FLUID FACILITIES AND MACHINERY

GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

PRACTICAL P3: PELTON TURBINE

1. EXPERIMENTAL PROCEDURE: PRACTICAL DEVELOPMENT

The procedure detailed below must be followed to perform the practical:

A. Switch on the discharge pump (switch - Figure 13). After switching on the pump, open the flow regulation valve (control valve - Figure 13).

B. Set the injector at two closure points by using the adjustment screw (Figure 14). The adjustment screw of the injector has a range of 5.5 turns from completely open to completely closed. WATCH OUT!: NEVER COMPLETELY CLOSE THE INJECTOR, IN ORDER TO AVOID SEIZURE OF THE CHOKE ON THE SEATING. Begin by setting the injector at completely open, which is a useful way to establish both measuring points:

Point 1: 3 turns
Point 2: 4 turns

C. Having set the closure level of the injector, adjust the main control valve on the hydraulic bench, for each position (Figure 13), so that the net head remains constant at $H_n = 6{,}0$ [m W.C.] (manometer measurement at the inlet of the injector).

D. Keep the net head constant at 6,0 [m W.C.] at each closure level of the injector, so that a constant flow rate is maintained (only applicable to an impulse turbine), $Q = Q\,(N) = \text{const}$. In this way, the relations for the mechanical torque, $C_m = C_m$ (N), the mechanical power, $P_m = P_m\,(N)$, and the efficiency, $\eta = \eta\,(N)$, will be defined in relation to the rotation speed, ***N***, of the turbine. Set different rotation speeds of the turbine for each closure level of the injector, by gradually tightening the upper lever (Figure 14) that will increase the resistance torque (friction of the drive belt).

E. Finally, maintain the injector opening in the position that corresponds to Point 2 (4 turns), and increase the net head up to 8,0 [m W.C.], by adjusting the flow regulation valve (Figure 13). With these new settings, experiment with different rotation speeds of the turbine, by changing the resistance torque, as described in the previous section. The measurement methods of each of the aforementioned physical variables are detailed below:

I. Flow rate

The flow rate is calculated as the quotient of water volume discharged over time of discharge. The volumetric scale (Figure 13) measures the volume of water that has been introduced into the volumetric measurement tank. It is recommended that the time (in seconds) needed to fill one particular volume (between 2 graduations on one scale) in the volumetric scale is measured, so that the measured time is longer than 30 [s] for each flow measurement. To do so, the ball valve of the bottom of the tank must be closed (Figure 15). After each measurement, the ball cock must be reopened.

Figure 15. *Drainage ball valve.*

II. Net head

The net head **(H_n)** in [m W.C.] can be directly read from the manometer (Figure 14).

III. Hydraulic power

Hydraulic power is a measurement of the energy provided to the turbine per unit of time. It basically depends both on the flow rate entering the turbine and on the net head: $P_h = \rho \cdot g \cdot Q \cdot H_n$

IV. Mechanical torque

The mechanical torque transmitted by the runner to the disc may be calculated by measuring the tangential force applied to the disc multiplied by the radius of the disc (**r = 0,03 [m]**). The tangential force is calculated as the difference between the readings in [N] of Dynamometer 2, D2, and Dynamometer 1, D1, (Figure 14). It follows that the resistance torque applied to the disc can be easily calculated:

$$C_r = (F_{D2} - F_{D1}) \cdot r$$

At the corresponding rotation speed, C_r will be equal to the mechanical torque, C_m, transmitted by the runner to the disc: $C_r = C_m$.

V. Rotation speed

Directly measured by means of a digital tachometer that provides direct measurements of the angular velocity, N, in [r.p.m.].

