FLUID FACILITIES AND MACHINERY

GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

THEME 5: KAPLAN TURBINE

1. REQUIRED BACKGROUND

Fluid Mechanics.

Hydraulic Machinery. Turbomachinery. Turbines.

2. PRE-LABORATORY

Detailed reading of the description of the practical for its completion within 1 [h]. See Video of P5.

3. OBJECTIVES

To calculate and to demonstrate the operation of a Kaplan reaction turbine:

- Visual analysis of the operation of the Kaplan reaction turbine.
- Experimental determination of the efficiency curves of the turbine for every available runner.
- Reading to gain an understanding of the parameters to take into account when selecting, designing, and optimizing the operation of a Kaplan reaction turbine.

4. THEORETICAL FOUNDATION

The Kaplan turbine is a reaction turbine. In the same way as with the Francis turbine, the following basic components define this turbine: i) the wicket gates (system composed of a crown of hydrodynamically shaped vanes that guides the water and regulates the flow rate, although these vanes are not adjustable; ii) the runner coupled to the turbine shaft that causes rotary movement as the water passes over the blades; and, iii) a draft tube at the outlet of the runner, to optimize the efficiency of the turbine.

The wicket gates are of a larger diameter than the runner, so that the movement of the water is centripetal in relation to the shaft. The Kaplan turbine of the Fluid Mechanics laboratory also has a flow rectifier located after the runner, in order to transform the rotational movement of the streamlines into linear paths, which minimizes energy loss due to turbulence. The end of this turbine is defined by the draft tube that flows into the water tank from which the turbine itself is supplied. The difference in elevation between the inlet of the turbine (crown of vanes) and its outlet (draft tube) is 0,72 [m].

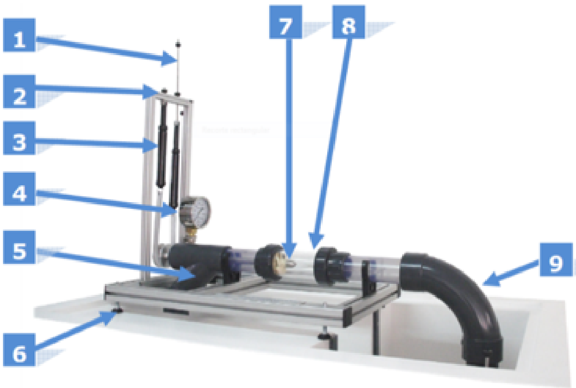
The different points of operation of a Kaplan turbine working at different rotation speeds can be experimentally obtained. Then, these points can be fitted to a curve by using a least squares method or similar.

These are the characteristic parameters that define the operation of a single turbine:

- Flow rate (Q)
- Net head (H_n)
- Hydraulic power (P_h)
- Mechanical torque (C_m)
- Mechanical power (P_m)
- Efficiency (η)

5. DESCRIPTION OF EQUIPMENT AND FACILITY

The Fluid Mechanics laboratory is equipped with a Kaplan turbine mounted on a multifunctional Armfield hydraulic bench (Figure 20).



1. Braking rod
2. Knurling nut
3. Dynamometer
4. Manometer
5. Water inflow tube
6. Adjustable feet
7. Runner
8. Casing
9. Water outflow

Figure 20: *Main components of the Kaplan turbine.*

Water is pumped from a tank in the lower part of the hydraulic bench by two pumps connected in parallel to the Kaplan turbine. The discharge flow can be regulated by means of a flow regulation valve and can be determined by a direct reading from an electronic gauge located at the inflow pipe of the turbine (in [L/min]). Once the water enters the turbine, its pressure can be measured by either a Bourdon type manometer at the inlet of the turbine or by a water column, when the pressure at the inlet is low. Once the water exits the draft tube, it returns to the tank of the hydraulic bench in a closed circuit. The main components of the turbine are shown in Figure 20.

Before starting to work with the turbine, it is necessary to check the adjustable feet of the apparatus so that the structure is level (Figure 21).

