DATE

Expt - 3

CHARACTERISTICS OF A CENTRIFUGAL PUMP

SHEET NO.

Objective :-

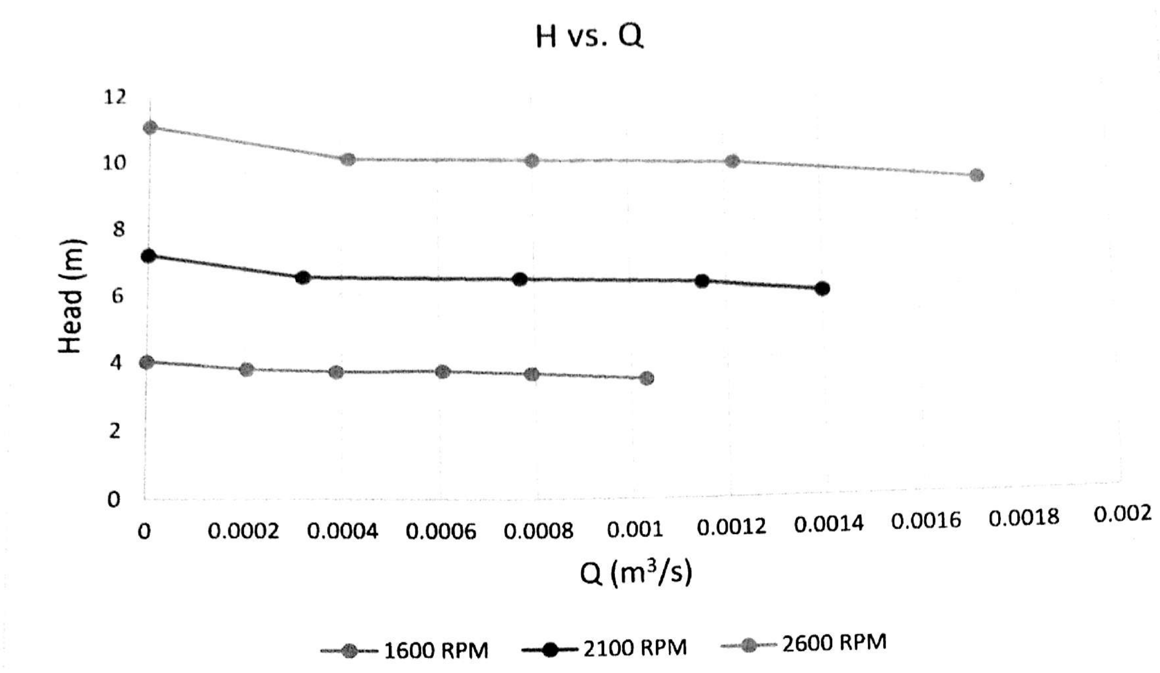
1. To determine the characteristics of a centrifugal pump at different speed.
2. To construct the characteristic curve in non-dimensional form.

