3D Airlift Pump Simulation with Variation of Pipe Diameter Based on Computational Fluid Dynamics

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Abstract. Airlift pump is a device for raising water that is the simplest and easiest to assemble, it can even be easily found in the community because basically an airlift pump only requires two fluids, namely water and air which have a mass flow rate to raise the water. However, the airlift pump has a drawback, namely that its efficiency is still quite low, therefore, in this study, it is to determine the efficiency of the airlift pump discharge and also the phenomena that occur based on variations in the inlet mass flow rate and also variations in pipe diameter.This study aims to determine the output discharge and contour pressure and streamline velocity phenomena that occur in the airlift pump by using variations in nozzle diameter and variations in the mass flow rate of the incoming air. The process of designing the geometry of the airlift pump using Solidworks software is then simulated using Computational Fluid Dynamics (CFD) based on ANSYS. The simulation is carried out using multiphase, namely air and water.Increasing the mass flow rate of incoming air at the airlift pump will result in a greater discharge. Increasing the diameter of the pipe results in a decreasing pressure in the pipe and reducing the diameter of the pipe results in a greater streamline velocity in the inner air chamber and results in a more random or turbulent fluid flow.

Keywords: Pump Simulation, Computational Fluid Dynamics, 3D.

1 Introduction

Airlift pump is a tool to raise liquid fluids, be it water or mud, from low places to high places or from one point to another. The working principle is by injecting compressed air through a nozzle into a pipe that is already filled with fluid or can also be a submerged pipe. The pressurized air can push the fluid to move up to the outside of the pipe or through the outlet channel. This can happen because of the buoyant force from the air. The way the airlift pump works is to take advantage of the buoyant force of the air when the air is injected at the bottom of the pipe, because the hydrostatic weight of the air and water mixture in the pipe becomes smaller than its surroundings, this causes this mixture to rise [1]. Airlift pumps can be applied in everyday life in pond water management, helping to circulate fish pond water, and can also increase the supply of oxygen in ponds, applications for operational gardening activities have also been carried out [2], also in aquaculture systems [6].

Airlift pumps have a very simple construction and minimal maintenance, one might even say without any significant maintenance compared to other types of pumps,

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because of this very simple construction, airlift pumps have relatively low assembly costs and materials are easy to obtain in everyday life. However, the airlift pump has a drawback, namely its low efficiency. The working fluid used in the airlift pump in this simulation uses a two-phase flow type, namely air as the primary flow and water as the secondary flow. Because there are two different types of fluids that meet in the riser, it can produce several flow patterns (laminar or turbulent). Parameters that affect the performance of the airlift pump include pump height, pipe diameter, and the air injection system [4]. In addition, there are several variables that cause flow patterns, such as the size and shape of the bubbles, pressure drop etc. [7].

The reason for researching an airlift pump in a CFD simulation is to observe a flow pattern in the airlift pump given the variation of the pipe diameter and the variation of the mass flow rate to the fluid outlet discharge. In order to obtain results in accordance with those in the field, the observations carried out several stages such as measurement, design, and also the set-up used must be in accordance with what is in the experimental.

The results from observations of airlift pumps based on originality are very different from those in the field or experimental. In this airlift pump simulation to determine the output discharge and also the type of flow pattern in the pipe (riser) based on variations in pipe diameter and variations in the inflow flow rate.

2 Method

2.1 2D Geometry

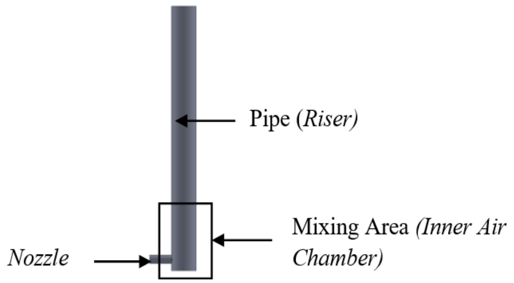

Fig. 1. Main Parts of the Airlift Pump

Pipe (Riser). The pipe functions to hold water which will be injected by air which later air and water will mix in the pipe. This pipe also produces several types of patterns as shown in Fig. 1.

Nozzle. The nozzle functions to circulate air at a predetermined mass flow rate, then it will be forwarded directly into the pipe so as to produce a buoyant force to help raise the water.

Mixing Area (Inner Air Chamber). The mixing area functions as a confluence between two fluids, namely water injected from the nozzle and water in the pipe.

2.2 Variation of Pipe Diameter

The variation of Pipe Diameter presented in Fig.2.

