Design of an Integrated Anti-Hardening System for Carbon-In-Leach Tanks*

[1]R. A. Ofosu, [1]E. Normanyo and [1]B. Essilfie-Nyame
[1]University of Mines and Technology, P.O. Box 237, Tarkwa, Ghana

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Abstract

Slurry density monitoring is of paramount importance in the industrial world. Most industries, especially cement and mineral processing industries, employ this method to obtain good quality products. However, most Carbon-In-Leach (CIL) tanks of gold processing industries do not use slurry density monitoring systems. As a result, many a time, agitation difficulties occur when the slurry begins to harden. This paper, therefore, seeks to design an integrated anti-hardening system for CIL tanks, with the aid of a microcontroller, to monitor the density of the slurry in order to prevent it from hardening. Slurry density measurement was achieved with the help of a strain gauge pressure sensor and a couple of level sensors. Atmega 328p microcontroller board was programmed to continuously compute the density of the slurry from values of pressure and level of slurry in the tank indicated by the pressure and level sensors, respectively. The microcontroller responds to slurry hardening by activating a light emitting diode and triggering the piezo buzzer when a set point is reached. The designed circuit was successfully simulated using Proteus 8.2 design suite software to ascertain its functionality. Based on the results obtained, the light emitting diode and piezo buzzer activated when the set point was reached. It was concluded that the anti-hardening system is effective for constantly monitoring the density of the slurry to prevent it from hardening. It was also recommended that the mining industries could employ the designed system to monitor the density in order to prevent hardening of slurry in CIL tanks.

Keywords: Carbon-In-Leach Tanks, Slurry Densisty, Strain Guage Pressure Sensor, Microcontroller

1 Introduction

Carbon-In-Leach (CIL) is a gold leaching process. In the process, cyanide is used to leach gold from a solid matrix (slurry) to form gold cyanide complex. In the extraction process, activated carbon is added to the slurry to adsorb gold cyanide complex from solution. Constant stirring of the mixture is required to enhance the leaching and absorption process and more importantly, prevent the slurry from hardening. It is therefore necessary to employ a control system that will prevent the slurry from hardening. This control system should constantly monitor the density or the thickness of the slurry to ensure that the density of the slurry is less than that which will cause it to harden.

A typical CIL plant consists of six to eight tanks of about 2500 m^3 to 3500 m^3 in volume. Each tank contains a carbon transfer pump, an intertank screen and an agitator. The carbon transfer pump transfers carbon from one tank to another. The intertank screen prevents carbon movement from one tank to another while the agitator stirs up the slurry, basically to keep the solids in suspension and to supply the required amount of oxygen. Agitation is further assisted by the use of tank baffles to increase the efficiency of agitation and prevent centrifuging of slurry. However, difficulty of slurry agitation occurs as a result of lack of insufficient power supply to the agitator motor, failure of bearings, lack of appropriate lubrication, misalignment of gear box coupling and the hardening of slurry (Anon., 2017a). This work however, tends to cover slurry hardening and how it can be prevented.

Slurry hardening causes the agitator motor to draw excessive current resulting in circuit breaker trips, agitator malfunction and subsequent hardening of slurry with the passage of time. In a number of CIL setups, the problem of hardening of slurry demands draining a portion of the slurry while increasing its water content. This exercise consumes valuable production time. At times, emergency shutdowns maintenance becomes necessary in order to solve the slurry hardening problem.

In most mineral processing setups, slurry density is monitored either manually or automatically. Most mining industries employ the traditional method of monitoring slurry density. This system involves fetching slurry samples and measuring the density manually at regular intervals daily. At Damang Gold Mine for instance, this is done every two hours. Other industries also make use of various automatic systems to monitor slurry density as the slurry flows through pipes.

Usually, the manual method is the traditional method where slurry samples are fetched at regular intervals for the manual measurement of density. Automatic methods include use of the Slurry Density Meter (SDM) system, by measuring the acoustic impedance of the slurry and they are mostly used in the cement industry and the Solid Fraction Monitor (SFM) system, which entails determination

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of liquid-solid ratios of slurry (Anon., 2016; Anon., 2017b).

