Design of Tools And Experimental Study of Filtration Systems

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ABSTRACT

On this research, the tool design and analysis of the head loss phenomenon in the filtration system experiment was done to determine the effect of head loss caused by variations in silica sand and silica sand composition. This design was to determine the performance of the head loss experimental device on the filtration system. In this design, most use sand as one of the main filter media, with 3 variations of Very Fine sand 0.05-0.1mm, Medium 0.1-0.25mm, Coarse 0.5-1.0mm, and 3 various compositions PS 50% KA 50%, PS 70% 30%, PS 80% 20%. In designing the head loss test channel using a variation of filtration to know value of head loss in the filtration system, a digital water meter to measure the water discharge is used to measure the pressure at the inlet and pressure at the outlet. This tool is also designed in a modular way, where in the experiment variation and without filtration can be used interchangeably. Experiments carried out using filtration produced an average theoretical value on the composition of PS 50% KA 50% sand with a variation of Very Fine silica sand 0.05 – 0.1 mm smaller than the composition of PS 70% KA 30% and PS 80 % KA 20% with a variation of Very Fine silica sand 0.05 – 0.1 mm and a variation of Very Coarse silica sand 0.5 – 1.0 mm. Meanwhile, the higher head loss value shows the composition of PS 50% KA 50% with variations of Very Coarse Silica Sand 0.5 – 1.0 mm.

I. INTRODUCTION

Water is necessary for all living things, including humans. The human need for water is endless, especially if clean water is available. Adequate provision of hygienic water plays a very important role in improving environmental health, because water is a very important part of human life, and to maintain human life, we always need clean water. Availability and existence of drinking water in rural areas are very crucial because the people in these areas are very active. (Rakhim et al., 2020).

Management of hygienic water needs can be done in several ways depending on the origin of the vehicle and the existing infrastructure. Piping and non-piping systems are included in the clean water system design (Monalisa, 2018). The piping system is used to carry the flow from one place to another. Flow occurs due to pressure divestment in the 2 regions, which may be caused by a pressure drop at the water level or the pump. Head loss is the decrease in circulation flowing through the pipe. The use of pipes in simple installations is also intended to assist research and planning for the supply of clean water itself.

Filtration is the process of separating solid particles from a liquid by passing the liquid through a filter medium or partition in which the solids are retained. It is possible to build portable water purifiers with modified filters for improved water quality. The function of this research is to provide a poor-quality water supply to become a good-quality water source. Portable filters are easy to use and maintain due to their simple shape and easy removal of the filter element.(Yaqin et al., 2020).

Designing and building a head loss phenomenon test tool with a filtration system so that it can be applied to research or learning studies of basic theoretical analysis in the fields of mechanics and design, construction, and heat transfer in the design of water piping channels as simple as phenomena with fluid variations with filtration and without filtration.

Analyzing the value of the head loss phenomenon in the pipeline with variations of silica sand in the filter so that a simple water pipeline phenomenon with variations with filtration and without filtration can be realized which can be utilized and modified again as a means of research and learning studies. Conduct experiments or variations based on filtration media to obtain parameters that affect head loss in filtration system experimental equipment.

II. LITERATURE REVIEW

A. *Fluid Flow*

A substance that can flow easily in the form of a liquid or stream is called a fluid. Fluid flows have much smaller molecular bonds than those found in solids which results in fluid flows that flow more easily and have a relatively smaller head loss in deformation due to friction.

Lack of power in the fluid in the piping flow can occur because there are pipes that flow fluid, bending the pipe, narrowing the pipe (contraction), and widening the pipe (expansion). Therefore, a test is carried out to observe pipe flow with a version of the pipe diameter along the fluid movement as a characteristic of the resistance value caused by the additional components.

The average flow velocity, density, viscosity, and pipe diameter all have a significant influence on the character of internal flow (inside the pipe) (Rahayu et al., 2021).

A. Fluid Flow Debit (Q)

To find out the water discharge, the formula used is like equation 2.1

$$Q = \frac{V}{t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

B. The Reynolds number

To evaluate the value of this kind of flow using the (Reynolds number) dimensionless parameter as follows:

$$Re = \frac{\rho \text{ varg D}}{\mu} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)$$

Laminar, transition, and turbulent flows can be distinguished by the Reynolds number, which is a dimensionless number.

