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MASTERS THESIS

Effects of Power Interruptions on Quality and Production in a Galvanizing Plant
Case Study: Roofings Rolling Mills Ltd, Namanve, Kampala

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16/U/13435/GMEM/PE

A Master's Thesis submitted to the Graduate School in Partial Fulfillment of the Requirements for the Award of the Master of Science Degree in Advanced Manufacturing Systems Engineering of Kyambogo University

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ABSTRACT

Steel is the most used engineering material industries. In Uganda, Roofings Rolling Mills Ltd (RRM) is the largest steel manufacturer; with mega industrial undertakings which is in line with national economic development strategy as it employs 2,000 people in the country. However, this is undermined by the negative effects of electric power interruptions. Thus, evaluation of the effects of power interruptions on quality and production in the sheet galvanizing plant was done in accordance to specific objectives to; determine the process parameters that influence the galvanizing; determine the effect of power interruptions on the process parameters; and assess the cost implications of power interruptions on the galvanizing line at RRM. During this study, the most affected processes were identified, damages were quantified and costs related to this effect were determined. To this effect the organization can negotiate for tax reduction levy due to the losses caused by power interruptions. The methods used were quantitative and qualitative, for determining the parameters influencing galvanizing. The various types of rejects, their causes and evaluating how power interruption affects quality and production which in turn affects the organizations performance. This was a success by participatory observation in accordance to a checklist, literature reviews and relating these to the set standards (ISO, ASTM, AGA, UNBS, etc.). To obtain results data analytical techniques (tables, regression analysis and Anova). Analysis have shown that, to obtain high quality products, there is need to ensure that parameters for galvanizing are in accordance to standards. The study showed that color coating and cold galvanizing are the most affected processes. The study shows the different effects of power for 2016 and 2017 on cold galvanizing line as; rejects from 5% to (25.35% and 0.77%), machine efficiency from 94% to (87.76 and 91.7%), production efficiency from 92% to (69.17% and 78.8%) for these years respectively. These resulted to increase in production costs, from UGX 7.5 billion per annum to UGX ≈ 8.65 billion per annum, amidst other investment challenges affecting the organization's performance. For improved performance, the affected lines need alternative power sources supplied to help always clear the products online in case of any power interruption, there is need to have alternative power to clear product on line and conduct risk assessment for the safety of workers, equipment and machinery during power interruptions. Furthermore, it's recommended, that the organization applies for connection to stable power supply line that will reduce on production losses. This will lead to more profits for the organization, thus economic benefits to the government and fulfilling "Uganda's Vision 2040."

DECLARATION

I **Atima Rose (16/U/13435/GMEM/PE)**, a student of Master of Science in Advanced Manufacturing Systems Engineering, of Kyambogo University, declare that the content of this document (thesis) is my original work and it has not been submitted to any university or higher institutions of learning for an academic award.

Signature ……………………………...

Date ……………………………………

ATIMA ROSE

16/U/13435/GMEM/PE

APPROVAL

This certifies that this work has been carried out by **ATIMA ROSE (16/U/13435/GMEM/PE)** under strict supervision, so it affirms that this thesis is confirmed as her own original work and is ready for submission to the Examination Board of Kyambogo University, the Graduate School, Department of Mechanical and Production Engineering; as partial fulfillment of the requirements for the award of Master of Science in Advanced Manufacturing Systems Engineering.

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Date ……………………………………

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My appreciation also goes to the head of department, Mechanical and Production Engineering, Dr. Watmon Titus, my supervisors, Dr. Wandera Catherine and Dr. Excellence Favor for the support and continued professional guidance during this research; not forgetting all my course mates for the consistent support, counsel and words of wisdom: Mr. Mafabi Peter, Matende Richard, Apora James, Omara Walter and Batia Stephen, with whom we shared the same class for the two years. God bless you all.

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LIST OF ABBREVIATIONS/ ACRONYMS

◦C	Degrees Centigrade
Al	Aluminium
Al-Zn	Aluminium Zinc
ASTM	American Standard and Measurements
Ave	Average
C	Carbon
CCL	Color coating Line
Cd	Cadmium
CGL	Coated Galvanizing Line
CRM	Cold Rolling Mill
DT	Down time
Eff,	Efficiency
Eqn.	Equation
Fe	Iron
Fe_2O	Iron Oxide
Fe_2O_3	Iron III Oxide
HCL	Hydro Chloric Acid
HRC	Hot Rolled Coils
Km	Kilometer
LPG	Liquid Petroleum Gas
Ltd	Limited
Mpt	Machine process time
MT	Metric Tons
Mm	Millimeters
Mw	Mega watts
MSc	Master of Science
N	North
N/A	Not Applicable
$NAOH_2$	Sodium Hydro Oxide

Pb	Lead
PPM	Parts Per Million
Rpm	Revolution per minute
RRM	Roofings Rolling Mills
Sept.	September
S	Sulphur
Si	Silicon
Sn	Tin
UGX	Ugandan shillings
UIA	Uganda Investment Authority
UNBS	Uganda National Bureau of Standards
USD	United States Dollars
Std	Standard Deviation
R	Regression coefficient
Sig	Significance level
f	Frequency test
H0	The null hypothesis
H1	The alternative hypothesis
MT	Metric tones
P	Probability
T	Test

LIST OF FORMULAE

Machine Efficiency (ME) = $\frac{\text{Total running time}}{\text{Total running time+total time internal failure}} X\ 100\%$ ……..... Eqn. 4:1

Production Efficiency (PE) = (Machine Output /Machine Input) ×100…..... Eqn 4:2

Linear Regression line y = bx + C…………………………….....……..…Eqn 4: 3

Standard Error (SE) = Standard Deviation /Mean = (δ/n)……………...……….……..Eqn 4: 4

Test results (T) = (Y-µo)/SE ……………………………………………………...….Eqn 4: 5

Tcal = test results calculated = (µ- Ȳ) /δ …………………………….……..…. Eqn 4: 6

CHAPTER ONE

INTRODUCTION AND BACKGROUND OF THE STUDY

1.0 Introduction

This chapter discusses in detail the background of the study, shows the values of steel in the world and Uganda as a country. It introduces the problem under investigation, the objectives that have led to the success of this study, justification and rationale (significance) obtained from this thesis, the scope of the investigation, the conceptual framework of this thesis, limitations that were met during the study and the delimitations that resulted to the success of the study.

1.1 Background to the Study

Steel is the most used engineering material worldwide in various industries; especially the construction, manufacturing, maintenance and transport industries. It is also used for training, which includes steel products such as sheets, beams, sections, channels and pipeline etc. In 2018, the global steel demand was 1.616 billion tones, while in 2019, the global steel demand is expected to reach UGX 1.627 billion due to the high demands and economic value in steel. In the baseline forecast, global steel demand grows by 1.4% per annum, to reach around 2.0 billion tons by 2035. World steel raises forecast for 2018 global steel demand growth to 1.8 percent (Maytal Angel, 2018). Depending on the environment, steel items once galvanized can last much longer than the non-galvanized steel items (AGA, 2018). The galvanizing process provides a tough metallic zinc envelope, this protects the steel surface from corrosive action due to atmospheric and chemical influence. Galvanizing processes can be carried out in different methods, depending on the properties required on the final product (Crown, 2013)".

In Uganda, steel production is rising in numbers as it is contributing greatly to the country's economic development because of its importance to other sectors. This has resulted to higher consumption of steel. Roofings Group, established in 1995, with its primary location at Lubowa on Entebbe Road, is the leading steel manufacturer in Uganda (Roofings, 2013), due to increasing demand with a good market reach throughout the East African region, a new production unit was constructed at the Namanve Industrial Park on Jinja Road, 6 km south of Kampala City Centre. This branch is called Roofings Rolling Mills (RRM) Ltd (Kazooba, 2016), where this organization earns government revenue as taxes from 2,000 employees people (Otage, 2013).

RRM consists of three production lines: the wire galvanizing line, the hot rolling (rebar's) mill and the cold galvanizing line. The Cold galvanizing line is the largest, with a capacity of 21.7 metric tons per hour for a 12-hour run/ day , with an investment of 127 million dollars (UGX 320 billion) out of a total investment of USD 175 for RRM (Roofings, 2013). According to "Uganda's vision 2040, 4.1.4-96", it emphasizes plans to support and develop industries for economic growth to facilitate a shift to higher income status for Ugandans (UIA, 2015).

Currently, the mild steel Hot Rolled Coil (HRC) sheet of SEA 1006 grade are imported from South Africa, Europe etc., these are being transported by trucks or rail, each roll weighing 2 tons. This exposes the steel to oxidation, especially on the outer surfaces of the coil. As conformity to standards, quality checks are conducted (ACME, 2017) on arrival, the metal is prepared and then it is galvanized. The galvanized sheets are sold in raw form or as pre-painted or color-coated iron sheets, which are formed to different profiles'; for example, super echo sheets, super tiles and echo tiles, which are oven baked to prevent corrosion (Roofings, 2013).

Overwhelmingly, all these processes involve the use of heavy capacity machinery and equipment, which consume a lot of power to 5,000 KVA for the machine to operate as this plant in category 4 (Era, 2018). But unfortunately, whenever there is an interruption in power supply, it results in increased volumes of rejects. This is believed to be one of the contributing factors leading to the decline of a plant's performance, which includes machine and production efficiencies. This is irrespective of other factors affecting line performance, among them are equipment failures, material shortages, and changeover time. Furthermore, production loss that can arise from issues like machine wear, substandard materials (rejects) and operator's inefficiency, as well as losses due to quality checks, all of which affect machine availability.

According to management, originally this plant (factory) was running at 98% efficiency, which later reduced to 94% including machine processes (allowable stoppages) during production, but currently there is also an increase in volumes of the rejects, which is believed to be affecting the organization's performance. This is considered as a threat to the organization, the government and the communities which are benefiting economically from this galvanizing line. This in turn affects their return on investments, due to loss of quality and production efficiency (UIA, 2015), due to unpredictable interruptions of power, hence reducing the organizational performance. Amazingly, RRM as an entity pays revenue to the government worth UGX 33,600,000 per day, as a result of consuming 42 megawatts per day, out of the daily country peak power demand of 500 Mw (UIA, 2015).

The productivity of most large and small scale businesses has been undermined by the negative effects of unstable electric power (World Bank, 2013). Though this company is focused on growth and development, it also faces challenges like high technology investments, competition, taxes, processing challenges and associated costs of utilities and materials, so it becomes much more with the challenge of low production efficiency, due to increased amount of rejects, especially during power interruptions. Then there was need to evaluate in this study whether there is no significant difference in the rejects of production in a galvanizing line between power interrupted process and that with no power interruption. Or else if there is significant difference in the rejects of production in a galvanizing line between power interrupted process and that with no interruption. As a principle, before one can stop rejects (waste) production, one should be able to see and recognize it as waste, asses what causes it and finally quantify its size and magnitude for an action to be taken to solve the challenge.

1.2 Statement of the Problem

The sheet galvanizing line of Roofings Rolling Mills Ltd generates rejects amounting to 5 % (approximately 7,500 tons); estimated at UGX 7.5 billion per annum, due to coil end sheet stripping as a normal quality control measure without power interruption, as before they were disconnected from the free load shedding power line. This has given the production at sheet galvanizing line to run at machine efficiency of 94%, with machine process time stoppages (RRM production records, 2017). Even though RRM Ltd benefits other partners towards economic development, the organization also pays revenue to the government worth UGX 33,600,000 per day, as a result of consuming 42 megawatts per day out of the daily country peak power demand of 500 Mw per day (UIA, 2015). It’s coupled with other investment challenges like competition, high technology investments, taxes and associated costs on utilities and materials, the common power interruptions have led to increased amounts of rejects. There is tremendous increase of rejects in the sheet galvanizing line since the organization was disconnected from the free load shedding power line, so this is consequently believed to affect the organization’s performance.

1.3 Main Objective

The main goal of the study is to evaluate the effects of power interruptions on quality and production at the different galvanizing processes.

1.3.1 Specific Objectives

To achieve the main objective of this study, the specific objectives that have guided the research include:

(i) To determine the process variables (parameters) influencing galvanizing processes.

(ii) To determine the effects of power interruptions on variables (parameters) of galvanizing processes.

(iii) To analyze the cost implications of power interruptions on the cold galvanizing line.

1.3.2 Hypothesis

These shall answer the probable situation to be evaluated in this study as;

Null Hypothesis (H_O) -There is no significant difference in the rejects of production in a galvanizing line between power interrupted process and that with no power interruption.

Alternative Hypothesis (H_i) – There is significant difference in the rejects of production in a galvanizing line between power interrupted process and that with no interruption.

Null Hypothesis (H_O) – There is no significant difference in quality of color coated sheet obtained between power interrupted and that with no power interruption.

Alternative Hypothesis (H_i) – There is significant difference in the quality of color coated sheet obtained between power interrupted process and that with no power interruption.

1.4 Justification

According to "Uganda's Vision 2040, 4.1.4-96", the government emphasizes plans to support and develop industries for economic growth to higher income status (UIA, 2015). Therefore in this study; there are production losses incurred during the power interruptions, by the organization which is contrary to Uganda's vision, so that further action can be taken to minimize the losses. The determination of the most affected areas by the power interruptions is made possible, so that a way forward can be found to this effect. Determination of various types of rejects in a hot dip galvanizing process, their causes and a way of reducing on the rejects can be sought. Furthermore, the influence of power interruptions has been determined and how this affects the organization and the government. The effects of power interruptions to the organization and government justify for lobbying of a power line free from load shedding, which will then lead to increase in profits due to improved production efficiencies for the organization. This can be used as a baseline in lobbying for a reduced tax levy, as accurate costing of damages/rejects has been quantified. Above all, RRM still pays revenue to the government, worth UGX 33,600,000 per day as a result of consuming 42 Megawatts per day out of the daily country's peak power demand of 500 Mw per day (UIA, 2015), So these challenges to the organizations need to be looked at.

1.5 Significance of the Study

This study establishes the impact of power interruptions on the steel hot dip galvanizing line, which affects the productivity and profitability of the organization, because the areas most affected by load shedding were identified and mitigation measures for those particular areas can be undertaken accordingly by the organization. Furthermore, if the organization is given a line free of load shedding, this will lead to increased productivity due to improved organizations performance. The organization's production costs will reduce further leading to increased profitability and furthermore tax revenue generated by the government, because government earns revenue as taxes from 2,000 employees (Otage, 2013). The knowledge generated led to recommendations that can be used and considered for economic development, thus meeting Uganda's Vision 2040.

In addition, this can also be used as a baseline for requesting the government to give a tax levy reduction due to the losses caused by power interruptions, in accordance to impact of the damage caused to the organization. So far UMEME Ltd, Uganda's power transmission and distribution company, in collaboration with the Electricity Regulatory Authority (Era); Uganda's power regulator, have installed a power monitoring unit at the RRM premises, but this is still under study to confirm how much time is lost during power interruptions.

1.6 Scope

The study was carried out at Roofings Rolling Mills Ltd, located at the Kampala Industrial and Business Park in Namanve, 6 km south of Kampala City Centre along Jinja road and 2 km off Jinja road (Kazooba 2016). The data collection for this study was finished by September 2018. This research focused on evaluating the effects of power interruptions in the sheet a hot dip galvanizing line.

1.7 Conceptual Framework

This conceptual framework summarized in figure 1.1, covers evaluation of power interruption during the hot dip galvanizing process. It involved study of parameters that influence galvanizing, determines its effects and the impact of power interruption to the galvanizing. Literature reviews been conducted, comparisons were made in accordance to the quality standards and the cost implications of these effects have been discussed. The results, conclusions and recommendations have been made in reference to this study.

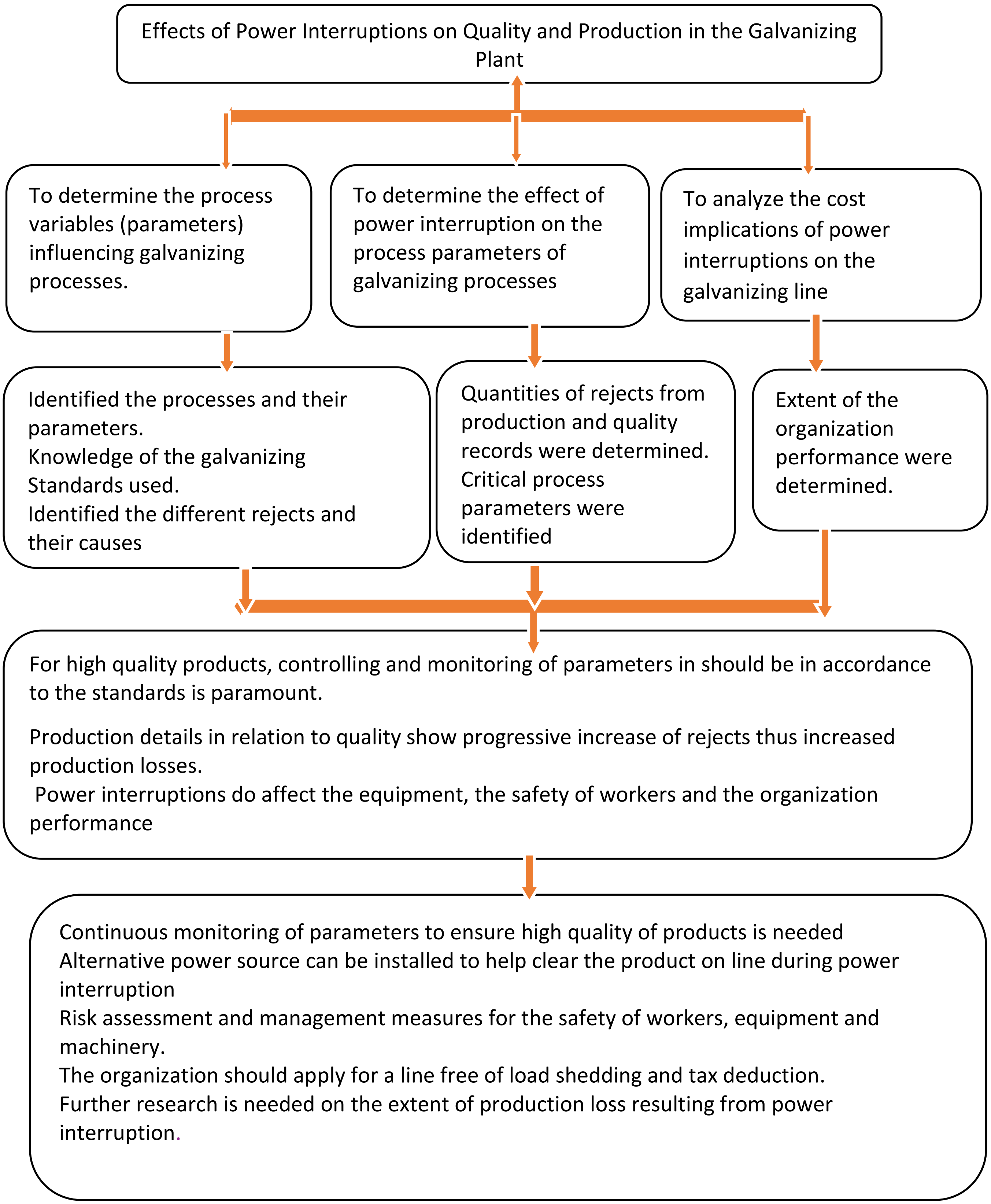


Figure 1-1 : Conceptual framework showing the effects of power interruption a galvanizing line

1.8. Limitations and Delimitations

1.8.1 Limitations

This study aimed at evaluating the effects of power fluctuations on the galvanizing line and the related cost implications from the various processes. However, production took place in three shifts, so collection of data on power fluctuations and the resulting effects on product quality during all the three work shifts, was difficult by a single data collector. Additionally, data collection was interrupted by some organizational activities such as maintenance and quality audits. Above all, the organization was a private company so there were some restrictions for easy access to basic and necessary information to students, even after authorizing the research to be conducted.

