Effects of Fluctuation in Discharge and Head on Flow Parameters and Head Losses in Pipeline Networks

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Effects of Fluctuation in Discharge and Head on Flow Parameters and Head Losses in Pipeline Networks

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Abstract. Discharge, head, flow velocity and Reynolds number are flow parameters in pipe networks. On the other hand, energy loss is one of the factors that affect the capacity of the pipe as a means of distributing water flow. Energy loss is caused by several factors including the roughness of the pipe walls associated with the pipe material. Due to the lack of attention to the interrelationship of these factors, sometimes there are piping networks that do not work optimally or do not function as expected. The purpose of this study was to determine the effect of changes in discharge and head on flow parameters and energy loss in the piping network. This study uses experimental research conducted in the laboratory. The primary data collection is quantitative analysis with the main data collection through measurements using a series of pipes as a test model, and is preceded by the collection of supporting data, namely the analysis of the characteristics of the water sample. The characteristics of the water samples used are density (ρ) 1,000 kg/m3, kinematic viscosity 0.804 x 10-6 m2s, dynamic viscosity (μ) 0.801 x 10-3 Nd/m2, viscosity 8.5x10-7 m2/ sec, and specific gravity (y) 1.00355 gr/cm3, and a temperature of 29.50C. There are 3 discharge variations used, namely Q1 = 0.004 m3/s, Q2 = 0.003m3/s and Q3 = 0.002 m3/s and variations in head H1 = 2 meters, H2 = 1 meter and H3 = 0.5 meters. The results showed that due to changes in discharge and fall height caused an effect on flow parameters in the piping network. The greater the discharge, the greater the energy loss, and the greater the head, the smaller the energy loss. Changes in flow rate have a more significant effect on changes in energy loss when compared to changes in head.

1. Introduction

Fluid flow in a closed channel is important so that an optimal planning process is needed [1,2,3]. Pipes as distribution media have been widely used in industry and public water distribution. The advantages of the pipe as a closed channel as a water distribution include lower water loss, and easier maintenance when a blockage occurs. Another advantage is that it can be more easily used in areas where the source has higher elevation than the distribution area. In addition, the pipeline flow is not directly affected by air but by hydraulic pressure, the required land used is not extensive, less disruption to current activities, and safety because the channel is closed, the risk to humans is less than an open channel during bad weather, the size is larger [4]. A rather smaller size than the open channel gives closed channel more flexiblity in its placement. It proveides a better water quality than the open channel because the water that flows is protected by the surface of the pipe.

In the installation of pipelines there will be flow resistance caused by factors of the pipeline installation itself such as flow velocity, changes in pipe dimensions and the presence of turns, as well as changes in the roughness of the pipe material. The flow resistance will cause a decrease in energy and pressure [5].

The process of designing and planning a closed channel (pipeline network) is a very broad aspect and requires an interrelated analysis of water demand (discharge), velocity, pipe diameter, pressure head fall and so on. Due to the lack of attention to this energy loss, some of the existing piping networks do not work optimally or in other words the network does not function as expected. Energy loss is one of the factors that affect the capacity of the pipe as a means of distributing water flow. One of the important things that affect network performance is energy loss. As a result of errors in calculating this energy loss, it can cause problems, namely sometimes what is planned is not in accordance with what is happening in the field, especially related to capacity and pressure on the piping network.

2. Theoretical background

Flow in closed channel

Closed channels which are usually circular in cross-section are used to flow fluids with full flow section. The fluid flowing through the pipe can be a liquid or a gas and the pressure can be greater or less than atmospheric pressure. If the liquid in the pipe is not full then the flow is included in open channel flow or because the pressure in the pipe is equal to atmospheric pressure, the flow is included in open flow. The pressure at the surface of the liquid along an open channel is atmospheric pressure. The basic difference between flow in an open channel and flow in a closed channel is the presence of a free surface which is (almost always) air in the open channel. So if the flow pipe is not full so that there is still a cavity filled with air, then the nature and characteristics of the flow are the same as the flow in an open channel.

