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Design and Analysis of Self-Cleaning Type Water Strainer

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***Abstract* - Water pollution is a major problem in today's world. Various industries dump their wastewater into rivers, lakes, and estuaries without proper and adequate treatment so they still contain high pollutants. All of these pollutants have caused an imbalance in water conditions and quality, thus endangering the survival of aquatic creatures, the environment, and humans. This study aims to examine one of the technologies designed to help overcome the problem of water pollution, namely a self-cleaning type of water strainer. A self-cleaning type of water strainer is a filtering device that can help remove particulates in a flowing fluid. The water strainer will collect dirt and debris without significantly hampering the performance of the flow system. The design designed and analyzed is a self-cleaning type water strainer with a DC motor as the blade drive. The components that make up the water strainer in this design include the body, cover, motor, exhaust valve, blade, and wire mesh. Design analysis using the finite element method (FEM) and ANSYS to determine the flow velocity out of the water strainer outlet. Based on the value of the discharge that enters through the specified inlet of 100 m^3/hour, the velocity of water leaving the outlet of the water strainers is 5.51605 m/s.**

Keywords: FEM, design, water filter, pollution, filtration.

I. INTRODUCTION

Water pollution is one of the major problems in the world today. Various industries such as petrochemicals, pharmaceuticals, textiles, electronics, mechanics, and so on, discharge their wastewater into rivers, lakes, and estuaries to provide adequate and adequate treatment so that they still contain elements of pollutants that are harmful to life. This pollutant has caused a loss of balance in the water environment it can endanger aquatic life and the surrounding environment [1]. In addition to industrial waste factors, the increasing demand for clean water and the pollution of clean water by human activities, caused by industrial progress and the increase in the number of human populations, further exacerbate the condition of the scarcity of water resources in the world [2]. One solution that is often raised and studied is the effort to treat dirty water, wastewater, seawater, or water that is not suitable for use into clean water suitable for use that is ready to be reused in supporting human activities [3].

One of the methods to clean water from pollutants is by means of filtration. Filtration is a process of cleaning solid particles in a fluid by passing the fluid through a filtering medium, where later solids will be deposited. Filtration separates colloids or solid particles from a fluid using a filtering medium or filter. Water containing a solid or colloid is passed through a filter medium with a pore size smaller than the size of the solid [4]. Filter operation usually requires a pressure difference to move fluid across the filter media, and this condition can be affected by fluid pressure upstream or downstream suction [5].

Assunção et al [6] classify filter mechanisms into two types, namely layer filters, and disc filters. Filter layer filtering uses the principle that the filter pores are smaller than the diameter of the particles to be filtered. While the filtering disc consists of a ring device with grooves molded on a cylindrical and perforated central support. The water will be filtered as it passes through the conductor.

A water strainer is a filter device that can help remove or separate impurities in the flowing fluid. The device is capable of collecting dirt and debris without significantly hampering the performance of the flow system. Filter design can vary widely because it must adapt to the needs and where the filter will be applied [7]. The application of water strainers is quite diverse in water filtration systems. A. Bennet [8] describes water strainers as widely applied in the industrial world. Some of the applications described include seawater filtration, drinking water filtration, wastewater filtration, the electricity industry, and food processing. Meanwhile, A. Silva et al. [9] applied an automatic water strainer to filter rainwater.

The location of the application of water strainers which varies greatly also gives rise to various types of water strainers as part of the adjustment. Several types of water strainers exist including flat type, cone type, "T" type, "Y" type, basket type, multiple types, type self-cleaning, and oil burner type [10].

This study aims to design a self-cleaning type water strainer with limited conditions for the design, namely the rotating speed in the strainer is 120 rpm and the water flow is

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100 m^3/hour at the inlet. The design of the self-cleaning type water strainer will be adopted from those already on the market, and will be redesigned according to the location requirements and allowable dimensions and will analyze the flow velocity value on the outlet side. The finite element method approach in this study is used to support the process of analyzing the speed of water flow coming out of the water strainer outlet and knowing the streamline of the moving water flow.

