LONG-TERM ATMOSPHERIC CORROSION TEST OF 55ALUMINIUM-ZINC COATING

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Abstract

The zinc coating and/or zinc alloyed coating is one the most frequently used type of corrosion protection. This study was carried out to investigate and evaluate the corrosion behaviour of aluminium zinc alloy coated steel sheet at atmospheric condition. The aluminium-zinc hot dip coating was exposed for 10 years at industrial atmospheric test site Kopisty, Norther Bohemia. The article gives the overall evaluation of long-term exposed coating and progress of degradation of coating on cut-edges.

Keywords: Zinc alloyed coating, 55%Al-Zn, atmospheric test, coating morphology, corrosion

1. INTRODUCTION

The zinc coating and/or zinc alloyed coating is one the most frequently used type of corrosion protection. The hot-dip procedure was developed for coatings alloyed by aluminium and magnesium; the electrolyte deposition procedure can be used for zinc coatings alloyed by iron, nickel or cobalt. As here are so many alloyed zinc coatings they long-term corrosion resistance is tested in various conditions, mainly in accelerated laboratory tests. It is quite well known that the alloyed zinc coatings have better corrosion resistance than the "pure" zinc coating.

Technology of hot dip galvanising by alloyed coating zinc-aluminium was till used in continual processes - e.g. coatings with 5% Al and 55% Al contents. In 1962, the Bethlehem Steel commenced investigations into a range of AZ coatings applied to steel in the range 0 % to 70 % aluminium. After approximately eight years of continued development, the results clearly indicated that the 55 % AZ coating was the optimum coating composition. The results obtained after 13, 20, 22, 25 and 30 years of atmospheric exposure at rural, industrial, marine and severe marine sites demonstrated that the AZ coating was at least two to four times more corrosion resistant in all atmospheric test sites than conventional galvanized coating of similar thickness [1, 2].

Producers on the basis of over 30 years of monitoring at test sites, over 30 years of manufacturing experience and over 30 years of continuous research and improvement have enabled him to give 55Al-1.6Si-Zn coating with coating thickness 25 µm a 25-year warranty against perforation due to corrosion [3 - 7]. The aluminium-zinc hot dip coating was exposed for 10 years at atmospheric test site Kopisty, Norther Bohemia. The article gives the overall evaluation of exposed coating.

2. ALUMINIUM-ZINC HOT-DIP COATING CHARACTERISTICS

Coating 55Al-1.6Si-Zn (commercial Aluzinc, Galvalume, Zincalume, Zintro-Alum, galval, Zalutite and other brand names) is used since 1970 on flat rolled products - sheets, strips. Aluzinc is suitable for application in roofing, wall claddings, gutters and downpipes, and other applications where long life is an essential requirement. It is formable, weldable and readily accepts paint finishes. Aluzinc coated steel has superior long term corrosion resistance in most atmospheric conditions. The technical parameters of these products are specified in EN 10346 *Continuously hot-dip coated steel flat products - Technical delivery conditions.* EN 10346 covers products that are used where cold formability, high strength, a defined minimum yield strength and corrosion resistance are the most important factors.

The characteristic silver metallic colour with small spangles gives Aluzinc a very attractive appearance. This is preserved over time without dulling, thanks to a thin, transparent layer of aluminium oxides formed on the surface. Aluminium dendrites hold the zinc corrosion products on the surface. Although the corrosion performance is mostly related to the aluminium zinc alloy, the addition of approximation 1.5% silicon is vital. The primary purpose of the silicon is to control the growth of a brittle intermetallic layer that would otherwise form during manufacturing of the product [8]. The Zn-Al phase diagram has an eutectic composition at about 5 wt. % Al and an eutectoid at 22 wt. % Al. Coating is a two phase coating: aluminium rich dendrites (80% vol.) and zinc rich interdendritic zones (20% vol.) containing silicon rich particles (**Figure 1**). At the interface with the steel, there is an intermetallic layer AlZnFeSi (1 to 2 µm thick). The thickness of the intermetallic layer at the coating/steel substrate interface is mainly determined by the speed of the strip throw the bath.

