Centrifugal pumps in Parallel and Series configuration

Objective

- To operate the setup in parallel and series combination subsequently
- To find the pressure head and flow rate in both parallel and series combination
- To plot Flow-rate vs. No. of Observation graph for parallel operation comparing to single pump operation
- To plot Head vs. No. of Observation graph for parallel operation comparing to single pump operation
- To plot Flow-rate vs. No. of Observation graph for series operation comparing to single pump operation
- To plot Head vs. No. of Observation graph for series operation comparing to single pump operation

Theory

In parallel operation of several pumps, the overall flow-rate is the summation of the flow-rates of individual pumps. Hence the flow-rate is measured as,

$$Q_{parallel} = Q_1 + Q_2 + Q_3 + \dots\dots\dots + Q_n = \sum_{i=1}^{i=n} Q$$

Where,

$Q_{parallel}$ = Flow-rate of pumps in parallel operation

Q = Flow-rate of individual pumps

n = Number of pumps

Head in parallel operation remains constant and is same as the head of individual pumps which are considered to be run at same speed.

Instead of flow-rate, head in series operation is the summation of the heads of individual pumps. Hence, the head in series operation is measured by,

$$H_{series} = H_1 + H_2 + H_3 + \ldots\ldots\ldots + H_n = \sum_{i=1}^{i=n} H$$

Where,

H_{series} = Total head in series operation

H = Head of individual pumps

n = Number of pumps

Here, in series operation flow-rate of the total configuration is considered to be constant and same as the flow-rate of individual pumps.

Components of Setup

- Gazi tank- 2 pcs
- Angle bar bases- 2pcs
- Marquis pumps- 2 pcs
- Globe valves- ¾ inch
- GI pipe- ¾ inch
- Pressure gauges- 3 pcs
- Water meters- 2 pcs
- Pipe fittings
- Level tubes- 2pcs
- Flexible pipe

Experimental Setup Layout

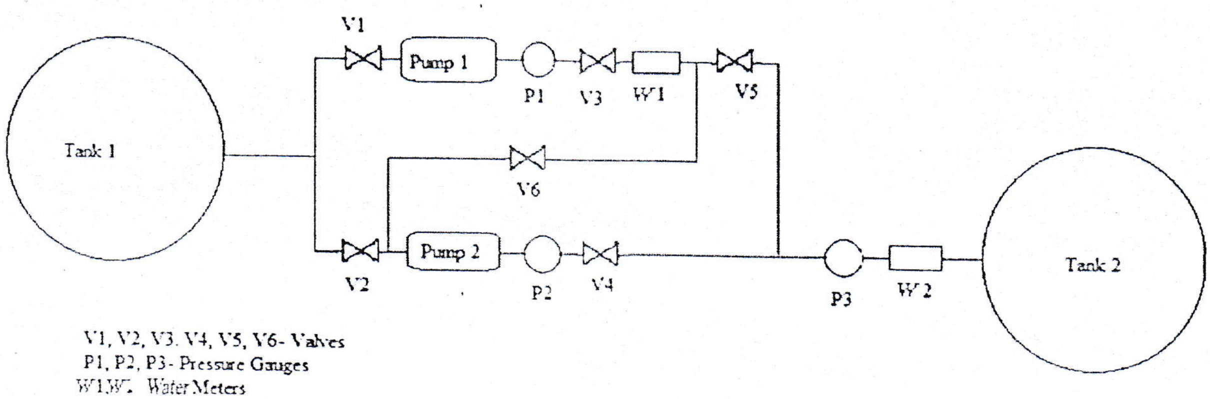

Figure: P&ID Sketch of Basic Experimental Setup

Working Procedures

Parallel

1. When pumps are in parallel connection both pump-1 and pump-2 are active and all the valves are open except valve-6.
2. Both pressure gauges 1 and 2 will show the same reading assuming both the valves 1 and 2 are equally open.
3. Calculating the time period of certain flow (50 liters/ 0.05 m^3) by stopwatch the volumetric flow-rate can be measured.
4. Water-meter 1 indicates the volume of water flowing through the single pump. Pressure gauge 1, 2, 3 shows the pressure head readings of the single pump (pump 1), both pump (when in series) or pump 2 (when in parallel) and the overall system respectively.
5. Water-meter 2 shows the volume of water flowing through the double pumps.

Series

6. When pumps are in series connection both pump 1 and pump 2 are active and all valves remain open except valve 2 and 5.
7. Pump 2 is started after the pump 1 initiation.
8. Pressure gauge readings and flow-rate measurements are taken similarly as process 3, 4 & 5.

