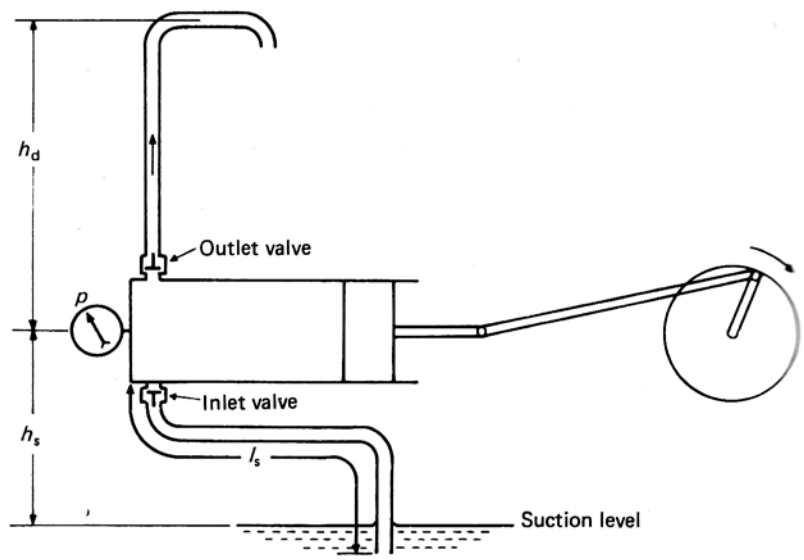
FLUID MACHINE

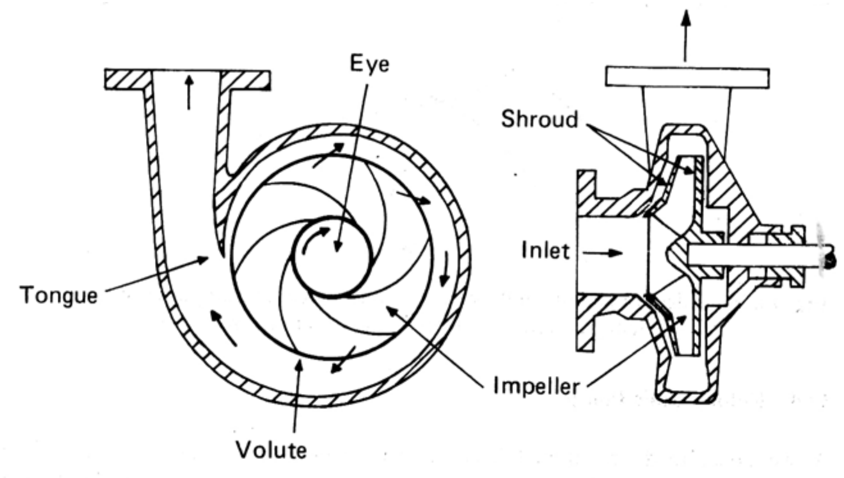
A fluid machine is a device either for converting the energy held by a fluid into mechanical energy or vice versa.

Fluid machine may be divided into two groups;