VI. Mechanical power

If the rotation speed of the runner-disc assembly in [r.p.m.] is N, then the mechanical power **(P_m)** can be easily calculated: $P_m = C_m \cdot 2 \cdot \pi\, N / 60$

VII. Efficiency of the turbine

Turbine efficiency may be calculated as the quotient of the Hydraulic Power **(P_h)** provided to the turbine over the Mechanical Power **(P_m)** transmitted to the runner:

$$\eta_{turbine} = P_m \cdot P_h^{-1}$$

F. Measure 10 combinations of $\boldsymbol{N}$, $\boldsymbol{F_{D2}}$, and $\boldsymbol{F_{D1}}$ at each of the two previous closure levels of the injector, in reference to Table 3. The extreme points must be defined: the maximum torque at null rotation speed (by applying the exact force needed to stop any turbine shaft rotation) and the maximum rotation speed (known as the runaway speed, N_{emb}) that is obtained without any braking friction. Moreover, some measurements should be concentrated close to the average rotation speed within the range $N_{emb}/2$, so that the maximum power and the efficiency values can be correctly defined. The experimental measurements should be presented in a similar way to Table 3 that appears below.

Table 3: *Experimental measurement data*

P3 Pelton turbine	Volume	Time	*X*	*N*	F_{D2}	F_{D1}
	[L]	[s]	turns	[r.p.m.]	[N]	[N]
measurement #1	Q_1		X_1	N_i =	F_{D2i} =	F_{D1i} =
				N_i =	F_{D2i} =	F_{D1i} =
				N_i =	F_{D2i} =	F_{D1i} =

2. RESULTS

Based on the experimental data, the following variables must be calculated for each measurement: the flow rate, Q [m³/s]; the hydraulic power, P_h [W]; the torque, C_m [N·m]; the mechanical power, P_m [W]; and, the efficiency, η [%]. A table of results containing all these data must be incorporated in the working file or Excel sheet. This table has to show the experimental data upon which the experimental results are based. Using the data in that table, the following charts must be drawn up:

- **Chart 1:** In a single chart, represent the torque for each injector position as a function of the rotation speed when the net head is H_n = 6,0 [m W.C.].
- **Chart 2:** In a single chart, represent the curve of hydraulic and mechanical power for each position of the injector as a function of the rotation speed when the net head is H_n = 6,0 [m W.C.].

- **Chart 3:** In a single chart, represent the curve of efficiency for each position of the injector as a function of the rotation speed where the net head is H_n = 60 [m W.C.].
- **Chart 4:** In a single chart, with the injector opening set at "Point 2", represent both the hydraulic and the mechanical power curves for two net head settings at H_n = 6,0 [m W.C.] and at H_n = 8,0 [m W.C.], as a function of the rotation speed.

All curves must be fitted to the corresponding polynomial degree, the regression must be clearly shown, and the corresponding equation must also be displayed. All graphs must have a title and each axis must be labelled with the corresponding units. These graphs must be presented in the report and the traceability of the information in each graph back to a primary source must be ensured.

3. CONCLUSIONS

In the Excel file, the students must explain the progression and the tendencies of their results and must detect the relevant parameters for the design and the selection of a turbine, so that it will operate at maximum efficiency.

4. EXPERIMENTAL DATA

Pelton turbine	H_n [m W.C.]	V [l]	t [s]	x [turns]	N [r.p.m.]	Fd_2 [N]	Fd_1 [N]
Measurement 1	5	20	40,3	2	1450	0	0
					1180	4,5	1
					1045	6,5	1,25
					874	8,5	1,5
					770	9,75	1,5
					690	10,5	1,6
					610	11	1,85
					443	12,3	2
					143	13,7	2,2
					0	13,5	2,75
Measurement 2	5	15	33,9	3	1450	0	0
					1253	2,5	0,1
					1105	4,2	0,5
					991	5,5	0,6
					849	6,6	1
					733	7,5	1
					634	8,2	1,07
					385	9,8	1,18
					245	10,5	1,3
					0	10,6	1,75
Measurement 3	5	15	48,7	4	1395	0	0
					1125	2,3	0,3
					1084	2,75	0,5
					888	4	0,5
					819	4,5	0,6
					778	4,9	0,6
					710	5,3	0,7
					462	6,3	0,85
					280	7	1
					0	7	1,2
Measurement 4	10	15	33,8	4	1995	0	0
					1750	3	0,5
					1588	5,3	0,8
					1333	7,5	1,1
					1070	9,5	1,4
					950	10,9	1,6
					738	12	1,8
					430	13,8	2
					129	15,4	2,3
					0	16,5	4,2