So if:

Re < 2100 then the flow is laminar

Re > 4000 then the flow is turbulent

C. Head loss

The force required to convert a unit mass of fluid into a suitable unit length as the corresponding unit pressure drop is known as the unit pressure drop (head loss). Head loss consists of major head loss (Hf), minor head loss (Hm), and total head loss (Htot) (Putra, 2017).

$$\text{Head Total} = \left(f.\frac{L}{D} + \Sigma KL\right)\frac{V^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots (2.9)$$

D. Filtration System

The filtration method is an appropriate technology that is simple, effective, efficient, and inexpensive, filtration is also commonly used as an experimental tool for learning media. Filtration is also an initial process for the separation between liquids and solids and is a form of a mixture of 2 or more substances that are not of the same nature but have relatively large size dispersed particles (colloids). In the filtration process, a filter media with a certain particle size is used. Because there is a pressure difference between the inside pressure and the outside pressure, the process of separation infiltration can be carried out.

To remove particles that cannot be absorbed by activated carbon, activated carbon is one of the filter media that can be used together with other technologies in water filtration systems. Filter sand, activated carbon, zeolite, bio balls, green sand, and manganese are some examples of filter (Yaqin et al, 2020).

E. Filtration Media

According to SNI 3981 (2008) In the filtering process, large enough particles will be filtered in the sand media, while the zeolite and activated charcoal media function to filter bacteria and metal content in water. The space between the grains serves as a place for the sedimentation of impurities in the water. The size (diameter) of the media grains affects the porosity, filtration rate, and filtering power. The thickness of the media will affect the duration of the flow and the amount of filtering power. The grain size of the sand used affects the absorption of water. The smaller the size of the sand, the aggregate structure or mineral groups will be denser so that the filter results will be better up to a certain limit (Sangadah and Kartawidjaja, 2020).

The size of sand according to the USDA classification (1938) is divided into:

1) Very coarse sand: 1.0–2.0 mm
2) Coarse sand (coarse sand): 0.5–1.0 mm
3) Medium sand (medium sand): 0.25–0.5 mm
4) Fine sand (fine sand): 0.1–0.25 mm
5) Very fine sand (very fine sand): 0.05–0.1 mm.

F. Activated Carbon

Activated carbon (Activated charcoal) is black, odorless, tasteless, and has much greater absorption compared to charcoal which is currently not subject to any activation method and has a large surface area ranging from three hundred to 2000m/g. Surface because carbon can adsorb gases and vapors or substances in the answer. The amount of activated charcoal produced depends on the fabric used, for example, coconut shell produces soft charcoal that can be used to purify water.

The best percentage of reduction in Fe levels in media with a diameter of 0.6-1.18 mm changed to 93.104% for activated carbon media under Indonesian Industrial Standards (SII No. 0258-79) (Fitriani, 2014). 80 cm thick sand and 40 cm thick activated carbon work with a difference in Fe content of 98.12%, according to research by Panigoro (2015) (Sangadah and Kartawidjaja, 2020).

G. Silica Sand

Quartz sand (SiO2) is used to remove silt or soil and sediments obtained from the source. In this media, materials containing impurities or materials that are different from the microbes in this media are filtered. Works well to remove physical properties like turbidity or sludge and odors. Silica sand is generally used as a filter in the initial range. The only treatment for silica sand filter media is the backwash method approach. The backwash method is a form of preventive maintenance that allows filter media to be reused (Yaqin et al, 2020).

Quartz sand has a combined composition of SiO2, Fe2O3, Al2O3, TiO2, CaO, MgO, and K2O, translucent white or other colors depending on the impurity compounds, hardness 7 (Mohs scale), specific gravity 2.65, melting point 17 -150oC, hexagonal crystal form, specific heat 0.185.

