Fluid Dynamics

Dean Albrecht

ABSTRACT

Fluid refers to either gas or liquid whereas dynamics entail motion. Therefore, fluid dynamics can be defined as the study of movement of fluids and their corresponding interactions whenever they come into contact while they are in motion. Fluid dynamics can be discussed ashydrodynamics that is concerned with the study of motion in liquids and aerodynamics, which is concerned with the study of motion in air (Patera and Anthony 467).

APPLICATIONS OF FLUID DYNAMICS

The concept of fluid dynamics can be used in traffic engineering where traffic is taken as continuous fluid flow. Fluid dynamics can also be used to determine the flow rates of material such as petroleum from pipes and it can be employed in the aeronautical fields where it is used to calculate and find the forces acting upon an airplane(Patera and Anthony 488).

In fluid dynamics, some forces are always incurred by object within the fluid or the fluid versus the vessel or within the fluid itself. These forces mostly act in an opposite direction to the displacement of particles on motion and the velocity. The forces depend on velocity. Fluid resistance is one of the forces thatis related fluid flow. It opposes the relative motion of an object through a fluid. For any object, precisely solid moving through a fluid, the graft is the constituent of the hydrodynamic or aerodynamicforces imposed opposite to the direction of the displacement. A lift is considered to be the component at right angles to this direction. Hence, drag hinders the motion of the object the fluid.

FLUID DYNAMICS EQUATIONS

According toPatera and Anthony (467), the fluid flow, of a liquid, is assumed to be incompressible thus it is considered;

ρ = constant, and hence

$\frac{P}{\rho}$ + g z + $\frac{v^{2}}{2}$ = K Or

$\frac{P}{\rho g}$+ z +$\frac{v^{2}}{2g}$= K Or

$\frac{P}{\rho g}$ + $\frac{v^{2}}{2g}$+ z = K

From the above equations,

$\frac{V^{2}}{2g}$ = kinetic energy per unit weight or kinetic head

$\frac{P}{\rho g}$ = pressure energy per unit weight fluid or pressure head

z = potential energy per unit weight or potential head

K= constant

ρ = Density

P = pressure

Streamline flow of the particle in the fluid flow to a direction S is considered. The mass of fluid particle and its acceleration give the net force in the stipulated direction S. The uniformity of the flow dictates that the flow of the compressible fluid is constant hence;

$\int$ $\frac{dP}{\rho}$+$\frac{V^{2}}{2}$ + g Z = K

The Bernoulli equation above differsslightly fromisothermal as well as adiabatic progressions.

It is noted here that,

ρ = fluid density Z = elevation point

Hence the equation can as well be written in another form as,

$q + P = P_o$

where;

q = dynamic pressure

P = Static pressure

P_o = total pressure

FLUID FLOW

Fluid flow is the science of fluids in motion. As denoted above in the definition of fluid dynamics, fluids do not include solids but can either be liquids or gases. Fluid flow essentially implies the movement of a fluid through various vessels or under several conditions like through a pipe or any other streamlined vessel (Yeh and Cummins 178). Fluids can either be compressible of incompressible and fluid flow talks about their properties when under flow.

Incompressible fluids abide by the equation of continuity of flow indicated as;

$A_1V_1 = A_2V_2$

While compressible fluids have their continuity of flow as,

$p_1A_1V_1 = p_2A_2V_2$

Where, A_1 and A_2 are Areas

p_1 and p_2 are pressures

V_1 and V_2 are volumes

There are two categories of fluid flow. These are;

(i) Laminar flow that is also known as Streamline flow

(ii) Turbulent flow

THE ARCHIMEDES PRINCIPLE

The principle states that when an object is completely or partially immersed in a liquid, it is associated with an upward force that is in correspondence to the amount of fluid displaced(Schultz et al 100).

Hence;

Force keeping the object on the fluid (buoyancy)=amount of fluid displaced .... (i)

The apparent weight of the object on water can therefore be calculated as;

Apparent weight of the object = Its original weight – the buoyant force exerted .... (ii)

Archimedes Principle Equation can therefore be derived from equations (i) and (ii)

where,

Buoyant force is given by:

$F_b = g\,\rho\,V$......................(i)

or

$F_b = W_a - W_f$......................(ii)

where,

g = Acceleration due to gravity

F_b is the Buoyant force

W_a = the original weight of the object when it is free in air

W_f = the apparent weight of the object when it is immersed in the fluid

ρ = Density of the fluid

V = Volume of the object inserted into the fluid

Incorporating equation (i) in (ii) to get equation (iii)

$g\,\rho\,V = W_a - W$............................ (iii)

Therefore,

$V = Wa - Wfg\rho$..........................(iii)

Putting equation (iii) in the formula for density we get equation (iv):

$\rho = (Wa - Wf)/gv$ which is theArchimedes Principle Formula.