The finite element method is a numerical technique for solving problems described by partial differential equations or can be formulated as functional minimization. A domain of interest is represented as a collection of finite elements [11]. The finite element method facilitates the analysis process by presenting a visual display of the phenomena that occur but is cost-effective because there is no need for prototyping.

In the mechanical design process, mechanical engineers need to consider certain limitations such as design and product costs, manufacturing time, product usability, or other limitations [12]. In this study, the output produced is the design of a water strainer that meets the specified needs, as well as analysis with ANSYS to determine the speed of water coming out of the designed self-cleaning type water strainer outlet.

II. METODOLOGY

The research was conducted using a simulation method using Solidwork software for the design process and Ansys for analysis of the flow rate at the outlet side of the designed self-cleaning water strainer. The research process begins with the identification of the problems experienced. After understanding the problem, then design a 3-dimensional water strainer. The design that has been designed then goes through a meshing process and fluid flow velocity analysis using the finite element method.

III. RESULT AND DISCUSSION

3.1 Water Strainer Design Process

3.1.1 Results of the Study on the Reference Design

The type of water strainer that the design adopted is the self-cleaning type, which is the type that can work to clean water continuously without disturbing the water flow. The design reference is taken from a water strainer manufactured by Iavant Filtering System, Brazil, the Iavant FA-20 model which has an inlet and outlet inner diameter of 80 mm, and a total surface area of the filtration element is 272,376 mm2 [13]. The design reference is shown in Figure 1.

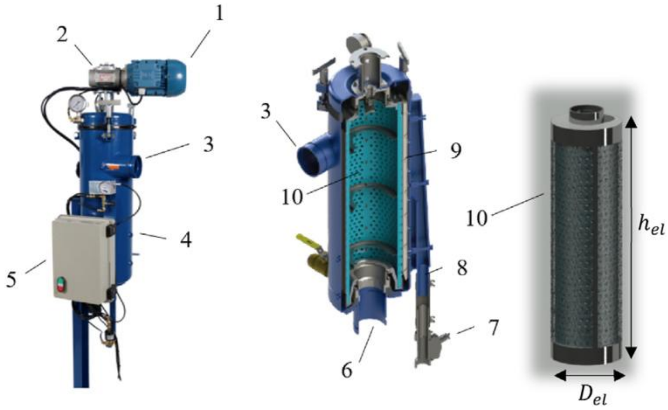

Figure 1: Water Strainer Iavant FA-20 (1: electric motor; 2: gearbox; 3: filter inlet; 4: filter housing; 5: control panel; 6: filter outlet; 7: flushing valve; 8: flushing pipe; 9: flushing cavity and brushes; 10: filter element; D_{el}: diameter of the filter element; h_{el}: diameter of the filter element). [13]

3.1.2 Water Strainer Components

The designed water strainer will be applied to the water disposal system and it is attempted for the manufacturing process not to incur too large a cost. The design concept that emerged was a simple concept to make it easy to manufacture and maintain but without reducing the important components in it, as well as reducing the dimensions of the components. The components needed include the body as a place where the water will be filtered with dimensions of 400 mm high and 165 mm in diameter. Inlet and outlet channels for water inlet and outlet are 3 inches in diameter. The lid will function as a cover as well as a place for the electric motor holder. The dimensions of the blade as a dirt sweeper attached to the filter element are designed according to the space that exists between the body and the wire mesh. The filter element is in the form of wire mesh as a colloid filter contained in the water. DC electric motor as blade drive with 120 rpm specifications. A sewer is a place to dispose of colloid that has been separated from the water.

3.1.3 Material

The materials used are relatively inexpensive and easy to produce. PVC material is selected on the body, drain, inlet, and outlet. For components that are produced requiring design flexibility, Polylactic Acid (PLA) material is chosen with a production process plan using a 3D printer.

3.2 The Result of the Self-Cleaning Type Water Strainer Design

Water strainer design modeling was carried out using Solid works software. The water strainer has several components, including the main tube (body), cover, helical blade, stainless wire mesh, and a driving motor. The design of the water strainer that has been designed is shown in Figure 2.

