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Research Article

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A study of velocity variation in open channel flow across the cross sections, including flow meter calibration and α (Energy Coefficient) value calculation

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Abstract Taking accurate measurements from any calibrated instruments before carrying out any experimental work, whether it is a flow meter or any other measuring instruments, is of paramount importance. Without calibrated measuring instrument, no further investigations can be carried out such as determining energy coefficient α, in Bernoulli's equation. The accuracy of any investigations is solely dependent on calibrated instrument. In this project, investigation is carried out to determine if the flow meter fitted on the laboratory flume coincides with other form of taking flow measurement, i.e. velocity probe, and compare the result with electromagnetic flow meter. Another finding of this project is to determine the energy coefficient, α which generally assumed as unity for theoretical purpose.

Keywords energy coefficient, velocity probe, flow meter, bridge pier, cross section, velocity variation

Introduction

In recent years water resources project and hydraulic engineering works have been developing rapidly throughout the world. The knowledge of hydraulics is essential to design of many hydraulic structures, has thus advanced by leaps and bounds [1]. So the basic aim of hydraulics is thus to understand, and so control for the benefit of society, the occurrence, movement and use of water, whether it is in lakes ,rivers, pipes, drains, percolating through soils or pounding the coastline as destructive waves [2]. Extensive research and development in the understanding and applications of flow meters are taking place all over the world. These activities include calculation of Manning's and Chezys roughness coefficient, n.

Briefly although not exclusively, the principal virtues of using flow meters in different sectors as:

a) Water sector
b) Food sector
c) Chemical sector
d) Industrial sector

The method using to obtain flow rate measurements in this experiment will be velocity probe meter and electromagnetic flow meter and also checking the difference in result between both methods. Velocity probe meter is used mainly for laboratory testing and specialized industrial testing. It can also be used where flow is physically accessible and the instrument can be positioned in a stable form for obtaining velocity readings. It is designed to measure, indicate and record low speed velocities of water or any conductive fluid. Again EM flow meter is another form of measuring the rate of flow directly, giving the readings in flow rate in m3/hr as opposed to velocity reading using the propeller meter. EM flow meter is more widely used than the velocity probe meter as it provides reading instantaneously on most enclosed pipes and can be used by variety of sectors as water sector, food sector, and chemical sector and so on. Another finding in this project is the value of energy coefficient α. This coefficient is placed in front of the velocity head thus: $\alpha V^2/2g$. The coefficient always has a value of 1.00 or greater. In many situations, however, the value is near enough to unity for it is taken as 1.00, and hence the energy equation is often written without α in front of the velocity head. The way to calculate α is to measure the velocity v, within smaller subsections of the flow. The new flow meter installed on the new laboratory flume was giving some uneven results, as reported by another student who previously worked on the same apparatus [3]. It is difficult to obtain the true or accurate readings of flow rate so that other investigations, such as determining the energy coefficient α, from Bernoulli's energy equation. Hence the main aim of this project is to cross check the calibration of new Magflo Electromagnetic flow meter fitted on the laboratory flume with a velocity probe. By taking the velocity of water using velocity probe meter which further gives the discharge and compare this with the discharge given by Electromagnetic flow meter. Another part of this investigation is to determine the energy coefficient α, which generally assumes as 1.0. To calculate α value a certain point was chosen across the flume and placing the probe which gives point velocity for each point. In this project for small flume 21 points were selected to take point velocity for each point. Again for large flume 15 points were assumed to calculate point velocity. Using this point velocity times the area of each grid which is dividing by the whole area of flume and average velocity finally gives the value of α, the energy coefficient

Methodology

The main aim of this experiment is to cross check the calibration of new Magflo Electromagnetic flow meter fitted on the laboratory flume with a velocity probe. By taking the velocity of water using velocity probe meter which further gives the discharge and compare this with the discharge given by Electromagnetic flow meter. Another part of this investigation is to determine the energy coefficient α, which generally assumes as 1.0. To calculate α value a certain point was chosen across the flume and placing the probe which gives point velocity for each point. In this project for small flume 21 points were selected to take point velocity for each point. Again for large flume 15 points were assumed to calculate point velocity. Using this point velocity times the area of each grid which is dividing by the whole area of flume and average velocity finally gives the value of α, the energy coefficient. The measuring instrument as shown in figure 1 is not only used to measure the depths of the channel but also helps with taking readings using the velocity probe by attaching a makeshift clamp on to it (Figure 2) and attaching the probe on other end of the clamp.