1. Positive displacement group
   * Reciprocating pump, etc



2. Rotodynamic group
    * Pelton wheel, etc



Depend on energy movement; fluid machine could be divided into three categories

1. Pump
2. Turbine
3. Jack

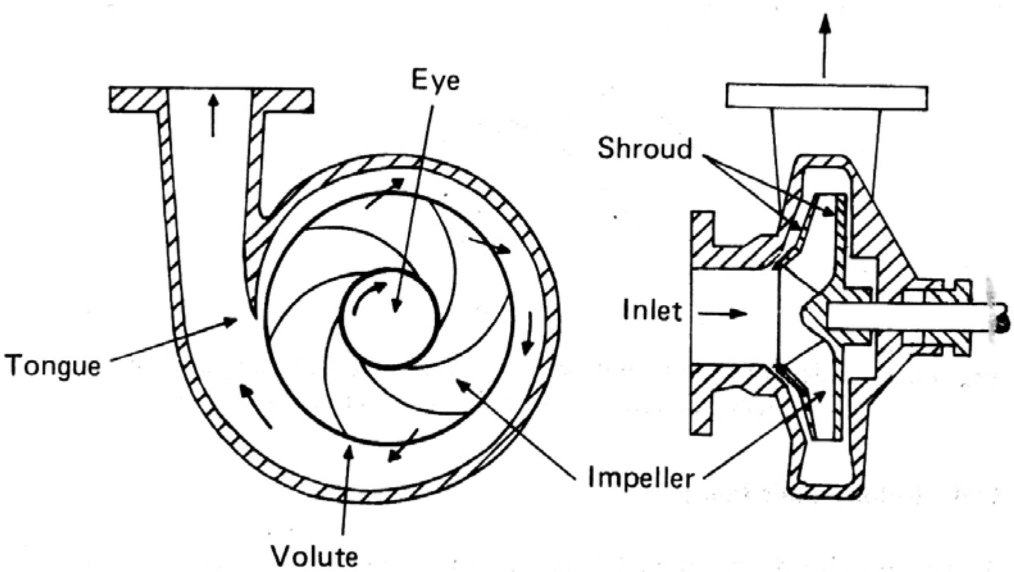
PUMP

INTRODUCTION

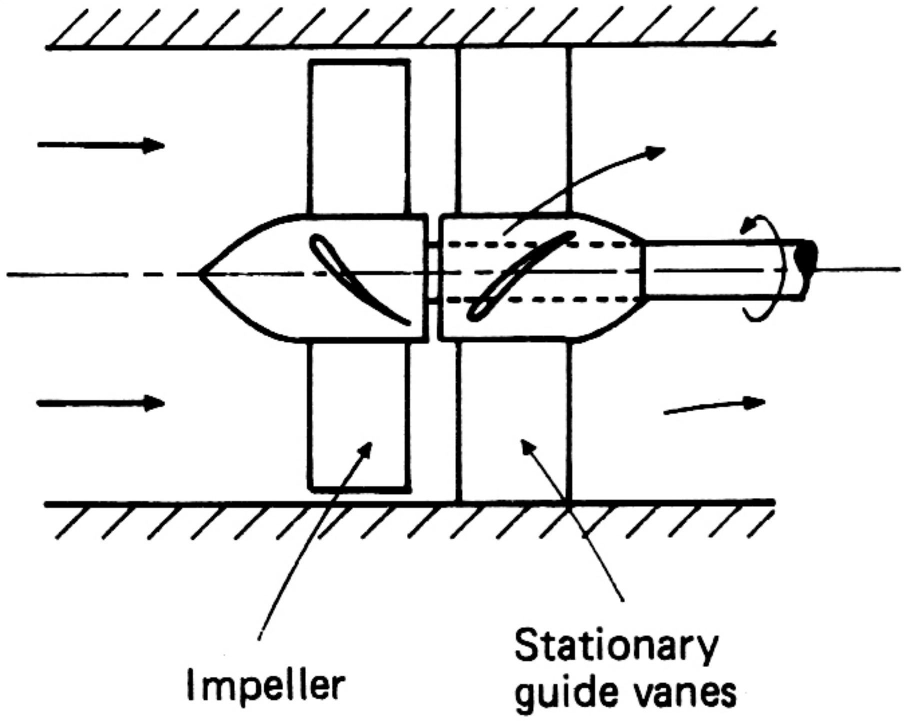
Rotodynamic pump is essentially a turbine 'in reverse'; which mean that mechanical energy is transferred from the rotor to the fluid.

It is classified according to the direction of the fluid path through them.