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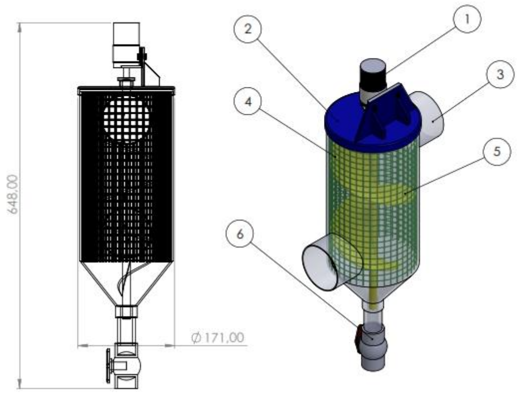

Figure 2: Water Strainer Design (1: electric motor; 2: cover; 3: water inlet; 4: wire mesh; 5: blade; 6: disposal valve)

3.2.1 Lid/Cover

The lid functions as a water strainer cover and as a motor holder for the blade. The lid is designed to be divided into two parts so that it can be removed from the body for maintenance purposes. The bottom lid attaches to the body permanently and has holes all around for mounting nuts and bolts. The top lid serves as a motor mount for the blade and has a hole in the center with a diameter of 30.5 mm for bearing mounting. The selected bearing has an inner diameter of 15 mm so that the shaft on the blade does not rub directly against the lid. Installation between the top lid and bottom lid using M8 nuts and bolts. The lid has an outer diameter of 205 mm and the same thickness is 5 mm. The lid is designed to be made with a 3D printer with Polylactic Acid (PLA) material. The 3D print will then be coated with resin to make it water-resistant. The lid design can be seen in Figure 3, Figure 4, and Figure 5.

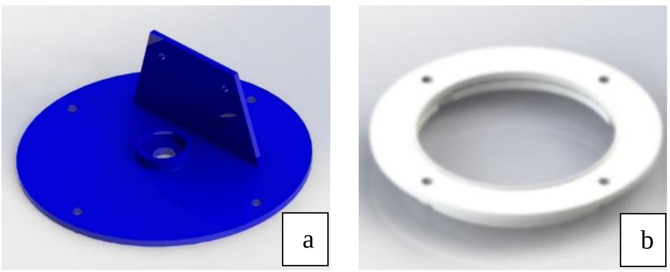

Figure 3: Cover/Lid Design (a) Top Lid, (b) Bottom Lid

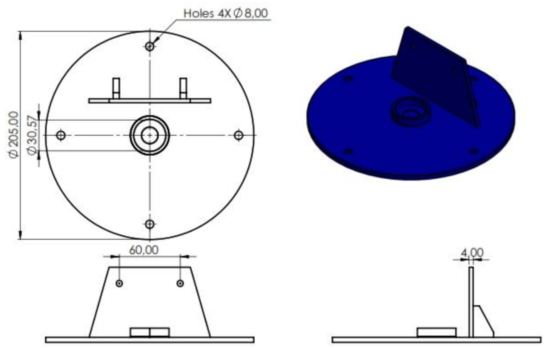

Figure 4: 2D Design of the Top Cover/Lid

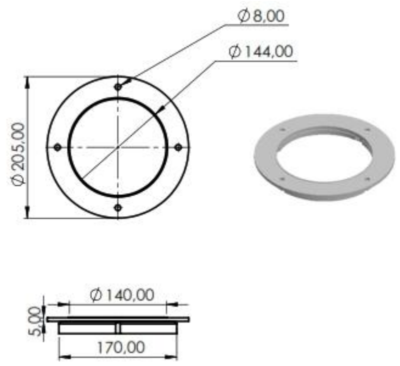

Figure 5: 2D Design of the Bottom Cover/Lid

3.2.2 Blade/Helix Drive Motor

The drive motor is useful for turning the blade/helix. The motor specifications used are DC motors with a maximum speed of 200 rpm and a voltage of 12 volts. These specifications were chosen because of the affordable price with sufficient specifications. The motor is equipped with a coupling shaft and a motor mount. The coupling shaft has an inner diameter of 10 mm according to the diameter of the motor shaft. The motor used is shown in Figure 6.

