



A review on recent approaches in the field of hot dip zinc galvanizing process



S.M.A. Shibli*, B.N. Meena, R. Remya

Department of Chemistry, University of Kerala, Kariavattom Campus, Thiruvananthapuram, Kerala 695 581, India

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ABSTRACT

The recent developments in the field of hot dip zinc coating are reviewed with special reference to different industrial applications. The improvements in physical and chemical structural composition due to pre- and post-modification processes are discussed. The present review has the focus mainly on the readership of young researchers engaged in this field. Very recent developments on the hot dip galvanization processes are highlighted. Their industrial competencies with aluminium dipping are also briefly discussed. The scopes for immediate future developments are also highlighted then and there.

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1. Introduction

Steel of different forms, is an integral part of building and construction industry due to its high strength and durability. Although many new and advanced materials have been developed for engineering

* Corresponding author. Tel.: + 91 85470 67230(mob), +91 471 2308682(off), +91 471 2167 230(Res).

E-mail address: smashibli@yahoo.com (S.M.A. Shibli).

applications, steel is still considered to be the main construction material for automobiles, appliances and industrial machinery [1]. Steel undergoes corrosion when exposed to different environments. There are different methods to prevent corrosion such as cathodic protection, anodic protection, and addition of inhibitors, protective coatings and metallic coatings. Zinc coatings are extensively used for the protection of steel. In such cases, the more active zinc metal corrodes preferentially than the steel substrate by a cathodic reaction that prevents steel from undergoing anodic corrosion reaction. Different types of zinc coatings include: hot dip galvanizing (batch or continuous), electroplating, metalizing (zinc spraying), mechanical plating and zinc rich paint. Among them, the hot dip galvanization process, offers a unique combination of superior properties such as high strength, formability, light weight, corrosion resistance, low cost and recyclability. In a conventional hot dip galvanizing process, a steel article is cleaned, fluxed and then immersed in a molten zinc bath at a temperature of about 450 °C [2]. Hot dip galvanized steels have been extensively used in industrial fields such as automobiles, electrical home appliances or construction due to their excellent corrosion resistance characteristics [3]. This technique has been adopted as a well proven feasible process since 1800 soon after the exploration of iron and zinc. The exploration of the process was attempted in 1742 when a French chemist Melouin presented a paper on hot dip galvanizing, and the process received commercial momentum with patents mainly in the 1830s. The reason for the extensive use of hot dip galvanization is the two-fold protective nature of the coating. As a barrier coating, it provides a tough, metallurgically bonded zinc coating that completely covers the steel surface and protects steel from corrosion. Additionally, the sacrificial action of zinc protects the steel even when damage or a minor discontinuity occurs on its surface.

A hot dip galvanized coating consists of a heterogeneous assembly of different phases which are formed due to metallurgical reactions between iron and zinc when a ferrite substrate is immersed into molten zinc [4]. After solidification, the coating consists of an outer layer of 100% zinc (η -eta layer) and inner layers called alloy layers consisting of intermetallic phases of iron and zinc such as zeta (ζ) layer (94% Zn–6% Fe), delta (δ) layer (90% Zn–10% Fe) and gamma (Γ) layer (75% Zn–25% Fe) [5–7] (Fig. 1). These intermetallic layers are relatively harder than the underlying steel and provide exceptional protection against coating damage. The characteristics of the intermetallic phases of hot dip zinc coatings are compared in Table 1 [8–11].

2. The process

2.1. Selection of substrate

The composition of a steel substrate has great influence on the hot dipping process and the performance of the resultant hot dip zinc

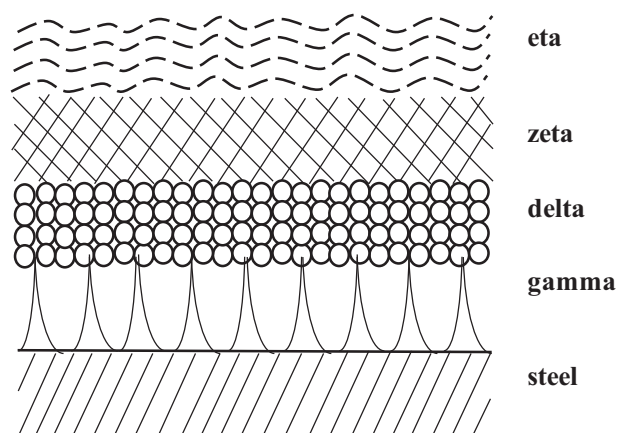


Fig. 1. The intermetallic layers present in a typical/conventional hot dip galvanized coating.

