigue

A periodic stress oscillating between some limits applied to a machine member is called repeated, alternating, or fluctuating. The machine obeys often fail under the action of these stresses, and the failure is called fatigue failure. As in general, a small crack event is enough to initiate fatigue failure. Hence, the stress concentration effect would became higher around the crack-spot and the crack will progresses rapidly. The strength of materials acted upon by fatigue loads could be calculated by performing a fatigue test provided by a R. R. Moore's high-speed rotating beam machine.

Generally, fatigue is understood as the gradual deterioration of a material which is subjected to repeated loads. In fatigue testing, a specimen is subjected to periodically varying constant-amplitude stresses by means of mechanical or magnetic devices. The most common loading is alternate tension and compression of equal numerical values obtained by rotating a smooth cylindrical specimen while under a bending load. A series of fatigue tests are made on a number of specimens of the material at different stress levels.

A fluctuating stress is a combination of a static plus a completely reversed stress. The component of the stresses are depicted in Figure 3. Where σ_{min} is a minimum stress and σmax is the maximum stress, σ_a the stress amplitude or the alternating stress, σ_m the midrange or the mean stress, σ_r the stress range, and σ_s the steady or static stress.

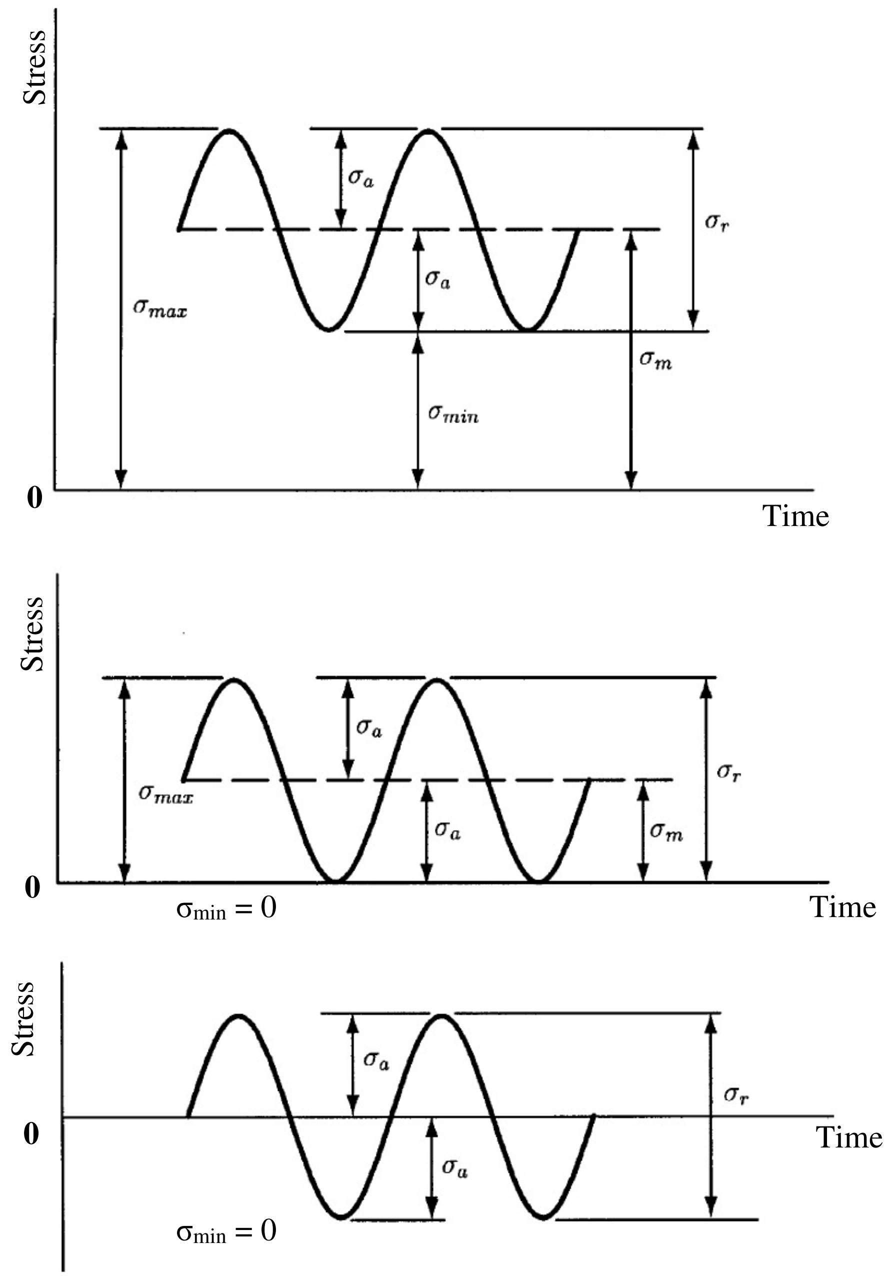

Figure 3. Fluctuating stresses.