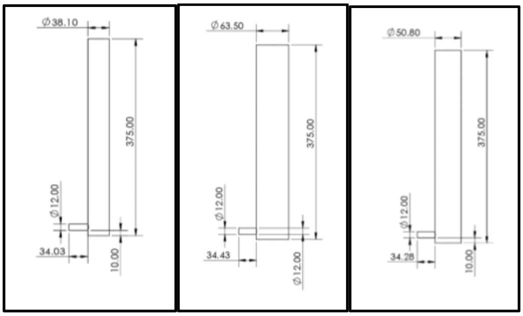

Fig. 2. Pipe 38.1 mm (1.5 inch), Pipe 50.8 mm (2 inch), and Pipe 50.8 mm (2.5 inch)

2.3 3D Geometry

Fig.3 shows the Airlift Pump 3D Geometry at Ansys.

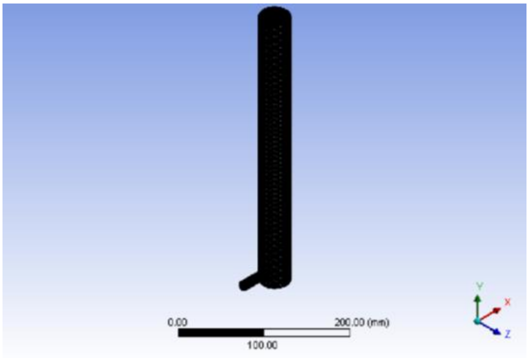

Fig. 3. Airlift Pump 3D Geometry at Ansys

Meshing is carried out after the boundary conditions and has different specifications for each variation of the Airlift pump pipe, as presented in Table 1.

Table 1. Specifications for Meshing Airlift Pump Pipes

Airlift Pump	1,5 inches	2 inches	2,5 inches
Number of Cell	420.475	630.735	836.600
Number of Nodes	429.878	646.164	856.014
Tipe Mesh	Hex dominant	Hex dominant	Hex dominant
Quality of mesh	Medium Smoothing	Medium Smoothing	Medium Smoothing

3 Result and Discussion

3.1 Effect of Changes in Pipe Diameter on Fluid Output Debit

This section will discuss the results of airlift pump simulations with variations in pipe diameter and mass flow rate. Pipe diameter uses three variations, namely 1.5 inches, 2 inches, 2.5 inches while for the mass flow rate of incoming air using variations of 0.015 kg/s, 0.020 kg/s, 0.025 kg/s, 0.030 kg/s, and 0.035 kg /s. Analysis of the simulation results will be presented in a comparative graph between water discharge (l/min) compared to variations in the mass flow rate of incoming air (kg/s), with a graph as shown in Fig. 4.

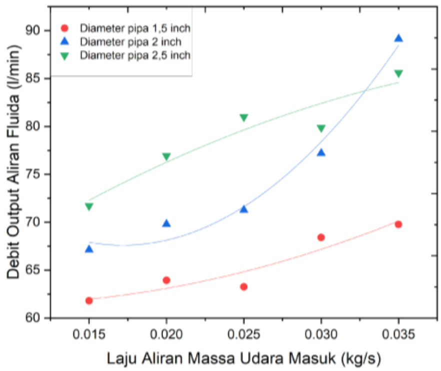

Fig. 4. Graph of Comparison of Pipe Diameter Variations and Mass Flow Rate of Incoming Air Against Pipe Flow Output Discharge

Fig. 4 shows that the variations given for each pipe diameter are 1.5 inches, 2 inches, 2.5 inches with a mass flow rate of 0.015 kg/s, 0.020 kg/s, 0.025 kg/s, 0.030 kg/s, and 0.035 kg/s s to discharge outlet produces different results on the results of the simulation. The simulation results obtained can be seen in Fig. 4 which shows the outlet discharge at variations in the mass flow rate in each pipe getting numbers that tend to increase, this is like what was done in research [3] but there is a phenomenon in the 2.5 inches pipe with a mass flow rate of 0.030 kg/s inlet air, the outlet discharge tends to decrease when compared to the mass flow rate of 0.025 kg/s of incoming air with the same pipe. The next phenomenon occurs in a 2 inches pipe with a mass flow rate of 0.035 kg/s which has an outlet discharge that tends to increase significantly, even bigger than a 2.5 inches pipe.