BERNOULLI'S PRINCIPLE

Theprinciple essentiallyrelates velocity to pressure and height of non-viscous fluid flowing in a horizontal surface.

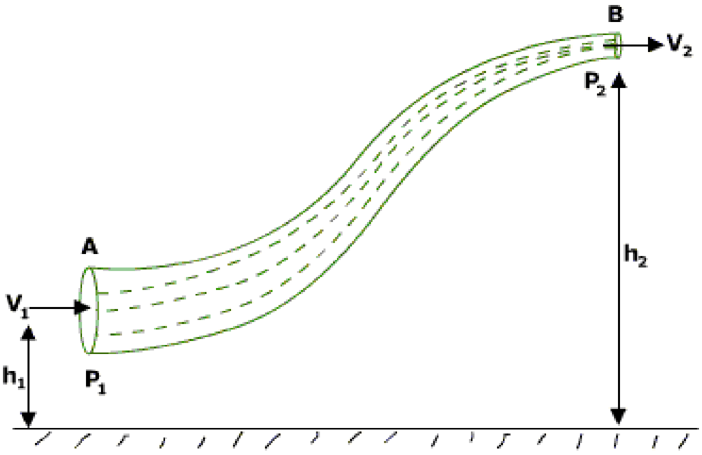
According to the principle, the pressureand speedof the fluid flowing are inversely proportional to one another (Schultz et al 98). This means that, whenever the pressure increases, there is a corresponding decrease on the speed.

It is quit noting that there are many Bernoulli equations that exist according to the fluid flow, basically liquid. It exposes that the law of conservation of energy as practical to moving liquids, where the sum of kinetic, potential and pressure energies of a liquid o motion must be constant..

Hence, the Bernoulli's equation for a unit mass of the moving fluid is given by,

$gh + 1/2v^2 + p/\delta$= constant

The ratio, p/δ, which is of pressure to density, gives the pressure energy per unit mass of the fluid on motion.Theabove equation can be derived considering a tube AB shown in the figure below.



The liquid flows from A to B with varying diameters and hence varied pressure Therefore, $p1 > p2$.

According to equation of continuity,

$A_1 v_1 r = A_2 v_2 r = m$

Suggesting $A_1 > A_2$ giving $v_1 < v_2$

The work done per second on the liquid at area A = $r_1 A_1 v_1$

This can be expressed as,

$= \rho_1 v_1$

Which corresponds to area B,

$= \rho_2 v_2$

Net work done per second from A to B

$= \rho_1 v - \rho_2 v$ (owing to the fact that $v_1 = v_2 = v$ according to the equation of continuity)

In accordance to the law of conservation of energy, the net work done per second increases the kinetic energy per second and potential energy per second through the AB. Hence;

$$p_1 v - p_2 v = (mgh_2 - mgh_1) + (1/2mv^2{}_2 - 1/2mv^2{}_1)$$

$$\text{or } p_1 v + mgh_1 + 1/2mv^2{}_1 = p_2 v + mgh_2 + 1/2mv^2{}_2$$

$$\text{or } p1vm + gh_1 + 1/2v^2{}_1 = p_2 vm + gh_2 + 1/2v^2{}_2$$

$$\text{or } p_1 \rho + gh_1 + 1/2v^2{}_1 = p_2 \rho + gh_2 + 1/2v^2{}_2$$

Hence the equation;

$gh + 1/2v^2 + p/\rho$= constant

FLUID FLOW RATE

In fluid flow, some volume of the fluid are getting out of the system as others occupy the void created to keep the constant flow. Fluid flow rate is therefore the time taken of the replaced fluid. Fluid flow rate is systematically calculated using mass flow rate which is the amount of fluid that goes through an opening in a specific time.

Mass flow rate = ρ A V Where

A = area

ρ = density

V = Velocity

Flow rate = Area × Velocity

Volumetric FlowRate is the volume of fluid that goes through a stipulated surface per unit time (Ford et al 477). It is denoted by letter Q and expressed as;

$Q = V A \cos\theta$

Where,

V = volume A = area

Θ = angle of flow

REFERENCES

1. *Ford, Matthew D, et al.* "Characterization of volumetric flow rate waveforms in the normal internal carotid and vertebral arteries." Physiological measurement 26.4 (2005): 477.

2. *Patera, Anthony T* "A spectral element method for fluid dynamics: laminar flow in a channel expansion." Journal of computational Physics 54.3 (1984): 468-488.

3. *Schultz, Richard C, Rudolph F. Dolezal, and James Nolan.* "Further applications of Archimedes' principle in the correction of asymmetrical breasts." *Annals of plastic surgery* 16.2 (1986): 98-101.

4. Yeh, Y_, and H Z Cummins. "Localized fluid flow measurements with an He–Ne laser spectrometer." Applied Physics Letters 4.10 (1964): 176-178.