1.8.2 Delimitations

The quality team and production team were equipped with the requisite knowledge and skills, which led to success of data collection during the various shifts. Also the organizations staff, especially supervisors, were cooperative and offered technical guidance during data collection. These contributed to the success of the research.

In conclusion, "Uganda's Vision 2040″ emphasizes that the government plans to support and develop industries for economic growth to gain higher income status (UIA, 2015). Steel is one of the most used engineering materials in various industries today for development. RRM Ltd is the largest steel manufacturer in Uganda. But this is undermined by the negative effects of electric power interruptions, which result in increased rejects production. So there is need to evaluate the effects of power interruptions on quality and production in the sheet galvanizing plant. This was possible by having knowledge on how the galvanizing process is performed and the processing parameters that influence galvanizing. This allows the organization to produce high quality galvanized products; thereby having reduced rejects. Also the organization can take further action to improve on plant efficiency, thus garnering greater profits.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents information of galvanizing steel and the properties that a steel product attains after being galvanized. Galvanizing processes can be carried out in different methods, depending on the properties required of the final product (Crown, 2013). it gives an overview of galvanizing processes and the parameters that influence the quality of galvanized steel. The different galvanizing defects, their cause are; ways to reduce them and how power interruption influences the formation of rejects during a galvanizing processes.

2.1 Galvanizing

Galvanizing provides a metallic zinc envelope which protects the steel surface from corrosive action due to atmospheric and chemical influence. This involves applying a thin layer of zinc coating and Aluminium to a thicker base metal, by immersing clean oxide-free iron or steel into molten zinc bath, to form a coating that is metallurgically bonded to the iron or steel surface. The steel is fully immersed in a bath of temperature of about (445◦C to 465◦C) or 850˚F and with a minimum of 98% pure molten zinc (Shibli et al, 2014). This results into further reaction with carbon dioxide (CO_2) to form zinc carbonate ($ZnCO_3$), which protects the sheet (Shibli et al, 2014; Louis, 2012; Beverly, 2012). Amazingly, galvanizing processes can be carried out in different methods, which can be dry or wet, depending on the properties required of the final product (Crown, 2013).

2.2 Properties of Galvanized Steels

Unalloyed steels can be affected by oxidation and corrosion, which results to frequent repairs and maintenance of steel products. Galvanizing of steel introduces a protective layer of zinc coating on the steel that enables sustainable use of the product, thus a significant reduction in the maintenance requirement over a long period of time, resulting to both environmental and economic benefits. Depending on the environment, galvanized items can last between 20 and 80 years (AGA, 2018; Kesley, 2016). This process of galvanizing provides a tough metallic zinc envelope, which protects the steel surface from corrosive action due to atmospheric and chemical influence (Marcello et al, 2017); (Kesley, 2016; Solazzi, 2012) while in use (Coni et al, 2009). An item that is well galvanized due to zinc coating provides protection to external and internal surfaces, making them impermeable to weather or humidity (ASTM, 2018; ACME, 2018). In comparison with other metals, the protection properties of zinc coatings are very good in sea water, industrial environment and construction (Azadeh & Toroghinejad, 2009). The galvanized coating provides the steel a longer duration during its usage, than the expected life span of steel that is not galvanized (ASTM, 2018).

Heavy coatings are usually form rougher coatings than lighter coatings, because adhesion shall not be well, because the irregularities of alloy layers tends to increase with thickness (Brooke, 2013). This can be worse with power interruption. Traditionally, the coating formed on the steel during a galvanizing process was made entirely of zinc; however, the developments in the galvanizing processes have resulted to the current use of a mixture of Aluminium and zinc in proportions of about 55% Al and 45%Zn - as the protective coating on galvanized steels (Coni et al, 2009). Amazingly, galvanizing can be done in different ways today, depending on the available technology and final requirements on the product quality.

2.3 Types of Galvanizing Processes

There are different methods of galvanizing steel to avoid or reduce the corrosion effect namely; electroplating, mechanical plating, sherardizing, painting with zinc-rich coatings, zinc plating, hot dip galvanizing, etc. (Shibli et al, 2014). According to studies, hot dip galvanizing (HDG) has no significant changes in the mechanical properties of the structural steels, their chemical and metallurgical properties are equivalent to the uncoated steel (Louis, 2012; AGA, 2017). Hot Dip Galvanizing is one of the better technologies used with high output especially when the parameters are not interfered.

2.4 Hot Dip Galvanizing Processes

Hot Dip Galvanizing (HDG) is the process most widely used for a long period in the galvanizing on steel. It is conducted in a hot state, by dipping a metal in a hot bath of zinc solution (560-630°C), which produces high quality and corrosion-resistant materials (Adetunji, 2010; Hanna & Nassif, 1984). The HDG process consists of the following basic steps: Surface Pre-paration (pretreatment), galvanizing, post-treatment and inspection.

2.4.1 Surface Preparation

Surface Preparation is a critical initial preparation step in the galvanizing processes (Beverly, 2012; Azadeh & Toroghinejad, 2009). Coatings usually fail earlier than their expected service life due to inadequate surface preparation of the item, this is because zinc poorly adheres to a steel surface. Each preparation step consists of either basic or acidic cleaner, this cleans the steel off the rust and dirt (AGA, 2018) and the preparation steps include degreasing, pickling, cold rolling, fluxing, galvanizing and post-treatment. Poor surface preparation of steel frustrate efforts to attain the desired property, this can be more evident in case there is power interruption.

Degreasing / Cleaning

The quality of the product is greatly affected by degreasing. During degreasing an item to be galvanized is dipped in a hot alkaline solution (caustic) or hydrochloric acid to remove any organic contaminants like dirt, paint, grease, oils and oxidants attached on the metal surface and then it's eventually removed (Adetunji, 2010; Hanna & Nassif, 1984).

2.4.2 Pickling

Pickling is a cleaning process of steel in preparation for another steel process. It involves the immersion of steel into a bath of chemical that is either caustic ($NAOH_2$) or HCL or H_2SO_4 to aid the removal of scales, oxidation products, and other substances like epoxies, vinyl, welding slag, etc. before the item is dipped into a rinsing tank of water or alcohol (AGA, 2018). During pickling with HCL, the component (item) to be cleaned is then dipped in a dilute solution of hydrochloric acid, of 10% - 20% concentration, with optimum concentration level of (15%) at 25^0C, which is then rinsed with water (Xiaoyan Zh et al, 2016). This process takes about 30 to 90 minutes, depending on the complexity of the item, the thickness of the material, the degree of contamination of the item being made (Juan Xu, 2016), concetration of the chemical being used and the line speed, any interruption of electric power will affect these parameters. During pickling, the chemicals are usually used together with inhibitors. The inhibitors prevent acid from reacting with the sheet and the squeezer rolls remove any acid concentration left on the sheet. Poor pickling procedures may fail to or over remove the adherent iron salts on the material, leading to defective products. This can lead to Under-pickling and Over-Pickling respectively (Xiaoyan Zh et al, 2016). Afterward, the properly pickled sheet may or may not be rolled to a required thickness and width, depending on the products thickness requirements, then the pickled item is ready for the next process.

2.4.3 Cold Rolling Mill (CRM)

In a cold rolling process, the HRC sheet is reduced to a particular thickness without application of heat. During cold rolling of the sheet material, these involves activities like trimming the sides of the coiled sheet to give the sheet a specific required width, this is in preparation for the next process.

2.4.4 Fluxing

Fluxing is done after degreasing, pickling, prior to dipping the steel into the galvanizing bath containing molten zinc and Aluminium (ASTM, 2018; (Coni et al, 2009). This takes a few minutes depending on the technology used. It is done to prevent further oxidation of the metal (AGA, 2016). Fluxing involves passing the surface of the cleaned item (sheet) through an alkali spray (caustic of 4 – 5 % concentration), then rinsed with hot water (60 ^{0}C), before its air dried (100 ^{0}C), then finally air cooled (30-40 ^{0}C), before the sheet is passed through the furnace for heat treatment process, depending on the desired property on to the sheet, before it is immersed in the zinc pot (galvanizing bath). Fluxing can be dry or wet, depending on the galvanizing process. In wet fluxing, the sheets are fluxed in hot zinc ammonium chloride solution at about (65-80)^{0}C to aid the wetting and the reaction between the molten zinc and the steel. The aqueous flux solution deteriorates by dilution and becomes weaker (Hanna & Nassif, 1984). The dipped or pre-fluxed of 30% zinc ammonium chloride with wetting agents, the material is then air dried (50^{0}C) ready for galvanizing.

2.5 Galvanizing bath

After fluxing, the metal (steel) is fully immersed in a bath of temperature of about (445◦C to b 465◦C) or 850˚F and with a minimum of 98% pure molten zinc. This results to further reaction with carbon dioxide ($C0_2$) collected from the engine room where its sub stored to form zinc carbonate ($ZNC0_3$), (Shibli et al, 2014; Louis, 2012; Beverly, 2012.) which protects the sheet. During the process of dipping the steel material, the parameters have to be moniterd to the required standards in order to produce aquality product, this requires no interference of process parameters . seen below is a summary of the major steps in hot dip galvanizing line and prepared item (sheet) is being galvanized as illustrated in Figure 2-1 and figure 2-2: respectively.

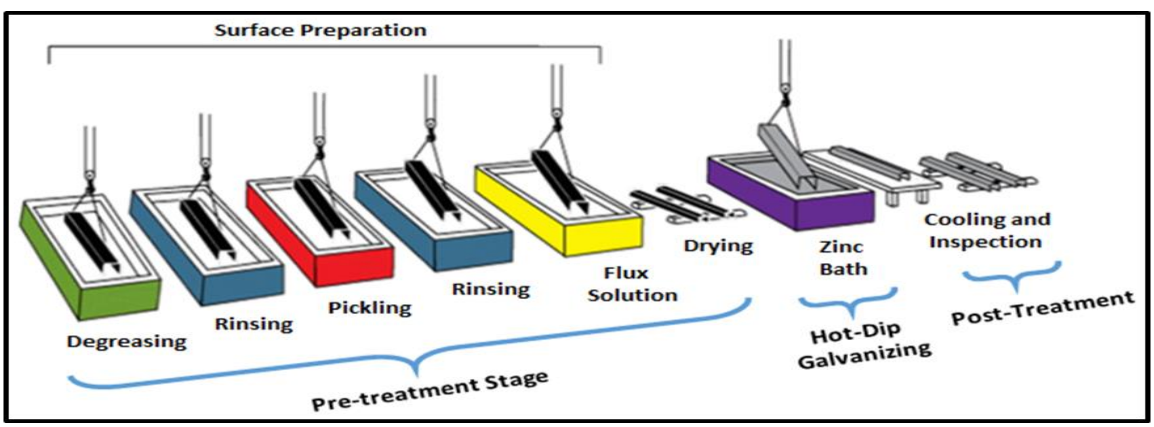


Figure 2-1 : Different processes in Hot Dip Galvanizing (AGA, 2016)

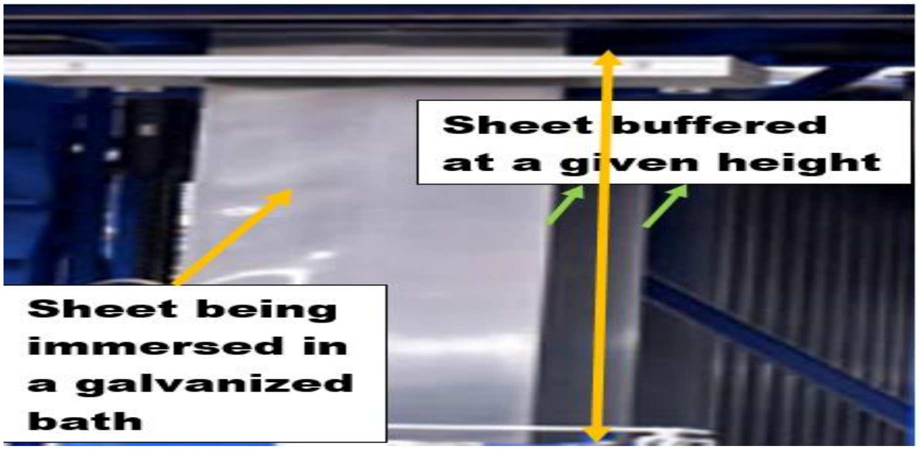


Figure 2-2 : Galvanizing of the sheet in process (on site pictures).

2.6 Post-treatment / Inspection

This involves monitoring on the quality standards of the galvanized items and then does an inspection. It depends on the process quality requirement (Beverly, 2012) for a given product. Products are galvanized according to established, well-accepted and approved standards (ASTM, 2018). The post-treatment steps that influence the coating quality are: the cooling air distribution, the degree of cleanness of the withdrawing rollers, the passivation step before storage. These steps are necessary to prove the compliance of the product (AGA, 2016). The properties that are scrutinized by physical visual inspection and laboratory tests to determine coating thickness, uniformity, adherence and appearance. Poor adherence to quality parameters during surface preparation (pretreatment) (Taixiong et al, 2014), galvanizing procedures and post treatment can lead to production of poor quality products, which then will lead to rejection of the final product.

2.7 Parameters influencing the Hot Dip Galvanizing Process

The hot dip galvanizing process is the most widely used method for galvanizing steel materials, ussually conducted in a hot state, by dipping an item in a hot bath (560-630°C) of zinc solution. The parameters that affect the quality of galvanizing and the finally the galvanized product include: drying temperature, dipping techniques**,** withdrawal speeds, Zinc bath additives, Aluminium content, the size of the kettle (bath), composition of the steel and the furnace pressure (Adetunji, 2010), these are discussed below;

i. **Drying Temperature**

The optimum drying temperature at 250 - 300 ^{0}C prior to the metal entering the bath (fluxing process). Good fluxing results to better quality products. High drying temperature causes black spots (burned flux) and too low a drying temperature leads to the appearance of uncoated areas (Adetunji, 2010). This therefore calls for high control of process parameters.

ii. Dipping techniques

The dipping technique used has much influence on the structure and coating thickness on the item being galvanized (Akhil et, al, 2012). After surface pretreatment, the dried sheets are dipped in the molten zinc bath for a short time (less than 1 min) and then withdrawn. A fully immersed item gets better coated than the sprayed items.

iii. Effect of bath temperatures and withdrawal speeds

The galvanizing bath temperature and withdrawal speed affect the alloy layer thickness of a galvanized item (Akhil et, al, 2012; Adetunji, 2010). High withdrawal speed of the material can result in defects like bare spots and the delayed withdraw of the material can result in defects like grey coatings, curtain formation, tears, peeling, flaking, etc.. This necessitates control of temperature and withdrawal speeds of which this requires steady supply of power, so there is need to correlate between the temperature of the zinc bath and the withdrawal speed for a given metal thickness.

iv. Steel sheet thickness

Sheet thickness has an effect on quality of the coating. The thickness layer depends on the material thickness (Akhil et al, (2012 and according to DIN EN ISO 1461, this affects up to 1.5mm material thickness by 45 microns. When the surface cleanliness of cold rolled sheet is poorer, the oil and residual iron can remain on the sheet surface, this increases with increasing sheet thickness (Taixiong et al, 2014), thus requiring further cleaning of the sheet after the rolling process.

v. The Zinc bath additives

The mode and amount of additives into the galvanizing bath greatly influence on the product quality. Aluminium and antimony are the most common metals added to the zinc bath to improve the quality of the coatings and this should be added in required proportions. The amounts of catalysts like titanium is used to catalyze iron-Aluminium reaction, to allow better inhibition of the substrate layer and delaying the growth of Fe- Zn intermetallic (Azadeh & Toroghinejad, 2009).

vi. The Aluminium content

The Aluminium content in the galvanizing bath do affect the coating structure and the properties of the galvanized steel item. The Aluminium content should be between 5 - 90 % (Hamid Abdel & Swaki,2003) and this always be controlled to maintain quality standards, failure can lead to rejects.

vii. The Immersion time

The immersion time in the galvanizing bath varies from a few minutes for light articles, to several minutes for relatively heavy articles, up to half an hour or longer for major structural members (Louis, 2012), but this depends on the thickness (size) of the item being galvanized (Akhil et al, 2012) and the chemical composition of bath. The bath soaking time should be long enough to promote the isothermal transformation of austenite into a fine pearlitic microstructure (Marcello et al, 2017; Azadeh & Toroghinejad, 2009). Interruption of parameters like this can lead to defects like outbursts, flaking's, etc. (Culcasi et al, 1999).

viii. The Size of the kettle

The size of the galvanizing bath or pot or kettle has an influence on the components to be galvanized. Galvanized items need to be submerged fully in the hot zinc solution. Very long items will require double dipping, which is associated with some defects (visible indentation of two dips overlap) (Louis, 2012).

ix. The **Composition of the steel**

The steel composition is key, because the amount of other constituent elements in the steel should be to the required limits. For example C in excess of 0.25%, Si 0.04% - 0.22%, may result to a galvanized coating having a duller or matt gray appearance, or a blotchy variable appearance, P in excess of 0.04%, Mn excess of 1.3%; as this can affect the quality of the galvanized material (Louis, 2012; IGA, 2013; Azadeh & Toroghinejad, 2009).

x. Good design

Good design of the galvanizing process line has a key impact on the end products; there should be good ventilations and drainage holes to permit free circulation of the air. The surface preparation area should allow passage of fluids like acid, water, etc. and zinc to all cavities, to ensure full coverage of a galvanized component. The zinc should travel freely (turbulence) in the galvanizing bath (Louis, 2012).

xi. The flow of Hydrogen and Oxygen

Hydrogen flow influences the formation of oxides on the surface of the sheet; that is, its circulation (75NM ^{3} /Hr.). Hydrogen should be monitored, due to oxidation as a result of the steel reacting with hydrogen and oxygen molecules. Oxygen flow at the oven should be maintained as low as possible (-

32 to -50 ppm), as this can lead to peeling or flaking of the galvanized sheet coating. If this is not well monitored can affects quality of the product.

xii. The Furnace pressure (324 Pa) and Exhaust pressure (-300 to - 400 Pa)

If this pressures are not well monitored, this results to defects like outbursts, flaking's, distortions and blast damage due to pressure flactuations. In order to maintain the quality of the galvanized sheet, these pressures and temperature have to be monitored, this helps to control the flue gasses which can affect the quality of the sheet.

xiii. The humidity of the Chromating area

The humidity of the Chromating area affects the adhere-ration of the Zinc Aluminium onto the sheet. The humidity has to be between 15 - 16 % for effective results. Very little humidity can result in peeling off effect and high humidity can result in excess coatings.

