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Surface treatments counteracting galvanic corrosion from steel screws – outdoor exposure

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Title

Surface treatments counteracting galvanic corrosion from steel screws – outdoor exposure

Summary

Screws of different materials are used as fasteners in aluminium constructions. Stainless steel and surface treated carbon steel are two widely used materials for the screws. There is a risk for galvanic corrosion when using screws made of other materials mounted to aluminium in atmospheres containing chlorides. In this project the combinations of steel screws with different surface treatments mounted to aluminium of alloy AA6063, anodised as well as not surface treated, were exposed to marine atmosphere. The galvanic action between the material combinations was investigated after 10 years of exposure.

The lack of quality regarding the surface treatments of the screws has influenced the results but this study gives some hints about using aluminium together with different screw materials.

Some conclusions are:

- Galvanic corrosion was seen under the screw head for all material combinations.
- The carbon steel screws were not fully protected by the surface treatments.
- The stainless steel screws, both with and without treatment, were more corrosion resistant than any of the surface treated carbon steel screws.

The combination of anodised extrusions/stainless steel screws showed the best corrosion properties.

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1 Introduction

Screws of different materials are used as fasteners in aluminium constructions. Stainless steel and surface treated carbon steel are two widely used materials for the screws. There is a risk for galvanic corrosion when using screws made of other materials mounted to aluminium in atmospheres containing chlorides. In this project the combinations of steel screws with different surface treatments mounted to aluminium of alloy AA6063, anodised as well as not surface treated, were exposed to a marine atmosphere. The galvanic action between the material combinations was investigated after 10 years of exposure.

2 Materials and Experimental

2.1 Materials

2.1.1 Screws

Screws of two different base materials, carbon steel and stainless steel, were included in the test. Different surface treatments were evaluated with respect to their ability to retard or prevent corrosion. The dimension of the screws was 6.3 x 38 mm. The base of the heads was 12 mm in diameter. The surface treatment and screw materials are shown in Table 1.

Table 1 The surface treatment and screw materials.

Code in this test	Base material, alloy	Surface treatment according to spec.
0	Carbon steel (Sapa 12 190), SS1370	5 µm zinc + yellow chromate
0R	Carbon steel (Sapa 12 190), SS1370	5 µm zinc + yellow chromate + Rotalyt
5	Stainless steel A2 (Sapa 12 185), SS2332	5 µm zinc + wax
5R	Stainless steel A2 (Sapa 12 185), SS2332	5 µm zinc + wax + Rotalyt

According to [1], the 5 µm zinc-plating (electro plating) and the yellow (transparent) chromate layer were present on the screws from Sapa. The mechanical plating using the Rotalyt-technique to obtain a zinc/aluminium layer on the screws were performed at G. Rösler Oberflächentechnik, Lüdenscheid, Germany.

Rotalyt is a well-established metal plating process by which different metals or metal combinations are plated onto the substrate. Zinc, zinc/tin, zinc/cadmium, and zinc/aluminium are common plating materials. Different adjustments of the process can be made, for instance in order to obtain material with thicker layers or lower friction. Further surface treatment such as chromating can be applied after the Rotalyt-treatment. In the present case zinc/aluminium was asked for without any friction reducing additives or subsequent chromating.

Referring to [1] the composition of the surface coating of unexposed screws was examined using SEM-EDX. The results were as follows:

- The zinc-layer of the carbon steel screws was thinner than planned and unevenly distributed. The thickness ranged from 0 to approx. 2 µm.
- There was no zinc-layer at all on the stainless steel screws.

- The Rotalyt layer was of tin/aluminium type (and not zinc/aluminium). The thickness of the layer varied from 0 to approx. 50 µm.

2.1.2 Extrusions

The screws were fixed to aluminium extrusions before the exposure to the corrosive environment. The aluminium alloy used was AA6063 (Sapa code HIP). Anodised as well as not surface treated profiles were included. The thickness of the anodised layer (average of five measurements) varied between the samples from 16 to 21 µm (with a standard deviation between 0.5 and 1.5 µm for each sample).