1. Radial / centrifugal flow



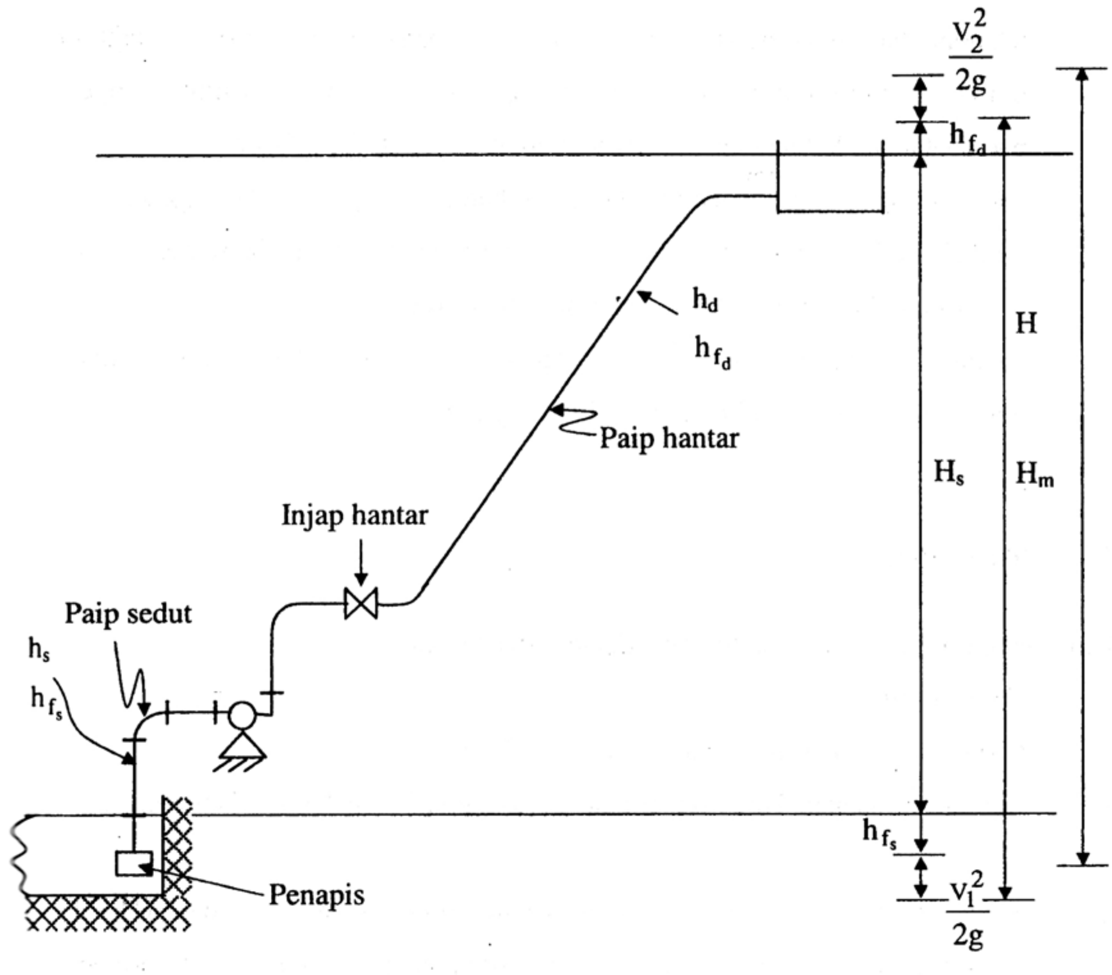
2. Axial flow
3. Mixed-flow type



In general usage, the word 'PUMP' is applied to a machine dealing with a liquid.

A machine in which the working fluid is a gas is more usually termed as fan, blower or compressor.

