Heaven's Light is Our Guide

Rajshahi University of Engineering and Technology

Course Code
ME 3220

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Basic Mechanical Engineering Sessional

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Lab Report 1: Performance Test of a Pelton Wheel

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Experiment No.: 01

Experiment Name: Performance test of a Pelton Wheel

Objectives:

i) To find performance characteristics at constant head i.e. to plot.

a) Unit discharge (Q_u) Vs unit Speed (N_u)

b) Efficiency (η) Vs Unit speed (N_u)

c) Unit Power (P_u) Vs unit Speed (N_u)

d) Efficiency (η) Vs speed ratio (ϕ)

ii) To compare these with the theoretical curve.

Introduction:

The pelton wheel is a hydraulic turbine used for high head ~~speed~~ hydroelectric applications, converting water energy into mechanical power. Invented by Lester Allan Pelton in the 1870s,. It is widely used in mountainous regions with fast-flowing water or high pressure dams. The turbine consists of specially shaped split buckets arranged around a wheel, allowing water to efficiently transfer energy.

Pelton wheels vary in size, with small units using houshold plumbing for water delivery. They operate best with heads from 15 to 1800 m & can achieve upto 88% efficiency.

Theory:

Parameters :

a) Head, $H = \Delta z + P/\gamma + \frac{V^2}{2g}$

Here, Δz = difference in height between the pressure gauge & nozzle.

P/γ = Pressure gauge reading

V = Velocity of water in pipe upstream of the nozzle

- Δz & $V^2/2g$ are very small compared to total head H & thus neglected. So Head, $H = P/\gamma$.

b) Power:

(i) flow rate, Q is measured by means of V-notch

$$Q = \frac{8}{15} \cdot C_d \sqrt{2g} \tan \theta/2 \, H_1^{5/2} = K H_1^{5/2}$$

H_1 is height of water surface over V-notch in m.

- (ii) Input hydraulic power,

$P_i = \gamma Q H$ watt $= g Q H$ kW where Q in m^3/sec; H in meters of water.

(iii) Output Power, $P_o = \frac{\pi D N W}{60}$ watt $= \frac{\pi D N W}{60 \times 1000}$ kW

where, D = Diameter of brake drum (m)

N = RPM of wheel

W = Net load at Brake drum (N)