Figure 1: Measuring Instrument

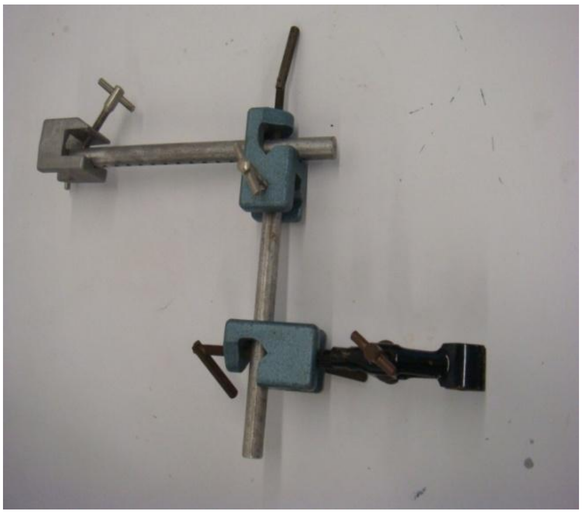

Figure 2: Makeshift Clamp

The measuring instrument consists of a long steel pointer which has an adjustable little scale in millimeters attached to it. The depth is measured by moving the pointer vertically and reading off the measurement from the side of other ruler displayed in centimeters. The steel needle can also be moved sideways to allow the depth to be taken across the width of the channel. Depths can also be taken along the whole length of the channel as the whole device sits on a platform with rollers so it can be slide on rails which are situated on top of the channel sides. The purpose of this instrument is to measure depths of water and is accurate to the nearest millimeters. In order to use the Nixon velocity probe a makeshift clamp was made so that the probe can be fixed at a certain point with correspondence to the steel pointer (Fig) so that the velocity readings can be taken as accurately an effectively as possible. For determining the appropriate method of obtaining accurate flow rate, a decision was to be made on how many points to take at one cross sectional area of the flow i.e. 9 different points or 21 different points. So therefore a small test was conducted on a smaller flume which already contained a functional calibrated flow meter. In this research a further experiment was carried out with new propeller to cross check the result got with previous propeller. For obtaining better average velocity frequency, 9 readings were recorded from the digital indicator at each point and since the digital indicator provided an option of retrieving readings at either 1 second or 10 second intervals, the latter of the two was chosen, simply because it displayed readings long enough to record down the readings. So from taking 9 points, 27 readings will be noted down (9×3) and likewise with 21 points, 63 readings will be noted down (21×3) [3-11].

Results and Discussion

After carrying out the investigation it was found that the percentage error on small flume for 21 points is 12.86% which was higher for 9 points. So 21 points is much more accurate which can be used in any further experiment. Again for same flume the energy coefficient for 21 points and 9 points is almost same. This is 1.003 for 21 points and 1.005 for 9 points. The average percentage error for large flume with 12 points is 51.648%. This percentage difference was a result of comparing velocity probe readings with the electromagnetic flow meter with 4 different flow rates.

Table 1: Results in comparison for small flume

Small Flume			
21 Points		9 Points	
VP	EM	VP	EM
4.81×10^{-3}	5.52×10^{-3}	4.64×10^{-3}	5.52×10^{-3}
% Error = 12.86%		% Error = 15.94%	
Comment: From results above it is apparent to see that a 21 point method for obtaining velocity provides a less percentage error than a 9 point method, thus being a slightly more accurate method. So from the results analyzed, the 21 point method will be adopted for main body of the experiment.			
Energy Coefficient (α) Calculation			
21 Points		9 Points	
1.003		1.005	
Comment: Generally the energy coefficient value always assumed to be unity for theoretical purpose but it is apparent from the experiment that the value is 1.00 which coincides with stated results.			