HEAD OF PUMP


v2²/2g
h fd
hd
hfd
Paip hantar
H
Hs
Hm
Injap hantar
Paip sedut
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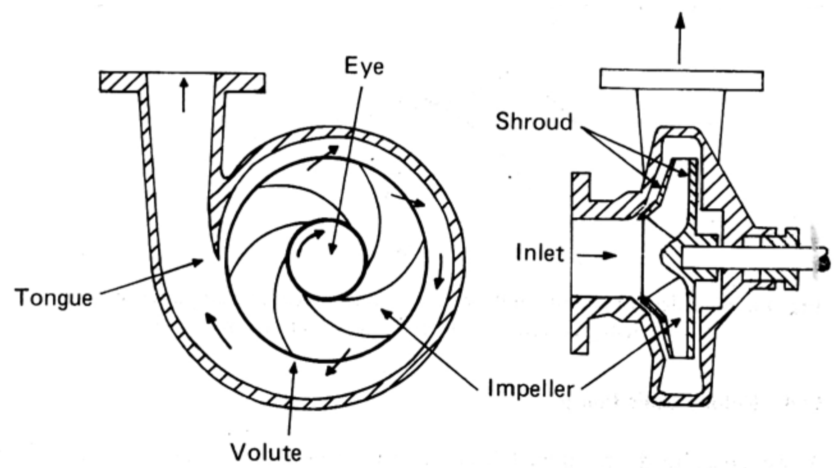
hfs
Penapis
v1²/2g

CENTRIFUGAL PUMP



This type of pumps is the converse of the radial-flow (Francis) turbine. Whereas the flow in the turbine in inwards, the flow in the pumps is outwards.

The rotor (impeller) rotates inside a spiral casing. The inlet pipe is axial, and fluid enters the 'eye', that is the center of the impeller with little, if any, whirl component of velocity.

From there it flows outwards in the direction of the blades, and having received energy from the impeller, is discharged with increased pressure and velocity into the casing.

It then has a considerable tangential (whirl) component of velocity which is normally much greater than that required in the discharge pipe.

The kinetic energy of the fluid leaving the impeller is largely dissipated in shock losses unless arrangements are made to reduce the velocity gradually.

Velocity triangle

Inlet ;

Tangential velocity of impeller

$$U_1 = \omega r_1$$

Absolute velocity vector at α_1 to tangent

$$V_1$$

Relative velocity to impeller blades

$$V_{r1} = V_1 - U_1$$

Components velocity of V_1

V_{w1} : whirl velocity

V_{f1} : radial flow velocity

Inlet blade angle

$$\beta_1$$

Outlet ;