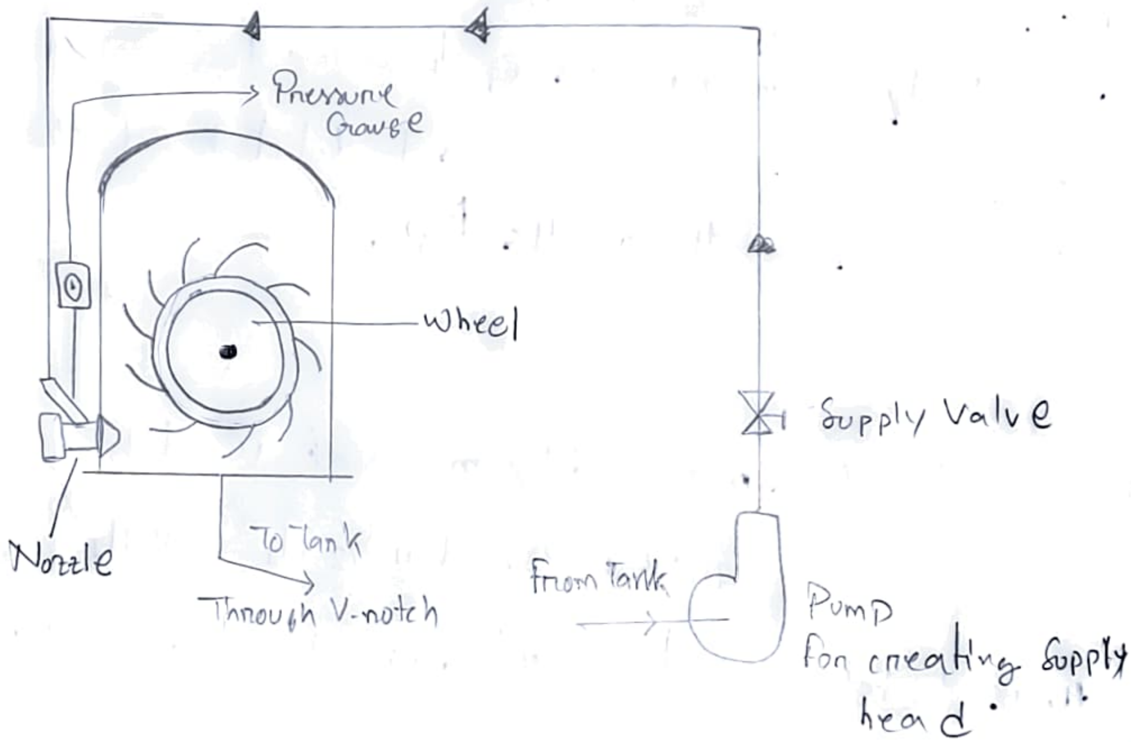

Fig 1: Pelton Wheeltest Setup

c) Overall Efficiency, $\eta = P_o / P_i$

d) Speed Ratio, $\phi = \dfrac{\text{Peripheral speed of wheel, } v}{\text{Velocity of water at nozzle tip, } V_o}$

Here, $v = \dfrac{\pi D_m N}{60}$; D_m = mean diameter of wheel.

$V_o = C_v\sqrt{2gH}$; C_v = coefficient of velocity $\cong 0.99$

e) Unit Parameters.

i) Unit speed, $N_u = \dfrac{N}{\sqrt{H}}$

ii) Unit discharge, $Q_u = \dfrac{Q}{\sqrt{H}}$

iii) Unit Power, $P_u = \dfrac{P_o}{H^{3/2}}$

Apparatus/Setup:

All the necessary equipment was pre-installed. The setup was used for this experiment.

Working Procedure:

~~i) Start the motor to pump water.~~

~~ii) Op~~

i) The motor was started to deliver water via the pump

ii) The supply valve was opened, & the spear was adjusted to the desired position.

iii) The brake was engaged with maximum possible tension.

iv) Speed, waterflow rate, gauge reading & brake drum' tensions were recorded.

v) Speed was increased by reducing the brake load while ensuring H remained constant by regulating the suppy valve.

vi) Step (iv) & (v) were repeated at least 5 times to record readings over a range of speeds.

vii) The spear position was adjusted, & steps (iv) to (vi) was Repeated, keeping H constant.

Data:

Wheel Diameter, D_m = 11.5 cm = 0.115 m

Brake drum diameter, D = 6 cm = 0.06 m

Angle of V-notch, $\theta = 60^\circ$

Co-efficient of discharge, $C_d = 0.86$

Co-efficient of velocity, $C_v = 0.99$

Speare Position (%)	Pressoury Gauge Reading H (m)	Scale Reading for Discharge, H_1 (cm)	Tachometer Reading, N (rpm)	Load for Braking Torque, (w_1-w_2), (N)
100	22	3.9	2250	0.7-0.2
	20	4.2	2000	1-0.3
	18	4.6	1840	1.3-0.4
	16	4.8	1620	1.6-0.5
75	21	4	2050	0.7-0.2
	19	4.5	1800	1-0.3
	17	4.7	1640	1.4-0.4
	15	5	1450	1.7-0.5
50	20	4.3	1880	0.6-0.2
	18	4.8	1680	0.9-0.3
	16	5	1480	1.2-0.4
	14	5.2	1260	1.5-0.5

Table 1: Recorded Values

Calculation:

For speare position at 100% & observation 1:

Flow rate, $Q = \frac{8}{15} \times C_d \sqrt{2g} . \tan\frac{\theta}{2} . H_1^{5/2}$

