THE EFFECT OF ANOTHER PROCESSING ON ADHESION OF HDG

Hana GEIPLOVA [1], Libor TUREK [1]

[1]SVÚOM Ltd., Prague, Czech Republic, EU
geiplova@svuom.cz

Abstract

The steel structure segments with HDG coatings are subject of another processing before steel structure assembly and usage. The parameters of these processing's may affect the adhesion of zinc layer - mainly the cutting edges and surface preparation as sweeping. The paper presents some results of practical study of these parameters.

Keywords: HDG coating, adhesion of coating, processing parameters

1. INTRODUCTION

It is commonly known that the chemical composition and surface conditions of steel, mass of steel structure segment and hot dip galvanising conditions may affect the quality of zinc coating, mainly appearance, thickness, structure and physico-mechanical properties of coating. Information can be found in standard EN ISO 14713-2 *Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures - Part 2: Hot dip galvanizing* which is under revision now.

The common practice for providing long-term durability of zinc coatings is application of paint systems. The best adhesion of paint systems can be achieve on zinc coating with suitable anchoring profile - roughness. The recommended technology for creation of fine rough surface is the so called sweeping. But this process may affect the zinc coating adhesion too.

The paper gives some results of case studies related to the HDG coating adhesion..

2. THE EFFECT OF CUTTING TECHNOLOGY ONTO ZINC COATING QUALITY

The steel segments used for steel structures must be prepared by cutting. In past, ca 20 years ago, the cutting technology was based on using hydraulic or eccentric drop shears - the cutting edge was formed at a high speed, in a cold cutting process, with burrs which had to be removed by grinding. There were no thermos-physical structural changes, no changes in chemical composition or changes in the material characteristics occurred at the point of cutting: i.e., there was no heat-affected area (HAZ) with its typical properties. The physical principle of hot-dip galvanizing with the diffusion transition and the formation of characteristic intermetallic phases took place on the cutting edges so formed, just as on the other free surfaces of the rolled material.

At present, due to high productivity and efficiency, the producers of steel structures have switched to technologies such as plasma, laser or hi-tech precise oxygen steel cutting. It brought along a step and thermally very steep effect on the cut surface within a relatively small depth (see the text below), inherently associated with its physical principle; the relevant area is further referred to as the heat-affected zone (HAZ) - **Figure 1**. In this case the HAZ is 100 - 150 µm. The metal in the heat affected zone (HAZ) undergoes a thermal cycle, which leads to significant micro- structural modifications [1].

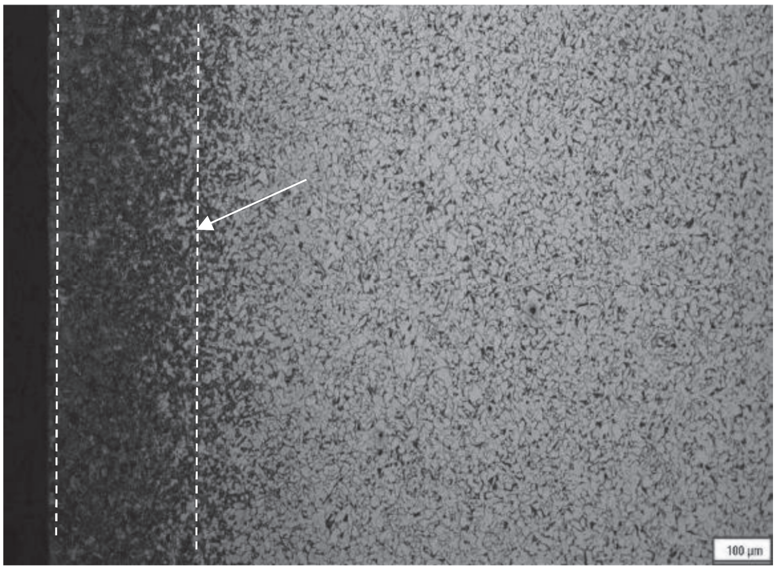

Figure 1 Heat-affected area of plasma cutting

The HAZ width depends on temperature and rate of cutting technology:

- OAB - energy 10^7 W.m^{-2}, temperature 1050-1380°C,
- plasma - energy 10^{11} W.m^{-2}, temperature 10 000°C,
- laser - energy 10^{15} W.m^{-2}, temperature 1200°C.

