FLUID FACILITIES AND MACHINERY

GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

THEME 7: AXIAL FAN

1. REQUIRED BACKGROUND KNOWLEDGE

Fluid Mechanics.

Hydraulic Machinery. Turbomachinery. Fans.

2. PRE-LABORATORY

Detailed reading of the description of the practical for its completion within 1 [h]. See Video of P7.

3. OBJECTIVES

To study of the characteristics of an axial fan:

- Visual observation of the operation of an axial fan.
- Use of the Pitot tube for flow-rate measurement. Obtaining the flow velocity profile in the suction (inlet) line.
- Experimental determination of the characteristic curves of an axial fan: static pressure, dynamic pressure, total pressure, power, and performance versus flow.
- Regulation of the axial fan by modifying its rotation speed, calculation of the characteristic curves at different rotation speeds, and the application of Similitude LAWS TO THE FANS.

4. THEORETICAL FOUNDATION

One of the oldest systems to determine flow is the measurement of dynamic pressure. It dates from the 18th century when Henri Pitot designed the tube that bears his name. This type of tube is used to measure the incidental velocity of a fluid and the graphical integration of these incidental measurements at surface points yields the flow rate.

Total or stagnation pressure can be accurately measured by placing a small solid object in the flow with a small piezometric hole at the stagnation point. The fluid in contact with the solid surfaces must satisfy the non-slip condition, and will therefore have a velocity equal to zero.

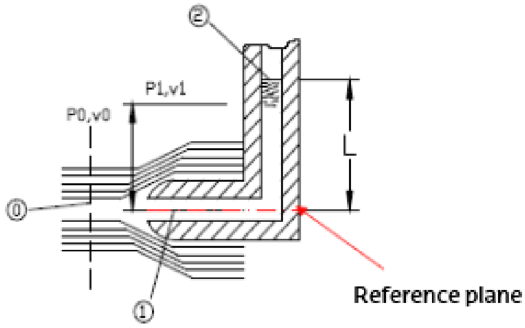


Figure 31: *Measuring total pressure or stagnation pressure.*

$$\frac{p_1}{\rho g} = \frac{p_0}{\rho g} + \frac{v_0^2}{2g} \qquad \text{therefore:} \qquad v_0 = \sqrt{\frac{2g(p_1 - p_0)}{\gamma}}$$

It has been proven that stagnation pressure can be measured by means of a Pitot tube, and static pressures can be measured in several ways, such as by means of piezometric openings. Hence, a Pitot tube can be used together with any static pressure device to obtain the necessary pressure difference, p_1-p_0, from which v_0 may be deduced. In this way, the specific velocity of the fluid can be measured, and it follows that the graphical integration of the values that represent a range of differential pressure points will yield the flow rate. The different operating points of the fan that are experimentally obtained as point clouds are then fitted to a curve using the least-squares method.

$$Q = K_{mean} \cdot p_e^{1/2}$$

$$\Delta p_e(Q) = A + B \cdot Q + C \cdot Q^2$$

$$P_{static}(Q) = Q \cdot \Delta p_e(Q) \quad / \quad P_{dynamic}(Q) = Q \cdot p_d(Q) \quad / \quad P_{useful} = P_{static} + P_{dynamic}$$

It will be necessary to calculate K_{mean} ($m^3 \cdot h^{-1} \cdot Pa^{-1/2}$), to establish the flow rate, which will depend on the static pressure and the flow rate. These calculations will be done in the first part of the practical, so that it will then be possible, later on, to link up the different operating points of the fan, so as to establish the flow rate.

Similitude laws are used to predict the operation of an axial fan under other conditions, such as at different rotational speeds:

- Once the Δp_e (Q) curve is known at a certain N:

$$\Delta p_e (Q) = A + B \cdot Q + C \cdot Q^2$$

- The Δp_e (Q) curve of this fan at another N' will be:

$$\frac{\Delta p_e'}{\Delta p_e} = \frac{N^{2\prime}}{N^2} = \alpha^2$$

$$\frac{Q'}{Q} = \frac{N'}{N} = \alpha$$

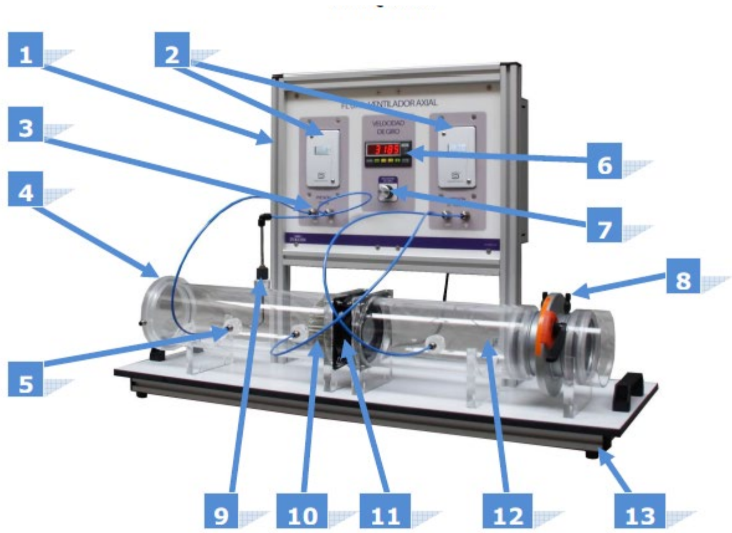
- Thus:

$$\Delta p_e' (Q') = A \cdot \alpha^2 + B \cdot \alpha \cdot Q' + C \cdot Q'^2$$

$$P_{static}' (Q') = Q' \, \Delta p_e' (Q')$$

5. DESCRIPTION OF EQUIPMENT AND FACILITY

The Fluid Mechanics laboratory is equipped with an axial fan and with the following basic elements (Figure 32):



1. Control panel.
2. Pressure transducers.
3. Connections (+ and -) to the pressure transducers.
4. Inlet to the suction pipe.
5. Static pressure tap.
6. Rotation speed display.
7. Rotation speed regulator.
8. Flow regulating Iris valve.
9. Pitot tube.
10. Flow regulation bee panel.
11. Axial fan.
12. Impulsion pipe.
13. Base of the equipment.

Figure 32: *Axial fan*.

This axial fan has a built-in frequency inverter (7) that can modify the speed of the impeller. This frequency inverter will be used to build up characteristic curves at different rotational speeds, with which the experimental results may be compared with those based on Similitude Laws.

Figure 33: *Frequency inverter of the axial fan.*

In addition, the fan has a lever that moves an iris valve located at its outlet section. This mechanism can reduce the diameter of the outlet pipe, thereby varying the delivery flow. The lever has 8 different settings.

Figure 34: *Impulsion flow-rate regulation lever.*

A Pitot tube is inserted vertically into the inlet on the suction pipe so that it is parallel to the flow. The probe is graduated every 10 [mm] so that the distance from the inlet to the tip of the probe can be measured in relation to the diameter of the tube.

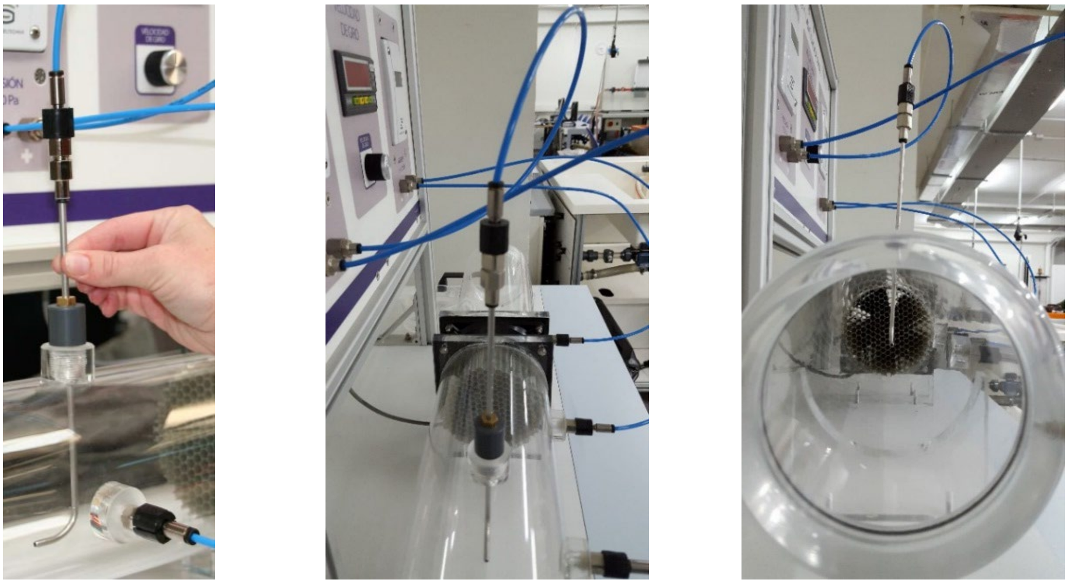


Figure 35: *Pitot located at the suction pipe, parallel to the streamlines.*
NOTE: Ensure that the Pitot tube inlet is always parallel to the flow, facing the air flow that enters the fan

The main characteristics of certain additional components of the facility are detailed below:

Internal diameters:

- Suction pipe
  - Internal diameter = 114 [mm]
  - External diameter = 120 [mm]
- Discharge pipe
  - Internal diameter = 114 [mm]
  - External diameter = 120 [mm]

Fan Features:

- Maximum pressure increase of 1000 [Pa]
- Maximum flow 500 [m^3/h]
- Nominal motor power 90 [W]
- Rotation speed 9500 [r.p.m.] - 158 [Hz]

Pressure gauges:

- ± 100 [Pa] pressure transducer
- Pressure transducer from 0 - 1000 [Pa]

Other elements:

- [r.p.m.] digital indicator
- Speed regulation through a potentiometer
- 4 [mm] ø Pitot tube