2.1.3 Assembling

The aluminium extrusions were flat panels, 50 mm wide and 2 mm thick. They were cut in 150 mm long sections for the outdoor exposure. On each section a central hole, 4.9 mm in diameter, was drilled for the screw fixing.

All four screw variants were tested with both kinds of aluminium surface, anodised and not surface treated. Duplicate samples of the Rotalyt treated combinations and one sample of the other variants were used.

2.2 Experimental

2.2.1 Field exposure

The outdoor exposures were performed at the test station Kvarnvik (Bohus Malmön) on the west coast of Sweden. The test station is located a few metres from the coast line, and during hard weather water droplets from the sea hit the samples. All samples were positioned with the surface 45° from the horizontal plane, in a direction towards south, as shown in Figure 1.

2.2.2 Investigations

The surface appearance of the screws and extrusions was visually investigated.

3 Results

3.1 Surface appearance of screws and extrusions

The appearance of the screw and extrusion was evaluated after 10 years of outdoor exposure to a marine atmosphere. The results for the screws are shown in Table 2. No red rust could be discovered on the stainless steel screws, irrespective of the surface treatment of the extrusion or the screw.

The appearance of the surfaces of the extrusions and screws before cleaning after 10 years exposure are shown in Figures 2a-h. The not anodised profiles had small corrosion pits evenly distributed over the surface. The corrosion was more severe under the screw head than elsewhere. This is the case irrespective of the surface treatment. The cause is galvanic corrosion. After 10 years no rust was seen on the stainless steel screws. Referring to [1], the carbon steel screws started to show red rust after two years of exposure and there was no difference in this respect between carbon steel screws with different surface treatments. After three years galvanic corrosion was visible close to the screws for the not anodised material (regardless of screw material).

Table 2 Surface appearance of the screws after 10 years exposure.

Material		Surface appearance of the screws after 10 years exposure*	
Extrusion	Screw	head	thread
No surface treatment	Carbon steel	3	3
No surface treatment	Carbon steel + rotalyt	3	3
No surface treatment	Stainless steel	0	0
No surface treatment	Stainless steel + rotalyt	0	0
Anodized	Carbon steel	3	2
Anodized	Carbon steel + rotalyt	3	3
Anodized	Stainless steel	0	0
Anodized	Stainless steel + rotalyt	0	0

* Codes: 0=No red rust

1=The surface has begun to rust

2=The surface is rusty

3=The surface is heavily rusty

3.2 Sections of extrusions

Sections of the extrusions were made for studies in light optical microscope, as shown in Figures 3a-h. The corrosion attacks seem to be severe and more widely spread on the not surface treated extrusions than on the anodised extrusions.

4 Discussions and conclusion

The results from outdoor exposure are in good accordance with the SWAAT results in Ref. [1]. The lack of quality in the surface treatment of the screws, which was found in the previous investigation has most probably influenced the results, but this study gives some hints about using aluminium together with different screw materials.

Some conclusions are:

- Galvanic corrosion was seen under the screw head for all material combinations.
- The carbon steel screws were not fully protected by the surface treatments.
- The stainless steel screws, both with and without treatment, were more corrosion resistant than any of the surface treated carbon steel screws.
- The combination of anodised extrusions/stainless screws showed the best corrosion properties.

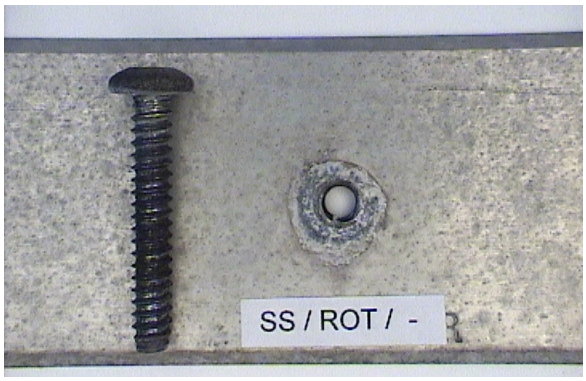
References

[1] Astrid Magnusson
Surface treatments counteracting galvanic corrosion from steel screws
Technical Report T95/951, August 9, 1995

