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Effect of water discharge variation on water levels and flow characteristics in pipeline networks

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Abstract: The ability of flow discharge is very necessary in pipeline. When changes in discharge flow in the pipe, the flow pattern and water level will be different. The design of test equipment used is a pipe network made of acrylic pipes with inner diameter ($d1$) 64 mm and ($d2$) 44 mm. The fluid used is standard water with a viscosity value of 1.14 cp, fat oil 0 mg/L, and specific gravity 1.0304 gr/cm³. Data collection on the testing pipeline is divided into 10 segments or 10 observation points (OP) per discharge. Variations of debits flowed are 0.5 liters/sec, 1.2 liters/sec, 3.5 liters/sec. The relationship between discharge and depth of flow or water level from the bottom of pipe and the relationship between discharge and flow velocity is directly proportional or linear. The greater of discharge value flowed resulted in a shift in the flow characteristics where the low discharge value, the laminar flow patterns and transitions and high discharge values of flow pattern becomes turbulent.

1. Introduction

In a flow that passes through the system or installation of wastewater pipelines, flow bottlenecks will occur due to the installation factors of the pipeline it self such as changes in velocity, cross section (pipe dimensions, bends, connections) and surface roughness. Flow bottle neck will cause decrease energy and pressure. This research is directed to find the relationship of wastewater characteristic, open channel flow and wastewater network systems. To find out the maximum and minimum discharges and their effects in the wastewater network system. The maximum discharge is intended to prevent the pipe erosion by solid materials contained in the pipe while the minimum discharge is intended for the process of self-cleansing so that waste water containing organic solids does not precipitate or suspended into sedimentation [1].

Discharge is a volume of water that flows per unit time. The ability to measure flow discharge is very necessary in pipelines network. When changes in discharge flow in the pipe, the flow pattern and water level will be different [2]. Geometric pipes where the elbow connection and pipe section changes will also have an effect. The formula of flow discharge [3] can be described in the following equation:



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$$Q = V/t \quad (1)$$

The flow patterns that occur in closed channels vary depending on individual observations and the conditions of flowing fluid, for certain flow situations. In a pipeline system, many problems are experienced by the flow inside. One of them is the problem of sudden reduction in cross section. In addition, there is also a problem of deflection of the pipe network system itself. And this is very influential on whether or not the flow in the pipe smoothly. Of course it also affects efficiency and productivity in the industry [4].

Viscous flow can be divided into 2 (two) types, i.e laminar and turbulent. In laminar flow the particles of the liquid moves regularly follow parallel paths [5]. This flow occurs when the small velocity or large viscosity. In turbulent flow, the particles of the fluid moves irregularly. This flow occurs when the large velocity and small viscosity.

In 1884, Reynolds [3] stated that there were 3 (three) factors that affects the state of flow, namely the liquid viscosity μ (μ), mass density ρ (ρ) and pipe diameter (D). The relationship of μ , ρ and D has dimensions equal to velocity.

$$Re = \frac{\rho dV}{\mu} \quad (2)$$

Based on the experiment of flow in the pipe, Reynolds determined that for Reynold's numbers below 2000, the flow under these conditions was laminar. Conversely, the flow will be turbulent if the Reynolds number lie between the two values $2000 < Re < 4000$. The Reynold's number of the two values above ($Re = 2000$ and $re = 4000$) is called the lower and upper critical limits, respectively. If the liquid in the pipe is not full then the flow is in the open flow or the pressure in the pipe is equal to atmospheric pressure (the liquid in the pipe is not full), the flow is in the open flow [6].

2. Methodology

2.1. Research site

The research was conducted at the Hydraulics Laboratory of the Department of Civil Engineering and the Environmental Engineering Laboratory, Faculty of Engineering, Hasanuddin University, Makassar.

2.2. Types of research

The research is an experimental research conducted in a laboratory. To obtain research data, the source of data used consisting of primary and secondary data. The primary data is obtained directly from a physical model simulation in a laboratory. While, secondary data is obtained from the literature and the existing results of research as previously conducted in laboratories and elsewhere in related to the study of flow patterns in the piping system.

2.3. Design of test equipment

The design of test equipment is a pipe network made of acrylic pipe with an inner diameter ($d1$) 64 mm and ($d2$) 44 mm, head height (h) 100 cm. The fluid used is standard water with a viscosity 1.14 cp, fat oil 0 mg/L, and specific gravity 1.0304 gr/cm^3 . Figure 1 shows a rectangular-shaped pipeline model with dimensions of 600 cm long, 100 cm wide and 7 cm and 6 cm high. This network is equipped with a bottom water reservoir, a top water reservoir, a table as a pipeline seat that can be adjusted, valves as discharge regulators, bends and connections, and a water pumping machine that regulates water supply from the lower reservoir to the upper reservoir.

