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THE GALVANIZING

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***Abstract**: This paper addresses some aspects of the process of wire galvanizing, with an emphasis on their zinc coating treatment. After producing wire by cold or hot drawing, the resulting structure consists of highly elongated crystals forming on the main direction. This structure influences the quality of deposited zinc layer and also the adhesion to the base material. In this case, the patent is strictly required for wire diameters up to 8-9 mm, because changing the crystalline structure helps to a much better grip of the coated zinc on the superficial layer, to the steel.*

***Key words:** galvanizing, patent, wires, tensions, corrosion.*

1. Introduction

In the past 50 years, about 1400 million tons of ferrous materials were scrapped due to corrosion, with an annual average of 28 million tons. By corrosion and wear annually lost about 4.5 % of gross social product.

It is estimated that in industrialized countries, the cost of corrosion is of order of 1-3 % of gross national product (GNP).

The most used and also the most economic method of long term corrosion protection for wires and cables is galvanizing.[1]

Following information provided by the International Association of Galvanizers, over 11 million tons of zinc are produced annually worldwide. Almost 50 % of this amount is used for galvanic protection of steel parts. Approximately 19 % is used to produce brass, 16 % is used in foundries to produce zinc alloys.[2]

2. Wire Galvanizing

Galvanizing is the process by which steel or iron products are protected from corrosion by a layer of zinc, formed by their immersion in a bath of molten zinc at a temperature of 450 ^{0}C.

Zinc layers can be obtained by diffusion (formation of intermetallic compounds with very good adhesion) and deposit (in which case a metallurgic link between zinc and steel is not formed, resulting in low adhesion).

Continuous Galvanizing is the process of applying zinc coating to the wires (SR EN 10244-2:2009) which are immersed in molten zinc through automated process.

Galvanized wire has many uses, from which we mention weaving, which is used in construction and cables, which are used in mining industry and in complex lifting-lowering systems.

Fig. 1. Steel cable formed by galvanized wire. [8]

Apart from using compatible galvanized steel, there are no mandatory requirements to be met for the design and manufacture of finished wire products. However bear in mind that some wires retain their mechanical properties only by cold working. Using an improperly steel with considerable cold working can result in fragility of the wire finished products (also called hardening fatigue), which is sometimes observed only after galvanizing.

Continuous steel wire galvanizing is made in precise and controlled manufacturing conditions, in which wires are coated with thermal zinc using high-speed production lines that controls not only coating quality but also the strength and firmness of steel products.

In continuous galvanizing, laminated steel roles are continuous rolled through cleaning and annealing baths before entering the molten zinc bath. Feeding speed is 200 m/min. As wires come out from the molten zinc bath, it contains an excess of zinc which, by various methods, can be thinned or removed to the desired thickness. Most wire galvanizing lines use steam, hot air or another gas (nitrogen) method. Steel wire then undergoes a series of mechanical or chemical treatments.[3]

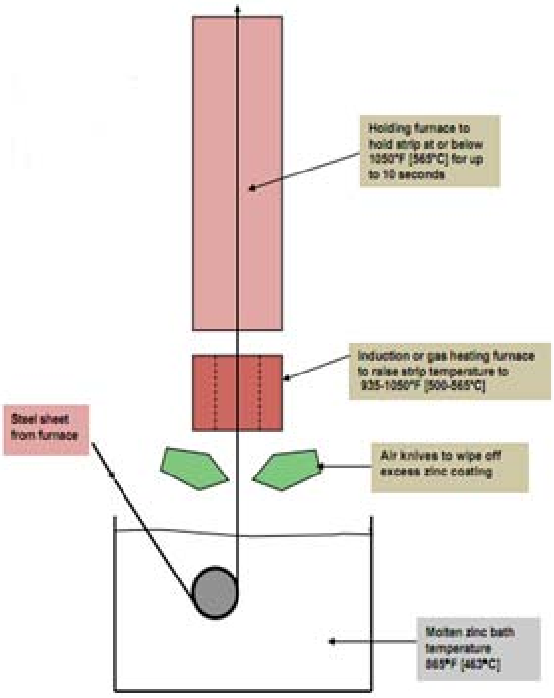

Fig. 2. The galvannealing process [9]

Coating lines use induction galvanneal furnaces. Typically they have 3 or more zones, which can reheat the strip from about 463 ^{0}C to as high as 565 ^{0}C in the few seconds available.

