ME-421

FLUID MACHINERY

Md. Hasibul Islam

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Mohammad Ali Sir

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1 Lecture 01: Introduction

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Booklist

Hydraulic Machines through worked out problems

Published by BUET

2 Lecture 2: Principles of Hydraulic Machinery

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2.1 Dynamic Action of Fluid

When a stream of fluid enters a machine, it generally follows a specific direction. However, in order to alter its velocity, either in magnitude or direction, a force must be applied to the fluid. This force, exerted by the motion of the fluid, is referred to as dynamic force. The power of the machine is determined by the dynamic force generated by the flowing fluid, which arises due to the change in momentum.

Momentum can exist in linear or angular form, with angular momentum being the moment of linear momentum. The force is the rate of change of linear momentum, while torque is the rate of change of angular momentum. According to Newton's second law, the rate of change of momentum is proportional to the applied force and occurs in the direction of the force. Specifically, if the resultant external force in the x-direction is F_x, the mass of the fluid is m, the velocity of the fluid is v_x, and the change in velocity over time dt is dv_x, then:

The change in momentum $= mdv_x$,
And the rate of change of momentum $= m\frac{dv_x}{dt}$

$$F_x = m\frac{dv_x}{dt} \tag{1}$$

eq^n (1) is knows as linear momentum eq^n.
This eq^n may be wriiten as -

$$F_x dt = mdv_x \tag{2}$$

This eq^n is known as impulse momentum eq^n.
For a control volume with fluid entering in uniform velocity v_{x_1}, and leaving after time t within uniform velocity v_{x_2}, then according to eq^n (2),

$$F_x = \frac{m}{t}(v_{x_2} - v_{x_1}) \tag{3}$$

Again,

$$\frac{m}{t} = \rho Q$$
$$\Rightarrow F_x = \rho Q(v_{x_2} - v_{x_1}) \tag{4}$$

Dynamic force exerted by fluid jet on stationary flat plate -

2.1.1 Plate normal to jet:

A fluid jet is issued from a nozzle and strike a flat plate with a velocity v. The plate is held stationary at perpendicular to the centerline of the jet. Let,

$$Q \longrightarrow \text{Volumetric flow rate}$$
$$\rho Q \longrightarrow \text{Mass flow rate}$$

Dynamic force on the fluid by the plate:
Applying eq^n 4,

$$F_x = \rho Q(v_{x_2} - v_{x_1})$$
$$\Rightarrow -F_x = \rho Q(0 - v)$$
$$\Rightarrow F_x = \rho Q v \tag{5}$$
$$\Rightarrow F_x = \frac{\gamma}{g} Q v \tag{6}$$

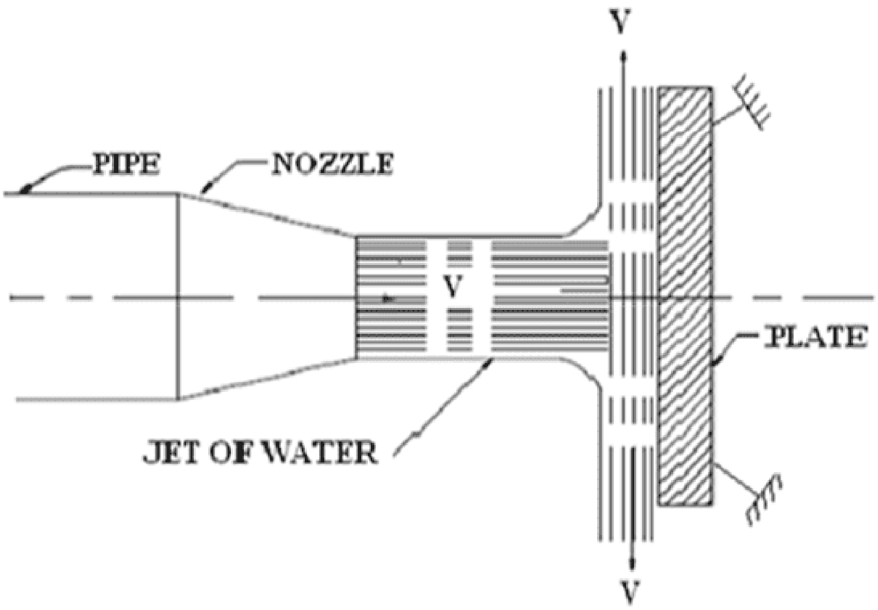

Figure 1: Plate normal to jet.