The steady stress could have any value between σ_{min} and σ_{max} and exists because of a fixed load. It is usually independent of the varying portion of the load. The following relations between the stress components are useful :

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

The stress ratios

$$R = \frac{\sigma_{min}}{\sigma_{max}}$$

$$A = \frac{\sigma_a}{\sigma_m}$$

Are also used to describe the fluctuating stresses.

Creep

In metals, creep is plastic deformation caused by slip occuring along crystallographic directions in the individual crystals, together with some flow of the grain-boundary material. After complete release of load, a small fraction of this plastic deformation is recovered with time. Most of the flow is nonrecoverable for metals. The most common are the long-time creep test under the stress-relaxation test and the constant-strain-rate test. The long time creep test is conducted by applying a dead weight to one end of a lever system, the other end being attached to the specimen surrounded by a furnace and held at constant temperature.

Hardness

Hardness has been variously described as resistance to local penetration, to scratching, to machining, to wear or abrasion, and to yielding. The multiplicity of definitions, and corresponding multiplicity of hardness-measuring instruments, together with the lack of a fundamental definition, indicates that hardness may not be a fundamentarl property of a material but rather a composite one including yield strength, work-hardening, true tensile strength, modulus of elasticity, and others.

Brinell hardness is determined by forcing a hardened sphere under a load into the surface of material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simplified as The Brinell number, is achieved by dividing the load used, in kilograms, by the actual surface area of the indentation, in square milimeters. The result is a pressure, but the units are rarely stated.

$$BHN = \frac{P}{\left[\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right]\right.}$$

Where,

BHN : The Brinell Number
P : Imposed Load (kg)
D : Diameter of the spherical indenter (mm)
d : Diameter of the resulting impression (mm)

DEFINITIONS

Bending stress - A physical quantity of combination amount of distance from 'centre – pooint' material and bending moment that divided by second moment area of section.

Bolts – A conjuction inbetween two separate material for a non-permanent fastening.

Combined Stresses – An event when stresses are present on each of the faces of a cubic element of material.

Creep – Plastic deformation caused by slip occuring along crystallographic directions in individual crystals.

Factor of Safety – An amount of elastic limit compared to the actual stress that had been given to material.

Fatigue – Gradual deterioration of material which is subjected to repeated loads.

Failure Event – An event that established as a result of crack propagation without plastic deformation at a stress well below the elastic limit.

Hardness – Resistance of materials to any force load from its outside surface such as local penetration, scratching, machining, abrasion or yielding.

Strain – How much an extension of any materials from its original length.

Stress – An amount of force load to a certain area of material.

Stress Concentration Factor (K) – A highest value of stress at discontinuity divided to an amount of stress at its minimum cross-section area.

Torsion – The twisting of an object due to an applied torque.

Ultimate Tensile Strength (UTS) – The maximum load sustained by the specimen divided by the original specimen cross-sectional area.

Welds – An activity to join two seprate material by an addition of metals or thermoplastics by causing coalescence.

NOMENCLATURE

A	: Area of cross section (m^2)
BHN	: The Brinell Number
D	: Diameter of the spherical indenter (mm)
d	: Diameter of the resulting impression (mm)
E	: Modulus Elasticity
e	: Strain
e_V	: Volumetric strain.
G	: Shear Modulus Elasticity / Modulus of Rigidity
h	: Height fallen mass (m).
J	: The polar second moment of area
k	: The strength coefficient
L	: Original Material Length (m)
l	: Length
I	: Second moment of area of section.
M	: Bending moment.
n	: The work-hardening exponent
P	: Imposed Load (kg)
P	: Loaded force (N)
p	: Pressure.(Pa)
T	: Torque
V	: Volume (m^3).
v	: Velocity (m/s)
x	: Extension of material (m)
x_s	: Steady extension (m).
y	: Distance from centroid to the point considered.

SYMBOLS

δ	: Total elongation (total strain)
σ	: Stress (Pascal / N/m^2)
σ_m	: Maximum tengsile stress (Pa).
σ_s	: Steady stress (Pa).
φ	: Bending stress.