# Estimation of Weibul Parameters for the System Control of Hydrogen Potential at the De-Coppering Section of Shituru Hydrometallurgical Plants

**Ngoie Kantumoya Gaston**

Higher Education and Technical Institute of LIKASI, (Democratic Republic of Congo)

**Abstract:** ***In this paper, we want to determine the reliability of the electromechanical control system of the hydrogen potential at copper and cobalt hydrometallurgical plants at the hydrometallurgical plants of SHITURU. To achieve this goal, the Weibul model was used. The results of this study show that the hydrogen potential control system appears as a chain whose weakest link is the glass sensor which must be replaced after a certain time corresponding to the correct operation. This has the effect of producing unwanted copper during shutdown times during which the glass electrode is replaced.***

**Keywords**: Hydrogen potential (pH), control system, de-coppering, Weibul parameters, glass sensor

## 1. Introduction

SHITURU's hydrometallurgical plants process mining products from surrounding concentrators located near the mining deposits.

The hydrometallurgical operations to which these concentrates are subjected essentially include electrolysis and de-coppering. If the electrolysis leads to the recovery of the metal by means of a direct electric current, the de-coppering is a precipitation operation of the copper-rich substances. The latter is based on the regulation of the pH value set by the operator [1].

The pH regulation is obtained by means of the lime sent into the solution in order to increase the basicity of the acid-based solution.

After a certain period of operation, the lime poured into the de-coppering tank causes the glass sensor to become fouled. This leads, on the one hand, to an incorrect display of the pH measurement on the transmitter and, on the other hand, to an erroneous transmission of the measurement signal to the controller. Under these conditions, an operator decides to voluntarily stop the electromechanical control system. This stop may be justified not only to replace the glass sensor, but also for reasons of failure arrangement of other electronic or electromechanical components of the control system.

The purpose of this study is to determine the impact of these shutdowns on the reliability of the pH control system and to evaluate its maintainability, availability and MTBF.

### 1.1. Composition and operation of electromechanically control system

The pH system control at the de-coppering is constituted [2]:

- A glass sensor. It converts the pH into an electrical signal. The pH sensor consists of a glass electrode and a reference electrode;
- A transmitter that displays on seven segments the pH value in the de-coppering tank;
- A PID regulator (Proportional Derivative and Integral). It compares the measurement with the set point, elaborates the error signal which undergoes a PID correction before being sent to an actuator via a pre-actuator;
- Silicon Control Rectifier pre-actuator or Triac depending on whether it is desired to obtain a command by modulation of the width or frequency of the pulses;
- And finally the solenoid valve which acts as the linear actuator and is intended to pour into the tank lime as needed by the electronic control.

The glass electrode converts the pH into an electrical signal using the NERST principle

$$E = E_0 - \frac{2{,}3\,RT}{F}\,pH \qquad (1)$$

In this expression, $E_0$ is the normal potential, $F$ is the Faraday constant, , $R$ is the gas constant and $T$ is the Absolute temperature.

The transfer function $C(s)$ of a PID corrector according to the proportional adjustment parameter $G_p$ , the integral parameter $T_i$ and the derived parameter $T_d$ used in SHITURU is

$$C(s) = G_p\left(1 + \frac{1}{T_i s} + T_d s\right) \qquad (2)$$

### 1.2. Equivalent schemes of the control system from the point of view of reliability

For a system, it is possible to establish an equivalent scheme from the point of view of reliability that takes into account the failure of each component. This scheme is based on how the failure of each component affects the overall or partial shutdown of the system. Therefore, the pH control system from the point of view of reliability is presented as a series system between the following elements: glass sensor, electronic regulator and solenoid valve. This assertion is due to the fact that the failure of one of the cited equipment completely implies the shutdown of the control system.

As we know, there is the technical repair time between two periods of good operation. This time corresponds to the moment during which there is intervention on one or more equipment that make up the control system. An intervention is required whenever there is a difference $E_m$ greater than 5% between the value displayed on the transmitter $pH_T$ and that provided by the portable pH meter $pH_m$.

$$E_m(\%) = \left[\frac{|pH_T - pH_m|}{pH_m}\right] * 100 \qquad (3)$$

## 2. Bibliography Survey

To assess reliability, it is necessary to resort to some mathematical tools for calculating probability.
In this study, we will use the Weibull model. According to Jean-Marie AUBERVILLE [3], this model is suitable for any failure rate and makes it possible to determine in which period of life is the studied system:

- Youth period (also known as the break-in period), or period during which the original high failure rate changes in descending order;
- Maturity period also referred to as the useful life period during which the failure rate is constant. During this period, fragile materials were eliminated;
- Period of old age also called obsolescence phase. During this period, there is a sudden increase in the failure rate leading to a deterioration of the equipment.

