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# OVERVIEW PRODUCTION PROCESS AND PROPERTIES OF GALVANIZED ROOFING SHEETS.

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## Abstract

In search for solution to the challenges posed by the degradation of roofing steel sheet in an aggressive environment, galvanization of steel sheet for roofing of buildings and manufacture of other Engineering structures has been a valuable remedy. Galvanization of steel in recent years has emerged as a physical barrier which minimizes the penetration of contamination of sulphide and chloride ion. Zinc coating of steel top surface is a strategy that has been found to be effective for wide range applications. Galvanized steel sheets have been widely used by various manufacturing company. Occasional switching from steel to other metal like aluminum have not been cost effective because of the present economically situation. This makes substituting galvanized steel difficult. This mini review provides insight to the production process, stages and properties of galvanized roofing steel sheet use in Nigeria and most part of Africa.

**Keywords:** Steel; Zinc; Coating; Galvanizing; Roofing.

## 1.0 Introduction

Prevention of Galvanized steel roofing sheet against degradation have become a ceaseless and intractable challenge of global interest. Deterioration of the sheet occurs naturally in an attempt to return their initial, stable, oxidized state. The magnitude and severity of the degradation of Galvanized steel roofing sheet is not only a function the material used but also its operating environment [1]. Global cost of replacement of roofing sheet in the developed and emerging economies is astronomical [2]. Galvanized steel sheet resist degradation by a sacrificing the topmost layer made of zinc so as to combat environmental degradations which could result in pitting of the surface [3]. Galvanized steel structures have been widely used for exterior constructions such as crash barriers, lamp poles, fences, buildings, facades, and roofs in the contemporary metropolitan society. The application of zinc on metallic surfaces had been carried out either by hot dipping or electroplating process [4]. Hot- dip galvanized steel sheet is produced on continuous zinc coating lines either by hot or cold rolling in coil form. The thickness of sheet produced from hot rolling ranges from 2.01 to 3.0mm while that of cold rolling ranges from 0.27 to 2.0mm [5].

By galvanizing, protection of the steel structures against corrosion resistance is improved by numerous degrees of magnitude; the corrosion protection achieved by zinc-based coatings is as a result of the galvanic effect, because zinc is anodic to iron which make it acts a sacrificial metal in an aqueous or humid environment [6], however, resistance to surface degeneration can be further enhanced by the incorporation of top coat on the galvanized surface [7]. Galvanized steel sheets are also known for excellent shiny surface and formability attributes besides satisfactory peel-off resistance and fusing of the coating completely to the steel surface [8].



Galvanized steel roofing is designed to serve for several years. Closed 50 % of the annual world zinc production which is about 3 million tons is utilized for the galvanizing steel so to minimize the corrosion rate of steel in a corrosive environment [9]. The Galvanization is the largest single use of zinc due the ability of zinc to form protective oxide and hydroxide layer that act as a barrier to environmental degradation. The presence of water usually increases the rate of corrosion, with the initiate corrosion product being zinc hydroxide which is further converted via the action of some air pollutants. However, it is very important to note that environments moisture penetrates unprotected zinc and expose the steel to white zinc corrosion, also known as “wet storage stain” or “white rust.” White rust is the result of electrolytic reaction which occurs within the steel sheets when water exists without oxygen. The red rust occurs when the zinc coating completely breaks off the back of the steel substrate. These challenges have continuously shortened the lifespan and also impact on the cost of replacement of the sheets [10].

Moreover, corrosion of galvanized steel sheet can occur via chemical or electrochemical reaction [11]. Destruction by electrochemical corrosion takes place via electrolyte action over the sheet metal. The conductive electrolyte solution such as saline or acidic solution can result in different forms of corrosion such as uniform, pitting or erosion of the zinc coated layer of the galvanized steel due to the passage of current from the anodic to the cathodic area. The fall of acidic rain on galvanized roofing sheet can be highly destructive. Acid rain is a product of the atmospheric reaction of Sulphur dioxide and nitrogen oxides with oxygen in the air to form sulphuric acid ( $H_2SO_4$ ) and nitric acid ( $HNO_3$ ) with pH of 5 or less, which falls on the roof as rain, snow or dust. Sulphur dioxide comes majorly from smelters and power plants use for coal burning. Flaring of gas, automobile exhaust and bush burning are the chief sources of atmospheric pollution that result in acid rain. Because an electrolyte is a requirement for corrosion, roofing sheets tend to corrode, wherever acid rainwater and/or condensation cannot flow off or becomes trapped [12]. However, Galvanized steel sheets can be corrosion free for a very long time if used in suitable environments. Galvanized roofing sheets can last for 15-18 years in rural regions and 3-8 years in areas of industrial locations especially in the Niger delta region of Nigeria [13, 14]. This is an indication that the galvanized sheets have greater service life compared to bare uncoated steel sheets. Weather resistance test has shown clearly that galvanized steel sheets are 5-30 times slower than that of steel sheets [15].