2.8 Quality Aspects in Hot Dip Galvanizing processes

Hot Dip Galvanizing (HDG) of steel products requires inspection to ensure compliance to required standards (ASTM, 2018; Hanna & Nassif, 1984). The inspection process requires a clear understanding of specification requirements and compliance measurement techniques to make an accurate assessment (AGA, 2016). Failure to meet the set quality standards results to rejects. Good results a rise from following good galvanizing procedures and focusing on factors that influence the galvanizing process. Some of the defects that can lead to rejection of an item, are mentioned in this section;

2.8.1 Poor Surface Finish

Usually, this is done by visual inspection on the surface of a material, by observing the conditions of the product, both internally and externally, to check for the bright and shiny spangled matte grey color on the item galvanized (AGA, 2016) and to see all contact points, welds, junctions and bent areas for its quality compliance. The main reasons that cause this type of defect are the excessive plastic deformations (Vagge et al, 2007). In order to form an alloy layer, the molten zinc and the steel surface need to be roughly at the same temperature about 450 – 490^{o}C (Jacek, 2017). This promotes the finish coating which must be smooth, uniform, continuous (Adetunji, 2010), with silver grey mate appearance (Azadeh & Toroghinejad, 2009).

2.8.2 Blasting Damage

Components blisters due to incorrect abrasive blasting procedures and poor surface preparation. The residual iron is formed on the surface of cold rolled steel sheet, which has not been pre cleaned well and this hinders the normal formation of coating (Taixiong et al, 2014). These procedures cause shattering and delamination of the coating as per ASTM D6386 (AGA, 2016). This calls for control of blast pressure, to avoid blasting damage when preparing HDG (ASTM, 2018).

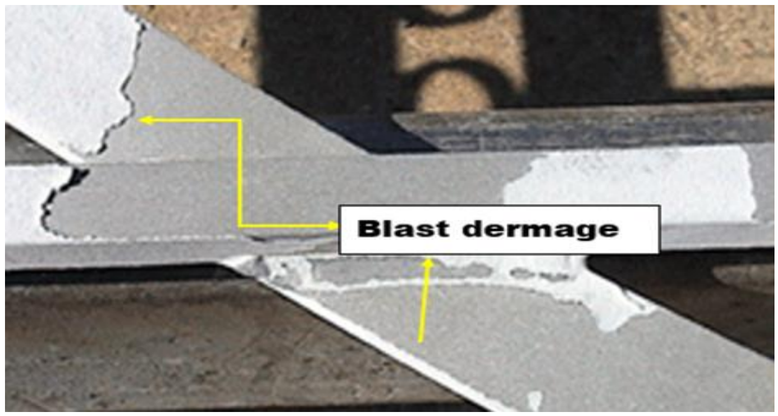


Figure 2-3 : Blasting Damage (AGA, 2016)

2.8.3 Clogged Holes

This is caused by molten zinc metal not draining well, the holes are partially or fully filled up. This is common from holes of less than 3/32" (3mm) in diameter, high humidity of the Chromating area, slow withdrawal of the galvanized item and due to the viscosity of the molten zinc, which may not drain easily (AGA, 2018). An example of a clogged hole is the screen on figure 2-4, this is minimized by making larger holes, the steel can also be preheated in a de-oxidizing atmosphere before galvanizing bath (Jacek, 2017). This requires controlled supply of heat on to the steel.

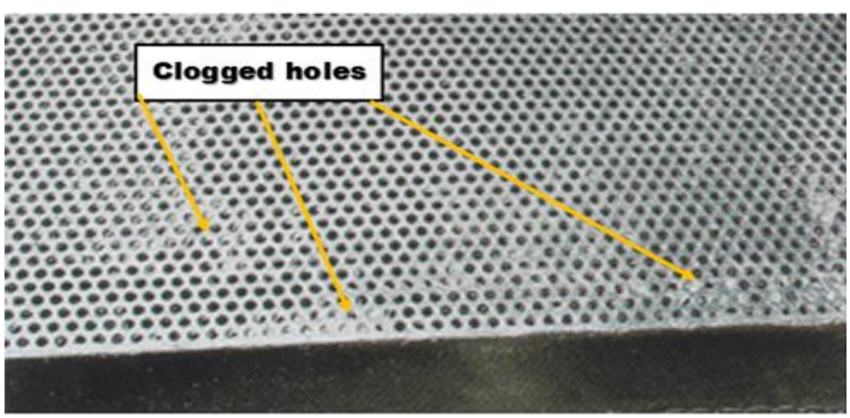


Figure 2-4 : Clogged Holes (AGA, 2016); (IGA, 2013)

2.8.4 Delamination

Peeling off zinc creates a rough coating on the steel surface especially on large galvanized parts, that take long to cool in the air and so forming zinc-iron layers. This is usually after it has been removed from the galvanizing kettle (bath). The coating leaves behind voids between the top two layers of the galvanized coating, as a result of poor sheet cleanness and temperature control (Azadeh & Toroghinejad, 2009) resulting to voids. When voids are many, the top layer of zinc can separate from the rest of the coating and peel off the part causing *"delamination"*. If the delaminated part meets minimum specification requirements, it can be accepted, or rejected or regalvanized (AGA, 2016).

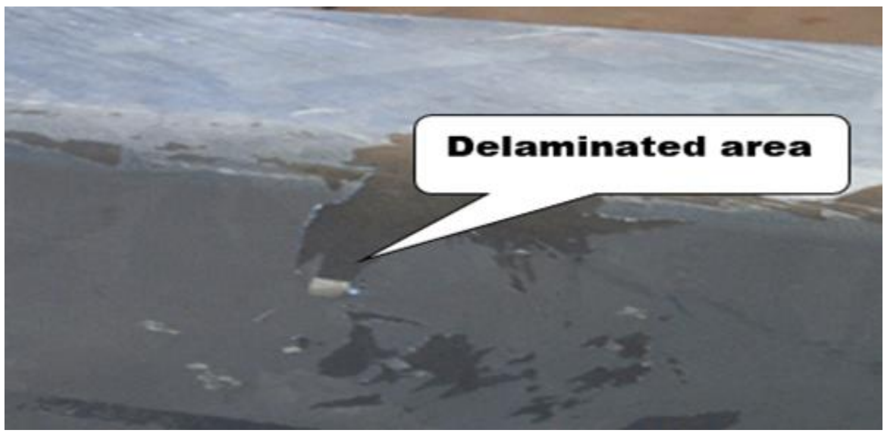


Figure 2-5 : Delamination (AGA, 2016)

2.8.5 Dross Inclusions

Dross inclusions are distinct particles of zinc-iron intermetallic alloys that get entrapped in the zinc coating. The dissolved Fe in steel sheet usually reacts with Al in zinc bath to form Fe-Al alloys, which are lighter than zinc bath and thus become surface dross. This is caused mainly by the residual iron on the surface of cold rolled steel sheets, which has not been pre cleaned effectively and this interferes the normal formation of coating (Taixiong. et al, 2014). If the dross particles are small and completely covered by zinc metal, they cannot affect the corrosion protection, and thus are acceptable (Hamid. & Swaki, 2003). But if they are large inclusions that prevent the full galvanized coating from forming on the steel, then the particles must be removed and the area repaired to reduce this effect (AGA, 2016). Dross defects can be avoided by changing the lifting orientation or redesigning the product to allow effective drainage (Reumont, 1998) of the zinc alluminium or else keep removing the dross, to stop it from accumulating (Hamid & Swaki, 2003) in the galvanizing bath.

Figure 2-6 : Dross Inclusions (AGA, 2016)

2.8.6 Excess Aluminum in Galvanizing Bath

The galvanizing bath should be of 98% pure zinc, while the remaining 2% is comprised of other additive elements. However, Aluminium or antimony increases the corrosion resistance of the coatings in industrial environments and moist air. When excess Aluminum is in the galvanizing bath, it creates black marks or bare spots on the surface of the steel. This may be repaired if only they are small areas; however, if this condition occurs over the entire part, it must be rejected, stripped, and regalvanized as per ASTM A123, A153, and A767 (AGA, 2016). However, maintaining required standard level of Aluminium is key.

Figure 2-7 : Excess Aluminum in Galvanizing Bath (AGA, 2016)

2.8.7 Flux Inclusions

This occurs when flux fails to be released during the hot-dip galvanizing process, due to poor surface preparation (Adetunji, 2010) and when the surface originally was rough, thus preventing the coating formation (Hanna & Nassif, 1984). Usually no coating grows under the inclusion. If it covers a large area, the part must be rejected. Usually parts rejected due to flux deposits can be stripped, regalvanized or the surface should be prepared well to provide an acceptable coating.

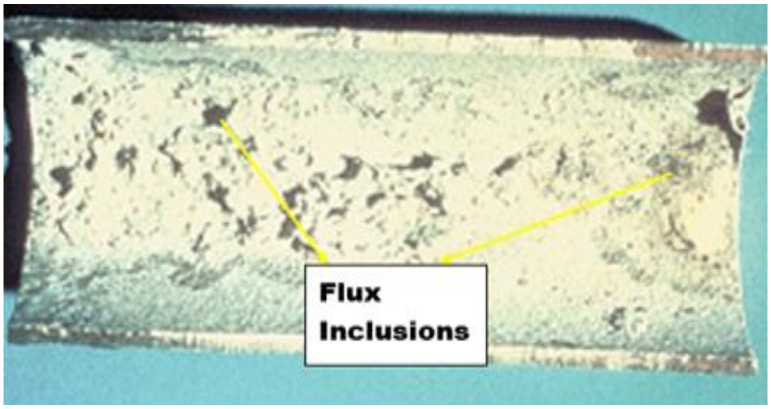


Figure 2-8 : Flux Inclusions from interior of pipe (AGA, 2016)

2.8.8 Zinc Skimmings

Zinc skimmings on the molten zinc surface get trapped on the zinc coating. These are always caused when there is no access to remove the zinc skimmings, during the withdrawal of the steel from the galvanizing bath. Occasionally, these deposits are ground to avoid rejection, as long as the zinc coatings underneath are not damaged during their removal and to meet the necessary specifications (AGA, 2016).

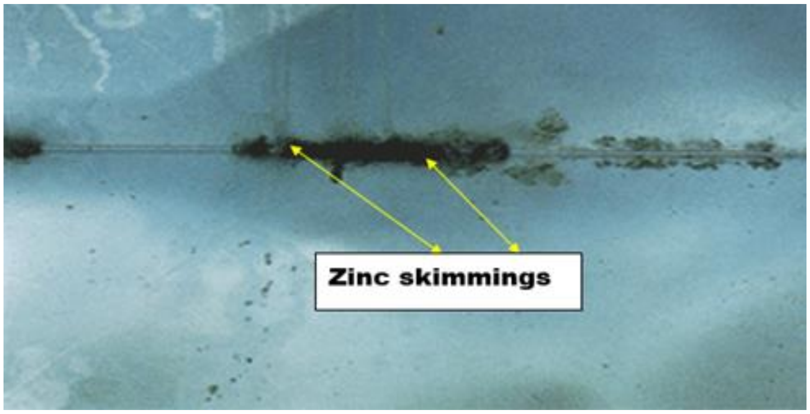


Figure 2-9 : Zinc Skimmings (AGA, 2016)

2.8.9 Zinc Spatter

Zinc spatter also known as splashes are loosely attached to the galvanized coating surface. They are formed when moisture on the surface of the galvanizing kettle causes liquid zinc to “pop” and splash droplets onto the product. Zinc splatter will not affect the corrosion performance of the zinc coating, but this can cause rejection depending on their coverage and intended use of the product. The splatter does not need to be cleaned off the zinc coating surface, but a smooth coating is required (AGA, 2016).

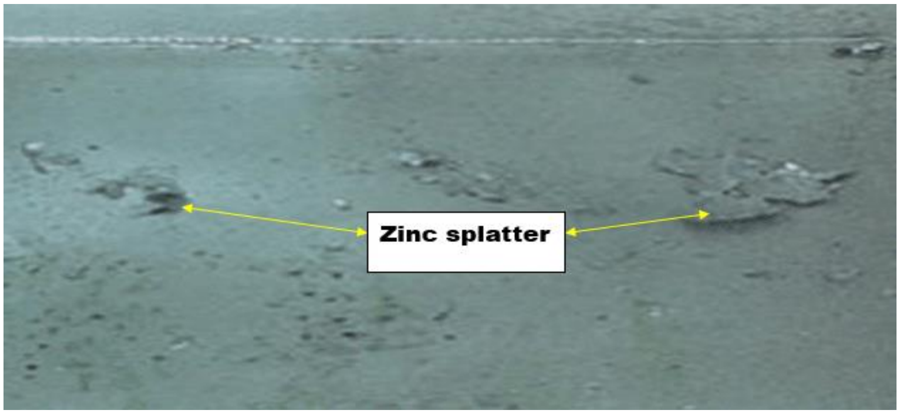


Figure 2-10 : Zinc Splatter (AGA, 2016)

2.8.10 Runs

These are localized thick areas of zinc on the surface of steel, usually caused when zinc freezes on the surface of the product, especially during fast removal of the metal from the zinc bath or when the bath temperature is too low (Brooke, 2013). Runs are mostly not rejected unless they affect the intended use of the part, but they can be avoided during the design of the product, as they may interfere with the intended application (AGA, 2016), and leads to much deposition of the coating thus making the process expensive.

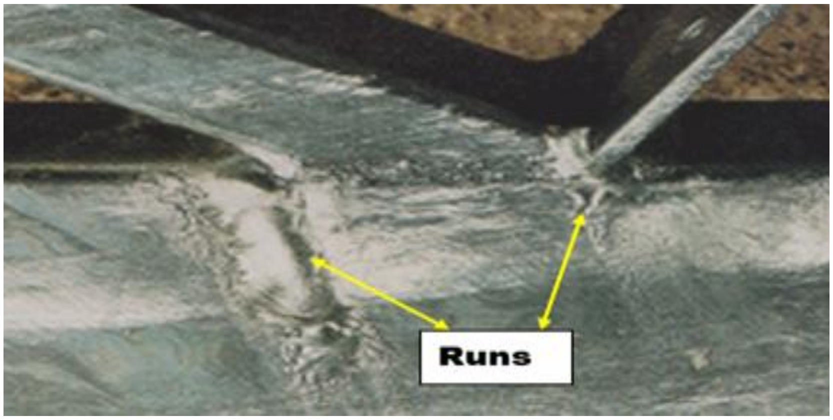


Figure 2-11 : Runs (AGA, 2016); (IGA, 2013)

2.8.11 Rust Bleeding

Rust bleeding are brown / red stains that leak from unsealed joints after the product has been hot-dip galvanized, usually caused by pre-treatment chemicals that penetrate on to the poorly sealed joints or due to interference of process parameters during galvanizing (Brooke, 2013). During galvanizing of the product, moisture boils off the trapped treatment chemicals, leaving anhydrous crystal residues in the joint, this later crystalizes residues that absorb water from the atmosphere, which attacks the steel on both surfaces of the joint, creating rust that seeps out of the joint. This can be controlled by sealing the joint properly or by leaving a gap greater than 3/32" (2.4mm) wide in order to allow solutions to escape and for zinc to penetrate during hot-dip galvanizing. If bleeding occurs, clean up by washing the joint to avoid rejection.

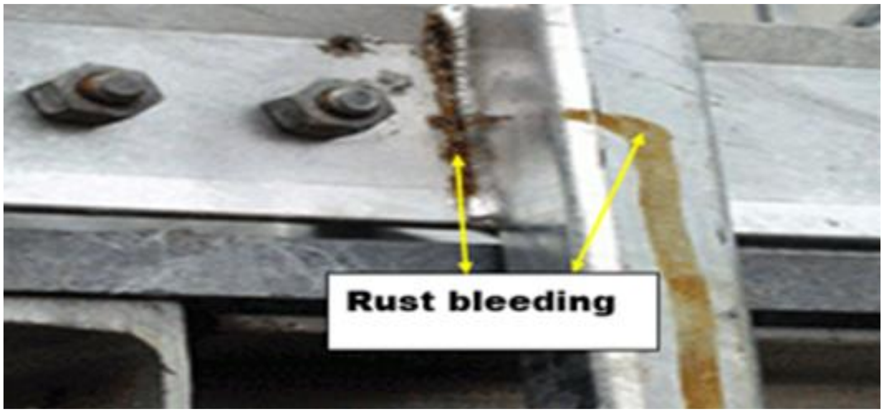


Figure 2-12 : Rust bleeding (AGA, 2016)

2.8.12 Striations/Fish-Boning

Striations are characterized by raised parallel ridges in the galvanized coating. This can be caused by the chemical composition of the steel. Striations are related to the type of steel that is galvanized, this affects its appearance. Fish-boning is similar to striations, they have an irregular pattern over the entire surface of the steel part. This is caused by differences in the surface chemistry of a large diameter steel piece and variations in the reaction rate between the steel and molten zinc (AGA, 2016), which can result from the surface preparation effect or the constituent elements on the steel (Azadeh & Toroghinejad, 2009). This need effective close control and monitoring of parameters to avoid chemical reactions between the steel and the alloying elements

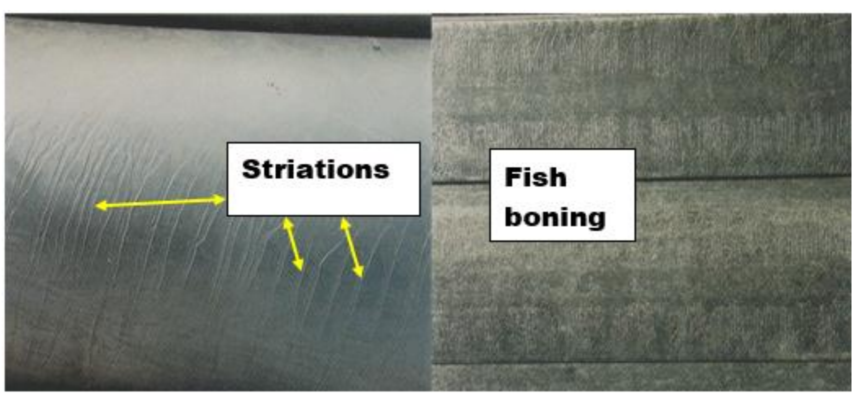


Figure 2-13 : Fish boning and Striations (AGA, 2016); (IGA, 2013)

2.8.13 Surface Contaminant

If contaminants on the steel surface are not removed during pretreatment, this will create ungalvanized areas where the contaminant was originally located. Usually surface contaminants are mechanically removed prior to a galvanizing process. If they cause bare areas on the final product, they must be repaired if they are small in size; however if they are too large, the part must be rejected and regalvanized (AGA, 2016).

