Evaluation of Total Pressure Velocimeter

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Abstract. An accurate and multifunctional water velocity meter is developed to fulfill the need for the appropriate water velocity measurement in Indonesia. The water flow velocity itself can be calculated using the principle of total pressure in the water flow. The total pressure to be detected for speed is obtained by using the basic workings of the Pitot Tube which is equipped with a pressure sensor in the form of four resistors arranged in a Wheatstone Bridge pattern. The output from the sensor in the form of a small electric current is processed into a digital signal to obtain an accurate reading. In the previous experiment, it was obtained that calm water measurement data resulted in a voltage of 0.03V and 0.21V at a depth of 2 cm and 10 cm from the surface. Whereas in flowing water, the voltage is 0.04V at small currents and 0.09V at heavy currents using a current source from the hydraulic bench. Furthermore, this speed measuring instrument will be calibrated to determine the response of the tool in graphical form and will be used as a digital readout. The calibration process was carried out using a comparison tool, namely orifice and free jet flow with orifice diameter hole of 6 mm which previously obtained a velocity coefficient value of 0.879. In the next research, the total pressure measurement method is expected to obtain data about the turbulence of a flow and turbulence flow with particles (emulsion) and can detect the speed and type of velocity and turbulence in the flow within a wide range.

1. Introduction

To be able to measure the velocity and turbulence of sediment carried by the flow, the development of research has been done recently. Some of these studies include the measurement of longitudinal velocity fluctuation (direction flow) with an impact-tube in an open channel flow with suspended natural particles [1]. Then the measurement uses a Laser-Doppler velocity meter to measure the velocity and fluctuation of the suspended flow velocity or the vertical dynamic motion of medium size sediment particles in the stream [4]. Subsequent developments using a Laser-Doppler device are also used to measure the velocity and turbulence of low concentrations of flow with plastic sand samples in horizontal pipelines [6]. Meanwhile, other studies have utilized two components of the Doppler Laser and measured the turbulence character of low concentrations of sediment flow [2].

Research on the evaluation of measuring instruments for regular flow velocity and flow with suspended sediments is needed. The tool was developed with the principle of total pressure and particle fluctuation which is then called the total pressure velocimeter (TPV). The principle of total pressure in this tool has been developed in the research of suspended sediments in turbulence and flow turbulence structures in 1993 [8] [9] [10] [11],...
where the author becomes a research assistant and has full rights in the development of a 29-year-old tool so that it can be used according to technological developments.

2. Methodology
The Total Pressure Velocimeter (TPV) evaluation research is divided into several aspects of testing to obtain results, namely the re-functioning of the TPV device, the magnitude or susceptibility of reading the relationship between voltage and flow velocity, and the response of the TPV tool to water pressure or into the water. To calibrate the tool, a velocity meter was prepared in the Jet Orifice laboratory to graphically determine the velocity of water passing through the orifice. Furthermore, the water velocity was measured using the TPV tool. To get accurate results, the water velocity coefficient is measured through the orifice to be used. This research has just arrived at the orifice coefficient research, while the speed calibration and modification of the tool will be carried out in future studies.

2.1. TPV Response Testing
The supporting device for the Total Pressure Velocimeter (TPV) is a power supply that functions to determine the amount of reading issued (in the form of an electric voltage) which is then connected to the resulting speed. Measurements on still water are carried out in still water conditions so that measurements can focus on hydrostatic pressure which depends on the depth of the liquid and is not affected by interference from waves or waves. To obtain valid data required at least three measurements with different depths and the maximum depth measured must be more than 5 cm [6].

2.2. Speed Coefficient Analysis
Flow velocity coefficient (Cv) on the application of the Total Pressure Velocimeter (TPV) using a Jet orifice speed measuring instrument. The media is in the form of a vertical glass tube with an orifice hole on the bottom wall of various sizes and shapes. Water can flow through the orifice and form a parabolic beamline. The parabolic line is then analyzed to produce the speed of water jets through the orifice. To get the speed variation, it is done by raising the water level on the glass tube, the higher the speed the greater the water jet and the farther the water jets are. The size and shape of the orifice can be used as parameters for measuring the velocity of the water jets when their properties and behavior and shape are known. This is a manifestation of the application of the Bernoulli equation which presents the calculation of the relationship between hydrostatic and water jet velocity.