With reducing width of beam the HAZ width increases but with increasing rate the HAZ width is reduced. E.g. during plasma cutting the material is heated in HAZ to the temperature of phase transformation in Fe-C diagram - ferrite-perlite structure changes onto martensitic structure with different hardness till 0.5 - 0.8 mm depth from surface [2]. The zinc coating formed on these surfaces has non typical properties (thickness, structure) and so standard EN ISO 14713-2 recommended removing this layer. In HAZ the γ phase of zinc coating does not create to obtain basic adhesion of zinc coating to steel. The hardness of steel in HAZ on cut edges is higher than 400 HV10 (steel with carbon equivalent CE ≥ 0.4 %) which means it does not fulfil requirement from EN 1090-2 *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures* specifying maximum allowed hardness 380 HV10. Defects of zinc coating on cut edges is shown on **Figure 2** illustrating that two edges treated by different technology have other adhesion.

Figure 2 The example of zinc coating on cut edges

There were performed some test of steel surface preparation of cut edges guaranteed to obtain zinc coating with required properties - abrasive blasting, chemical pickling, etc. [3]. The test of grinding of cut edges onto zinc coating properties was performed on flat samples with thickness 12 and 20 mm from steel with chemical composition correspond to class B (Sebisty steel) according to EN ISO 14713-2 - **Table 1** which had been cut by laser with two different rates (**Figure 3**). Following grinding of cut edges led to decreasing of hardness with higher reduction (0.3, 0.6, 0.9, 1.2 and 1.5 mm).

The hardness of cut edges was measured by Time Hardness Tester TH 130 and by Microhardness Tester FM-700, Future-Tech Corp., aaccording to standard EN ISO 6507-1 *Metallic materials - Vickers hardness test - Part 1: Test method* on all 4 edges - **Figures 3** and **4**. The samples had been galvanised in the same conditions and zinc coating properties had been evaluated - appearance, thickness and adhesion.

Table 1 Steel composition of samples (wt. %)

Thickness (mm)	C	Mn	Si	P	Cu	Ni	Cr	Mo	V	Ti	Al	N
12	0.19	1.41	0.18	0.012	0.06	0.04	0.04	0.005	0.005	0.005	0.034	0.006
20	0.15	0.59	0.19	0.017	0.01	0.01	0.03	0.001	0.002	0.003	0.032	0.007

Figure 3 The example of cut edges - laser cut (a) and grinded (b)

The results show that the lower rate of laser cut more effect the cut edge but neither on these cut edges the hardness did not exceed the maximum allowed hardness for galvanising - 380 HV (**Figure 4a**). The higher effect was found for thin samples when temperature is higher. Just after the first reduction of 0.3 mm the hardness value had been decreased for 50 % and was measured in range 120 to 180 HV.

The microhardness values are significantly higher, but all other trends are same as for hardness measurement. In case of thin samples the microhardness was higher than maximum allowed value - it was ca 440 HV (**Figure 4b**).

Even though the chemical composition of samples is nearly the same the appearance of zinc coating are different. Zinc coating on thin samples has practically on whole surface “mottled” appearance. Zinc coating on thick samples is gloss and rough.

The thickness of zinc coating on samples is given in **Table 2**. The thickness of zinc coating on cut edges was in range 50 to 60 μm and on sample area was relatively the same without respect to sample thickness and was in range 220 to 240 μm. In the majority of cases the coating thickness was the same on cut edges after grinding of HAZ - 220 to 240 μm. The differentiation between depths of grinding is not significant.

