

Chapter 11

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THE INSTRUMENT OF DEVELOPMENT IN THE ZINC PLATING TECHNOLOGIES MANAGEMENT

Abstract: The chapter includes theoretical contents, the technology of development and technologies management in practice on the example of a research object. The first part of the chapter includes information concerning the available technologies of metal products zinc plating. The next fragment of the chapter concerns the characteristics of the instrument of improving the production processes, followed by demonstrating its practical use in metallurgical industry, in relation to production of galvanized wire. The last part of the chapter contains the comparison of popular zinc plating methods.

Key words: galvanized wire, instruments of development of production process.

11.1. Theoretical basis

Zinc occurs in nature as a micronutrient necessary for living organisms, because is responsible for appropriate functioning of, e.g. sight sense, or immune system. Besides, zinc is contained in drugs, car tires, paint pigments (www.cynkowanie.com.pl).

The process of zinc plating is whole operations aiming at covering the surface of steel with a thin layer of zinc. It is commonly used in car, building and aviation industries. Zinc coating, in the city, corrosive environment, shows from a few to several times higher corrosion resistance than non-galvanized steel. The reason is the fact that standard potential of zinc is much more electronegative than the potential of iron. Zinc corrodes in the first place, and the products of this process will slow

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down the further corrosion. In case of breaking zinc coating tightness, it will still protect the base material from corrosion.

In the literature two the most famous types of zinc plating can be distinguished (www.portal-cynkowniczy.pl):

- hot dip galvanization,
- electrogalvanizing (electrolytic galvanizing).

The forefront of many applications of zinc coatings is protecting steel from corrosion by hot-dip galvanizing. The origins of this process dates back to the eighteenth century, when the French chemist Malouin found silver coating on the steel element immersed in liquid zinc. Today, the process of galvanizing is conducted in galvanizing plants of high quality standards, and consists of a number of preliminary steps (I – V), preceding a direct dipping of clean surface steel element in a zinc bath (VI), resulting with forming a mechanically stable and impermeable layer protecting against corrosion.

I. Abrasive blasting

The first step of the process is mechanical removal of contamination adhering to a surface of a steel, i.e. sand, rust, scale, slag or residues of old coating, by using of abrasive metal materials in a closed circuit. During the processing a stream of compressed air enriched with abrasive material (i.e. cast steel, cast iron, grain cut from steel wire) is directed to the surface subjected to mechanical cleaning. Depending on the type of abrasive material used, and the speed at which it hits an object, the effect of smoothing, curing, heating, deformation, or strengthening the surface structure may be obtained. Another example of small size steel elements preparation to covering by the zinc layer is vibro-abrasive machining. The term is used to describe mechanical smoothing or polishing a surface, removing the product of gas corrosion and rust. These processes are carried out in vibration temper mills, in wet conditions, with chemical additives, abrasives and synthetic resins of different shapes and attrition efficiency. A specific form of abrasive machining is tumbling; wherein the impact of abrasive material on a steel surface takes place in a mixing device while the rotation of the drum.

II. Degreasing

In the process of hot- dip galvanizing an extremely important role is played by chemical cleaning of steel surfaces. Steel components, before immersing in a zinc bath, shall be free from grease, oil and waxy substances which preclude the reaction of iron with zinc. The degreasing step is aimed to obtaining a chemically clean surface, on which the alloy of steel with zinc will be formed. A number of inorganic solutions of alkaline, of acidic and neutral reaction have cleaning and degreasing properties.

The process of degreasing has makes a significant contribution to:

- reducing the duration of the next phase of the process (etching)
- reducing the level of pollution of the etching bath,
- reducing of the costs and labor inputs,
- limiting the consumption of hydrochloric acid, flux and zinc.

III. Etching of the surface

The third stage of zinc plating allows to efficient removing of non-metallic substances (i.e. rust, scale and other corrosion products) formed during rolling and annealing of construction elements. The most popular method of etching is the bath in hydrochloric acid. In exceptional cases, when the removal of sand from cast iron components by etching in hydrochloric acid does not produce the expected results, a solution of hydrofluoric acid, or a mixture of acids can be used.

IV. Fluxing

This step consists of immersing the steel components in an aqueous solution of zinc chloride and ammonium chloride ($ZnCl_2/NH_4Cl$), in order to ensure proper chemical reactions that occur during the zinc plating. In the dry method, ammonium chloride is 15% of solution; in wet method, salts are present in a ratio of 1:3. The task of fluxes is to clean the steel surfaces from trace amounts of oxides, what effectively minimizes the risk of oxidation of the steel before it is introducing it into the liquid zinc bath.