Procedure :-

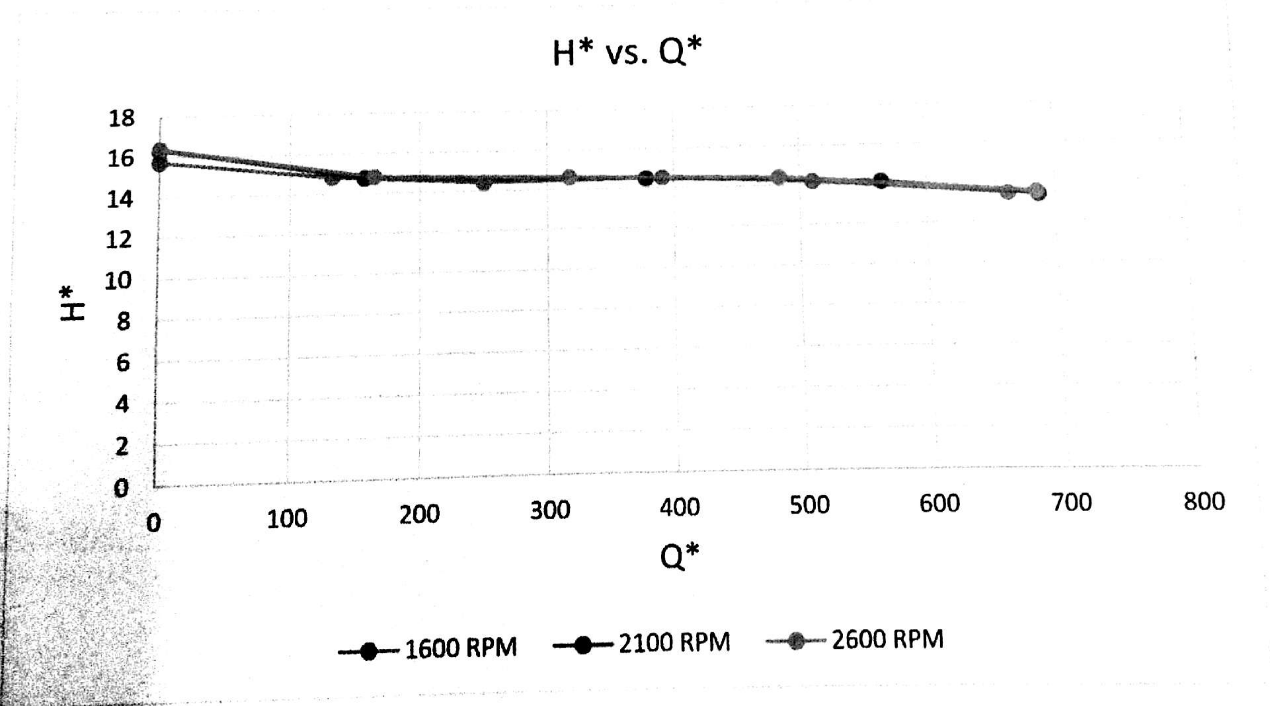
1) Initially, the suction valve is opened.
2) Now the discharge valve is closed. ~~and~~
3) The motor is started and is maintained till the desired flow is obtained, maintained at a fixed RPM.
4) Repeat the same for partial openings of the discharg tube, like 25%, 50%, 75%, 100% etc.
5) Repeat it for different RPMs.
6) Note the readings like Pin, Torque etc. and note in an observation table.
7) Plot relevant graphs and discuss.

RPM	Q (m^3/s)	Torque (Nm)	Power input (kW)	ΔH (cm)	Head (m)	Power (mech) (kW)	Power (hydraulic) (kW)	$\eta_{overall}$ (%)	η_{mech} (%)
[illegible]	0.00103	0.6	0.28	27.3	3.4398	0.100531	0.034756771	12.41313255	34.57319958
1600	0.000792	0.5	0.26	28.8	3.6288	0.0837758	0.028194034	10.8438593	33.65414929
[illegible]	0.000607	0.5	0.245	29.5	3.717	0.0837758	0.022133508	9.034085057	26.41992951
1600	0.000388	0.4	0.23	29.3	3.6918	0.0670206	0.014052025	6.109575871	20.96671088
[illegible]	0.000205	0.4	0.225	30.1	3.7926	0.0670206	0.007627108	3.38982588	11.38023728
1600	0	0.4	0.22	31.9	4.0194	0.0670206	0	0	0
2100	0.0014	0.8	0.435	46.7	5.8842	0.1759292	0.080813603	18.57783972	45.93530127
2100	0.00115	0.7	0.4	49.4	6.2244	0.153938	0.070220569	17.55514215	45.6161249
2100	0.00077	0.6	0.38	50.7	6.3882	0.1319469	0.048254546	12.69856483	36.57118846
2100	0.00032	0.5	0.33	51.6	6.5016	0.1099557	0.020409823	6.184794764	18.56185242
2100	0	0.5	0.3	57.1	7.1946	0.1099557	0	0	0
2600	0.00173	1.2	0.68	72.4	9.1224	0.3267256	0.154818987	22.76749811	47.38501362
2600	0.00122	1	0.61	77.2	9.7272	0.2722714	0.116417075	19.0847664	42.75773758
2600	0.0008	0.9	0.54	78.4	9.8784	0.2450442	0.077525683	14.356608	31.63742487
2600	0.000415	0.8	0.49	79.4	10.0044	0.2178171	0.040729413	8.312125114	18.69890601
2600	0	0.7	0.445	87.8	11.0628	0.19059	0	0	0

