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Study on the Effects in Different Pipes Based on Fluid Flow Experiment

Liwei Fang

Wenzhou Polytechnic, Wenzhou 325035, China

Abstract

This report will describe the effects the pipe diameter have on the apparent smoothness and explain the ideals for some questions later in Part 1, and compare the different instruments and evaluate those and provide make comment on the relationship between the radius squared and the velocity to the flow rate on the Pitot traverse graph in Part 2.

Keywords

Fluid friction, fluid velocity, Pitot tube, Venturi meter.

1. Introduction

Fluid flow rate can be hardly estimated without instruments in daily life. People only fell it by tactile sense and determine it according to the degree of comfort. However, in many situations, accurate fluid flow rate is highly required to complete special tasks. In addition, the friction losses in pipes should be taken into account, which can influence the fluid flow significantly, adding problem in process of measurement. Thus, a variety of measurement meters and determination methods of friction losses emerge to find out the exact air flow rate for controlling field [1]. TQ H408 Fluid Friction Apparatus and the combination of an Orifice plate, Pitot tube and a Venturi Meter can be one considerable approach solving problems correspondingly.

2. Part 1 – Friction Losses in Straight uPVC Pipes

2.1. Objectives

To determine the friction losses in smooth and roughened straight uPVC pipes

2.2. Results (Tables and Calculations)

Since Re for smooth pipe (35, 34) is 3521.1, the friction factor displayed on the Moody Diagram read from the tendency of the Laminar flow line is 0.020.

For the other two pipes, the Re exceed 800, which can be estimated from the chart. But the line of Relative Roughness does not stretch through the whole diagram. Only from the tendency of the line can f be read, i.e. approximately 0.090 for smooth pipe (7, 8) and 0.080 for smooth pipe (31, 30).

2.3. Analysis and Discussion of Results

Commonly, Blasius equation is used for smooth turbulent flow. The Renolds number of flow is the determination for whether it is turbulent or laminar. In Table 1 Re of pipe (7, 8) and (35, 34) are both under 2000, which means they are laminar flow. Therefore, actually, it is not appropriate to apply Blasius equation to evaluate the friction factor [2].

However, if they must be calculated in this way and compared via the results, from the equation $f=0.079(Re)^{-1/4}$, $Re=ud/v$ and $u=Q/A=4Q/\prod d^2$ by Blasius method (the calculated Darcy frictional coefficient f exceed 1, not logical in real life), the final equation can be derived into $f=Qd^3/4\prod v$. It is apparently that the growth of pipe diameter can spur the friction factor to

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increase. This is in accordance with the results when the two smooth pipes are selected to compare. The pipe diameters for smooth pipes (7, 8) and (35, 34) are $0.017m^2$ and $0.004m^2$ correspondingly, and 0.0147 and 0.0103. In addition, theoretically the flow rate should be same; in reality the operation and reading errors are unavoidable. Though there is a little difference between the two calculated flow rates, it is extremely tiny numbers. Thus the difference of d^3 comes dominant in the influence of magnitude of friction factor.

Table 1 The calculation results of Part 1

Tapping (X, Y)	Time for 500ml (s)	Flow Rate (Q) (m^3s^{-1})	Internal Diameter (d) (m)	Area (A) (m^2)	Length (l) (m)	Upstream Tapping (X)(mm)
(7, 8)-Smooth Pipe	45.2	$1.1062*10^{-5}$	0.017	$2.27*10^{-4}$	0.091	500
(35, 34)-Smooth Pipe	44.9	$1.1136*10^{-5}$	0.004	$1.26*10^{-5}$	0.036	/
(31, 30)-Roughened Pipe	43.5	$1.1494*10^{-5}$	0.017	$2.27*10^{-4}$	0.019	353

Downstream Tapping (Y) (mm)	Difference h=X-Y (m)	Flow Velocity, u (ms^{-1})	Re	$f=2gdh/4lu^2$	Blasius, $f=0.079(Re)^{-1/4}$
492	0.008	0.0487	824.6	3.165	0.0147
/	/	0.8838	3521.1	/	0.0103
211	0.142	0.0506	856.8	243.152	0.0146

McMullan, R has stated that the “ranges from about 0.005 for smooth pipes to 0.01 for rough pipes” (2007).The obtained numbers lies between 0.01 and 0.02, no matter it is smooth pipe or rough pipe. Although the values are much smaller than 1, it is still beyond the normal standard. From this perspective, it can be summarized that the values obtained for the smooth pipes cannot suggest that the pipes are perfectly smooth [3].