The theoretical correction of the water jet velocity that occurs in the orifice hole needs to be corrected because in this hole there is an "energy loss" which affects the value of the water jet velocity. Thus, to get an accurate measurement result of an orifice, it is necessary to take into account the velocity coefficient (Cv) and the contraction coefficient (Cc) which results in the emission coefficient (Cd). The following is presented the media analysis using orifice media which is presented in Figure 2.1 below.
2.3. Speed Measurement

The velocity coefficient and beam coefficient are determined by measuring the shape of the parabolic path of the water jets coming out of the orifice hole in the steady flow condition of the water level in the head tank [3] [5]. The theoretical equation used in determining the velocity (vt) of emission in a tank with an orifice on the side is:

\[ vt = \sqrt{2gh} \]  

The value of h is the water level above the orifice and g is the acceleration due to gravity. The velocity resulting from the above equation is the ideal velocity because the influence of the kinematic viscosity of the liquid is not taken into account in this equation. In practice, the velocity that occurs is smaller than the theoretical velocity because of the velocity coefficient which is written as the following equation:

\[ v = C_v \sqrt{2gh} \]  

Cv is the velocity coefficient which allows the effect of the viscosity of the liquid so that the value of Cv < 1. The actual beam velocity (v) in the above equation is the velocity that occurs in the contracta vein, where the diameter of the beam hole is minimal and the velocity that occurs is maximum. With the above equation, the discharge that occurs (Q) is written as follows:

\[ Q = v Ac \]  

Where Ac is the area of the hole that radiates water in the contracta vein as shown in Figure 2.2. Thus the area of Ac will be smaller than the area of the orifice hole (Ac < Ao). Thus the following equation is obtained:

\[ Ac = C_c Ao \]  

Where Cc is the contraction coefficient so that the value of Cc <1
From the above equation, if equations (2) and (4) are substituted into equation (3), the following equation will be produced:

\[ Q = C_v C_c A_o \sqrt{2gh} \]  

(5)

The product of \( C_v \) by \( C_c \) is called the coefficient of discharge (\( C_d \)). Thus equation (5) can be written as:

\[ Q = C_d A_o \sqrt{2gh} \]  

(6)

Furthermore, in the water jet, if the effect of the resistance due to friction of the water jet and the air is neglected, the water jet in the horizontal direction can be assumed to be constant. So that the relationship between the distances of water jets on the horizontal axis (\( x \)) and the time of radiation (\( t \)) can be formulated as follows:

\[ x = v \cdot t \]  

(7)

Then for water jets in the vertical direction (\( y \)) (in Figure 4.3) will have an acceleration proportional to the acceleration due to gravity (\( g \)). Thus at a given beam time (\( t \)), the vertical position of the beam (\( y \)) can be calculated by the following equation:

\[ y = \frac{1}{2} g t^2 \]  

(8)
By moving the segment in equation (8) to calculate the time function, the equation is:

\[ t = \left( \frac{2y}{g} \right)^{0.5} \]  

(9)

If equation (9) and equation (2) are substituted in equation (7) it will produce the equation:

\[ x = Cv \sqrt{2g h \left( \frac{2y}{g} \right)^{0.5}} \]  

(10)

Equation (10) can be rearranged to find the value of \( Cv \) and the following equation can be obtained:

\[ Cv = \frac{x}{2 \sqrt{y h}} \]  

(11)

So, for testing in steady flow conditions, namely the water level at a stable head tank, the value of \( Cv \) can be determined from the water jet coordinates measured using a needle (xy).

In the implementation of the test, the author uses a water level (head) of 28.5 cm. Future studies will use varying water levels to obtain more accurate performance results.