Table 2: Average velocity comparison for large flume with different depth

Large Flume with 12 Points							
Water Depth (0.0583m)		Water Depth (0.0519m)		Water Depth (0.060m)		Water Depth (0.0625m)	
VP	EM	VP	EM	VP	EM	VP	EM
5.857×10^{-3}	0.01463	4.288×10^{-3}	0.01073	0.01023	0.01879	0.01224	0.02194
% Error = 59.97%		%Error = 60.01%		%Error = 45.31%		%Error = 41.3%	
Comment: The average error is 51.648%. This percentage is the result of comparing velocity probe with EM flow meter at 4 different flow rates. This is a phenomenal amount of difference, however the probe used in this experiment was high speed probe and since none of the readings were higher than 60cm/sec when the valve was fully opened, which may effect on the result difference.							

Table 3: Energy coefficient comparison for small bridge pier

u/s	d/s									
	10	20	30	40	50	60	70	80	90	100
1.001	1.692	1.375	1.115	1.043	1.023	1.016	1.003	1.017	1.01	1.00
Comment: Generally the energy coefficient is assumed as 1.00 which is found at 70cm d/s of the pier, whereas the u/s coefficient value is 1.00. After this distance the coefficient is approximately equal to 1.00 that means the water regain its natural flow.										

Table 4: Energy coefficient comparison for large bridge pier

u/s	d/s									
	10	20	30	40	50	60	70	80	90	100
1.008	1.336	1.35	1.244	1.208	1.157	1.124	1.096	1.09	1.08	1.031

d/s	110	120	130	140	150
	1.008	1.000	1.01	1.02	1.03

Comment: Generally the energy coefficient is assumed as 1.00 which is found at 120cm d/s of the pier, whereas the u/s coefficient value is 1.008 which is approximately same as 1.00.. After this distance the coefficient is approximately equal to 1.00 that means the water regain its natural flow.

The possible limitations of the experiment were:

- The Makeshift clamp might have swayed by few millimeters when taking readings at high flows. This might be approximately 5mm.
- It is difficult to get accurate depth readings with higher flow rates as the surface flow fluctuated a lot.
- Error on scale reading might be ± 1mm.
- Velocity probe accuracy is ± 1.5%.
- Electromagnetic flow meter accuracy is ± 0.5%.
- Taking reading at midpoint due to hydraulic jump may alter in taking readings given by probe due to joint at channel midpoint.

Conclusion

To conclude from the investigation carried out, the electromagnetic flow meter did prove to have an average of 51.648% difference when compared with the readings taken with the velocity probe. Such a high difference may suggest there is any difficulty either in the probe of any other instrument as the makeshift clamp has not fully stable when the low velocity is higher. As this same work done by another undergraduate student last year shows the average difference is 49.5% which is closer to this result. This may be able to verify if this experiment has done with new probe. I had waiting up to last week for new probe to come to cross check whether this big difference is due to probe or other instrument but unfortunately it had not arrived. So it is important to work with new probe if any other person will work on this type of experiment.

Another thing may influence the big difference in result as the water in flume was not so clear. Containing more debris and dust on water may lead to increase the high flow velocity and also can disturb the propeller from its normal flow.

Again the way of readings were obtained using the velocity probe and the measuring instrument may also affect the overall result of the investigations, such as taking more point across the cross sectional area of the flow. The problem may also arise in measuring the depth of flow, as the flow fluctuates at its surface more i.e. it's not steady.

Another finding of this project was calculations of energy coefficient value in Bernoulli's equation, also the influence of bridge pier on energy coefficient value. This includes the comparison of upstream and downstream value of energy coefficient i.e. at what distance the downstream coefficient coincides with the upstream value. For large flume the coefficient value at upstream is almost same as unity which was found as same at 110cm downstream of the flume. Again in case of smaller bridge pier the energy coefficient value at upstream is same as large pier u/s, but the downstream value coincides at the distance of 70cm downstream. The d/s distance is higher for larger bridge pier which may due to the size of the pier that has large influence on velocity fluctuations. As there is very little error in result which may due to getting the proper flow velocity and the flow depth. The flow disturbed by the pier may fluctuate the flow to get accurate value of the depth.

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