Effect of pipe diameter changes on the properties of fluid in closed channels using Osborne Reynold Apparatus

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Abstract. The flow profile in the channel will affect the velocity of fluid distribution. One factor that influences the flow profile in a closed channel is its diameter. Therefore, this study aims to analyze the effect of changes in pipe diameter on the nature of fluid flow in closed channels using Osborne Reynold Apparatus. This tool uses a vertical glass pipe with a diameter of 1 cm and 3 cm. The operation of the Osborne Reynolds Apparatus is carried out by flowing the fluid through a channel with a PVC type pipe pumped with a Submersible pump into an acrylic tub, then passing a vertical clear glass pipe. The Reynolds value obtained from each test equipment is 1,323-5,748 with friction factor 0,03 -0,04 on Osborne Reynold Apparatus 3 cm diameter and 1,103-4,512 with friction factor value 0,03 -0,05 at Osborne Reynold Apparatus 1 cm diameter. It is known that the greater the channel diameter, the greater the Rey nolds value will be, while the friction factor will be smaller. Regression and correlation analysis are carried out with the aim to determine the relationship the values obtained and it is obtained that there is a very strong relationship among time, discharge, flow velocity, Reynolds number and friction factor in each test equipment. It is evidenced with the coefficient of determination and the correlation coefficient obtained (R^2 = 0.994-1.000 and r = 0.981-1.000).

1. Introduction
Characteristics and types of flow profiles in a fluid in closed channels are important factors in the fluid flow process. The flow profile occurs laminar, transition and turbulent flow [1]. To know the flow conditions, Osborne Reynold Apparatus is used to visualize the flow characteristics in the pipe. Osborne Reynolds Apparatus visualize flow and determine the flow characteristics easily. This tool uses vertical flow with the principle of the fluid observed going through the gap in the glass tube. The use of vertical flow will cause the effect of any small deviation on the density of the dye to be observed against the mechanism of the fluid flow. The fluid will operate in a manner supplied from each small gap in a flexible way from the available hose [2].

The Reynolds number describes the regime of fluid flow in a channel or the surface of an object. The flow profile will affect the speed of fluid distribution. If it is laminar, the flow rate is slow. Vice versa, turbulent flow shows that the fluid velocity in the channel is high [3].

The larger the diameter (D) of the test pipe is, the friction coefficient value (λ) will increase. On the other hand, if the smaller the diameter (D) of the test pipe is, the coefficient of friction (λ) will
decrease [4]. So it shows that one of the factors that affect the flow profile is the diameter of the pipe to be tested. Therefore the researcher will analyze by giving variations to the diameter 3 cm and 1 cm in diameter. So that from the modification and operation of this tool can display the flow characteristics in closed channels [5].

2. Materials and Method

2.1. Tools Operation

Before being operated, first checking is useful to prevent errors during the study. After ensuring that the condition of the equipment and materials are good, the Osborne Reynolds Apparatus is ready to operate. The first step is activating the pump that aims to drain the fluid that will observe from the reservoir into the acrylic tub. Making sure that the fluid available is sufficient so that there is no air inside the pump which will cause cavitation on the pump that makes the pump pressure low and will affect the pump capacity in flowing fluid. Next, adjusting the faucet openings to make continuous systems \((Q_{in}=Q_{out})\) [6].

After reaching a continuous system, the dye (ink) that functions as an ingredient will help visualizing the fluid flow characteristics inserted into a clear glass pipe. Performing flow profile analysis that occurs in the clear glass pipe by observing the shape of the ink. The tap openings on the channel are arranged to obtain laminar flow type, a transition to turbulent. Then, the flow rate is calculated based on the volume and time that occurs during the observation, and the temperature of the observed fluid is measured in Osborne Reynolds Apparatus [7][8].

The data obtained during the experiment to determine the flow velocity are processed using the following formulas [9]

\[ Q = \frac{V}{t} \]  

Effect of Reynolds Numbers (Re) on Fluid Flow Characteristics

\[ Re = \frac{\rho v d}{\mu} = \frac{v d}{v} \]  

Friction factor \((f)\)

a. Friction factor for laminar flow according to Hagen-Poiseulle and Darcy Weisbach:

\[ f = \frac{64}{Re} \]  

b. Friction factor for turbulent flow according to Blasius:

\[ f = \frac{0.316}{Re^{0.25}} \]  

c. Friction factor transitions contents:

\[ f = \frac{f_l + f_t}{2} \]
2.2. Data Analysis
Regression analysis performed is linear regression analysis using SPSS 16.0 program to see the effect of variable X on Y variables, obtained after measurement using Osborne Reynold Apparatus diameter 3 cm and 1 cm so that the influence between variables can determine through F test, and coefficient of determination ($R^2$). Linear regression analysis is aimed to know the effect of the variables obtained, time, flow rate, flow velocity, Reynolds value and friction factor [10].

Correlation analysis is carried out using Pearson correlation and the SPSS 16.0 program to see how strong the relationships between variables obtained after measured using Osborne Reynold Apparatus diameter 3 cm and 1 cm so that it can be seen whether it shows positive, negative or uncorrelated correlation.

