INFLUENCE OF PROCESSING SPEED ON HIGH CARBON STEEL WIRE GALVANIZED WEIGHT AND MECHANICAL PROPERTIES

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Abstract

The zinc coating both increases the corrosion resistance and lubricated to minimize the friction for subsequent diameter reduction steps. The course of the reaction between the steel surface and the molten zinc depends upon the formation and growth of the iron-zinc alloy layers. The type and quantity of zinc coating layer produced depends on many factors particularly, immersion time, zinc temperature, steel wire composition, zinc composition and condition of the wire surface. PChange of the processing speed is an important factor as it will affect both the galvanizing time and the wiping of the coating. The as-fabricated galvanized steel wire needs to pass a number of quality tests before going on the market, concerning mechanical and corrosion properties. This paper presents data obtained from trials and production records on the effects of hot dip galvanising on wire properties. In this study, mechanical properties(tensile, elongation) and microstructure of alloy layer for different process speeds on wt. % 0.83 carbon wires at 3.20 mm diameter were investigated..

Keywords: Hot-dip galvanizing, high carbon steel wire, coating weight, mechanical properties

1. INTRODUCTION

The galvanized coatings are used in applications such as the automotive and whiteware industry, which are particularly required for corrosion resistance. Hot dip galvanising produces a coating that consists of an iron-zinc intermetallic alloy layer and a free zinc layer [1,2]. The alloy layer is formed in the zinc bath by the reaction between the steel and the molten zinc and the coating thickness depends upon immersion time, zinc temperature and, to a lesser extent, steel silicon content [3,7]. The free zinc layer has the same composition as the zinc in the bath and the thickness depends on the processing speed and to a lesser extent, the wire or rod diameter.

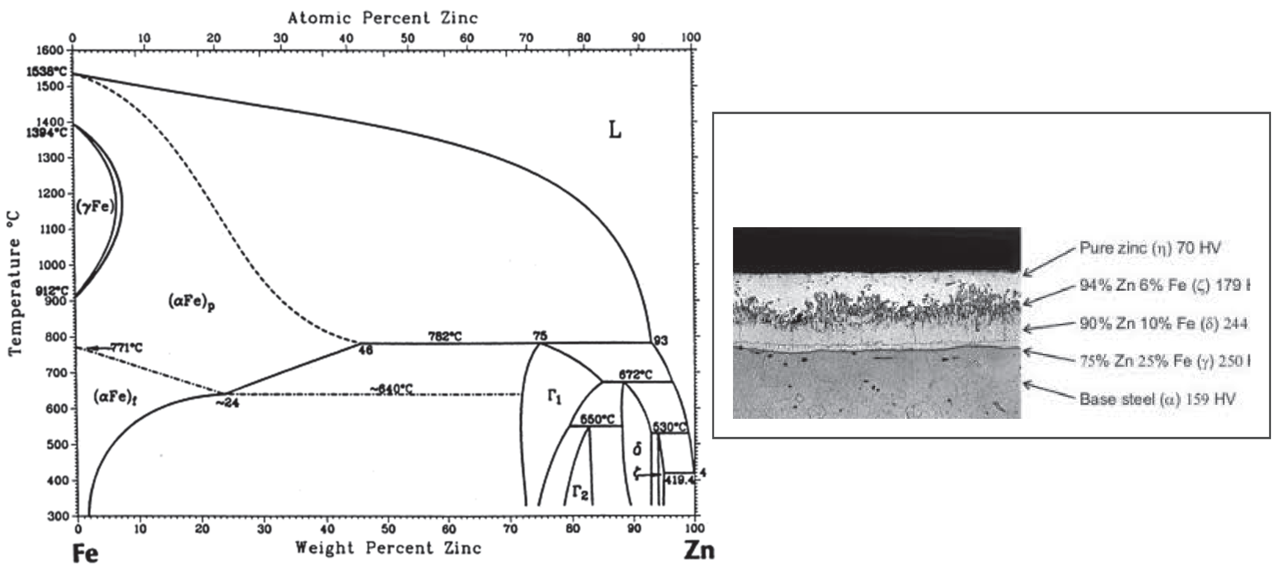


Figure 1a Fe-Zn binary phase diagram **b.** layer of galvanize coating [1]