Reynolds number

Reynolds number (Re) is a number that does not have dimension which is an important factor in analyzing the type of flow (laminar, turbulent or transition). Re is the ratio of the inertial force to the viscosity force. Reynolds number:

$$Re = \frac{V\rho d}{\mu} \quad ..... (1)$$

Where

Re = Reynolds Number
v = average velocity of flow in closed channel (m/s)
d = pipe's inner diameter (m)
ρ = density of fluid (kg/m3)
μ = dynamic viscosity of fluid (kg/m.s)

Head losses

Energy loss (Head losses) is a factor that affects the capacity of the pipe as a means of conducting flow of both water and pipes [6,7,8]. Energy losses are divided into major and minor losses. Meanwhile, minor losses are caused by changes in cross-section, joints, bends, valves and other pipe components. Major Headloss (major losses) Major losses are losses in the flow in the pipe caused by friction that occurs along the fluid flow that flows against the pipe wall. In a liquid flowing in the boundary plane, there will be shear stress and velocity gradient throughout the flow field because of the viscosity. The shear stress will cause a loss of energy during flow. The formula for finding the major pressure loss is as follows:

$$hf = f\frac{L}{D}\frac{v^2}{2g} \quad ......(2)$$

Minor Headloss (minor losses) Losses that occur in the pipe system are caused by bends, elbows, joints, valves. And Others are called minor losses [5].

Viscosity

The viscosity of a fluid is a measure of its resistance to the rate of deformation [6]. Viscosity or the viscosity of a fluid is very important in analyzing fluid conditions and fluid motion. Real liquids are substances that have a viscosity, while ideal liquids have no viscosity. This happens because of the nature of cohesion between the liquid particles. The difference in particle velocity in the flow field occurs because of the viscosity of the liquid. Liquid particles adjacent to the boundary wall will have zero velocity or rest, while those located at a certain distance from the wall will move. The change in velocity is a function of the distance from the boundary wall. The flow of real liquids is called viscous flow. This flow can be divided into 2 (two). If the effect of viscosity (viscosity) is dominant enough so that the particles of the liquid move regularly in a straight line, the flow is said to be laminar. Laminar flow occurs when the viscosity is large and the velocity is small. With the decrease in the effect of viscosity or the flow rate increases, the flow will change from laminar to turbulent [9].

Pitot tube speed
Bernoulli's law statement is the sum of the pressure, kinetic energy per volume, and potential energy per volume at any point along the fluid flow is the same. That is, as the fluid flow increases, the fluid pressure will decrease. Thus, the potential energy of the fluid will also decrease. Conversely, when the fluid flow velocity decreases, the fluid pressure will increase. This law can be applied to various types of fluid flow with several assumptions, as follows:
a) The fluid is incompressible.
b) The fluid has no viscosity (inviscid).
c) Fluid flow does not change with time (steady).
d) Laminar fluid flow (constant, no eddies).
e) There is no loss of energy due to friction between the fluid and the wall. And there is no energy loss due to turbulence.
f) No heat energy is transferred to the fluid either as heat gain or loss. Bernoulli's equation is as follows:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_1 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \ldots(3)$$

where:
P = Pressure (Pascal)
ρ = Density of fluid (kg/m3)
v = fluid Velocity
g = gravitational force (g= 9.8 m/s 2)
h = height (m)
Bernoulli's law is very useful in everyday life and is used in the following applications:
a) Pitot tube
Pitot tube is an instrument for measuring pressure in fluid flow. The Pitot tube was invented by the French engineer, Henry Pitot [10] and modified by the French scientist, Henry Darcy [11]. Pitot tubes have been widely used to determine the speed of aircraft and measure air and gas velocity in industrial applications [12]. The velocity of the air in the pipe can be calculated using the equation:

$$v = \sqrt{2gh} \ldots(4)$$

b) Venturimeter
In ideal conditions in fluid dynamics the Bernoulli equation and the continuity equation are the basic equations used by the venturimeter pipe, through the translation and substitution of the equations, the formula for determining the flow rate in the venturi meter pipe is obtained. Based on the continuity theory that the inlet and outlet holes of the venturimeter pipe which have different cross-sectional sizes are so regular, the discharge between the holes is the same.