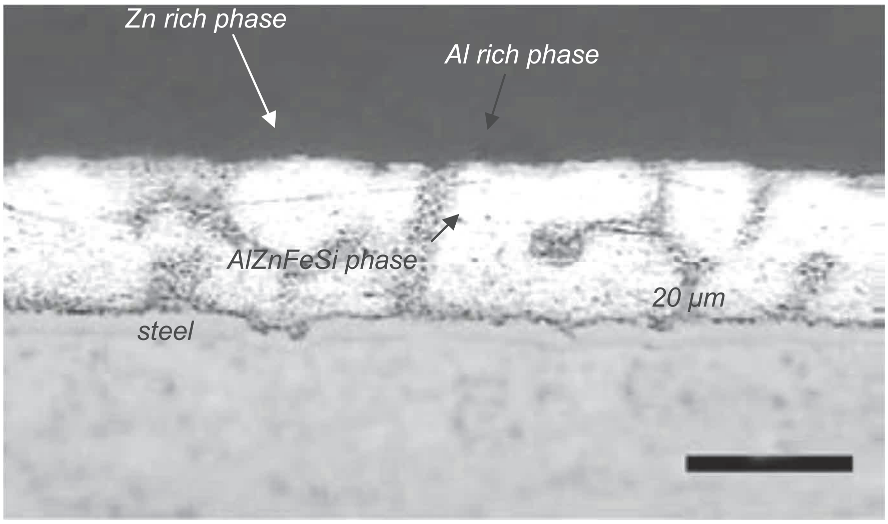


Figure 1 Micrographic cross-section of Aluzinc coating´s structure

Aluzinc combines the advantages of the two major components of the coating: the barrier effect of aluminium and the sacrificial protection of zinc, resulting in excellent resistance to surface corrosion. The aluminium protects the steel substrate, creating a shield between the surface and the atmosphere. The aluminium protects zinc melt age in concentrations from 10^{-3}% by creation very thin Al_2O_3 film on its surface and protects against quickly oxidation of coating. This aluminium barrier is very stable, as the aluminium oxide coating that forms on the surface is insoluble in most environments, thus ensuring a long-lasting resistance to corrosion. This gives the steel much improved corrosion resistance compared to traditional galvanised material through the joint action of the sacrificial cathodic action of the zinc, and the barrier of aluminium present on the surface. This gives the material more corrosion resistance to normal zinc galvanised coatings, making it ideal for the most demanding of corrosive environments. This high level of aluminium in the coating also aids the material in keeping its aesthetic appearance much longer than zinc galvanised material. Corrosion resistance of the product is proportional to the coating thickness, hence to its mass. According producer the corrosion rate, i.e. the thickness of the aluminium-zinc coating that is lost every year in a normal environment to which Aluzinc is freely exposed, is a maximum 0.2 µm.

The zinc component provides sacrificial cut edge protection - coating is anodic to substrate steel, so it gives the protective effect on the cut edges which duration depends on the environment corrosivity, the thickness of the coating, and the thickness of the steel sheet. Aluzinc coating is unable to protect a cut edge that is thicker than 1 - 2 mm.

In case of the limited access to oxygen, i.e. during storage in coil in high humidity or under snow cover, the oxide film will not re-form sufficiently quickly, and corrosion attack will occur. The products of corrosion will be black, normally very thin and does not affect the anti-corrosion properties of the coating, and is only an aesthetic blemish.

3. EXPERIMENTAL

3.1. Material and methods

Test site Kopisty, performed according to ISO 8565 [9] is located in Northern Bohemia region, near to Most city, where heavy industrial pollution was in past. On-site measurement of environmental data (temperature, relative humidity, rain, air pollution, etc.) was done during the exposure. The atmospheric corrosivity of locality was regularly estimated according to EN ISO 9223 [10] for zinc and aluminium, too.

Aluminium-zinc alloy coated steel sheet samples (55AlZn) were prepared for the study by cutting into 250 x 300 x 1.5 mm panels and exposed on rack at 45° to south. According to the commercial data, the thickness of coating layer was approximately 15 ~ 20 µm. In given yearly periods (1, 2, 3, … to 10) the panels had been withdrawn and evaluated. In 2016 the 10 years´ exposed panels were evaluated.

3.2. Atmospheric corrosivity at test site

On-site measurement of environmental data was statistically treated on yearly average values (**Table 1**). Based on coupons´ yearly corrosion loss, the corrosivity of atmosphere at the test site is estimated by degree C2 according to ISO 9223 for zinc (4.69 $g.m^{-2}$) and aluminium (0.23 $g.m^{-2}$).

