IMPACT OF JETS

A jet of water issuing from a nozzle has a velocity and hence it possesses a kinetic energy. If this jet strikes a plate then it is said to have an impact on the plate. The jet will exert a force on the plate which it strikes. This force is called a dynamic force exerted by the jet. This force is due to the change in the momentum of the jet as a consequence of the impact. This force is equal to the rate of change of momentum i.e., the force is equal to (mass striking the plate per second) x (change in velocity).

We will consider some particular cases of impact of a jet on a plate or vane.

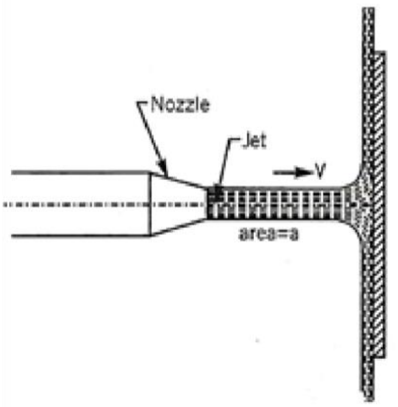


Fig. 18.1.

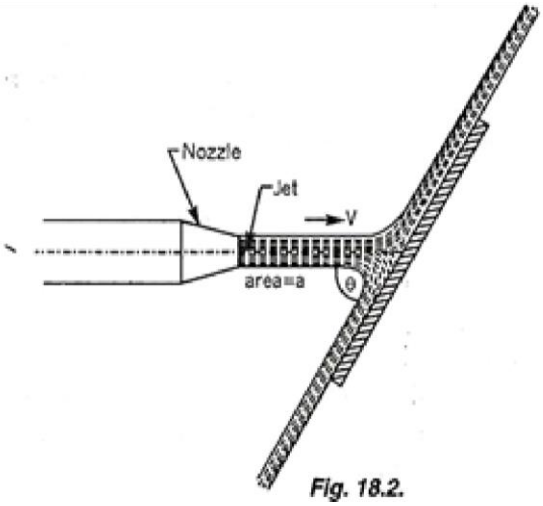


Fig. 18.2.

Direct Impact of a Jet on a Stationary Flat Plate:

Consider a jet of water impinging normally on a flat plate at rest.

Let, a = Cross-sectional area of the jet in metre^2.:

V = Velocity of the jet in metres per second.

M = Mass of water striking the plate per second.

∴ M = ρaV kg/sec where ρ = density of water in kg/cum Force exerted by the jet on the plate- P = Change of momentum per second = (Mass striking the plate per second) x (Change in velocity)

$= M (V - 0) = MV = \rho aV.V. \therefore$
$P = \rho aV^2$ Newton

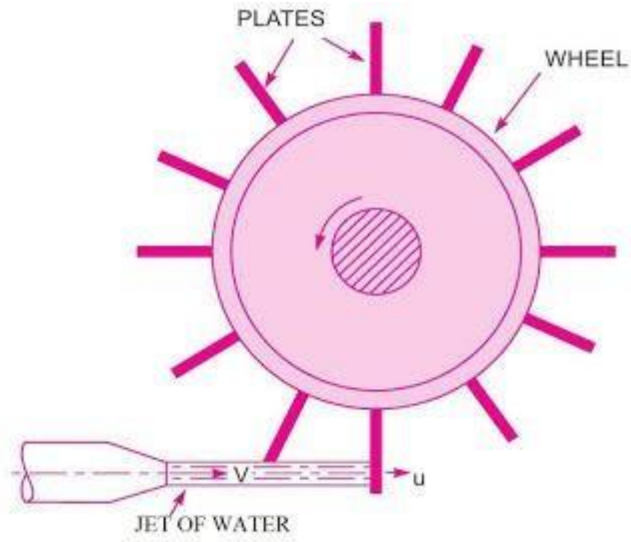
Direct Impact of a Jet on a Moving Plate:

Let,
V = Velocity of the jet v
= Velocity of the plate.
Velocity of the jet relative to the plate = $(V - v)$
We may consider as though the plate is at rest and that the jet is moving with a velocity $(V - v)$ relative to the plate. ∴ Force exerted by the jet on the plate
$= P = \rho a (V - v)^2$ Newton
In this case, since the point of application of the force moves, work is done by the jet.
Work done by the jet on the plate per second
$= Pv = \rho a (V - v)^2 v$ Nm/s or Joule/sec

Force exerted by a jet of water on a series of vanes

If we see practically, force exerted by a jet of water on a single moving plate will not be feasible. Therefore, we will see the practical case where large number of plates will be mounted on the circumference of a wheel at a fixed distance apart as displayed here in following figure.

Jet will strike a plate and due to the force exerted by the jet on plate, wheel will be started to move and therefore second plate mounted on the circumference of wheel will be appeared before the jet and jet will again exert the force to the second plate.



Therefore, each plate will be appeared successively before the jet and jet will strike each plate or jet will exert force to each plate. Therefore, wheel will be rotated with a constant speed.

Let us consider the following terms as mentioned here

V = Velocity of jet d = Diameter of jet

a = Cross-sectional area of jet = (π/4) x d^2 u

= Velocity of vane

Mass of water striking the series of plate per second = ρaV

Jet strikes the plate with a velocity = V-u

After striking, jet will move tangential to the plate and therefore velocity component in the direction of motion of plate will be zero.