3. Parameter and research design

The variable of research used to determine water level and flow characteristic is discharge. Discharge used in three variations of discharge with the fluid used is standard water as previously tested at the Environmental Engineering Laboratory. Determination of discharge value can be determined by

measuring the water volume (v) per unit time (t) [3]. Uptake of debit is done when the fluid will pass through the pipeline (Q_{inlet}) and after pass through the pipeline (Q_{outlet}). In general, the procedures of research as follow:

- Prepare the experimental pipeline by regulate the valve so that the fluid will flow throughout the pipeline.
- Prepare the fluid as research material that has been tested for its physical properties and then put it in a reservoir that will be flowed into the experimental pipe.
- By opening the drainage valve, water will flow through the experimental pipe to the final pipe. Flow discharge (Q) is set by adjusting the discharge valve. Calculate the flow discharge by accommodate the water volume (v) per unit time (t).
- Wastewater flow in the experimental pipe continues to be observed until the fluid in the pipe does not exist or stops flowing. Record every change in discharge (Q) that occurs. Repeat the experiment with different discharge (Q) to produce three discharge data (Q).
- Experimental procedures (1) to (4) are done in succession to collect data with different discharges.

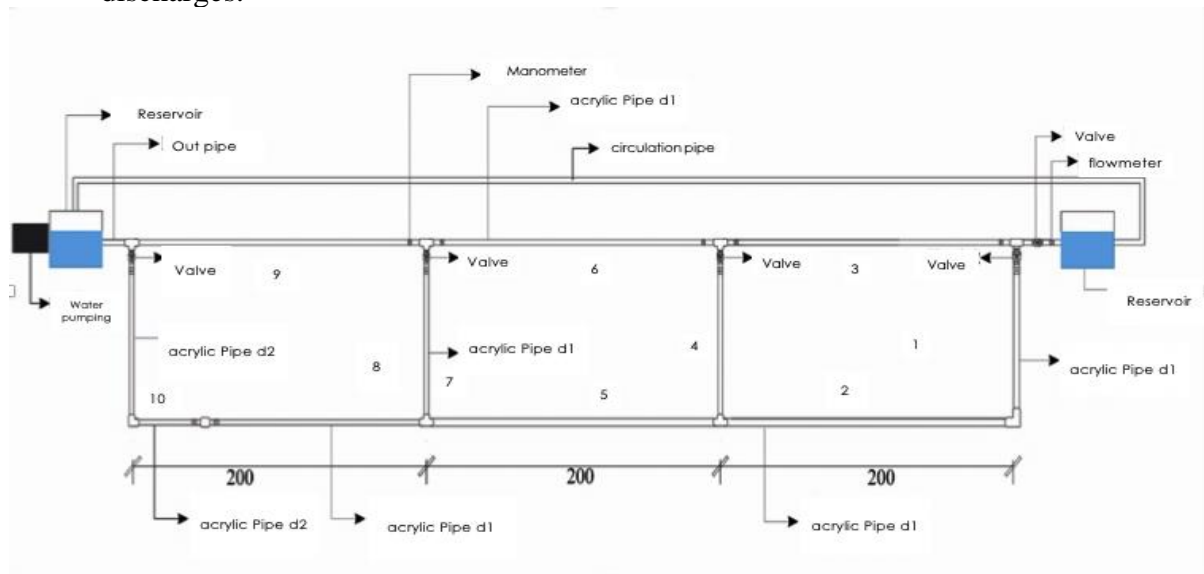


Figure 1. Set Up of Test Equipment.

Data obtained from subsequent experiments were analyzed and summarized the results. The analysis will be done descriptively and analytically. Relationships between significant parameters are made to form dimensionless parameters that are arranged based on the principle of dimensional analysis while still being guided by appropriate relation forms theoretically.

4. Result and discussion

Determination of discharge can be known by doing the opening of the valve. To get the flow discharge through measurement of water volume (v) per unit time (t), the resulting discharge variations are 3.5 l/sec, 1.2 l/sec and 0.5 l/sec. Data collection on water level and flow characteristics in the pipeline is divided into 10 (ten) segments or observation points (OP) for each discharge. The observation points (OP) consists of 100 cm and 200 cm in observation range. These observation points can be seen in table 1.