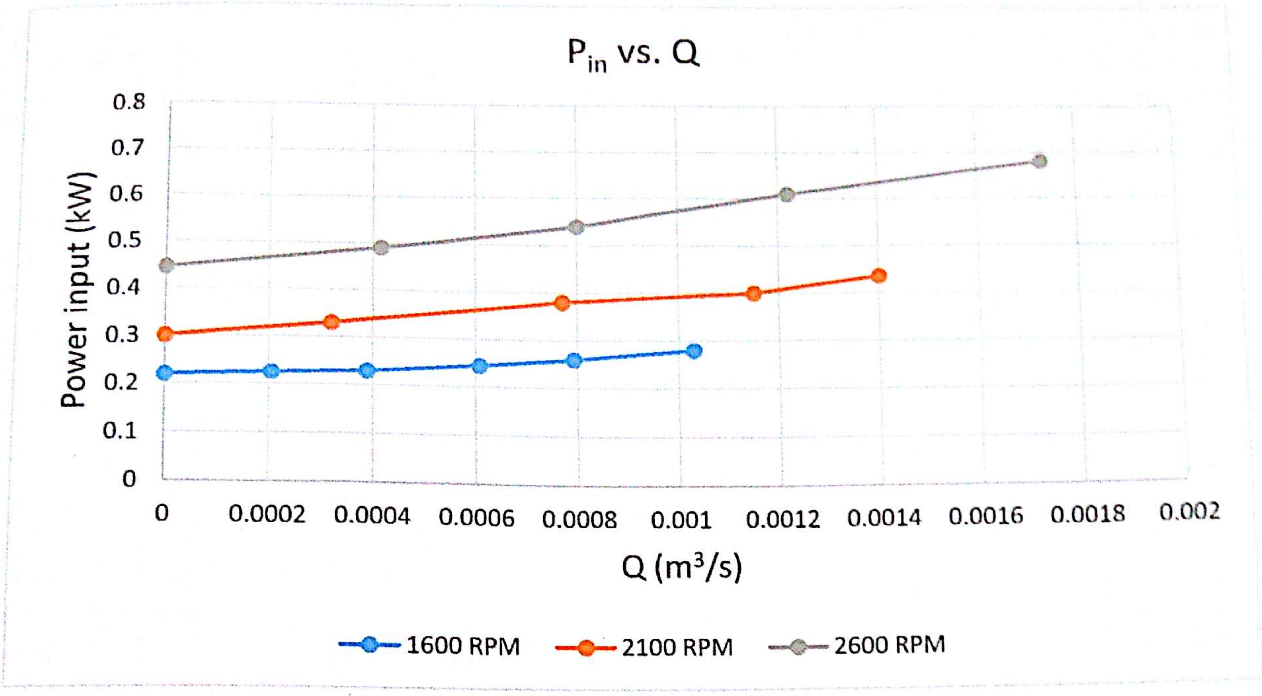
Observation Table



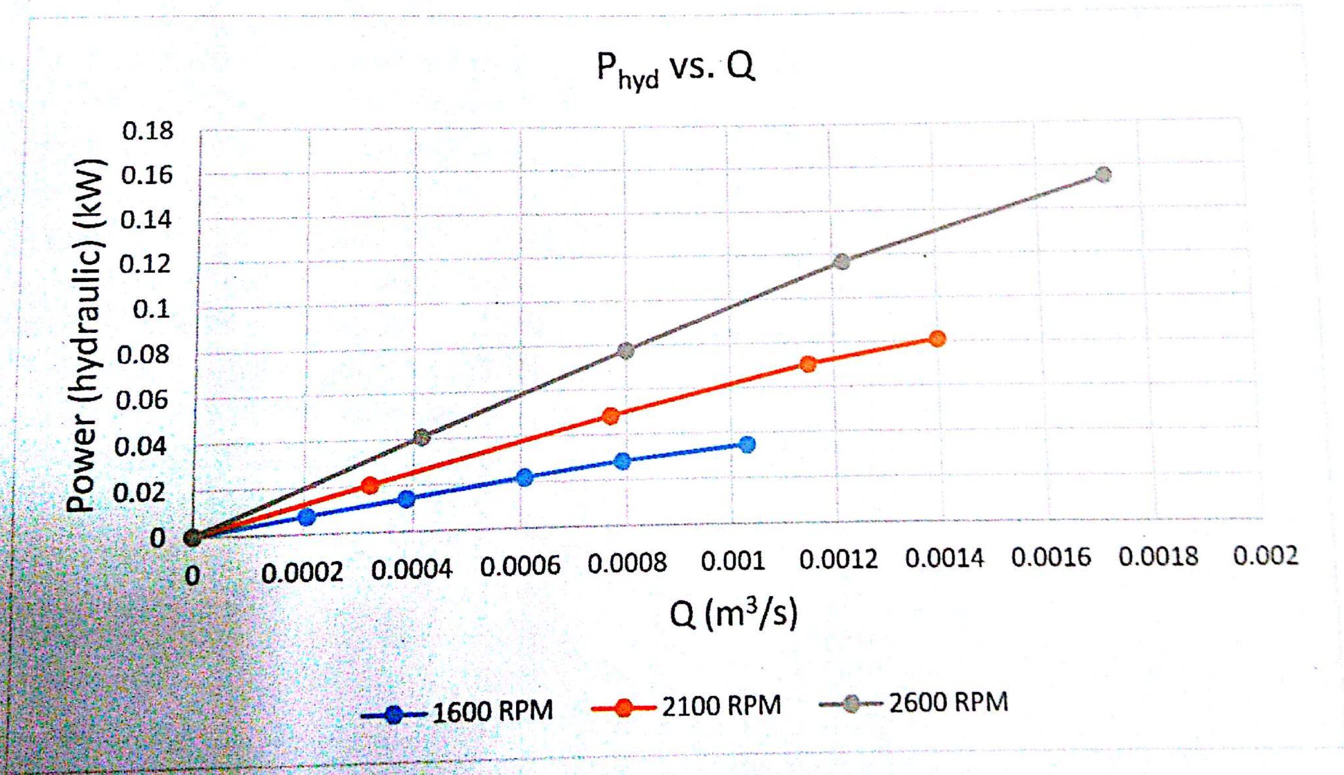
H vs. Q
Head (m)
12
10
8
6
4
2
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM



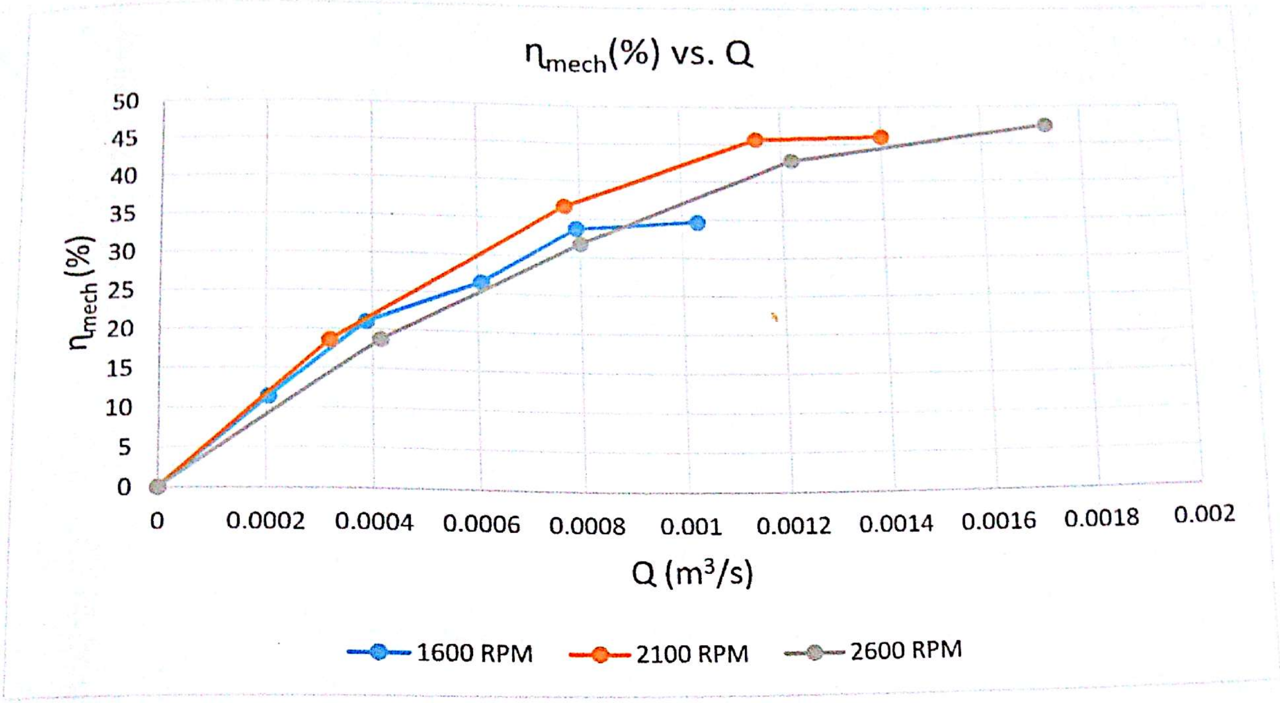
H* vs. Q*
H*
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
Q*
1600 RPM
2100 RPM
2600 RPM