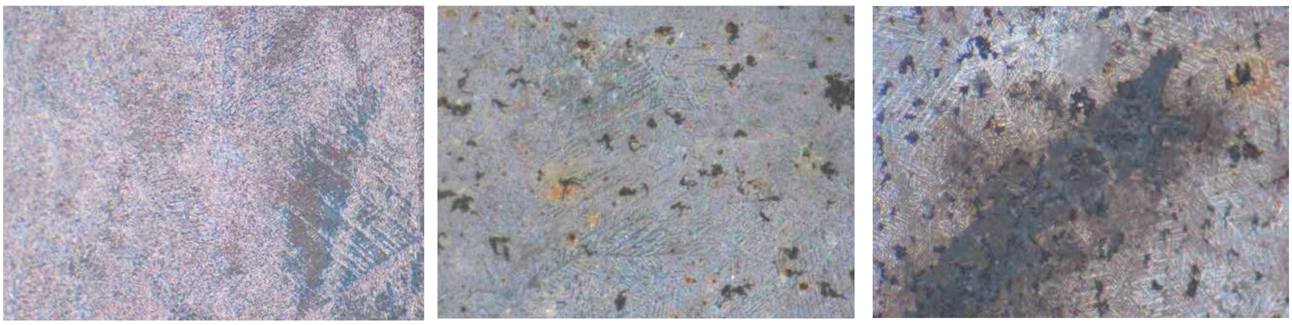
Table 1 Selected average annual environmental parameters at test site

T (°C)	RH (%)	SO_2 ($\mu g.m^{-3}$)	NO_x ($\mu g.m^{-3}$)	rain (mm)	pH of precipitation
10.1	76	17	26	527	5.4

3.3. Evaluation of exposed panels

After each year withdrawn the exposed coatings were examined under optical microscopy (50 x magnitudes) (**Figure 2**) and 3D digital microscope Keyence HVX-5000 (**Figure 3**). This figures show the non-uniform reduction of coating layer - different corrosion of zinc and aluminium phases. The average high difference is 3.5 µm between zinc and aluminium phases.

The 55AlZn coating thickness was measured by non-destructive magnetic method according to EN 13523-1. Measured values only negligible differ in each year exposure. After 10 years´ exposure the average reduction of thickness was only ca 3 µm from the original value.



1 year 5 years 10 years

Figure 2 Appearance of Aluzinc panels after various exposure periods (50x magnitudes)

The cross section of 10 years´ exposed coating was examined and presented in **Figure 4**. 55AlZn coating corrodes by uniform corrosion. The corrosion on the panel is evident as very thin homogenous layer of corrosion product on coating created by Al phase. The corrosion was concentrated in interdendritic Zn-rich region. In spot where the Zn phase is reach the coating surface the corrosion attack deeply penetrate in coating and follows the Zn phase. The residual coating thickness was measured on cross section, too. The average value of residual coating layer was 25 µm and confirms the very low corrosion rate of coating.