3. Research Method
The research was carried out in the laboratory by making a distribution network pipe model. To obtain research data, the source of data used comes from primary data, namely data obtained directly from simulations of physical models in the laboratory and secondary data obtained from literature and existing research results, both those that have been carried out in the laboratory and carried out elsewhere. related to velocity distribution research. The design of the network test equipment carried out in this study is as shown in the following figure.

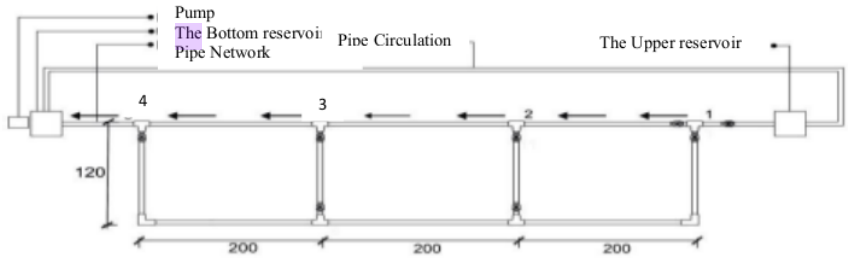

Figure 1. Set up test equipment

Figure 1 shows a model of a rectangular test equipment set up. This network is equipped with a lower water reservoir and an upper water reservoir as a place for water circulation, a valve as a discharge regulator, a water pump machine that regulates the water supply from the lower reservoir to the upper reservoir and a flow velocity measuring device.

This pipe test is intended to observe the flow characteristics that occur from the beginning of the flow (upstream) to the end (downstream) with variations in discharge (Q). The initial stage includes the preparation of tools and materials needed during the research. The calibration of the equipment was carried out on manual pitot tubes and digital pitot tubes to obtain the relationship between the readings of these tools. Manual pitot tube calibration is carried out with a digital pitot tube and installing the pitot tube at the Measurement Point (TP) in the test pipe. And pitot is placed with the same height, which is 2 cm from the bottom of the test pipe. This test is carried out based on changes in discharge and fall height. Variations in flowrate changes are Q1 = 0.004 m3/s, Q2= 0.003 m3/s and Q1 = 0.002 m3/s. While the change in height of fall is H1 = 2 m, H2 = 1 m and H3 = 0.5 m.

4. Results and Discussion

Results

The characteristics of the water samples used in this study are specific gravity = 1000 kg/m3, Density = 995.2 kg/m3, viscosity = 0.0804 x 10^-6 m2/sec and temperature = 29.5 oC. Meanwhile, the results of the high pressure test due to changes in discharge and fall height on a straight pipe network can be seen in the following table.

Table 1. The results of the high pressure test on the Pitot tube

Running	TP	h pitot (cm)		
		Q1	Q2	Q3
HEAD 200 cm	TP1	49.49	37.40	22.40
	TP2	45.71	34.10	18.72
	TP3	41.39	32.84	17.35
	TP4	31.88	19.20	5.00
HEAD 100 cm	TP1	48.08	37.01	18.75
	TP2	44.93	36.52	12.64
	TP3	43.52	32.15	12.36
	TP4	19.09	11.47	5.00
HEAD 50 cm	TP1	31.00	19.93	5.83
	TP2	25.18	17.39	5.50
	TP3	22.55	15.10	5.38
	TP4	16.15	10.80	5.00

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Discussion

Effect of changes in discharge and fall height on flow velocity

To calculate the flow velocity on the network, Equation 2 is used, the results of which are shown in the following figure:

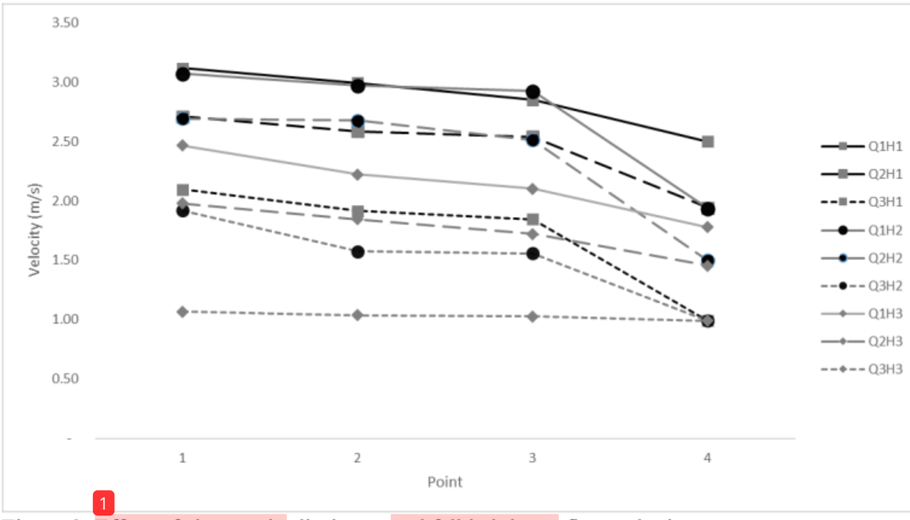

Figure 2. Effect of changes in discharge and fall height on flow velocity

From the picture above shows the effect of changes in flowrate on speed that the greater the discharge, the speed also increases, and vice versa if the discharge decreases, the speed also decreases. In the same condition, due to a decrease in head also results in a decrease in speed.

Effect of changes in discharge and height of fall on the Reynolds Number

The effect of changes in discharge and height of fall on the Reynolds number can be seen in the following figure

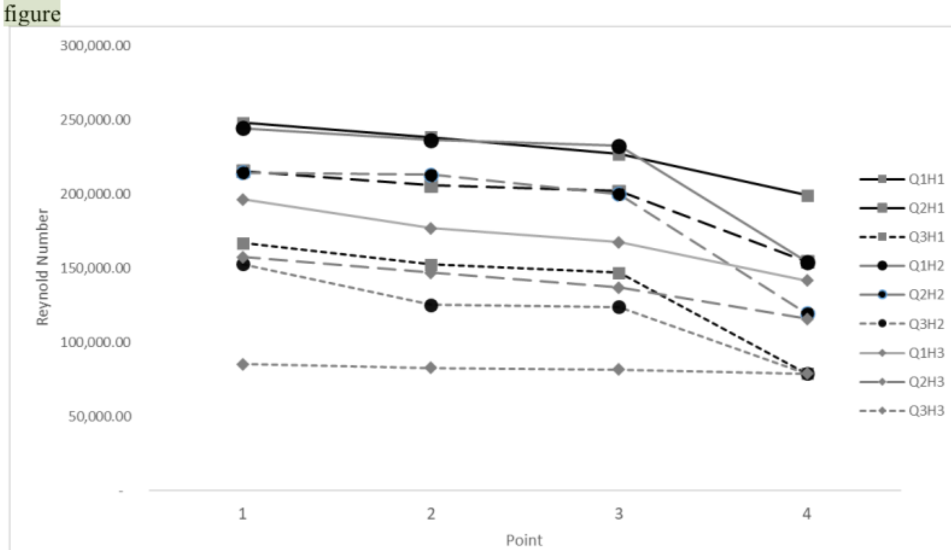

Figure 3. Effect of changes in discharge and height of fall on the Reynolds Number

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In the picture above, it can be seen the effect of changes in discharge and height of fall on the Reynolds Number. The smaller the discharge, the Reynolds Number also decreases, and vice versa if the discharge is large, the Reynolds Number will increase. Likewise, the decrease in the value of the Reynolds Number is caused by a decrease in the height of the fall. This is because a decrease in both discharge and fall height causes a decrease in velocity which results in a decrease in the Reynolds number. A large speed will cause an increase in the Reynolds number in the pipeline network.