Following the heating furnace zones the electrically heated holding zone is used to optimize the iron content of the coating. Older galvanneal coating lines use gas-fired furnaces, with which it can be more difficult to obtain a well-controlled alloying reaction. Induction galvannealing is inherently different than the gas-fired convection/radiation version since, with the former, the heat for diffusion comes from within the strip, not externally as with the latter process.

The reactions that convert a liquid zinc coating to a solid zinc-iron coating begin at the steel interface and are dependent on a number of factors. In approximate order of importance they are: heating time and temperature, percent aluminum in the coating, coating bath temperature, steel grade, coating weight, and line speed. These variables are not all necessarily independent, and each coating line has to determine the necessary protocol to produce a product for a particular end use. For instance, a higher aluminum in the coating requires a higher reheating temperature and/or a longer soak time. Too high a temperature and/or too low an aluminum will result in high iron and excess powdering.

Stabilized IF grades reacts faster and plain carbon steels. Steels with higher phosphorous levels react slower in the galvannealing furnace than low phosphorous steels. [9]

Besides the benefit of a corrosion protection system of finished products from wire, galvanizing of these products confers rigidity also because the twine stability is amplified further as a result of solidification of zinc layer in areas where wires overlap.[3].

3. Stress and Strain in the Galvanizing Process

Generally, deformation of parts, is a result of uneven distribution of residual stresses (mechanical, thermal, structural). Wire deformation during zinc coating is caused by relaxation of residual stresses at the time of their heating at galvanized temperature.

During thermal zinc coating wires/cables can distort and alter the shape and dimensions.

The main factors that cause deformation are: the quality of steel used (coefficient of thermal expansion, elastic modulus, yield point σ_0), size, distribution and direction of residual stresses at the time of the galvanizing bath, the shape and dimensions of the product, galvanizing operation parameters, thermal stresses arising during zinc coating etc.

At galvanizing temperature, yielding point σ_c is reduced almost by half from its value at ambient. Elastic modulus also changes with temperature. For steel, the value drops from 215 N/mm^2 at ambient temperature, to 170 N/mm^2 at 140 ^{0}C.

Because residual stresses (σ_{rem}) are accompanied by local elastic deformation, their size is determined by:

$$\sigma_{rem} = E \cdot \varepsilon_{rem} \qquad (1)$$

in which:
E = longitudinal elasticity;
ε_{rem} = relative residual elastic deformation.

Residual stresses my not exceed – as size - yield stress:

$$\sigma_{rem} \leq \sigma_c, \qquad (2)$$

as by overcome this limit, in the specific part a permanent plastic deformation arises: [2].

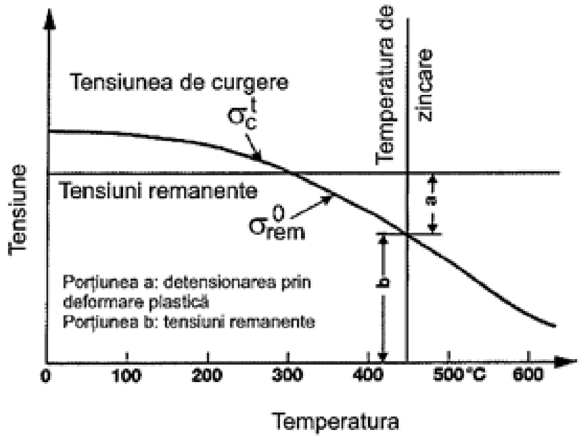

Fig. 3. Steel Elasticity variation limit scheme with increasing temperature and stresses that lead to deformation

Figure 3 exemplifies that at a temperature of 450 ^{0}C, yielding point is less than residual strain and as a result, the products will deform; so on the section "a" a discharge of strains by plastic flow (deformation) occurs.

