SALT SPRAY CHAMBER TEST OF A COATED STEEL MOUNTED ON ALUMINUM PROFILE

Technical Report

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Objective:
Evaluation of a helideck setup performance after 672 h of exposure in the salt spray chamber.

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SUMMARY

Tranberg – one of the manufacturers of helideck offshore installations and equipment – requested DNV GL, Bergen to expose in the salt spray chamber for 672 h (4 weeks) a helideck design and evaluate its performance. The main purpose of the test was to examine the susceptibility to galvanic corrosion of the aluminium helideck under the coated steel coupons. As a reference, uncoated steel coupons were installed on the helideck as well.

The results showed excellent corrosion resistance of the stainless steel coupons and the coating, and no signs of galvanic corrosion on the aluminium helideck under the coated steel coupons. On contrary, the aluminium helideck under the uncoated coupons was corroded significantly.

It was concluded that the coated steel coupons did not induce any galvanic corrosion on the aluminium deck during the exposure in the simulated marine environment (salt spray chamber). As long as both materials are electrically isolated from each other by an undamaged coating or comparable means, no galvanic corrosion is expected in the field.
1 INTRODUCTION

A helideck is considered as one of the integral parts of the overall offshore installation. In most of the cases it is constructed of light, uncoated, seawater resistant aluminium alloys. When higher strength materials are needed to support the designed structure, steel alloys are used.1 However, on the connections between aluminium and steel materials, a danger of galvanic corrosion exists. As one of the precautions the steel materials are coated.

To evaluate the performance of their helideck design (Figure 1-1), Tranberg – one of the manufacturers of helideck offshore installations and equipment – requested DNV GL, Bergen to expose the setup in a salt spray chamber for 672 h (4 weeks). The main purpose of the test was to examine the susceptibility to galvanic corrosion of the aluminium helideck under the coated steel coupons. As a reference, uncoated steel coupons were installed on the helideck as well.

![Figure 1-1 Test sample setup scheme](image-url)
2 PROCEDURE

Tranberg delivered a test sample composed of a helideck plate with coated and uncoated metallic coupons, mounted on the plate using blind rivets (Figure 2-1) to DNV GL, Bergen. According to the documentation received from Tranberg, the following materials were used in the test setup:

- Helideck plate: aluminum alloy EN 6082-T6, 1000 mm x 281 mm
- Coupons: stainless steel AISI 316L, 50 mm x 50 mm
- Blind rivets: Avdel Monobolt 2717 A4, stainless steel AISI 316, Ø 4.8 mm

The test sample was exposed in a salt spray chamber under the following conditions shown in Table 2-1.

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<td>Electrolyte</td>
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<td>pH</td>
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<tr>
<td>Pressure [kPa]</td>
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<tr>
<td>Relative humidity [%]</td>
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<td>Exposure time [h]</td>
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Figure 2-1 Test sample composed of an aluminum helideck plate, and coated & uncoated stainless steel plates, mounted on the plate using stainless steel blind rivets.

After the test termination the test samples were visually inspected. The test setup was subsequently disassembled to perform further microscopic examination of the plate, coupons and blind rivets. Both surface and the cross-section of the materials were investigated to reveal the signs of corrosion. The results are presented in the following section.
3 RESULTS

3.1 Blind rivets

Macroscopic appearance of the blind rivets after 672 h of exposure in the salt spray chamber is shown in Figure 3-1: A. Most of the blind rivets did not show any signs of corrosion observed macroscopically. However, some of them had orange-brown "deposits" between the nut head and the mandrel, presumed to be iron oxides and/or hydroxides compounds – common corrosion products on low-alloyed steel materials.

Considering the steel grade from which the blind rivets were manufactured (stainless steel, grade 316) the observed corrosion products are more likely to form in highly acidic, i.e. low pH, environments. Given that the test in the salt spray chamber is performed under neutral pH conditions, a possible explanation of the formed iron compounds between the nut head and the mandrel could be the presence of a crevice.

![Figure 3-1](image.jpg)

**Figure 3-1** Blind rivets after exposure (A) and zoomed-in entrance of the nut showing a crevice presence (B).

Examining the nut head under stereo microscope revealed the presence of a crevice between the nut head and the mandrel, indeed (Figure 3-1: B), confirming thus the possibility of extremely low pH environment generation inside the observed gab. The main reason for pH decrease and the resulting dissolution of a passive layer on stainless steel materials in such environments is the oxygen depletion inside the narrow crevices. The outer material presents a large cathode area in such cases, while the inner acts as an anode. Inside the gap iron cations accumulate, causing a substantial diffusion of aggressive chloride ions into the crevice in order to maintain the electrical neutrality. Consequently, the unstable iron chlorides hydrolyze and highly acidic conditions inside the crevice are formed./2/
3.2 Steel coupons

Macroscopic appearance of the steel coupons after 672 h of exposure in salt spray chamber is shown in Figure 3-2.