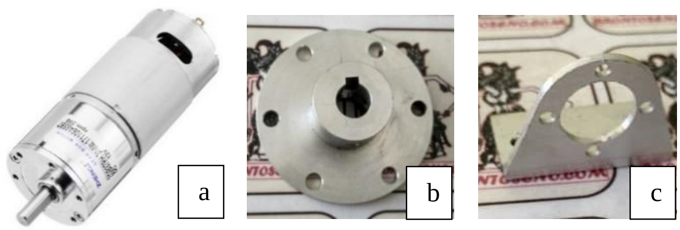

Figure 6: (a) DC Motor, (b) Motor Coupler, (c) Motor Mount[14]

3.2.3 Body

The design of the water strainer body and the main components of the body can be seen in Figure 7. The detailed dimensions in the 2D drawing are shown in Figure 8.

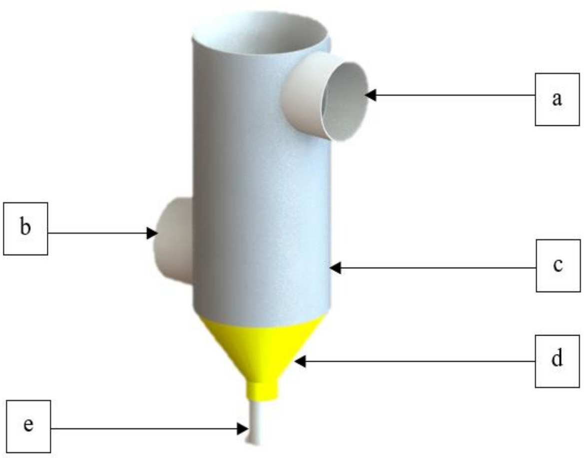

Figure 7: Body Design (a: water inlet; b: water outlet; c: main body; d: cone; e: disposal pipe)

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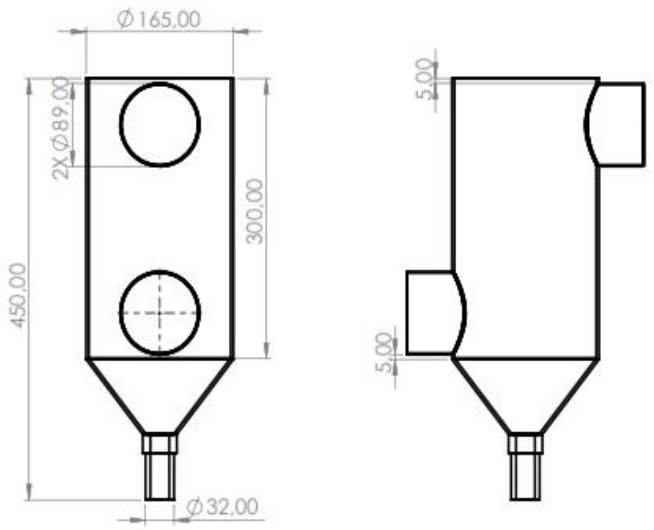

Figure 8: 2D Body Design

The function of the components in the body water strainer shown in Figure 7 can be explained as follows:

a. Inlet

The inlet is the entry point for the water flow. The inlet is designed to be constructed using a 3-inch PVC pipe.

b. Outlet

The outlet is where the filtered water comes out. The outlet is also designed to be made using a 3-inch PVC pipe.

c. Body

The main body functions as a place for all components to be connected and as a place for water to flow to be filtered. The body is designed to be made using a 6-inch PVC pipe with a height of 300 mm.

d. Cone

The cone is marked in yellow in figure 8. The cone is useful as a connector between the main tube and the drain. Cones are designed to be made using 3D printing made of PLA. The design of the cone height is 100mm.

e. Sewer

As the name implies, the sewer serves to remove water that still contains impurities that are not filtered properly. At the end of the drain valve is installed. The drain is designed to be made using a 1-inch PVC pipe with a length of 50 mm.

3.2.4 Helical Blade

The blade is connected to the drive motor to rotate the water-containing impurities. The helix rotation aims to rotate the water so that it is filtered on the stainless mesh installed in the tube wall. The blade has a span specification with a diameter of 150 mm, a height of 422 mm, and a shaft diameter of 14 mm which is then coupled with a motor that has the same hole- diameter. The blade is designed to be made with a 3D print made of PLA, by dividing it into several parts. The blade design is shown in Figure 9 and the 2D design is shown in Figure 10.