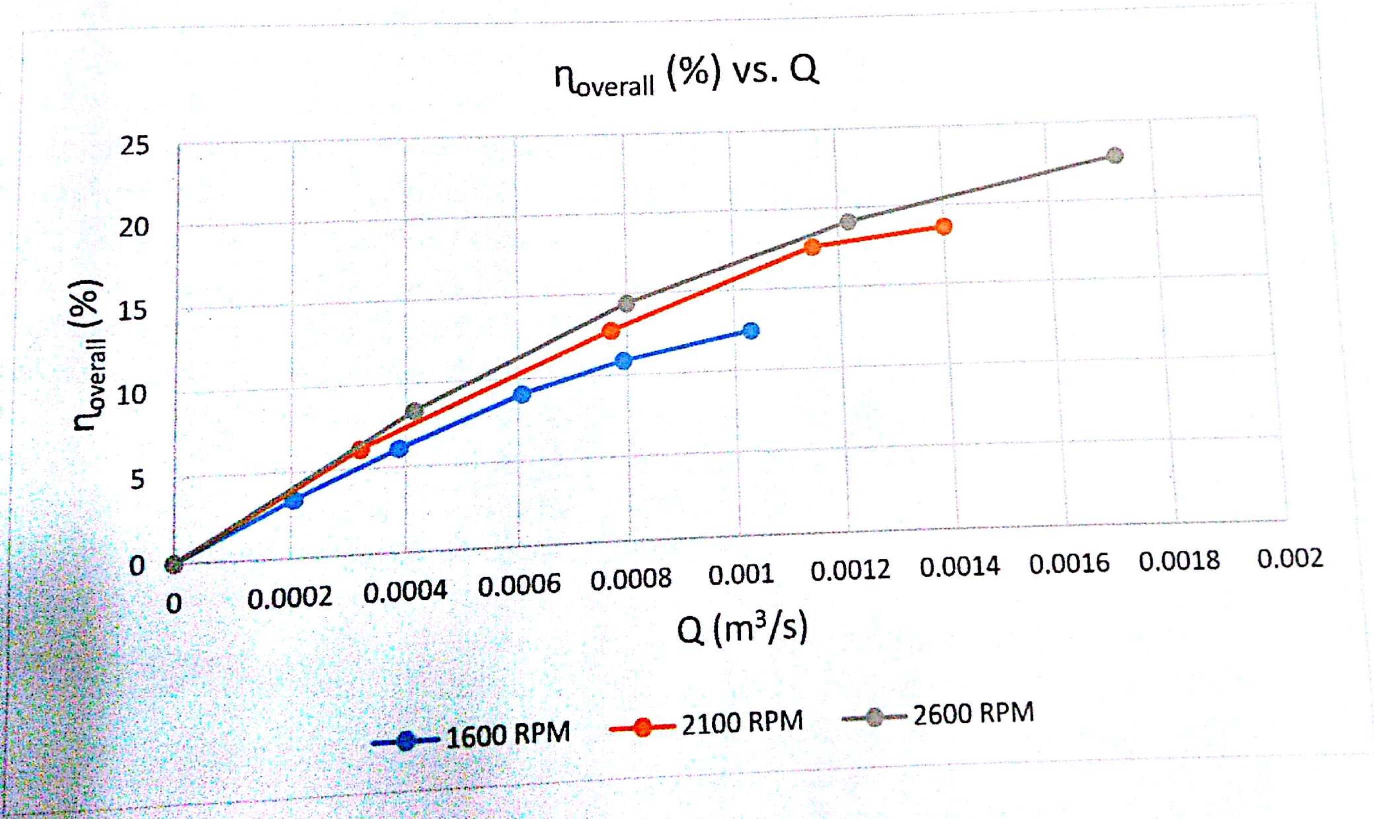
P_{in} vs. Q
Power input (kW)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM



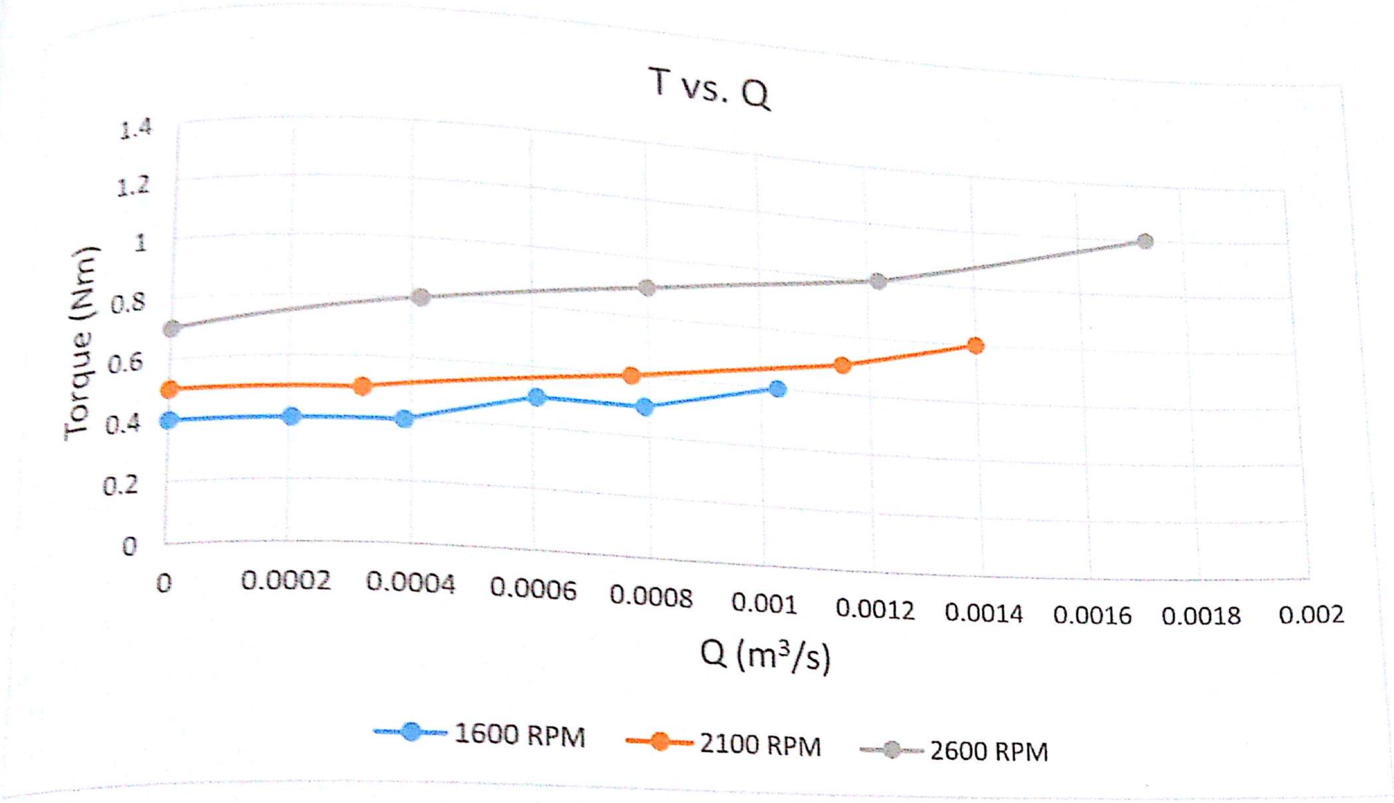
P_{hyd} vs. Q
Power (hydraulic) (kW)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM



η_{mech}(%) vs. Q
η_{mech} (%)
50
45
40
35
30
25
20
15
10
5
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM



$\eta_{overall}$ (%) vs. Q
$\eta_{overall}$ (%)
25
20
15
10
5
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM


T vs. Q
Torque (Nm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Q (m³/s)
1600 RPM
2100 RPM
2600 RPM

Discussions :-

From the graphs, we can see that the torque, hydraulic (overall) efficiency ($\eta_{overall}$) and mechanical efficiency (η_{mech}) increase as the flow rate (Q) increases.

Q. Why is the flow control valve placed after the meter towards the discharge tube ?

A. If the control valve is placed in the pump suction line, it will cause cavitation causing bubbles of vapour in the liquid which collapse after arriving at higher pressure region. This collapsing occurs at very high speed ejecting minute jets of high velocity ~~fluid~~ liquid. When these jets impinge on a solid surface, extreme erosion occurs. This can destroy even the hardest material. Hence, flow control valve is towards discharge tube and not in the suction line

Non-dimensional Analysis :-

Buckingham Pi Method

We have six basic parameters dealing with pump performance. $\rightarrow$ $P = f\{\rho, N, D, (g\Delta H), Q\}$

But we have 3 dimensions [M L T]. Therefore 3 dimensionless groups can be obtained.

$g\Delta H$ can be considered as one quantity for simplicity.

