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Microstructure and Hardness of Galfanized Steel

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Abstract: A new and more effective method for protecting steel from corrosion is coating it with galfan. Galfan is a metallic melting composed of 95% Zn and 5% Al. In this alloy, purely steel samples are dipped; during this process reactions between iron, zinc and aluminum are caused. As an outcome, we gain a new material, steel coated with a galfanic layer. The microstructure of galfanized steel and some mechanical properties are presented here.

Key words: Galfan, steel, microstructure, layer, hardness, eutectic

INTRODUCTION

Unprotected steel is subject to corrosion. To avoid corrosion of steel, its coating with a protective layer is applied. Among the metals, zinc is the mostly used for the construction of the protective layer over the surface of the steel.

The alloy, in which the steel samples are dipped, composed of 95% Zn and 5% Al, is called galfan (there are trace of cerium and lanthanum). The microstructure of galfanized steel shown in Fig. 1 (Coutsouradis *et al*., 1984). By dipping of steel samples in this alloy, a galfanic layer is built on the steel; this represents the newest achievement in the direction of improving the protection from corrosion. The preferences of this method for protecting steel from corrosion are: the galfanized steel is easily elaborated, the high resistance against corrosion and the low melting-point of this alloy, 382°C.

The role of aluminum in that coating is essential. At low contents, the aluminum inhibits growth of intermetallics and thus, ensures a coating as ductile as possible (Coutsouradis and Walmag, 1995).

The diffusion process on the metal mostly happens through the vacancy on the structure of the crystal lattice (lattice diffusion) and also through the granular borders and substitutions. Since, the diameters of aluminum and zinc atoms are approximately the same, aluminum can't diffuse on the hard zinc layer through lattice, but only through vacancy, substitutions and granular borders. Therefore, a change of places must happen with the atoms of the hard zinc layer (Nunninghoff and Hagebolling, 1995).

The substituted zinc passes on to the galfan alloy and there reacts with aluminum to create the eutectic Al-Zn.

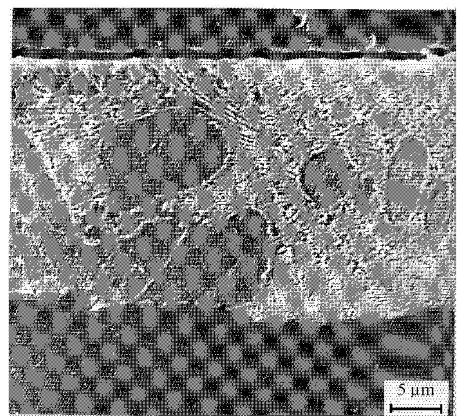

Fig. 1: Microstructure in the galfanized steel sample (Coutsouradis *et al*., 1984)

After a very long dipping the lattice diffusion of aluminum on the hard zinc crystal happens and the crystals melt. Finally, we can say that in the galfan layer is a mixture of intermetallics compounds Al_xFe_y with double and triple eutectic parts (binary and ternary) and primary zinc crystals (Nunninghoff *et al*., 1992).

From the thickness and the composure of the layer depends the resistance to corrosion. With the increment of the thickness of the layer, the resistance to corrosion is also increased. The increment of the thickness of layer of zinc coated sample, in one side depends on the method and the other, the chance to change the form is limited by the increment of the thickness of the layer (Mager, 2002).

MATERIALS AND METHODS

The chemical composition of steel samples is represented in Table 1. The steps, through, which the

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Table 1: Chemical composition of steel C78D

Elements	Wt. Pct
C	0.780
Si	0.200
Mn	0.670
P	0.008
S	0.011
Cr	0.030
V	0.001
Nb	0.020

zinc coating with galfan is achieved are: cleaning from grease with acetones, denudation 2 min in 10% HC1, dipping in a fluid preparation 30 sec, in a temperature of 60-70°C then drying. The two samples are dipped in a temperature of 450°C, one of them in time of 30 sec and the other 10 min in a container filled with galfan. The composition of the galfan container was 4.98% Al and 95% Zn. Galfanization is achieved by using the method double hot-dip galvanizing.

The metallographic elaboration follows these steps: cutting of the sample, embedding of the sample, grinding of the sample and polishing of the sample. The samples that are used in this process are stained in a solution with 0.5% HNO_3 in time of 2-4 sec. All the samples are photographed twice with an optic microscope Neophot 30, Carl Zeiss Jena. For measuring the material's hardness is used Vickers's method, in the automatic micro-hardnessmeter PCE from LECO. For investigating the microstructure and the composition of the phases are used EDS and SEM.