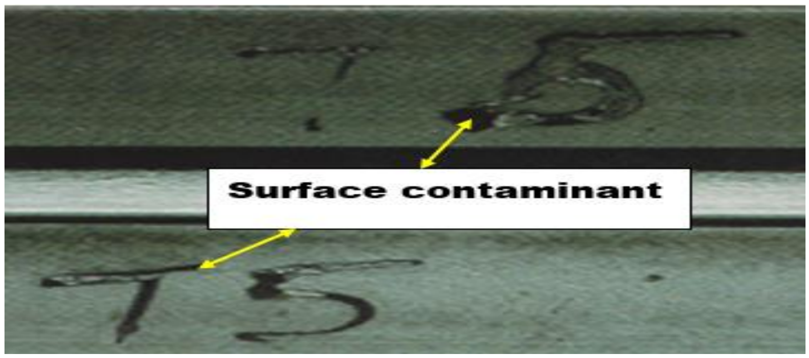


Figure 2-14 : Surface Contaminant (AGA, 2016); (IGA, 2013)

2.8.14 Weeping Weld

Weeping welds usually stain the zinc surface at welded connections on the steel, caused by entrapped cleaning solutions that penetrate the gaps between the two pieces. During galvanizing of the product, moisture boils off the trapped treatment chemicals, leaving anhydrous crystal residues in the joint. This later crystalizes residues absorbed as water from the atmosphere, which attacks the steel on both surfaces of the joint, creating rust that seeps out of the joint. This can also be due to interference of process parameters during galvanizing (Brooke, 2013) for example during electric power interruption. Weeping welds can be prevented by providing a 3/32" (2.4mm) or larger gap between the two pieces during welding, to allow penetration. A weld should be made with gaps instead of continuous weld bead, actually make a stronger joint when the process is complete as per ASTM A123 or ASTM A153 and ASTM A385(Philip, 2005). Weeping welds may not be rejected unless it is too much (AGA, 2016).

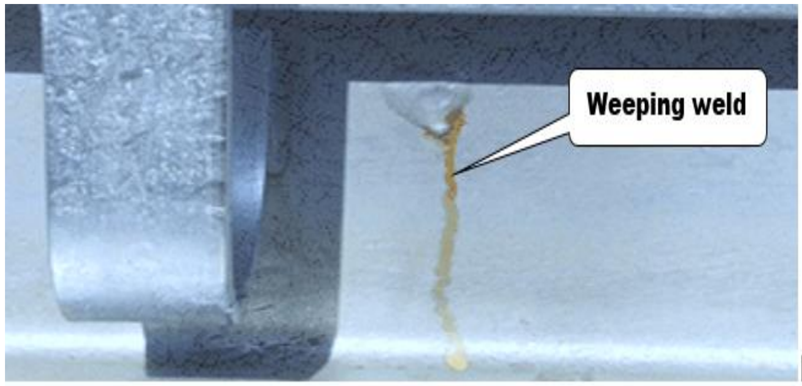


Figure 2-15 : Weeping Weld (AGA, 2016)

2.8.15 Welding Spatter

Welding spatters (residues) appear as lumps on the galvanized coating, adjacent to the weld areas left on the surface of the fabricated part. So welding residues (spatters) that may be covering the zinc coatings should always be removed prior to hot-dip galvanizing. If this defect occurs, the area must be cleaned and properly repaired, then the item may be regalvanized (AGA, 2016), as per ASTM A123 or ASTM A153 and ASTM A385 (Philip, 2005).

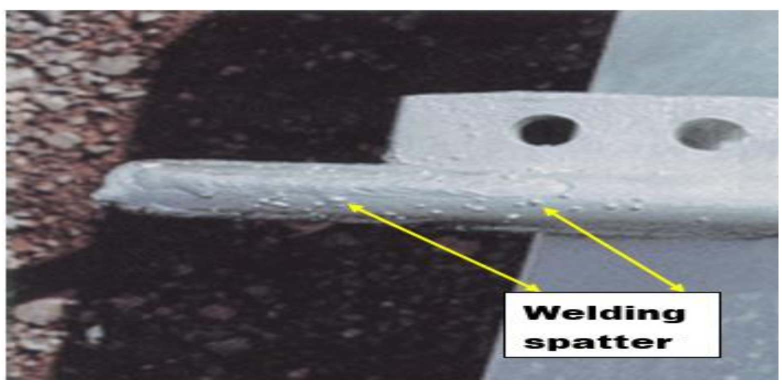


Figure 2-16 : Welding Spatter (AGA, 2016)

2.8.16 Wet Storage Stain

Wet storage stains are white powdery surface deposits on freshly galvanized surfaces, usually caused by the surfaces being covered by moisture such as rain, dew, or condensates and with no airflow over the surface. The moisture then reacts with the zinc metal surface to form zinc oxide and zinc hydroxide (AGA, 2016). This happens especially on stacked and bundled items, like galvanized sheets, plates, angles and bars take some time bundled together in an area.

Figure 2-17 : Light Wet Storage Stain (AGA, 2016)

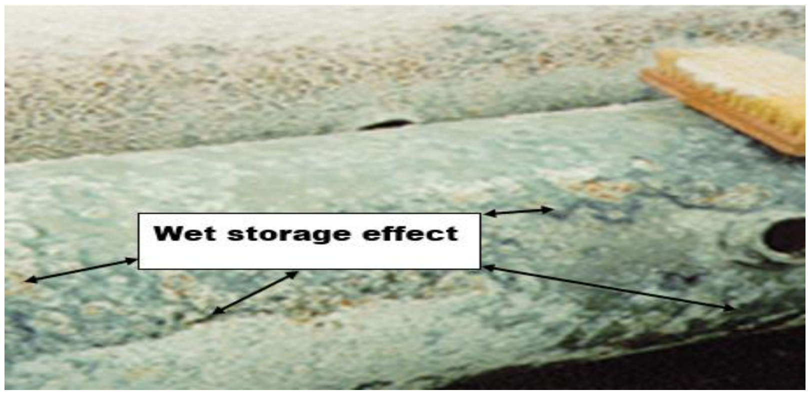


Figure 2-18: Heavy Wet Storage Stain (AGA, 2016)

2.8.17 Welding Blowouts

A welding blowout is a bare spot around a weld or overlapping surface hole, caused by pre-treatment liquids penetrating the sealed and overlapped areas that boil out during immersion in the liquid zinc. Blowouts cause localized surface contamination and prevent the galvanized coating from forming. To prevent welding blowouts, check weld areas for complete welds to ensure there is no penetration of fluid. Also products can be preheated prior to immersion into the galvanizing kettle in order to dry out overlap areas. Bare areas caused by welding blowouts should be repaired for the part to be acceptable (AGA, 2016) as per ASTM A123 or ASTM A153 and ASTM A385 (Philip, 2005).

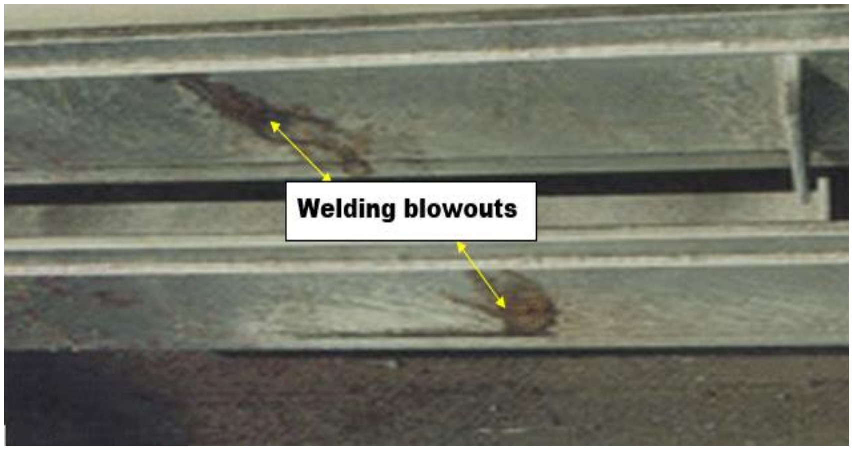


Figure 2-19 : Welding Blowout (AGA, 2016); (IGA, 2013)

2.8.18 Bare Spots

Bare spots are uncoated areas on the steel surface, due to inadequate surface preparation. The excess Aluminum in the galvanizing kettle or lifting devices prevents the coating from forming in a small area (AGA, 2018). Too high a drying temperature causes black spots. Bare spots are caused by incomplete wetting during dipping of the item into the bath (Saravanan & Srikanth, 2018). In order to avoid bare spots, the galvanizer must ensure that the surfaces are clean and without any oxide after pretreatment. Have the required galvanizing parameter and use right lifting equipment's. Small size of the bare spot can be ignored but bigger numbers of spots can lead to rejection, then the parts may be stripped and re-galvanized (AGA, 2016) as per ASTM A780-01 (Philip, 2005). Bare/Grey spots represent absence of a passivation step - the chromate film produced on the coating is not permanent but should be sufficient to protect the coating during storage and transit periods.

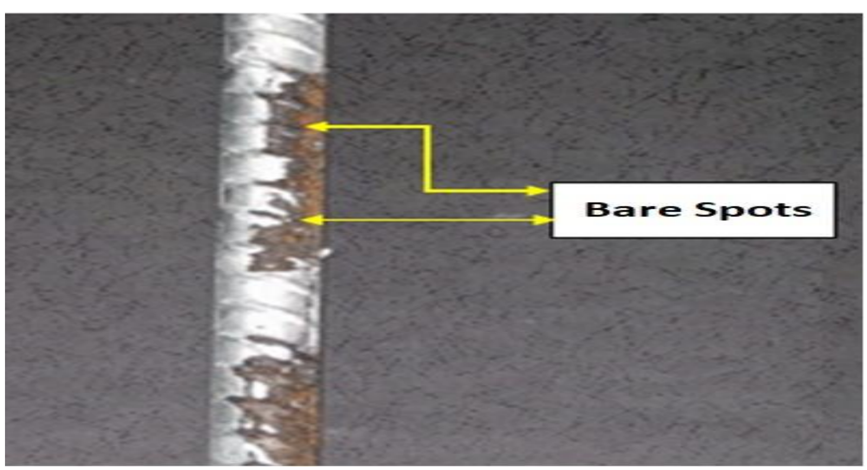


Figure 2-20 : Bare Spots on a Galvanized Steel Rod (AGA, 2016)

2.8.19 Drainage Spikes

Drainage spikes or drips are tearing like drops of zinc. This happens along the edges of a product, as the metal is removed from the galvanizing bath horizontally. This can also be due to slow withdrawal of the galvanized item from the galvanizing bath or if there's no proper drainage of the zinc from the surface. This defect can be removed during the inspection, by grinding off the excess protrusions or regulate the rate of item withdraw from the galvanizing pot. Therefore, this necessitates the removal of the drainage spikes before the part can be accepted (AGA, 2016).

Figure 2-21 : Drainage Spikes(AGA, 2016)

2.8.20 Clogged Threads

Clogged threads are caused by poor drainage of a threaded section after the product is withdrawn from the galvanizing kettle, especially when the withdrawal rate is so low. This can be cleaned by using post-galvanizing operations, for example centrifuge, or by heating them with a torch to approximately 260^0 C, then brushing off the excess zinc with a wire brush to remove the defect to meet the specifications (AGA, 2018; AGA, 2016).

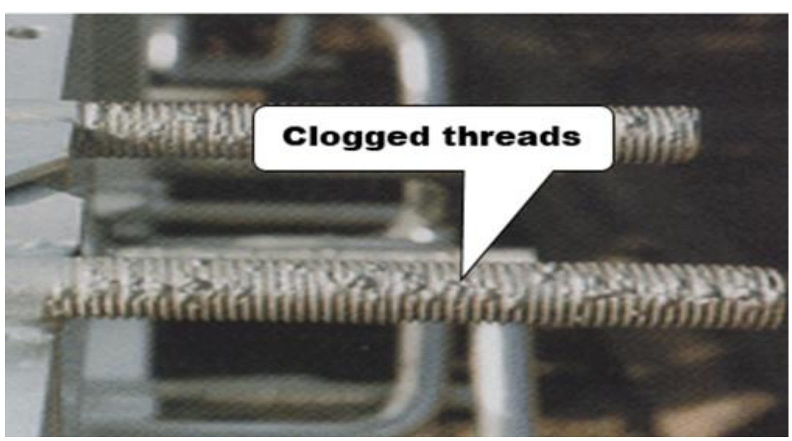


Figure 2-22 : Clogged Threads (AGA, 2016); (IGA, 2013)

2.8.21 Oxide Lines

Oxide lines are light colored film lines on the galvanized steel surface, created when there is inconsistency during the withdrawal or due to the shape of the product or the drainage conditions. Oxide lines will fade over time as the entire zinc surface weathers. Oxide lines have no effect on the corrosion performance and therefore cannot cause rejection of hot-dip galvanized parts.

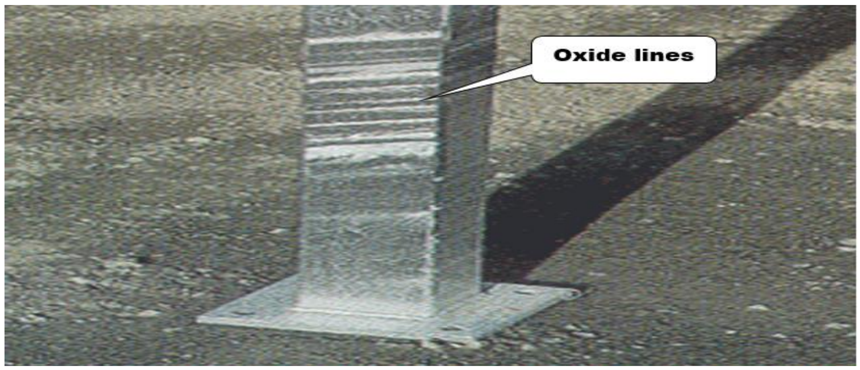


Figure 2-23 : Oxide Lines (AGA, 2016)

2.8.22 Rough Surface Condition

Rough surface condition or appearance is a non-uniformly textured appearance over the entire product, as a results of steel chemistry or poor surface preparation. This can be corrected by mechanical cleaning (Adetunji, 2010). Rough surface condition can be a good effect on corrosion performance because a thicker zinc coating is produced and therefore is not always a cause for rejection. However, they can be rejected if it impacts the intended use of the product. Other uncoated or rough coatings surfaces are due to extremely low drying temperature (AGA, 2016). Steel requires enough soaking time in the bath to promote the isothermal transformation of austenite into a fine pearlitic microstructure, resulting to uniform structure (Marcello et al, 2017) this requires continuous supply of heat from the furnaces.

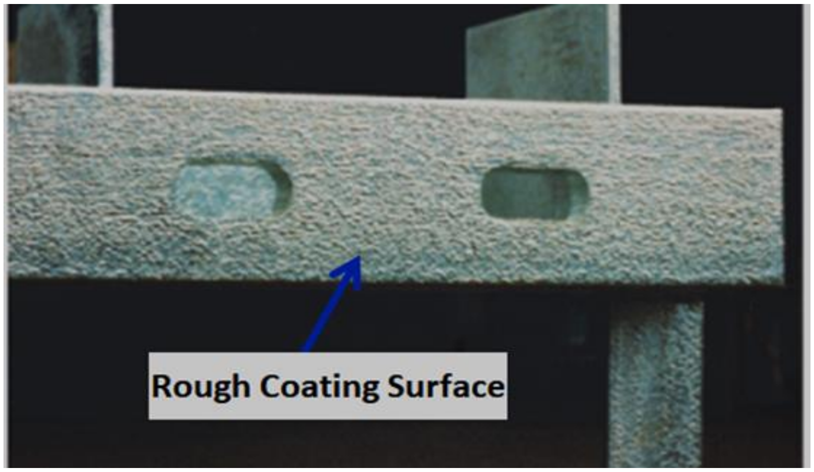


Figure 2-24 : Rough Surface Conditions (AGA, 2016)

In conclusion, the quality of hot-dip-galvanized steel sheets is considerably improved by controlling the surface precleaning (pretreatment) that is the chemicals used for cleaning , the dipping techniques used, the type of galvanizing processes that is the bath chemistry management, post-treatment on the product and also the steel products storage. Most defects that affect the galvanized products are surface defects. These are encountered in galvanizing and Galva-annealed products (Saravanan & Srikanth, 2018). There are various defects evident in galvanization of steel (uncoated areas, bare spots, blisters, flux spots, dross inclusions, flaking, sheet distortions, blast damage, etc.) their causes are identified in hot-dip-galvanized. The way to control or eliminate this is by especially following the process parameters. Failure to do these can cause defects leading to rejection or reworks of the galvanized product (Hanna & Nassif, 1984; Saravanan & Srikanth, 2018).

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents an elaborate description of the research methods, data collection tools, and data analysis techniques used. These are being guided by the specific objectives of the study, which include determination of processing parameters that influence galvanizing, effects of power interruptions in galvanizing processes, and analysis of the cost implications of power interruptions on the galvanizing line. This study was undertaken at Roofings Rolling Mills Ltd, Namanve, it focused on the effects of power interruption on quality and production in a steel at the galvanizing line. The research approach used was deductive within stipulated boundaries of the sheet galvanizing plant.

3.1 Research Design

This is an analytical study accomplished using a mixed method research design, consisting of qualitative and quantitative methods. A qualitative method was used to establish the different process parameters, their effects and causes to the galvanizing process. Additionally, quantitative methods were used, to determine the influence of processing parameters (variables) in galvanizing, the effects of these parameters in accordance to the set standards of galvanizing steel and the cost implications of power interruptions on the galvanizing line. Also quantitative data obtained these consisted of the daily, monthly and annual production records collected from quality and production sections of the galvanizing line during power interruptions.

Participatory observations of the production processes were made to identify the influencing process parameters, different rejects and their causes for rejection in the galvanizing products or materials. The materials in a galvanizing line are those unfinished items (*e. g. sheet metals that are not yet galvanized*) those to be used in the next process, while products are the items (*e.g. galvanized sheets*) that have gone through significant stages or all processes of the production line. Subsequently, the product or material rejection at different production processes was related to the occurrence of power fluctuation. The observations were made in collaboration with personnel in the production line and in the quality assurance section, focusing on areas which were affected by power interruptions. Sampling method was employed as a way to test the effect of power interruption, data analysis tools like regression analysis and Anova were used to check on data collected. Additionally, the literature was reviewed to identify the common quality-related issues in a galvanizing line with respect to applicable quality standards, namely: Uganda National Bureau of Standards (UNBS), International Standards Organization (ISO), American Standard and Measurements (ASTM) and Australian Galvanizing Association (AGA). A summary of the details of this project are illustrated in Table 3-1 which shows the details obtained in every objective. In this is a brief discussion of the specific objectives used in this study;

3.1.1 Determining Parameters influencing Galvanizing

The different process parameters in the galvanizing line namely: Pickling, Fluxing, Cold Rolling, Galvanizing, and Color Coating that affect the productivity and quality of galvanizing were identified, with the guidance of the quality standards governing galvanizing processes of steel (ASTM, ISO, UNBS, and AGA). This was achieved through critical participatory observations of the various controllable parameters following the check list, at the different processes of the galvanizing line during real time production. The different rejects were identified, their causes at the different processes in the galvanizing line were also determined and how these parameters influence rejection of a finished product.

