Experiment n°3

Laminar and turbulent flow for the mass flow ratio

Objectives

The goal of this experiment is to show the effect of a laminar flow and a turbulent flow on the mass flow rate in a hydraulic circuit.

Theories

The flow regime of a fluid in a circular pipe is defined by the Reynold's number:

$$Re_D = \frac{\rho U D}{\mu} = \frac{UD}{\nu}$$

If Re<2000, it is a laminar flow, the convection is low and the trajectories of particles are parallel to the flow. If Re>2000 the flow is turbulent, the convection can't be ignored.

The flow is supposed permanent, adiabatic and incompressible. Between two point 1 and 2 in a pipe we can apply:

- Flow rate conservation:

  $$Qv = S_1U_1 = S_2U_2$$

- Bernoulli formula:

  $$P1 + \frac{1}{2}\rho U1^2 + \rho g z1 + \Delta Ppump = P2 + \frac{1}{2}\rho U2^2 + \rho g z2 + \Delta Ps + \Delta Pl$$

- Head losses:
  Head losses are consequences of the actions between the water and pipe, the friction between the water and the pipe result in a loss of pressure. The formula used to calculate head losses is the Darcy-Weisbach formula:

  $$\Delta Ps = \xi * \frac{L}{D} * \frac{1}{2} * \rho * Um^2$$

  The coefficient ξ depend on the flow of the fluid:

  Laminar flow: $\xi = \frac{64}{Re}$ Poiseuille Formula

  -Turbulent flow in a smooth pipe: $\xi = \frac{0.316}{\sqrt[4]{Re}}$ (Blasius fromula)

  -Turbulent flow in a rough pipe: $\frac{1}{\sqrt{\xi}} = -2log10\left[\frac{\varepsilon}{3.71D} + \frac{2.51}{Re\sqrt{\xi}}\right]$ (Colebrook formula)

For singular head losses (minor losses): $\Delta Ps = K * \frac{L}{D} * \frac{1}{2}\rho Um^2$ K singular head losses coefficient.

For the flow rate, passing through multiple pipe in parallel involve that the flow rate in each pipe is the circuit entry flow rate divide by the number of pipe (for example, a 100m^3/s flow rate go through 2 pipe in parallel, the flow rate in each pipe is 50m^3/s)

Material

Pipes 1 and 2/3 of the Hydraulic bench

U shaped manometer

Mobile valve

Graduated glass

Laminar flow experiment

a) Check the opening of the exit valve;
b) Open the valve of the pipe 1;
c) Connect the U-shaped manometer to the pressure connector of the pipe 2/3 (the first two connectors from the left);
d) Place the mobile valve on the connector before the rotameter;
e) Activate the pump;
f) Open tube 2 to 9 one by one (that ensure the fluid go in each tube);
g) You can change the flow rate by modifying the opening of the control valve (after the rotameter).
h) Open the mobile valve and measure the flow rate by filling the glass and measuring the time needed.

Pick up the value of the manometer in the following table:

Qv m^3/s	h1 mm	h2 mm	Δh m	Δp Pa	U m/s	Qv measured m3/s	Re

Turbulent flow experiment

a) Check the opening of the exit valve;
b) Open the valve of the pipe 1;
c) Connect the U-shaped manometer to the pressure connector of the pipe 2/3 (the first two connectors from the left);
d) Place the mobile valve on the connector before the rotameter;
e) Activate the pump;
f) You can change the flow rate by modifying the opening of the control valve (after the rotameter).
g) Open the mobile valve and measure the flow rate by filling the glass and measuring the time needed.

Pick up the value of the manometer in the following table:

Qv m^3/s	h1 mm	h2 mm	Δh m	Δp Pa	U m/s	Qv measured m3/s	Re