H. Filter Media Arrangement

The composition of the silica sand-activated carbon and activated carbon-silica sand filter media with each filter media size of 0.005mm–0.1mm. The decrease in Fe content with activated silica-carbon sand filter media on media with a diameter of 0.6-1.18mm was 89.511% and on a diameter of 1.18-2.36, mm was 83.013%. Arrange the filter media with a white sponge with a thickness of 0.005m on the top layer, then silica sand with a thickness of 0.2m, covered with a white sponge with a thickness of 0.005m on the top layer, then silica sand with a thickness of 0.2m covered with a white sponge with a thickness of 0.005m as a separator between the filter media and the next arrangement is activated carbon with a thickness of 0.2m, coated with a white sponge with a thickness of 0.005m as a separator with gravel buffer media with a thickness of 0.05m which is at the bottom layer (Sangadah and Kartawidjaja, 2020).

The filter thickness is 40cm, with a filter media thickness of 20cm of silica sand and 20cm of activated carbon. Whereas silica sand media with a height of 10cm has a turbidity removal efficiency of 42%, a height of 30cm with a removal efficiency of 57%, and a height of 50cm with an efficiency of 62%.

III. METHODS

A. *Tool design description*

This equipment is designed in a modular way by using 8 sockets in the design with filtration, each design on the fittings and measuring devices are connected using a socket to make it easier to disassemble according to the channel that will be tested. Testing with a filtration system uses 2 flowmeters to determine the pressure before and after using filtration (P in and P out), the other components are only used as water flow so that the flow position remains stable. The length of the design support board is 80cm and 160cm wide. The installation drawings can be seen in Figure 3.2.

This equipment is designed in a modular way using 6 sockets in a design without filtration. Testing without using filtration uses 2 flowmeters to determine the inlet and outlet pressures (P in P out). To change the test without a filter, you can do it by dismantling the filtration system, because the test that will be carried out in the experiment without a filter is different from the test in the experiment using a filter.

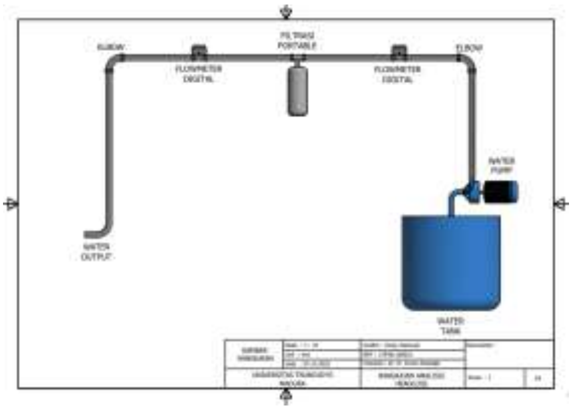

Fig. 1. Installation design within filtration

The following is an explanation of the tools and materials used in the installation of phenomena with and without a filtration system.

1. Frame
2. Water pumps
3. Pipe ¾ inch
4.Elbows 90°
5.Digital flowmeters
6. ¾ inch socket connection
7. Portable filtration
8. Filtration housing ¾ inch
9. Filtration bracket
10. Water bath
11. Tee ¾ inch

B. *Filtration Arrangement Variations*

The experimental design used in the analysis of the head loss phenomenon in a filtration system experimental device with the specifications of a cartridge length of 260mm, width of 64mm and a sponge of 25mm;

1. Comparison 1

The composition of the variations used in empty cartridge filtration with a percentage of 80%: 20%. Silica Sand as much as 80% (168mm) and 20% Activated Carbon (42mm).

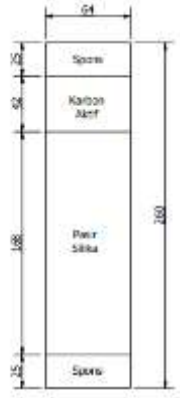

Fig.2. Filtration variations of PS 80% KA 20%

2. Comparison 2

The composition of the variations used in the empty cartridge filtration with a percentage of 70%: 30%. Silica Sand as much as 80% (168mm) and 20% Activated Carbon (42mm).

