

SEM STUDY OF INTERMETALLIC PHASES GROWTH IN A HOT-DIP GALVANIZING PROCESS

*ESTUDIO POR SEM DEL CRECIMIENTO DE FASES INTERMETALICAS EN EL
PROCESO DE GALVANIZADO POR INMERSION*

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The influence of both the cooling rate and the base steel roughness upon the Al-rich phase was analyzed. For this, steel sheets were coated in a simulator of the hot-dip galvanized process working at 470 °C up to reaching an average roughness value of 1.30 or 0.90 μm; besides, either an air or water spray flow was used in order to obtain cooling rates between 7 and 22 °C s⁻¹, respectively. The galvanized plate surfaces were characterized by means of SEM and XRD analysis. From the experimental results the following conclusions could be drawn: a) the Al-rich phase grows as an intermetallic (Al₃Fe₂), that crystallizes forming an orthorhombic lattice in which increasing cooling rates do not change the morphology but stop the growing of the crystals, and b) an increase of the steel roughness makes that outburst structures but not the Al-rich phase develops at the bottom of pits.

Keywords: *outburst, intermetallic growth, hot-dip galvanized steel, cooling rate, surface topography.*

INTRODUCTION

Affected by the chemical activity as well as by the diffusion and subsequent cooling processes, the complex structure of layers comprising a galvanized coating differs meaningfully not only in chemical composition but also in physical and mechanical properties. Furthermore, small differences in coating composition, bath temperature, immersion time, cooling rate and substrate characteristics give rise to significant changes in the coating appearance and properties [1]. An Al-rich layer is formed when a steel plate is brought into contact with a zinc bath containing more than 0.1% Al. This layer is thought to hinder the alloying between the steel sheet and molten zinc, reason by which is referred to as the inhibition layer, since it inhibits the formation of Fe-Zn phases (Γ , δ and ξ) [2]. The aim of the present work was to analyze the influence of both the cooling rate and the base steel roughness upon the Al-rich phase growth.

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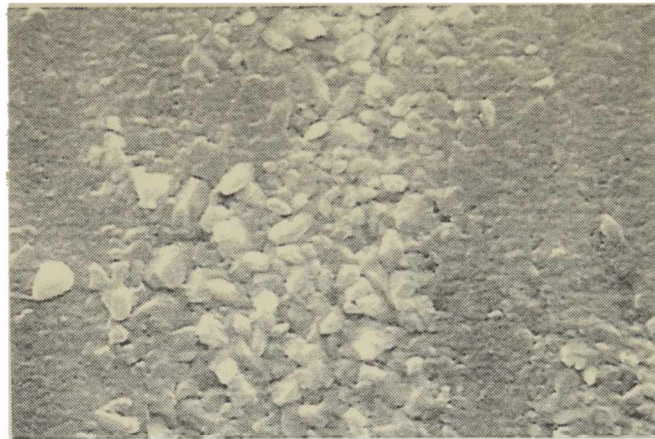
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(a)



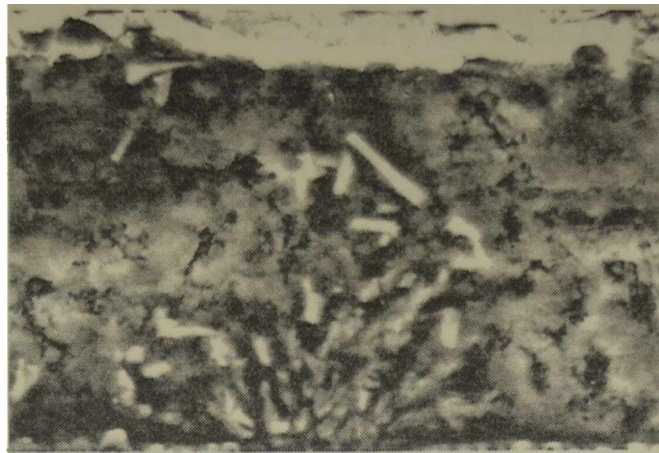
(b)

Fig.1.- Micrographs of the cooling rate effect on the Al-phase growing.
a) 7°C s^{-1} (7700X); b) $22^{\circ}\text{C s}^{-1}$ (7700X).

