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INTRODUCTION

Scope

Mechanical Engineering is a branch of engineering science that applies the principles of mathematics and physics that studies the energy and the source for analysis, design, manufacturing and maintenance of a mechanical system. Mechanical systems could be either aircraft, industrial plant, industrial machinery, home appliances, etc.

Some of the areas included in the scope of mechanical engineering include mechanics of solids and fluids, heat transfer, thermodynamic, strength of materials, materials of engineering, machine elements, manufacturing processes, mechanical vibrations, engineering tribology, engineering design, machine of energy conversion and finite element method. Scientific fields which should be understood with a solid foundation is Mechanics and Thermodynamics.

Mechanics includes all the causation movement of a system for example, a system that moves a rotating, translational or a combination of both. Or with different systems such as solid with variuos shapes and fluid systems etc. Thermodynamic include all the related with the transfer of energy (heat) as a result of a dynamic system. Another definition is to study how the interaction of a system with the environment. System-environment interaction that is much discussed is about energy. Law of conservation energy is the basis in this science.

General Considerations

A. Thermodynamic

Thermodynamics is both a branch of physics and an engineering science. Engineers are generally interested in studying systems and how they interact with their surroundings. To facilitate this, engineers have extended the subject of thermodynamics to the study of systems through which matter flow. In a thermodynamic analysis, the system is the subject of the investigation. Normally the system is a specified quantity of matter and/or a region that can be separated from everything else by a well-defined surface.

The defining surface is known as the control surface or system boundary. The control surface may be movable or fixed. Everything external to the system is the surroundings. A system of fixed mass is referred to as a control mass or as a closed system. When there is flow of mass through the control surface, the system is called a control volume, or open, system. An isolated system is a closed system that does not interact in any way with its surroundings

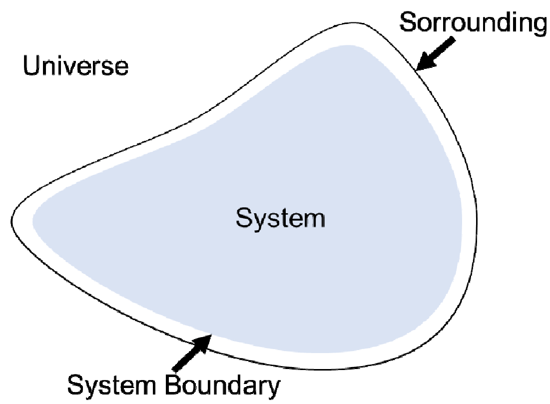

Figure 1: Thermodynamic System.

The condition of a system at any instant of time is called its state. The state at a given instant of time is described by the properties of the system. Extensive properties depend on the size or extent of the system, examples are volume, mass, energy, and entropy. Intensive properties are independent of the size or extent of the system, examples are pressure and temperature. Two states are identical if, and only if, the properties of the two states are identical. Process is when any property of a system changes in value there is a change in state, and the system. When a system in a given initial state goes through a sequence of processes and finally returns to its initial state, it is said to have undergone a cycle.

The term phase refers to a quantity of matter that is homogeneous throughout in both chemical composition and physical structure is all solid, or all liquid, or all vapor (or equivalently all gas). A system can contain one or more phases. A pure substance is one that is uniform and invariable in chemical composition. A pure substance can exist in more than one phase, but its chemical composition must be the same in each phase.[2]

B. Heat Transfer

Heat has been known to move from a place with a higher temperature to a lower temperature and this is called heat transfer. Heat transfer is the science that studies the rate of heat transfer between the material/object because of the temperature gradient (hot and cold). The science heat transfer useful for planning a heat exchanger, calculate the need for heating medium / cooling on a reboiler or condenser in the distillation column, the calculation of furnace, boiler design, evaporator and chemical reactors.

There are three processes heat transfer:

1. Conduction, which is of greatest interest in solid bodies but also occurs in fluids where it is often overshadowed by convection.
2. Convection, which occurs in fluids when energy is transferred due to the motion of the fluid.
3. Radiation, which occurs between two systems at different temperatures which need not be in contact provided any intervening medium is transparent to the radiation.

In practice, all three process occur simultaneously and it is necessary to draw up a balance at a boundary. For example, energy may be conducted to the surface of an electric storage heater and is then conducted and radiated to the surroundings. Thus calculations can become complex, and in this particular case where energy is added at certain times this is a continuously varying situation.[7]

C. Materials of Engineering

Material is an objects with its typical use in buildings, machinery, equipment and products for needs of people. Materials of engineering is the study of basic knowledge about the structure, properties and processing of materials. There are two types of materials that is material of metals and nonmetals.