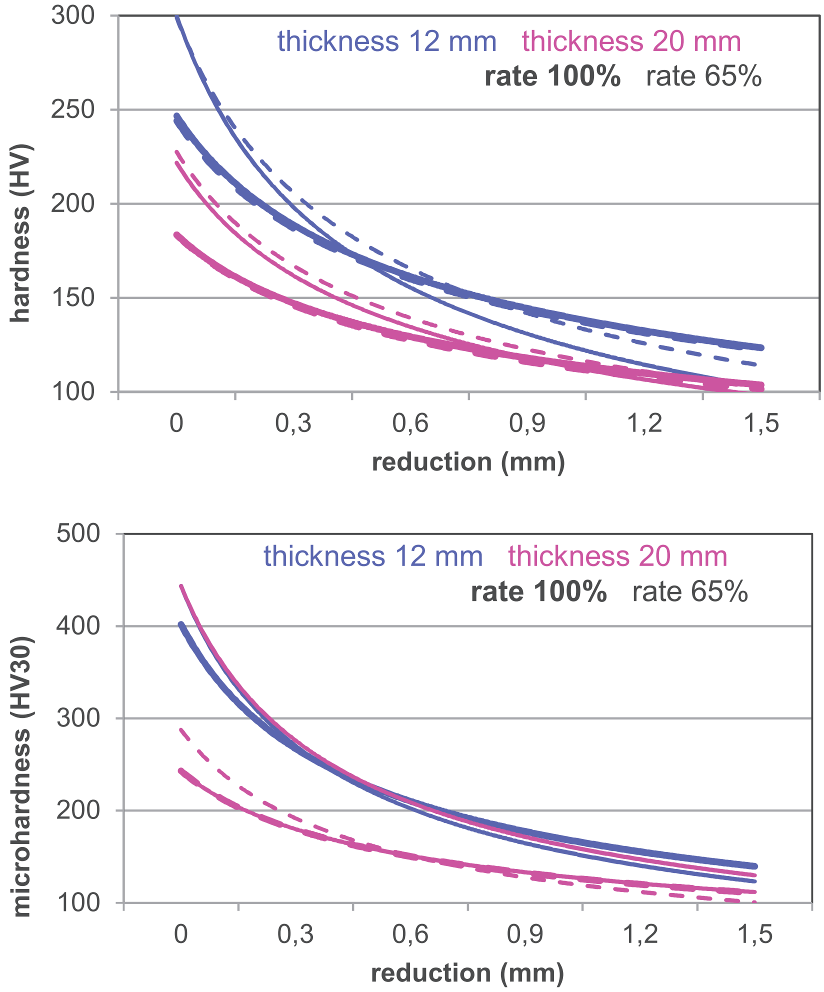

Figure 4 The decreasing of hardness and microhardness of cut edges after grinding reduction

Table 2 Thickness of zinc coating on samples

thickness of sample (mm)	location	Coating thickness (µm)		
		average	minimum	maximum
12	area	239	232	248
	cut edge	56	51	63
20	area	225	170	286
	cut edge	60	53	70

The adhesion of zinc coasting was tested by impact test (ASTM A123 *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products* (removed in 1989 edition) and DIN 50978 *Prüfung metallischer Überzüge; Haftvermögen von durch Feuerverzinken hergestellten Überzügen (Testing of metallic coatings; adherence of hot-dip zinc coatings)* [4]. The appearance of samples after test is on **Figure 5**. The effect of grinding was in the most cases negative - the adhesion of zinc coating was poor. The higher effect then hardness of HAZ of surface has the profile of cut edges. The cut edge without grinding had “anchoring” profile for zinc coating adhesion - see **Figure 2**.

sample 12 mm
zinc coating in area - „mottle“ appearance, 240 μm
poor adhesion
cut edge - lower rate cutting, no grinding
zinc coating on edge - 55 μm, good adhesion

sample 20 mm
zinc coating in area - rough appearance, 225 μm
acceptable adhesion
cut edge - lower rate cutting, no grinding
zinc coating on edge - 60 μm, good adhesion