3. Results And Discussion
The data that has been obtained in the test using Osborne Reynold Apparatus with a diameter of 1 cm and 3 cm then performed data processing, so that the value of flow discharge, flow velocity, Reynolds value, and friction factor obtained.
3.1 Relationship between Discharge and Reynolds Number

From Figure 2a it is known that Osborne Reynolds Apparatus is 3 cm in diameter that the largest discharge occurs in turbulent flow with a range of 100,000-125,000 mm$^3$/sec and the smallest discharge in laminar flow 28,500-31,200 mm$^3$/sec. Whereas the largest Reynolds number value also occurs in turbulent flow with a range of 4,600-5,800 and the smallest Reynolds number in laminar flow with an average of 1,300-1,450. For Figure 2b the results of testing Osborne Reynolds Apparatus with a diameter of 1 cm, the largest discharge also occurs in turbulent flow with a range of 30,000-33,000 mm$^3$/sec and the smallest discharge on laminar flow 7,900-8,200 mm$^3$/sec. Whereas the largest Reynolds number value also occurs in turbulent flow with a range of 4,250-4,550 and the smallest Reynolds number on laminar flow with an average of 1,310-1,350.

From the data obtained, it can be seen that the flow rate has a directly proportional relationship with the Reynolds number value. The greater the measured flow rate is, the greater the Reynolds number formed will be. The measured debit will affect the flow velocity in the fluid, in this test the flow velocity will affect the Reynolds number value in the fluid being tested.

3.2 Relationship between Flow Velocity and Reynolds Number

From the data obtained, it can be seen that the flow rate has a directly proportional relationship with the Reynolds number value. The greater the measured flow rate is, the greater the Reynolds number formed will be. The measured debit will affect the flow velocity in the fluid, in this test the flow velocity will affect the Reynolds number value in the fluid being tested.
Figure 3a shows the test results for each flow properties analyzed in Osborne Reynolds Apparatus 3 cm diameter, it is known that the largest flow velocity occurs in turbulent flow ranges from 140-180 mm/sec and the smallest flow velocity in laminar flow with a range of 40-44 mm/sec. Whereas the largest Reynolds number value also occurs in turbulent flow with an average of 4,700-5,800 and the smallest Reynolds number in laminar flow with an average of 1,300-1,500. For Figure 3b on Osborne Reynolds Apparatus with a diameter of 1 cm, the largest flow velocity occurs in turbulent flow with a value range of 390-415 mm/sec and the smallest flow velocity in laminar flow with a range of 100-104 mm/sec. Whereas the largest Reynolds number value also occurs in turbulent flow with a range of 4,200-4,600 and the smallest Reynolds number in laminar flow with a range of 1,100-1,200.

From the data obtained, it can be seen that the flow velocity has a directly proportional relationship with the Reynolds number value. The greater the flow velocity that occurs, the greater the Reynolds number generates. Evidenced by the research conducted of Taufik (2011), where the greater the flow rate of the pipe, the greater the Reynolds number value obtained so that it will affect the type of Reynolds number flow. In addition to flow velocity, channel width and kinematic viscosity will affect the Reynolds number value on the test performed.

3.3. The Relationship between Flow Velocity and Friction Factor

Figure 4a shows the results of the tests carried out for each flow properties which are analyzed using Osborne Reynold Apparatus of 3 cm diameter that the largest flow velocity occurred in turbulent flow ranges from 140-180 mm/sec and the smallest flow velocity in laminar flow with a range of 40-44 mm/sec. While, the greatest friction factor values occur in laminar flow with an average of 0.04 and the smallest friction factor in the transition flow with an average of 0.3. From Figure 4b the Osborne Reynold Apparatus is 1 cm in diameter that the largest flow velocity occurs in turbulent flow ranging from 390-415 mm/sec and the smallest flow velocity in laminar flow with an average of 100-104 mm/sec. Meanwhile, the greatest value of friction factor occurs in laminar flow with an average of 0.05 and the smallest friction factor in the transition flow with an average of 0.03.

From the data obtained, it can be seen that the flow velocity has an inversely proportional relationship with the value of the friction factor. The greater the flow velocity that occurs, the lower the friction factor value. Friction factor occurs because the fluid flowing in a channel will make contact with the channel wall, so that if the fluid in the channel is longer then the value of the friction
factor will increase. Therefore if the flow velocity in a fluid is large, then the time of the fluid in the channel is smaller. So that the friction factor that occurs during the flow is also small.

3.4 Regression and Correlation Analysis

The results of regression and correlation analysis using Osborne Reynold Apparatus show that the strong correlation as evidenced by the coefficient of determination and the correlation coefficient obtained for $R^2 = 0.997-1.000$ and $r = 0.998-1.000$ on Osborne Reynold Apparatus diameter 3 cm and $R^2 = 0.994-1.000$ and $r = 0.981-1.000$ on Osborne Reynold Apparatus diameter 1 cm.

4. Conclusions

Reynolds number on Osborne Reynold Apparatus 3 cm diameter is 1,323-5,748 with friction factor 0.03-0.04, while at 1 cm diameter obtained 1,103-4,512 with friction factor value 0.03-0.05. The greater the diameter of the channel is, the greater the Reynolds value will be, and the smaller the friction factor value. The results of regression and correlation analysis on Osborne Reynold Apparatus show that the strong correlation as evidenced by the coefficient of determination and the correlation coefficient obtained for $R^2 = 0.997-1.000$ and $r = 0.998-1.000$ on Osborne Reynold Apparatus diameter 3 cm and $R^2 = 0.994-1.000$ and $r = 0.981-1.000$ on Osborne Reynold Apparatus diameter 1 cm.

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