There are three properties of materials as follows:

1. Physical Properties of Materials: melting point, boiling point, electrical conductivity, thermal conductivity, density and phase.
2. Chemical Properties of Materials: structure of atoms, geometry of atoms and corrosion resistance.
3. Mechanical Properties of Materials: Strength, stiffness, elasticity, plasticity, ductility, toughness, brittleness, fatigue, creep and hardness.

D. Strength of Materials

Strength of materials is the science that discuss the force equilibrium (mechanics) are working on a structure. In materials science, the strength of a material is its ability to withstand an applied load without failure. Strength of material refers to the point on the engineering stress–strain curve (yield stress) beyond which the material experiences deformations that will not be completely reversed upon removal of the loading and as a result the member will have a permanent deflection. The ultimate strength refers to the point on the engineering stress–strain curve corresponding to the stress that produces fracture.

$$\varepsilon_x = \sigma_x / E \qquad \varepsilon_y = \varepsilon_z = -\upsilon\sigma_x / E$$

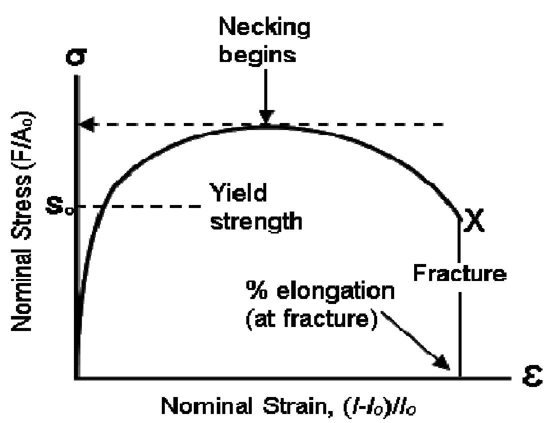

Figure 2: Stress-Strain Curve.

Where σ_x is the stress (force per unit area, psi or Pa) in the x direction of applied unidirectional tensile load, $\mathcal{E}_x$ is the strain (length per unit length or percent) in the same direction $\mathcal{E}_y$ and $\mathcal{E}_z$ are the contracting strains in the lateral directions, E is Young's modulus (the modulus of elasticity), and υ is Poisson's ratio.[4]

E. Engineering Design

Mechanical engineers are associated with the production and processing of energy and with providing the means of production, the tools of transportation, and the techniques of automation. The skill and knowledge base are extensive. Among the disciplinary bases are mechanics of solids and fluids, mass and momentum transport, manufacturing processes, and electrical and information theory. Mechanical engineering design involves all the disciplines of mechanical engineering.

The design can be generally defined as the formulation of a plan to meet human needs. In the process, the design is an activity that is usually iterative. The idea and creations of then analyzed and tested. This iterative activity is schematically shown in Figure 3.

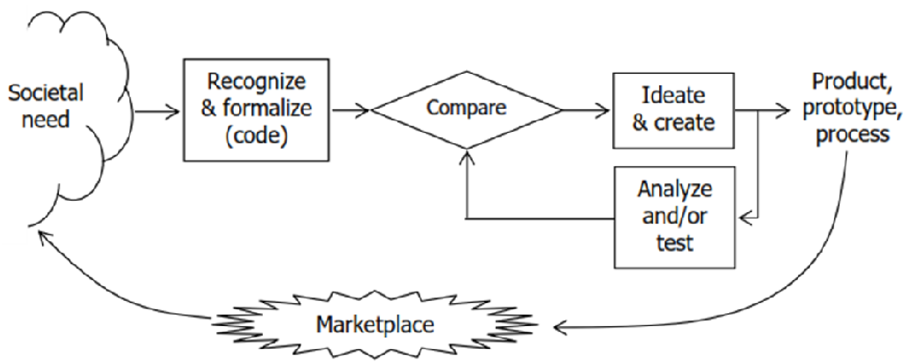

Figure 3 : An Iterative Process In The Design.

Planning design in the field of engineering carried out by technical experts and designed by engineers, there are many forms of products and services. Thus the engineering design can be defined as iterative series of activities that apply a variety of techniques and scientific principles which aims to define the equipment, processes, or systems in detail so that it can be realized.

F. Manufacturing Processes

In the manufacture of a product includes process planning such as the materials selection and process, equipment, tooling, and preparation of the sequence of operations required to change the shape raw materials into the desired product. The production process is process of turning of raw materials into semi-finished materials or materials accordance with desired in the form parts or components. The manufacturing process is a process of applying the branch of industry and media process equipment to transforming raw materials into finished goods either for use or sale.

