Accuracy Analysis Of An Ultrasonic Sensor Over An Open Channel Rectangular Notch For Rainwater Harvesting

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Abstract: Rainwater gathering could be a Technology Administration used for twenty-four collection and storing fresh water any more rooftops, the half of land surface or rock catchments exploitation easy techniques like jars and pots moreover as additional complicated techniques like underground check dams. The conventional analytical method of measuring flow rate are through weir/nothes and flow hall effect sensors, in this paper we analysed the flowrate data of a open channel rain water. The measurement of flow rate of a notch/weir is a laborious task, which involves the continuous mathematical analysis. Still there is a scope of occurring error while calculating the coefficient of discharges and volumetric equations. In this present study an ultrasonic sensor is integrated to an Arduino, which is taking the real time input signal from sensor and estimating the flow, based on notch equation and prior calibrated optimized coefficient of discharge (Cd). It is possible to estimate up to 450 cm height of water column of a notch with high precision of 2mm. By using Arduino it is possible to reduce the competency time of calculation of flow rate and the iteration process is looped easily with Arduino coding. The proposed system is cost effective and highly accurate with an accuracy range of 96 – 98 % can be widely used for rain water harvesting.

Index Terms: Notch/Weir, Ultrasonic Sensor, Arduino, Rainwater Harvesting.

1. INTRODUCTION

India is facing the worst water crisis in its history. As per a report by NitiAyog twenty one cities in India can run out of groundwater by 2020. In keeping with a report printed by Water Aid around eightieth of India’s surface water is contaminated. A majority of the population depends on the groundwater that is once more troubled to stay pace with the requirements of the rising population. whereas around two hundred,000 folks area unit dying every year because of inadequate access to safe water, things can seemingly decline because the population can increase. Flow and its rate is vital parameter in chemical, pharmaceutical, food and process industries in estimation of correct composition and confirmation of accurate volume to be mixed. There are adequate measuring instruments available to estimate the volume and rate of flow but the selection is based on accuracy and reliability not the least is cost, hence the selection of right measuring instrument for a specific application is challenging. Most of the measuring instruments are intrusive category in which primary sensing element need to be immersed across the flow to be measured. Hence the usage of those is limited for flow of fluids in a confined channels not be suitable for open channels [1][8]. This paper emphasises over the significance of using ultrasonic sensor for the estimation of flow rate through an open channel rectangular notch [1][8]. Rectangular notch is a one of the type of weir crusted in rectangular shape make simple in construction. The rectangular notch is the best suitable for small flow rate at open channels.

2. EXPERIMENTAL SETUP AND METHODOLOGY:

A process flow diagram of experimental setup for measurement of flow rate on a rectangular notch using ultrasonic sensor with Arduino shown in Fig. 4. An ultrasonic sensor (HC-SR04) with operating voltage of 5V (DC), operating current of 15 mA, range of 2 cm to 450 cm measuring angle 15 degrees, triggering input signal of 10µS TTL pulse and dimensions of 9 cm x 6 cm x 2 cm is used. A metallic rectangular tank of 30cm x 30 cm is used to collect the sample flow from notch shown in Fig 4. Rectangular notch is constructed on width side of a plastic box having dimension of 26cm x 26cm. Arduino is used to collect the real time height of water column above the notch and to process the data. Laptop display is used to display the information of flow and sketches.

2.1. Implementation:

The Rectangular notch is fed with constant flow by a Water pump setup which is connected to a reservoir. The water height over the notch maintained at a particular value and collected over known volume rectangular container. The raise of water level is calibrated to estimate the water flow rate. The Ultrasonic sensor is calibrated to read the level of water over the notch and programmed using Arduino IDE to measure rate of flow through the notch using equation 1. The comparison is made over the two flow rates and observed the accuracies.

\[ Q = \frac{2}{3} cd b (2 g) 1/2 h 3/2 \]

where b and h are width and height of water column of the
2.2. Estimation and optimization of Cd
The estimation and optimization of coefficient of discharge plays a vital role in the measurement of flow rate using notch. Here the Cd is estimated by taking four observations. In each observation the width of notch is fixed (1 cm), in contrast the height of the water column is varied. The height is varied from 1.5 cm to 3 cm, with a resolution of 0.5 cm. Finally, the Cd from equation 2, is estimated by calculating the ratio of volume collected in reference tank to the volume flow value obtained from Arduino height. The optimization is achieved by taking average of Cd’s estimated from all observation.

\[
Cd' = \frac{0.78623 + 0.792 + 0.8119 + 0.8015}{4} = 0.7979 \quad ---- \text{Eq 2}
\]

\(Cd'\) is the average of all Cd’s.