Force exerted by the jet in the direction of motion of plate

F_X = Mass striking the series of plate per second x [Initial velocity – final velocity]

F_X = ρaV [(V-u)-0] = ρaV (V-u)

Work done by the jet on the series of plate per second = Force x Distance per second in the direction of force

Work done by the jet on the series of plate per second = F_X x u = ρaV (V-u) x u

Kinetic energy of the jet per second = (1/2) x mV^2

Kinetic energy of the jet per second = (1/2) x ρaV V^2

Kinetic energy of the jet per second = (1/2) x $\rho a V^3$

Efficiency = Work done per second / Kinetic energy per second

Efficiency = ρaV (V-u) x u / (1/2) x $\rho a V^3$

Efficiency = 2 u (V-u)/V^2

$$\eta = \frac{2u[V-u]}{V^2}$$

Maximum efficiency will be 50 % and it will be when u = V/2

WORKDONE Of Jet Impinging On A Moving Curved Vane:

Consider a jet of water entering and leaving a moving curved vane as shown in fig.

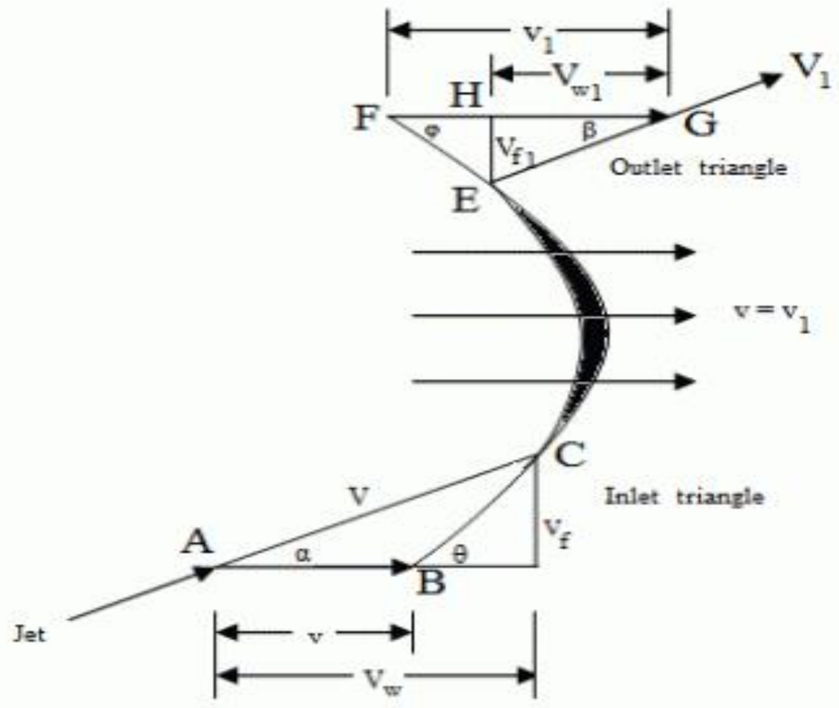


Fig-4 : Jet impinging on a moving curved vane

Let,

V = Velocity of the jet (AC), while entering the vane,

V1 = Velocity of the jet (EG), while leaving the vane,

v1, v2 = Velocity of the vane (AB, FG)

α = Angle with the direction of motion of the vane, at which the jet enters the vane,

β = Angle with the direction of motion of the vane, at which the jet leaves the vane,

Vr = Relative velocity of the jet and the vane (BC) at entrance (it is the vertical difference between V and v)

Vr1 = Relative velocity of the jet and the vane (EF) at exit (it is the vertical difference between v1 and v2)

Ɵ = Angle, which Vr makes with the direction of motion of the vane at inlet (known as vane angle at inlet),

β = Angle, which Vr1 makes with the direction of motion of the vane at outlet (known as vane angle at outlet),

Vw = Horizontal component of V (AD, equal to). It is a component parallel to the direction of motion of the vane (known as velocity of whirl at inlet),

Vw1 = Horizontal component of V1 (HG, equal to). It is a component parallel to the direction of motion of the vane (known as velocity of whirl at outlet),

Vf = Vertical component of V (DC, equal to). It is a component at right angles to the direction of motion of the vane (known as velocity of flow at inlet),

Vf1 = Vertical component of V1 (EH, equal to). It is a component at right angles to the direction of motion of the vane (known as velocity of flow at outlet),

a = Cross sectional area of the jet. As the jet of water enters and leaves the vanes tangentially, therefore shape of the vanes will be such that Vr and Vr1 will be a long with tangents to the vanes at inlet and outlet.

The relations between the inlet and outlet triangles (until and unless given) are: (i) V=v1 , and

(ii) Vr=Vr1 We know that the force of jet, in the direction of motion of the vane,

$$F_x = Mass\ of\ water\ flowing\ per\ second \times Change\ of\ velocity\ of\ whirl$$

$$\Rightarrow F_x = \frac{waV}{g}(V_w - V_{w1})$$

$$= \frac{W}{g}[V_w - V_{w1}]\ Newton$$

Work done per second $= \frac{W}{g}[V_w - V_{w1}]\ v\ \ Nm/sec.$

Work done per second per N of water

$$= \frac{1}{g}[V_w - V_{w1}]\ v\ \ Nm/sec/N\ \text{ of water}$$

te. *If the direction of velocity of whirl at outlet is opposite to that at inlet then the work done per second per N of water*

$$= \frac{1}{g}[V_w + V_{w1}]\ v\ \ Nm/sec/N\ \text{ of water}$$

References

Fluid Mechanics & Hydraulic Machines - Dr. R.K.Bansal