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Damage micromechanisms in a hot dip galvanized steel

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Abstract

Hot-dip galvanizing is one of the most used methods to apply zinc-based coatings on steels in order to provide sacrificial protection against corrosion over all the steel surface. The aim of this work is the analysis of the hot dip zinc coated steel plates mechanical properties by means of a non-standardized bending test performed minimizing both the bending moment differences along the bending axis and the interactions between the clamping system and the specimen coating. Bending tests are performed both on non-coated and on hot dip zinc coated plates, correlating the measured variables (applied load and crosshead displacement) with the bending moment and the specimen bending angle. Tests are characterised by a good repeatability. Results show that the main damaging mechanisms depend on the different mechanical behaviour of the intermetallic phases and on their thickness. For all the investigated coating conditions, radial cracks are observed. They initiate corresponding to the Γ phase and propagate up to the ζ–η interface. The coating thickness increase implies both an increase of the importance of the cracks in δ and ζ phases and the presence of cracks at ζ–δ interfaces.

*Keywords:*Hot dip galvanizind; Ipersandling; Damage.

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1. Introduction

Hot-dip zinc coating is known as one of the most used technique for protecting cold rolled steels against corrosion (ASTM 1999, De Abreu 1999).

The steel to be coated is firstly cleaned to remove all oils, greases, soils, mill scale and rust. Cleaning usually consists in a degreasing step followed by acid pickling, in order to remove scale and rust, and by fluxing, in order to

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apply a protective surface and inhibit the steel oxidation before dipping in molten zinc. As result of this procedure, the coating is constituted by a succession of the intermetallics observed in the Fe-Zn system. Starting from the α (Fe) substrate, δ, ζ, and η phases are more or less evident (Figure 1), according to the zinc coating procedure.

Usually, the Γ layer, constituted by Γ1 and Γ2 compounds, is really thin (Marder, 2000). These phases are characterized by different mechanical and physical properties (Reumont 2001): Young module ranges between 75 GPa (corresponding to the Zn layer) and 140 GPa (corresponding to the δ phase); 0.25 N microhardness ranges between 70 VHN (corresponding to the Zn layer) and about 280 VHN (corresponding to the δ phase). Although the microstructure and the phases growth kinetics have been investigated in detail, poor efforts have been made on the analysis of Zn coatings adhesion and mechanical properties (Tzimas 2001).

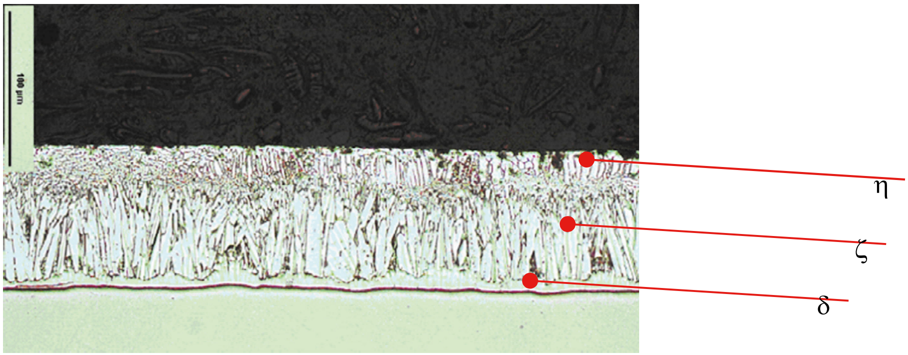

Fig. 1. Zinc coating phases.

This work analyses the mechanical behavior of hot dip galvanized Zn coatings submitted to a bending test by means of a non-standardized procedure that allows to obtain pure moment loading conditions (Duncan 1999, Natali 2004).

2. Material and experimental procedure

For all the investigated Zn coatings procedures, 3 mm thick commercial carbon steel plates are considered. Table 1 shows the steel chemical composition. Zn bath is Fe saturated.

Table 1: Chemical composition of the steel used as substrate (wt%).

C	Si	Mn	P	S	Al	Fe
0.090	0.167	0.540	0.010	0.004	0.051	Bal.

Prior to galvanizing, steels samples are degreased and rinsed with alcohol. Subsequently they are pickled in an aqueous solution 20% H_2SO_4 at 50°C for 10 minutes, washed in fresh water, fluxed in an aqueous solution containing 280 g/l $ZnCl_2$ and 220 g/l NH_4Cl at laboratory temperature for 2 minutes and then they are dried for 10 minutes at 100°C. After this procedure, they are immediately dipped into the galvanizing bath, that is held at 440 ± 2 °C, for different durations (respectively 15, 60, 180, 360, 900 seconds). Finally, they are water cooled.

Bending test are performed by means of a non-standard device (figure 2) and they are repeated at least three times for each considered dipping duration. Tests are performed using an electromechanical 100kN testing machine, considering a crosshead displacement equal to 35 mm, that corresponds to a bending angle equal to 30° (figure 3b). Furthermore, in order to analyse the coatings damage development, bending tests are performed up to bending angles respectively equal to 10° and 20°, considering a dipping duration equal to 60 s. Finally, in order to identify the damaging mechanisms for each investigated dipping duration and loading conditions, longitudinal sections of the bended specimens are metallographically prepared and observed by means of an optical microscope (LOM). The damage level was evaluated in term of "cracks density", that corresponds to the cracks number contained in a specimen length equal to 1000 µm (Kim 2000).