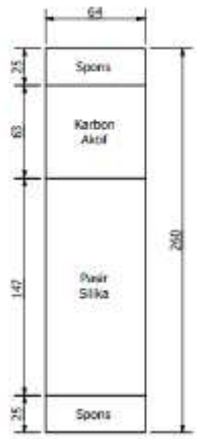

Fig. 3. Filtration variations of PS 70% KA 30%

3. Comparison 3

The composition of the variations used in empty cartridge filtration with a percentage of 50%: 50%. Silica Sand as much as 50% (105mm) and 50% Activated Carbon (105mm).

Fig. 4 Filtration variations of PS 50% KA 50%

C. *Preparation of Trial Design*

The experiment of this tool was designed to determine the value of head loss of filtration and non-filtration systems, the device designed is influenced by factors such as head loss phenomenon, due to friction, filtration and variable cross-sectional area. Theoretically, the loss coefficient caused by the geometry of the pipeline is very influential on the occurrence. Experimental data collection for the dependent variable (Head loss) with the composition of PS 80% KA 20%, PS 70% KA 30% and PS 50% KA 50% using silica sand size 3 variations, namely very coarse 0.1-2.0mm, medium 0 .25-0.5mm, Ultra Fine 0.05-0.1mm. The results of the calculation of the filtration variation experiment can be displayed in a table as shown in Table 3.1

TABLE I RETRIEVAL OF DEPENDENT VARIABLE DATA (HEAD LOSS)

		No	Variabel bebas 1: Ukuran pasir silika					
			Sangat Halus 0,05-0,1 mm		Sedang 0,1-0,25 mm		Sangat Kasar 0,5-1,0 mm	
			In	Out	In	Out	In	Out
Komposisi Variabel bebas 2:	Komposisi PS 50% KA 50%	1						
		2						
		3						
	M Rata-rata							
	Vin Rata-rata							
	Vout Rata-rata							
	Head Loss							
	Komposisi PS 70% KA 30%	1						
		2						
		3						
	M Rata-rata							
	Vin Rata-rata							
	Vout Rata-rata							
	Head Loss							
	Komposisi PS 80% KA 20%	1						
		2						
		3						
	M Rata-rata							
	Vin Rata-rata							
	Vout Rata-rata							
	Head Loss							
	Tanpa filtrasi	1						
		2						
		3						
	Head Loss 1							
	Head Loss 1							
	Head Loss 1							

IV. RESULTS

The frame functions as a support for the installation made of angle iron measuring 3x3 which is connected in the form of a vertical board with dimensions 100cm long and 160cm wide, pump support board 50cm high, plywood using a thickness of 14mm and cut with a width of 160cm and a height of 80cm as a tool holder such as flowmeter, ¾ pipe, filtration, pump.

A. *Data retrieval*

Based on the results of experimental tests on the design average head loss with a variation of Very Fine Silica Sand 0.05–0.1 mm, the condition for the head loss value is the composition of 80% PS 20% KA 20%. smaller than the composition of PS 50% KA 50% and PS 70% KA 30%. While the composition of PS 50% KA 50% produces the greatest head loss. Such a result is because the faster the flow rate, the higher the value produced by the digital flowmeter, and the composition of PS 80% KA 20% filtration installed does not cause head loss that is too large to produce a small flow rate.

The results of subsequent experimental tests on the design mean head loss with a variation of Medium silica sand 0.1–0.25 mm resulted in a condition where the head loss value for the composition of PS 70% KA 30% was smaller than the composition for PS 80% KA 20% and PS 50% KA 50%. While the composition of PS 50% KA 50% produces the greatest head loss. Such results are due to the fact that the faster the flow rate, the higher the value produced by the digital flowmeter, and the composition of PS 70% KA 30% filtration installed does not cause too large a head loss resulting in a high flow rate.

The results of subsequent experimental tests on the design mean head loss with a variation of Very Coarse silica sand 0.5 – 1.0 mm resulted in a condition where the head loss value in the composition of PS 80% KA 20% was smaller than the composition of PS 50% KA 50% and PS 70% KA 30%. While the composition of PS 50% KA 50% produces the greatest head loss. Such a result is because the faster the flow rate, the higher the value produced by the digital flowmeter, and the composition of PS 80% KA 20% filtration installed does not cause head loss that is too large to produce a high flow rate.