3.1.2 Determining Effect of Power Interruptions

The daily, monthly and annual production and quality reports of the galvanizing line were examined to determine the historical records of rejection of products in relation to the power interruptions. The critical process parameters in each stage in the galvanizing line (Precleaning, galvanizing and post-treatment) were subsequently identified. Precleaning involves the processes of pickling, cold rolling and fluxing. Galvanizing involves the process of dipping the steel sheet in the hot galvanizing bath. Post-treatment involves the process of Chromating the galvanized sheet and inspection to ascertain the presence of any defectiveness of a galvanized product. All these processes should be in accordance to a required standard. The quantities of rejects from production and quality records, especially during power interruptions, were identified. Data analysis tools like regression analysis, Anova, charts, sampling was done to ascertain the effect of power interruption on production and quality on the galvanizing line and color coating line was evaluated as it’s the final process area for galvanized sheet.

3.1.3 Determining the Cost Implications of Power Interruptions

The extent of the production losses to the organization was determined using the existing production, quality records and the additional costs incurred due to power interruption etc. The cost implications of power fluctuation on the galvanizing line were analyzed through comparison of the production losses caused by power fluctuation with the typical production costs related to galvanizing. These production losses included unplanned costs these are; increased amounts of rejects, cost of damaged components and materials, down time, re-start ups, unplanned maintenance, re-scheduled production, etc., especially during power interruptions on the galvanizing line.

3.2 Data Analysis Techniques

This presents analytical techniques used during the study. The details during this study were presented in graphs, figures, tables, charts with respect to the different galvanizing process parameters that affect the sheet galvanizing line. These details show the level to which power interruption has affected the production and quality of the galvanizing line, even though the quality standards (ASTM, ISO, UNBS, and AGA) were being monitored. These study involved the use of both qualitative data from machine operators, the organization where studies were conducted and the use of quantitative data obtained through data analysis techniques like Anova, graphs, tables and the use of organizational records as seen in the next chapter of results and discussions.

Here with are Summaries of tables; that show the research design that show the methods and tools used for data collection and also the data analysis techniques used to obtain data. These is structured as seen from table 3 – 1 and table 3 - 2 respectively.

Table 3-1: Summary of the Research Design

Specific Objective	Research Method	Data Collection Tools	Data Obtained
(i) To determine the process parameters influencing the galvanizing processes.	Qualitative Approach	✓ Participatory observation ✓ Check list	The different process parameters and their effects were determined. Standards used in galvanizing (ASTM, ISO, UNBS, AGA). The different rejects and their causes were identified.
	Quantitative Approach	✓ Check list	The process parameters (variables) that affect quality and production. Causes of rejection and how these parameters influence rejection of a product, with reference to recognized Standards used (ASTM, ISO, UNBS, AGA).
(ii) To determine the effects of power interruptions on variables of galvanizing processes.	Qualitative Approach Quantitative Approach	✓ Observation ✓ Literature reviews ✓ Check list ✓ Sampling ✓ Anova ✓ Regression analysis	Records of Quantities of rejects from the departments of production and quality at RRM was identified. Critical process parameters were determined with aid of Eqns 4:(1,2,3,4). The parameters influencing galvanizing processes with the guidance of the quality standards governing of steel were identified.
(iii) To analyze the cost implications of power interruptions on the galvanizing line.	Quantitative Approach	✓ Literature review	The extent of the production losses to the organization; using the existing production and quality records on additional maintenance and production costs (reworks, restart ups, etc.) due to power interruption etc.

Table 3-2: Summary of Data Analysis Techniques

Specific Objective	Data Obtained	Data Analysis Techniques used
To determine the process variables influencing the galvanizing processes.	Process parameters and their effects.	Tables 4-1, 4-2, 4-4, 4-5: show the processes that need close monitoring, to reduce on quality interference.
	Process variable ranges, types of rejects & their causes, Standards used (ASTM, ISO, UNBS, AGA).	Figures 4- 1, 4- 2, 4- 4, 4- 6, 4- 8 show how critical power interruption affects parameters.
To determine the effects of power interruptions on variables of galvanizing processes.	Number of rejects from production and quality records, Critical process parameters.	Anova Table 4-14, 4-16 to check the extent of power interruption Regression analysis shows the trends of power interruption in relation to the rate of rejection as shown on Figure 4-13, 4-15. The effect on production table 4-12. Sampled power interrupted days. Table 4-8 shows how it's affecting the galvanizing, using Eqns 4:(1,2,3,4).
To analyze the cost implications of power interruptions on the galvanizing line.	Extent of the production loss (material, earlier processing, over time, down time, re-start ups, unplanned maintenance, etc.).	Material costs – valuated the common affected materials during power interruption as seen Table 4-19, 4-20, Umeme Power Tariffs records (Era, 2018) provided, related to the standard power supplied.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This study shows findings, discussions and results on the different processes get affected during power interruptions on the galvanizing line. The results discussed show how quality and production is affected at different processes of the organization. These processes include; Pickling, cold rolling, cold galvanizing and color coating. The major focus of discussion will be on the cold galvanizing line from which this topic of study is focused on. This is in accordance to the methodology presented using the different data collection tools, methods and techniques being guided by the specific objectives.

4.1 Process parameters affecting the galvanizing processes

These are parameters (variables) that affect different processes during sheet galvanizing. These process parameters if not observed will lead to rejection of the galvanized product (sheet), thus affecting production and quality of steel as guided by the galvanizing standards. These results are discussed in the different processes.

4.1.1 Process parameters influencing Pickling Process

Results show that, the HRC coils delivered are cleaned with the help of an acid and rinsed with water, to prepare the HRC for the further processes as discussed in chapter two. The parameters that affect the pickling process are seen from table 4-1. The pickling process, if not well handled can lead to under or over pickling as seen from figure 4-1;

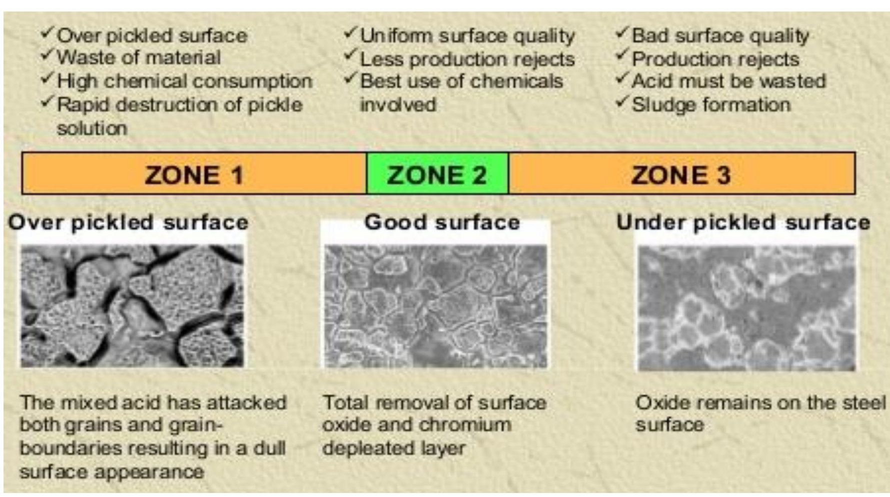


Figure 4-1 : Comparison of surface finish during pickling process (Foster chemicals 2014)

i. Over pickling

Results show that, during a power interruption some acid remains of the surface of the sheet resulting to pitting effect or over pickled surface. This causes excess zinc consumption at the galvanizing bath leading to an increase in coating weight and this also accelerates attack of molten zinc on the steel surface (IGA, 2013). Other parameters affecting pickling during a power interruption are discussed on table 4- 1. i.

ii. Under pickling

Results show that power interruption interferes with the sheet full cleanness or when weak acid concentrations is used or higher content of iron salts in the pickling bath, it results into black spot in galvanizing (Valentina Colla, 2011). Good quality of pickling can be achieved when the iron salts under normal parameters of pickling remains in the range between 8-10% in the bath.

Table 4-1 : Parameters Affecting Pickling Process

No.	**Parameters**	**Expected range**	**Operation Level**	**Remarks/ Purpose**	**During power fluctuation**
1	HCL Concentration	15 -19	17	It fluctuates depending on the condition of HRC.	Some droplets remain on the sheet
2	HRC are delivered with Fe_2O_3, 2FeO (rust) (%)	95-99	96-97	Dependent on the condition of weather during transportation.	Not effective cleaning is realized
3	Inhibitors	To be available	Not available	To prevent any acid to remain onto the sheet.	Their absence resulted to over pickling
4	Sheet thickness	1.8-2.5mm	Proportional to speed of the line and rolls	Thin sheets use high speed for effective cleaning thus grade.	Thin sheets could easily get torn
5	Flow rate of the acid (litres /hour)	420-1000	750	Depends on sheet thickness and pressure of the acid	Flow rate gets interrupted - lowered
6	Pressure of acid (bars)	3 - 6.5	5.5	To cause the acid is in turbulence.	Pressure drops occur thus no effective cleaning
7	Pressure of water (bars).	2.5 - 4.0.	3.0	Pressure of water to cause turbulence during rinsing.	Pressure drops occur thus no effective rinsing

4.1.2 Process Parameters Influencing Cold Rolling Mill

It was observed that incase of power interruption, the cold rolling machine parameters like; roller clearance settings, gear meshing get interfered especially it has caused a roller seizer, because the bearings gets damaged during power interruption. Results show that, during cold rolling the line speeds do affect the quality of the sheet to be rolled (Akhil et al, 2012). The trends on figure 4-2 in reference to data from Table 4-3, these show that line speed is greatly dependent on the plate thickness during rolling, example smaller plate thickness require lower line speeds. Furthermore in case of power interruption it's seen that, the cooling water temperature increases because the chiller units get switched off. These parameters if not well monitored can lead to rejection rolled sheet, due to effect of heat on to the sheet affecting quality of the sheet. Here is table 4-2: which shows a summary of parameters that influence cold rolling process.

Table 4-2 : Parameters affecting the Cold Rolling Milling

No.	Parameters	Expected range	Operation Level	Remarks/Purpose
1	Roll speed (meters/hour)	300 - 800	500	Dependent on the thickness of the sheet, thinner gauges usually use increased speed.
2	Line speed (rpm)	500-1800	1200	Line speed is dependent on the thickness of the sheet
3	Number of rolls	6 rolls	Dependent	This is dependent on the thickness/ gauge being processed. More rolls are used for thicker gauge.

Table 4-3 : Line speeds in relation to plate thickness during rolling

Line speed (meters/hour)	Plate thickness(mm)
180	0.18
60	0.60
50	0.80

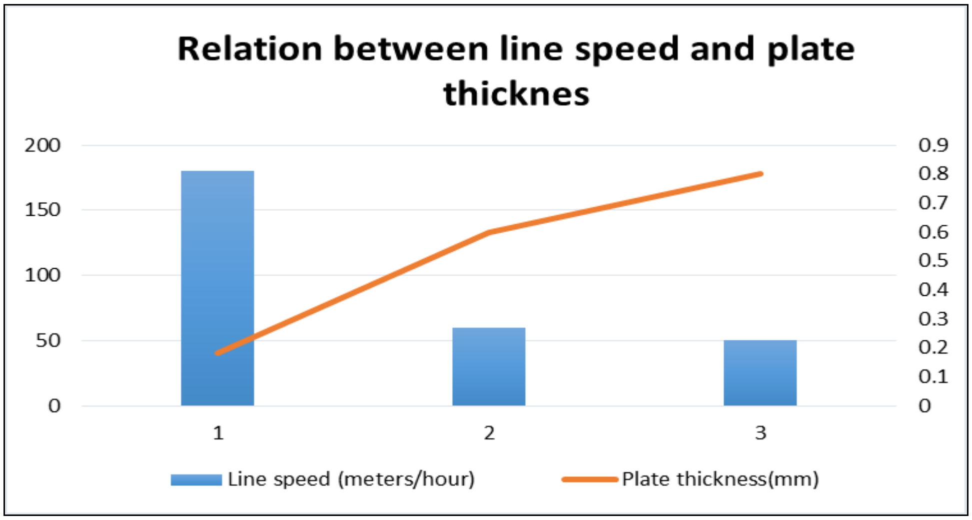


Figure 4-2 : Comparison of line speed and plate thickness during rolling

4.1.3 Process Parameters Influencing Cold Galvanizing

Results show that, precleaning of the sheet remains paramount (Beverly, 2012); (Azadeh & Toroghinejab, 2009). However, the uncontrollable aspect like electric power once it gets interrupted affects quality. Once there is power interruption, results show a parameter like rate of lifting (withdrawal) of the sheet from the bath gets interfered, this prevents the coating from forming uniformly leaving out un-galvanized small areas (bare spots) (Akhil et al, 2012); (Adetunji, 2010).

Furthermore Temperature control of the galvanizing bath, heating zones, furnaces (hot dry air, hot water, oxidizing zone) get interrupted when there is any power interruption, because these parameters require continuous control and monitoring. The galvanizing bath temperatures, gets interfered resulting to development of high stresses at the interface of the steel, due to difference in expansion or contraction of the steel (Saravanah & Srikanth, 2018; (Azadehi & Toroghinejab, 2009) this affects the material properties.

However it's observed that, parameter like pressures (galvanizing bath, furnaces, exhaust), need no interferences, these affects preparations of the material and adhesion of zinc Aluminium into the item being galvanized. Results show that, a parameter like the immersion time of the steel sheet in the galvanizing bath, is interfered because immersion time varies from a few minutes for light articles, to several minutes up to half an hour or longer for major structural members depending on the articles being galvanized (Louis, 2012), thus power interruption affects the adhesion of the zinc Allumin to the steel.

Furthermore, the flow rates of parameters like Hydrogen content / Percentage (75 NM^3/hour), Nitrogen content /percentage (300 NM^3/hour), Oxygen content / Percentage (-32 to -50PPM) and Dew point related to oxygen (- 50 to + 50 PPM). The flow rates of these parameters if altered due to interruption by power affects processes which eventually leads to rejects.

All in all results have shown that, once there is power interference this affects the parameters, which in turn affects the quality and production of the galvanized sheet. Table 4-4 has a summary of results of the process parameters or variables that get influenced by the power interruptions, yet they need to be controlled to avoid parameter interferences which may lead to rejects thus affecting quality and production.

4.1.4 Process Parameters Influencing Color Coating

During this study, results show that the color coating line is the final process for sheet after the galvanizing. The sheet gets further protection from corrosion, gets good color appearance and adds good feel to the sheet, this is done by jet spray painting. These results show that the parameters that affect color coating during a power interruption are mentioned in table 4-5 of which once there is a power interruption get interfered leads to rejection.

Table 4-4 : Parameters influencing the galvanizing process

No.	Parameters	Expected range	Reasons / purpose	Effect of power interruption
1	Galvanizing pot (bath) composition elements %	54-55 Aluminium, 43-44 Zinc, 1.6 Silicon and other trace elements	Should be within range to reduce defects.	Poor control of alloying elements, interference of the adhesion of the elements
2	Alkali –caustic	4-5%	Sprayed to reclean the sheet for any further oxidation that could have happened.	Inadequate degreasing and rinsing can reduce life by a factor of steel (ASTM 2018)
3	Hot water (^oC)	40 – 70	Water is sprayed to flash off any caustic effect on the sheet.	Water cools down
4	Hot dry clean air at (^oC)	80-150	To dry air before the sheet is finally passed into the air coolers. The presence of steam, fumes, exhaust gases, dust and grit are detrimental to good painting.	Air cooling and dryness factor lowered
5	Furnace temperature (^oC)	900- 1100	But this depends on the thickness of the material (sheet)	Is lowers below expectation and some areas get overheated
6	Radiant due furnace (RDF) zone (^oC)	700	Is activated only when annealing the sheet e.g. for color coating	Parameters interfered
7	Jet cooling set (JCS) zone (^oC)	550	The cooling of the sheet ready for galvanizing (seed).	Temperature cools down
8	The condition of the rollers.	Shouldn't be damaged	Presses and guides the sheet	Roller gets seizure effect, misaligned
9	Chromating the galvanized sheet, (^oC),	Air cooled (60-65^{o}C), hot water tank (100- 110^o C), hot air compressed, humidity of the area (15-17%).	This cleans, dries the sheet to prepare it for Chromating. This is dependent on the sheet thickness.	Dependent on sheet thickness
10	Brush scrapper,	Brush bristles should be longer <1″	To clean off any foreign material from entering the heating furnace zones.	Bristles clog thus less cleaning impact

Table 4-5 : Parameters affecting color coating process

No.	Parameters	Expected range	Operating levels	Effect of power interruption
1	Oven temperature ^oC	216-232 ^oC	220	Affects the curing proceeds; over and under baked paint or even burnt paint, peeling off the paint. Oven temperature is proportional to line speed interruption affects its effectiveness by the sheet getting burnt, over painted or even tear of the sheet
2	Speed of the line	50-18 Meters/ Hour	Depends on material thickness	
3	Spraying Nozzle openings	Always should be open	Was open	Because they are controlled by sensors which get switched off immediately, this lead to over or under coat of the sheet in case the line is stops the sensor off earlier than the line respectively

4.2 Effects of power interruptions at Roofings Rolling Mills

These results show the levels of damages due to power interruptions from the different sections of the galvanizing processes. It shows how power interference affects the different processes parameters during the production of galvanized sheets, thus affecting the formation of the Al-Zn coating. In these discussion and results, the data was collected from the operators, technicians and quality assurance team (members), then analyzed in accordance to the objectives;

4.2.1 Effects of Power Interruption on Pickling Process

The results depict how the process of pickling is affected by the power interruption during production of a pickled sheet. Details of the results are shown in the table 4-6.

Table 4-6 : Effects of power interruption in a Pickling process

No.	Parameters/ effect	Expected range	Required parameter	Effect(s) of power interruption
1	Reactor temperature (^oC)	410 - 454	410^o	Red oxide fumes, spray boom get burnt, this affects eye sight of workers, the fan speed is reduced, Pickled sheet occasionally gets defective.
2	Acid fumes	To get in contact with other machine components	N/A	May increase in due time, machine depreciation rate and maintenance as it gets contact with machine parts (Bearings, bolts, nuts, sensors get broken due to vibration).
3	Acid generation into the pickling tanks	Time taken to generate a drum (550 litres) of acid	Takes 60-70 minutes to generate a drum of acid	Production delays- acid mode takes 20hrs for the acid to stabilize to reheat mode yet this supplies acid to pickling section. Lowers the level of acid regeneration thus increasing the expense on acid purchase from the market for pickling.
4	Total down time	-	Takes 70 – 100 minutes	Production loss, material loss, safety is questioned due to pollution(people and sheet) from acid, fatigue, etc.