Review of related works indidates that limited work has been done as far as monitoring the density of slurry is concerned. So far, only Osei *et al.* (2016), have examined the possible causes and measures to mitigate siltation of ore particles in leaching tanks. Their work employed particle analysis, slurry settling rate test and efficiency of agitation to determine potential causes of siltation whiles deflocculation test and grind analysis were conducted to ascertain mitigation measures. Results from their study indicated that, high settling velocity of particles, inefficient milling and classification, poor slurry agitation and particle flocculation were the major causative factors leading to siltation. They concluded that increase in milling residence time and particle deflocculation are potential remediation measures for curbing siltation.

This paper proposes a system that monitors the density of slurry within the CIL tank and signals the control engineers when the density of the slurry exceed a certain setpoint value so that appropriate control action can be taken to avoid slurry hardening for easy agitation.

The Integrated Anti-Hardening (IAH) System, which is the main focus of this paper, is also an automatic way of monitoring the density of slurry. Although SDM and SFM systems monitor slurry density automatically, these methods are applied outside a tank. However, the IAH system always monitors slurry density right within a tank.

2 Resources and Methods Used

The design concept and block diagram of the integrated system are provided in Fig. 1 and Fig. 2, respectively.

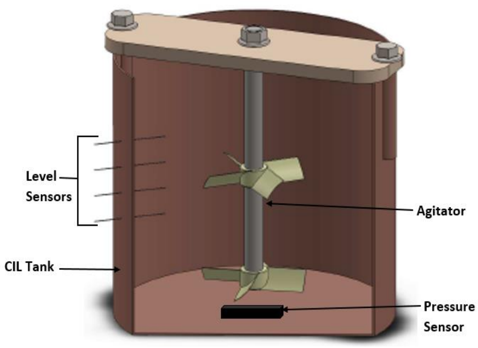

Fig. 1 Design Concept Representation of Slurry Anti-Hardening System

The density of the slurry to be monitored by the control system was determined by measuring the pressure due to the weight of the slurry and the level of the slurry in the tank. The pressure due to the weight of the slurry was determined using a pressure sensor, placed at the bottom of the tank. The level of the slurry was also determined using level sensors, placed on the wall of the tank. The microcontroller was finally used to compute the density of the slurry based on the pressure and level sensor output values.

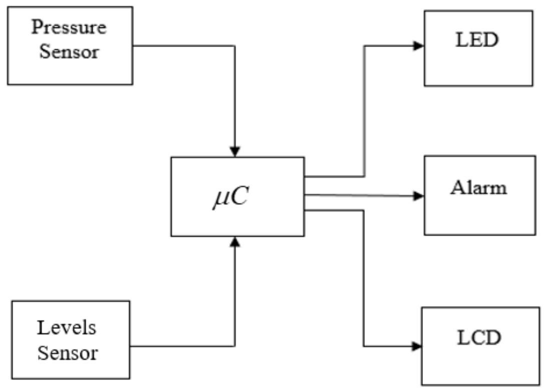

Fig. 2 Block Diagram of the Integrated Anti-Hardening System

2.1 System Instrumentation

A sensor is a device that produces a useful output in response to a specific physical quantity. It accesses a physical quantity like pressure and converts it to a form, such as electrical signal, suitable for processing (Ripka, 2013). In this work, consideration was given to strain guage pressure sensor and conductive level sensors as the main sensors to determine the density of the slurry.

2.1.1 Pressure Sensing and Measurement

A strain gauge pressure sensor converts force, pressure, tension, weight, etc., into a change in electrical resistance, which can then be measured. The strain gauge exhibits a change in resistance in response to the surface strains sensed (Hannah and Reed, 1992; Hermann, 1998). The relationship between the resistance and the strain is given by the Gauge Factor (G) of the gauge foil. The Guage Factor (G) is defined as presented in Equation (1) (Hannah and Reed, 1992; Hermann, 1998);

$$\Delta R = GR_o \varepsilon \qquad (1)$$

where, G=guage factor, ΔR = the change in resistance caused by strain, R_o = the resistance of the undeformed gauge, ε = strain.

For common metallic foil gauges, the gauge factor is usually a little over 2. For a single active gauge and three dummy resistors of the same resistance about the active gauge in a Wheatstone bridge configuration, the output voltage (V) from the bridge is given by (Hannah and Reed, 1992; Hermann, 1998):

$$V_0 = \frac{V_s.G.\varepsilon}{2} \quad (2)$$

where, V_o = output voltage from the bridge; and V_s = the bridge excitation voltage.