Effect of changes in discharge and fall height on energy loss

The major losses caused by friction of the liquid with the pipe wall and minor losses due to the connection were taken into account in the study. The effect of changes in discharge and height of fall on the complete energy loss is shown in the following figure

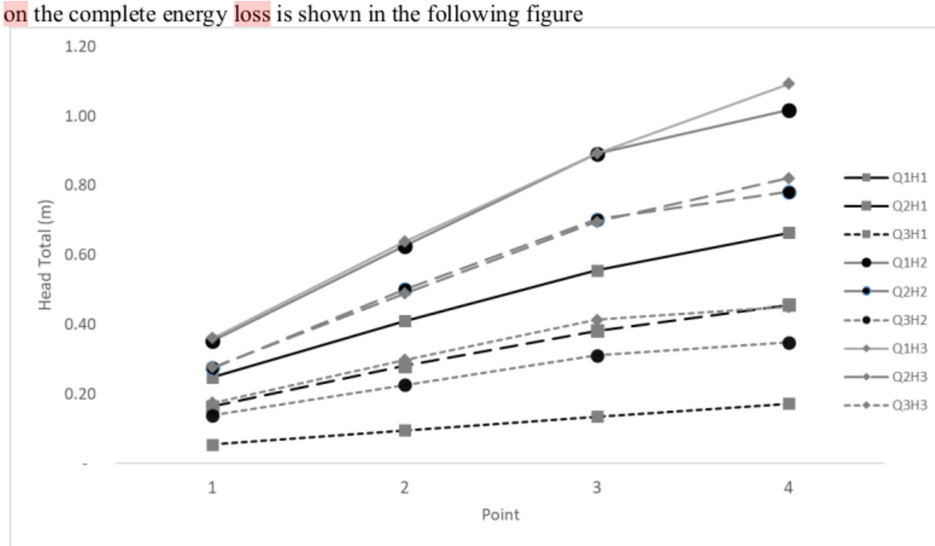

Figure 4. Effect of changes in discharge and fall height on energy loss

The effect of changes in discharge on energy loss (head loss) in straight pipe networks is that the greater the discharge, the more energy loss (head loss) will be, and vice versa if the discharge decreases, the energy loss (head loss) will also decrease. This can be seen at point (TP1) at the H1 fall height (0.2 m), there is a decrease in the level of energy loss (head loss) from Q1 to Q2, namely from 0.25 meters to 0.17 meters or by 33.62%. Likewise, the decrease in energy loss (head loss) from Q2 to Q3 is 0.17 meters to 0.05 meters or by 66.87%. And at the point (TP2) at the H1 fall height, there was a decrease in the level of energy loss (head loss) from Q1 to Q2, namely from 0.41 meters to 0.28 meters or 31.59%. Likewise, the decrease in energy loss (head loss) from Q2 to Q3 is 0.28 meters to 0.1 meters or 65.96%. In TP3 there is a decrease in the level of energy loss (head loss) from Q1 to Q2, from 0.56 meters to 0.38 meters or 31.29%. Likewise, the decrease in energy loss (head loss) from Q2 to Q3 is 0.38 meters to 0.14 meters or by 64.55%. TP4 there is a decrease in the level of energy loss (head loss) from Q1 to Q2, namely from 0.66 meters to 0.46 meters or 31.16% from Q2 to Q3 which is 0.46 meters to 0.17 meters or 62.18%.

On the other hand, the effect of changes in head on energy loss (head loss) is that the greater the height of the fall, the smaller the energy loss (head loss). This can be seen at point (TP1) with Q1 discharge an increase in energy loss (head loss) from H1 to H2, from 0.25 meters to 0.35 meters or 41.98%. Likewise, the increase in energy loss (head loss) from H2 to H3 is 0.35 meters to 0.36 meters or 2.4%. At point (TP2) with Q1 discharge there is an increase in energy loss (head loss) from H1 to H2, namely from 0.41 meters to 0.6 meters or by 52.66%. Likewise, the increase in energy loss (head loss) from H2 to H3 is 0.626 meters to 0.639 meters or 2.05%. At point (TP3) with Q1 discharge there is an increase in energy loss (head loss) from H1 to H2, namely from 0.556 meters to 0.892 meters or 60.25%. Likewise, the increase in energy loss (head loss) from H2 to H3 is 0.892 meters to 0.893 meters or 0.12%. At point (TP4) with Q1 discharge there is an increase in energy loss (head loss) from H1 to H2, namely from 0.664 meters to 1.017 meters or 53.11%. Likewise, the increase in energy loss (head loss) from H2 to H3 is 1,017 meters to 1,093 meters or 7.4%.