3. EXPERIMENTAL RESULTS AND ANALYSIS:
The experimental data is tested in three conditions by changing the water column height over the notch at 2 cm, 2.5 cm and 3 cm, keeping the notch width is constant at 1 cm. The response of the ultrasonic sensor in terms of height is shown in following figures.

**Fig. 3. Process flow diagram**

**Fig. 4. Experimental setup**

<table>
<thead>
<tr>
<th>S.no</th>
<th>Width of notch in cm</th>
<th>Height of water column in Notch cm</th>
<th>Flow in (liters/quarter minute using ultrasonic sensor)</th>
<th>Volume collected in 3cm*3cm square tank/quarter minute</th>
<th>Estimated Cd value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.50</td>
<td>0.813660</td>
<td>0.63972</td>
<td>0.78623</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2.00</td>
<td>1.250</td>
<td>0.990</td>
<td>0.792</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2.50</td>
<td>1.750717</td>
<td>1.4215</td>
<td>0.8119</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>3.00</td>
<td>2.3013</td>
<td>1.84449</td>
<td>0.8015</td>
</tr>
</tbody>
</table>

**Table No. 1:** Accuracy Estimation of Flow measurements at Notch water level at 1 cm

Cd = average of all the 4 instances
The final integrated flow per every quarter minute for 3 ranges of height is shown in the below Fig

**Fig8 :** collected water Flow rate in the standard container for notch water level at 2cm, 2.5cm and 3cm.

The accuracy of ultrasonic sensor to estimate the flow of water over the rectangular notch is obtained by comparing the ultrasonic data over the volume collected in the container and the results are tabulated in Table No: 2, 3 and 3.

<table>
<thead>
<tr>
<th>S.n o</th>
<th>Integrated Flow indication</th>
<th>Integrated Flow value per every 15 minutes from ultrasonic sensor(Qx) in liters</th>
<th>Integrated Volume collected in 30cm*30 cm square tank/quarter minute(Qn) in liters</th>
<th>Error in milliliters</th>
<th>%error</th>
<th>% Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Q1</td>
<td>1.8759</td>
<td>1.794</td>
<td>81.9</td>
<td>4.57</td>
<td>95.43</td>
</tr>
<tr>
<td>2</td>
<td>Q1+Q2</td>
<td>3.69875</td>
<td>3.712</td>
<td>13.2</td>
<td>0.36</td>
<td>99.64</td>
</tr>
<tr>
<td>3</td>
<td>Q1+Q2+Q3</td>
<td>5.5123</td>
<td>5.589</td>
<td>76.7</td>
<td>1.37</td>
<td>98.63</td>
</tr>
<tr>
<td>4</td>
<td>Q1+Q2+Q3+Q4</td>
<td>7.34126</td>
<td>7.4189</td>
<td>77.6</td>
<td>1.05</td>
<td>98.95</td>
</tr>
<tr>
<td></td>
<td>Average Accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>98.16</td>
</tr>
</tbody>
</table>

**Table No. 2 :** Accuracy Estimation of Flow measurements at Notch water level at 3 cm.

4. CONCLUSION:
The results obtained depicts that the selection of Ultrasonic sensor to measure the flow and rate of flow of any open channel notch is promising and the obtained accuracy range is 96 to 98% and it is also observed that better the height of water level over the notch giving better accuracy. The deviation of 2 to 4 % of error can be minimized if necessary actions to maintain the level over the notch steady and also leakage factors into consideration.

5. FUTURE SCOPE:
In the present study a test has been carried over a notch having dimensions of 1 cm X 2 cm, 1cm X 2.5 cm, 1 cm X 3 cm. The same methodology can be extended for the large dimensions like open channels of river canals and streams for smart estimation of flow in future, with high range ultrasonic sensor as the present ultrasonic sensor (HC-SR04) has a technological limitation of estimating distance with 30Cm with high accuracy and better estimation of coefficient of discharge. The Arduino embedded hardware has limitation of process speed that may effect the readout data transfer rate[7].

6. REFERENCES:


