EXPERIMENTAL STUDY ON THE FLUID FLOW IN THE CONDUCTS

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ABSTRACT: Fluids are high mobility environments that, under the action of external forces, are continuously and irreversibly deformed. The flow of fluid through a pipe is ensured by a pressure difference between its ends. The presented paper aims to experimentally determine the velocity profile of flowing a Newtonian fluid through a circular section pipe by measuring the local speed at five points on the pipe radius.

KEY WORDS: laminar, turbulent, flow, Reynolds criterion

1. Introduction

Fluid materials, that is, those which may undergo temporary deformations of shape and volume, can be transported by pipelines or channels. The duct is a closed space through which flowing material flows, the pipe wall being in contact with the entire circumference of the material. In channels, material contact with the wall is mostly partial. The section of the pipes and channels may have various geometric shapes, more commonly used being circular, ovoid or rectangular.

Fluids move through pipes, channels and appliances under the action of an energy received from outside or under the action of potential energy created by a level difference. The transfer of energy from an external source to the fluid is accomplished by static or machine tools with moving mechanical assemblies. The energy received is converted into energy of energy, potential energy and kinetic energy of the fluids [1].

The flow phenomenon is important for the transport of liquids, gases and dispersions through pipelines for the discharge of liquid, gaseous or slurry effluents in the practical realization of all physicochemical effluent treatment and depollution processes in assessing the dispersion of pollutant concentrations regardless of their state of aggregation in soil, water or air. Local swirling currents occur mainly in flowing sections with variable dimensions and areas with oscillatory hydrodynamic potential, a phenomenon that generates intense global scale mixing of fluid mass. These currents are responsible for transporting or depositing sediment from fluids, erosion or alteration of fluid flow profile, local concentration of materials transported by fluid streams [2].

2. Theoretical notions

The flow of a fluid can be characterized by the time variation of the parameters describing it or by its regime. The first criterion shares the flow in the stationary flow, when the parameters do not vary over time and non-stationary flow, when the parameters are variable over time. From the point of view of the flow regime, the flow can be laminar or turbulent. The flow is laminar when the layers of fluid that travel at different speeds remain parallel between them during the flow.

This is possible if the external force that drives the flow is comparable to the resistance force caused by the fluids between the fluid layers and which is proportional to the viscosity of the fluid. If the force that drives the flow is much higher than the frictional force, the parallelism of the layers is no longer preserved, and disordered movements of the elementary fluid volumes, with the formation of vortices or turbines, are called turbulent. Transition from one regime to another is not net, with a transitional regime, called an interim regime. This regime is unstable because flow with parallel layers can flow with turbines or vice versa [4].

Because laminar or turbulent flow depends on the intensity of the friction forces, the quantitative appreciation of the flow is done by the Reynolds criterion. The Reynolds criterion is a non-dimensional ratio of inertial force and frictional force, which, for flow in the pipe is [1]:

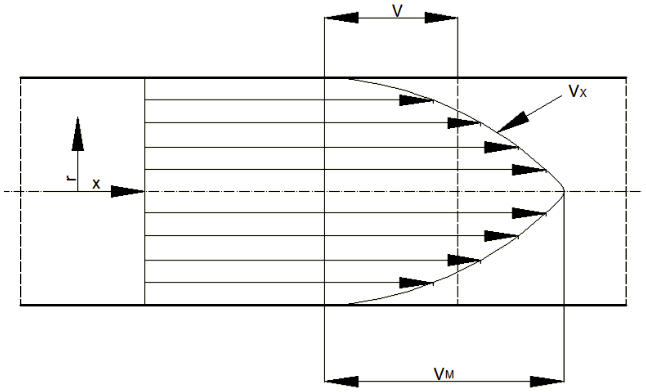
$$Re = \frac{\rho\cdot v\cdot d}{\eta} = \frac{v\cdot d}{\vartheta} \qquad (1)$$

where:
ρ – fluid density [Kg/m^3];
v – the average speed in the pipe [m/s];
d – the inner diameter of the pipe [m];
η – dynamic fluid viscosity [Ns/m^2];
ν – kinematic viscosity of the fluid [m^2/s];

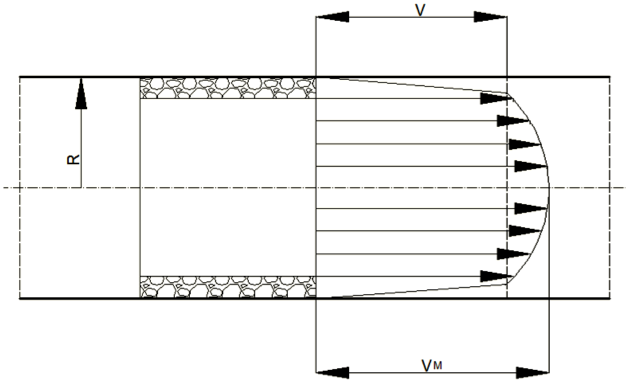
When flowing through straight pipes, the delineation of flow patterns is done using the following values of the Reynolds criterion:

- laminar, for Re < 2300;
- intermediar, for2300 < Re < 10000;
- turbulent, pentru Re > 10000.