Deformations can be reduced by minimizing residual stresses from previous wire processing, such as wire drawing.

2-6 mm thick wires are likely to deform, so an increase attention is given both to the galvanizing bath temperature and speed of movement of the wire through zinc bath.

For these reasons, the problem of the emergence and manifestation of stress in castings preoccupied and concerned up to the day many producers of castings and researches in this area.

To get a better grip of zinc layer to the surface of the wire, it is recommended that wires with diameter of 8-9 mm to be subjected to patent thermic treatment. This operation is performed before galvanizing and preliminary and/or intermediate to the wire drawing [5].

4. Wire patent

Wire patent is made is achieved by continuous flow and consist in heating the wires in wire held, followed by their isothermal cooling in molten lead bath.

Steel wires which are suitable for patent are those containing more than 0.35-0.4 % carbon and crystalline structure composed of highly elongated crystals resulted from the process of wire drawing or pulling.

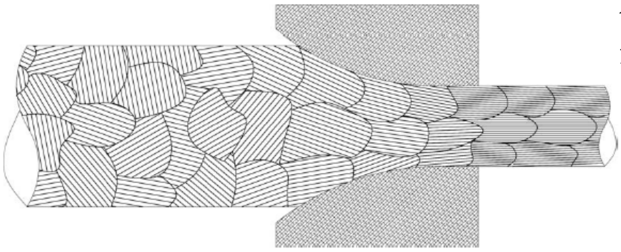

Fig. 4. Schematic representation of deformation in the pearlite colonies in wire drawing.[6]

For patent wires, continuous flow paten installations are used. They made both patent and surface preparation for drawing wire. Typically, these facilities consist of four main areas: coils dispensers and envelopes, heating furnace with lead bath for isothermal hardening, acid cleaning and under pressure water cooling tanks with phosphate and whitewashed tanks and drying area consisting of under pressure hot air ovens.

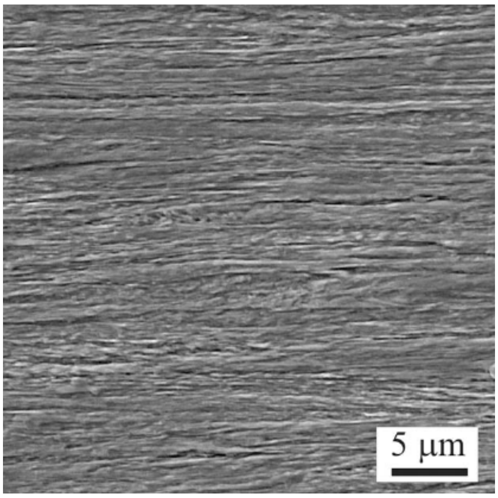

Fig. 5. Longitudinal section in a patented steel wire. [6]

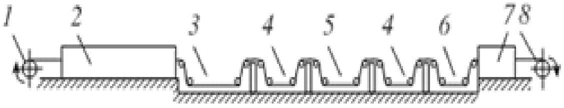

Fig. 6. Wire patent installation scheme. [4] Unit for patenting in lead (salt) melt: (1) drum from which wire is unwound; (2) heating furnace; (3) bath with lead melt (salt); (4) washing bath; (5) etching bath; (6) bath for applying lubricant substrate layer; (7) dryer; (8) drum on which wire is wound.

An important role in the treatment of patenting wires is held by austenitisation temperature, which in practice is determined by formula:

$$T_A = 1000 - 233,3 \cdot C \qquad (3)$$

in which:

T_A = austenitisation temperature, [^{0}C];

C = carbon content of the wire, [%].

To achieve austenitisation of the entire section of the wire, it must be maintained a certain period in the austenitisation furnace.

For heating to lead to a homogenous cross-section wire structure, it is recommended that from the total heating time, the largest share, about 70 %, to be used for equalization (to maintain the prescribed temperature heating) and only the remaining 30 % to be used for heating to the prescribed temperature.