In this paper the unbounded strain gauge was used. The unbounded strain gauge was selected because it has the ability to convert the weight exerted by the slurry into an electrical signal. It also has the ability to operate in a wide normal temperature range as compared to other pressure sensors, such as capacitive, electromagnetic and piezoelectric sensors. As the name goes, it does not necessarily require being directly bonded to the material under study. It is also very sensitive to temperature, very stable and has the ability to determine a high magnitude of force due to its gauge length (Al-Naimi, 2016; Anon., 2014).

Pressure measurement, at this point, is basically achieved by instrumenting the weight of slurry per unit area. In this process, the strain gauge pressure sensor was placed at the bottom of the tank to measure the pressure P. Hence:

$$P = \frac{mg}{A} \quad (3)$$

where, P = pressure due to weight of slurry; ρ = density of slurry in the tank; g = acceleration due to gravity; m = mass of slurry in the tank and A = cross sectional area of the tank.

The different values of pressure are constantly measured by the sensor and a signal is sent to the input of the microcontroller.

2.1.2 Level Sensing and Measurement

Level sensors are employed basically to detect the level of fluids, including water and slurry. The fluid to be measured can be inside a container or in its natural form. Probes are based on the principle of measuring level by making contact with water or other conductive liquids that have free ions. A low AC voltage is applied between the probe electrode and the tank wall. A conductive path is established between the electrode and the tank wall when the liquid comes into contact with the electrode tip. The current sensed is used to indicate the level of the liquid in the tank (Ejiafor and Oladipo, 2013; Anon., 2017c). Conductive level sensors or probes can be used for applications involving corrosive substances. The slurry in the CIL tank contains cyanide, which is corrosive. Hence, the probes are more effective for detecting the level of the slurry in the CIL tank as compared to other level sensors. They are also readily available in the market. Probes can also function with less power source. Since they make use of less power, probes are safe to use and also meet international standards for hazardous locations. They are also very simple to install. In view of these unique characteristics, conductive level sensors probe is used in this research.

2.1.3 Density Measurement

Density, ρ, is given by:

$$\rho = \frac{m}{V} \quad (4)$$

where, V = volume of slurry in the tank.

But volume of slurry in the tank is given by:

$$V = Ah \quad (5)$$

where, h = level of slurry in the tank;

Hence, density can be computed as:

$$\rho = \frac{m}{Ah} \quad (6)$$

Multiplying Equation (6) by $\frac{g}{g}$, gives;

$$\rho = \frac{mg}{Ahg} \quad (7)$$

Substituting Equation (3) into Equation (7), gives

$$\rho = \frac{P}{hg} \quad (8)$$

Hence, the density of the slurry at any point in time is given by the pressure due to the weight of the slurry, the height due to the level of slurry in the tank and the acceleration due to gravity. This is constantly computed by the microcontroller.

2.1.4 Set Point Determination

The process involves setting slurry level and pressure to a particular range of values. For each level, a random pressure value is recorded and the density is calculated. The process is repeated several times after which the average density is computed from the various density outputs. This value is used as the setpoint. For instance, for the following range of values, Pressure ranging from 50 Pa to100 Pa and levels, 10 m, 15 m, 20 m and 25 m, the density setpoint, using Python2.7 software for the process, was computed as 0.6320 kg/m^3.

2.2 Flow chart for the Proposed Design

The flow chart for the slurry anti-hardening system is as shown in Fig. 3. The system was programmed to work automatically, such that the microcontroller accepts inputs from the level sensors as well as the pressure sensor as shown in Fig 3. The steps of the flow chart are as follows:

(i) Measure the slurry level and the pressure using the probe and the strain gauge pressure sensor, respectively.
(ii) Use the microcontroller to compute the density from pressure and level inputs.
(iii) Compare the calculated density to the setpoint value and if it less than the setpoint value, the process is repeated till the density computed is above the setpoint.
(iv) If the density is above the setpoint value, activate the LED and Buzzer to signal the control engineers to take appropriate control action to prevent the possibility of the slurry hardening.