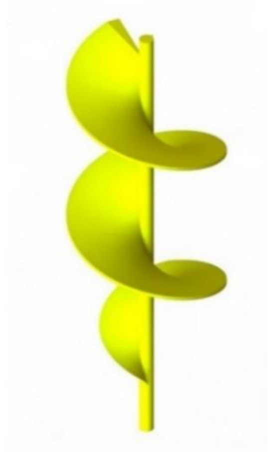

Figure 9: Helical Blade Design

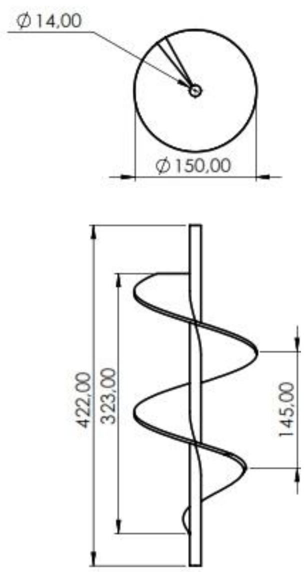

Figure 10: 2D Blade Design

3.2.5 Wire mesh

The wire mesh that surrounds the inner wall of the tube as shown in Figure 11 serves to catch the dirt contained in the incoming water. At the inlet, the wire mesh is made into a hole according to the size of the inlet diameter with the aim that the dirt in the incoming water is not directly filtered so that it has the potential to block the water inlet. The size of the wire mesh used is wire mesh 4 with a hole-size of 4.33 mm as shown in Figure 12.

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Figure 11: Wire Mesh

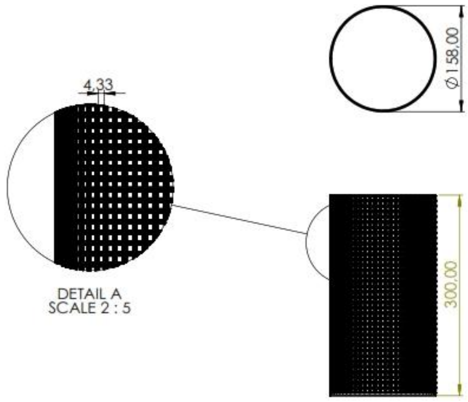

Figure 12: 2D Wire Mesh Design

3.3 Design Analysis

Analysis of water flow velocity at the outlet was carried out using numerical methods with the help of ANSYS software. The steps taken in the analysis process are input geometry that has been made, geometry meshing, setup, and finally the results of the simulation.

3.3.1 Geometry Data Input

The design that has been made is a solid form, so it is necessary to make fluid parts that flow in the design. Fluid parts are made with fill and Boolean subtract features. The geometry input step is shown in Figure 13 below.

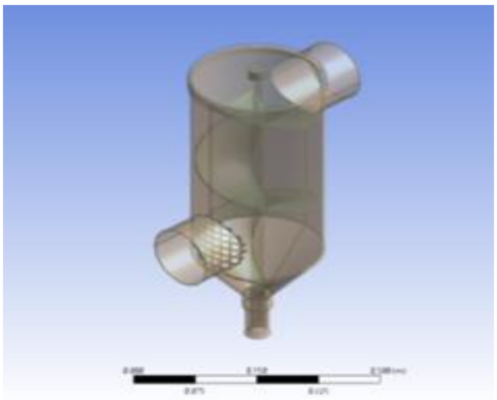

Figure 13: Geometry Data Input Parameter

3.3.2 Meshing

The mesh settings are applied to the design using the default settings with an element size of 2.8259e-2 m. The quality of the mesh obtained is shown in Figure 14 and Figure 15. The figure explains that the geometry has an average mesh-skewness of 0.23477. For mesh statistics, the design has 825,321 nodes and 4,854,930 elements.