Tangential velocity of impeller

$$U_2 = \omega r_2$$

Absolute velocity vector at α_2 to tangent

$$V_2$$

Relative velocity to impeller blades

$$V_{r2} = V_2 - U_2$$

Components velocity of V_2

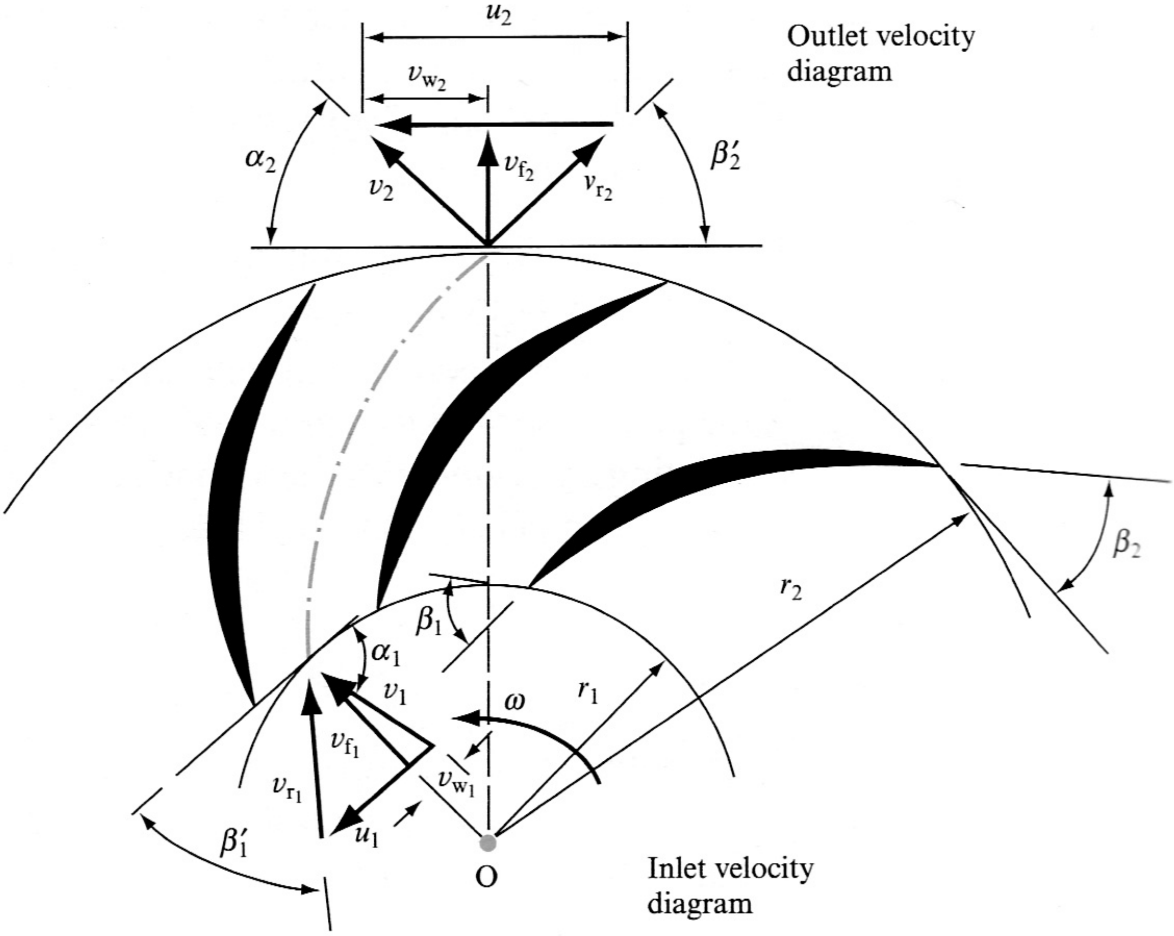
V_{w2} : whirl velocity

V_{f2} : radial flow velocity

Inlet blade angle

$$\beta_2$$

Velocity triangle for centrifugal pump:



Calculation is done base on "Euler's Turbine Equation". The one-dimensional theory simplifies the problem very considerably by making the following assumptions:

1. The blades are infinitely thin and the pressure difference across them is replaced by imaginary body forces acting on the fluid and producing torque.
2. The number of blades in infinitely large. Thus, $\frac{\partial v}{\partial \theta} = 0$
3. No variation of velocity in the meridional plane (z-axis). Thus,

In reality, $v = f(r, \theta, z)$

Torque = Rate of change of angular momentum

Angular momentum = (Mass) x (Tangential velocity) x (Radius)

Specific energy, $Y = gE = \frac{P}{\dot{m}}$ (unit : J/kg)

Euler's Head ;

$$H_E = \frac{1}{g}\left(v_{w2} \cdot u_2 - v_{w1} \cdot u_1\right) \qquad \text{(unit : m)}$$