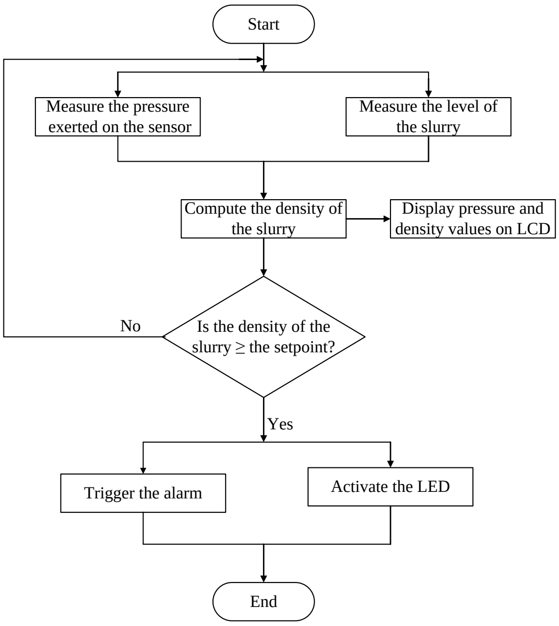

Fig. 3 Flowchart for the Slurry Anti-Hardening System

2.3 System Design

The circuit diagram (see Fig. 4) is made up of a 5 V DC source, the strain gauge sensor represented by the potentiometer, probes represented by conductors (denoted by LEVELS 1-4), buzzer, Arduino Uno Microcontroller, switches representing the slurry, LED, 10 kΩ resistors as pull-up resistor for the purpose of achieving Transistor-Transistor Logic (TTL), 100 Ω resistors to limit the current to the base of transistors to prevent them from damage and NPN transistors labelled Q1-Q4. The 5 V DC source supplies power to the circuit. The potentiometer is connected to the analog input pin (A0) of the Arduino Uno microcontroller. One terminal of a conductor is connected to a digital input pin of the microcontroller through a 10 kΩ resistor. LEVEL 1 was given to pin 13, LEVEL 2 to pin 12, LEVEL 3 to pin 11 and LEVEL 4 to pin 10. The other terminal of the conductor was connected to a switch through a transistor and a 100 Ω resistor. The buzzer and LED are connected to pin 1 of the microcontroller through transistor Q5. The buzzer and LED are switched ON and OFF by the transistor Q5. A 100 Ω resistor is also connected in series with the buzzer and LED. The LCD inputs are also connected to pins 2 to 7 of the microcontroller.

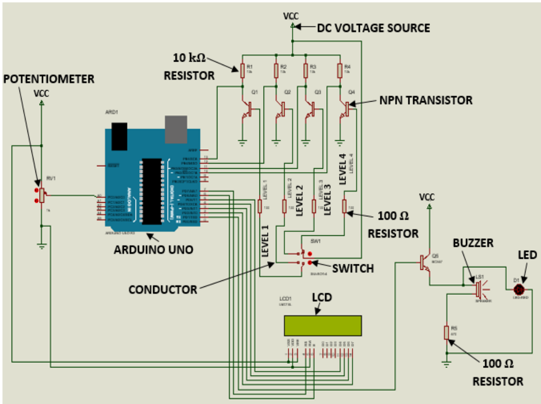

Fig. 4 Circuit Simulation with Proteus Software

In operation, when the conductor comes into contact with the slurry (i.e. conducting mode), the circuit at that level is closed and current flows. Hence, the height at that level is indicated. When the slurry is below that level (i.e. non-conducting mode), the circuit is opened and no current flows. Therefore, no reading is taken at that level. In non-conducting mode, the transistor base-emitter region will not have sufficient voltage to get biased, hence, it offers a high impedance to the flow of current from the source to ground. At this point, voltage at the collector terminal is maximum. In this case, the microcontroller sees HIGH at its input. Therefore, the microcontroller assigns a value of zero to that level to show that the particular level is not conducting. In conducting mode, the transistor base emitter region is forward biased, hence, current flows from the source to ground. At this point, voltage at the collector terminal is zero. Therefore, the microcontroller sees LOW at its input. The microcontroller then assigns the corresponding value to the level in that circuit. In effect, that is the value of height used.

3 Results and Discussion

3.1 Simulation Results

The results presented are based on the circuit simulation of the integrated anti-hardening system for CIL tanks. The density and pressure values are constantly displayed on the LCD screen. Under normal conditions or at density (0.6320 kg/m^3) below the set point, the LED and buzzer are not activated. Both the red LED and buzzer are off, as shown in Fig. 5.