Experimental Data

Specifications:

Pipe diameter- ¾ inch

Tank volume- 1000 liter or 1m^3 each

Pump power- 1HP each

Water meter readings- 0.01 m^3= 10 liter

Parallel Connection

Table 1: Flow Rate and Pressure Data in Parallel Connection

Observation No.	Volume, V (Liter, L)	Time, t (Second, s)	Flow rate, Q (L/s)	Avg. Flow rate (L/s)	Pressure, P (Kg/cm^2)
Single pump					
1	50				
2					
3					
4					
5					
Both pump					
1	50				
2					
3					
4					
5					

Series Connection

Table 2: Flow Rate and Pressure Data in Series Connection

Observation No.	Volume, V (Liter, L)	Time, t (Second, s)	Flow rate, Q (L/s)	Avg. Flow rate (L/s)	Pressure, P (Kg/cm^2)
Single pump					
1	50				
2					
3					
4					
5					
Both Pump					
1	50				
2					
3					
4					
5					

Experiment No. 06

Performance Test of Pelton Turbine

Objectives:

1. To determine the coefficient of velocity (C_v) for the nozzle.
2. To find the efficiency (η) of the wheel.
3. To find the performance characteristics curves i.e. to plot:

    i. Head vs. Flow rate

    ii. Speed vs. Flow rate

    iii. Torque vs. Flow rate

    iv. Output power vs. Flow rate

    v. Output power vs. input power

Apparatus

Pressure gauge, water meter, stopwatch, tachometer and spring balance.

Schematic Diagram

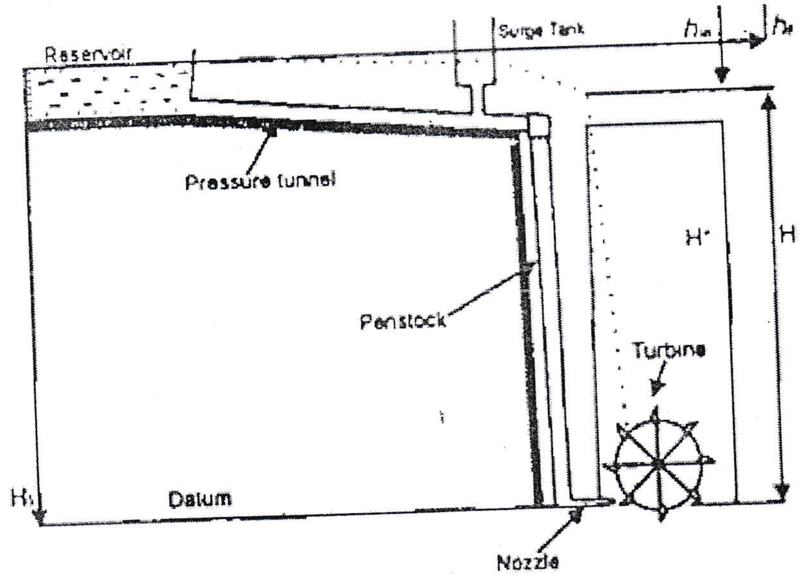

Figure: Schematic diagram of a Pelton wheel driven power station.

Theory

a) Head, $H(m) = \Delta Z + \frac{P}{\rho g} + \frac{v^2}{2g}$

Note that the velocity head is around 1% of the total head, and is usually neglected. Again $\Delta Z = 0$, because nozzle and pressure gauge is on same plane.

Thus the head becomes,

$$H(m) = \frac{P}{\rho g} = \frac{P}{\gamma}$$

Where, γ = specific weight of water.

b) Power:

i. Flow of water can be measured by a water meter. Thus using a stop watch, flow rate can be calculated.

ii. Inlet hydraulic power (P_i):

$$P_i(Watt) = \gamma \times Q(m^3/s) \times H(m)$$

iii. Output power (P_o):

Can be measured by dynamometer.

$$P_o(Watt) = (T_1 - T_2)(kg) \times g(ms^{-2}) \times \omega(rad.s^{-1}) \times R(m)$$

Where,

T_1 and T_2 are the tensions at the brake drum.

R is the radius of the brake drum.

ω is the angular speed of the wheel $= \frac{2\pi N}{60}$

N is the rpm of the wheel.

c) Overall efficiency, $\eta = \frac{P_o}{P_i}$

d) Flow rate, $Q = Av_a$

$$v_a = \frac{Q}{A} = \frac{4Q}{\pi d^2}$$

e) Coefficient of velocity, $C_v = \frac{v_a}{\sqrt{2gH}}$

f) Peripheral speed of the wheel, $u = \frac{\pi DN}{60}$

Here, D = mean diameter of the wheel

=12 *inch*

g) Speed ratio, $\phi = \frac{u}{v_a}$

Where, u= Peripheral speed of the rotor $(\omega.r)$

v_a= Actual velocity of water at the nozzle tip, ($v_a = C_v\sqrt{2gH}$)

h) Specific speed, $N_s = \frac{N\sqrt{P_o}}{H^{\frac{5}{4}}}$

Where, (N in rpm, P_o in kW, H in m).