For circular section pipes, in the stabilized flow zone, the visualization of the two regimes and the profile of the fluid bed velocities is shown in fig.1.



a



b

Fig.1. *Gear profiles in straight pipes: a-laminar; b-turbulent.*

In the laminar flow of newtonian fluids through circular cross-section pipes (fig.1.a), the speed of displacement of the layers varies parabolically depending on the pipe radius, having the maximum V_M on the pipe axis X and the zero value on the pipe extreme [3] .

The distribution of the velocities in laminar flow is given by the equation [1]:

$$V_x = \frac{\Delta P\cdot R^2}{4\eta\cdot L}\left[1-\left(\frac{r}{R}\right)^2\right] = V_M\left[1-\left(\frac{r}{R}\right)^2\right] \qquad (2)$$

unde:
v_x – local speed [m/s];
V_M - maximum speed [m/s];
r – the current radius [m];
R – pipe radius [m];
ΔP – pressure difference at the pipe ends [N/m^2];
L – pipe length [m].

The average pipeline speed is calculated using the formula [1]:

$$V = \frac{1}{S}\int_S^{\infty} V_x\, dS = \frac{1}{\pi R^2}\int_0^R 2\pi v_x\, r dr = \\ = \frac{\Delta P\cdot R^2}{8\eta\cdot L} \qquad (3)$$

where:
S – flow section [m^2].

Knowing the average speed, we can calculate the volume flow with relation [1]:

$$M_V = v \cdot \pi \cdot R^2 \tag{4}$$

In turbulent mode, the fluid layers are not parallel turbines forming the characteristics of this flow (Fig.1.b). Due to the forces of adhesion between the fluid and the pipe wall, the layers adjacent to the wall maintain parallelism so that the flow in the near remains laminar. The velocity profile in the duct is different from that of the laminar flow, the velocity distribution over the pipe radius being given by a parabola with the flattened tip. For turbulent flow, the variation of the local speed with the radius of the pipe is given by the relation (5) [1]:

$$V_x = V_M \left[1 - \left(\frac{r}{R}\right)^{1,25}\right]^{1/7} \tag{5}$$

The ratio between the average speed and the maximum speed is no longer constant and depends on the value of the Reynolds number. Experimentally it has been shown that V / V_M = 0.84, so [1]:

$$V_x = 1{,}19V \left[1 - \left(\frac{r}{R}\right)^{1,25}\right]^{1/7} \tag{6}$$

3. Case study

3.1. Description of the installation

Experimental determinations were made using liquid water that has newtonian behavior. The experimental installation (fig. 2) consists of the following elements:

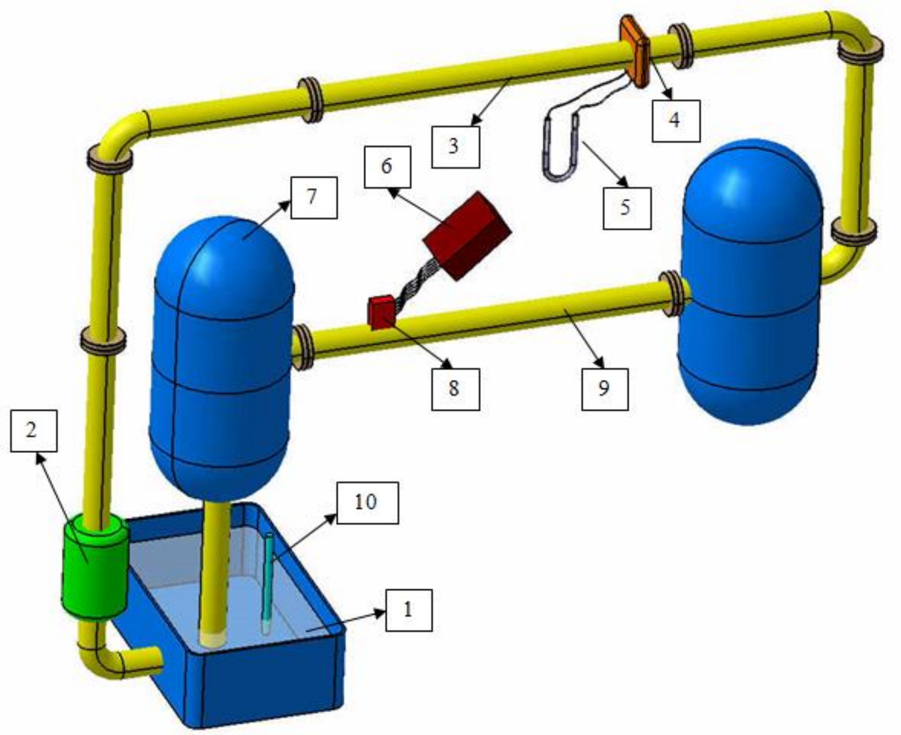


Fig.2. *Experimental stand*

The centrifugal pump (2) aspire the liquid from the tank (1) and refuses it through the pipe (3) provided with the diaphragm (4) for measuring the flow. The measurement of the velocity profile and the visual flow tracking is done in the pipe (9) made of a polymethyl methacrylate tube having an internal diameter of 56 mm and a length of 2500 mm. To avoid drainage of the pipe (9) when the system is switched off, it is fitted between two buffer tanks (7) provided with a water level control system on the inside. The type of flow can be viewed by injecting a dye into the pipe (9) through a seal with a sealed cap. To measure the flow, the diaphragm (4) connected to the mercury differential pressure gauge (5) is used. The water temperature is measured in the tank (1) using the thermometer (10). The wires will be measured in the pipe (9) by means of the device (8) made up of 6 capillary tubes arranged so that 5 will be parallel to the pipe axis at different distances to the wall and one perpendicular to the axis of the static pressure measurement pipe. The capillary tubes are mounted in a stainless steel support, each communicating with a piezometric tube connection for measuring the pressure. Piezometers are made of glass tubes arranged in a box (6), the inclination of which is adjustable.

3.2. Experimental data

The measured data was performed for two flows. For the first flow, the data were centralized in Table 1 and for the second flow in Table 2.

Table 1.

Nr crt	**h_0 [mm]**	**T [ºC]**	**ρ [Kg/m^3]**	**η [Ns/m^2]**	**h_s [mm]**	**r [mm]**	**h_t [mm]**
1	16	22	1000	1,025	3	0	12
2						8	11
3						16	9
4						22	7
5						25	6

Table 2.

Nr crt	**h_0 [mm]**	**T [ºC]**	**ρ [Kg/m^3]**	**η [Ns/m^2]**	**h_s [mm]**	**r [mm]**	**h_t [mm]**
1	24	24	1000	1,025	7	0	18
2						8	17
3						16	15
4						22	13
5						25	12

where:

h_0 - water height at diaphragm pressure gauge;

T – water temperature;

ρ – density of water;

η – kinematic viscosity of the water;

h_s - the water height in the capillary tube measuring the static pressure;

r – the radius on which the capillary tube is disposed;

h_t - the height of the water in the tubes measuring the total pressure.

Knowing h_0, we calculate the flows M_{v1} şi M_{v2} with the equation:

$$M_v = 390{,}014 d_0^2 \cdot \alpha \cdot \sqrt{\frac{h_0}{\rho}} \qquad (7)$$

where:

d_0 – the diameter of the aperture of the diaphragm [14mm];

α – diaphragm flow coefficient [α = 1,4 for laminar flow and α = 1 for turbulent flow]

So,

$M_{v1} = 0{,}103\ m^3/s$

$M_{v2} = 0{,}415 m^3/s$

For the two flows we now calculate the average speed in the pipe (9) with the inside diameter d = 56mm, with the equation:

$$v = \frac{M_v}{S} = \frac{4 \cdot M_v}{\pi \cdot d^2} \qquad (8)$$

So,

$v_1 = 42{,}10\ m/s$

v_2 = 167,22 m/s

We now calculate Reynolds number with equation (1):

Re_1 = 2300 – laminar;
Re_2 = 11200 – turbulent.

4. Conclusion

Experimental determinations have also been made with the plant but it has been found that at axial velocities below 25 m/s no measurements can be made. This is because the dynamic pressures of the fluid are small and can not be measured by reading the bumps in the piezoelectric tubes.

The limit of transition from laminar to intermediate mode was determined to be at a flow rate of 0,1 m^3/s and a pipeline water velocity of 42 m/s. The flow rate between 0,1 – 0,4 m^3/s recorded an intermediate mode and at flow rates above 0,4 m^3/s the flow regime was turbulent.

In the case of low axial velocities, the flow regime is determined by reading the dynamic pressures at the five points on the pipe radius.

5. Bibliography

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