$= \frac{8}{15} \times 8.6 \sqrt{2 \times 9.8} . \tan 30° . (0.039)^{5/2}$

$= 3.521 \times 10^{-4}$ m³/s

Input hydraulic power, $P_i = \gamma Q H$

$$\cancel{= 1000 \times 9.81 \times 2.688 \times}$$

$$= 1000 \times 9.8 \times 3.521 \times 10^{-4} \times 22$$

$$= 75.91 \text{ W}$$

Output Power, $P_o = \frac{\pi D W N}{60}$

$$= \frac{\pi \times 0.06 \times (0.7 - 0.2) \times 10 \times 2250}{60}$$

$$= 35.343 \text{ W}$$

Overall Efficiency, $\eta = \frac{P_o}{P_i} = \frac{35.343}{75.91} = 46.56\%$

Speed ratio, $\varphi = \frac{v}{V_o}$

$$v = \frac{\pi D_m V}{60} = \frac{\pi \times 0.115 \times 2250}{60} = 13.55 \text{ m/s}$$

$$V_o = C_v \sqrt{2gH} = 0.99 \times \sqrt{2 \times 9.8 \times 22} = 20.56 \text{ m/s}$$

$$\therefore \varphi = \frac{v}{V_o} = \frac{13.55}{20.56} = 0.659$$

Unit speed, $N_u = \frac{N}{\sqrt{H}} = \frac{2250}{\sqrt{22}} = 479.7$

Unit discharge, $Q_u = \frac{Q}{\sqrt{H}} = \frac{3.521 \times 10^{-4}}{\sqrt{22}} = 7.51 \times 10^{-5}$

Unit Power, $P_u = \frac{P_o}{H^{3/2}} = \frac{35.343}{22^{3/2}} = 0.342$

Simillarry, Calculating for all the observations in table 1, the following data can be achieved.

Spear Position (%)	Pressure Gauge Reading H (m)	Flow Rate, Q, (m^3/s)	Input Hydraulic Power, P_i (W)	Output Power, P_o (W)	Overall Efficiency η, (%)	Wheel Perip. Speed v	Water Velocity v_o	Speed Ratio, ϕ	Unit Speed, N_u	Unit Discharge Q_u	Unit Power P_u
100	22	3.52×10^{-4}	75.97	35.34	46.52	13.55	20.57	0.66	479.70	7.50×10^{-5}	0.34
	20	4.24×10^{-4}	83.19	43.98	52.87	12.04	19.61	0.61	447.21	9.48×10^{-5}	0.49
	18	5.32×10^{-4}	93.94	52.02	55.38	11.08	18.60	0.60	433.69	1.25×10^{-4}	0.68
	16	5.91×10^{-4}	92.76	55.98	60.35	9.75	17.54	0.56	405.00	1.48×10^{-4}	0.87
75	21	3.75×10^{-4}	77.25	32.20	41.68	12.34	20.10	0.61	447.35	8.18×10^{-5}	0.33
	19	5.03×10^{-4}	93.75	39.58	42.22	10.84	19.11	0.57	412.95	1.15×10^{-4}	0.48
	17	5.61×10^{-4}	93.56	51.52	55.07	9.88	18.06	0.55	397.76	1.36×10^{-4}	0.74
	15	6.55×10^{-4}	96.38	54.66	56.72	8.73	16.96	0.51	374.39	1.69×10^{-4}	0.94
50	20	4.49×10^{-4}	88.09	23.62	26.82	11.32	19.61	0.58	420.38	1.00×10^{-4}	0.26
	18	5.91×10^{-4}	104.36	31.67	30.34	10.12	18.60	0.54	395.98	1.39×10^{-4}	0.41
	16	6.55×10^{-4}	102.81	37.20	36.18	8.91	17.54	0.51	370.00	1.64×10^{-4}	0.58
	14	7.22×10^{-4}	99.16	39.58	39.92	7.59	16.41	0.46	336.75	1.93×10^{-4}	0.76

Table 2: Calculated data from using table 1.