$D \rightarrow$ impeller diameter

$$\therefore \quad g\Delta H = \phi(\rho, N, D)$$
$$= \pi_1 \times \rho^a N^b D^c$$

$$M^0 L^2 T^{-2} = (ML^{-3})^a (T^{-1})^b (L^1)^c$$

$$\Rightarrow a = 0, \quad b = 2, \quad -3a + c = 2$$
$$\Rightarrow c = 2$$

$$\therefore \quad \pi_1 = \frac{g\Delta H}{N^2 D^2}$$

or $\pi_1 = \dfrac{gH}{N^2D^2} = H^*$ (Non-dimensional head)

Also,

$$Q = \phi(\rho, N, D)$$

$$= \pi_2 \, \rho^a N^b D^c$$

$$M^0 L^3 T^{-1} = (ML^{-3})^a (T^{-1})^b (L^1)^c$$

$\Rightarrow \quad a = 0 \qquad b = 1 \qquad -3a + c = 3$

$\Rightarrow c = 3.$

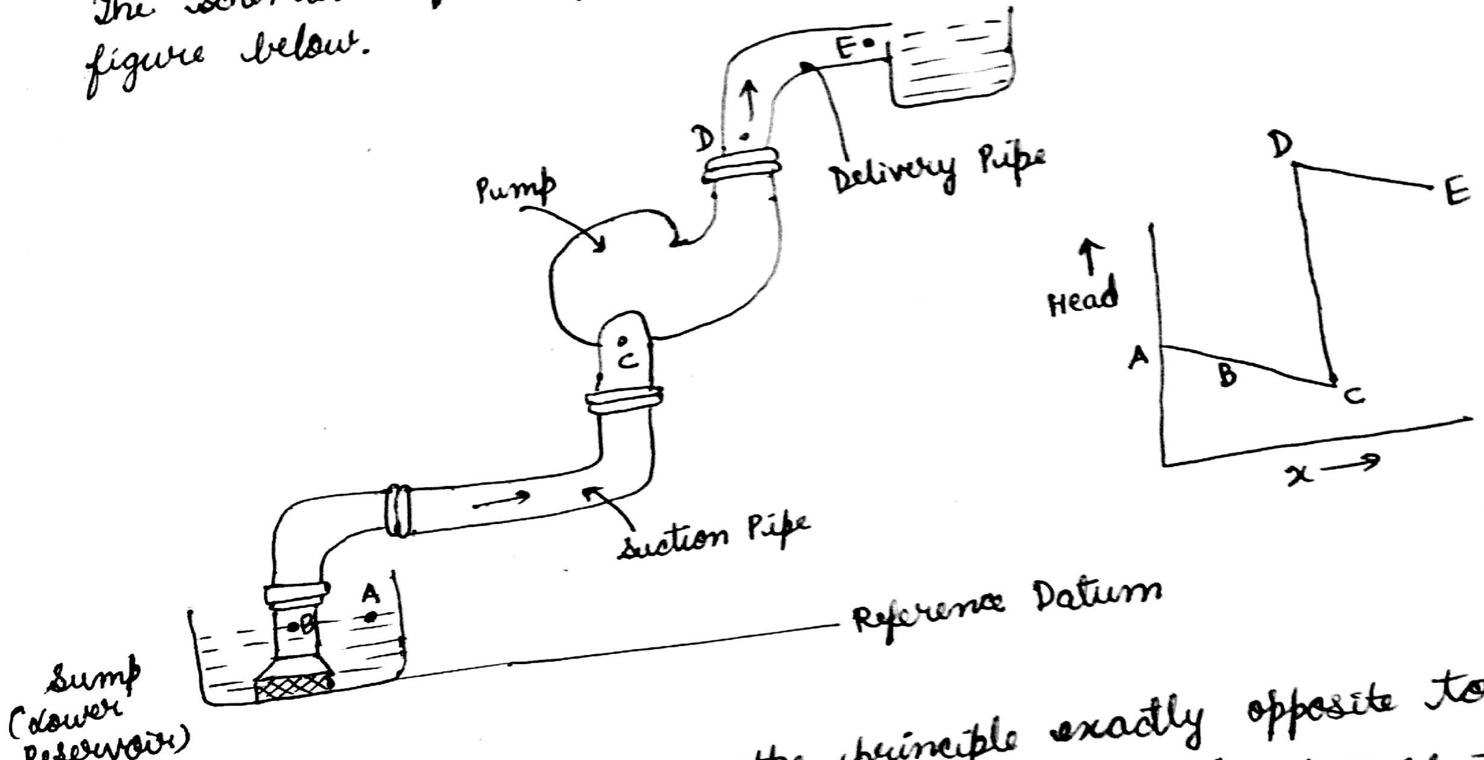
$\therefore \quad \pi_2 = \dfrac{Q}{ND^3} = Q^*$ (Non-dimensional flow rate)