Experimental Procedures

- Open the gate valve of main pipe line.
- Initially apply 2 lb load to brake drum with the help of nut bolt which is attached with the frame.
- After applying the load, open the ball valve ahead of nozzle. As a result, jet will strike the buckets. The runner will start rotating as well as the brake drum.
- Set a pressure using ball valve.
- Measure the flow rate of water using the water meter & stopwatch.
- Measure the speed, N of the wheel using tachometer.
- Take the reading from spring balance.
- Repeat the same process for different pressures (12psi-30psi).
- When the experiment is over, remove the load from the brake drum and close all the valves.

Data Table

- Radius of the brake drum = 0.09 *m*
- Diameter of nozzle = 0.45 *inch* = 0.01143 *m*

No. of obs.	Time (s)	Volume (m^3)	Flow rate, Q (m^3/s)	Pressure, P (psi)	Pressure, P (Pa)	Speed, N (rpm)	T_1 (lb)	T_2 (lb)	Load for braking torque, (T_1-T_2) (lb)	(T_1-T_2) (kg)
01.										
02.										
03.										
04.										
05.										
06.										
07.										
08.										
09.										
10.										

Calculation

Area of the nozzle, $A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times (0.01143)^2 = 1.026 \times 10^{-4}\ m^2$

No. of Obs.	H (m)	Q (m^3/s)	v_a (ms^{-1})	C_v	P_i (W)	P_o (W)	Speed ratio, φ	Efficiency, η (%)	Specific speed, N_s (rpm)	Torque, T (N.m)
01.										
02.										
03.										
04.										
05.										
06.										
07.										
08.										
09										
10.										

Experiment Name:Study of A Centrifugal Pump and Pump Characteristics.

Theory:

A centrifugal pump is a machine which converts mechanical energy into kinetic and pressure energy through centrifugal force.

A centrifugal pump consists of two main parts:

- A rotating element, including an impeller and a shaft.
- A stationary element made up of a casing, stuffing box and bearings.

The shaft of the pump is driven by power from an external source by which means the impeller along with the vanes inside is rotated. The fluid receives energy from the vanes during flow through the rotating impeller resulting in an increase in both velocity and pressure. Fluid flows from the suction pipe due to the formation of partial vacuum in the center of impeller. A large part of the total energy of the fluid leaving the impeller is kinetic energy. It is necessary to reduce the absolute velocity and transform the large portion of the velocity head into pressure head. In overcoming the delivery head of the pump the high pressure head of the leaving fluid is utilized.

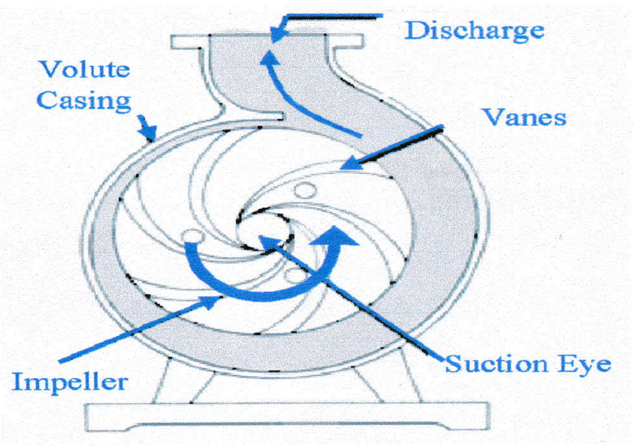

Figure 1: Liquid flow paths of a centrifugal pump

The actual head rise (H) produced by acentrifugal pump is a function of the flow rate (Q). It is possible to determine the head-flow relationship by appropriate selection of the geometry of the impeller blades. Normally, pumps are designed so that the head decreases with increasing flow since such a design results in a stable flow rate when the pump is connected to a piping system. A typical head flow curve for a pump is shown in Figure 2.