V. Drying

After processing in the fluxing bath, steel components are subjected to drying at 120 ° C - 150 ° C. It is a step requiring high precision and extreme care. It is important to control the temperature of the system permanently. A sudden change of thermal conditions may cause inflammation of the chemicals included in the flux and contribute to reducing the effectiveness of processing. Drying should be carried out quickly and efficiently to prevent the etching of iron and formation of iron compounds which adversely affect processes with the participation of fluxes.

VI. Zinc plating

The last stage of zinc plating process consists in immersing the formerly prepared steel substrate in a bath of molten zinc at a temperature of 445 ° C - 455 ° C. Under these conditions, zinc and iron undergo very a fast chemical reaction which reduces time of immersion steel surfaces in liquid zinc to several minutes. By diffusion, so the permeation of zinc atoms into the outer layer of steel, a surface iron-zinc alloy, containing a different ratio of the two components is formed. The outer layer of the coating reflects a composition of galvanizing bath used in the process. Fire zinc coating after cooling in water is characterized by high mechanical resistance and aesthetic appeal. The chemical composition of steel, especially the content of carbon, silicon and phosphorus determines the smoothness, gloss and adhesion fire zinc coatings. The thickness of the protective layer applied to the steel structures in the process of hot-dip galvanizing is specified in PN-EN ISO 1461 norm. The final product of hot- dip galvanization is multi-layer protective coating, as shown in Fig. 11.1.

The outermost layer (so-called Gamma- 1 Layer) is formed by of Fe and Zn, in which the iron constitutes its 25%. The thickness of this layer is about 1 µm. Below there is a Delta- 2 Layer. The iron content in the sub- layer reaches 10%. The next is a Zeta – 3 Layer, wherein the proportion of iron is the lowest. A layer existing directly at the steel surface is almost pure zinc- 4.

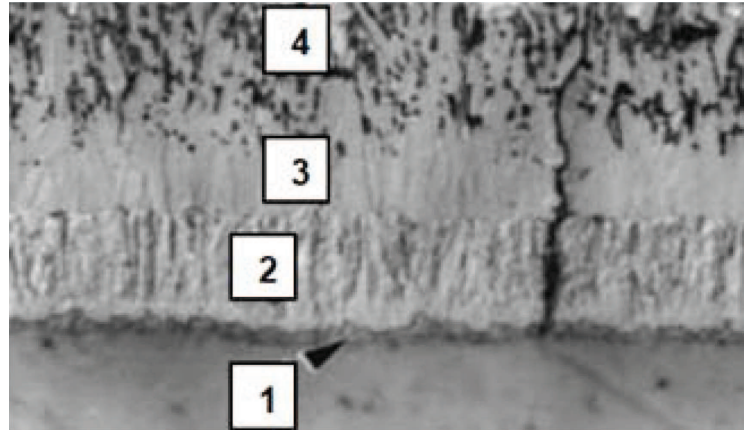


Fig. 11.1. *The microstructure of the coating after galvanizing.*

Source: own study

The minimum thickness of zinc coating is calculated basing on the following data:

- thickness of galvanized steel,
- residence time of the feedstock in the zinc bath,
- silicon and phosphorus contents in the zinc material.

Electrolytic coatings are being applied in the process of electrolysis on a conductive substrate. The metal products which are properly cleaned, degreased and free from oxide layer, designed for coating are immersed in an electrolyte solution containing ions of the metal coating. During the flow of direct current through the electrolyte, metal ions move toward the coated substrate (cathode) and secrete on it, forming the coating.

The galvanization technology consists of three phases:

- preparation of the substrate surface,
- electrolytic imposing of the shell,
- finishing processing.

Galvanic coatings require very careful preparation of the metal substrate surface to electrolysis, i.e. mechanical cleaning, degreasing,

etching and pickling, carried out immediately before coating in order to remove the oxide layer.

Between subsequent operations of preparing the object, a washing process shall be performed, in order to prevent transmission of individual baths components.

Items for the galvanic plating shall be completely finished in terms of machining and shall possess the correct size and the required degree of smoothness of the surface and edges.

11.2. The instrument of development- 5x why method?

In order to identifying the sources of emergence of problems in an enterprise, a method “5x why?” is helpful, because, as an integral part of Kaizen through an appropriate set of five questions "why?" it strives to development. The detection of the root cause of the problem takes place after a few responses already (BORKOWSKI S., ULEWICZ R. 2009).