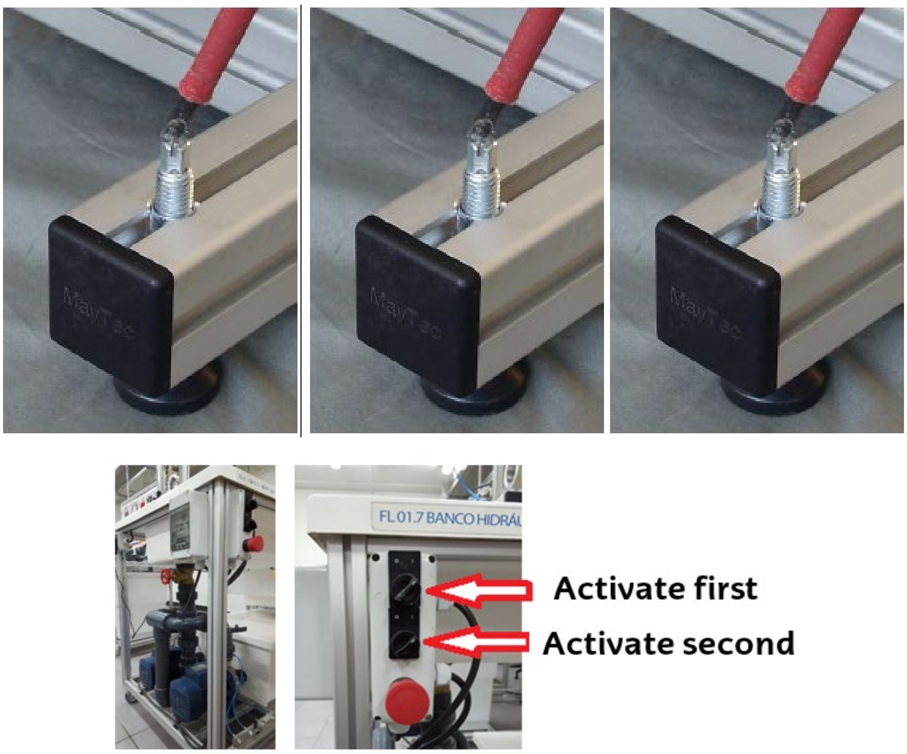


Figure 21: *Levelling system of the turbine and switches for the pumps activation*.

The hydraulic bench has two pumps and it is very important that they are properly activated in the right order (Figure 21); the upper switch must be activated first of all (no effect will be apparent until the lower switch is activated) and then, the lower switch (which activates the whole system). Once the pumps of the hydraulic bench are functioning, the regulation valve should be gradually opened, and the turbine will start rotating.

By using the friction brake, the load of the turbine can be regulated and it can even be completely stopped. Calculation of the applied torque when doing so can be done by reading the dynamometer measurement of applied force. The hydraulic brakes of the dynamometer should be loosened to perform this task properly until they reach a value of zero, <u>when the turbine is not in operation</u> (the knurled nut of each dynamometer is used to make this adjustment). Once in operation, tightening the upper knurled nuts will brake the turbine until the desired rotation speed is reached. At that point, the force that is applied will equal the difference between the readings of the two dynamometers.

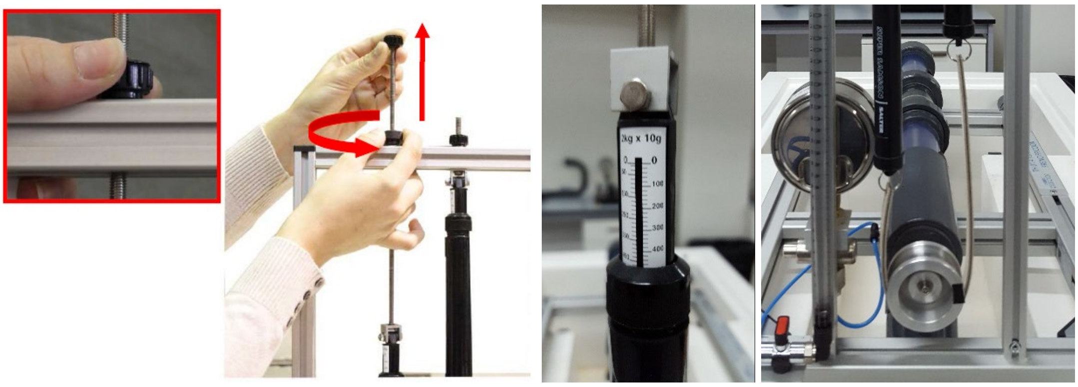


Figure 22: *A: Dynamometer and detail of the knurled nut. B: Detail of the measurement of the dynamometer. C: Turbine brake*.

The pressure measurement can be taken in two different ways: either with a Bourdon type manometer [mbar] or with a water column [mm W.C.] reading. The Bourdon manometer, used to measure higher pressures, is activated by pressing the piston shown in image (a) of Figure 23. The water column, used to measure low pressure at the inlet (less than 50 [mbar]), is activated by lining up the tap, shown in image (b) of Figure 23.

Figure 23: A: *Pressure measurement with the Bourdon manometer piston. B: Alignment of tap for pressure measurement with the water column. C: Water column*.