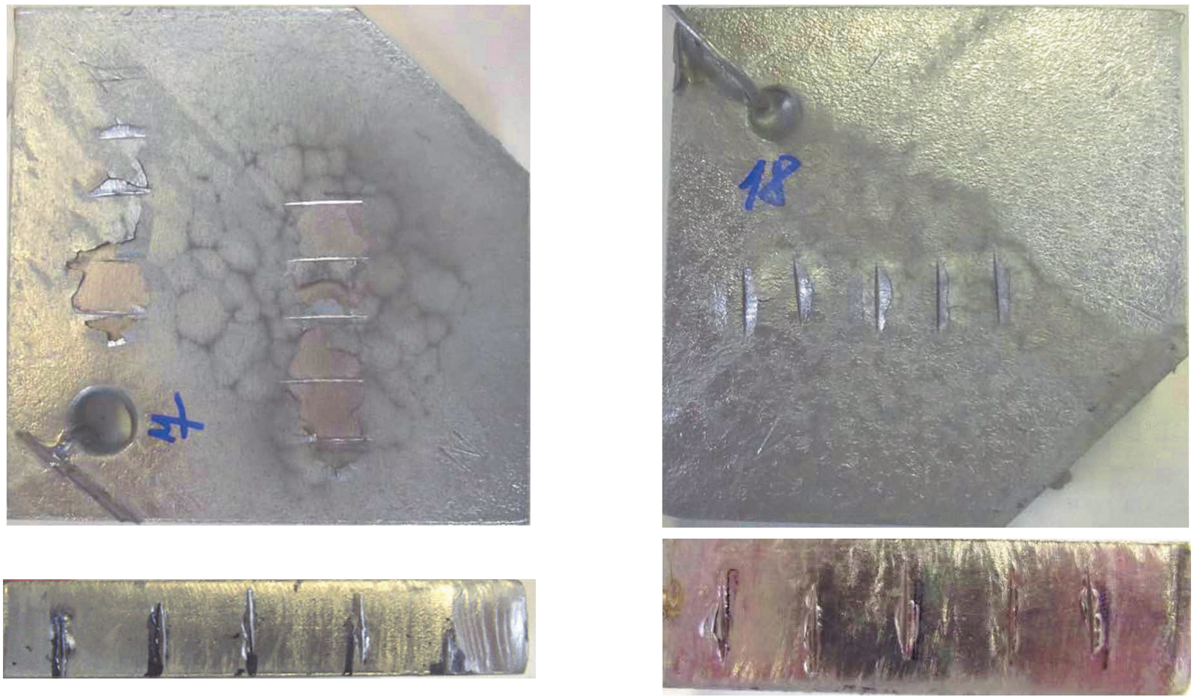

Figure 5 The example of adhesion test

3. THE EFFECT OF SURFACE TREATMENT ON ZINC COATING ADHESION

The low adhesion of zinc and paint coating after sweeping of zinc coating was identified in past for columns of auxiliary structures and the defect was ascribe to the non-suitable chemical composition of steel substrate as the appearance, thickness and structure of coating show to this factor [5].

In this case the tube with diameter 110 mm was evaluated. The tube was coated on external surface by traditional paint system formed by epoxy primer and polyurethane topcoat. The surface preparation was done by sweeping. As the tube shape the internal surface was fully galvanised too. The sample was mechanically stressed leading to deformation of tube wall. In mechanically damaged areas on external surface the whole protective system is delaminated including zinc coating. The practically any zinc intermetallic layer was not remained on steel surface - see **Table 3**. On internal surface the zinc coating is brightly grey and it was not delaminated even on deformed areas. The thickness of zinc coating meets the specification of EN ISO 1461 *Hot dip galvanized coatings on fabricated iron and steel articles - Specification and test methods*.

Table 3 Thickness of coating on tube

area	Thickness (μm)		
	average	minimum	maximum
External surface - zinc and paint system (duplex)	332	237	396
External surface - delaminated area	3.5	1.0	11.1
Internal surface - zinc coating	82	73	100

The metallographic evaluation of cross section of zinc coating samples taken from external and internal surface of tube had been done - **Figures 6** and **7**. On the zinc coating from external surface the reduction of η phase thickness by sweeping is evident and on the some areas only ζ phase reaches to top of zinc coating. The ζ phase seems to increase space between individual crystals. The thin cracks exist in this coating, too.