The iron - zinc equilibrium diagram (**Figure 1-a**) shows that there are three intermetallic compounds that can form during galvanising, all in the zinc rich region. The gamma phase (ɣ) has composition corresponding to $FeZn_3$ with zinc content between 72.2 % and 77 %. The structure of alloy is body centred cubic. The delta phase (δ) is observed at higher zinc levels. Its composition corresponds to $FeZn_7$ and it exists in the range 88.5 % - 93 % zinc. The structure is hexagonal. There is a δ phase but this is unstable at temperature below about 600 ˚C. The zeta phase (ζ) exists in a narrow range of concenrations between 93.8 % and 94 % with a composition corresponding to $FeZn_{13}$. The structure is monoclinic. The ζ phase is very brittle. There is a fourth phase, η, which is of interest. This is almost pure zinc, taking the form of a solid solution of iron in zinc. The maximum solubility of iron in zinc is about 0.03 % at 450 °C, reducing to 0.008 % at ambient temperature. The galvanising bath will normally contain iron in axcess of the solubility limit and therefore consist of η phase. The free zinc layer picked up by the wire as it leaves the zinc bath is also η [2,3,5,7].

Zinc baths are usually operated at 450 ˚C. Lower temperatures are rarely used, ensuring a safety margin from solidification of the zinc (420 ˚C) [6]. In this study, the experimental study was carried out by keeping the temperature constant at 450 ˚C. With vertical extraction the pick-up of free zinc depends upon the processing speed and feed diameter. In the case of oblique extraction the data available suggests that the diameter does not materially affect the free zinc coat weight. The total expected coat weight values can be calculated as the sum of the alloy layer and free zinc. As galvanizing speed increases the immersion time decreases together with the alloy coat weight. At the same time, the increasing speed gives an increase in free zinc coat weight.

The galvanizing temperature also caused the change in the mechanical properties of high carbon steels. The zinc coating does not contribute to the breaking load of the wire but by increasing the wire diameter it reduces the tensile strength. The magnitude of this change is dependent only on the coating thickness, which determines the increase in area of the cross section. To eliminate the effects of size change, it is convenient to consider the effects of heat treatment on the breaking load rather than the tensile strength.

The aim of the study is to investigate the effect of galvanizing speed on coating thickness, coating weight, mechanical properties by keeping all parameters constant. Microscopic analyses both the alloy and free zinc coat thickness have been obtained by analysis of data from both trials and production operations.

2. EXPERIMENTAL DETAILS

The steel material for the experimental study was Ø 3.20 mm wire from wt.% 0.83 C (**Table 1**). The wires were subjected to galvanizing in industrial conditions on the galvanizing production line. Before galvanizing process the wires were subjected to a surface chemical treatment, for example washing in water, pickling in HCl, by washing in a cold water and then fluxing.

Table 1 Steel chemical composition (wt.)

C %	Mn%	Si%	P%	S%	Cu%	Cr%	Ni%	N%	V%
0.83	0.66	0.20	0.015	0.007	0.08	0.3	0.03	0.004	0

Table 2 Galvanizing process parameters and technical specifications

Diameter (mm)	Temperature (˚C)	Galvanizing speed 1 (m/min)	Galvanizing speed 2 (m/min)	Galvanizing speed 3 (m/min)	Galvanizing speed 4 (m/min)
3.20	450	25.1	32.1	39.1	46.1
All the samples are galvanized at the same distance All samples were exposed to vertical extraction					