Relation of u_2, v_{w2} and H_E

$$H_E = \frac{1}{g}\left(v_2 u_2 \cos\alpha_2 - v_1 u_1 \cos\alpha_1\right)$$

$\alpha_1 = 90^\circ$ ➔ $v_{w1} = 0$ and $v_1 = v_f$

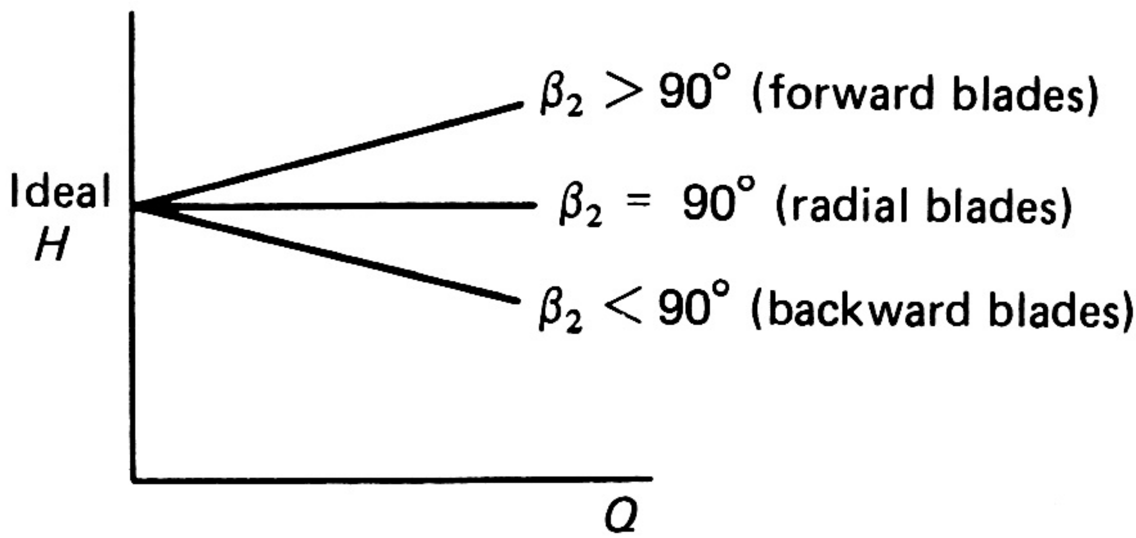
$$H_E = \frac{v_{w2} \cdot u_2}{g}$$

relation of β_2 and H_E

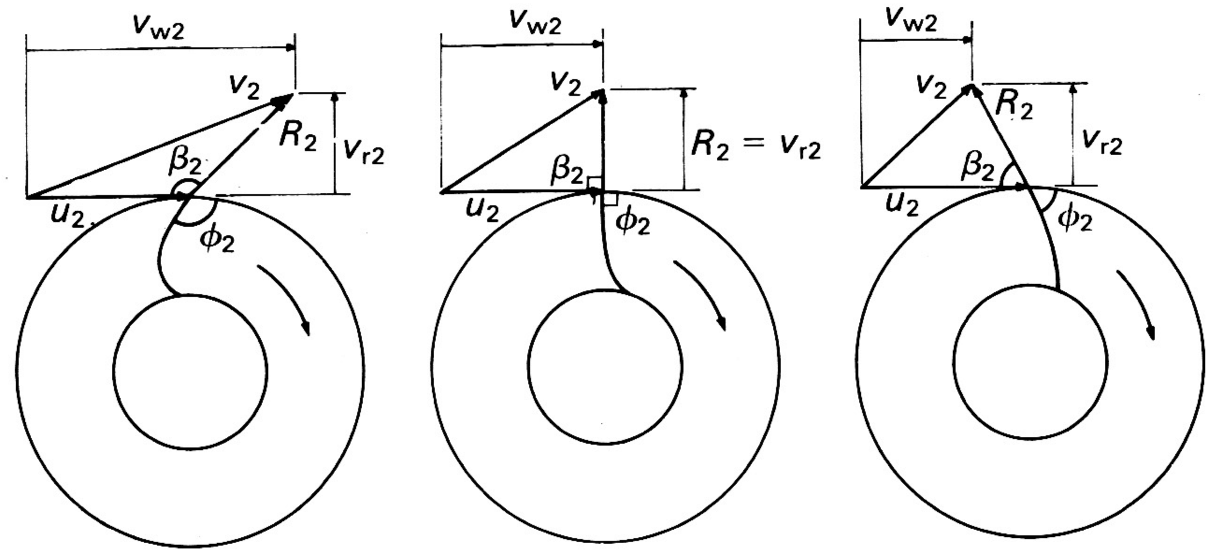
from ;

$$H_E = \frac{v_{w2} \cdot u_2}{g} = C_1 + C_2 Q \cdot \frac{1}{\tan\beta_2}$$

Euler's head is depends on the value of β_2



<u>velocity triangle and the position of blades</u>



Forward-facing blades, $\phi_2 > 90°$ | Radial blades, $\phi_2 = 90°$ | Backward-facing blades, $\phi_2 < 90°$

Blade condition with $\beta_2 = 90^\circ$ has the highest Euler's head value.

