The effect of diameter downcomer in air entrainment process from vertical plunging water jet with downcomer

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Abstract. The development of technology on flotation in water-waste treatment is very fast. This environmentally friendly technology using bubbles. The characteristic of the bubble causes the material to separate into the material hydrophilic or hydrophobic. Obviously with the addition of other chemicals. At the time of bubble formation, air entrainment events occur. This study aims to determine the parameters that affect the entrainment of air events that is the relationship of diameter downcomer and jet velocity to air entrainment. Set up tools used are pump, nozzle, downcomer, flow meter, reducer and glass water tank. All that is connected with the pipe, the data obtained in the form of video and photos using the camera. From there obtained quantitative and qualitative data, for quantitative data in the process using image processing program. Results from this research that jet velocity affects air entrainment, whereas the diameter of the downcomer affects the value of the air entrainment.

1. Introduction

The development of technology is growing very fast. This happens also in flotation technology and water-waste treatment, one of microbubble technology. This technology is growing rapidly as human needs on flotation and desalination process. Jameson cell is one of the flotation technology.

Jameson cell was developed by Prof. G. J. Jameson of the University of Newcastle and Mount Isa Mine Ltd. Jameson cell is used in the mining industry as a mineral extractor. The Jameson cell that has downcomers, as the first contact on the bubbles and particles takes place, the high-pressure jet makes the air entering the water and produces bubbles (Harby, Chiva, & Muñoz-Cobo, 2014). These bubbles can be hydrophilic and hydrophobic.

Bubbles are used as a medium for flotation and a good bubble type for flotation is Microbubble. Microbubble is an air bubble with diameter of 10-50μm (Agrawal, Ashutosh, Wun Jern Ng. Yu Liu, 2011). Microbubble can be said to be environmentally friendly technology, because microbubble can produce highly reactive free radicals without using harmful materials.

In every microbubble forming process, there will be an air entrainment phenomenon. Air entrainment is natural occurrence which is often seen, where the air is immersed in water as an external flow of water. This occurs because of the dynamic properties of fluid mechanics. One example of natural occurrences of air entrainment in water is found in rivers, especially in areas where there are waterfalls. air entrainment is responsible for the infusion of oxygen to the water that is intended for the flora and fauna in the river.

This study aimed to document the effects of downcomers diameter on the dynamic properties of fluid mechanics. The downcomers diameter contribute a lot on trapping the air so that the air is not being interfered by its environment, along with variables and constants discussed in the following chapters.

The properties of the water jet are very important as they will be the contact point where the incoming air occurs. These affect the level and momentum of the air below the surface and the bubbles formation. In this air entrainment study on microbubble was done in Fluid Mechanics laboratory of Department of Mechanical Engineering, Universitas Indonesia. This study aimed to determine the characteristics of air entrainment from the perspective of fluid mechanics.
2. Methods
In studies using a model of vertical air entrainment plunging water jets where the liquid will move down towards the surface of the pond. The air entrainment process resulted the air coming through a vertically downcomers pipe. Factors affecting air entrainment are the size of the nozzle and downcomers diameter, the distance between the water surface in the pool against the nozzle tip, the physical properties of the fluid, the jet turbulence, and the jet velocity during the collision. However, the variable which will be used in this study are nozzle diameter, diameter downcomers, jet drop and water discharge.

The tools used are as follows.

1. Air Flowmeter
2. Nozzle
3. Downcomer
4. Water Flowmeter
5. Water Tank
6. Pump

Figure 1. Schematic Apparatus

The tools used for the study were water tank, pump, water and air flow meter, downcomers, nozzle, pipes, reducer and flanges. Water tank was made by glass, with length of 910 mm, width of 610 mm, and height of 620 mm. This water tank had thickness about 2 mm, and filled by water. The pump had the capacity of 10-18 L / min, with engine pump rotation up to 2900 RPM.

In the piping system, PVC pipes were used with diameter of 1 " in. In the suction section, the pipe was connected to the drain of the water tank vertically along the length of 20 cm. This pipe was connected with a 'T' connection, where one side flows to the gate valve which was parallel to the outlet pipe and drainage of the laboratory. On the other side it is connected to horizontal pipe with length of 70 cm, and that also included additional connection with the inlet at 1.5 ".

At the discharge section, the pipe of 1.5 " was reduced its diameter into 1 " in. Pipe extended to 70 cm before the gate valve was installed. Gate valve is used to regulate the water discharge coming out of the pump, so that the water discharge could be easily adjusted. After the water had been passed through the flowmeter, the water would be passed through pipe of 1 " and installed the flange at the end. Nozzle connected with pipe of 1 " and nozzle also was covered with downcomer of 700 mm, so that air trapped in downcomer.

In the observation water tank, white LED light was given behind the water tank. At the back of the water tank was covered by polyfoam with the thick of 2 mm. This was useful as the LED light so it could be scattered well. Photography technique used was backlighting.

