FLUID FACILITIES AND MACHINERY

GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

PRACTICAL P6: PROPELLER 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 27 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 should be about 190 [L/min], the guide vanes should be fully opened at 100 [%], and the pressure at the inlet of the turbine should be 14 [m W.C.].

B. Take measurements at three successive opening levels of the wicket gates of the turbine: 100 [%], 75 [%] and 50 [%]. The turbine must be working at a constant head of 14 [m W.C.] for each opening level.

C. Set the wicket gates at a particular opening level that will regulate the flow rate, in order to reach a desired pressure of 14 [m W.C.] at the inlet of the turbine. Then, set 8 successive turbine rotation speeds, by changing the resistance torque (applying higher friction to the belt), gradually tightening the upper nut (Figure 28). 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 of time. It basically depends on the flow rate that enters the turbine and on the net head: $P_h = \boldsymbol{\rho} \cdot g \cdot Q \cdot H_n$.

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:

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

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

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 $\boldsymbol{N}$, then the mechanical power **(P_m)** can be easily calculated: $\boldsymbol{P_m = C_m \cdot 2 \cdot \pi\, N / 60}$.

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:

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

D. Set three opening levels of the wicket gates (100 [%], 75 [%] and 50 [%]), and 8 combinations of rotation speed (N in [r.p.m.]) and force ($F_{D2} - F_{D1}$, in [g]) and, for each combination, measure the inlet flow rate and the pressure at the inlet. Present the results in a similar way to Table 6. 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 efficiency values can be correctly defined. The experimental measurements should be presented in a similar way to Table 6 below.

Table6: *Experimental data of the measurement.*

P6 – Propeller turbine						
Position of the wicket gates	**Flow rate [L/min]**	**p_{in} [m W.C.]**	**p_{out} [m W.C.]**	**N [r.p.m.]**	**F_{D2} [g]**	**F_{D1} [g]**
Opening [%]				N_i =	F_{D2i} =	F_{D1i} =
				N_i =	F_{D2i} =	F_{D1i} =
				N_i =	F_{D2i} =	F_{D1}=

2. RESULTS

Based on the experimental data, the following variables must be calculated for each measurement: the flow rate, Q [m^3/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 on which the experimental results are based. Using the data in that table, the following charts must be drawn up:

- **Chart 1:** variation of the hydraulic power with the rotation speed for each of the three wicket-gate positions.
- **Chart 2:** variation of the torque with the rotation speed for each one of the three wicket-gate positions.
- **Chart 3:** variation of the mechanical power with the rotation speed for each of the three wicket-gate positions.
- **Chart 4:** variation of the efficiency with the rotation speed for each of the three wicket-gate positions.
- **Chart 5:** variation of the pressure at the runner outlet as a function of the rotation speed of the turbine.

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

% Opening = 100%

Pressure [m W.C.]	14
Q [L/min]	192
Q [m^3/s]	0,0032
Axis distance [m] =	0,03
H suction pipe [m] =	0,725

Measurement Nº	N [rpm]	F_1 [g]	F_2 [g]	P_{in} [m W.C.]	P_{out} [m W.C. or cm Hg]
1	4930	0	0	14,0	2,1
2	4380	400	125	14,0	2,0
3	3900	700	200	14,0	1,8
4	3350	1000	325	14,0	1,5
5	2950	1300	450	14,0	1,2
6	2650	1600	600	14,0	1,0
7	1900	1900	650	14,0	0,6
8	1250	2200	725	14,0	0,2
9	550	2500	800	14,0	0,1
10	0	2875	1125	14,0	-2,0

% Opening = 75%

Pressure [m W.C.]	14
Q [L/min]	133
Q [m^3/s]	0,0022
Axis distance [m] =	0,03
H suction pipe [m] =	0,725

Measurement Nº	*N* [rpm]	F_1 [g]	F_2 [g]	P_{in} [m W.C.]	P_{out} [m W.C. or cm Hg]
1	3900	0	0	14,0	1,2
2	3800	300	0	14,0	1,1
3	3400	550	100	14,0	1,0
4	3100	700	175	14,0	0,9
5	2750	900	250	14,0	0,8
6	2450	1100	325	14,0	0,6
7	2100	1300	400	14,0	0,3
8	1500	1500	450	14,0	0,1
9	1050	1700	525	14,0	0,0
10	0	1900	675	14,0	-1,0

% Opening = 50%

Pressure [m W.C.]	14,0
Q [L/min]	111,0
Q [m³/s]	0,00185
Axis distance [m] =	0,03
H suction pipe [m] =	0,725

Measurement Nº	*N* [rpm]	F_1 [g]	F_2 [g]	P_{in} [m W.C.]	P_{out} [m W.C. or cm Hg]
1	3500	0	0	14,0	0,8
2	3200	400	0	14,0	0,7
3	2900	500	50	14,0	0,6
4	2750	600	100	14,0	0,5
5	2580	700	150	14,0	0,4
6	2400	800	175	14,0	0,3
7	2050	1000	250	14,0	0,2
8	1620	1200	350	14,0	0,1
9	1350	1300	375	14,0	0,0
10	1150	1400	400	14,0	-1,0