FLUID FACILITIES AND MACHINERY

GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

5. PRACTICAL P5: KAPLAN TURBINE

1. EXPERIMENTAL PROCEDURE: PRACTICAL DEVELOPMENT

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

A. Activate the pumps as specified in the Figure 21 and gradually open the valve until it is fully open. As a reference, the value of the average flow rate measured by the electronic gauge must exceed 310 [L/min], regardless of the runner that is installed.

B. Take measurements with two types of runners. At first, the runner that is already installed will be used and then, once the required experimental points have been measured, the data-collection procedure will be repeated with another type of runner chosen by the teacher.

C. Working with one particular runner, successively set the turbine in operation at 8 different rotation speeds, by gradually tightening the upper lever (Figure 22) that adjusts the resistance torque (applying higher friction to the belt). In this way, the mechanical torque, $C_m = C_m(N)$, the mechanical power, $P_m = P_m(N)$, and the efficiency $\eta = \eta(N)$ values will change, in relation to the rotation speed, N, of the turbine. These parameters will therefore be influenced, each time the rotation speed, the pressure and/or the flow rate change. The measurement methods for each of the above-mentioned physical variables are described below.

I. Net head

The net head **(H_n)** in [m W.C.] is calculated by measuring the pressure at the inlet, in [m W.C.], and the elevation difference between the level at the inlet and outlet of the turbine, that corresponds to 0,72 [m].

II. Hydraulic power

The hydraulic power is the energy provided to the turbine per unit time. It basically depends on the flow rate that enters the turbine and on the net head: $P_h = \rho \cdot g \cdot Q \cdot H_n$.

III. **Mechanical torque**

The mechanical torque transmitted by the runner to the disc is 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, D_2, and Dynamometer 1, D_1, (Figure 14). The resistance torque applied to the disc can then be easily calculated with the following expression:

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

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

IV. **Rotation speed**

The rotation speed may be directly measured with a digital tachometer that provides direct measurements of the angular velocity, ***N***, in [r.p.m.].

V. **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: $P_m = C_m \cdot 2 \cdot \pi \, N / 60$.

VI. **Efficiency of the turbine**

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

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

D. Each runner that is selected will be tested with 8 combinations of rotation speed (*N* in [r.p.m.]) and force ($F_{D2} - F_{D1}$, in [g]) and, for each combination, the inlet flow rate and the pressure at the inlet must be measured, as shown in Table 5. 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. Present the experimental measurements in a similar way to Table 5 below.

Table 5: *Experimental measurement data.*

P5 - Kaplan turbine					
Type of runner	**Flow rate [L/min]**	**p_{in} [mm W.C.] or [mbar]**	**N [r.p.m.]**	**F_{D2} [g]**	**F_{D1} [g]**
runner X			**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: flow rate, Q [m^3/s]; hydraulic power, P_h [W]; torque, C_m [N·m]; mechanical power, P_m [W]; and, 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:** variation of the efficiency, the mechanical power, and the torque as a function of the rotation speed working with the first runner.
- **Chart 2:** variation of the efficiency, the mechanical power and the torque as a function of the rotation speed working with the second runner.

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, 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

	MAXIMUM
Fixed Head [mm] =	965
Deposit Level [mm] =	265
Axis distance [m] =	0,03
Q [L/min]	310,0
Q [m^3/s]	0,00517
P_h (p·g·Q·H) [w]	35,4795

Measurement Nº	***N* [rpm]**	**F_1 [g]**	**F_2 [g]**	**P_{in} [mm H_2O]**
1	1700	0	0	0,0
2	1500	200	90	0,0
3	1300	370	140	0,0
4	1100	560	180	0,0
5	900	750	240	80,0
6	700	900	290	140,0
7	500	1090	330	200,0
8	290	1250	370	278,0

	AVERAGE
Fixed Head [mm] =	965
Deposit Level [mm] =	265
Axis distance [m] =	0,03
Q [L/min]	330,0
Q [m^3/s]	0,00550
P_h (ρ·g·Q·H) [w]	37,7685

Measurement Nº	*N* [rpm]	F_1 [g]	F_2 [g]	P_{in} [mm H_2O]
1	2150	0	0	0,0
2	1870	170	90	0,0
3	1550	450	160	135,0
4	1250	700	230	150,0
5	1050	880	290	165,0
6	750	1090	350	170,0
7	550	1230	370	175,0
8	300	1370	420	180,0

	MINIMUN
Fixed Head [mm] =	965
Deposit Level [mm] =	265
Axis distance [m] =	0,03
Q [L/min]	335,0
Q [m^3/s]	0,00558
P_h (ρ·g·Q·H) [w]	99,795495

Measurement Nº	*N* [rpm]	F_1 [g]	F_2 [g]	P_{in} [mm H_2O]
1	3620	0	0	110,0
2	3310	290	100	125,0
3	3030	540	180	135,0
4	2710	790	250	150,0
5	2415	1010	320	165,0
6	2095	1150	360	170,0
7	1750	1340	420	175,0
8	1450	1510	470	180,0