B. *Factorial Level Combination*

This sub-chapter discusses the factorial level combinations that have the most influence on the experimental results of the head loss phenomenon using a 2-level filtration device:

1. Level factorial composition 3 repetitions 5050 (PS 50% KA 50%), 7030 (PS 70% KA 30%) and, 8020 (PS 80% KA 20%).

2. Factorial level of silica sand variations of 3 kinds 0.05 – 0.1 mm (0.005), 0.1 – 0.25 mm (0.10), 0.5 – 1.0 mm (0.50) based on the average value of the head loss calculation results.

C. *General Factorial Regression*

ANOVA results show that the average value that has a significant effect on the value of head loss is the factor that comes from the size of the sand. This is evident from the P-Value of Sand 0.006 <0.05 which indicates a significant condition for this factor. Meanwhile, the composition factor does not show a significant effect. This is evident from the Composition P-Value of 0.965 > 0.05 indicating an insignificant condition.

TABLE 2 RESULT OF *ANALYSIS OF VARIANCE*

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	10	0.000001	0.000000	1.59	0.196
Blocks	2	0.000000	0.000000	0.40	0.679
Linear	4	0.000001	0.000000	3.64	0.027
Komposisi Karbon Aktif	2	0.000000	0.000000	0.04	0.965
Ukuran Pasir	2	0.000001	0.000000	7.24	0.006
2-Way Interactions	4	0.000000	0.000000	0.15	0.960
Komposisi Karbon Aktif*Ukuran Pasir	4	0.000000	0.000000	0.15	0.960
Error	16	0.000001	0.000000		
Total	26	0.000001			

D. *Chart of Normal Probability*

This optimal standard level chart can be determined and seen from the graph of the average calculation results for composition levels (5050.7030 and, 8020) and sand (0.05, 0.1 and, 0.5). Figure 4.15 below is a graph of the responses obtained from Minitab 19 based on the average values for composition and sand. Based on the

Pareto Chart diagram in the Figure, it is known that the factor that contributes most to the average is the size of the sand.

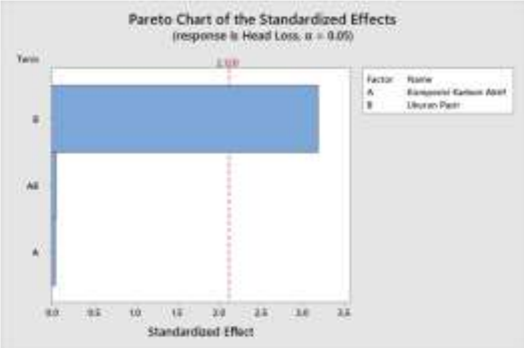

Fig. 5. *Standardized effects*

V CONCLUSSION

In designing the head loss phenomenon test equipment, the head loss phenomenon experimental tool is used in water pipe installations. To measure the flow rate used in finding flow velocity and time using a digital flowmeter. The design of this tool also requires fittings in the form of elbows and shocks which are used to connect pipes, and use pipes connected to threaded sockets so that each gauge and fitting can be disassembled (modular). The frame is used as a support for the installation which is shaped like a board according to the dimensions of the installation channel after it is assembled. Based on the experiments carried out on the design of the head loss phenomenon with the fitting system, the resulting value of head loss in the composition of PS 50% KA 50% with variations of Very Fine silica sand is 0.05–0.1 mm smaller than the composition of PS 70% KA 30% and PS 80% KA 20% with a variation of Very Fine silica sand 0.0 –0.1 mm and a variation of Very Coarse silica sand 0.5–1.0 mm. Meanwhile, the higher head loss value shows the composition of PS 50% KA 50% with variations of Very Coarse Silica Sand 0.5–1.0 mm. In the data collection experiment using the DOE Factorial, the P-Value for Composition was 0.965> 0.05 indicating an insignificant condition and the P-Value for Sand 0.006> 0.05 indicated a significant condition. The factorial chart shows the condition that sand (B) is very influential on the occurrence of head loss in water flow. Based on the experiments carried out on the results of the trial design of head loss without filtration, it produces conditions with a high average head loss value because there is no head loss which inhibits it so that the flowmeter value that comes out is quite high.

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