G. Mechanics of Solids and Fluids

Solid mechanics is the study of the deformation and motion of solid materials under the action of forces. It is one of the fundamental applied engineering sciences, in the sense that it is used to describe, explain and predict many of the physical phenomena around us.

In designing and evaluating or analyzing an appliance, machine and structure, the engineers used the concepts and methods of solid mechanics. Engineer must have the education background of the science of static, dynamic, mechanics of materials and other related science. For example, dynamics of rigid bodies is needed in generalizing the spectrum of service loads on a car, which is essential in defining the vehicle's deformations and long-term durability.

Fluid mechanics deals with the study of all fluids under static and dynamic situations. Fluid mechanics is a branch of continuous mechanics which deals with a relationship between forces, motions, and statically conditions in a continuous material. This study area deals with many and diversified problems such as surface tension, fluid statics, flow in enclose bodies, or flow round bodies (solid or otherwise), flow stability, etc.[1]

H. Machine Elements

Machine elements are sections of a construction which has the form and function its own, such as bolt-nut, pins, shafts, couplings, belt-pulley, sprocket-chain and gears. Machine element serves as an element of binder, element of transfer or transmission, the element of buffer, lubricating elements, protective elements and etc. The principle of planning machine element is the planning component are made to meet the needs of the mechanism of a machine.

Stages of design machine elements include determining the need, selection mechanisms, mechanical loads, materials selection, determining size, working drawings, manufacture and quality control. Calculations on the planning machine element is based on the theories of engineering mechanics and strength of materials.

I. Mechanical Vibrations

All the objects that have mass and elasticity is capable of vibrate. In machine design and engineering structures is needed for consideration of the nature oscillation will occur vibration. Systems of oscillating are widely classified as linear or non-linear. The principle of superposition is valid for the analysis of linear vibrating system.

Vibrations are categorized as free and forced. Free vibration occurs when external forces are absent and the system oscillates under the action of forces within the system it self. Forced vibration is when there are external forces (excitation forces) that act on the system. Consider a particle of mass *m* suspended from a spring with the elastic constant *k*, (figure 4).

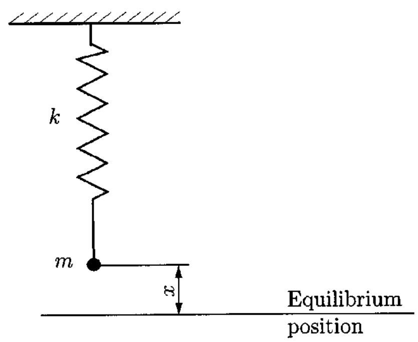

Figure 4 : Oscillations of a Mass Suspended On a Spring.

When the particle is displaced from its rest or equilibrium position the mass m will oscillate about the equilibrium position with simple harmonic motion. The displacement x of the mass from the equilibrium position is a sine wave.[6]

J. Finite Element Method

Mechanical components in the form of simple bars, beams, etc., can be analyzed quite easily by basic methods of mechanics that provide closed-form solutions. Actual components, however, are rarely so simple, and the designer is forced to less effective approximations of closed-form solutions, experimentation, or numerical methods. There are a great many numerical techniques used in engineering applications for which the digital computer is very useful. In mechanical design, where computer-aided design (CAD) software is heavily employed, the analysis method that integrates well with CAD is finite-element analysis (FEA). The mathematical theory and applications of the method are vast.

In their present form the finite element method formulated by civil engineers. Previously, this method is proposed and formulated in various manifestations by mathematician and physicist. The basic concept of the finite element method is discretization. Discretization is bisected an object into objects a smaller sized to be more easily management. Discretization implies an approach from a reality and continuity.

There are a multitude of FEA applications such as static and dynamic, linear and nonlinear, stress and deflection analysis; free and forced vibrations; heat transfer (which can be combined with stress and deflection analysis to provide thermally induced stresses and deflections); elastic instability (buckling); acoustics; lectrostatics and magnetics (which can be combined with heat transfer); fluid dynamics; piping analysis; and multiphysics.

DEFINITIONS

Adiabatic process – thermodynamic process in which there is no transfer of heat between the working substance and the surroundings.

Allow – a substance with metallic properties composed of two or more chemical elements, at least one of which is a metal.

Annealing – heating a metal to, and holding at, a suitable temperature and cooling at a suitable rate so as to reduce hardness, improve machinability, ease cold working, etc.

Bending moment – the algebraic sum of the moments of all the forces to either side of a transverse section of a beam, etc.

Bending modulus – a property of a section equal to the bending moment divided by the maximum bending stress.

Bulk modulus – the ratio of pressure (three dimensional stress) to volumetric strain of a material.