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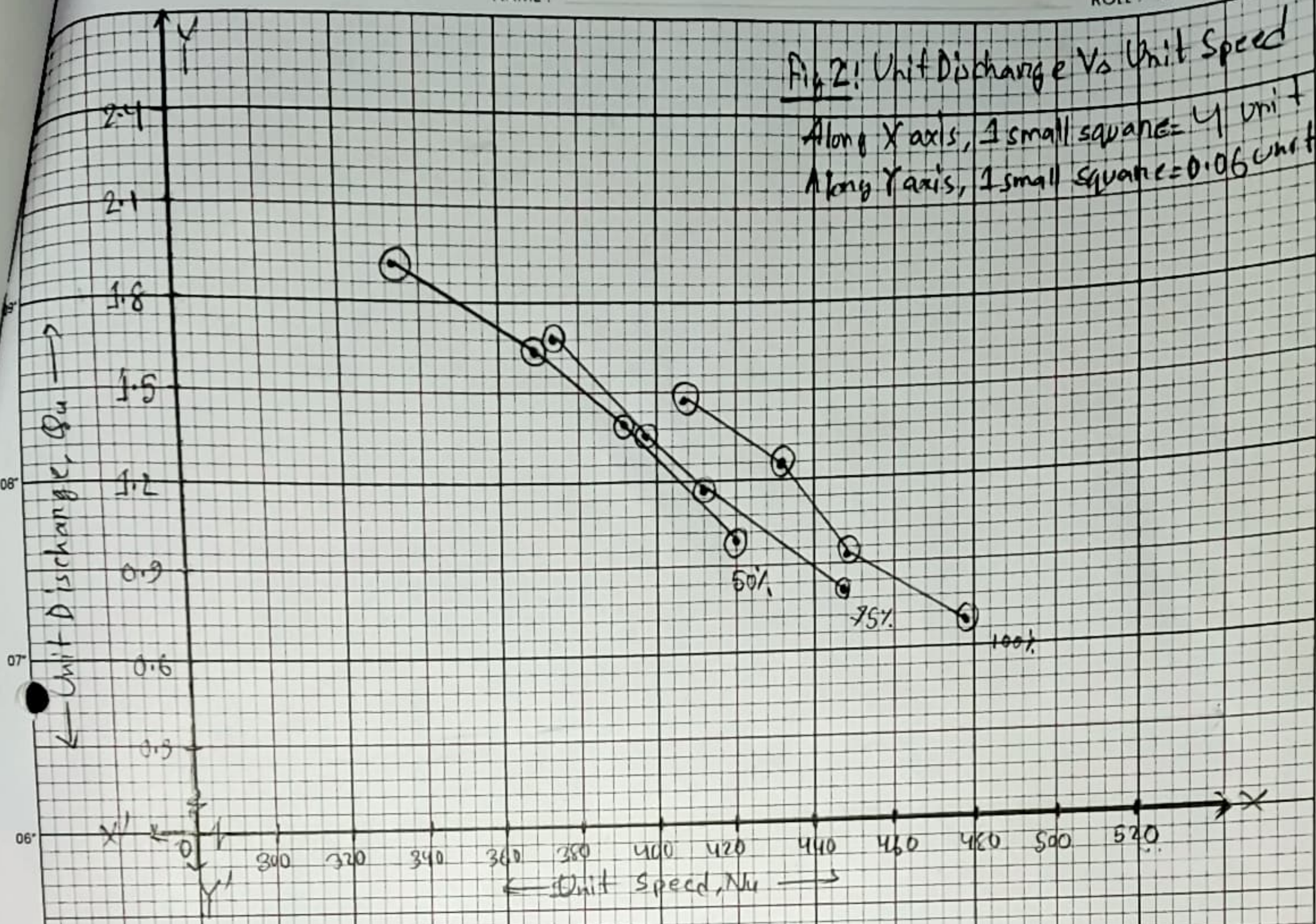