Depending on the oven, keeping time of the wire in the furnace (wire speed) can be calculated using the following relations:

- radiation oven:

$$v_p = \frac{0,9 \cdot L_T}{\tau_{inc}}, [m/min] \qquad (4)$$

in which:

v_p =patenting speed, [m/min];

L_T =oven total length, [m];

τ_{inc} =heating time,[min];

$\tau_{inc} = (0,36 - 0,60) \cdot \Phi$,[min], Φ, [mm];

multiplication factor of the diameter which is chosen as follows:

0,36 for Φ =2,2 mm,

0,40 for Φ =2,5-3,5 mm,

0,45 for Φ = 3,8-4,5 mm,

0,50 for Φ = 4,8-5,5mm,

0,55 for Φ = 6-8 mm,

0,60 for Φ = 8,5-14 mm.

- radiation and forced convection ovens:

$$k = v \cdot d, \left[\frac{m \cdot mm}{min}\right] \qquad (5)$$

in which:

k = is the characteristic of the oven and depends on the length and diameter of the wire (information can be found in the oven documentation), [mm/min];
v = wire speed, [m/min];
d = wire diameter, [mm];

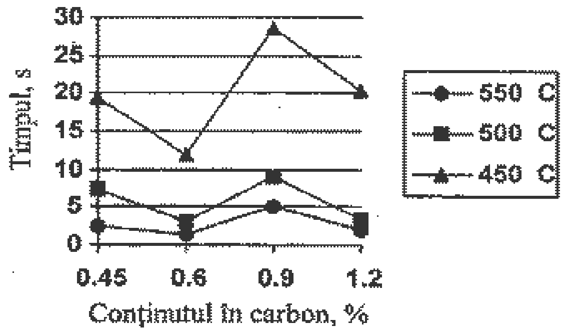

Fig. 7. Patent time variation depending on carbon content and temperature

Due to presence of residual elements in steel, as well as patenting outside the optimum temperature zone, the required duration for transformation also increases. For this reason it is recommended that the minimum value to be not less than 15s, regardless of the wire diameter.[5]

5. Conclusions

It highlights the importance of thermal treatment prior to wire galvanization process.

It defines and presents the galvanizing process, its importance and the existence of crystalline structures of steel, required to achieve good adhesion between zinc layer and layer of steel wire.

Article includes a summary classification of tensions and deformations that occur in the process of galvanizing and the mail factors that cause deformation. Also in this section is presented schematically the relationship between the temperature at which steel wire is subjected during zinc coating and residual stresses arising in wire. With increasing in galvanizing temperature, there is a decrease in residual stresses (stress relief).

It analyzes the heat treatment of wire patent, concluding that for smaller wire diameters of 9-10 mm, this treatment is necessary prior to galvanizing process. Finally, great importance should be given to patent process parameters:

- austenitisation temperature which is strictly related to the type of furnace and which depends on the carbon content of the wire.
- time-keeping or wire speed through the oven, which is dependent on the nature of the oven (length, type of heating) and also on the diameter of the steel wire.
- patent temperature is also an important feature of the patent process, choosing a wrong patent temperature can lead to the formation of metallographic structures and to poor mechanical properties, improper to galvanizing process. Patenting temperature must be between 420 ^{0}C and 590 ^{0}C.
- patent duration is dependent on the carbon content of steel and temperature and it is recommended that the minimum amount to be not less than 15s regardless of the wire diameter. Galvanizing process remains the most widely used method of corrosion protection of steel and cast iron. If prior to zinc coating, the treatments are correctly performed, then on the long term galvanization will prove itself to be the most economic anti-corrosion protection method.

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ZINCAREA

Rezumat: Această lucrare abordează unele aspecte ale procesului de zincare a sârmelor, punând accent asupra tratamentului de acoperire cu zinc. După obținerea sârmei prin trefilare la rece sau la cald, structura rezultată este reprezentată de cristale alungite care se formează pe direcția principală. Această structură influențează calitatea stratului de zinc depus și de asemenea, aderența zincului la materialul de bază.

În acest caz, patentarea sârmelor este strict necesară pentru diametre de până la 8-9 mm, deoarece schimbarea structurii cristaline ajută la o aderență mult mai bună a stratului superficial de zinc la stratul de baza din oțel.

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