Simulation of Dewatering System in A Mine Shaft Using A Prototype Model Driving by Arduino Microprocessor

Omer Haitham Kanam¹, Abdullah H. Ibrahim²
¹,²Department of Mining Engineering, College of Petroleum and Mining Engineering, University of Mosul, Mosul, Iraq, 41002.
¹Omer.kanam@uomensul.edu.iq , ²abdallh.hussen@uomensul.edu.iq

Abstract

Dewatering is a process which is related to water removing from the excavation worksite during mining. In this research, a prototype model of shaft mine has been fabricated and the system is simulated using ultra sonic sensors and ARDUINOUno microprocessor and a control monitor has been built by LABVIEW software to drive the system. Horizontal slice Method has been applied in calculations of water level. An extensive tests are carried out by measuring the water level inside the mine shaft and is compared to predicted data from the system. The recorded error is 0.22 % of the whole tank capacity at full load condition. A desired water level is calculated based on the desired time and this one is compared to the speed of sound with an interesting result of average error 0.00036s in time. This mechanism is absolutely passed with no modification and it has a flexibility to apply in various industrial aspects efficiently with low cost.

Keywords: Water Level, Horizontal Slice Method, Arduino, Labview, Dewatering, Mine shaft

1. Introduction

Water flooding is being major destructive issue in many industries especially in underground mines; therefore, these industries with different aspects are using an automatic liquid level controller system varies in linking method. Liquid level controlling system had been developed from the integrated circuit of simple IC to modern control devices as well as the radar controller system. X. Xuening, has been used the single chip microcomputer with LABVIEW to design a level control system. The model deals with SCM hardware circuit and has realized by LABVIEW. The measurements were compared to laboratory level system and both the real curve and time are presented on the screen [3]. A remote access has created by Vishal, for driving water filling system automatically by using LABVIEW software with the help of smartphone and Cross-platform communication toolkit platform. The system was showed a flexibility to measure the desired water level and monitoring by panel screen [4].

Laith Abed Sabri and Hussein Ahmed Al-Mshat have been investigated the water level system using Labview program. They used fuzzy and PID controller to implement the measures and to maintain the level to the desired point. It has found, the fuzzy logic is more precise, better performance method with no overshoot, more enhanced than PID, low setting time[5]. Asaad Ahmed Mohammedahmed Eltaieb and Zhang Jian Min, refers to manage the water pumping of a tank by Arduino microprocessor. They divided the desired tank into 4 levels (0%,
25%, 50%, and 100%) while measuring. The study is focused on measuring the water level in both supply and desired tanks to stop or operate the pump automatically and the data were shown on LCD display as well as a beep sound generated by Buzzer output part [7]. Eka Cahya Primaa et al., proposed automated water filling tank to control the water pump while operation based on Arduino microprocessor with ultrasonic sensor. The measuring of water level and duration of water filling up is considered to overcome the flooding because the system is already automated. The error between desired and actual level of water was 6.07[\%] which is fair good [8]. Hemin Ismael Azeez et al., suggested a prototype model that control the water level in overhead tanks. Labview was the interfacing software used to programmed the Arduino microprocessor and other objects. The absolute error is presented the difference between the actual and wanted water level with maximum error of 2.3 mm in the volume of water which is satisfied [9].

The designed model used LABVIEW to control ARDUINO UNO board to automate the water level in an overhead mine shaft and indicating the level of the water. Ultrasonic sensors were used as an alternative to conductors as a sensor based on distance measurement of the water surface from the established minimum and maximum scales and emphasize the water level is continuously detected.

2. Theory

2.1 Prototype Description

The overall scope of the prototype is presented in Figures 1 and 2. The proposed system is composed of a mine shaft, a pump to pump the water from the mine shaft to the tank. The ARDUINO UNO board operates based on the program written in LABVIEW will detect the water level via ultrasonic sensors as well as instruct the relay circuit when predefined water level limitations reached.

Fig. 1: The Designed Prototype

Fig. 2: Sketch of The Designed Prototype

2.2 Connected Parts of The System

The ultrasonic sensor used to measure the water tank level and gives the information about the depth which can
use to set minimum and maximum level, also the ultrasonic sensor sent data to the Arduino. The relay connected to
the Arduino used to control the pump. The circuit is connected as shown in figure 3.

![Fig. 3: Schematic Diagram of Connected Parts](image)

To start the detection ranging, first a pulse with 10uS is needed to trigger the input and Secondly, eight cycle at
40 kHz of ultrasound will sent and raise its echo. The pulse width is a distance object, can calculate. The formula
used to calculate the range of the time interval between sending trigger signal and receiving echo signal is timing
diagram of ultrasonic sensor operation shown in Figures 4 and 5 respectively [3].

![Fig. 4: Ultrasonic Sensor Working Principle](image)

![Fig. 5: Hc-Sr04 Ultrasonic Module Timing Diagram](image)
The required speed can be calculated from equations 1 and 2 below at standard speed of sound (340m/s) [8],

\[ Speed = \frac{Range}{Time} \] \hspace{1cm} \ldots (1)

\[ Range = \left(\frac{Speed \times Time}{2}\right) \] \hspace{1cm} \ldots (2)

2.3 Software and Flowchart

2.3.1 Arduino-Uno

Arduino-Uno microprocessor is programmed by a language, similar to (C++) with some development, called Wiring-based language, and a Processing-based integrated development environment [2].