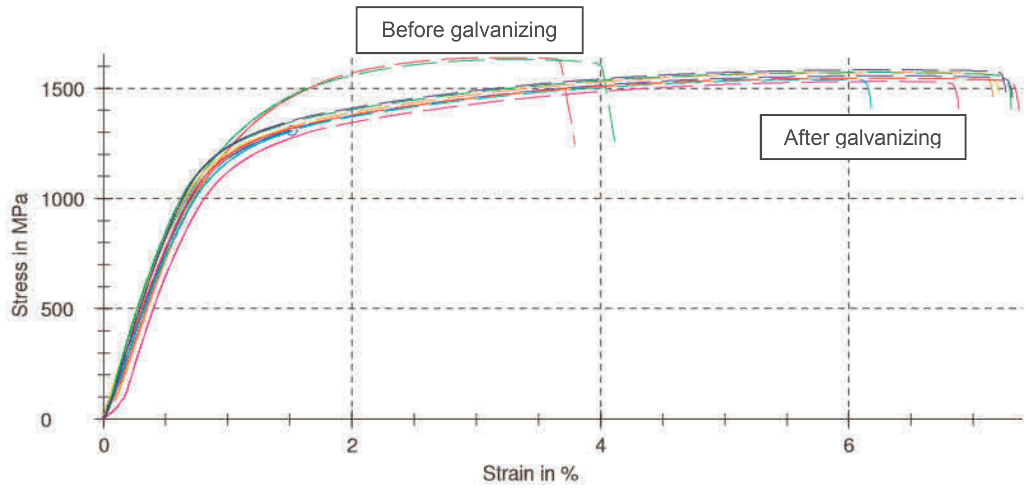
The technical characteristics of the galvanize bath and the temperatures used in the experiments are shown in **Table 2**. The galvanized wire specimens were pulled to the universal tensile testing unit (Zwick 5 kN, strain rate:0.006 s^{-1}) in accordance with TSE EN ISO 6892-1 standard. Yield strength, tensile strength and elongation after the test were compared. Subsequently, coating weight was determined by volumetric method and coating thickness was analysed by optical microscope.

3. RESULTS AND DISCUSSION

The cold drawing activates in the steel wire a strain hardening mechanism, so that it produces a clear improvement of mechanical properties obtained from a standard tensile test: both the yield strength ($\sigma_{0.2}$) and the ultimate tensile strength (σ_m) increase with cold drawing, while the elastic modulus (E) remains constant and the elongation (ductility) decreases with it. The galvanizing temperature is 450 ˚C and this temperature causes a change in the mechanical properties of the material. The research presented in **Table 3** shows that galvanizing parameters on the line to galvanizing steel wire significantly affect its mechanical properties. In addition, σ-ε curves are shown below before and after galvanizing.

Table 3 Mechanical properties of galvanized steel wires

Diameter (mm)	Galvanizing speed (m/min)	$\sigma_{0.2}$ MPa	σ_m MPa	% ε
3.20	Bright (Before galvanizing)	1227	1640	3.0
	25.1	1082	1482	6.0
	32.1	1132	1572	7.3
	39.1	1138	1557	6.4
	46.1	1142	1547	7.2



Hot dip galvanizing affects the wire tensile properties as a result of the effects of heat treatment during the galvanizing process, usually from the zinc bath and any stress relieving treatment. The zinc coat does not contribute to the breaking load of the wire but by increasing the wire diameter it reduces the tensile strength. The magnitude of this change is dependent only on the coat thickness, which determines the increase in area of the cross section. To eliminate the effects of size change, which can be easily calculated, it is convenient to consider the effects of heat treatment on the breaking load rather than the tensile strength. **Figure 2** shows that change of mechanical properties with galvanizing speed.

