

Definition of Terms Fluid Mechanics & Hydraulics

Fluid Mechanics

- is a physical science that deals with the actions of fluids at rest

Fluid Mechanics can be subdivided into two major areas

- Fluid Statics - deals with fluids at rest
- Fluid Dynamics - concerned with fluid in motions

Hydrodynamics - applied to the flow of liquids or to low velocity gas flows where the gas can be considered as being essentially incompressible

Hydraulics - deals with the application of fluid mechanics to engineering devices involving liquids, usually water or oil.

Fluid - Any substance that flows or deforms continuously when subjected to shearing forces.

Two categories of fluids

Ideal fluids

- Exhibit infinite viscosities
- Non uniform velocity distribution when flowing
- Compressible
- Experiences friction and turbulence in flow

Real Fluids

- Assumed to have no viscosity
- Incompressible
- Have uniform velocity when flowing
- No friction between moving layers of fluid
- No eddy currents or turbulence

Real Fluids Divided into

- Newtonian Fluids
- Non-Newtonian Fluids
 - Pseudoplastic Fluids
 - Dilatant Fluids
 - Bingham Fluid

Fluid Properties

Mass Density - the density of a fluid is its mass per unit of volume.

Specific Volume - volume occupied by a unit mass of fluid

Unit Weight - the weight of a unit volume of a fluid

Specific Gravity - dimensionless ratio of a fluid's density to some standard reference density

Viscosity - the property of a fluid which determines the amount of its resistance to shearing forces

Kinematic Viscosity - ratio of the dynamic viscosity of the fluid, to its mass density

Surface Tension - a force within the surface layer of a liquid that causes the layer to behave as an elastic sheet

-the membrane of skin that seems to form on the free surface of a fluid is due to the intermolecular cohesive forces

Compressibility - the fractional change in the volume of a fluid per unit change in pressure in a constant temperature process

Bulk Modulus of elasticity - ratio of the change in unit pressure to the corresponding volume change per unit of volume

-expresses the compressibility of the fluid

Pressure Disturbances - imposed on a fluid move in waves. The velocity or celerity of pressure wave known as acoustical or sonic velocity

Vapor Pressure - the equilibrium pressure exerted by these free molecules

Volatile liquids - liquids near their boiling point or that vaporizes easily

Boiling - occurs when the liquid temperature is increased to the point that the vapor pressure is equal to the local ambient pressure

Principles of Hydrostatics

Pressure - force per unit area exerted by a liquid or gas on a body or surface, with the force acting at right angles to the surface uniformly in all



directions

Pascal - the pressure exerted onto a liquid a transmitted undiminished to all portions of the liquid

Absolute Pressure - pressure above absolute zero

Gage Pressure - pressure above or below the atmosphere and can be measured by pressure gauges or manometers

Atmospheric pressure - pressure at any one point on the earth surface from the weight of the air above it.

Vacuum - space that has all matter removed from it

Relative Pressure - pressure above or below the atmosphere and can be measure by pressure gauges or manometers

Pressure head - the height h of a column of homogenous liquid of unit weight that will produce an intensity pressure

Manometer -a tube, usually bent in a form of a U containing a liquid of known specific gravity

Open Manometer -a tube bent into a U-shape to contain one or more fluids of different specific gravities. It is used to measure pressure

Differential Manometer - Without an atmospheric surface and capable of measuring only difference of pressure

Piezometer -The simplest form of open manometer

-It is a tube tapped into a wall of a container or conduit for the purpose of measuring pressure

Total Hydrostatic Forces

Dam - structures that block the flow of a river, stream, or other waterway

Types of Dams

Gravity Dam - used only the force of gravity to resist water pressure

Embankment Dam - gravity dam formed out of loose rock, earth, or a combination of these materials

Buttress Dam - consist of wall, or face, supported by several buttresses on the downstream side

Buoyancy

Archimedes Principle- Anybody immersed in a fluid is subjected to an upward force called buoyant force equal to the weight of the displaced fluid.

Buoyant Force - the net upward force acting on the body

Stability of Floating Bodies

Metacenter - the point of intersection between the axis of the body and the line of action of the buoyant force

Metacentric height - the distance from the metacenter to the center gravity of the body

Equilibrium -When the ship is in upright position, the force of buoyancy(up thrust) and the force of gravity(weight) acts through the center of buoyancy B and the Center of gravity respectively, in the same vertical line. Then the ship is said to be in equilibrium.

Fundamentals of Fluid Flow

Discharge or Flow Rate - amount of fluid passing through a section per unit of time

Discharge - the volume of liquid passing a cross section of a stream

Fluid may be: Steady or unsteady, uniform or non uniform; continuous; laminar or turbulent; one dimensional, two dimensional or three dimensional; and rotational irrotational

Steady Flow - the discharge Q passing a given cross section is constant with time

-Type of flow where the flow rate does not change over time.

Unsteady Flow - If the flow Q at the cross section varies with time



-Type of flow where the mean velocity of flow for a given length or reach is the same at every cross section.

Uniform Flow -the average velocity of flow is the same at every cross-section

Non-uniform Flow - If the cross section and velocity changes

Continuous Flow -It occurs when at any time, the discharge Q at every section if the stream is the same

- Type of flow where at any time, the discharge or flow rate at every section of the stream is the same.

Critical Flow -Type of flow in which, for a fixed rate of flow, the specific energy is minimum.

Incompressible Flow -Type of flow in which the density of the fluid is constant from one point to another.

Laminar Flow - when the path of individual fluid particles do not cross or intersect

-Uninterrupted flow in a fluid near a solid boundary in which the direction of flow at every point remains constant.