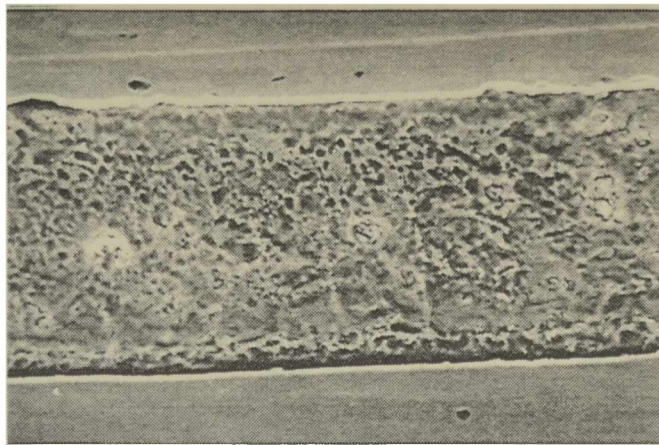
EXPERIMENTAL DETAILS

SAE 1004 steel plates were coated in a simulator of the hot-dip galvanized process at laboratory scale, containing a bath whose chemical composition was: Al, 0.2%; Fe, 0.02%; Sb, 0.09%. The remainder was zinc. The specimens surface topography was modified up to the average roughness values: 1.30 and 0.90 μm . The bath temperature and immersion time were kept constant at 470 $^{\circ}\text{C}$ and 30 s, respectively. Besides, either an air flux of 600 $\text{l}\cdot\text{min}^{-1}$ or a water spray were used as cooling media, given cooling rates of 7 and 22 $^{\circ}\text{C s}^{-1}$, respectively.

For SEM studies, some galvanized plates were submitted to pickling with sulfuric acid, using arsenious anhydride as inhibitor so that, from the selective dissolution of Zn (dezincification), the aluminium-rich phase could be observed using a plant view [3]. The other samples were placed in slides and etched with nital 1%, then rinsed with distilled water and newly etched using this time a chromic acid solution in order to be observed by cross-section.



(a)



(b)

**Fig.2.- Development of outburst structures as a function of the steel surface roughness;
a) $R_a = 1.30\mu\text{m}$ (1490X) and b) $R_a = 0.90\mu\text{m}$ (500X).**

RESULTS

Fig.1 shows the cooling rate effect on the aluminium-rich phase growing; the compound formed was identified as Al_5Fe_2 by XRD. This intermetallic phase crystallizes as an orthorhombic lattice ($a = 7.675$, $b = 6.403$, $c = 4.203$) and develops through the nucleation-growing mechanism forming equiaxial crystals, Fig.1a. Its morphology is not changed by an increase of the cooling rate but these last stop the crystals growing, Fig.1b. Under such conditions, not only smaller crystals but also some of them showing a preferential development (heterogeneous growing) were obtained. Furthermore, a greater growing could be observed at the base steel boundary grains, where the higher surface energy causes the growing not only of this phase but also the Fe-Zn intermetallic derived from the same. The steel roughness would not affect the Al-rich phase morphology; nevertheless, when the roughness increases this phase cannot develop at the bottom of the pits, sites at which Zn diffuses through the Al_5Fe_2 and reacts with the Fe atoms giving rise to the development of Fe-Zn phases (“outburst

structures”), Fig.2a. On the other hand, on less rough steel surfaces this effect is either avoided or delayed, Fig.2b.

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REFERENCES

- [1] ASMs Handbook.- Vol. 13, **Corrosion**, ASM International ed. (1992=.
- [2] Lin, C.S.; Meshii, M.- **Galvatech’95 Conference Proc.**, p.335 (1995).
- [3] Kjusalaas, R.; Engberg, G.; Klang, H.; Schedin, E.; Schan, L.- **Galvatech’89 Conference Proc.**, p.485 (1989).