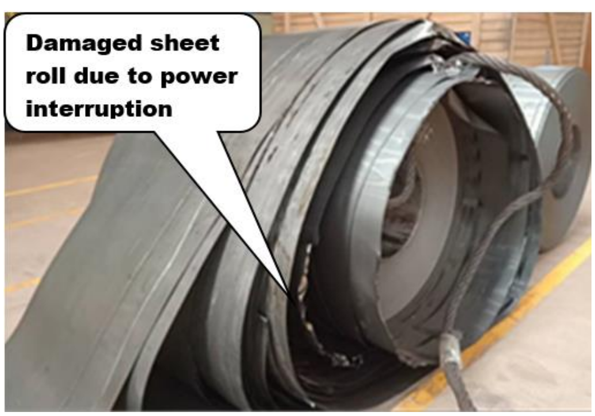
In this section, results show that, the sheet that is being pickled (at the pickling bath) develops pits due to acid on the sheet as it remains embedded inside the tank, no time to rinse that particular section which is in contact. But this effect is minimal on the sheet being pickled, as all the acid gets drained back to the acid tanks and also back to the acid regeneration processing unit (tanks). If the time lag is long then the sheet is lost (30 meters). But it’s observed that, this interferes with machine processes thus reduction of machine availability and production efficiency of the galvanizing line.

4.2.2 Cold Rolling Mill

During this process, results show that time is lost and the cooling water temperature (10-15^0 C) for the rolls increases which affects the quality of the sheet as a result of interlock, because the sheet and other processing equipment generate heat during the process and this requires supply of electric power. Other parameters that usually get affected by power interruption are shown in table 4-7;

Table 4-7 : Effects of Power Interruption on Cold Rolling Mill

No.	Parameters / Effect	Expected range	Time lost (minutes)	Effect(s) of power interruption
1	Roller	10 – 30 minutes	60	Roller damage as seen in figure 4- 3, caused by the failure of the bearings thus leading to restriping or regrind or replacement the damaged roller, machine checkups, startups and set ups.
2	Rolled Coil	N/A	30	Rolled coil gets damage; leads to recoiling of the damaged coil (0.2-6MT), as seen in figure 4-5; usually this is done at low speed, because sometimes the coil gets internal damage
3	Sheet tear	20 minute to join sheets	40	Abrupt tensional forces due to high speeds on thin sheet thickness cause tear. Checkups, startups, to flying debris can injure personnel
4	Seizure on rollers	N/A	40	Sudden stoppages, checkups, startups, these reduces machine performance
5	Total time lost in an interruption		115	Depends on the intensity of power interruption; but results to losses on production (time, material, more rejects) safety questioned and rejection of products as seen on figure 4-3.



(a) **(on site pictures)**

(b) **(on site pictures)**

Figure 4-3 : (a) Damaged coil (edges) and (b) Collapsed coil (0.6MT)

This results shown on figure 4-3(a) and (b) are damaged and collapsed coils respectively, this affects the organizational profits due to additional expenses to the organization.

4.2.3 Effects of Power Interruption on Cold Galvanizing

These results show power interruptions has resulted to quality issues that have led to rejection of the product or interference of the galvanizing process thus causing production losses, as a result of increased machine processes, rescheduling of production plans, human resource planning, etc.

Also results show that there is material loss which is direct or indirect;

- **The indirect losses -** These loss of material value is lost in terms of grades (1^{st}, 2^{nd}, 3^{rd} grades) that is they are sold at different prices, consumables like fuel (liquid petroleum gas) for heating the heaters of the galvanizing bath, to maintain the bath heat for Zn-Al from not to stick onto the bath, a loss of production time due to machine processes and downtime this affects profits, this results to increased production costs due to overtime, increased power consumption during restart ups and startups, due to high starting torque, replacement of spare parts during unplanned maintenance, all these are indirect additional costs to the organization.
- **The direct losses** - These involve damages of machine components like the bearings, bolts and broken sensors, rejected (wasted) materials as scrap which could amount to about 400 to 700 kilograms in every power interruption, as shown in the discussions and figures 4- 6, 4- 7, 4- 8, 4- 9, 4- 10, 4- 11 and B8 on the appendix B;

i. **Bare Spots**

Results show that, due to power interruption, it results to inadequate surface preparation, because embedded items or oxides cannot be cleaned effectively, causing more Aluminum in the galvanizing bath to be removed, or this can also prevent the coating from forming in a small area (AGA, 2018). This results rejects like black spots, as seen on figure 4- 6 (AGA, 2016).

Figure 4-4 : Rejected sheet - black spots (on site pictures)

ii. Delaminated areas/ peeling off

Results have shown that power interruption results to changes in temperature, which in turn results to development of high stresses at the surface of the steel due to differential expansion or contraction of the steel. During cooling, the coating leaves behind voids on layers which shear off from the steel surface so it causing either delamination or peeling off as seen in figure 4- 5.

Figure 4-5 : Delamination’s and peel offs (on site pictures)

iii. Rough surface conditions

Furthermore, power interruption results to the galvanized sheet to sluggish withdrawal of the sheet from the galvanizing bath, because the motors motion is interrupted and the action of the doffing (cleaning) rollers becomes insufficient to wipe off the excess zinc from the sheet causing much of the zinc to adhere more on to the sheet. This results to rough surface condition as seen in figure 4- 6.

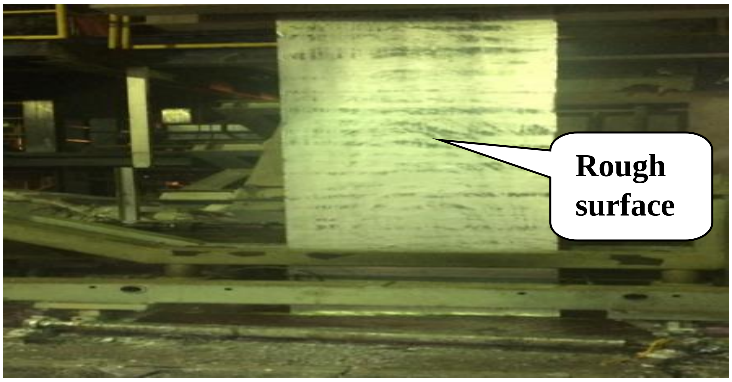


Figure 4-6 : Rough surface conditions on the sheet (on site pictures)

iv. Oxidized /burnt sheet

Results depict that, in case of power interruption, the conveying of the sheet is interrupted thus exposing the non-galvanized part into the effect of the circulating air on the atmosphere this eventually results to oxidation due to presence of the hydrogen and oxygen molecules in the atmosphere. Also its observed that, the concentrated heat is imposed to the sheet, because of abrupt stoppage due to power interruption exposes the sheet to much heat onto a particular area results to burning of that particular area as seen in figure 4- 7, both situation lead to rejection of the sheet.

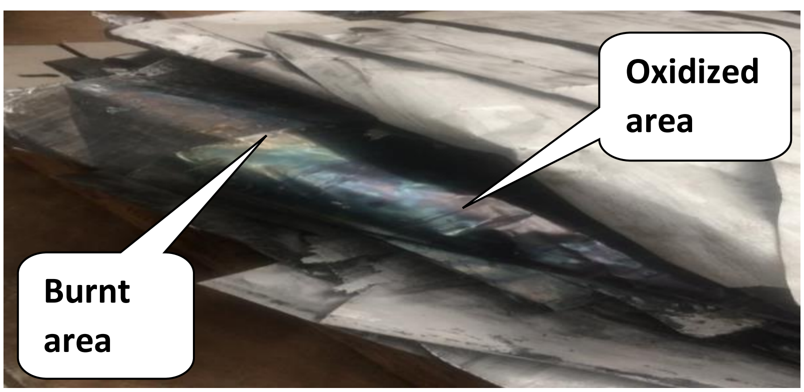


Figure 4-7 : Rejected sheet oxidized and burnt (on site pictures)

v. Flaking

Power interruptions do cause drastic temperature difference during galvanizing process resulting into flaking's, the alloy layers formed during galvanizing process are very hard and inflexible. This results from high stresses developed at the surface of steel, due to differential expansion or contraction of the steel (Louis, 2012), this causes some areas of the alloy layers to shear off from the steel surface, so the zinc becomes flaky separating from the steel surface as in figure 4- 8.

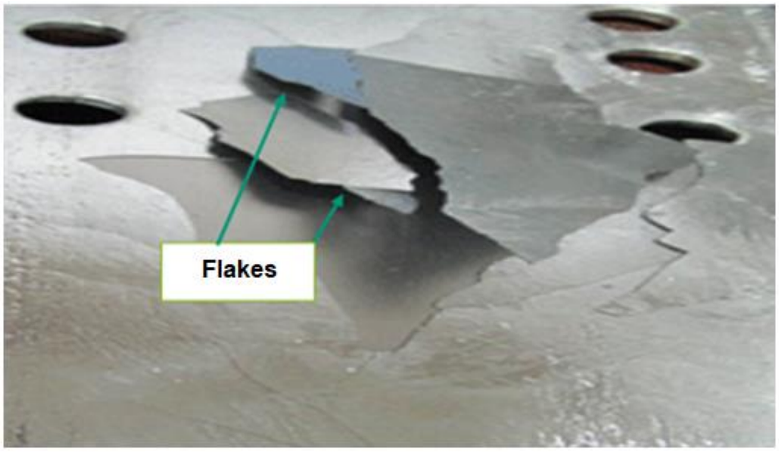


Figure 4-8 : Flaking's (on site pictures)

vi. Distortion

Results show that, Power interruption leads to distortion of the part due to temperature differences. This occurs due buckling of the sheet as a result of thermal expansion and contraction resulting from high-stress levels developed by the sheet. Thin plate sections are most prone to distortion due to rapid differential interrupted heating and cooling of the sheet (AGA, 2081; ASTM, 2018). Furthermore, results show that the condition of the rollers can cause distortion, especially when rollers are deformed or not running true, this is caused by frequent roller seizure due to vibration imbalances which happens during power interruption, as seen in figure 4- 9 which shows some of the distorted sheets.

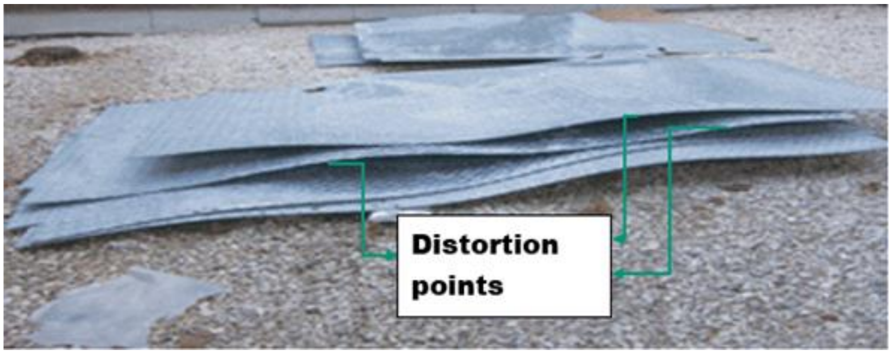


Figure 4-9 : Distorted sheets (on site pictures)

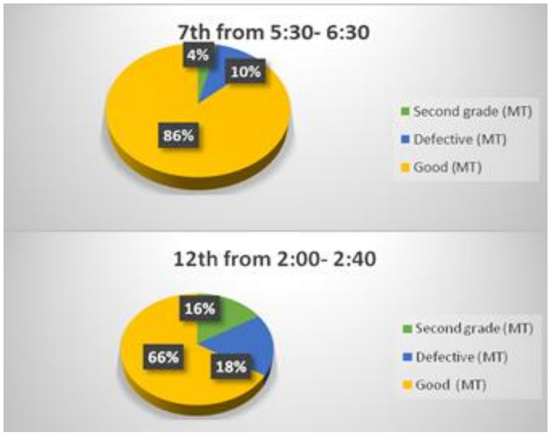
Other rejects that lead to rejections of the sheet during power interruptions are; dents (folds), waviness (wrinkles), over and under coating, pitting marks, scratch lines, build ups on sheet, blisters (pin holes), feathery marks, slag inclusions, dents, waviness, dross marks and inclusions, etc. Results show that these occur due to power interruption, but they are dependent also on the handling of the material, design of the equipment and the time taken by the power interruption

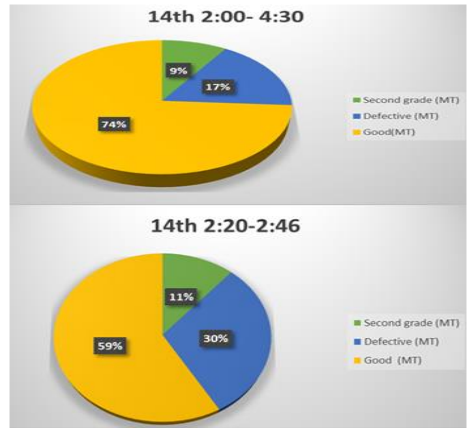
Furthermore, results from the organization have been sampled from the months of September 2018 as seen is table 4- 8, showing the production details for rejects caused by power interruption at the sheet galvanizing line to check whether power interruption still has an effect to the organization. This was sampled out from some days of the month of September 2018, as shown in Table 4- 8:

Table 4-8 : Production records of rejects for CGL for September 2018 in Metric Tones (MT)

Date-Sept.	Down time	Production (MT)	Second grade (MT)	Defective (MT)	Total production (MT)	Effect of power interruption
7th	5:30- 6:30	77.035	3.701	9.463	85.21	It led to line restart
10th	3:50- 3:53	77.705	-	3.305	81.09	Resulted to strip tear at cooling tower
12th	2:00- 7:00	3.64	1.855	2.080	7.575	Shrink roll & scraper cylinder got disconnected, which led to line maintenance
13th	8:00- 9:00	78.98	8.76	-	87.74	Resulted to reduced Pressure of N_2 & H_2
14th	6:10- 8:20	None	none	None	-	Strip breakage at start of line, which caused change of production plan
14th	10:58- 2:00	2.395	1.585	4.29	8.27	Strip breakage at zinc pot, and their was resultant noise pollution at this moment
14th	2:00- 4:30	8.43	1.57	3.005	13.005	Outburst – the sealing water oozed
14th	2:40 -2:46	112.66	3.68	-	116.34	Led to restart of the line
16th	11:44- 11:50	110.39	1.895	1.295	113.58	Resulted to restart of the line
Total	**867 Minutes**	**471.235**	**23.046**	**23.438**	**427.6**	**Losses as; materials, time and production loss**

By sampling out some production records, to analyze further the effects of power interruption on the cold galvanizing line. This results illustrate how contact time as a parameter has effect on the material during galvanizing process, results, show the influence of immersion time clearly seen on results in figure 4-11.





(a) **(b)**

Figure 4- 10 : (a) and (b) Effects of power interruption for 7^{th}, 12^{th}, 14^{th} 14^{th} Sept.2018 (different time interval)

These results shown in figures 4-10: (a) and (b) depict that the relation of contact (resident) time and furnace temperature during galvanizing bath at the moment of power interruption. This is summaried in figure 4- 11: The results confirm that resident time of the material in the galvanizing bath increases the amount of the rejects produced (Culcasi et al, 1999).

Table 4-9 : Summary of the sampled days of September 2018

Date	Down time (mins)	Rejects %
7^{th}	30	14
12^{th}	40	34
14^{th}	30	26
14^{TG}	26	44
16^{th}	6	3.19

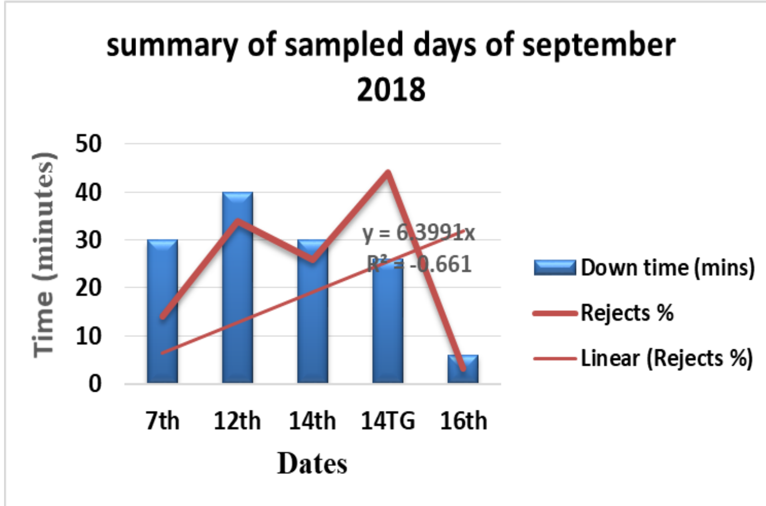


Figure 4-11 : summary of sampled days of sept 2018

This results are summarized in table, 4-7, 4-8 and figure 4-11; show the how time is lost and the effect of rejects to the galvanizing process thus causing production losses as seen on table 4-10 and table 4-12. This is because every power interruption causes down time resulting to organizational losses as production and machine efficiency

These results show, the machine efficiencies for the sampled days of September 2018 for the galvanizing line alone, for 2016 and 2017 for both the cold galvanizing and color coating. The calculations done are using eqn. 4-1, with the following assumptions that;

During the production runs for extra ideal of 24 hours a day, there is no programme for maintenance time in 5 days for 24 production hours is 150 hours (9,000 minutes). In production run of 22 hours a day and 2 hours are for machine processes, Total run time in 5 days for 22 production hours is 110 hours (6,600 minutes), The total down time for power interruption for the sampled days is 867 minutes. The total down time shown on table 4-8.

From Machine efficiency $= \frac{\text{Total running time}}{\text{Total running time+total time internal failure}} X\ 100\%$ ...Eqn. 4:1

Table 4-10 : Machine efficiencies for cold galvanizing and color coating lines

Condition/section	Programmed Working time (hours)	Total running time (hours)	Dt /failure time (minutes)	Machine Eff. %	Lost Machine Eff. %
Considering machine processes on for /downtime on table 4-8;	22	110	14.45	88.42	11.58
Without Considering machine processes/ ref table 4- 8; downtime	24	150	867	91.21	8.8
CGL 2016	66,000	5,680	920	87.76	12.24
CGL 2017	66,000	56,000	600	91.7	8.3
CCL 2016	66,000	5,802	798	89.32	10.68
CCL 2017	66,000	5,410	1190	84.72	15.28

This results in table 4-10, show even with no machine processes how power interruption has an effect on machine efficiency, so machines cannot operate at full capacity, this eventually affect the organization performance.

However results also show how power interruption has affected production efficiency as seen in table 4-12: as guided by calculation of equation 2. In this table 4-11, results shown are production details per month giving the total down time for the years 2016 and 2017 for the cold galvanizing line (CGL) and color coating line (CCL).

→ Production efficiency as shown in Eqn 4:2

Table 4-11 : Down time for both CGL and CCL for 2016/2017 in Metric tons (MT)

Month/ year	Down time CGL 2016	Down time CGL 2017	Down Time CCL 2016	Down Time CCL 2017
January	69.4	97.6	59	39
February	102	121	90	34
March	109	111.6	89.2	44.65
April	123.6	143	73.1	66.31
May	101	98.7	70.4	55.97
June	60.4	76.8	60.4	54.37
July	82	87.9	72.9	54.78
August	66.2	99.5	66.2	46.41
September	80	68.9	67.5	38.12
October	88.5	105	50	54.81
November	76	99.6	58	68.11
December	45	90.3	45	43.21
Total	**1003.1**	**1199.9**	**801.7**	**599.74**

Table 4-12 : Total annual production in Metric Tons (MT) of CGL and CCL for 2016/17

Year	Total production (MT)	Machine input (MT)	Machine output (MT)	Production Efficiency (%)	Lost production Efficiency (%)	Rejects
CGL 2016	64,830	64, 405	50, 751.15	69.17	30.83	575
CGL 2017	73,869	74, 407	51, 467.33	78.8	21.2	538
CCL 2016	30,820	30,691.8	29,013	94.53	5.47	128.192
CCL 2017	35,234	35,290	32,920	93.2	6.8	56

Furthermore, table 4-13 represent production rejects of the cold galvanizing line for the 2016 and 2017 in Metric Tons. But under normal production the standard, the allowable amount of rejects is 0.5 MT, figure 4-12; shows the trends of regression analysis on how production was affected by the power interruption.