Turbulent Flow - when the path of individual particles are irregular and continuously cross each other

One-Dimensional Flow -This occurs when in an incompressible fluid, the direction and magnitude of the velocity at all points are identical

Two-Dimensional Flow -This occurs when the fluid particles move in planes or parallel planes and the streamline patterns are identical in each plane.

Rotational Flow -A type of flow in which the fluid particles rotate about their own axis while flowing along the streamlines is called a rotational flow.

Irrrotational flow - If the fluid particles while flowing along the streamline do not rotate about their own axis

Streamlines -These are imaginary curves drawn through a fluid to indicate the direction of motion in various sections of the flow of the fluid system.

Streamtubes - These represents elementary portions of a flowing fluid bounded by a group of streamlines which confine the flow.

Flow Nets -These are drawn to indicate flow patterns in case of two-dimensional flow, or even three-dimensional flow.

Energy -consists of the kinetic and potential energy

Head -the amount of energy per pound or Newton of fluid.

Kinetic Energy - the ability of fluid mass to do work by virtue of its velocity.

Elevation Energy -energy possessed by virtue of its position with respect to the datum line.

Pressure energy -energy possessed by virtue of its pressure.

Total Flow Energy -sum of kinetic and the potential energies

Power and Efficiency - the rate at which work done

Bernoulli's Energy Theorem

Bernoulli - in any stream flowing steadily without friction the total energy contained is the same at every point in its path of flow

Bernoulli's Principle - states that, " As the speed of a moving fluid (liquid or gas) increases, the pressure within that fluid decreases, and vice versa

Pump - used basically to increase head

Turbine - extract flow energy to do mechanical work which in turn converted into electrical energy for turbines

Energy and Hydraulic Grade Lines

Hydraulic Grade line -known as pressure gradient hydraulic grade line

- The graphical representation of the total potential energy of flow.

Hydraulic Gradient - a line joining the points of highest elevation of water of a series of vertical open pipes rising from a pipeline in which water flows under pressure

Energy Grade Line - Graphical representation of the total energy (the sum of kinetic and potential energies)

Fluid Flow Measurement

Orifice - an opening with a closed perimeter through which fluid flows

Venturi Meter - an instrument used in measuring the discharge through pipes

Nozzle - a converging tube installed at the end of a pipe or hose for the purpose of increasing the velocity of the issuing jet

Pitot Tube - used to measure the velocity of fluid flow or velocity of air flow as used in airplane speedometer

Gates - an opening in a dam or other hydraulic structure to control the passage of water

Weir - overflow structures which are built across an open channel for the purpose of measuring or controlling the flow of liquids

Torricelli's Theorem - The speed of efflux is equal to the speed of free fall from the surface of the reservoir

Fluid Flow in Pipes

Pipes - are closed conduits through which fluid or gases flow

Laminar Flow - when the path of individual fluid particles do not cross or intersect

Turbulent Flow - when the path of individual particles are irregular and continuously cross each other

Critical Velocity - the velocity below which all turbulence are damped out by the viscosity of the fluid.

Reynolds Number - defines as the ratio of inertia force to viscous force and interpreted as the ratio of dynamic pressure to shearing stress

Head Losses in Pipe Flow

Head Losses in Pipe classified into

Major head loss - caused by pipe friction along straight sections of pipe of uniform diameter and uniform roughness

Minor head loss - caused by changes in velocity or directions of flow and are commonly expressed in terms of kinetic energy

- These changes may be due to sudden contraction, sudden enlargement, valves, bends, and any other pipe fittings

Open channel

Specific Energy - defined as the energy per unit weight relative to the bottom of the channel

Boundary Shear Stress - the average boundary shear stress acting over the wetted surface of the channel

Normal Depth - depth at which uniform flow will occur in an open channel

Most efficient cross section - known as economical sections, these are sections which for a given slope S , channel cross sectional area A , and roughness n , the rate of discharge is a maximum

Froude Number - It is a dimensionless value that describes different flow regimes of open channel flow

Critical Depth - defined as the depth at which for a given total head, the discharge is maximum, or conversely, the depth at which for a given flow, the specific energy is minimum

Critical slope - slope required to give uniform flow at critical depth is known as the critical slope S_b

Hydraulic Jump - abrupt increase in depth of rapidly flowing water

Hydrodynamics

Hydrodynamics - deals with the study of the motion of a fluid and of the interactions of the fluid with its boundaries. This chapter will discuss the forces developed by moving fluids as it is important in the analysis and design of such objects as pumps, turbines, airplanes, rockets and many other

hydraulic devices.

The basic principles used in hydrodynamics are the Newton's laws of motion which can be stated as follows:

I. A body at rest will remain to be at rest or in motion will remain in motion with a uniform velocity along a straight line until acted upon by an external force. **(Law of inertia)**

II. A particle acted upon by an unbalanced force system has an acceleration inline with and directly proportional to the resultant of the force system and inversely proportional to its mass. **(Law of force)**

III. In every action there is always an equal and opposite reaction. **(Law of stress)**

Drag -component of the resultant force exerted by a fluid on a body PARALLEL to the relative motion of the fluid

Drag Force - It acts opposite to the direction of the oncoming flow velocity

2 Types of drags

1. **Pressure drag** -the resultant of all pressure forces exerted on the forces of the body.

2. **Friction Drag** -the resultant of the shear stress along the surface of the body in the direction of motion.

Lift - component of the resultant force exerted by a fluid on a body PERPENDICULAR to the relative motion of the body.

Water hammer - a pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly

