Experiment 5

VELOCITY DISTRIBUTION IN PIPES

I. INTRODUCTION

Not all fluid elements travel at the same velocity within a pipe. The velocity of the element in contact with the pipe wall is essentially zero and increases from the wall to center of the pipe. The shape of the velocity curve (the velocity profile across any given section of the pipe) depends on the types of flow. There are two types of flow: laminar flow ($Re \le 2320$) and turbulent flow ($Re \ge 10^4$).

In laminar flow, elements of the fluid flow move along a well-defined paths which are straight and parallel to each other. There is no radial motion. In a round-shape pipe, all fluid element belongs to the same concentric circle will have the same velocity. The velocity distribution at a cross - section will be parabolic in the shape with maximum velocity at the center being about twice the average velocity in the pipe:

$$\frac{W_{tb}}{W_{\max}} = 0{,}5$$

In turbulent flow, the motion of fluid is very complicated. There are both axial and radial movement. The velocity of each fluid element always change in both direction and value. Therefore, the velocity is characterized by mean value rather than instanneous one. For this type, a fairly flat velocity distribution exists across the section of pipe. The ratio between maximum velocity at the center and the mean velocity in the pipe is as following:

$$\frac{W_{tb}}{W_{\max}} = 0{,}8 - 0{,}9$$

To measure fluid flow velocity at any point in the pipe, a pitot tube is used.

Velocity of fluid flow at a given point is determined as following:

$$W = \sqrt{\frac{2\Delta P_W}{\rho}}, \qquad m/s$$

where : ΔP_W - dynamic pressure, N/m^2 ;

ρ - mass density of the fluid, kg/m^3

To calculate mean velocity, velocity at different points in a cross - section of the pipe is measured. Then, velocity profile will be determined.

II. PURPOSE

- Measure fluid flow velocity at different points in a cross-section of pipe in order to determine velocity distribution as well as mean velocity of the fluid flow.

III. EXPERIMENT SETUP

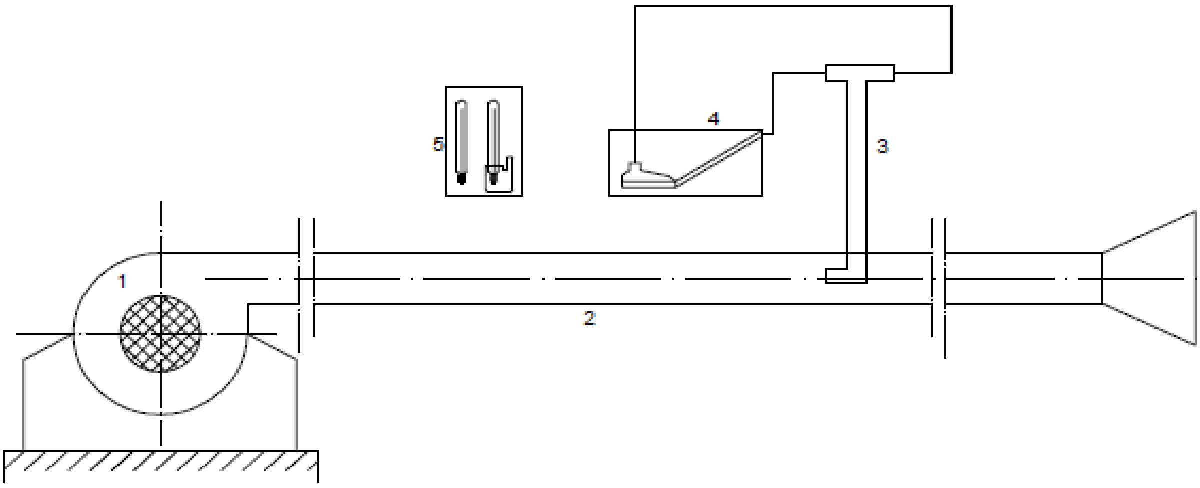


Fig. 5.1: *Experiment setup*

1. Centrifugal fan
2. Pipe (d_{in} = 145mm, L = 6120mm)
3. Pitot tube
4. Manometer
5. Hygrometer

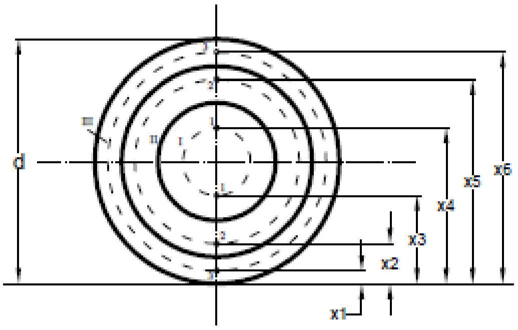


Fig 5.2: *The division of a pipe cross - section into annulus with equal area*

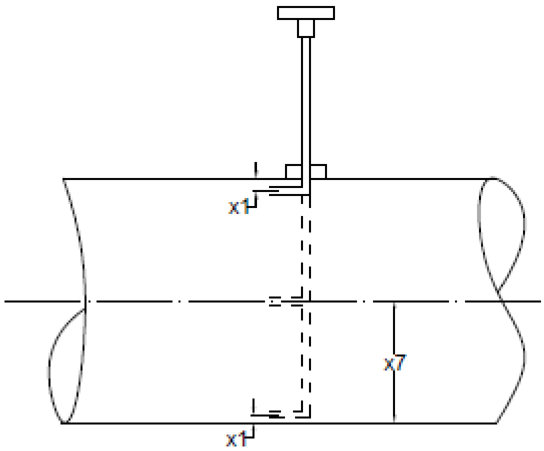


Fig 5.3 : *The position of Pitot tube at boundary points*

IV. PROCEDURES

1. Study experiment set up
2. Check measurment tools: manometer, hygrometer, pitot tube, barometer…

3. Turn on the fan. Wait until the flow is steady. Measure fluid flow velocity at different points on a given cross - section

4. The simple and popular method to determine mean velocity of the fluid flow in a pipe is as following:

- Divide cross-section of the pipe into annulus with equal area I, II, III (see Fig. 5-2 and 5-3). Each annulus is divided into two equal parts (dash line). Points 1, 2, 3 on the dash line are average points of annulus I, II, III. Measured velocity at points 1, 2, 3 is mean velocity of areas I, II, III. Because of equally areas, mean velocity of points 1, 2, 3 is the average fluid flow velocity. The more number of annulus, the more precise value can be.