There are numerous applications that have necessitated the use of galvanized steel due to their formability. Although the major attraction for the choice of galvanized steel have been on the ground of corrosion resistance ability. However, zinc-coated steel sheets with better corrosion resistance with high degree of formability can be achieved if the processing parameters such as the zinc bath composition are controlled. [16] used the results of tensile test and simulated experiment to evaluate steel sheet formability. Two important parameters of the sheet; work hardening anisotropy and exponent coefficient can be determined using tensile test. These two parameters are criteria against these parameters thinning and necking during plastic deformation, respectively. More so, the study carried out by [17] provided an insight into the crack propagation and fracture behaviour of galvanized steel sheet. The initiation of Cracks in galvanized coatings were discovered to take place near the interface of the steel coating layer as a result of thermal stresses which eventually propagates towards the exterior layer of the

coating. However, the susceptibility of the galvanized coatings layer to crack propagation due to thermal stress can be minimized by increasing the coating thickness [18].

Generally, coating of steel substrate is commonly utilized to prevent degradation in contaminated atmosphere [19]. However, coatings of steel with only zinc have been discovered not to be as effective as the inorganic and organic coated galvanized steel sheet [20]. They were found to possess unique metallurgical features and better corrosion resistance in under a destructive weather condition. In the same vein, Galvalume coated steel sheets (steel coated with some percentage of Al-Zn) have also been to exhibit better mechanical and electrochemical properties [21] such as yield, tensile strengths, lower total elongation and corrosion resistance compared to galvanized steel sheets. Galvalume coated steel sheet was also discovered to retain its appearance at a higher temperature range compared to galvanized steel sheets [22]. More so, comparative study of corrosion behaviour of galvanized steel carried out by [23] revealed that galvanized steel roofing sheet failed in a simulated carbonate and chloride environments. This assertion and the work of other researchers instigate a search for better, alternative or improved roofing materials especially in industrial area where chloride or carbonate contamination is possible. Recently, the use of organically and inorganically coated galvanized steel products in a wide variety of industries has grown dramatically due to growing requirements on performance [24]. From the assertion made by [25] materials used for roofing required essential properties such as formability, good corrosion and high-quality appearance. However, environmental friendliness of material is becoming essential. Development of 55% Al-Zn alloy coated steel sheet with organic composite coating suppresses the progress of corrosion and surface cracks prominent with the roof made of zinc or Al-Zn coated steel sheet. The organic composite coatings instinctively form a protective film which was able to inhibit the triggered corrosion mechanism in the steel under severe condition such as acidic rain or presences of dissolved salt. More so, the mixture of a pigment of the phosphate type with a calcium-containing pigment produced considerable corrosion inhibition of galvanized steel in a somewhat acid medium [26].

## 2.0 Production Process of Galvanized Steel Roofing Sheet

Galvanized steel roofing sheet is produced by the continuous hot-dip coating process. During the production roofing sheet production, the molten zinc is applied to the surface of the steel substrate in a continuous process as shown in Fig.1 [27]. The coating of the steel is achieved by passing it through a bath of molten zinc at speeds of about 600 feet per minute in the form of a continuous ribbon. The thickness of the steel sheet ranges from 0.12mm to 0.55mm and width up to 1830mm. Generally, the continuous hot dip coating process starts with cleaning the steel with the use of alkaline liquid followed by rinsing and drying. The cleaned steel is conveyed into the annealing or heating furnace to make it softer and also impart formability and desired strength. The heating furnace steel is operated under a low gas atmosphere, consisting of nitrogen and hydrogen so as to enable the removal of traces of oxide that may be on the surface of the steel. Vacuum chamber known as 'Snout' is connected to the exit end of the furnace and to the molten zinc coating bath to avoid the re-oxidation of the heated steel product by air. In the zinc coating bath, the steel product is conveyed round about a submerge roll and reacts with the molten zinc metal so as to form the adhesive coating, and then withdrawn in a vertical direction. After the removal of the coated steel from the bath, any excess molten zinc is removed using high-pressure air to obtain a coating thickness that can be closely controlled. Finally, the steel is allowed to cool to enable the zinc coating solidify onto its surface. Solidification of

the molten metal before it makes contact with another roll is paramount to avoid damaging or deformation of the zinc coating [28, 29]