Relation of β_2 and H_E with Bernoulli equation.

Euler's head：

$$H_E = H_P + H_V = H_P + \frac{{V_{w2}}^2}{2g}$$

Reaction degree of pump =

$$\frac{H_E}{H_P} = 1 + \frac{{V_{w2}}^2}{2gH_E} = \frac{1}{2}\left[1 + \frac{V_{f2}}{U_2 \cdot \tan\beta_2}\right]$$

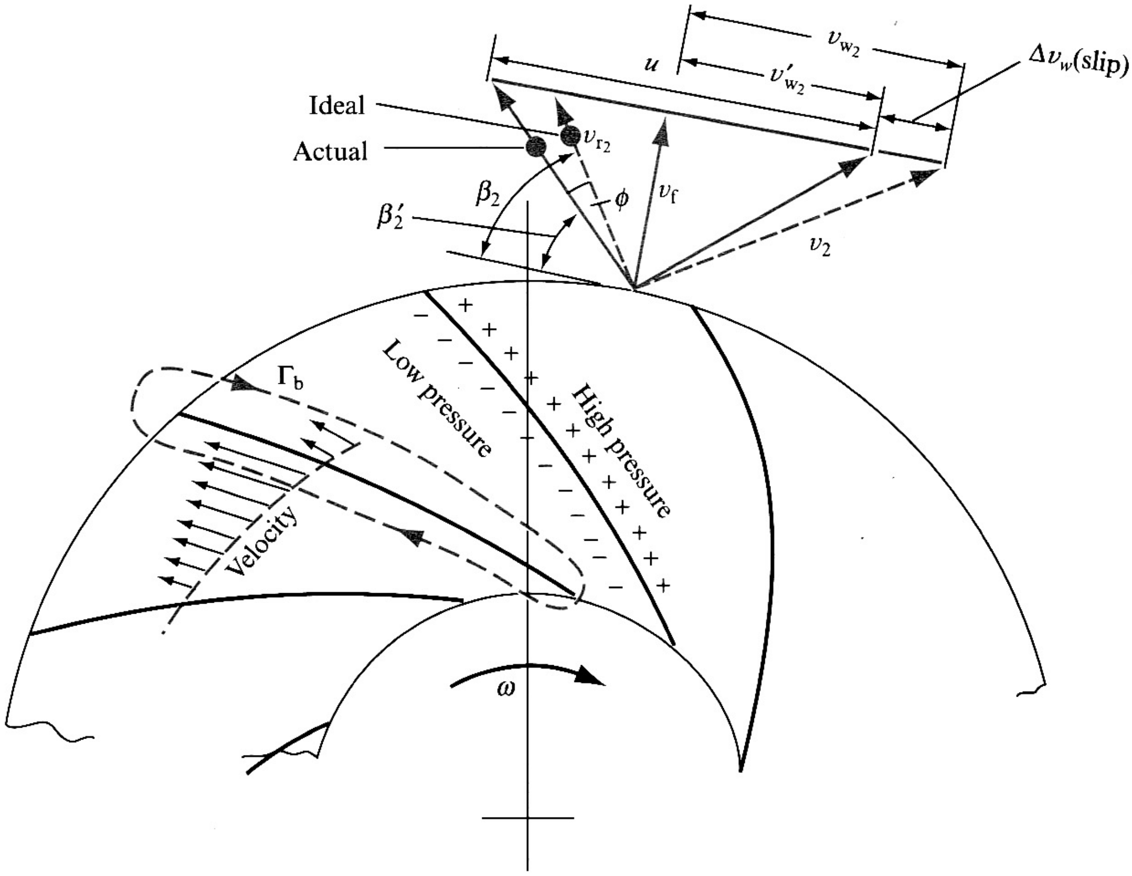
LOSSES IN PUMP

3 major types of losses

1. Losses of hydraulic power
    a. Circulatory flow
    b. Friction
    c. Shocking in impeller
2. Loss of volume
3. Loss of mechanical energy