Figure 1

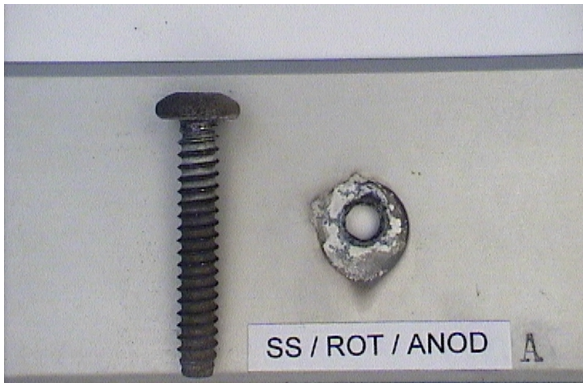
A photo of the samples during exposure at the test station Kvarnvik (Bohus Malmön).

a) Stainless steel screw / no surface treated extrusion



b) Stainless steel screw / Rotalyt / no surface treated extrusion

c) Stainless steel screw / anodised extrusion



d) Stainless steel screw / Rotalyt / anodised extrusion

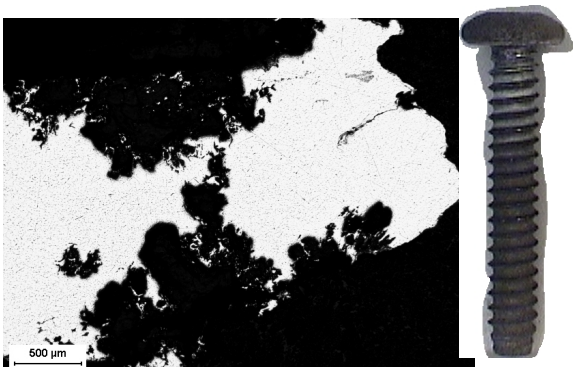
e) Carbon steel screw / no surface treated extrusion

f) Carbon steel screw / Rotalyt / no surface treated extrusion

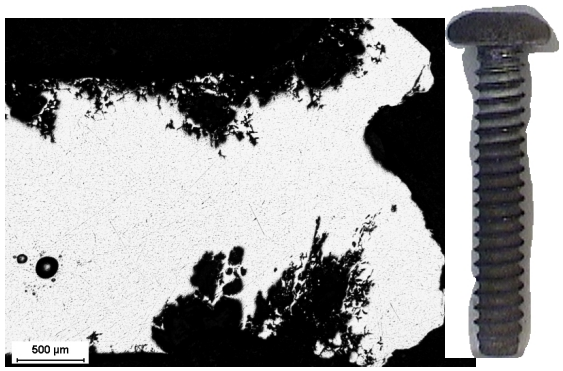
g) Carbon steel screw / anodised extrusion

h) Carbon steel screw / Rotalyt / anodised extrusion

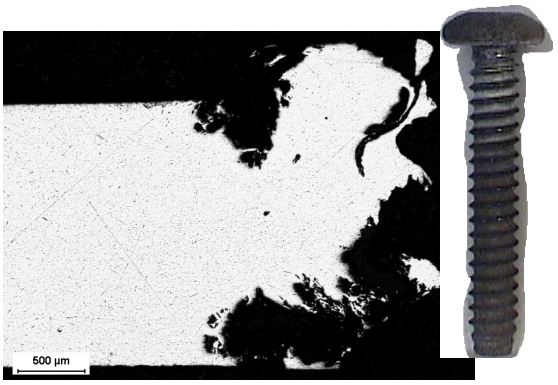
Figure 2 The appearance of the surfaces of the extrusions and screws after 10 years exposure.