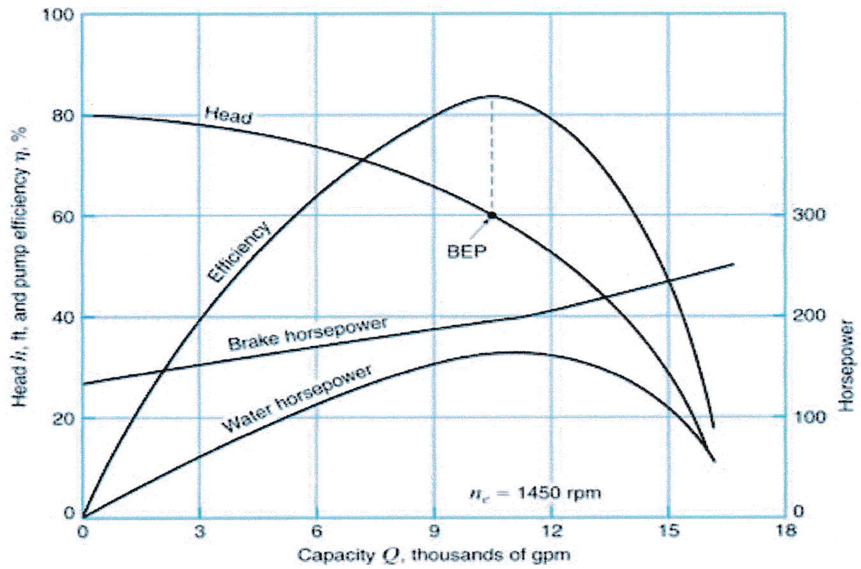

Figure 2: Characteristics curve of Centrifugal Pump.

If the mechanical energy equation is applied, section 1 is located as the pump inlet and section 2 asthe pump outletbetween two points in a piping system onopposite sides of the pump, then

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 + H_m = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_f$$

$$H_m = \frac{P_2 - P_1}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + Z_2 - Z_1 + h_f$$

$H_m$is the pump head and it is the summation of pressure head, velocity head, elevation head andh_f is the total head loss in the associated piping. Theefficiency is defined as the ratio of the fluid work to the shaft power input to the pump:

$$\eta = \frac{\gamma Q H_m}{P}$$

Experimental Setup

Figure 3: Centrifugal Pump Test Rig

Objective:

The objective of this experiment is to

- ✓ To do the performance test of different centrifugal pumps by varying their flow rates.
- ✓ To check the performance of centrifugal pump with different head and rpm.
- ✓ To plot the characteristics curve for different centrifugal pumps.

Apparatus:

Stopwatch, Wattmeter, Tachometer, Measuring Tape

Experimental Procedure

- ➢ Set up the centrifugal pump to the test rig.
- ➢ Wire connection to the pump.
- ➢ Measure power, voltage and current with Wattmeter.
- ➢ Measure RPM of the pump with non-contact Tachometer.
- ➢ Do this for all the pumps 0.5hp, 1hp, 1.5hp, 2hp & 3hp respectively.
- ➢ Open the gate valve at suction side of sump tank.
- ➢ Open the gate valve at delivery side of measuring tank.
- ➢ Turn on the pump.
- ➢ Take the value of flow rate at suction side and delivery side with flow meter and stopwatch.
- ➢ Take the value of pressure with pressure gauge at both sides.
- ➢ Reduce the flow of the water by controlling gate valve at delivery side step by step. Keep the flow rate of water at suction side constant.
- ➢ Now reduce the flow of the water by controlling gate valve at suction side step by step. Keep the flow rate of water at delivery side constant.
- ➢ Record all the values.
- ➢ Calculate friction in the delivery and suction side.
- ➢ Calculate the velocity head and total head.
- ➢ Calculate the pump efficiency.

Data Table:

Pipe Diameter (Suction) = 1.5 inch

Pipe Diameter (Delivery) = 1 inch

Pipe Length (Suction) = 96 inch

Pipe Length (Delivery) = 273 inch

Elevation Head, H = 2.7432 m

Height of Base = 72 cm

Width of Base = 38 cm

Pump Speed, N [r.p.m]	No Of Obs	Inlet Pressure, P_{in} [KPa]	Outlet Pressure, P_{out} [KPa]	Flow Rate, Q [m^3/s]	Inlet Velocity, V_{in} [m/s]	Outlet Velocity, V_{out} [m/s]	friction in Suction H_s [m]	friction in Delivery H_v [m]	Elevation Head,H [m]	Pressure Head [m]	Velocity Head [m]	Total Head, H_t [m]	Output Power [w]	Hydraulic Power [w]	Pump Efficiency [%]

Calculation:

Flow rate, Q = AV

Reynolds Number, $Re = \frac{\rho VD}{\mu}$

Friction, $H_f = \frac{flV^2}{2gd}$

Total Head,

$$H_m = \frac{P_2 - P_1}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + Z_2 - Z_1 + H_f$$

Efficiency, $\eta = \frac{\gamma Q H_m}{P}$