If a is the area of jet,

$$F_x = \frac{\rho}{g} avv$$

$$\Rightarrow F_x = \frac{\rho}{g} av^2 \tag{7}$$

2.1.2 Inclined Plate

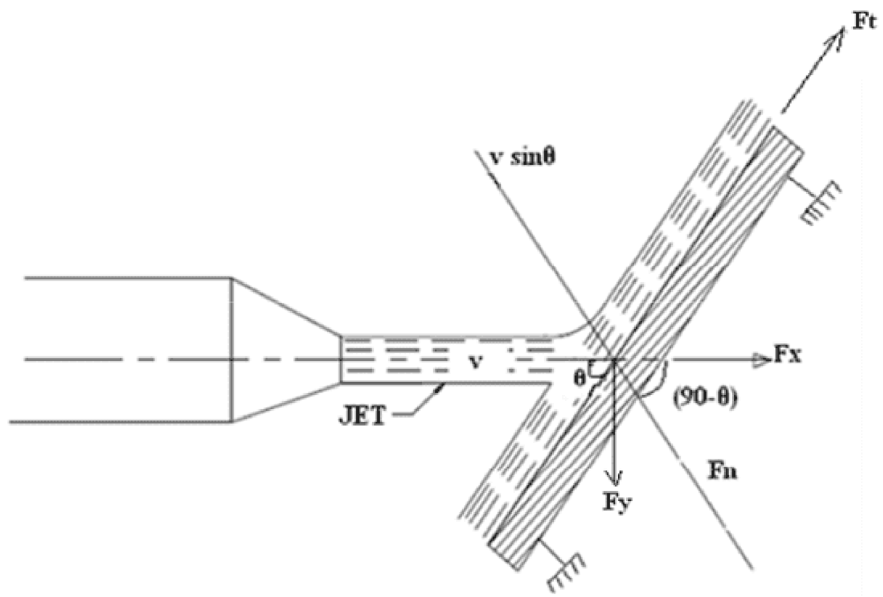

Figure 2: Plate inclined to jet.

$$F = F_n = \rho Qv sin\theta$$

Again,

$$F_x = F sin\theta$$

$$= (\rho Qv sin\theta) sin\theta$$

$$F_x = \rho Q v sin^2\theta \tag{8}$$

And,

$$F_y = F cos\theta$$
$$\Rightarrow F_y = \rho Q v sin\theta cos\theta \tag{9}$$

Determine of division of flows: Let F_s (F_t in fig. 2) be the force along the inclined surface of plate and Q_1 and Q_2 are quantities of flow along the surface. As there is no change in elevation of pressure before and after impact, the magnitude velocity leaving the plate will remain the same.

since no force is exerted on the fluid by the plate in "S" direction, then,

$$F_s = 0 = \rho Q V cos\theta \tag{10}$$

Again,

$$\rho Q_1 v - \rho Q_2 v = 0 \tag{11}$$

From eq^n (10) & (11),

$$\rho Q v cos\theta = \rho Q_1 v - \rho Q_2 v$$
$$\Rightarrow Q cos\theta = Q_1 - Q_2 \tag{12}$$

From continuity eq^n,

$$Q_1 + Q_2 = Q \tag{13}$$

From eq^n (12) & (13),

$$\boxed{\begin{aligned} Q_1 &= \frac{1}{2}Q(1 + cos\theta) \\ Q_2 &= \frac{1}{2}Q(1 - cos\theta) \end{aligned}}$$