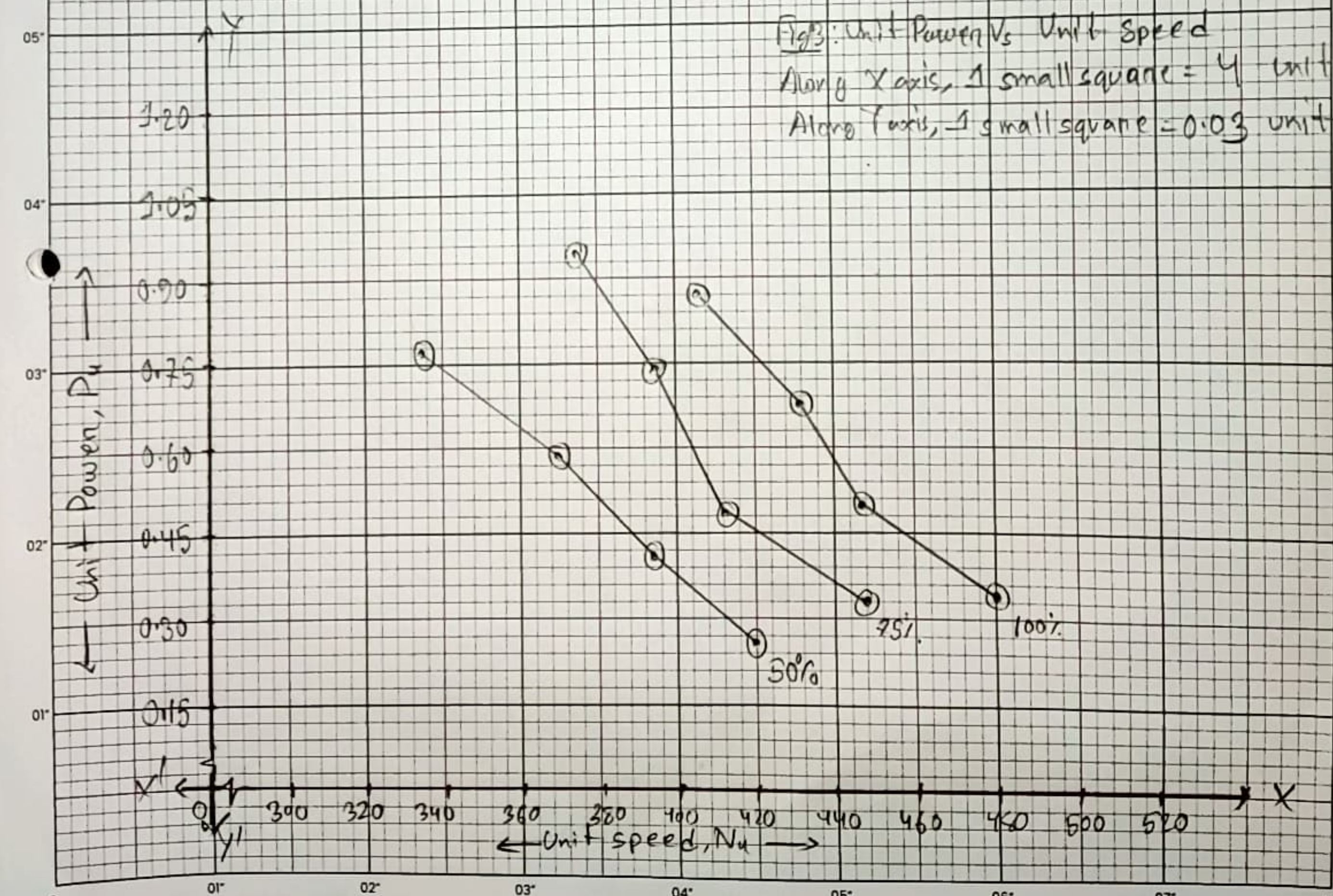