$$\therefore \quad H^* = \frac{gH}{N^2 D^2}$$

$$Q^* = \frac{Q}{ND^3}$$

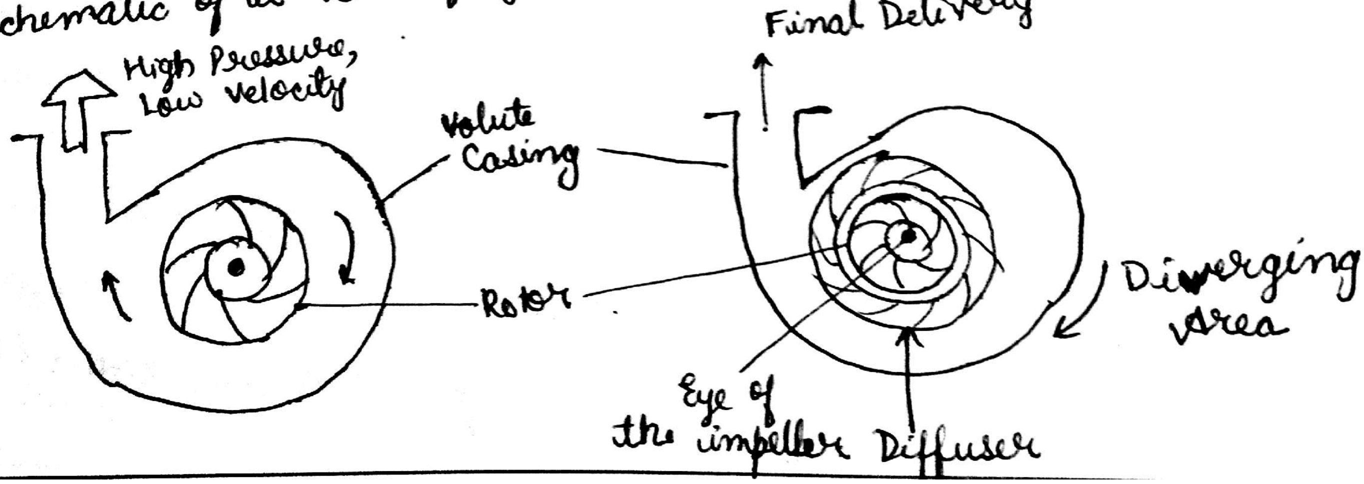
● Discussions

① A centrifugal pump is a type of Rotodynamic pump. The schematic of a typical rotodynamic pump is given in the figure below.



② A centrifugal pump works on the principle exactly opposite to that of Francis Turbine. Here, the inlet is axial whereas the outlet is radial and tangential.

③ The schematic of a centrifugal pump is shown below.



SHEET NO.

DATE

(4) Centrifugal pumps are generally classified into 3 categories

(a) Radial flow - a centrifugal pump in which the pressure is developed wholly by centrifugal force.

(B) Mixed flow - a centrifugal pump in which the pressure is developed partly by centrifugal force and partly by the lift of the vane of the impeller on liquid

(c) Axial flow - a pump in which pressure is developed by the propelling or lifting action of the vanes on the impeller of the liquid.

(5) A pump's vertical discharge "pressure-head" is the vertical lift in height at which pump can no longer exert enough pressure to move water. At this point, the pump may be said to have reached its "shut-off" head pressure. In the flow curve "shut-off" head pressure is the point on the graph where flow rate is zero.

(6) Vibration of the system has to be reduced as the life of the mechanical seal is directly related to shaft movement and vibrations can cause carbon face chipping and seal face opening.

(7) Pump efficiency is directly related to "the specific speed number" with efficiencies dropping dramatically below a number. Testing also shows that smaller capacity pumps exhibit lower efficiencies than higher capacity designs.

(8) Pump efficiency is also closely related to the shape of the impeller, and the choice of impeller shape is usually dictated

by the operating conditions.

9) Specific speed is a term used to describe the geometry (shape) of a pump impeller. People responsible for the selection of pump can use this specific speed to

a) Select the shape of the pump curve.
b) Determine the efficiency of the pump
c) Anticipate motor overloading problems.
d) Predict NSPH requirements.
e) Select the lowest cost of pump for the application.

- Flow control valve is placed after the meter to avoid CAVITATION effects. It is not placed in the suction line as it would cause immense cavitation which will destroy the material eventually.