As discussed above, there should be some problems and errors in the experiment. The flow rates measured in three tubes are very close and these are accessible and can be used for analysis and comparison. The big difficulty appears in the results of pressure measurement, for pipe (35, 34), the upstream and downstream both exceed the maximum measuring range. The possible error source may come from the tappings. For other two tubes, even thought the results can be calculated, the statistics obtained is not logical. It is easy to see that the Darcy friction coefficient is impossible larger than 1. Furthermore, despite that Blasius friction factor is smaller than 1, in fact, it cannot give evidence that pipe (7, 8) is smooth according to the rule of thumb, because it is very near to the friction factor of roughened pipe (7, 8). Thus, it is possible that the smooth pipe is not smooth any more and it should be roughened by probable reasons, for example long time no use and it can be observed that some algae grow inside the pipe which can increase the roughness.

2.4. Conclusion

In conclusion, the experiment seems fail since the calculated result is not reasonable in real life. A variety of possible error sources can be raised influencing the final results. The friction factor obtained from Moody Chart can only be estimated basically by the rational Reynolds number. And furthermore, according to the standard in Environmental Science in Building, the smooth pipes are not so smooth in the view of calculated result. To achieve a better consequence, the experiment need to be improved and practice several times and the instrument should be checked for proper maintenance and replacement.

3. Part 2 – Flow Measurement Using an Orifice Plate, Pitot Tube and a Venturi Meter

3.1. Objectives

To measure water flow using an Orifice plate, Pitot tube and a Venturi Meter

3.2. Results (Tables and Calculations)

Table 2 The calculation results of Task 1 in Part 2

Orifice Plate Readings				Venturi Meter Readings			
Tapping 24-h_1 (mm)	Tapping 25-h_2 (mm)	Difference (Head loss) (Δh) (m)	Flow Rate (Q) (ms^{-1})	Tapping 29-h_1 (mm)	Tapping 28-h_2(mm)	Difference (Head loss) (Δh) (m)	Flow Rate (Q) (ms^{-1})
255	372	0.117	$2.89*10^{-4}$	354	258	0.096	$2.86*10^{-4}$

Data for Orifice Plate	
Cd	0.601
d1	51.09 mm
d2	20.0 mm

Data for Venturi Meter	
Cd	0.96
d1	26.0 mm
d2	16.0 mm

Table 3 The calculation results of Task 2 in Part 2

Pitot Position (mm)	Radius from pipe centre (mm)	Radius^2 (r^2) (m^2)	Downstream tapping (mm)	Upstream tapping (mm)	Pressure Difference (△h) (m)	Flow Velocity $u=(2g\Delta h)^{0.5}$ (ms^{-1})	$\Delta q=(r_2^2-r_1^2)\Pi(u_1+u_2)/2$
10.925	0	0	298	343	0.045	0.9391	0
8.925	2	$4.0*10^{-6}$	298	343	0.045	0.9391	$1.1801*10^{-5}$
6.925	4	$1.6*10^{-5}$	297	341	0.044	0.9287	$3.5207*10^{-5}$
4.925	6	$3.6*10^{-5}$	298	342	0.044	0.9287	$5.8352*10^{-5}$
2.925	8	$6.4*10^{-5}$	299	342	0.043	0.9180	$8.1227*10^{-5}$
2.425	8.5	$7.23*10^{-5}$	298	341	0.043	0.9180	$2.3937*10^{-5}$
1.925	9	$8.10*10^{-5}$	298	340	0.042	0.9073	$2.4946*10^{-5}$
1.425	9.5	$9.03*10^{-5}$	298	339	0.041	0.8964	$2.9217*10^{-5}$
0.925	10	$1.0*10^{-4}$	299	339	0.040	0.8854	$2.7149*10^{-5}$
Flow rate=(sum of last column)=$2.92*10^{-4}$							

3.3. Analysis and Discussion of Results

The two flow rate measurement instruments are both based on the Bernoulli principle. The pressure difference obtained has a tight connection with the change in velocity. The enlargement or constriction in the pipes could generate pressure difference to determine the flow rate.

From the results, the flow rates are measured slightly different, which reminds that the Bernoulli principle is an ideal theory and ignore the energy loss caused by friction. While actually, the existence of energy loss in reality is inevitable and has to be taken into account in measurement if it requires for high accuracy. Thus to which degree the two meters restrict the flow is equal to decide to what extent the energy loss take place during the measurement process. First in Orifice Meter, there is a sudden constriction positioned in it and the pressures read from the front and back tappings are the main record data for calculation. In Venturi Meter, which consist of a throat and a duct, the cross section of reduction changes gradually between the throat and duct, comparing to Orifice Meter. Consulting to the information in Environmental Science in Building (2007), there are a variety of forms of energy

loss, such as velocity of flow, area of the pipe wall, turbulence of flow, etc, and the main cause is the friction between the liquid and the pipe walls. In a word, according to these known information, it is hard to decide which meter restrict most flow [4].