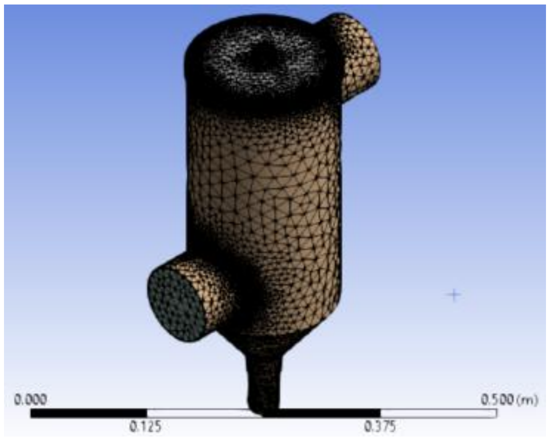

Figure 14: Mesh Result

Details of "Mesh"

Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.900000)
Smoothing	Medium
Mesh Metric	Skewness
Min	7.5395e-005
Max	0.99991
Average	0.23477
Standard Deviation	0.12457
Inflation	
Advanced	
Statistics	
Nodes	825231
Elements	4854930

Figure 15: Mesh Detail

3.3.3 Setup

Setup is a step taken to apply certain boundary conditions to the design. The applied conditions are the type of condition including pressure-based type, absolute velocity formula, and steady time, as well as the presence of acceleration of gravity of -9.81 m/s^2 to the Y axis. The model used is k-ω SST with the selected fluid type of water -liquid and the solid material is aluminum. The helix condition will rotate about the positive Y axis with a rotational speed of 120 rpm. The boundary condition in the form of water inflow velocity is set with a water discharge of 100 m^3/hour. The solution method chosen is SIMPLE and the calculation process is carried out for 2000 iterations.

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The calculation of the conversion of water discharge to velocity is in accordance with Equation 1 below.

$$v = \frac{Q}{A} \qquad (1)$$

Where v is the velocity of the water, Q is the water discharge, and A is the cross-sectional area of the inlet.

3.3.4 Simulation Results

After running the simulation, the results will be obtained which can be accessed in the result. Display of the flow of water, it can be made using the streamline feature in the software with the variable to be displayed, namely velocity. The average velocity that comes out at the outlet is 5.51605 m/s. The results of the streamlined display profile and water flow velocity can be seen in Figure 16. Figure 17 shows a calculator function to display the required value.

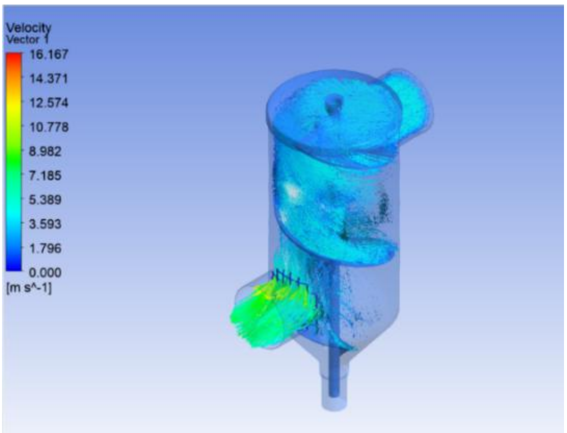

Figure 16: Water Streamline Profile

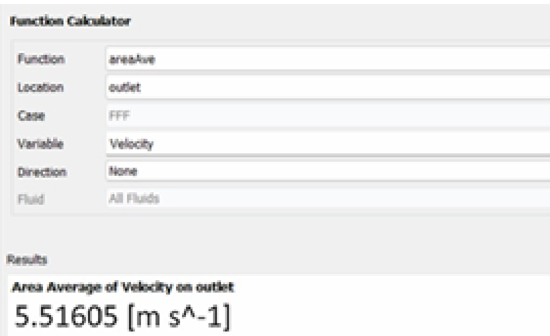

Figure 17: Velocity on the outlet

IV. CONCLUSION

Based on the research that has been done, it can be concluded that the design of the water strainer is designed with a body made of PVC pipe, wire mesh as a dirt filter media, a helix as a water player, and a dirt sweeper to stick to the mesh, DC motor with 12V voltage and 200 rpm rotation, and the valve for the discharge of water that still contains impurities has an average water velocity coming out of the outlet of 5.51605 m/s with an inlet water flow of 100 m^3/hour.

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