Table 1

Characteristics of Fe–Zn intermetallic phases of hot dip zinc coatings [8–11]. Source: Comput. Mater. Sci., Vol. 50, 2011, pp. 2502 (Elsevier).

	η phase	ζ phase	δ phase	Γ phase	Γ phase
Stoichiometry	Zn	FeZn13	FeZn10	Fe5Zn21	Fe3Zn10
Wt.% of iron	0	5–6	7–11.5	17–19.5	23.5–28
Crystal structure	HCP	Monoclinic	Hexagonal	FCC	BCC
Atoms/unit cell	6	28	555	408	52

coating. The change in the composition of the substrate not only influences the rate of attack of steel by molten zinc but also changes the mode of attack at a given galvanizing temperature [12]. The compositional variation of the steel used for hot dip zinc coating is an important factor that determines the zinc drainage, coating morphology and protection capacity of the coating. The chemical composition of the steel substrate also influences the metallurgical properties of the hot dip zinc coatings. The presence of Si, P, C and Mn in the steel substrate can influence the Fe–Zn solidification mechanism depending on their concentration. The presence of critical amount of silicon and phosphorus in the steel substrate is necessary to control the coating weight and the presence of carbon & phosphorus accelerates the growth of the alloy layer, thereby improving the adherence of the coating [13,14]. There are mainly two groups of steels that are used for hot dip galvanization namely low carbon, non-killed steel with low silicon and reactive steel with high silicon content.

2.2. Preparation of the base surface

Surface preparation is an important step in hot dip galvanization because zinc does not metallurgically react with steel surface when it is not completely clean. The effective cleaning of steel substrate can be achieved by a variety of processes. Surface preparation typically consists of degreasing, pickling and fluxing. Oils, greases and other saponifiable compounds present in the steel substrates are removed through degreasing. Alkaline solutions are normally used for this purpose since they are less expensive than vapour degreasers using costly organic solvents. Yuttanant et al. [15] and R. Sa-nguanmo et al. [2] used to degrease the low carbon cold rolled steel substrate using 10% NaOH solution at 60 °C for 10 min prior to hot dip galvanization. The steel substrate could also be degreased using 5% NaOH solution at 50 °C to ensure that the substrate is free from foreign materials [16].

Normally steel substrate contains oxides of iron, even after the removal of greasy substances and that are to be removed by pickling. The warm/hot acid solutions such as HCl and H₂SO₄ are commonly used for the pickling process as both provide same pickling effect. But most of the researchers prefer HCl as pickling agent due to its use at low temperature, with less volume. Moreover, it is easy to inhibit and the steel substrate doesn't require any caustic treatment [17]. Shibli et al. have reported about the usage of 8% HCl as a pickling agent for steel substrate [16]. It should be noted that steel coupons could also be pretreated by pickling in 14% HCl at room temperature for 20 min [15,2]. Stieglitz et al. have reported the use of a pickling solution of HCl and H₃PO₄ to ensure a stable coating [18].

Fluxing is required to dissolve any oxide films formed on the steel surface after pickling. It should be ensured that a clear metal surface contacts the molten zinc during the galvanization process. The fluxing treatment provides good adherence of liquid zinc on the steel substrate and facilitates adequate metallurgical interaction between zinc and steel. It also suppresses in-situ oxidation of the steel surface by atmospheric oxidation. Fluxing solutions consist of alkali and alkaline earth metal chlorides or fluorides with zinc chloride. The conventional fluxing solution consists of a mixture of zinc chloride (ZnCl₂) and ammonium chloride (NH₄Cl) in 1:3 mol ratio [19]. The presence of ammonium chloride in the flux promotes drying of the flux on the steel substrate before its entry into the molten zinc bath and zinc chloride protects the steel

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