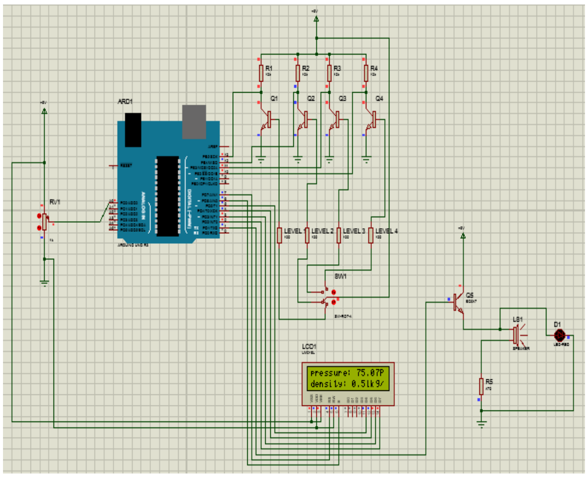

Fig. 5 Screenshot of Simulation of Designed Circuit (Red LED and Buzzer OFF)

However, at density equal to or above the set point of 0.6320 kg/m^3, the red LED blinks and the buzzer sounds an alarm to prompt the control engineers to take appropriate control action in order to prevent the slurry from hardening. This is illustrated in Fig. 6.

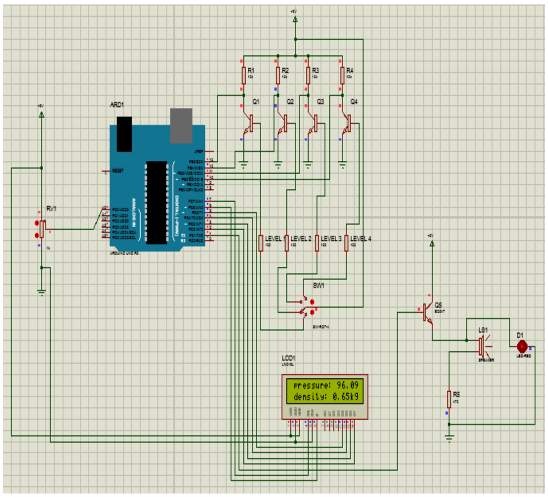

Fig. 6 Screenshot of Simulation of Designed Circuit (Red LED and Buzzer ON)

3.2 Discussion

The results obtained from the simulated circuit indicate how the density of the slurry in the tank was successfully monitored at any point in time. Both the pressure and density values of 75.07 Pa and 0.51 kg/m^3 and 96.09 Pa and 0.65 kg/m^3 respectively were displayed on the LCD screen, as shown in both Fig. 5 and Fig 6. In Fig. 5, it was also observed that the LED and buzzer were off, indicating that the density of the slurry at that point was normal for effective slurry agitation. However, in Fig. 6, the LED and buzzer were activated because the density of the slurry at that point was above the setpoint likely to cause the slurry to harden.

4 Conclusion and Recommendations

In conclusion the anti-hardening system is effective for constantly monitoring the density of the slurry and responds accordingly by informing engineers to take action to prevent the slurry from hardening. This, in effect, will prevent long term shut down maintenance due to slurry hardening. It is therefore recommended that field test should be done to ascertain its practicality in actual implementation.

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Authors

Robert Agyare Ofosu is a Lecturer in the Electrical and Electronic Engineering Department at the University of Mines and Technology (UMaT), Tarkwa, Ghana. He holds the degrees of BSc (Electrical and Electronic Engineering) from UMaT and MSc (Electrical and Electronic Engineering) from JKUAT, Kenya. He is a member of the Institute of Electrical and Electronic Engineers (IEEE). His research interests include control engineering, industrial automation, embedded systems, electrical machines and drives, artifical intelligence, frequency control of power system and electrical cable tension control.

Erwin Normanyo is a Senior Lecturer in the Electrical and Electronic Engineering Department at the University of Mines and Technology, Tarkwa, Ghana. He holds MSc (Electromechanical Engineering) from Kharkov State Technical University, Ukraine. He is a member of the Ghana Institution of Engineers. His research interests include industrial automation, industrial energy management, instrumentation systems, control engineering, automated electric drives and mechatronics.

Benjamin Essilfie-Nyame is a national service personnel at the Electricity Company of Ghana (ECG). He holds a BSc degree in Electrical and Electronic Engineering from the Univeristy of Mines and Technology, Tarkwa, Ghana. His research interests include machine learning and control systems.