### 2.1 The reliability model of Weibul

Weibul's law is expressed by

$$R(t) = exp - \left(\frac{t-\gamma}{\eta}\right)^{\beta} \qquad (4)$$

The three parameters β, η and γ are respectively called shape parameter, scale parameter and position parameter. The shape parameter is an indicator of the life cycle period of the system being studied. The scale parameter is an indicator of the MTBF and the standard deviation of the distribution. The position parameter indicates the origin of the failures.

According to this model, the shape parameter β provides the indications on the failure rate. If it is less than 1, the system operates with a decreasing failure rate. He is in the youth phase. If the parameter β is equal to or has a value close to 1, the system is in a mature state because the failure rate is constant. For a value greater than 1 of the shape parameter, the system is in a state of obsolescence [4].

Taking into account the distribution function $F(t)$, the linearization of equation (5) leads to the expression

$$\ln\left[ln \frac{1}{1-F(t)}\right] = \beta \ln(t-\gamma) - \beta \ln \qquad (5)$$

## 3. Methodology and approach

For the development of this study, we used the documentary technique, the processing and analysis of the data collected and the statistical approach.

The documentary technique allowed us to collect the data found in the step sheets used at the hydrometallurgical plants of SHITURU. The values recorded on the leaves are taken after a two-hour deadline.

The analysis and data processing made it possible to determine the operating times and the technical repair times not clearly recorded in the step sheets of the de-coppering section I and II.

The statistical approach was used to determine MTBF, reliability using the Weibul model. In short, two materials are used for this study: the historical file and the walking sheets.

What is meant by historical file at the factories of SHITURU is nothing other than a document on which are listed the interventions on the equipment that make up the regulation system. These interventions cover two major activities namely troubleshooting and repair. On the historical files are also reported the situation of stocks consumables.

The leaves contain on a column the pH value provided by the transmitter and on the adjacent column the exact pH value in the tank provided by the precision portable pH meter. When the gap between the two values becomes unacceptable, a human operator decides to stop the electromechanical system to check the level of dirt that covers the glass sensor.

### 3.1 Determination of Weibul parameters

To analytically determine the Weibul parameters, we first deduce the TBFs (Time Between the Failures) in the control system monitoring documents, then we assign a rank $i$ to each TBF and we deduce the cumulative frequencies $F(i)$, approximation of the distribution $F(t)$.

The calculation of the cumulative frequencies depends on the size of the sample $N$ of the TBFs [5]-[6].Three cases are considered: the case where $N > 50$, the case where $20 < N < 50$ and finally the case where $N < 20$. In the first case, the cumulative frequencies $F(i)$ is calculated by the formula

$$F(i) = {}^{i}/_{N} \qquad (6)$$

In the second case, it is the formula (7) which is used.

$$F(i) = \frac{i}{N+0{,}4} \qquad (7)$$

In the latter case, the average rank approximation formula (8) is used.

$$F(i) = \frac{i+0{,}3}{N+0{,}4} \qquad (8)$$

### 3.2 Calculation of MTBF and failure rate $\lambda(t)$

With the Weibul model, the Average Time Between the Failure (MTBF) is calculated by

$$MTBF = A\eta + \gamma \quad (9)$$

In formula (9), A is the gamma function as

$$A = \Gamma\left(1 + \frac{1}{\beta}\right) \quad (10)$$

## 4. Results and Discussions

### 4.1 Results

The values given in the table have been deduced from the first and second de-coppering worksheets.