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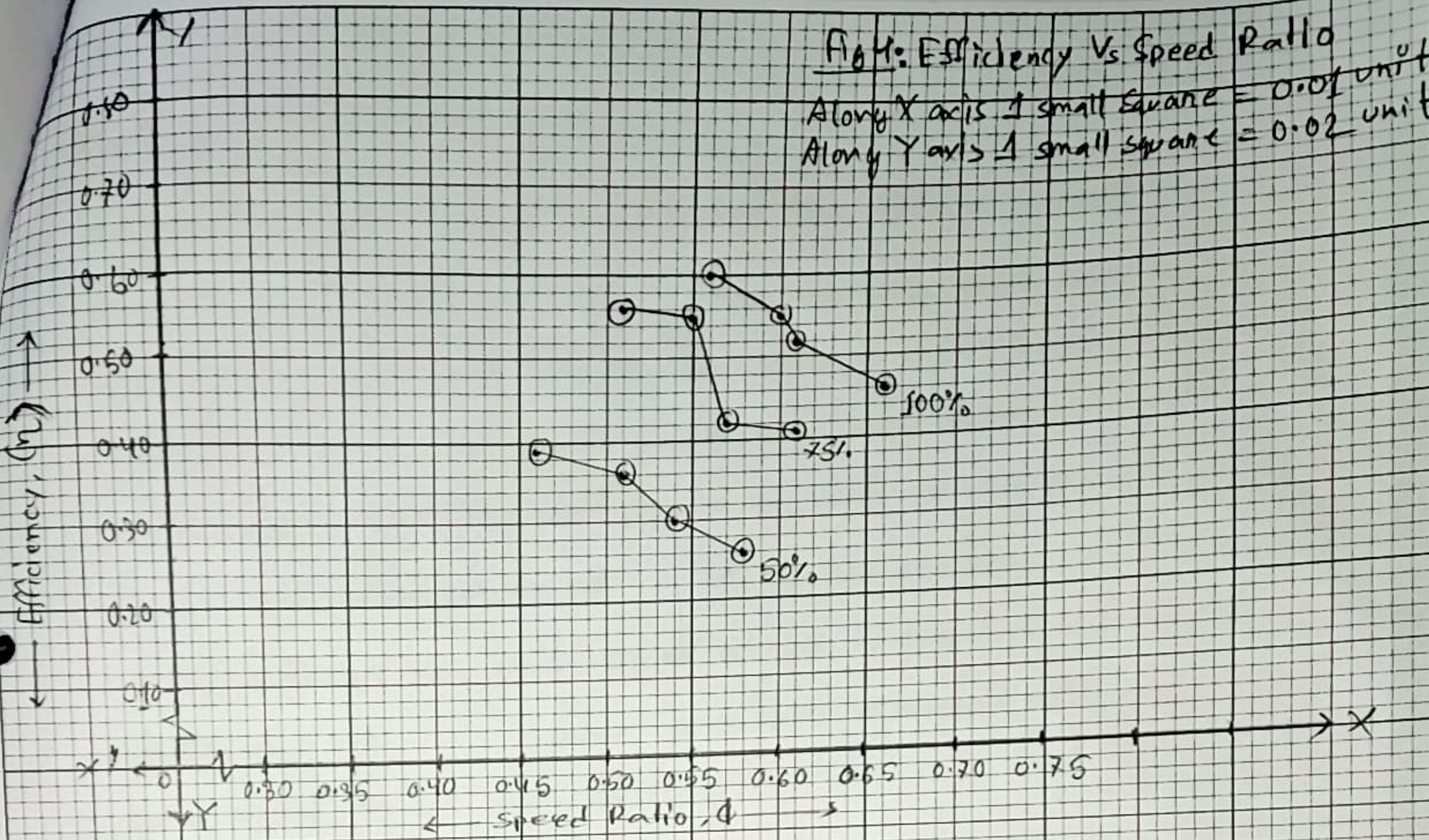