![Steel coupons](image)

**Figure 3-2** Stainless steel coupons after cleaning: outer uncoated and coated side (A) and inner (aluminum plate side) uncoated and coated side (B).

No significant difference on the outer and inner coupons surface can be seen on the photos (Figure 3-2: A vs. B). Uncoated steel surface contains some mechanically induced marks/scratches. These could be attributed to the coupons “handling”, since they were observed also prior to the test.

Further microscopic examination of the surface topography (Figure 3-3) revealed no signs of corrosion on the uncoated coupons (Figure 3-3: A) nor coating damage on the coated coupons (Figure 3-3: B). The steel surface was somewhat rougher under the coating, due to the sand blasting and chemical treatment prior to the coating application, as confirmed by Tranberg.
3.3 Aluminum plate

Macroscopic appearance of the aluminum helideck plate below the installed steel coupons is shown in Figure 3-4.

A clear indication of aluminum degradation can be observed below the uncoated steel coupons (Figure 3-4: A). The surface is rougher and show signs of pitting corrosion, confirmed with the cross-section analysis (Figure 3-5: A1 and A2). The pits were deeper on the section directly in contact with the coupons (Figure 3-5: A2), but more dense on the flat section of the plate (Figure 3-5: A1).

On the other hand, aluminum surface below the coated steel coupons did not show any major signs of corrosion (Figure 3-4: B). The surface was slightly discolored, but smooth, with no signs of corrosion attack on the flat portion of the plate (Figure 3-5: B1). However, the section that was directly in contact with the coupons revealed signs of general corrosion (Figure 3-5: B2). Since the coated metal coupons that were attached on this part of the aluminum plate did not show any signs of coating or steel
degradation whatsoever (as noted in the text above, Section 3.1), the possibility of galvanic corrosion in this case can be excluded. Therefore, the observed preferential dissolution of aluminum on this particular location on the plate could be explained by the presence of a narrow crevice between the plate and the coupon, causing thus a localized (i.e. crevice) corrosion to occur. Such assumption could be supported also by the fact that the passive layer on the aluminum tends to dissolve under extremely low pH conditions, which are commonly generated inside the narrow gaps, as already explained in the text above (Section 3.1)./2/./3/

Based on the observed differences in the appearances of the aluminum surface below the coated and uncoated steel coupons, one can conclude that the main reason for the observed corrosion of the aluminum plate under the uncoated steel coupons is the galvanic corrosion, due to the direct contact of two different metallic materials (aluminum – steel) and the presence of an electrolyte (i.e. seawater) between them. Also, no indication of galvanic corrosion in the system setup can be seen at the connection point between the aluminum helideck plate and the coated steel coupons.

**Figure 3-5** Surface topography of aluminum plate below the uncoated (A1, A2) and coated steel coupons (B1, B2)
4 CONCLUSIONS

After the exposure of a helideck plate (aluminum alloy EN 6082-T6) with mounted coated and uncoated stainless steel coupons (grade 316L) and blind rivets (grade 316) in the salt spray chamber for 672 h (4 weeks), the following observations were made:

- 20 % of blind rivets experienced crevice corrosion between the nut head and the mandrel
- excellent corrosion resistance of the stainless steel coupons and the coating
- significant galvanic corrosion on the aluminium plate below the uncoated steel coupons
- no signs of galvanic corrosion on the aluminium plate below the coated coupons

Based on the observations above, it can be concluded that the coated steel coupons did not induce any galvanic corrosion on the aluminium deck during the exposure in the simulated marine environment (salt spray chamber) after 672 hours. As long as both materials are electrically isolated from each other by an undamaged coating or comparable means, no galvanic corrosion is expected in the field.
5 REFERENCES

/1/ NORSOK standard C-004, Rev. 1, September 2004


APPENDIX A
Photographic documentation

This following section shows photos of 10 blind rivets and 6 coupons, exposed additionally to the helideck setup in the salt spray chamber for 672 h.
Figure A-1  Appearance of stainless steel blind rivets after 672 h of exposure in the salt spray chamber.
Figure A-2  Appearance of stainless steel blind rivets after 672 h of exposure in the salt spray chamber.
Figure A-3  Appearance of both sides of uncoated stainless steel coupons after 672 h of exposure in the salt spray chamber.
Figure A-4  Appearance of both sides of coated stainless steel coupons after 672 h of exposure in the salt spray chamber.
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