Experiment n°8

Evaluation of the performances of manometers in turbulent flow

Objective

The aim of this experiment is to highlight the different measure of a same manometer in a laminar flow and in a turbulent flow in order to decide which manometer is the more suited for the task.

Theories

Bernoulli formula $Pa + \frac{1}{2}\rho Ua^2 + \rho gZa = Pb + \frac{1}{2}\rho Ub^2 + \rho gZb$

Flow rate equality: $Qv = UaSa = UbSb$

For the venturi tube:

$$Pa - Pb = \frac{1}{2}\rho * (Ub^2 - Ua^2) \Leftrightarrow \frac{2}{\rho}(Pa - Pb) = Qv^2(\frac{1}{Sb^2} - \frac{1}{Sa^2}) \Leftrightarrow Qv = \sqrt{\frac{2\Delta P}{\rho(\frac{1}{Sb^2} - \frac{1}{Sa^2})}}$$

For the orifice plate:

$$Pa - Pb = \frac{1}{2}\rho * (Ub^2 - Ua^2) \Leftrightarrow \frac{2}{\rho}(Pa - Pb) = Qv^2(\frac{1}{Sb^2} - \frac{1}{Sa^2}) \Leftrightarrow Qv = \sqrt{\frac{2\Delta P}{\rho(\frac{1}{Sb^2} - \frac{1}{Sa^2})}} =$$

$Sb\sqrt{\frac{2\Delta p}{\rho(1-(\frac{d}{D})^4}} = CdSb\sqrt{\frac{1}{1-\beta^4}} * \sqrt{\frac{2\Delta p}{\rho}}$ introducing the Cd coefficient (because it is not a perfectly laminar flow) and the β=d/D, d diameter of the orifice (m), D diameter of the pipe (m)

$Qv = CSb0\sqrt{\frac{2\Delta p}{\rho}}$ Introducing C= $Cd\sqrt{\frac{1}{1-\beta^4}}$ Sb0 area of the orifice

Coefficient of discharge can be calculated with the Reader-Harris/Gallagher equation:

$$C=0.5961 + 0.0261\beta^2 - 0.216\beta^8 + 0.000521\left(\frac{10^6\beta}{REd}\right)^{0.7} + (0.0188 + 0.0063A)\beta^{3.5}\left(\frac{10^6}{REd}\right)^{0.3} + (0.043 + 0.080\exp(-10L1) - 0.123\exp(-7L1))(1 - 0.11A)\frac{\beta^4}{1-\beta^4} - 0.031\left(M2' - 0.8M2'^{1.1}\right)\beta^{1.3} + 0.011(0.75 - \beta)(2.8 - \frac{D}{0.0254})$$

$A=\left(\frac{19000\beta}{REd}\right)^{0.8}$

$M2'=\frac{2L2}{1-\beta}$

L1=L2=0

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)

Description

The HD98 bench is used, alongside pipes n°2, 3. Pipe n°2 is equipped with a venturi tube, a flow meter device based on the venturi effect. Pipe n°3 is also equipped with a venturi effect based flow meter: an orifice plate. The circuit use a rotameter (which will be considered the reference here).

Experiment

a) Check the opening of the exit valve;
b) Calculate the flow rate maximal for a laminar flow in each flowmeter
c) Open one pipe;
d) Connect manometers to the desired pipes;
e) Activate the pump;
f) Open other pipe in order to divide the flow rate in each pipe;
g) Pick up values of the manometers in the following table;
h) Compare each manometer to the rotameter;
i) Conclude

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