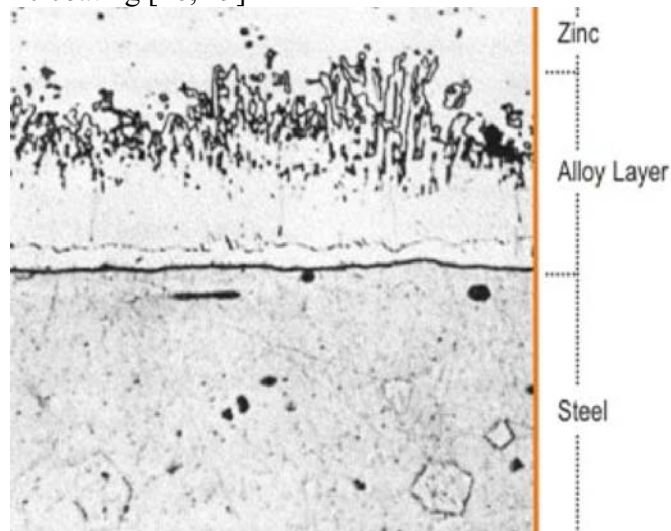


Figure. 1: Microstructure of a typical hot dip galvanized coating (Amazon, 2010)

### ***2.1. Stages of the production process of galvanized steel roofing sheet***

Production of galvanized steel roofing sheets can be classified into about six distinct stages. They are;

- **Welding process:** One continuous sheet is formed by welding the steel sheet ends that has been sheared to the preceding sheets.
- **Straightening process:** A high-performance tension leveler is employed to straighten the steel sheet. This will result to excellent flatness.
- **Cleaning process:** The steel sheet is cleaned in an alkali bath and brushed for initial degreasing so as to reduce surface oxides so as to achieve complete adhesion of coating. The sheet is then dipped in an acidic bath to activate.
- **Continuous annealing process:** This involves the reduction of the oxidized film on the surface of the steel sheet by passing it continuously through a reduction furnace.
- **Galvanizing process:** The sheet is left in a reduction atmosphere and immersed directly into a bath of molten zinc. The steel sheet is the rolled around a roller that is dipped into the coating bath and it is removed from the bath vertically by pulling. Removal of excess molten zinc using high-pressure air is carried out to obtain a coating thickness that can be closely controlled.
- **Chemical treatment process:** The coated zinc sheet is exposed to different chemical treatments in accordance to the desired use. The treatment includes phosphate treatment for excellent paintability, and chromate free special treatment for good corrosion resistance [30, 31].

## ***2.2. Forms of galvanised steel roofing sheet***

Galvanized steel roofing sheet is one of the most used roofs in homes, industries and commercial premises. Galvanized steel roofing sheet usually comes in different form of long run roofing such as trapezoidal, trough section/ concealed fix, corrugated. It also sometimes comes in the form of flat sheets, tile and shakes. The roofs are made up of mild steel coated with zinc. The long run roofing is normally fixed in place using lead-headed nails. [ 32, 33]

## ***2.3. Effect of Coating Thickness and Mass on Galvanized Steel Roofing Sheet***

Coating in continuous hot-dip coating process is carried out at a high speed and the thickness and mass of the coating is controlled by the process. Coating thickness is measured in  $g/m^2$  or microns. The degradation resisting ability of galvanized steel roofing sheet is a function of the coating thickness. For example, for any environmental conditions, a G90 coating will last longer than a G60 coating, maintenance, painting and all other factors being equal [34]. Where G means galvanized. Although, Higher coating thickness of galvanized steel results in better corrosion resistance [35], however, it can lead to low formability of the steel sheet. Hence, the coating thickness must be optimized to achieve a favourable combination of corrosion resistance and formability of sheet for the critical roofing applications [36, 37]. The thickness of the coating can be accurately measured by measuring stripped off from the steel substrate using measuring gauge. Other methods of determining the zinc coating thickness are via magnetic thickness Gauges, weighing before & after galvanizing and optical Microscopy (ASTM B 487). Coating weight or mass control consists in coating uniformly either transversely or longitudinally and transversely, both sides of the sheet with a specified zinc weight. The knife gap, knife gas pressure and line speed are the variable that affects the coating mass and thickness. This is because the weight or mass control is being applied at the knife strip which must be between the upper and the lower limit at any point on the strip in order to meet the standard requirement. Therefore, the coating mass should be optimized by the effective monitoring of the coating thickness [38, 39]

## ***2.4. Relationship the thickness, width, length, tensile strength and the mass of coating of the corrugated zinc***

The thickness of the coating is proportional to the coating mass. However, the length and width can be chosen base on the required specification and purpose. The thickness of hot dip galvanized coatings is determined by the thickness of the zinc-iron alloy layers that form when the steel reacts with the zinc. The alloy layer is usually 95% and 5% iron. Thicker galvanized coatings provide enhanced durability. The tensile strenght of the zinc coated layer increases with increase in thickness [40].

