3D Airlift Pump Simulation With Variation of Nozzle Diameter Based on Computational Fluid Dynamics

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Abstract. Water is a liquid that plays an important role in our daily lives that has properties that are easy to distribure from high to low pressure places and the opposite from high to low pressure places using an airlift pump that working principle in the form of transporting water with the help of a mass flow rate of water or the flow rate of air masses flowed through a nozzle connected to a pipe containing water to be pumped to the riser up to the top of the pipe. The purpose of this study is to determine the performance of the airlift pump when operated with different variations of nozzle diameter and mass flow rate and the shape of the resulting flow pattern. In the implementation of making this airlift pump simulation, it is designed and simulated using Ansys 3D simulation based on Computational Fluid Dynamics (CFD) which is operated using a two-phase mixture (multiphase) in the form of air and water phase. In simulation tests, variations in the size of the nozzle diameter and mass flow rate are given to find the magnitude of the value of the fluid outflow rate. The research method used was to use an ansys 3D simulation based on Computational Fluid Dynamics (CFD) with variations in nozzle diameter sizes of 10 mm, 12 mm, 14 mm and 16 mm and also giving variations in mass flow rates of 0,010 kg/s, 0,015 kg/s, 0,020 kg/s, 0,025 kg/s and 0,030 kg/s. The process in this simulation research starts from the actual measurement of the air lift pump to desribing the Solidworks 2020 application to design an airlift pump and after that we need to continue to running it in an ansys 3D simulation based on Computational Fluid Dynamics (CFD). The result obtained from this study are in the form of discharge result produced by the airlift pump by providing variations in the size of the nozzle diameter that are getting larger will cause a decrease in the discharge value of the fluid outlet. In addition, the result obtained from each mass flow rate variation and the increasing size variation in the diameter of the nozzle produce a random contour pressure shape in each variation with a variety of pressure ranges. The shape of the streamline velocity flow pattern obtained is become more and more regular with a decreasing range of velocity values.

Keywords: 3D Airlift Pump Simulation, Nozzle Diameter, Computational Fluid Dynamics

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1 Introduction

Airlift pump is a pump that is used to channel and raise fluid from low pressure areas to high pressure areas with a help of a mass flow rate of air flowing from the nozzle at the bottom of the pipe so that the fluid can rise up the pipe (riser up). The working principle of airlift pump is to use the buoyancy force from the air flowing through the nozzle to lift fluids in the form of liquids or solids. Airlift pumps are commonly used to transport fluids in the form of water or fluids with a mixture of solid materials [2].

Airlift pump works on a multiphase flow of a mixture of air and water which is based on the phenomenon of aeration. Aeration is contacting a water with an air [5]. Multiphase flow is also referred to as a fluid flow consisting of wto or more phase [1]. Multiphase flow itself is a flow that flows simultaneously and consists of various phases which in this study uses a two-phase flow which consists of two phase components and has different chemical substances such as solid-gas, liquid-solid and gas-liquid. Apart from being distinguished by phase, multiphase flow is also distinguished by flow direction and channel position. The main advantage of the airlift pump is that it is a resistant to liquids that are corrosive to metals, explosives, radioactive and chemical substances [2] and also used for underwater operations such as sample collection [6] as well as mining [7]. In addition, lower tool maintenance costs and higher reliability in applications such as raising corrosive, abrasive and dense grit liquids. Airlift pump has a drawback, namely the efficiency produced is still very low [3]. To improve the efficiency of the airlift pump, it's necessary to engineer the piping system and regulate the capacity of the airflow to be injected [4].

This airlift pump simulation research was conducted to study and find out the flow patterns that occur in airlift pump simulation process which cannot be seen by experimental research and also to see the optimum point for producing a fluid outlet discharge of airlift pump with variation of nozzle diameter and mass flow rate. This simulation reasearch was conducted by applying the working principle of the airlift pump to be able to study and understand the phenomena that occur in the simualtion process. The formation and measurement of the size of the airlift pump is carried out in such a way as to resemble its experimental form for optimal result. The simuation work is carried out in stages starting from measurement, drawing and application in the form of a simulation of the ansys application based on Computational Fluid Dynamics (CDF). In forming flow patterns, it can be influenced by pressure as well as geometric contruction, bubble shapes, pressure drops and so on. The greater the gas injected into the pipe, the shape of the flow pattern that is formed will become increasingly random/irregular (turbulent) which causes the discharge of the fluid outlet to be smaller.