a. Circulatory Flow

SF : Slip Factor



$$SF = \frac{V_{w2}'}{V_{w2}} = \frac{H_{actual}}{H_{ideal} = H_E}$$

b. Friction losses

$$h_f = k_1 \cdot Q^2$$

h_f : Friction losses

k_1 : Constant

Q : Flow rate

c. Shock losses

$$h_{sh} = k_2 \left(Q - Q_o\right)^2$$

k_2 : Shock losses

Q : Designed flow rate

Q_o : Actual flow rate

EFFICIENCY OF PUMP

Overall Efficiency :

$$\eta_o = \frac{\rho g Q H_m}{P_i}$$

Mechanical Efficiency :

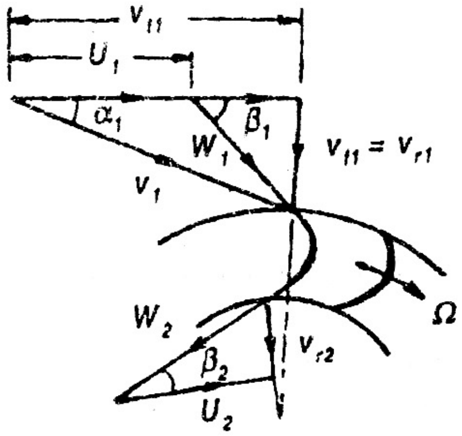
$$\eta_{mech} = \frac{\rho g (Q + \Delta Q)\left(\frac{1}{g}\left[V_{w2}U_2 - V_{w1}U_1\right]\right)}{P_i}$$

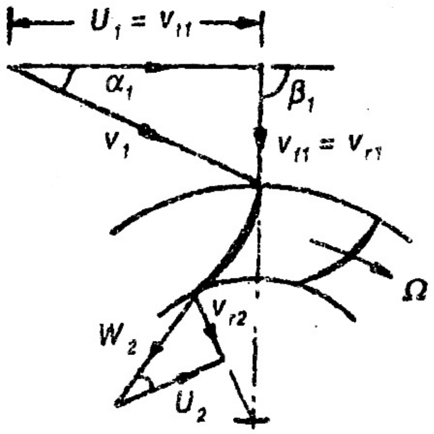
Manometric Efficiency :

$$\eta_{mano} = \frac{gH_m}{V_{w2}U_2 - V_{w1}U_1}$$

Volumetric Efficiency :

$$\eta_v = \frac{Q}{Q + \Delta Q}$$


V_{t1}
U_1
α_1
β_1
W_1
$V_{t1} = V_{r1}$
V_1
Ω
W_2
V_{r2}
β_2
U_2


$U_1 = V_{t1}$
α_1
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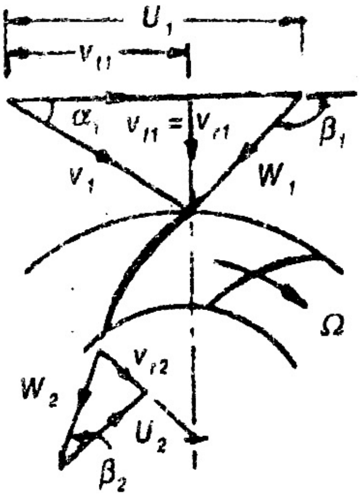
U_1
V_{t1}
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$V_{t1} = V_{r1}$
β_1
V_1
W_1
Ω
V_{r2}
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U_2
β_2