Table 4-13 : Production rejects in Metric tons (MT) for the Cold Galvanizing Line

Month/ year	**2016**	**2017**
January	69.21	37.65
February	7.45	55.825
March	19.47	35
April	22.3	46.58
May	8.77	44.87
June	36.835	44.02
July	59.95	29.7
August	79.49	75.51
September	107.35	17.035
October	89.24	24.365
November	54.55	92.915
December	42.365	34.055
Total	**575**	**538**

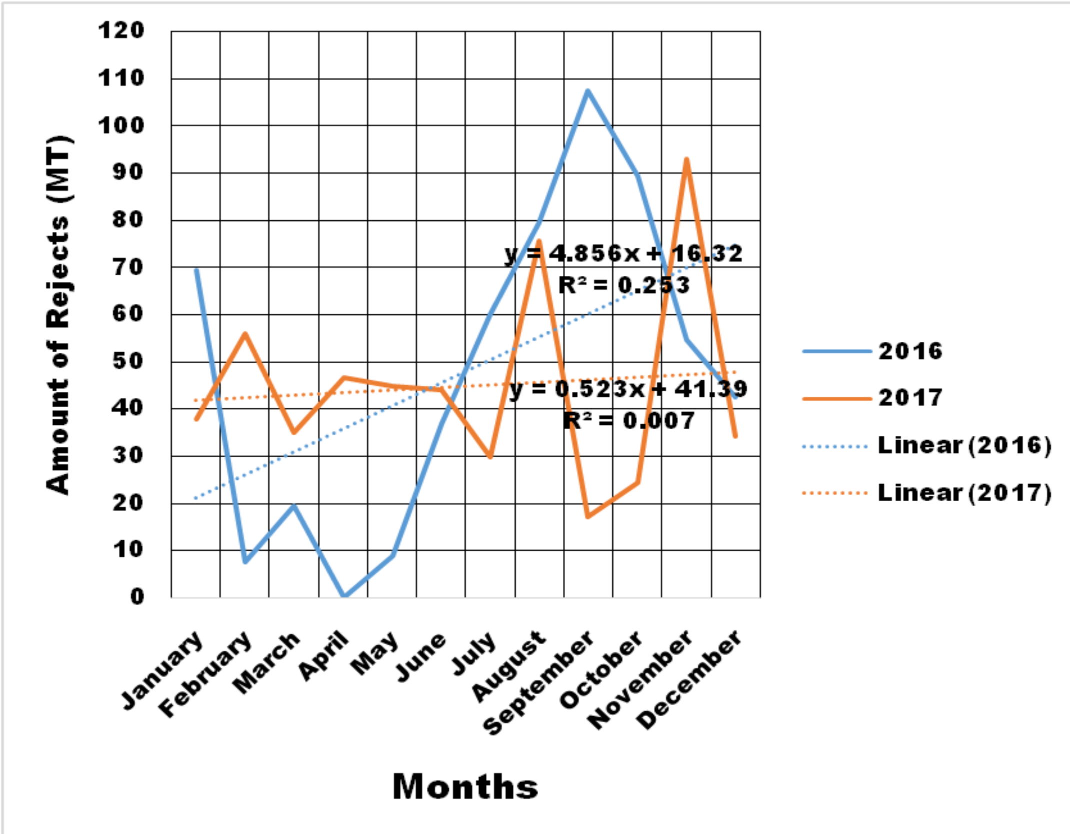


Figure 4-12 : Production rejects for Cold Galvanizing Line for 2016/17

The study results of analysis of details shown on table 4-12 are represented on figure 4- 12, which show the details of a regression analysis but the results show that, there is less significant effect on 2017 than in 2016 on how power interruption affects production of the galvanizing line. These results show increasing trends as indicated by the intercept and the regression lines for both years. The r^2 (regression coefficient) value for 2016 is 0.2535, showing that the rate of rejection is 25.35%, and for 2017 is 0.0077; which is 0.77%, the regression lines for both years show increasing trend lines, so the average is (25.35 + 0.77) /2 = 13.06 %.

From these rejection results, on the data on table 4-13 and this resulted further analysis to table 4-14 on the effects of the power interruption on the cold galvanizing line and on the color coating line as seen on table 4-14 and table 4-16 respectively. This is by using t-test and one way ANOVA, it checks 24 month of 2016 and 2017. This another data analysis tool is to check (confirm) the effect of power interruption.

Table 4-14 : Results for the Cold Galvanizing Line Production Rejects (MT) for 2016/17

Months	Ȳ	Y	(Y - μ)	$(Y – μ)^2$
January	0.5	69.21	22.02229167	484.9813303
February		7.45	-39.73770833	1579.085464
March		19.47	-27.71770833	768.2713553
Aprill		22.3	-24.88770833	619.3980261
May		8.77	-38.41770833	1475.920314
June		36.835	-10.35270833	107.1785698
July		59.95	12.76229167	162.8760886
August		79.49	32.30229167	1043.438047
September		107.35	60.16229167	3619.501339
October		89.24	42.05229167	1768.395234
November		54.55	7.362291667	54.20333859
December		42.365	-4.822708333	23.25851567
January		37.65	-9.537708333	90.96788025
February		55.825	8.637291667	74.60280734
March		35	-12.18770833	148.5402344
April		46.58	-0.607708333	0.369309418
May		44.87	-2.317708333	5.371771918
June		44.02	-3.167708333	10.03437609
July		29.7	-17.48770833	305.8199428
August		75.51	28.32229167	802.1522053
September		17.035	-30.15270833	909.1858198
October		24.365	-22.82270833	520.8760157
November		92.915	45.72729167	2090.985203
December		32.055	-15.13270833	228.9988615
	Sum (Σ)			16894.41205
	Mean(μ)	47.18770833		
	Variance(S)	734.5396543		
	Standard Deviation (δ)	27.10239204		
	Standard Error (Ɛ)	1.085525159		
	Tcal = x =	43.00932865		
	Ttab	2.06865761		
	Probability (P)	8.79037E-24		

Results on table 4-14; Tcal>Ttab,: show that there is significant difference in production results of the galvanized sheets between the process with power interruption and that with no power interruption, as shown by the standard error and probability deviations.

4.2.4 Effects of Power Interruption on Color Coating of a galvanized sheet

In case of any power interruption in this area, results show that the color coating cannot proceed with production, because all the sensors that control the nozzles that spray the paint onto the sheet get triggered off, this results to rejection due under coating. In case there is a delay on the closure of the nozzle, this will lead to rejection due to over coating of the sheet, because the paint will be jet sprayed on to a particular area. Also results show that this causes production losses due to start ups, material loss as paint and sheets. Furthermore, it's also evident that, this usually leads to a loss of about 600 - 700 Kgs (for gauges 30 &32), on every power interruption.

Table 4-15 : Quality records in Metric tons (MT) for Color Coating Line

Month/year	**2016**	**2017**
January	11	8.175
February	3.278	3.05
March	13.228	10.965
April	14.324	8.165
May	34.108	3.65
June	0.66	8.23
July	14.309	0.52
August	0.6	0.53
September	9.645	4.605
October	0.65	1.45
November	15.6	2.75
December	10.79	3.565
Total	**128.192**	**56**

From the table 4-15: above is a representation results of quality rejects for the 2016 and 2017 for the Color Coating Line and figure 4-13. Results of the regression analysis on how power interruption has affected quality and production. Results show that, the trends of rejections are increasing as seem by the regression lines for both years as seen in figure 4-13, but there is less significant effect on 2017 than in 2016 as shown by the intercept lines.. The r^2 (regression coefficient) value for 2016 is -0.428, that is 42.8%, rejection rate and the r^2 for 2017 is -1.028; that is rate of rejection is 102.8%.

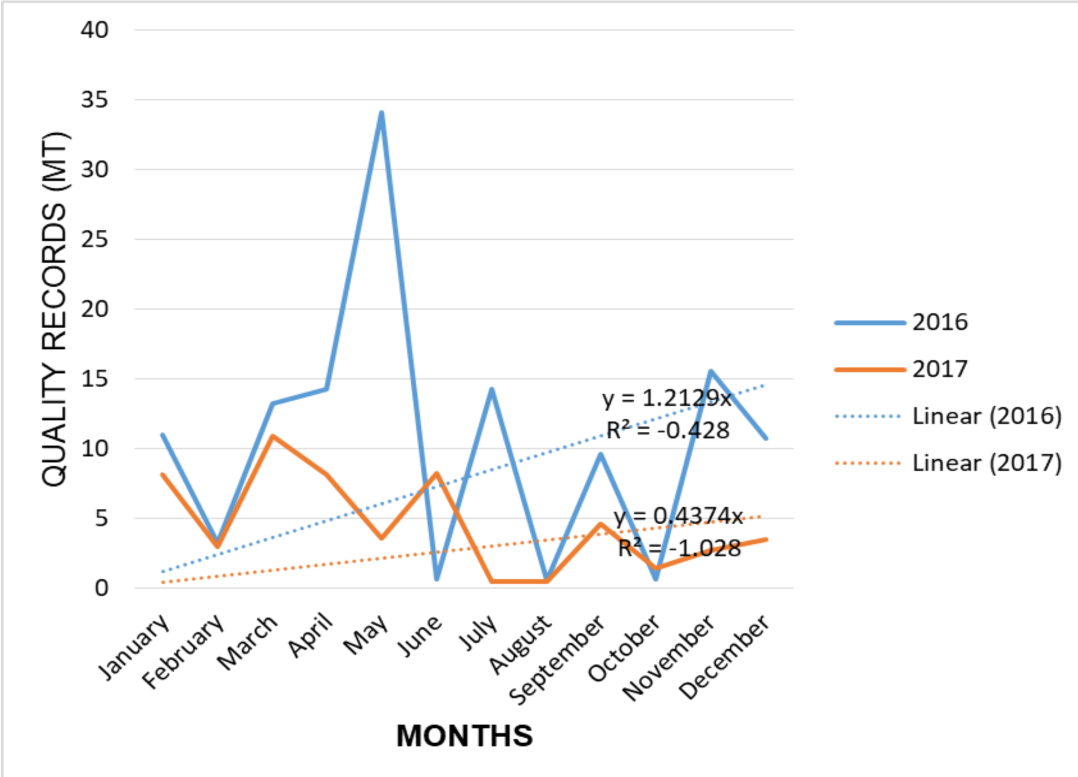


Figure 4-13 : Quality rejections for Color Coating Line for 2016/17

Further analysis is conducted on the data on table 4-16 to assess the effects of the power interruption on the color coating line respectively. This is checked also using t-test and one way ANOVA tool, it checks 24 month of 2016 and 2017 for the color coating line. This is to confirm the data analyzed, from table 4- 15 and results seen in figure 4- 13, but this is consideration the normal production the standard, the allowable amount of rejects is 0.1 MT, figure 4-16: this shows the trends of how quality is affected by the power interruption.

Table 4-16 : Results for the Color Coating Line quality Rejects (MT) for 2016/17

Months	**Ȳ**	**Y**	**(Y - μ)**	**$(Y – \mu)^2$**
January	0.1	11	3.339708	11.15365
February		3.278	-4.38229	19.20448
March		13.228	5.567708	30.99938
April		14.324	6.663708	44.40501
May		34.108	26.44771	699.4813
June		0.66	-7.00029	49.00408
July		14.309	6.648708	44.20532
August		0.6	-7.06029	49.84772
September		9.645	1.984708	3.939067
October		0.65	-7.01029	49.14419
November		15.6	7.939708	63.03897
December		10.79	3.129708	9.795074
January		8.175	0.514708	0.264925
February		3.05	-4.61029	21.25479
March		10.965	3.304708	10.9211
April		8.165	0.504708	0.254731
May		3.65	-4.01029	16.08244
June		8.23	0.569708	0.324568
July		0.52	-7.14029	50.98377
August		0.53	-7.13029	50.84106
September		4.605	-3.05529	9.334807
October		1.45	-6.21029	38.56772
November		2.75	-4.91029	24.11096
December		3.565	-4.09529	16.77141
	Sum (Σ)			1313.93
	Mean(μ)	7.660291667		
	Variance(S)	57.12741291		
	Standard Deviation (δ)	7.558267851		
	Standard Error (Ɛ)	0.573254168		
	Tcal = x =	13.18837627		
	Ttab	2.06865761		
	Probability (P) =	1.64144E-12		

Tcal>Ttab, The results on table 4-16: show that there is significant difference in the quality of color coated sheets between the process with power interruption and that with no power interruption.

Where;

μo = average value of Y

δ = Standard Deviation

Y = each parameter of rejects recorded per month

SE = Standard Error = (δ/n)

T = test results = (Y-μo)/SE

Tcal = test results calculated = (μ- Ȳ) /δ

Ttab = test results got from the table = Tinv (Ȳ, n-1)

Ȳ = the standard allowable amount of rejects (quality allowable aspect) in MT 0.5 and 0.1 for cold galvanizing and color coating respectively in every production.

n = is 24 months of 2016 - 2017

T_{n-1} – under the null hypothesis

However, the comparison between production processes of cold galvanizing and color coating line recorded after power interruptions and with no power interruption was conducted for 24 months (from January 2016 to December 2017 in each case as shown in Table 4-13: Table 4-15: respectively. The result using t-test and one way ANOVA, however, showed significant difference ($p<0.05$) between the production processes with power interruptions and that without power interruption. These results implies that power interruptions significantly affect negatively the quality of the galvanized and color coated sheets respectively. These results show a significant effect on a factor of production cost implications to the organizations performance. These is evidently shown by the probability values, there is a much deviation from the standard (expected average) amount of rejection (Y) of on both of the Anova analysis shown on table 4-14 and table 4- 16. It's paramount to note that the configurations Tables 4-13: and table 4-15: has been used in reference as 24 months, with allowable rejection of 0.05 and 0.01 for CGL and CCL respectively as seen on the one way ANOVA combination table.

Other effects of power interruption on the galvanizing line are shown on table 4- 17; which shows how different machines, equipment's, materials, and personnel are affected in one way or the other.

Table 4-17 : Effects of power interruptions on production in the galvanizing process

Effect / Section	**Effects during normal run**	**Effects during an interrupted power supply**
Strips /scrap at edges(CRM)	Loss of 600 - 800kg / 8hrs shift	Depends on the impact of the interruption (can be 600-800 Kgs/interruption)
Sparks/fire (CRM)	N/A	Sometimes depending on seizure
Regenerated Acid /hour (PPL)	550 liters of acid/ hour	Less /no Acid regenerated
Wasted acid (PPL)	20,000 litres	> 20,000 litres lost
Acid fumes(PPL)	Less fumes effect	More pollution due to fumes
Blockages of pipes, pumps, valves > 80^0C crystalizes - chock age / replace a new one	N/A	20-30 minutes/1 hour respectively
Sheet gets torn or cut(PPL,CRM &CGL)	N/A	600 -700 Kgs of sheet is lost
Consumption of LPG(heaters, reactors)	30mins more LPG for ≈1.56NM galvanizing heaters alone	More LPG is consumed depending on the time taken for power to be reinstated
Various types of rejects(CGL& CCL)	Negligible	Peel off , burnt materials, over coated and undercoated, over heated
Depreciation of machines and Equipment's (PPL,CRM &CGL)	Less or no effect due to less contact of acid, its fumes, less vibration effect	Much effect or damage due to contact of acid, its fumes, seizure, vibration impact
Pollution of environment(PPL,CGL.CCL)	Minimal accepted	Acid spillages, heat, Fumes (red oxide, acid, paint, smoke), etc.

In conclusion, the final summary of results as seen on table 4-18: that show how power interruption affects different process parameters, which eventually interfere with the quality parameters thus affecting the production at the different sections and subsections of the galvanizing line. Results show how machine efficiency, production efficiency and production losses based on rejection details majorly for 2016 and 2017.

Table 4-18 : General summary of effects/ impact realized during power interruption

Description	Quantity / impact	Comment
Machine efficiency for sampled month of 2018 (September $(7,10,12,14,17)^{th}$)for CGL	88.42%	Had lost machine efficiency of 11.58 % days September
CGL-2016 CGL- 2017 CCL- 2016 CCL- 2017	87.76% 91.7% 89.32% 84.72%	Assessed for the details of down time from the organization, in relation to Eqn 4.1
Rejection -2016 - 2017	42.8% -102.8%	For CCL from regression analysis
Rejection -2016 - 2017	25.35% 0.77%	For CGL rom regression analysis
Production efficiency for ideal run	91.21%	for only five days for 24 hours but with power interruption for CGL
CGL-2016 CGL- 2017 CCL- 2016 CCL- 2017	69.17% 78.8% 94.53% 93.20%	Analysis based on the total productions , machine inputs and machine out puts in relation to Eqn, 4.2

All in all, results show that any power interruptions cause interferences of the process parameters, this leads to various types of rejects which affect quality and leads repetition of machine processes thus affecting production of the galvanizing process. All these affect the organizations performance.

4.3 The cost implications of power interruptions

The effects of damage (*rejects, equipment, and production losses)* identified in production and quality are converted into financial value. These results calculated in these findings are maintaining the assumptions that;-

The organizational production loss of 1% is equivalent to UGX 1.5 billion ($394,736.6) (UIA. (2015) due to fluctuation of the dollar rate, one dollar (1 $) is at UGX 3800, the electric power tariffs is UGX. 383.8 as per 2018 rates (Era, 2018).