**Table 1:** Valuation of TBF and TTR **at** the first de-coppering

| *i* | *TBF* | *TTR* |
|---|---|---|
| 1 | 739 | 5 |
| 2 | 663 | 9 |
| 3 | 736 | 8 |
| 4 | 707 | 13 |
| 5 | 734 | 10 |
| 6 | 713 | 7 |
| 7 | 741 | 3 |
| 8 | 720 | 1 |
| 9 | 715 | 5 |
| 10 | 712 | 8 |
| 11 | 717 | 3 |
| 12 | 738 | 6 |

**Table 2:** Valuation of TBF and TTR at the second de-coppering

| *i* | *TBF* | *TTR* |
|---|---|---|
| 1 | 730 | 14 |
| 2 | 664 | 8 |
| 3 | 725 | 19 |
| 4 | 712 | 8 |
| 5 | 713 | 7 |
| 6 | 705 | 15 |
| 7 | 711 | 9 |
| 8 | 716 | 4 |
| 9 | 741 | 3 |
| 10 | 740 | 4 |
| 11 | 706 | 14 |
| 12 | 741 | 3 |

After treatment of the results and calculations, we obtain for the first de-coppering:

- $\beta$ form parameter is 4.73 ;
- Scale parameter $\eta$ = 122. 42
- Position parameter $\gamma$ = 607.75 hours
- MTBF = 719.78 hours
- The reliability value at the MTBF is 51% and the failure rate is 0.013 failure / hour.

For the second de-coppering, we obtain:

- Form parameter $\beta$ is 2.29
- Scale parameter $\eta$ = 4, 92
- Position parameter $\gamma$ = 608.63 hours
- MTBF = 612.42 hours
- The reliability value at the MTBF is 41% and the failure rate is 0.016 failure / hour.

### 4.2. Discussions

In view of the results, as the chape parameter exceeds 1, it can be said that the pH control system used in the de-coppering section is in a phase of obsolescence. The value of the MTBF corresponds to the duration at the end of which the glass electrode is covered by the dirt coming from the lime used.

The failure is to be interpreted as any event leading to a very strong difference between the measurements provided by the transmitter and those provided by the precision pH meter.

Taken in this sense, the sensor is the major element by which failures occur. The MTTR corresponds to either the time during which the dirt is removed from the sensor or the time during which the replacement of this sensor takes place.

However, observing the equipment that makes up the system does not support the obsolescence argument. Indeed, in the factories of SHITURU, regulating equipment in new condition and sometimes using advanced technology, are kept in stock. These are glass electrodes, regulators, electrodes, pre-actuators and solenoid valves.

Thus after installing or stripped the electrode of the grime, the control system is returned to normal operation and will not stop after a time corresponding to the MTBF. There is no youth phase. The system does not operate according to a mechanical scheme: break-in, maturity and obsolescence. The system operates according to a cycle: the regulation leads to the release of lime which stops the system through the fouling of the electrode responsible for measuring this pH.

The control system appears as a chain consisting of a chemical sensitive part, an electronic part and a mechanical part. It is heterogeneous. Its reliability depends more on the sensitive part consisting of the glass electrode. It appears as a weak link in the chain.

The theory built around the Weibul model better explains the homogeneous systems than the heterogeneous systems. By homogeneous system is meant purely mechanical systems, purely electrical systems.

## 5. Conclusion

In this study, it was discussed to determine the reliability estimators of the pH control system at the de-coppering of the hydrometallurgical plants of SHITURU. To achieve this, the Weibul model was used. The parameters calculated from the data taken during the first de-coppering and the second de-coppering, do not explain better the behavior of the control system. The system operates according to a cycle: the regulation leads to the release of lime which stops the system through the fouling of the electrode responsible for measuring this pH. This system appears as a heterogeneous chain whose electrode appears as a weak link.

It is up to the scientific world to deepen the research on the Weibul model in order to incorporate parameters that take into account this type of system or to develop models more appropriate to the study of this type of system.

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## Author Profile

**NGOIE KANTUMOYA Gaston** received the B.S. degree in Pedagogy and in Engineering with specialization in electronic computing from Higher Education and Technical Institute of LIKASI in 2007. From 2007 to the present day, I am a full-time lecturer of courses related to Automation, Control and Remote Communication. I am a researcher in the field of improvement and adaptation of the applications installed on the new technologies of the information and the communication by the populations in rural areas. Some of my research is oriented towards the efficiency of the automatic systems used in the mining companies located in the province of HAUT KATANGA in the DEMOCRATIC REPUBLIC OF CONGO.