4.1. Water level

Determination of water level that occurs in the experiment pipeline can be seen and read on the measuring ruler found at each point of observation in the pipeline. The water level at each discharge is recorded at a distance of 20 cm at each observation point (OP). The following graph illustrates the water level at each observation point (OP). Water level at each observation point (OP) with an

observation range of 100 cm can be seen in figure 2. Water level at each observation point (OP) with an observation range of 200 cm can be seen in figure 3.

Table 1. Observation points of the pipeline

No	Observation Point (OP)	Observation Range (cm)
1	OP 1	100
2	OP 2	200
3	OP 3	200
4	OP 4	100
5	OP 5	200
6	OP 6	200
7	OP 7	100
8	OP 8	200
9	OP 9	200
10	OP 10	100

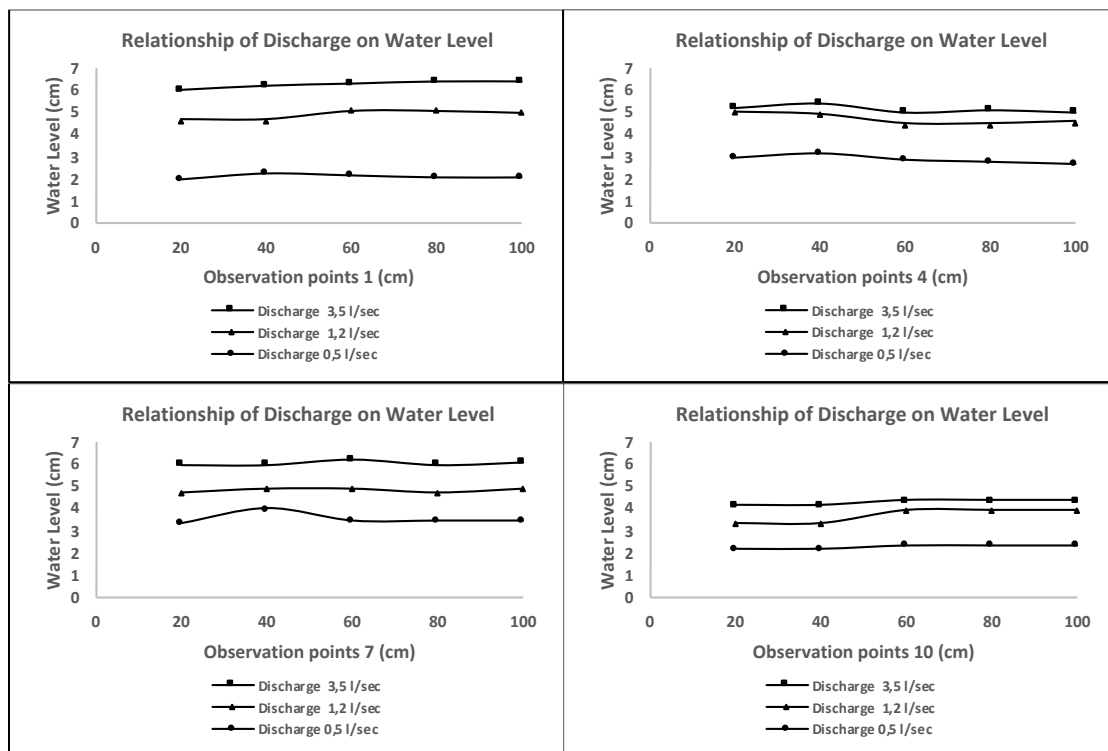


Figure 2. Relationship of Discharge on Water Level at an Observation Range of 100 cm.

Based on figures 2 and 3 it can be seen that the discharge of 3.5 l/sec is higher water level than 1.2 l/sec and 0.5 l/sec. It caused the increase of drainage volume, the greater of discharge. Also, the graph illustrates the flow patterns that occur.

4.2 Flow characteristics of pipe lines

To describe the flow in the pipe, it can be classified into types of flow namely laminar, turbulent and transition. In analyzing the flow in a closed channel, it is very important to know the type of flow that drainage in the pipe [5]. For this reason, the large of Reynold’s number must be calculated by knowing the parameters of known amount. Based on the liquid thickness μ (*mu*), mass density ρ (*rho*) and pipe

diameter (D) and the large of Reynold (Re) number by using equation (2), it can be known the flow characteristics of pipeline. As data of water level in figures 2 and 3 provide a visual illustration of flow at each observation point.

In figure 2 with a range of 100 cm observation point lie in the middle of the experiment pipe span. Flow patterns tend to laminar. While, in figure lie on the edge of the observation point tends to turbulent, especially at observation points 3, 6 and 9. It caused by the observation point lie in the area near the upstream which has high pressure and velocity. Flow characteristics as seen in the pipeline vary depending on the flow discharge that occurs. The greater of drainage, the greater of velocity, and the flow pattern is formed irregularly. The resulting flow patterns from this experiment are laminar, transition and turbulent.