The purpose of the reaserch on airlift pump with the application of ansys based on Computational Fluid Dynamics (CFD) is to determine the characteristics of the flow pattern for changes in nozzle size variations and fluid outlet flow rates.

2 Method

2.1 2D Model

The first step in working on this simulation is to draw a sketch of the 2D shape of the airlift pump using Solidworks 2020 which can be seen in Fig. 1.

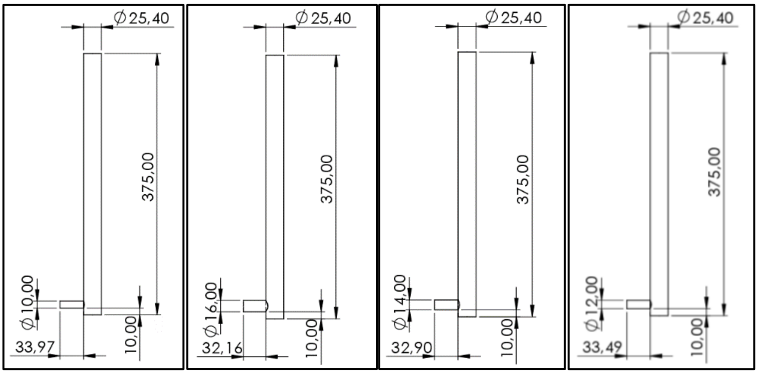

Fig. 1. Airlift pump geometry 10 mm, 12 mm, 14 mm, 16 mm nozzle variation

2.2 3D Model

From the result of the 2D sketch of the airlift pump using the Solidworks 2020 aplication, we can proceed to the next stage, namely entering the 2D image into the Ansys Fluent 19.2 application to get a 3D image from the result of the exiting sketch as we can seen in Fig. 2.

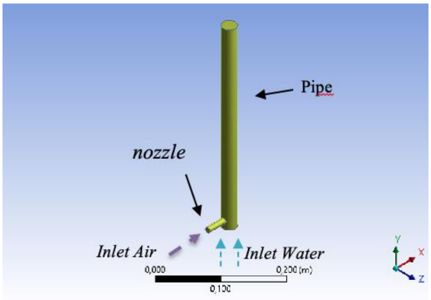

Fig. 2. Airlift pump geometry 10 mm nozzle variation

2.3 Meshing Process

The meshing process is very important and determines the accuracy of the simulation calculations. In this simulation using a hex-dominant type of meshing which has high accuracy in calculations that are close to real and have a simple geometry. This stage can be seen in Fig. 3.

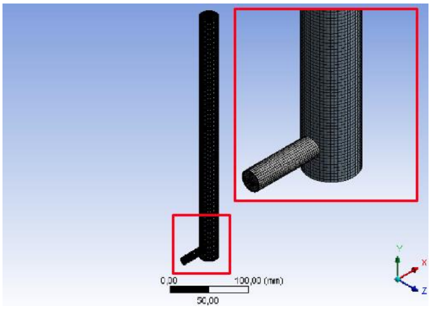

Fig. 3. Meshing of airlift pump

3 Result and Discussion

3.1 Effect of nozzle diameter size on fluid outlet debit

This section will focus on the discussion regarding the effect of variations in nozzle diameter sizes of 10 mm, 12 mm, 14 mm and 16 mm with mass flow rate variations of 0,010 kg/s, 0,015 kg/s, 0,020 kg/s, 0,025 kg/s and 0,030 kg/s to the fluid outlet discharge. The result obtained from the variations are in the form of a comparison graph of the size of the nozzle diameter with the mass flow rate to the fluid outlet discharge which can be seen in Fig. 4.