To get the data accurately as possible, it used applications to process the data (image processing), i.e. 'ImageJ', which is an open source Java image processing software. The software was capable of filtering the image with 2048 x 2048 pixels only in 0.1 seconds, 8-32 bit on RGB color in wide format. 'ImageJ' offered image enhancement as an option, due to the need to take high-speed photo capturing.
3. Results

Figure 2. Air Entrainment and Air entrainment mechanism: (a)-(d) show subsequent phases of the phenomenon as a disturbance in the jet moves downwards (Bin, 1993)

Air entrainment visual observation through photography. Air entrainment from vertical plunging water jet is a phenomenon that generates bubbles (Chanson & Manasseh, 2003). When the jet hit the water flat surface, it will form a depression in the meniscus at the water surface (Smith, 2007). As jet velocity increases, depression in the meniscus also increases. Air trapped in the water, and will burst produce bubbles. Air entrainment can be observed alternately.

Figure 3. Air Bag

Air cavity on the vertical jet is caused by energy coming from the jet. This energy comes from jets that hit the water surface (Zhu, Oğuz, & Prosperetti, 2000). Jet which hit make an stress rupture and create a vacuum in the form of water cavity. The breaking of the surface tension causes the meniscus to form a pouch, where it will break apart as air enters into the bag and produces bubbles.
Figure 4. Graph between Jet Velocity and Downcomer Diameter with Air Entrainment

Figure 5. Graph between Jet Velocity and Downcomer Diameter with Depth Penetration
Diameter of downcomer and jet velocity used to determine the value of air entrainment that occurs. Downcomer used measuring 26mm, 36mm, and 46 mm. In the graph with a diameter of 6 mm nozzle, jet velocity of 3.53 m / s up to 9.44 m / s. From graph plotting, gas entrainment tends to rise when the jet velocity is increased, and at 36 mm downcomer diameter, the incoming air is smaller than the 26 mm and 46 mm diameter downcomers. At each different jet height, 36mm diameter downcomers also experience small air entrainment values. For higher jet velocity, air entrainment or air in the vacuum more. For 8 mm and 11 mm nozzle diameters also have the same result with 6 mm diameter nozzle.

Graphs between jet and downcomer velocity to depth penetration, if seen in diameter nozzle 6 decreased to 26 mm and 46 mm downcomer diameter, but on the contrary the 36 mm downcomer has increased. Many anomalies on 36 mm downcomer diameter. Stagnant graph trends are indicated in 8mm and 11mm nozzle diameters.
At 6mm nozzle diameter, the bubble spread decreases, due to the water entering the downcomer. For a 46 mm diameter downcomer, the graph declines. The decline occurred in all the conditions of the nozzle, the height of the jet, and the jet velocity. This decrease occurs because, the air is not brought into the water, so the water entrainment is less effective. For graphs with jet velocity and 36 mm downcomer diameter, bubble dispersion area increases in all conditions. With increasing jet velocity, the bubble dispersion area also increases in this condition. And the nozzle diameter values of 6mm, 8mm, and 11mm indicate that jet and downcomer diameter does not significantly affect the dispersion width distribution of bubble.

Based on the graph above shows the experimental data, that the diameter of the downcomer influenced by the volume of air to air entrainment. Jets that hit the surface of the water will form the meniscus, where the meniscus will form an air sac, and burst into bubbles. The effect of the downcomer on bubble production affects the air volume values for air entrainment. Where air entrainment occurs and produces bubbles. In order for bubbles to be produced as desired, it must change the geometry of the experimental apparatus. Changing the nozzle diameter, the height of the jet, the jet velocity, and the diameter of the downcomer.

Graph of the relationship between the water level in the downcomer with the downcomer diameter and jet velocity. The height of the water that goes into the downcomer tends to rise every condition, this is because the difference of downcomers are immersed with the air flow into the downcomer through the feed, consequently water into the downcomer. Another factor is the difference in the diameter of the nozzle, the diameter of the downcomer, and the height of the jet. The result also increases only the difference in height values in each condition. The water that goes into the downcomer is also due to the pressure difference in the downcomer with the pressure in the downcomer environment. The pressure difference gets bigger if the smaller downcomer resulted in much water coming into the downcomer. The incidence of water coming into the downcomer is due to the pressure difference between the downcomer and inside the downcomer, different jet velocity cause different water levels as well. The effect of the large diameter of the downcomer does not cause any change in the number that goes up or down.

4. Conclusions

air entrainment occurs when the jet hit the water level in the pond, the entry of air into hiding due to water jet causes the formation of pouches are then divided into a bubble of air as it goes deeper into the pockets. Jet velocity affects air entrainment, the faster the velocity the more the air gets sucked. The diameter of the downcomer can determine the value of a lot of air is sucked, according to (Tasdemir, Tasdemir and Oteyaka, 2011) the diameter of the downcomer does not affect the water entrainment, this is contrary to the results of this study. The velocity of the jet and the downcomer diameter also affect the water that goes into the downcomer. Jet velocity and downcomer diameter do not affect depth penetration. Jet velocity and downcomer diameter do not affect the area of bubble dispersion.

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