3. Result and Discussion

The results of the evaluation of the tool developed in the form of calibration were started by utilizing the water level of the media head tank of 28.5 cm and an orifice diameter of 0.006 m [5]. The following is presented in Table 3.1 the results of the reading of the Total Pressure Velocimeter (TPV) tool are as follows:

| Needle No. | Dia Orifice (m) | Head (h) m | Horizontal Distance x (m) | Vertical Distance y (m) | Yh root (m) |
|------------|----------------|------------|---------------------------|-------------------------|-------------|
| 1          | 0.006          | 0.285      | 0.050                     | 0.000                   | 0.000       |
| 2          | 0.006          | 0.285      | 0.100                     | 0.007                   | 0.045       |
| 3          | 0.006          | 0.285      | 0.150                     | 0.017                   | 0.070       |
| 4          | 0.006          | 0.285      | 0.200                     | 0.032                   | 0.095       |
| 5          | 0.006          | 0.285      | 0.250                     | 0.052                   | 0.122       |
| 6          | 0.006          | 0.285      | 0.300                     | 0.080                   | 0.151       |
| 7          | 0.006          | 0.285      | 0.350                     | 0.112                   | 0.179       |
| 8          | 0.006          | 0.285      | 0.400                     | 0.148                   | 0.205       |

Then the reading results are analyzed in graphical form to determine the relationship between the horizontal distance x and the square root yh so that the resulting slope value is \( 2 \, Cv \) (velocity coefficient). The following is presented in Figure 3.1 the relationship between the horizontal distance x and the square root yh.
Figure 4. Relationship between horizontal distance \( x \) and square root \( yh \)

The magnitude of the slope value obtained from the analysis of the graph above shows a magnitude of 1.758 so that by testing the orifice with a thickness of 6 mm, the velocity coefficient \((C_v)\) is 0.879 [5]. The magnitude of this velocity coefficient is the basis for calculating the theoretical water jets from the orifice to be calculated in equation (2). Besides, the calibration process can be done by positioning the guiding tube of the Total Pressure Velocimeter (TPV) device to face parallel to the water jets from the orifice and observing the behavior of the value of the voltage generated by the TPV device because the comparison of the tool as a calibration process is the result of the reading of the output voltage from the TPV amplifier. As for the test to determine the results of the comparison and response to the amount of TPV voltage on water media with laminar flow, the following is the test variation with a water depth \((h)\) of 0 cm, 2 cm, and 10 cm in the form of Figure 3.2 below [5].

Figure 5. Measurement graph of voltage relationship with water depth \((h)\)
The results obtained from measuring the relationship between voltage and water depth (h) in an open channel with laminar water flow (calm), the output voltage at low speed is 0.04 V and a maximum speed of 0.09 V [5].

This research is preliminary research that needs to be continued with the following steps:

1. Measurement calibration by first measuring the velocity coefficient (Cv) with various water levels to get an accurate Cv value.
2. Measuring the velocity in the orifice hole using the TPV tool to get the relationship between the voltage response and the real flow velocity, to obtain a formula for the relationship between the voltage response and the water velocity.
3. Measure changes in frequency and deviation of voltage vibrations to obtain the amount of turbulence in water flow.
4. Measuring the velocity and turbulence of water flow by using water medium with fine and medium sediment, so that the results of velocity and turbulence of water flow with mud suspension can be obtained.

4. Conclusion
The use of a Total Pressure Velocimeter (TPV) as a tool for measuring flow velocity using the working principle of total flow pressure and water depth has been carried out. The tool has been successfully functionalized again and experiments have been carried out on the response of the tool to changes in water depth and giving a good response between 0.004 Volt to 0.09 Volt. The Jet Orifice calibration tool has been improved and the Cv speed coefficient has been measured, which can then be continued to calibrate the TPV tool. The Cv value for one water level in the Jet orifice tube has been obtained. Further research will be carried out by focusing on measuring calibration, measuring the velocity at the orifice hole using a TPV tool to obtain the relationship between the voltage response and real flow velocity, measuring changes in frequency and deviation of voltage vibrations, and measuring the velocity and turbulence of water flow using sediment-water media.

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