Conservation of energy – the energy in a closed system cannot be changed but only interchanged, e.g. potential to kinetic energy.

Damped vibration – vibrations reduced in amplitude due to energy dissipation.

Density – the mass of a unit volume of a substance.

Enthalpy – thermodynamic property of a working substance equal to the sum of its "internal energy" and the "flow work" (pressure multiplied by volume). Used in the study of "flow processes".

Emissivity – the ratio of the thermal radiation from a surface to the radiation from an ideal black surface at the same temperature as given by the Stefan–Boltzmann law**.**

Elongation – in tensile testing the increase in length of a specimen at fracture as a percentage of the original length.

Equilibrium – the state of a body at rest or in uniform motion. A body on which the resultant force is zero.

Fatigue – Phenomenon leading to the failure of a part under repeated or fluctuating stress below the tensile strength of the material.

Heat Treatment – heating and cooling of solid metals to obtain the desired properties.

Isobaric process – a thermodynamic process taking place at constant pressure.

Isothermal process – a constant temperature process.

Isochoric process – is a thermodynamic process during which the volume of the closed system undergoing such a process remains constant.

Irreversible processes – processes in which the system and its surroundings cannot be simultaneously returned to their initial states after the process has been completed.

Internal energy – the difference between the heat energy supplied to a system and the work taken out. The energy is in the form of heat as measured by the temperature of the substance or its change of state.

Manometer – an instrument used to measure the pressure of a fluid. The simplest form is the "u tube" containing a liquid.

Mass – the quantity of matter in a body. Equal to the inertia or resistance to acceleration under an applied force.

Poisson's ratio – the ratio of transverse to axial strain in a body subject to axial load.

Principal stresses – normal stresses on three mutually perpendicular planes on which there are no shear stresses.

Probability – the number of ways in which an event can happen divided by the total possibilities.

Quenching – the rapid cooling of heated metal to anneal, harden, etc.

Refrigerant – the working fluid in a refrigerator. It may be a gas or a vapor.

Reversible process – processes in which both the system and its surroundings can be simultaneously returned to their initial states after the process has been completed.

Shear modulus – (modulus of rigidity, torsional modulus) The ratio of shear stress to shear strain within the elastic limit.

Stiffness – the ability of a metal, etc., to resist elastic deformation. It is proportional to the appropriate modulus of elasticity.

Thermal resistance – a heat property and a measurement of a temperature difference by which an object or material resists a heat flow.

Tensile strength – ratio of maximum load to original cross-sectional area of a component. Also called 'ultimate strength'.

Tensile stress – tensile load divided by cross-sectional area.

Torque – the algebraic sum of couples, or moments of external forces, about the axis of twist.

Velocity – the rate of change of position of a point with respect to time.

Wrought iron – iron containing fibers of slag (iron silicate) in a ferrite matrix.

Young's modulus – property of plane sections used in bending-stress calculations. It is equal to the ratio of bending moment to maximum bending stress.

NOMENCLATURE

Q	= Heat Transfer	(kJ)
W	= Work Transfer	(kJ)
ΔE	= Energy Change	(kJ)
q	= Specific Heat Transfer	(kJ/kg)
w	= Specific Work Transfer	(kJ/kg)
Δe	= Specific Energy Change	(kJ/kg)
(U, u)	= Internal Energy	(Joule)
m	= Mass	(kg)
h	= Enthalpy (*for Thermodynamic*)	(kJ/kg)
Δgz	= Change in Specific Potential Energy	
$\dot{Q}$	= Heat Transfer Rates	(kJ)
$\dot{W}$	= Work Transfer Rates	(kJ)
$\dot{m}$	= Steady Mass Flow Rate	(kg/s)
ρ	= Density	(kg.m^{-3})
A	= Area	(m^3)
η	= Efficiency	(%)
T	= Temperature	(K)
P	= Pressure	(Pa)
R	= Gas Constant	(J/kgK)
V	= Volume	(m^3)
c_v, c_p	= Specific Heat Capacities at Constant Volume and Constant Pressure	
k	= Thermal Conductivity	(m^3)
σ	= Stefan-Boltzmann Constant 5.67 x 10^{-8} W m^{-2} K^{-4} (*for Heat Transfer*)	
ε	= Emissivity of The Body	(m^3)
h	= The Surface Heat Transfer Coefficient (*for Heat Transfer*)	(W^{-1} K^{-1})

σ	= Stress	(Pa)
e	= Strain	
E	= Young Modulus	(Pa)
τ	= Shear Stress	(Pa)
ϕ	= Shear Strain	
G	= Shear Modulus	(Pa)
v	= Poisson Ratio	