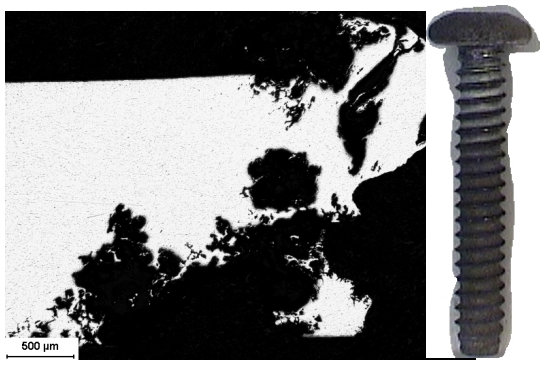
a) Stainless steel screw / no surface treated extrusion



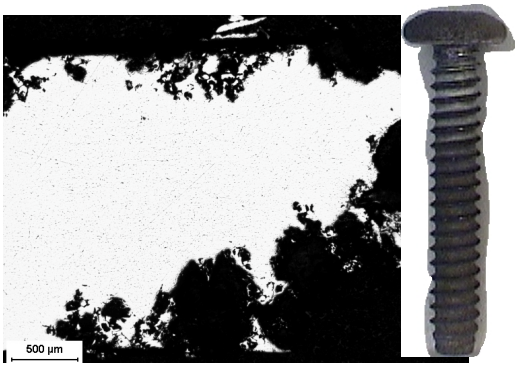
b) Stainless steel screw / Rotalyt / no surface treated extrusion



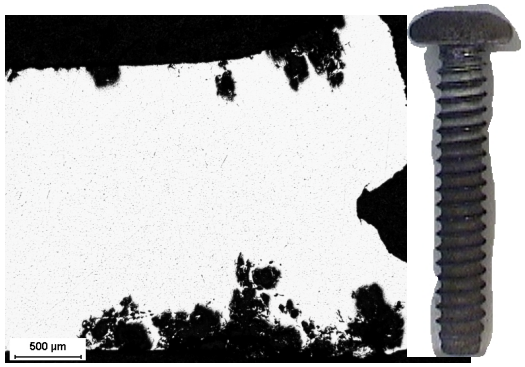
c) Stainless steel screw / anodised extrusion



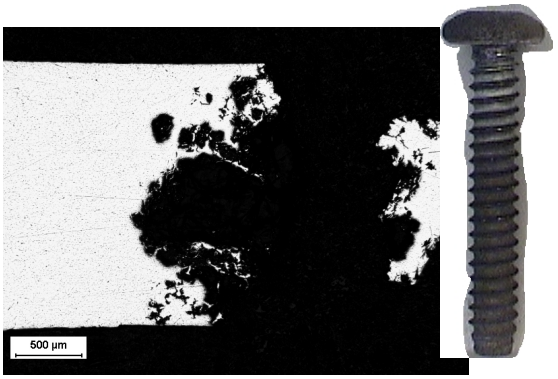
d) Stainless steel screw / Rotalyt / anodised extrusion



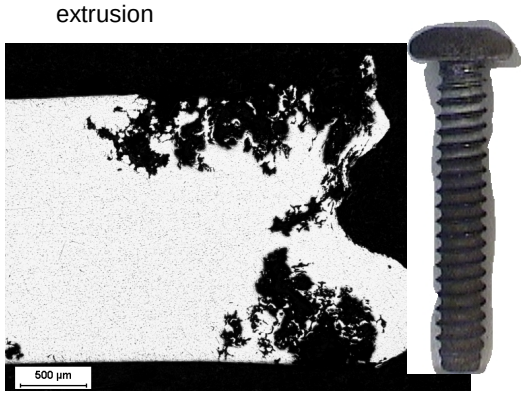
e) Carbon steel screw / no surface treated extrusion



f) Carbon steel screw / Rotalyt / no surface treated extrusion



g) Carbon steel screw / anodised extrusion



h) Carbon steel screw / Rotalyt / anodised extrusion

Figure 3 Sections of the extrusions after 10 years exposure. Sections were made through the holes. The screw was positioned to the right in the figures with the screw head turned up. The screw is not in proportion to the profile in the figures. The thickness of the profile is 2 mm and the screw length is 38 mm.

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