11.3. Galvanizing technologies management

The tested X company is located in central Poland and is engaged in manufacturing wires, nails, wire products and conducts third-party services in the field of rolled metal surface treatment and zinc plating of small- size components, i.e.:

- zinc plating in the process of electrolytic deposition of zinc chromate coating; colors available: white, blue, yellow. Thickness of the coating is made according to the standard or adapted to the customer’s needs. The electrolytic process in the weakly acidic bath is performed on an automated drum line. 7500 kg of small- size components are produced within 24 hours.
- zinc plating in the process of mechanical imposing of zinc coating. Nominal coating thickness of 40-100 µm. 6000- 8500 kg of small-size elements are produced within 24 hours.

The company's tested product is soft galvanized wire with the symbol "Na" 3.0, which meets the requirements of PN-67/M-80026 norm and standards related to it, having a circular cross-section with a diameter of 3 mm ($T = 0.11$), made of general purpose low-alloy steel. Technology for producing such a wire is cold drawn from a rolled metal having a diameter of 6 mm. Thickness of zinc coating of wire is determined by Keller- Bohack method, and for the type in question it shall be 70 g/m^2 . The galvanized wire surface *per se* shall be smooth, without uncovered places.

In the steel wire production process it is necessary to impose a metal coating, in case of which zinc is the most commonly used material. It stays the first place among the most durable anticorrosion protections. Zinc coating wires are subjected to a program of research contained in the objective standards, which include the determination of:

- weight of protective covering,
- thickness of the zinc coating,
- its adhesion to the steel substrate,
- the protective ability against corrosion,
- continuity and uniformity of the coating.

Figure 11.2 shows the graphical application of the “5 x why?” method, by demonstrating the main problem of the company: crossing the deviation diameter of galvanized wire. The analysis indicates the primary cause of the problem- inadequate interpretation of the documentation. It turned out that in order to eliminate it, the staff training in the requirements of PN-67/M-80026 norm is necessary. Furthermore, additional staff trainings can be performed, and adequate work instructions can be provided.

What is the problem?

Exceeded deviations diameter of Zn galvanized wire



Why?

Bad service machines DRAWING



Why?

*Operator exchanges the drawing die inadequate in terms
of dimensional*



Why?

Operator does not verify a proper drawing die



Why?

Problem with drawing exchangeable parts identification machine



Why?

Document incorrect identification

Fig. 11.2. Application of the method 5 × why for the problem of crossing the tolerances in diameter galvanized wire.

Source: own interpretation based on the materials from the company

The comparison of zinc plating technologies shows that covering with zinc is not possible without pre-treatment in case of both zinc

plating technologies. Figure 11.3 shows the surfaces of components after the zinc plating process in accordance to two different technologies.



Fig. 11.3. Comparison of methods zinc by using samples after 1500h of salt spray.

Source: http://www.cynkowanie.com/JET_termodyfuzja.pdf

The hot- dip galvanizing provides a thicker protective layer of steel product (better protection against corrosive agents), but at the expense of covering accuracy; unlike in the case of electrolytic zinc coating. Electrolytically galvanized products have a relatively thin layer of zinc, and therefore they are characterized by a nice and smooth finished surface appearance. This method is perfectly suited for small-sized products.

11.4. Summary

In terms of zinc plating technologies management, an instrument of developing called “5x why?” can be used.

The analysis concludes that staff trainings should be carried out, and appropriate work instructions should be provided to the personnel, in order to appropriate interpretation of work documents. Improving the production process of galvanized wire involves the use of certain measures at the respective stages of the process.

Bibliography

1. BORKOWSKI S., ULEWICZ R. 2009. *Instrumenty doskonalenia procesów produkcyjnych*. Wydawnictwo PTM. Warszawa.
2. GOLIS B., PILARCZYK J.W., BŁAŻEJOWSKI Z. 2003. *Druty stalowe*. Wydawnictwo Wydziału Inżynierii Procesowej, Materiałowej i Fizyki Stosowanej. Częstochowa.
3. Materiały udostępnione przez badane przedsiębiorstwo.
4. Norma PN-67/M-80026.
5. Strona internetowa: www.metalurgia.pl z dnia 21.10.2013.
6. Strona internetowa: www.portal-cynkowniczy.pl z dnia 21.10.2013.
7. Strona internetowa: www.ocynkownia-ogniowa.pl z dnia 21.10.2013.
8. Strona internetowa: www.pg.gda.pl/~kkrzysztskrypt.html z dnia 21.10.2013.
9. Strona internetowa: www.cynkowanie.com/JET_termodyfuzja.pdf z dnia 21.10.2013.