The distance from pipe wall to points 1, 2, 3 is determined according to following formular:

$$x = \frac{d}{2}(1 \pm \sqrt{\frac{2n-1}{2N}}) \qquad (5\text{-}2)$$

where : d – pipe diameter, m;

n – the number of circles which devides annulus into two equal parts. (from the center of the pipe);

N – the number of annulus area.

Note:

"+" for points x which are positive.

"-" for points x which are negative.

Formular 5-2 is established from condition: areas of I, II, III are equal.

Record the measured values in following table:

No.	x	ΔP_w, mm ethanol			ΔP_w, mean value		Velocity, m/s
		Time 1	Time 2	Time 3	mm ethanol	N/m^2	
1							
2							
3							
4							
5							
6							
7	x = d/2						

5. Finish: turn off the fan; tidy up and clean working space. Record experimental data in Lab notebook.

V. QUESTIONS

1. Distinguish local velocity, instantaneous velocity, mean velocity of fluid flow in a pipe?

2. What is the distribution of the fluid flow velocity in laminar flow and turbulent flow?

3. What is the relationship between mean velocity and maximum velocity of the fluid in laminar and turbulent flow?

4. Construction and working principle of pitot tube?

VI. CALCULATION

1. Mass density of humic air:

$$\rho = 1{,}293\frac{B - P_{bh}}{101325}.\frac{273}{T} + \varphi.\rho_{bh} \qquad (5\text{-}3)$$

where :

B- reading value of hygrometer, N/m^2 ;

φ - relative humidity of air (based on reading value of hygrometer and lookup table).

P_{bh} – pressure of saturated vapor (at dry – bulb temperature), N/m^2 .

T – air temperature, ^{0}K.

ρ_{bh} – mass density of saturated vapor (at dry – bulb temperature), kg/m^3.

101325 – dry air pressure (at standard conditions), N/m^2.

2. Mean velocity of fluid flow:

$$W_{mean} = \frac{\sum_{i=1}^{i=6} W_i}{6}, m/s \qquad (5\text{-}4)$$

3. Ratio between mean velocity and maximum velocity:

$$A = \frac{W_{mean}}{W_{\max}} \qquad (5\text{-}5)$$

4. Reynolds number :

$$\mathrm{Re} = \frac{d.W_{mean}.\rho}{\mu} \quad (5\text{-}6)$$

Where :

d – pipe diameter, m;

ρ - mass density of the fluid (humic air), $kg.m^3$

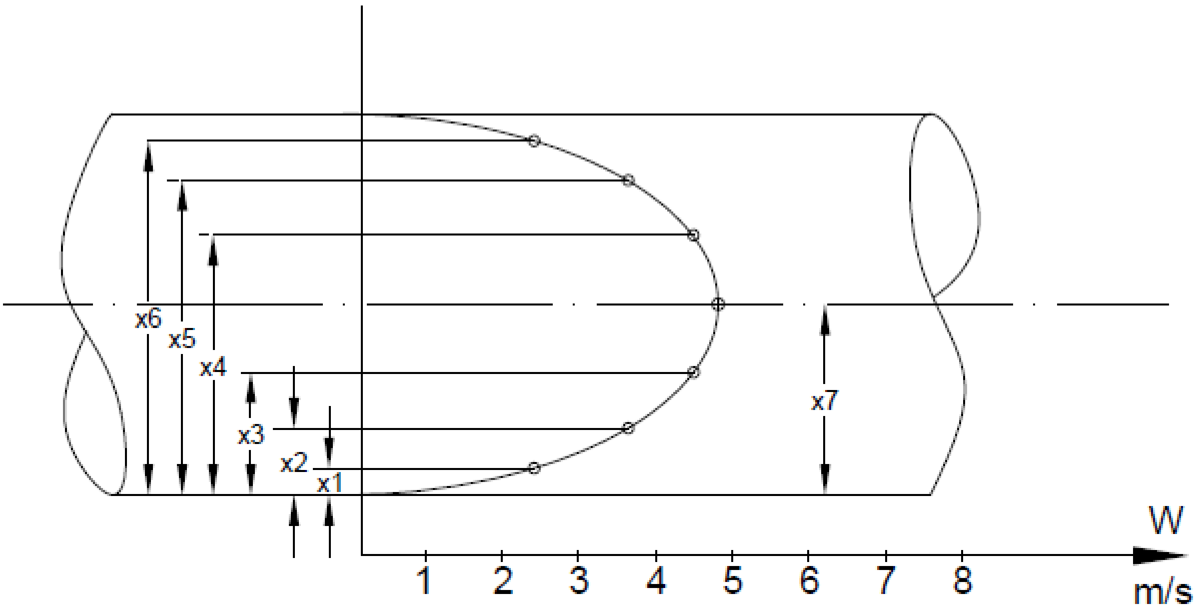
μ - viscosity of the fluid, Ns/m^2 (at dry – bulb temperature).

5. Flowrate of the fluid :

$Q = W_{mean}.F$, m^3/s (5-7)

With: F is cross – sectional area of the pipe , m^2.

6. Draw velocity profile:



7. Comments on experiment