This turbine also offers the possibility of experimenting with different types of runners to check the influence of their design (see Figure 24). The Kaplan turbine runner incorporates autoregulation of the vane angle, in order to achieve the desired efficiency according to the net head (with no excessive changes) and the flow rate (this parameter can change to a greater extent) with which it is working at each moment. However, the only way to conduct an experimental study in one laboratory of the effect of the vane angles of the runner is by swapping runners with particular inlet and outlet angles.

Figure 24: *Different types of runners available to work with the Kaplan turbine*.

Different runners may be installed. Firstly, the pump of the hydraulic bench must be closed, so that no water moves through it. Once the circuit has been emptied, the connections of the three pieces located on both sides of the casing must be loosened with both hands (Figure 25). The draft tube must then be gently removed from the clamps that hold it in place, so that the casing can be reached more easily. Then, the casing that covers the runner can be removed. The runner can be loosened for its removal with an Allen key and by holding onto the back of the pulley, before fitting a new one.

NOTE: After having used the device, the shaft might be hot due to friction; if so, some protection (e.g., gloves) is advisable to hold the spindle. Once the runner has been removed, a new one can be mounted.

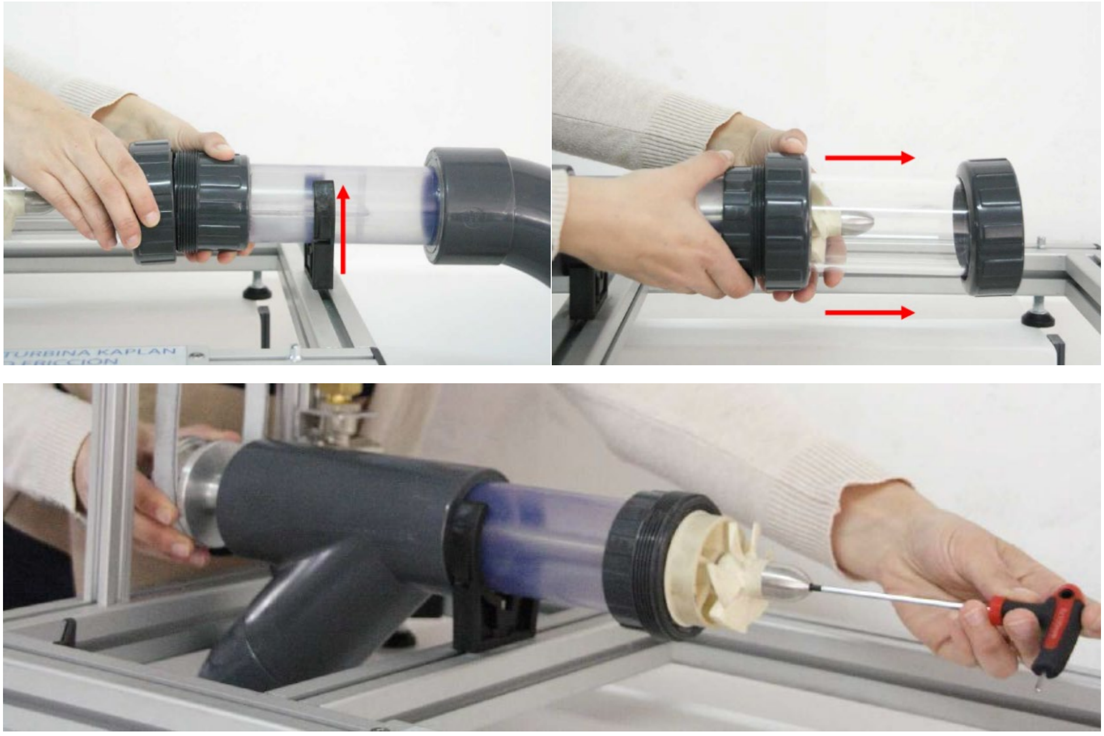


Figure 25: *Changing the runner.*

Some additional components of the facility are described below:

Diameters:

- Discharge pipe, external diameter = 63 [mm], internal diameter = 56,5 [mm]

Manometers:

- Bourdon type with glycerine, from 0 [mbar] to 400 [mbar]

Dynamometer:

- 2 x dynamometer, 2 [kg] x 10 [g]

Characteristics of the turbine:

- Type: Kaplan
- Number of runner blades: 6
- Angle of runner blades
  - Minimum angle (inlet/outlet): 26[º]/11[º]
  - Average angle (inlet/outlet): 41[º]/26[º]
  - Maximum angle (inlet/outlet): 49[º]/34[º]