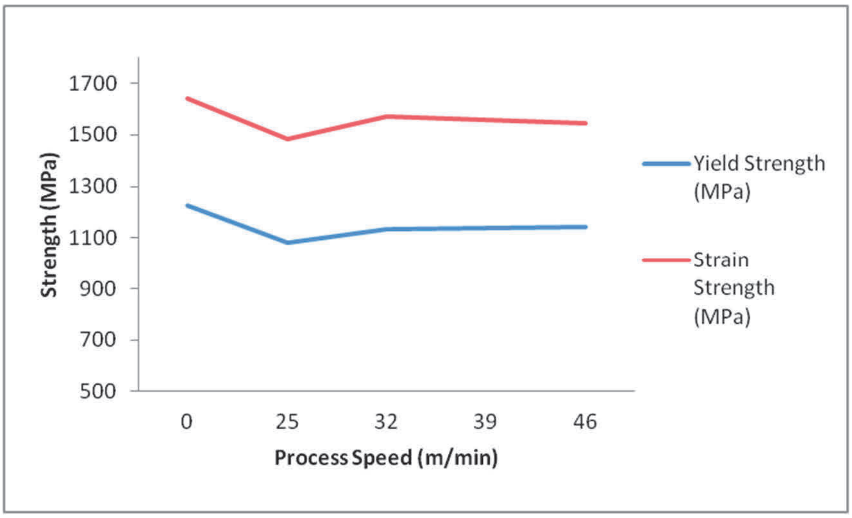


Figure 2 Change of mechanical properties with galvanizing speed

The total expected coat weight values can be calculated as the sum of the alloy layer and free zinc. As galvanising speed increases the immersion time decreases together with the alloy coat weight. At the same time, the increasing speed gives an increase in free zinc coat weight (**Table 4**).

Table 4 is characteristic of the relationship between coating weight and speed, in this case for a 3.20 mm wire with an immersion length of 8.50 m and vertical extraction. Initially the loss of alloy layer with increased speed is greater than the gain in free zinc and the total coat weight reduces. At higher speeds the increase in free zinc more than offsets the loss in alloy layer contribution and total coat weight increases. There is a speed at which a minimum total coat weight is obtained.

Table 4 Galvanized properties and image of optical microscope

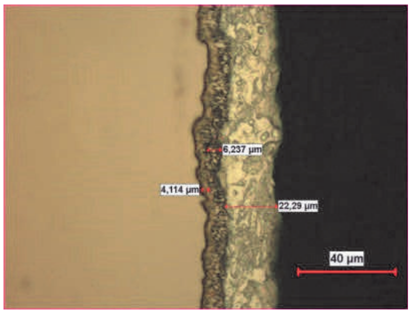
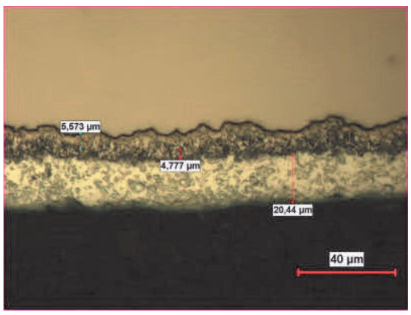
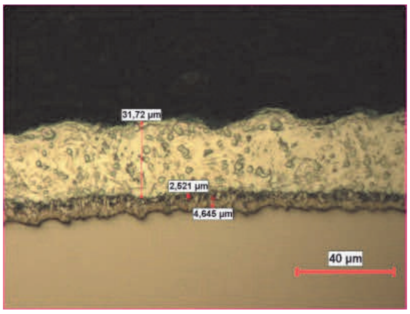
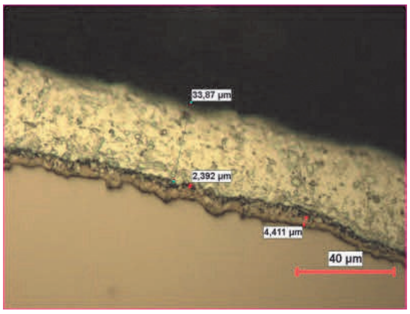
Φ (mm)	**Galvanizing speed (m/min)**	**Coatin g mass (gr/m^2)**	**Coating thickness (µm)**	**Alloy layer thicknes s (µm)**	**Free zinc layer thickness (µm)**	**Image of optical microscope**
3.20	32.1	241	32.641	10.351	22.29	
	25.1	231	30.790	10.452	20.33	

Table 4 - Continue						
Φ (mm)	**Galvanizing speed (m/min)**	**Coatin g mass (gr/m²)**	**Coating thickness (µm)**	**Alloy layer thickness (µm)**	**Free zinc layer thickness (µm)**	**Image of optical microscope**
3.20	39.1	252	38.886	7.166	31.72	
	46.1	260	40.673	6.803	33.87	

4. CONCLUSION

Wire drawing is a cold deformation method and causes deformation hardening in the material during this process. Hot dip galvanizing affects the wire tensile properties as a result of the effects of heat treatment during the galvanizing process, usually from the zinc bath and any stress relieving treatment. Experimental study shows that galvanization process in wire applied cause of decrease mechanical properties 7-10% was observed. One of the many parameters affecting galvanizing properties is the processing speed. Experimental studies have shown that the increase in process speed increases the coating thickness and coating weight.

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