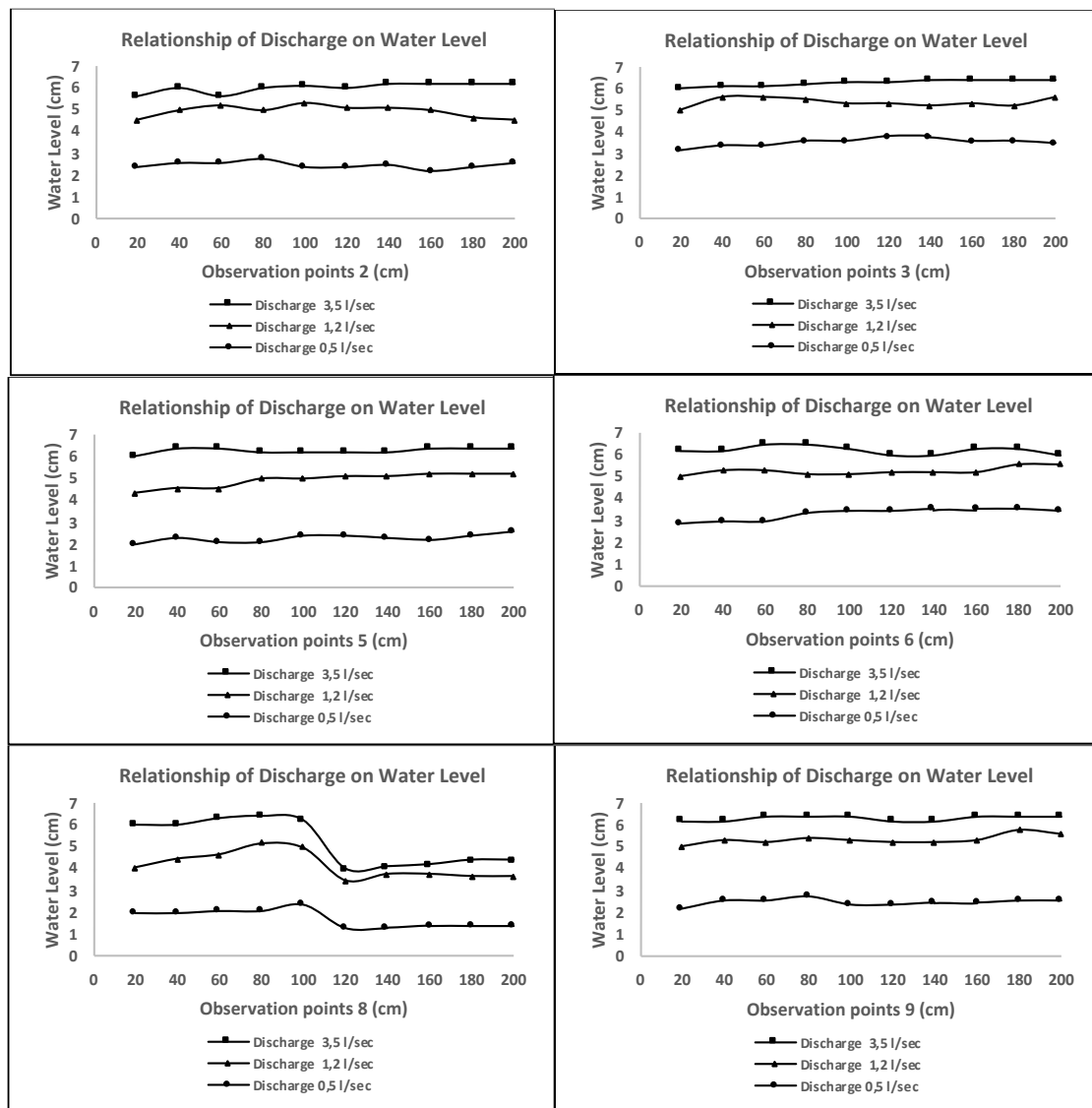


Figure 3. Relationship of Discharge on Water Level at an Observation Range of 200 cm.

5. Conclusions

- The relationship of discharge and water level from the bottom of the pipe is directly proportional. The greater of discharge, the greater of water level from the bottom of the pipe.
- The greater of discharge flow, the greater of flow velocity on the pipe. This relationship is directly proportional between the flow velocity and discharge.

- The greater of flow discharge causes a shift in flow characteristics where the low discharge value is laminar and transition while the high discharge values is turbulent.

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