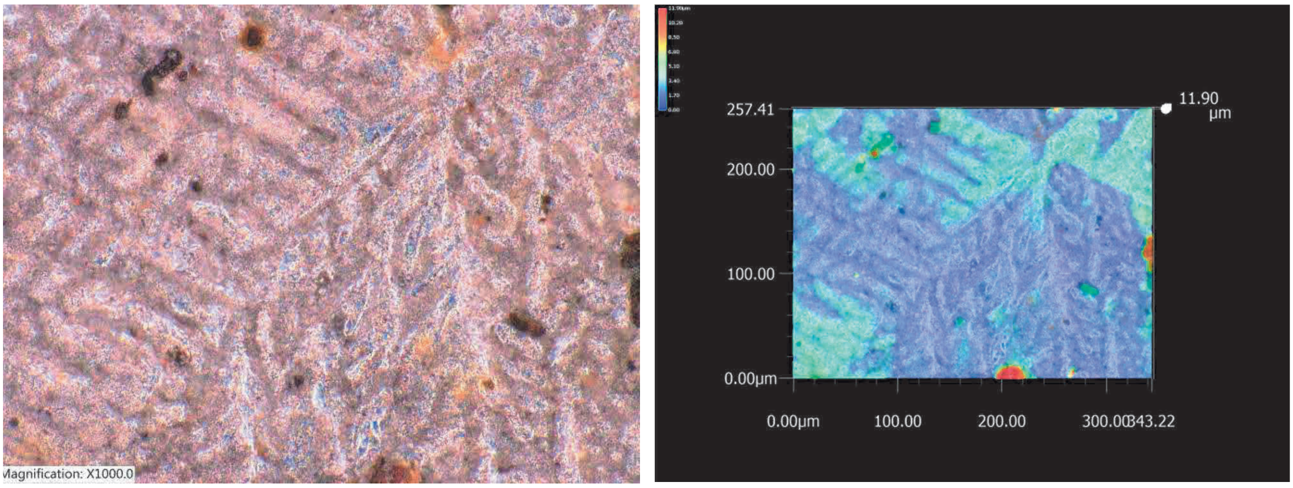


Figure 3 Detail of Aluzinc surface after 10 years exposure period

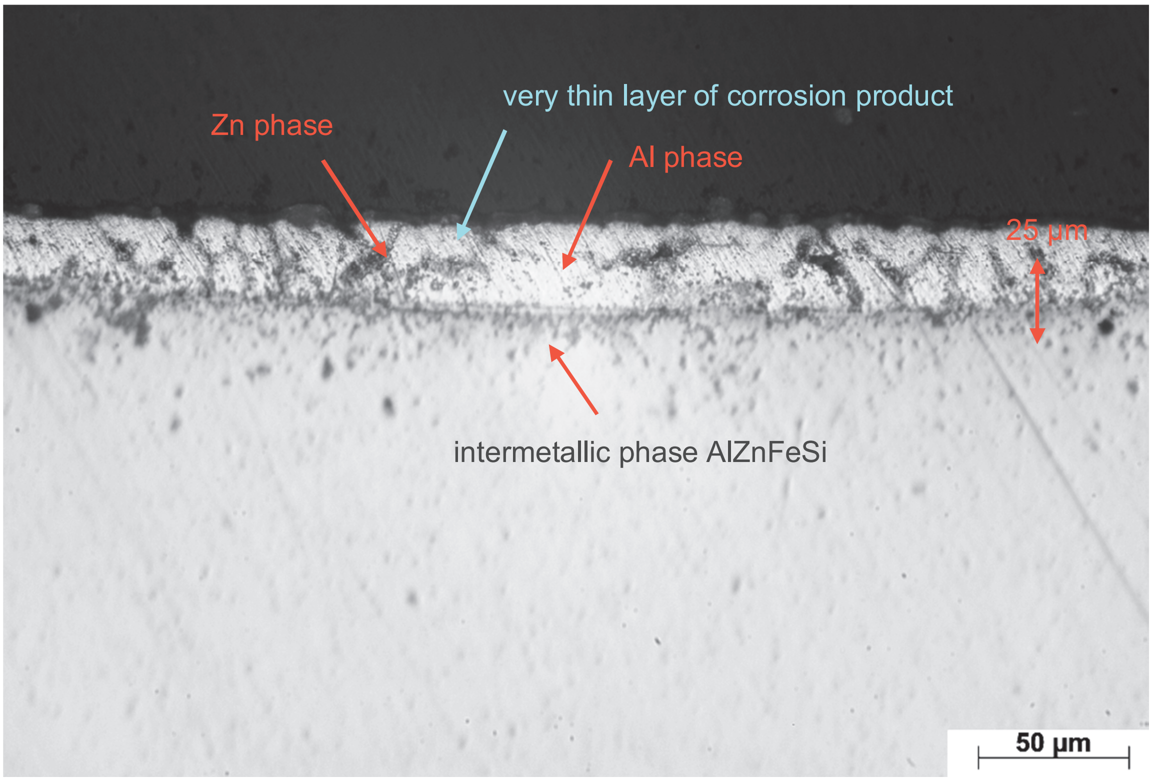


Figure 4 Cross section of of Aluzinc panels after 10 years exposure

The 55AlZn sheets are mostly used as non-painted roof or cladding of building the corrosion of cut-edges is very important factor. The corrosion progress on cut-edges is evident after 10 years of exposure (**Figure 5**). The 55AlZn coating was corroded from the side edges to ca 200 µm where the 55AlZn was removed and thin layer of steel corrosion product formed. On the lower edge (slope 45°) the affected area was only ca 50 µm and the voluminous layer of steel corrosion product formed. Zinc/aluminium alloy coatings may have a tendency to weather to either a white or a medium- to dark- grey colour depending on the environment. This oxidation does not affect their service life. As corrosion product formed a very thin layer the XRF analysis showed only the dust deposition. FTIR analysis shows presence of zinc chloride composition but not the simple one.