RESULTS AND DISCUSSION

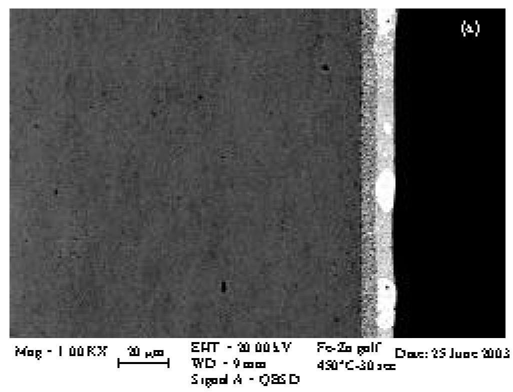
The galfan layer on the steel sample is built with the method of double dip and then investigated. The process developed on a temperature of 450°C in two different times of dipping, 30 sec and 10 min. After the galfanization, a layer with shining silver is built, which covers the steels substratum all in all. Microstructure of galfan depends on the composition of aluminum in the zinc container inside the specification intervals and on the speed of refrigeration. Figure 2 represents a typical microstructure of galfan layer. Over the steels substratum the previous alloy layer Fe-Zn lies, inside of which within a short period of time diffuse the aluminum atoms. After the previous alloy layer Fe-Zn the eutectic Al-Zn comes with crystals of primary zinc inside. The high speed of refrigeration after the outcome of the sample leads to the suppression of the zinc layers and to the creation of a thin phase eutectic structure. The refrigeration is done in a spontaneous way in room temperature. From Fig. 2, we can assume that the thickness of the layer depends on the time of dipping.

Table 2: Content of Zn, Fe, Al and Si by percent in the galfanized steel sample, to 450°C and 30 sec

Points of measurements	Zn	Fe	Al	Si	Phase
	----------(%)----------				
1	69.63	10.97	18.78	0.63	Fe-Zn-Al alloy
2	74.36	7.13	17.97	0.54	Fe-Zn-Al alloy
3	98.03	0.50	1.19	0.28	Zn granule
4	85.97	0.68	12.87	0.48	Fe-Zn-Al alloy
5	95.33	0.49	3.90	0.27	Eutectic Zn-Al

Table 3: Content of Zn, Fe, Al and Si by percent in the galfanized steel sample, to 450°C and 10 min

Points of measurements	Zn	Fe	Al	Si	Phase
	----------(%)----------				
1	93.54	2.12	3.96	0.39	Fe-Zn-Al alloy
2	98.00	0.85	0.81	0.34	Zn granule
3	29.62	25.66	43.25	1.47	Fe-Zn-Al alloy
4	94.78	0.31	4.27	0.64	Eutectic Zn-Al



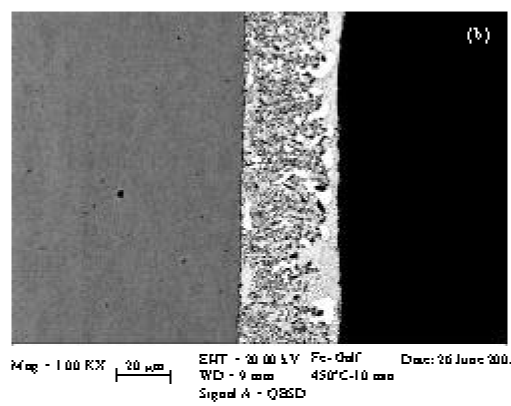


Fig. 2: Microstructure of galfanized steel samples, a: 450°C, t_a = 30 sec picture and b: 450°C, t_a = 10 min

Figure 3 represents the construction of the galfan layer in the 10 min. period of dipping. The dipping time of 10 min. achieves through the diffusion of aluminum to destruct the former alloy layer Fe-Zn (the layer built from the first dipping of the steel sample on the purely zinc fusion).

In order to set the aluminum content inside the alloy layer Zn-Al, the galfanized steel sample was investigated with EDS analysis. The results of the EDS analysis are represented in Table 2 and 3. Figure 4 and 5 represent the

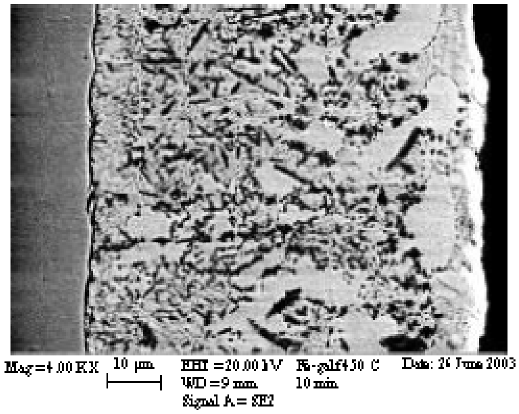


Fig. 3: Microstructure of galfanized steel samples in T_S = 450°C and t_S = 10 min

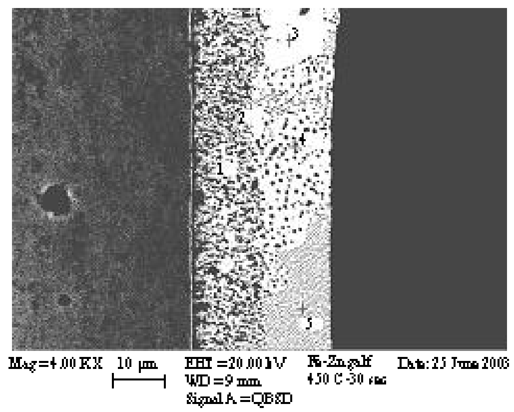


Fig. 4: The points of measurements with EDS in galfanized steel sample 450°C, 30 sec

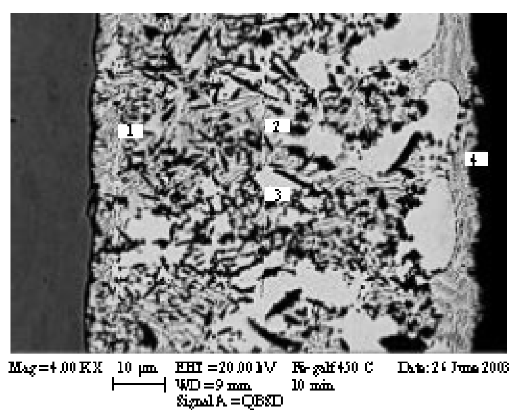


Fig. 5: The points of measurements with EDS in galfanized steel sample 450°C, 10 min

measurement locations of the corresponding points. In principle, the aluminum content in the previous alloy layer (the layer built from the first dipping of the steel sample on the purely zinc fusion) is higher than the value of aluminum content inside the galfan fusion. This happens because of the high affinity of aluminum to iron.

Table 4: The average value of hardness by galfanic layer

	Hardness of Al-Zn-eutectic	Hardness of Fe-Zn-alloy
Fe-Galfan alloy (450°C, 30 sec)	56.03	74.00
Fe-Galfan alloy (450°C, 10 min)	62.17	83.23

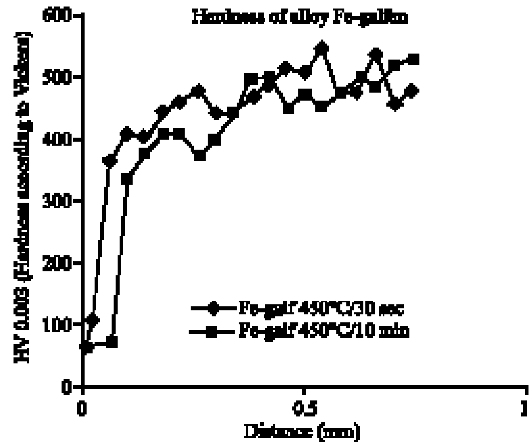


Fig. 6: Hardness of galfanized steel samples (T_S = 450°C, t_S = 30 sec and t_S =10 min)

The hardness of the layer on the galfanized steel sample: Figure 6 represents the hardness of the galvanized steel sample in T_S = 450°C and t_S = 30 sec and t_S = 10 min.

The Table 4 is built from some other more densely hardness measurements only inside the layer, from which can be concluded that the hardness of the former alloy layer Fe-Zn is higher than that of the eutectic Al-Zn.

CONCLUSION

Over the steels substratum the previous alloy layer Fe-Zn lies, inside of which within a short period of time diffuse the aluminum atoms. After the previous alloy layer Fe-Zn the eutectic Al-Zn comes with crystals of primary zinc inside. The thickness of the layer depends on the time of dipping. Based on measurements we concluded that the hardness of the former alloy layer Fe-Zn is higher than that of the eutectic Al-Zn.

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