## ***2.5. Parameters that affect the appearance of Galvanized steel coatings***

Galvanized steel sheet is used for different application. However, different application requires specific appearance. Spangles (snowflake-like pattern is the common attribute of a galvanized surface. Zinc coatings with spangles are decorative coatings. The appearance of coating is a function of the substrate steel parameters such as; chemical composition of the steel, Surface conditions e.g. Surface defect or roughness (associated with rolling, and manufacturing)

processing properties, Temperature of the coating bath, Coating time and coating speed and Mechanical Behaviour of Galvanized Steel Roofing Sheet

Mechanical properties of galvanized steel roofing sheet describe their behaviour under the application of external [42]. The vital mechanical properties are:

- **Strength:** This is the resistance offered by the roofing sheet when an external load is applied. The strength of the roofing sheet is a function of its ability withstands external forces. The stress on the steel roofing sheet can be compressive, tensile, compressive, and tensional or shear.
- **Elasticity:** The galvanized steel roofing sheet should have the ability to return back to its initial position after undergoing deformation when the load is withdrawn. The elastic limit of the roofing sheet is the maximum stress it can withstand without permanent deformation.
- **Plasticity:** This is the ability of the steel sheet to deform permanently to some degree without rupture. Plastic deformation occurs when the elastic limit is exceeded. Generally, plasticity level rises with increasing temperature. Plasticity is one of the material properties to consider during the secondary forming processes. Plasticity enables the transformation of the galvanized steel sheet into different product of desired shape and sizes via the application of heat, pressure or combination of heat and pressure [43].
- **Ductility:** This is the property that enables drawing of the steel on the application of load or force. The base metal of galvanized steel roofing sheet is mild steel which is known to be ductile which enables drawing by extrusion or pulling through hole in a prepared die. The ductility of the steel sheet decreases with increase in temperature. Elongation and reduction are the key measuring parameter for ductility [44].
- **Malleability:** Malleability is the flattening ability of the steel into sheet without crack propagation during the cold and hot working process. Malleability is a compressive property while ductility is a tensile property. Malleability of a material increases with a rise in temperature [45].
- **Brittleness:** The brittleness of the steel sheet is its ability to break without permanent distortion. The mild steel base of the galvanized sheet is less brittle this enables it not to break after much deformation unlike glasses and cast iron[46].
- **Toughness:** This is the steel sheets ability to resist elastic and plastic deformations. It galvanized steel sheet exhibits sizable degree of toughness due to the presence of some trace alloy elements. The amount of energy the galvanized roofing steel sheet can absorb before fracture is its toughness [47].

### **3.0 Prediction of Mechanical Properties of Galvanized Steel Sheet from Literature**

Mechanical properties of steel sheet or coil can be predicted before the galvanizing process so as to produce of galvanized steel sheet or coil that suitable for the customer's use. This will at the same time minimize wastage of materials. [48] carried out a comparative examination of mechanical properties of different steel coils before been galvanized. The authors evaluated the models established via linear and non-linear, bagging and other construction techniques. The author made predictions using a total of 30models; predictions were arrived at for each parameter so as get meaningful information about the capacity of these models and techniques. The author tested each of the models against each data several times and also constructed model

to ascertain the steel grades relevance and recommend model for each parameter. [49] predicted the mechanical characteristics of galvanized steel sheet, utilizing data mining techniques such as neural network, support vector machine, regression analysis and regression tree methods. The use of a neural network technique was found to produce the best result in the prediction of the mechanical properties of galvanized steel. The prediction was achieved by collecting relevant information about the chemical compositions, thickness and width of sheets, strip speeds and annealing temperatures via the predictive models, such that when a sheet is to be produced in a galvanizing line, all of the uncontrollable parameters and temperature and speed as controllable parameters will be inputted to the model and obtain the precise results. Finally, by varying the controllable parameters, the best value for them will be established before commencing the production [50].

The galvanized steel sheets may be referred to as a composite made of a metallic coating link to the steel substrate by an intermetallic phase that is brittle in nature. Micro cracks are generated during the forming operation which is found between the Zn-coating and the intermetallic phase. Generally, the cracks within the grains of pure zinc coatings are found to be parallel to one another. Careful observations have shown that the zinc crystals exhibit predominant anisotropic deformation [51].

#### 4.0 Conclusion

Galvanized steel has been found to be effective for wide range applications in various manufacturing company. Galvanized steel roofing sheet which have in several years been produced by the continuous hot-dip coating process as a result of the flexibility of the techniques is still very much in vogue. The choice of Galvanized roofing sheet is borne out of its ruggedness and longevity. Ungalvanized steel will corrode within a short period of time which will directly or indirectly affect the economy of a nation.

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