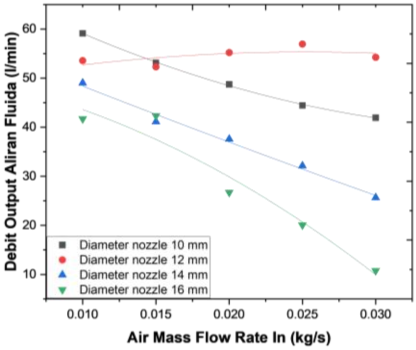

Fig. 4. Graph of effect of mass flow rate and size of nozzle diameter on fluid flow outlet debit

The result obtained from the simulation work tend to show a relatively decreasing value of the fluid outlet discharge. In the analysis carried out there are different phenomena. This phenomenon occurs in variations of the 12 mm nozzle diameter with mass flow rates ranging from 0,020 kg/s, 0,025 kg/s and 0,030 kg/s which experience an increase in the fluid output discarge value which is inversely proportional to the mass flow rate variations of 0,010 kg/s and 0,015 kg/s which shows a decrease in the discharge value of the fluid outlet with the same nozzle size variation. From the results of the data obtained in the form of fluid outlet debits in graph of Fig 1, we can see the optimum point of airlift pump performance. The optimum point for producing a fluid outlet discharge

I sat at a 10 mm nozzle diameter variation with a mass flow rate of 0,010 kg/s with a discharge of 59,126 l/m. meanwhile, the smallest discharge for the fluid outlet is obtained at the 16 mm nozzle diameter variation with a mass flow rate of 0,030 kg/s of 10,781 l/m.

3.2 Contour Pressure

The form of the phenomenon and the value of the pressure range can be seen in the contour pressure image. In Figure 5 the comparison of the contour pressure for giving a mass flow rate of 0,020 kg/s at a 10 mm nozzle diameter variation obtained a range of pressure values in a range -1.297 kPa to 1.338 kPa. In Fig. 5 is an example of a comparison image of contour pressure with a mass flow rate of 0,020 kg/s with a nozzle diameter variation of 10 mm which displays a pressure drop zone which has a pressure value below 0 kPa which is denoted in blue in the figure contour pressure. This can identify the occurrence of the bebble flow pattern phenomenon.

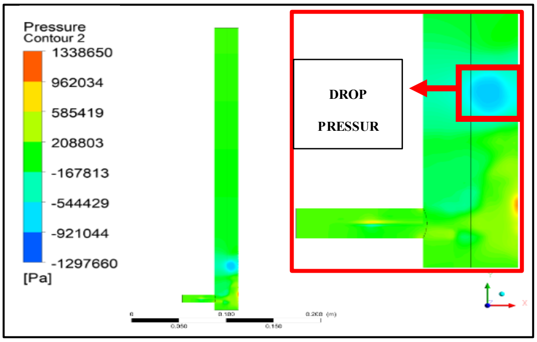

Fig. 5. Comparison of contour pressure mass flow rate 0,020 kg/s 10 mm nozzle

3.3 Streamline Velocity

The result of giving variation causes the value of the velocity to get smaller by giving the nozzle diameter size can be seen in the streamline valocity image which by giving a larger nozzle diameter size will experience a decrease in the velocity value and is directly proportional to the discharge of the fluid outlet tend to experience a decrease in the value of the debit as can seen in Fig. 6.

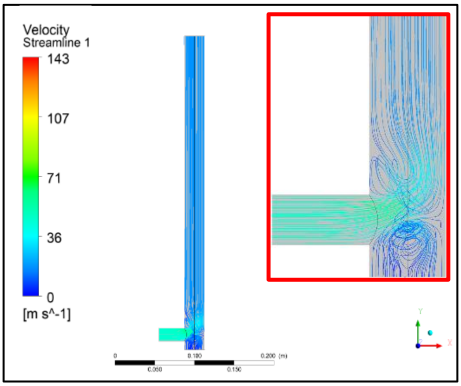

Fig. 6. Comparison of streamline velocity mass flow rate 0,010 kg/s 16 mm nozzle

4 Conclusion

Based on research on the result of a 3D airlift pump simulation with a variation of nozzle diameter based on Computational Fluid Dynamics, it can be concluded that in the simulation test with variations on nozzle diameter of 10 mm, 12 mm, 14 mm and 16 mm at mass flow rates of 0,010 kg/s, 0,015 kg/s, 0,020 kg/s, 0,025 kg/s and 0,030 kg/s with variations in diameter size the larger the nozzle diameter will cause a decrease in discharge value of the fluid outlet. The results obtained from each application of variations in mass flow rate and variations in the size of the nozzle diameter which are increasingly enlarged produce a random contour pressure ranges. The shape of the streamline velocity flow pattern obtained becomes more regular with a decreasing range of velocity values. Beside that, we can see which nozzle size produces the highest discharge value from this simulation research.

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