Nevertheless, another easier way can determine this if the operation is correct and the equipment is accurate. See the flow rate directly, the value for Orifice Meter is larger than that for Venturi Meter [5]. Suppose there is no mistake in manipulation and installation, the smaller one can be suggested to the one which restricts most flow, since that the pressure drop is smaller due to the less energy loss.

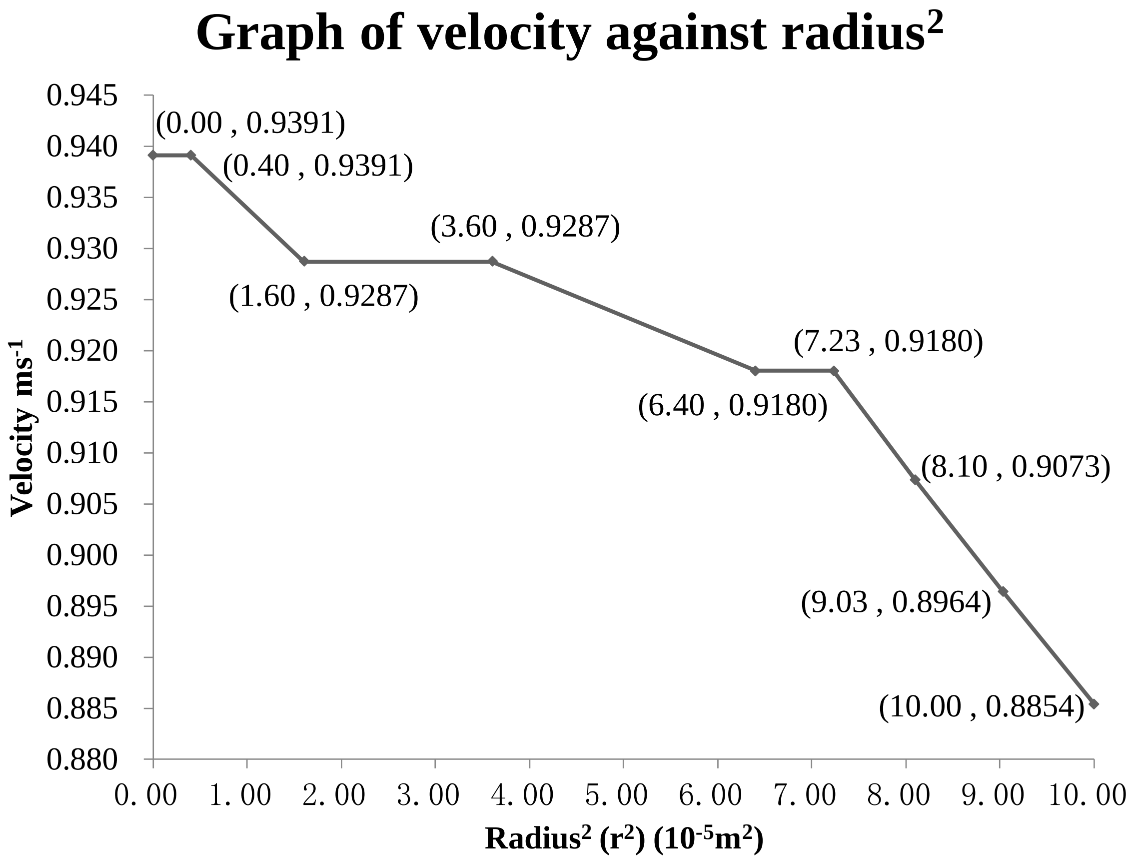

Figure 1 Graph of velocity against radius^2

The volume flow rate can be obtained by the sum of volume of divided hoop pieces and can be supposed to be the area under the line in Figure 1. The area of the piece can be illustrated as $A=(r_2^2-r_1^2)\prod$ and the velocity can be assumed to the average of the velocities at the correspondingly boundaries, $u=(u_1+u_2)/2$. Thus the final equation can be simple as $q=(r_2^2-r_1^2)\prod(u_1+u_2)/2$, sometimes $r_2^2-r_1^2$ can be presented as Δr^2. Therefore, the flow rate is $Q=q_1+q_2+\ldots q_n$.

3.4. Conclusion

In conclusion, the experiment provides students an good access to the flow rate measurement. From the reasonable calculated results, the flow rates are similar by different measurement instruments. Moreover, they are also very close to value gained by the simple derived method. Accordingly, further improvement in the experiment to increase the accuracy can be achieved and the method perhaps can be developed or generated from other perspectives to make the current result closer to the actual value.

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