The results that show the extent to which power interruptions have affected the organization as shown in the table 4-17: and table 4-18:

Table 4-19 : Costs of production from the material lost

No.	Parameter		Expected loss	Loss due to power interruption	Impact of power interruption
1	Material weight loss produced per shift (CGL gauge 30)		20kgs per roll/10 rolls/day	flicker age / minutes	A loss of 200 Kgs@ $ 1781/ton (UGX 1, 354, 320)
2	Production delays or down time per minute		N/A	At CCL ≈.28MT/minute	$498 (UGX1, 896, 048)
				CGL$(674+1375)	$573.86 (UGX 2,180, 668)
	Roller replacement(CRM)		According to schedule	Depends on intensity	$375 (UGX 1,425, 000)
3	Materials	Bolts & nuts	Depends on sizes	Common due to seizure	$13-79 (UGX 50,000-300, 000)
		Bearing-line, ϕ 60mm	N/A	Depends on intensity	$174(UGX 661, 200) $499(UGX 1, 896, 200)
		Paint (ordinary)	red@$3.8/minute	600 -700 Kgs	$ 1354 (UGX 5, 146, 416)
		Paint (wrinkle)	@$ 4.75/minute	600 -700 Kgs	$1692.9 (UGX 6, 433, 020)
4	HRC Coil damage		N/A	1 Roll	$674.5 (UGX 2, 563, 100)
5	Damaged rolled coil		None	1 coil (1.2mm)	UGX 5, 000, 000
6	Damaged color coated sheet		None	600 -700 Kgs (250 meters)	$ 1250 UGX 4,750, 000
7	**Total cost of materials lost per interruption**				**$ 8, 817.36 UGX 31, 519, 772**

Table 4-20 : Production costs due to electric power interruptions (Ugx '0000')

	Power supplied (MW)		Standard Power supply (MW)	Power Interruptions (MW)			Costs for the Year	
Months	**2016**	**2017**	**General**	**2016**	**2017**	**Unit Price (Ugx)**	**2016**	**2017**
Jan	1036	1064	1176	140	112	383.8	53732	42985.6
Feb	1092	1068	1176	84	138	383.8	32239.2	52895.4
March	1120	1120	1176	56	56	383.8	21492.8	21492.8
April	1064	1078	1176	112	98	383.8	42985.6	37563.4
May	1092	1020	1176	84	156	383.8	32239.2	59794.4
June	1148	1008	1176	28	168	383.8	10746.4	64478.4
July	1064	1036	1176	112	140	383.8	42985.6	53732
Aug	840	896	1176	336	280	383.8	128956.8	107320
Sept	588	1120	1176	588	56	383.8	225674.4	21492.8
Oct	700	1148	1176	476	28	383.8	182688.8	10746.4
Nov	1092	816	1176	84	360	383.8	32239.2	137988
Dec	1120	1092	1176	56	84	383.8	21492.8	32239.2
Total	**13,972**	**12,470**	**14,112**	**2,156**	**1,676**		**827,473**	**642,728.4**
Average/month				**179.67**	**139.67**			
Average power interruptions /day				**5.99**	**4.66**			

The results show that the production losses from electric power interruptions for 2017 and 2016 are discussed respectively, with reference to table 4-19 and table 4-20;

UGX. {642,728, 400 + 827, 473, 000) 1000 =725, 475,700/=.

The total material loss per year per power interruption (5.99 + 4.66)/2 = 5.33 × 31, 519,772

= UGX. 168, 000, 384.76

Hence the total production losses include; material loss and power losses due to every power interruptions amount to 725, 475,700 + 168, 000, 384.76

= UGX. 893, 476, 084.76 or $ 235, 125.29

Average production losses per each year

UGX. = (893, 476, 084.76/2) =446, 738, 042. 38 ×12

= 5, 360, 856, 508.56/annum or $ 1, 410, 751.71

But according to the above assumptions declared in the introduction of this chapter which show that still 1% of the production loses are equivalent to Ugx 1.5 Billion Shillings ($ 394,736.6) (UIA. (2015),

Thus if 1 % =UGX 1.5 Billion Shillings (1, 500, 000, 000)

Then Production percentage loss = (1, 500, 000, 000/5, 360, 856, 508.56) × 100 = 27.98%

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter suggests ways to solve and reduce the effects of power interruption on the galvanizing line, how to reduce amount of rejects and improve on production efficiencies. This is according to the findings and results of the study as summarized below:

5.1 Conclusions

The effects of electric power interruption on quality and production during sheet galvanizing are summarized that;

- **i.** In order to obtain high quality products, it is important to ensure that parameters for galvanizing follow specified standards and there should be continuous monitoring of parameters. These can cause different types of defects resulting from the different galvanizing processes. Power interruptions interfere with parameters that affect the galvanizing processes. The parameter changes that affect the galvanizing process during a power interruption are due to changes in; pressures (pickling and galvanizing bath, oven exhaust, furnaces), temperatures (pickling bath, fluxing, coolers of cold rolling mill, galvanizing bath, oven), the condition of the dross in the galvanizing pot, the line speeds. Other parameters that also affects quality and production are; the concentrations / percentage of hydrogen, nitrogen, and oxygen content. All these parameters are affected by any electric power interruption.
- **ii.** Analysis of the production output shows progressive increase in numbers of rejects from 0.77- 25.35% for CGL and from 42.8 -102.8% for CCL for 2016 and 2017 respectively. This is due to interference of production preset parameters, deviates parameters from specified standard set parameters. This has resulted to reduced average production efficiencies from 94 % to (69. 17 % and 78.8 %) for CGL, from 94% to (94.53% and 93.20 %) for CCL, for 2016 and 2017 respectively for both lines. CCL is less affected quantity wise than CGL, because its equipment's parts are so sensitive to power, but unlike the equivalent financial loss in CCL is more expensive than CGL, because it involves all costs of inputs from other sections. This also has led to increased production costs from UGX 7.5 billion to UGX. ≈ 8.65 billion per annum due to additional costs of

production (directly or indirectly), amidst other investment challenges. So power interruption greatly affects the organization's performance.

iii. There are increased costs involved due to power interruptions, risks involved to workers, machinery and equipment during power interruptions. These risks include dangerous fume emissions from different heat and chemical areas, acid stagnation in the process lines, fatigue due to failures, flying debris, etc. Power interruptions also affect the equipment depreciation rate, as a result of high torque during startups, seizure, frequent maintenance which causes fatigue and loss of morale to workers. These can lead to further cost implications to the organizations thus increasing decline of the organizations performance.

5.2 Recommendations

These are used to help the organization improve on their performance, which will lead to more profits thus economic benefits to government and fulfilling "Uganda's Vision 2040". These should be looked upon;

i. The most affected lines (Color Coating Line and Cold Galvanizing Line) need to have alternative power sources, or have delay stop motors to help always clear the line off (product) of what is being produced in case of any power interruption. The parameters for these lines need no interference from the set standard parameters in order to reduce the rate of rejection and continuous monitoring of parameters is a high prerequisite to ensure high quality products thus organizational performance.

ii. The organization should apply for a line free of load shedding and apply for tax levy due to the impact of the damage caused during power interruptions, due to more rejects experienced during power interruptions. These measures shall lead to reduced production losses, this will increase profits, and this will lead to better performance, which eventually gives better economic benefits thus meeting Uganda's vision of 2040.

iii. Further research on identifying alternative power sources for immediate clearing off the product on line especially at the critical areas. Also further research can be conducted on risk management and control measures for the safety of workers, machinery and equipment need to be assessed during power interruptions. This is due to the dangers fumes emit from different heat and chemical areas, acid stagnation in the process lines, fatigue due to un programmed (maintenances, production plans, reworks of products) failures, flying debris, etc..

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APPENDICES

Appendix A: ASTM Specifications of High Quality Zinc Coating on Steel

The pertinent ASTM Specifications of High-Quality Zinc Coating on Steel are presented in Table A. These are guidelines followed by the manufactures for conformity of the product(s) to required quality set standards of a galvanized item.

Table A1. ASTM Specifications of High Quality Coating in Steel

ASTM A123/A123M	Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153/A153M	Specification for Zinc Coating (Hot-Dip) on Iron and Hardware
ASTM A767/A767M	Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
ASTM A780	Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A143/A143M	Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
ASTM A384/A384M	Practice for Safeguarding Against Warpage and Distortion during Hot-Dip Galvanizing of Steel Assemblies
ASTM A385	Practice for Providing High-Quality Zinc Coatings (Hot-Dip)
ASTM B6	Specification for Zinc
ASTM B201	Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces
ASTM B960	Standard Specification for Prime Western Grade - Recycled (PWG-R) Zinc
ASTM D6386	Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Paint
ASTM D7803	Practice for Preparation of Zinc (Hot-Dip Galvanized) Coating Iron and Steel Product and Hardware Surfaces for Powder Coating
ASTM E376	Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Examination Methods

Appendix B: Different conditions of materials and products at Roofings Rolling Mill.

These show the various materials and products of the various processes both non-defective and the defective ones affected by the power interruptions. These results how power interruption affect the different section as shown by figures; B1 is for PPL; B2,B3, B4 are from internet; B5,B6,B7 are from CRM; B8,B9, B10, B11,B12 are for CGL.

Figure B-1 : The coiled rolls ready to be pickled (on site pictures)

Figure B-2 : Pickled coiled roll to be fluxed (Alibaba.com)

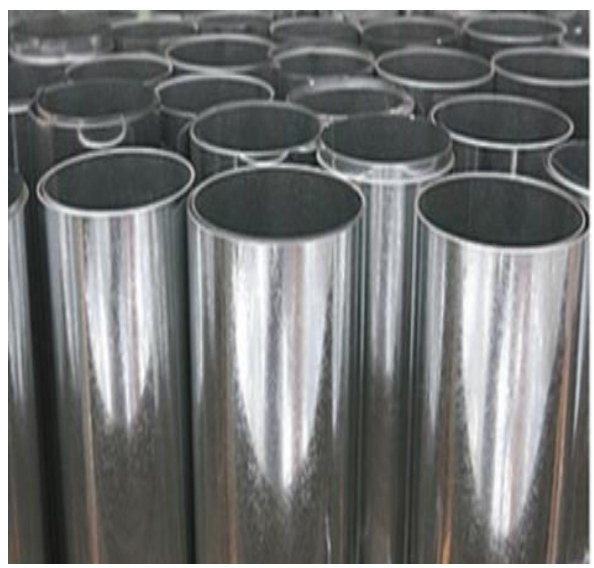

Figure B-3 : Galvanized rolls of sheet (Alibaba.com)

Figure B-4 : Galvanizing of the sheet in process- galvanizing bath (on site pictures)

Figure B-6 : Damaged roll of coiled sheet (edges)   (on site pictures)

Figure B-5 : Sheet Being Rolled (Alibaba. com

Figure B-7 ***: collapsed roll of coiled sheet (on site pictures*****)**

Figure B-8 : Coiled cut strips of sheet (rejects) (on site pictures)

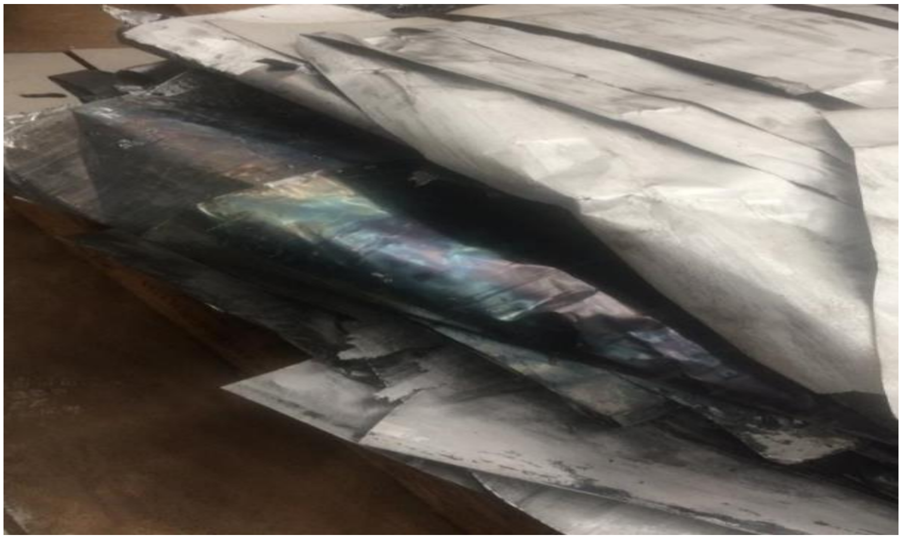

Figure B-9 : Damaged sheet (burnt) (on site pictures)

Figure B-10 : A heap of Scrap rejected sheet (on site pictures)

Figure B-11 : Damaged sheet (burnt and black spots) (on site pictures)

Figure B-12 : Rough Surface condition on the Sheet (on site pictures)

Figure B-13 : Torn galvanized sheet at the galvanizing bath (on site pictures)

Appendix C: Uganda end user Electricity tariffs 2018

THE ELECTRICITY END-USER RETAIL TARIFFS FOR THE FOURTH QUARTER 2018 AS SET AND ANNOUNCED BY ELECTRICITY REGULATORY AUTHORITY

UMEME
Powering Uganda

Umeme hereby informs its Esteemed Customers that on 04th October 2018, the Electricity Regulatory Authority notified us of the following End-User retail tariff rates for the period October to December 2018;

Customer Category	Time of Use	2018 Base Tariffs	Q3 2018 Tariffs	Quarterly Tariff Adjustment Factors Relative to the Base Tariffs Applicable for Q4 2018 Period: Inflation Adjustment Factor (IEAF)	Exchange Rate Adjustment Factor (FERFAF)	Fuel Adjustment Factor (FFAF)	Total Adjustment Factor	Resultant Retail Tariffs for Q4 2018	Average Percentage Movement relative to Q3 2018 Retail Tariffs
		shs/ kWh	shs/ kWh	shs/ kWh	shs/ kWh	shs/ kWh	shs/ kWh	shs/ kWh	shs/ kWh
Domestic Consumers - CODE 10.1 Low Voltage single phase supplied at 240 volts	First 15 kWh in a month	150.0	250	Not applicable	Not applicable	Not applicable	Not applicable	250.0	0%
	Above 15 kWh in a month	718.9	771.1	5.6	59.1	(14.1)	50.6	769.5	(0.2%)
Commercial Consumers - CODE 10.2 Three phase low voltage load not exceeding 80 Amperes supplied at 415 volts	Peak	639.6	678.1	2.8	42.5	(7.5)	37.8	677.4	(0.1%)
	Shoulder	446.3	485.0	2.8	42.5	(7.5)	37.8	484.1	
	Off- Peak	401.4	440.1	2.8	42.5	(7.5)	37.8	439.2	
	Average	448.3	487.0	2.8	42.5	(7.5)	37.8	486.1	
Medium Industrial Consumers - CODE 20 Low voltage supplied at 415 volts, with maximum demand up to 500kVA	Peak	746.2	769.0	3.2	27.2	(8.5)	21.9	768.1	(0.1%)
	Shoulder	589.8	612.6	3.2	27.2	(8.5)	21.9	611.7	
	Off- Peak	366.1	388.9	3.2	27.2	(8.5)	21.9	388.0	
	Average	592.5	615.3	3.2	27.2	(8.5)	21.9	614.4	
Large Industrial Consumers - CODE 30 High voltage 11000 volts or 33,000 volts with maximum demand exceeding 500 kVA but up to 1,500 kVA	Peak	497.1	505.4	1.5	13.4	(8.4)	6.5	503.6	(0.5%)
	Shoulder	382.6	390.9	1.5	13.4	(8.4)	6.5	389.1	
	Off- Peak	247.7	256.0	1.5	13.4	(8.4)	6.5	254.2	
	Average	375.5	383.8	1.5	13.4	(8.4)	6.5	382.0	
Extra Large Industrial Consumers - CODE 40 High voltage 11000 volts or 33,000 volts with maximum demand exceeding 1,500 kVA and dealing in manufacturing	Peak	491.8	491.8	1.4	(52.1)	(7.9)	(58.6)	433.2	(0.5%)
	Shoulder	378.5	321.5	1.4	(52.1)	(7.9)	(58.6)	319.9	
	Off- Peak	246.5	189.5	1.4	(52.1)	(7.9)	(58.6)	187.9	
	Average	371.1	314.1	1.4	(52.1)	(7.9)	(58.6)	312.5	
Street Lighting- CODE 50	Average	701.9	752.8	4.4	54.4	(8.5)	50.3	752.2	(0.1%)

Notes

1. The Electricity Regulatory Authority announced that the schedule of Electricity end-user retail tariffs shall be applicable to all consumer bills raised based on meter readings taken from October to December 2018 for customers on post paid billing system.
2. The Electricity end-user retail tariffs shall apply to electricity purchases made by our customers on the prepaid system in October to December 2018.
3. The first monthly 15 kWh for the domestic customers shall be charged at a life line tariff of UGX 250 per kWh.
4. Other charges such as fixed monthly charges, maximum demand charges, inspection fees, new connection charges, reconnection fees and penalties for power theft remain unchanged.
5. The Electricity end-user retail tariff shall apply to the estimated unbilled consumption resulting from either power theft or any instance leading to unbilled consumption from October to December 2018.

For customer service inquiries call 0800 285285 / 0800 385385 (Toll Free), 0312 185185 or email callcentre@umeme.co.ug, SMS to 8155, Website: www.umeme.co.ug or follow us on Umeme Limited @UmemeLtd 0772 285285

Figure C-1 : Umeme tariff rates used the customers

Appendix D: Glossary

Actual run time - time a line actually runs once external lost time and downtime have been subtracted.

Availability – it is a measure of the time an individual machine runs at capacity as a proportion of the time it could have run at capacity.

Capacity – is the best observed speed at which the machine is designed to run at a given time.

Coefficient of determination (r^2) - R-squared is always between 0 and 100%, 0% indicates that the model explains none of the variability of the response data around its mean, 100% indicates that the model explains all the variability of the response data around its mean.

Cold Galvanizing Line – at the organization this is the line where hot dip galvanizing is carried out from, but the word "Cold" is because the HRC sheet is rolled in a cold state for the galvanizing process.

Down time - this a time when a machine is not actively on production usually it's caused by a fault (a malfunction) of the machine or the attachments that aide the functioning of a given machine.

Era – is an electrical company that deals with the transmission and distribution of electric power (electricity) in Uganda.

Extra Ideal run - with no power interruption; there are programmes for maintenance and the production hours are 24 hours each day there are hours for other processes (machine startups, machine set up, machine resets, quality checks, etc.).

Machine Failure time – this is the time the machine is not working not due to a breakdown

Ideal run- with only power interruption; there is no programme for maintenance and the production hours are 24 hours each day there are no hours are for processes (machine startups, machine set up, machine resets, quality checks, etc.).

Machine process time (Mpt) - this is time during production that is allocated for machine startups. It includes machine set up, machine resets, quality checks, etc. usually it's not counted as down time.

Materials -are those unfinished items (*e. g. sheet metals that are not yet galvanized*) that are supposed to be used in the next process.

Power interruptions - is a time electric power disappears from a working or running line (the supply is fully cut off) due to supply interference.

Power outrages - is a very brief time electric power tends to flicker due to interference that could have happened during the supply.

Products- are the items (*e.g. galvanized sheets*) that have gone through significant processes or all stages of the production line.

Products online – the items that are being conveyed on the production line.

Rejects - are the number of units not accepted to go to the market for quality reasons during production, i.e. excluding unsaleable units produced during downtime.

True running - is a component rotating perfectly without warbling.

Appendix E: Check list

This tool was used for data collection during this study on the effect of power interruption on the production and quality on the galvanizing line.

No	Item to observe /check	comment
1.	The different stages and processes of galvanising practiced	
2.	The various processes / operations that are affected	
3.	Procedures of the quality checks conducted	
4.	The parameters that are monitored by the quality assurance	
5.	The critical parameters affected after the power interruption	
6.	Causes of defects and ways to reduce or eliminate	
7.	The impact of power interruption to the organisation and government	
8.	Records on power fluctuation frequencies	
9.	Check for the availability for research and development department to review and do comparisons of the available studies	
10.	Any available plans to sort out the effects of power fluctuations.	
11.	Other critical areas of concern	