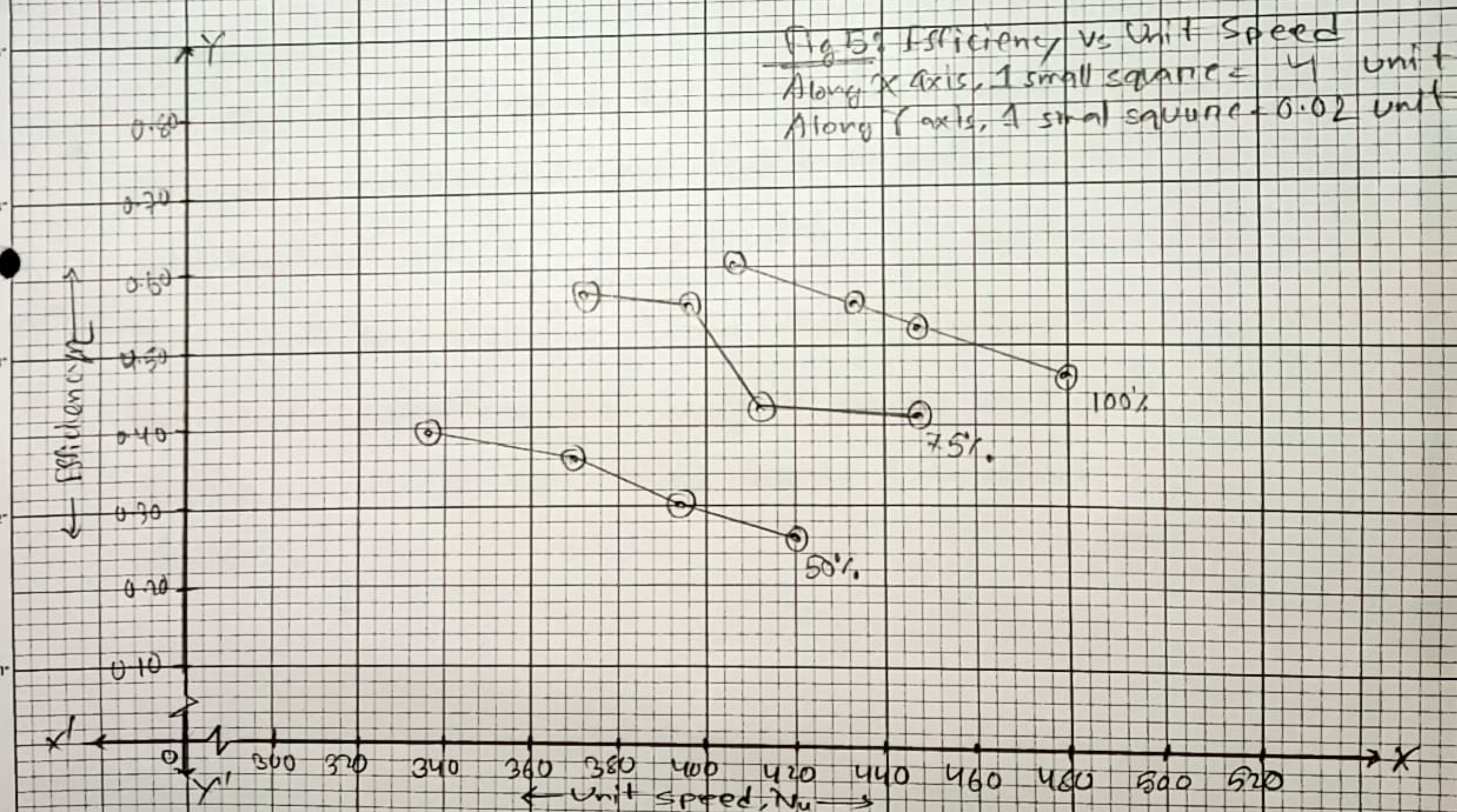

Discussion:

The performance characteristics of the Pelton wheel at constant head were evaluated under varying conditions of unit power, rotational speed, flow rate & water head. From the efficiency vs. unit speed graph, efficiency decreased with increasing speed. The unit power vs. unit speed graph showed maximum power at spear position, while unit discharge vs. unit speed graph indicated maximum discharge at spear position. Overall efficiency was found to be satisfactory.

Conclusion:

The experiment was conducted at constant head under different operating conditions. Maximum efficiency of was recorded at rpm with spear position. The results confirmed the Pelton wheel's suitability for high-head applications. Efficiency & power output could be improved by optimizing nozzle & turbine blade design.