3.2 The Phenomenon of Fluid Flow Patterns in Contour Pressure and Streamline Velocity

Contour pressure in the simulation cannot be a benchmark for specific types of airflow patterns, such as bubbly flow, slug flow, semi annular flow, annular flow, and misty flow [5], because the contour pressure in the simulation displays air pressure and water that has been mixed, so it cannot determine the types of bubbles that occur, but the contour pressure can identify parts that have the potential to produce bubbles or areas with low pressure (drop pressure). The low-pressure area is generated from injection from the nozzle to the mixing area (inner air chamber), the low-pressure area is intentionally created to raise fluid from low pressure to higher pressure. Parameters that affect the airlift pump include pump height, pump diameter, and the air injection system [4].

The mass flow rate injected through the nozzle can produce different speeds depending on the diameter of the nozzle and the diameter of the pipe used, from the speed it can be seen that the type of flow produced in the flow pattern, the flow pattern created can be laminar/turbulent. The greater the velocity, the greater the type of flow formed in a turbulent pipe, and vice versa. A more specific determination of laminar/turbulent flow can be seen from how large the Re number is obtained.

3.3 Phenomenon of Contour Pressure in Flow Patterns

Contour pressure shows areas of low pressure at one time which can be seen in Fig. 5. Fig. 5. shows the pressure area on a 1.5 inches diameter pipe that is larger than the 2 inch and 2.5 inches diameters with respective values having a range of 1,695 kPa–1,297 kPa, 1,360 kPa–934.6 kPa, and 1,006 kPa – 391 .8 kPa.

Contour pressure can also identify areas that experience drop pressure, as shown in Fig. 5. The drop pressure that occurs in this simulation has an average pressure below 0 Pa, and in the figure the contour velocity is marked in blue.

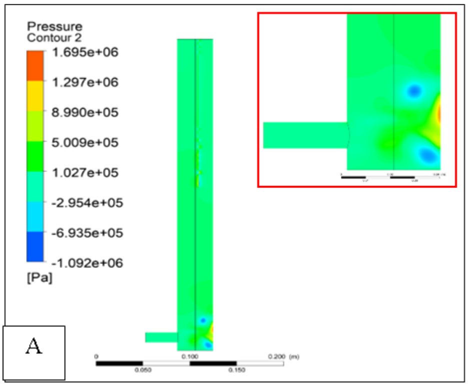

Fig. 5. Contour Pressure mass flow rate 0,015 kg/s Pipe 1.5 inches

3.4 Phenomenon of Streamline velocity in Flow Patterns

Streamline velocity shows the velocity of the fluid that can be seen in the mixing area of the two fluids, but the magnitude of the speed displayed cannot be a benchmark for how much the outlet discharge is because the velocity in the pipe displays two different fluids simultaneously and cannot be related to the concept prevailing physics. In Fig. 6

the streamline velocity shows the magnitude of the velocity in the pipe which is relatively decreasing due to the enlargement of the pipe diameter, the 1.5 inches pipe has a velocity range of 100 m/s – 66 m/s, the 2 inch pipe has a velocity range of 97 m/s – 65 m/s, and the 2.5 inch pipe has a velocity range of 98 m/s – 65 m/s. With this higher speed value, you can see that the flow patterns are increasingly random or turbulent.

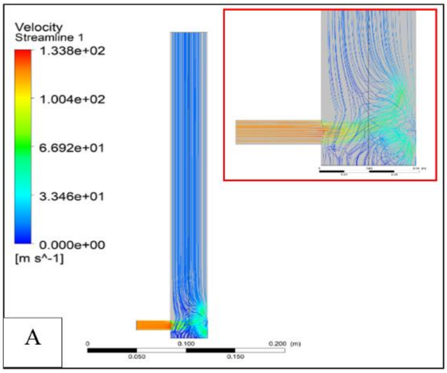

Fig. 6. Streamline Velocity mass flow rate 0,015 kg/s Pipe 1.5 inches

4 Conclusion

The simulation was carried out using variations in pipe diameters of 1.5 inches, 2 inches and 2.5 inches with mass flow rates of 0.015 kg/s, 0.020 kg/s, 0.025 kg/s, 0.030 kg/s and 0.035 kg/s s shows that the larger the diameter of the airlift pump pipe, the greater the discharge generated. Contour pressure is affected by the diameter of the pipe used and also the mass flow rate of incoming air, the larger the diameter of the pipe, the smaller the pressure in the pipe. The streamline velocity generated in the test shows that the smaller the pipe diameter, the greater the flow velocity in the resulting pipe, and the resulting fluid flow becomes more random or turbulent.

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