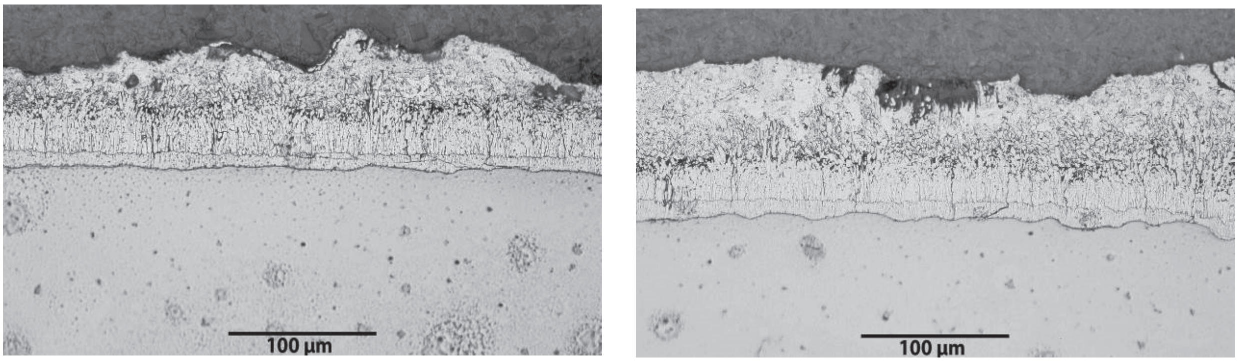

Figure 6 Cross section of zinc coating on external surface (no deformed area)

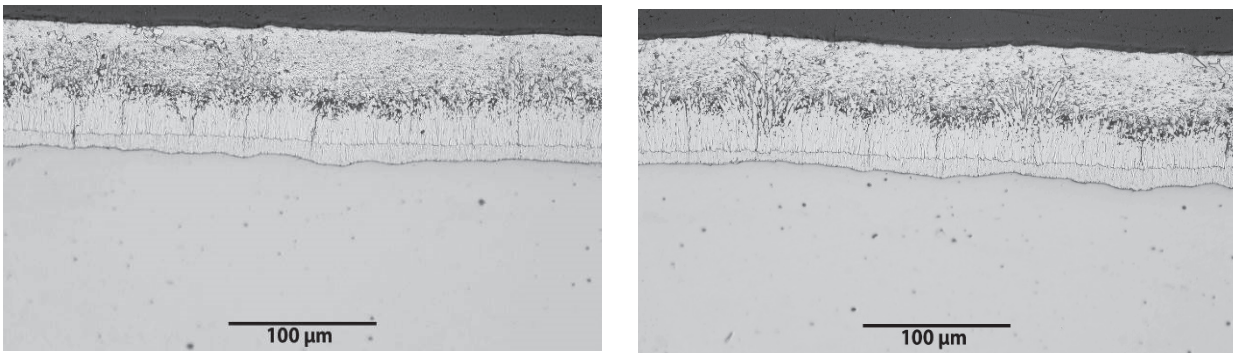

Figure 7 Cross section of zinc coating on internal surface (no deformed area)

The chemical analysis of substrate steel had been done too - **Table 4**. The chemical composition of substrate steel on tube sample is between the classes A (low Si steel) and C (Sandeline steel) according to EN ISO 14713-2. In respect to morphology of zinc coating representing the most typical phase's occurrence and thickness (**Figure 7**) the class A is most probably.

Table 4 Steel composition of sample (wt. %)

Mn	Si	P	Cr	Mn	Fe
0.32	0.05	0.01	0.03	0.32	99.53

The adhesion test was done on tube sample on both sides of tube - see **Figure 8**. The difference between external and internal sides is evident.

4. CONCLUSION

For more than 150 years the application of hot-dipped zinc coatings has been a standard method of corrosion protection of steel. It is a common mistake that the hot-dip galvanized coating is relatively easier to specify. Although hot-dip galvanizing has been utilized to protect steel for generations, the galvanizing process continues to evolve with many problems. Appearance and thickness are basic parameters of zinc coating and may indicate the problems with their adhesion.