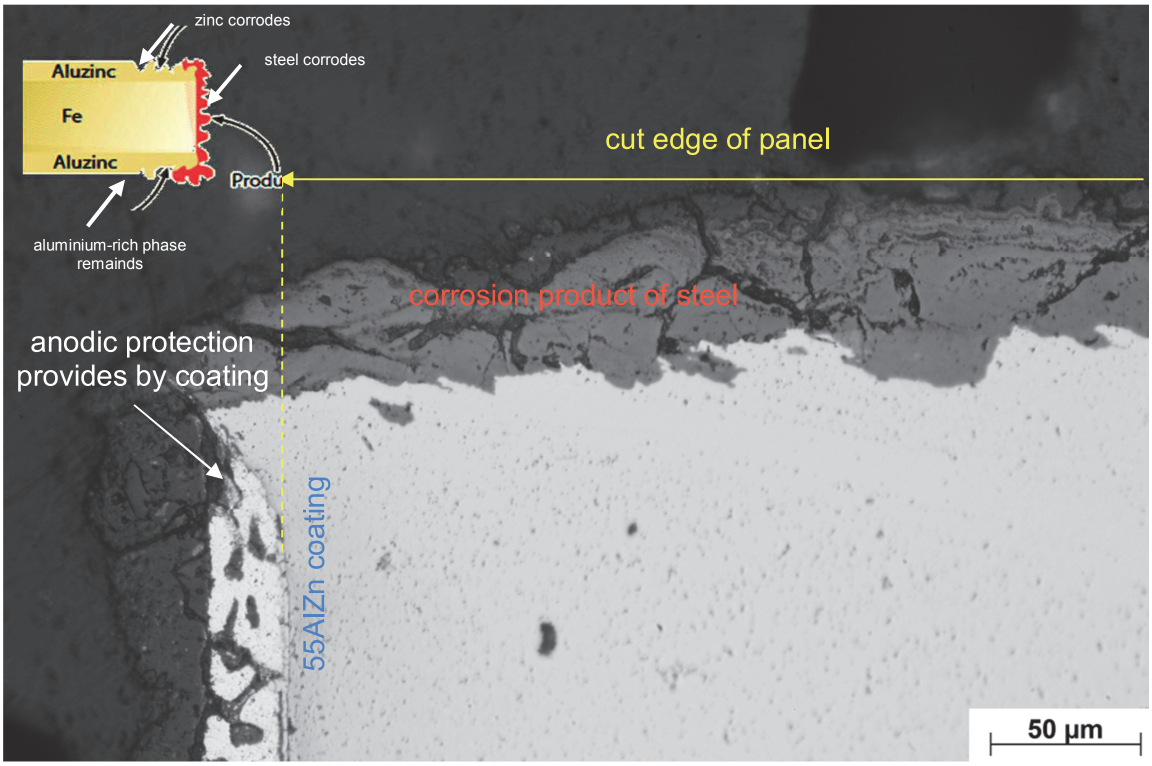


Figure 5 Cross section of of Aluzinc panels after 10 years exposure

4. DISCUSSION

Prediction of durability of zinc coating can be done on the basis of knowledge of their thickness and zinc corrosion rate in given environment. The general values for atmospheric environments are published in technical standards EN ISO 9223 and EN ISO 9224. For zinc and zinc coating there is available a lot of corrosion data. The alloyed zinc coating as 55Al-1.6Si-Zn is more corrosion resistant in field and laboratory tests [11]. Average corrosion rate after 10 years exposure at atmospheric test site Kopisty was:

- 0.33 $\mu m.a^{-1}$ for metallic zinc,
- 0.50 $\mu m.a^{-1}$ for hot dip galvanised coating; and
- 0.30 $\mu m.a^{-1}$ for 55AlZn coating - mainly in Zn phase.

These results are not such promising as published data, but it may be caused the fact the tests performed in 1970-1980s years were mostly conducted in more corrosive atmospheres.

Aluminium has a strong oxidation tendency in an atmosphere, and forms a layer of alumina $2Al_2O_3$ which is compact and stable. A thin film of Al_2O_3 has a good protective ability to prevent the Al-rich alloy phase from further corrosion. The Zn-rich phase, however, does not have the ability to form this type of protective film. Therefore, corrosion took place first in the Zn-rich phase. The durability of the sheared edges is linked to the mount of zinc in coating in relation to the ratio between coating and sheet thickness. The critical thickness limits of the substrate and coating with respect to corrosion must be established in each case individually, depending on the application.

5. CONCLUSION

In building and construction, metallic coated sheet has been used in the form of profiled parts for roofing, cladding and as cold formed sections for many years. The surveys of roofs from 55Al-Zn sheets with a nominal coating thickness of 20-25 µm and a nominal coating weight of 150 g/m^2 in both the USA and Europe shows their good to excellent condition both technically and aesthetically [12]. Roofs examined were mainly in urban, industrial, marine and acid rain environments, and ranged in age from 9 to 30 years. Most had a slope of less than 10°.

This study was carried out to investigate and evaluate the long-term corrosion behaviour of aluminium zinc alloy coated steel sheet exposed for 10 years comparing with those of the Zn-coated steel [13]. The mechanism of corrosion in 55AlZn coating can be explained quite well because of the coating structure and different corrosion behaviour of zinc and aluminium phases. In industrial or rural atmospheres this coating behaves like an aluminium coating with edge protection being provided by the galvanic action of the zinc-rich phase [14].

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