2.3.2 Program Flowchart

The basic flow process to control the system is described in figure 6.
1. The overhead tank has two levels, maximum and minimum
2. Ultra-sonic sensors are used to continuously detect the water level (WL) in the tank.
3. Via Arduino UNO, and the LABVIEW monitors the water level and shows the current level of the water.
4. If scale exceed the maximum (WL), the buzzer will be on for Warning.

![Fig. 6: Program Flowchart That Shows Process of Controlling](image)

2.3.3 LABVIEW software

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) programs is a graphical programming language which uses icons for creating applications such as instrumentation, data-acquisition, communication and control with automation [6].

2.4 Calculations Procedure

A 30-cm-diameter air shaft was sunk 40 cm to the bottom of a coal seam. It was subsequently abandoned and
allowed to fill with water to within 5 cm of the collar, 5" pipe. The single-stage characteristic submersible pump curve is shown in figure 7.

![Figure 7: Characteristic Submersible Pump Curve](image)

The method of horizontal slices is applied in calculations by dividing the shaft depth to slices which were on the positions of 10 cm, 20 cm and 30 cm, and by neglecting the shock losses. The flow rate of the dewatering system is 3 L/min, and with the help of pump characteristic curve as in figure 7, the total head and power can be obtained as 1.94 cm and 3.6 w respectively.

### 3. Results and Discussion

The designed front panel by LABVIEW program to monitor the dewatering system is shown in figure 8 below.

![Figure 8: System Panel Designed](image)

The head loss calculations for the build system was determined based on Darcy-Weisbach equation as shown in equation 3 and the designed panel of head loss calculations is also shown in figure 8. Where this front panel includes inputs and outputs, the inputs are type of fitting, sizes of fitting, flow rate, head static, number of fittings, length of pipe, diameter and the surface roughness, and the results are displayed as total head outputs [1].

\[
H_l = f \frac{L V^2}{D g}
\]  \( \cdots (3) \)

The data shown in Table 1, are representing required and actual range of water level values in the overhead tank. The range of required water level are in between 3 cm which is the minimum water level in the tank and 31 cm
which represent the maximum level of the overhead tank. The difference between the actual and required values are expressed as absolute error related to position. As it can be seen from the table, the maximum error occurred is 0.3507 cm, this shows how the system has great extent in precision.

Table 1: Required and Actual Range of Water Level Values in The Overhead Tank

| Actual Range of Water Level (cm) | Required Range of Water Level by Sensor (cm) | Absolute Error Position (cm) | Error Percentage (%) |
|---------------------------------|---------------------------------------------|-----------------------------|---------------------|
| 3                               | 3.3141                                      | 0.3141                      | 10.47               |
| 5                               | 5.1185                                      | 0.1185                      | 2.37                |
| 7                               | 7.2704                                      | 0.2704                      | 3.8628              |
| 9                               | 9.2377                                      | 0.2377                      | 2.641111            |
| 11                              | 11.1945                                     | 0.1945                      | 1.768182            |
| 13                              | 13.2702                                     | 0.2702                      | 2.078462            |
| 15                              | 15.1929                                     | 0.1929                      | 1.286               |
| 17                              | 17.0113                                     | 0.0113                      | 0.078824            |
| 19                              | 19.2423                                     | 0.2423                      | 1.275263            |
| 21                              | 21.1034                                     | 0.1034                      | 0.492381            |
| 23                              | 23.1556                                     | 0.1556                      | 0.676522            |
| 25                              | 25.0443                                     | 0.0443                      | 0.1772              |
| 27                              | 27.1231                                     | 0.1231                      | 0.455926            |
| 29                              | 29.0984                                     | 0.0984                      | 0.33931             |
| 31                              | 31.0638                                     | 0.0683                      | 0.220323            |

The Error percentage were fluctuated between 10.47 % as a maximum and reduced to 3.86% as a second maximum value then progressively decreasing down to minimum value that equal to 0.06 %. Practically, this results are agreed without any modification.

According to the data obtained in Table.1, The actual time must be calculated theoretically because the ultrasonic sensor depends on the speed of sound and it’s considered constant. Similarity, the required time is calculated based on the required range of water level. Figure 9, is clearly shows the relationships between time and required water range of water level. The slop at any position on the red line represents the speed of sound. Also, the black circles represent the calculated manual data.

Fig. 9: Water Level Vs. Time
The average error of the required time is calculated to be 0.00036s and added to the required time for the purpose of determining the required range of water level nicely as shown in figure 10. The blue line represents the slope of the required speed of sound and the black circles are the calculated manual data.

![Fig. 10: Water Level Vs. Time After Adding the average error of the Required Time](image)

4. Conclusions

The dewatering problem must be controlled by means of automated system to prevent any collapsing in underground mines; therefore, the fabricated model is simulate a prototype of water mine shaft and how to control the water level using developed code written by IDE’s Arduino microprocessor software. An interesting part of this system which is the front panel designed by LABVIEW program to visually monitor the changing in water level. The system can predict the level of water to the accuracy limit of average error (0.00036s) based on the speed of sound. The maximum error is equal to 0.350cm in terms of length for tank depth. The head losses is calculated according to horizontal slice method which was very accurate and it can be clearly monitored on the front panel. In general, this system was able to cut down the consuming time and cost with the available common electronic tools based on the theoretical part. Finally, it can be used in different aspects not only to simulate the dewatering of underground mine shaft but also in civil and other industrial places.

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