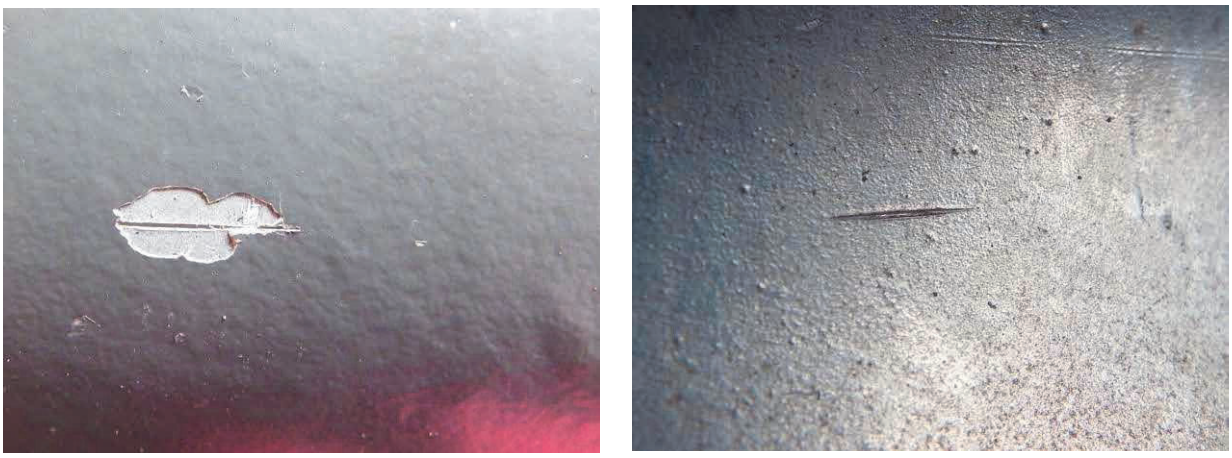

Figure 8 Zinc coating adhesion after test on external surface (left) and internal surface (right)

The test of effect of HAZ on cut edge shows some interesting results:

- the HAZ is more significant for thin steel plates,
- the thickness of zinc coating was the some on sample area and grinding cut edges,
- the hardness values are different according to used techniques - in field condition performed non-destructive measurement may give lower values than microhardness measured in laboratory conditions and with laboratory equipment,
- the adhesion of zinc coating was poor on practically all grinded edges,
- besides the hardness the profile has effect on zinc coating adhesion, too.

The case study shows the sweeping may negatively affected the adhesion of zinc coating (and also together with paint coating) but the adhesion decreasing occurred only as result of mechanical deformation of product or steel structure.

ACKNOWLEDGEMENTS

This paper was prepared in frame of project TH02020550 Research of the effect of chemical composition and metallurgical surface conditions of substrate steel onto quality of galvanized coating.

REFERENCES

[1] SEPPER, S.; PEETSALU, P.; MIKLI, V.; SAARNA, M.: The effect of substrate microstructure on morphology of zinc coatings, In: *8th International DAAAM Baltic Conference INDUSTRIAL ENGINEERING*, 19-21 April 2012, Tallinn, Estonia

[2] KŠIŇAN A., BARTOŠ M., Problematika prilňavosti a odlupovania zinku na plazmou delených plochách stykových dosiek a uzlov konštrukcií v energetike, In *All for power*, 2017, Vol. 11, No. 2 (in Slovak)

[3] WEGRZYNKIEWICZ S., The Influence of Surface Preparation of Steel 41Cr4 on the Nature and Corrosion Resistance of the Hot-dip Zinc Coating, In *METAL 2016: 25th International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2016, pp. 898-903.

[4] KREISLOVA K., GEIPLOVA H., TUREK L., BARTAK Z., KUDLACEK J., The parameters affecting adhesion of zinc coating, In *METAL 2016: 25th International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2016, pp. 904-909.

[5] GEIPLOVA H., MINDOS L., JAGLOVA M., Hot dip galvanized coating in practice, In *Proceedings of 19th Hot Dip galvanizing Conference*, 2013, Spindleruv Mlyn, ISBN 978-80-905298-1-6, pp.120- 133.