Level of Effect of Changes in Discharge and Head Falls on Energy Loss
In this study, the discharge variation carried out is from Q1 = 4 lt/sec to Q2 = 3 lt/sec and Q3 = 2 lt/sec. This means that the decrease in discharge from Q1 to Q2 is 25% and Q1 to Q2 is 50%. While the variation of the drop in height fell from H1 = 2 m to H2 = 1 m and H3 = 0.5 m. So the percentage decrease in discharge from H1 to H2 is 50% and H1 to H3 is 75%. Figure 5 shows the level of influence of changes in discharge and head on energy loss due to a decrease in discharge and fall height. The purple color represents energy loss during Q1H1 which is the starting point for changes in discharge and head.

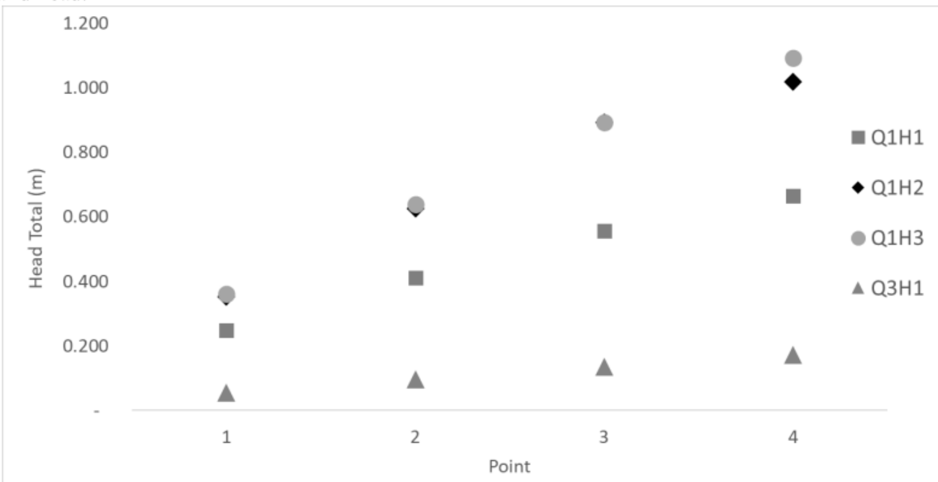

Figure 5 Energy loss in straight pipe due to decrease in discharge and height of fall
Based on the picture above, it can be seen that changes in discharge result in greater energy losses when compared to changes in height falling at the same observation point. For example Observation Point 1, the change from Q1H1 to Q1H2 is from 0.249 to 0.353 m or a change of 41.97% with a 50% decrease in H1 to H2 while the change from Q1H1 to Q3H1 is from 0.249 to 0.055 m or a change of 78% with a decrease in Q1 to Q3 by 50% or equal to the percentage change in height falling from H1 to H2. Likewise at Observation Point 2, the change from Q1H1 to Q1H2 is from 0.410 to 0.626 m or a change of 52.66% while the change from Q1H1 to Q3H1 is from 0.41 to 0.096 m or a change of 76.71%. Observation point 3, the change from Q1H1 to Q1H2 is from 0.556 to 0.892 m or a change of 60.25% while the change from Q1H1 to Q3H1 is from 0.556 to 0.136 m or a change of 75.64%. Observation point 4, the change from Q1H1 to Q1H2 is from 0.664 to 1.017 m or a change of 53.11% while the change from Q1H1 to Q3H1 is from 0.664 to 0.173 m or a change of 73.96%.

Conclusion
Based on the purpose of this study, it can be concluded several things from the results of the research that has been done, namely: The effect of changes in discharge on energy loss can be concluded that the higher the discharge, the level of energy loss also increases. Vice versa, the smaller the discharge, the lower the energy loss. This is because the increased discharge causes the mass of the liquid that rubs or contracts with the pipe wall to increase in number. On the other hand, the effect of a change in the height of the fall on the tissue is inversely proportional to the change in energy loss. The greater the height of

the fall, the less energy loss (head loss) at the same discharge condition. This is because an increase in head will cause an increase in speed, an increase in speed causes an increase in the Reynolds Number. Changes in discharge are more significant in influencing changes in energy loss when compared to changes in head.

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