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Galvanic corrosion in steel-aluminium connections

Ole Øystein Knudsen





Successful use of AI offshore

Insulation of AI from steel



Photo:
Roald Lilletvedt
NTNU



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Galvanic corrosion in submerged conditions



- Aluminium parts on subsea ROV
- Stainless steel parts mounted on anodized aluminium (thick film anodized, 50 μm)
- Corrosion in the crevices
- No cathodic protection?
- CP probably not able to penetrate the crevice due to high resistance



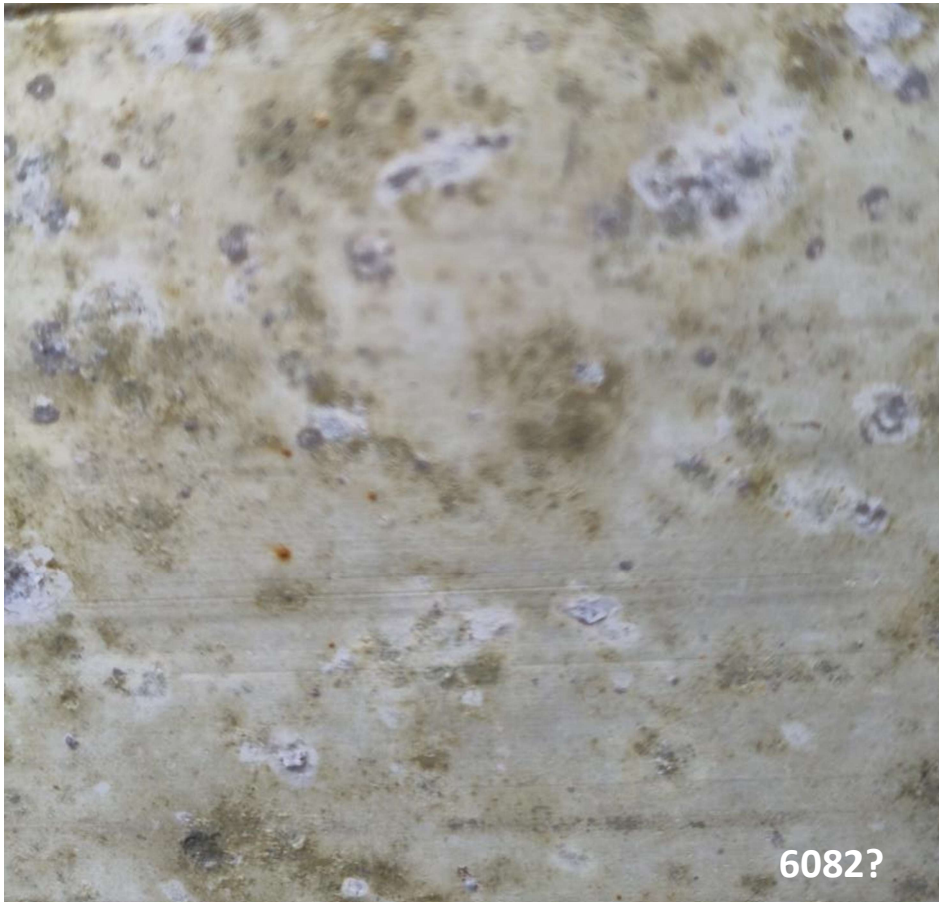
Aluminium corrosion on O&G plattform 1990 – 2021



<https://www.nrk.no/vestland/her-vert-gyda-plattform-sendt-rett-i-bakken-1.16600957>



The surfaces look good





Galvanic corrosion





Report

- Standards and design codes
- Corrosion tests for Al in marine environments
- Coating tests for Al in marine environments
- Reported issues with corrosion in marine environments

The cover of the project report features a background image of turbulent, dark blue and green water. In the top left corner, there is a small SINTEF logo. In the top right corner, there is a logo for 'marinAl' which includes a stylized wave graphic above the text 'marinAl'. The main title 'Project Report' is displayed in a large, bold, dark blue font. Below this, the title 'Corrosion of aluminium in marine environments' is shown in a smaller, bold, dark blue font, followed by the subtitle 'Reported issues and standards' in a smaller, regular font. The authors 'Ole Øystein Knudsen, Jan Bertram' are listed under the heading 'Author(s)'. The report number '2022:00249 - Unrestricted' is provided under 'Report No:'. The client 'MARINAL consortium' is listed under 'Client(s)'. At the bottom of the cover, the SINTEF slogan 'Teknologi for et bedre samfunn' is written in white, and the English translation 'Technology for a better society' is written in white on a dark blue background.



Project Report

Corrosion of aluminium in marine environments

Reported issues and standards

Author(s):

Ole Øystein Knudsen, Jan Bertram

Report No:

2022:00249 - Unrestricted

Client(s):

MARINAL consortium

Teknologi for et bedre samfunn

Technology for a better society

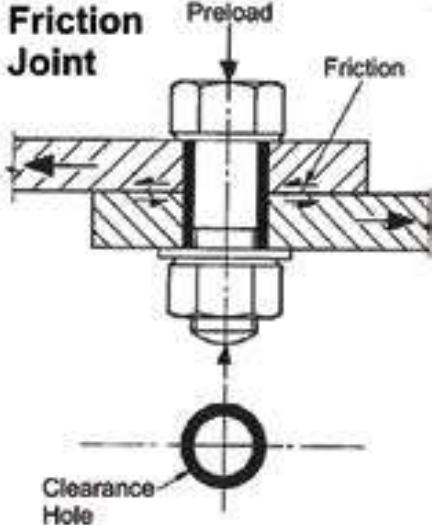
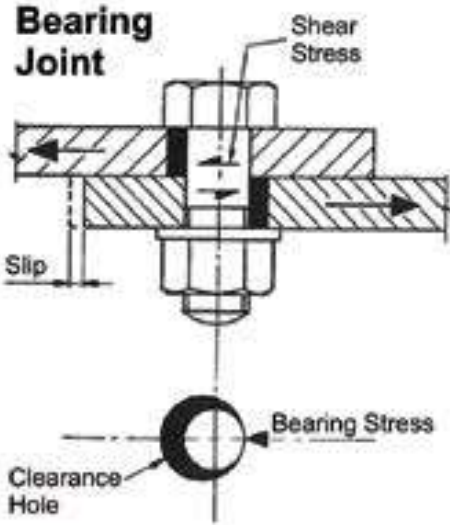


Al-steel joint design



Electrical insulation has sometimes failed

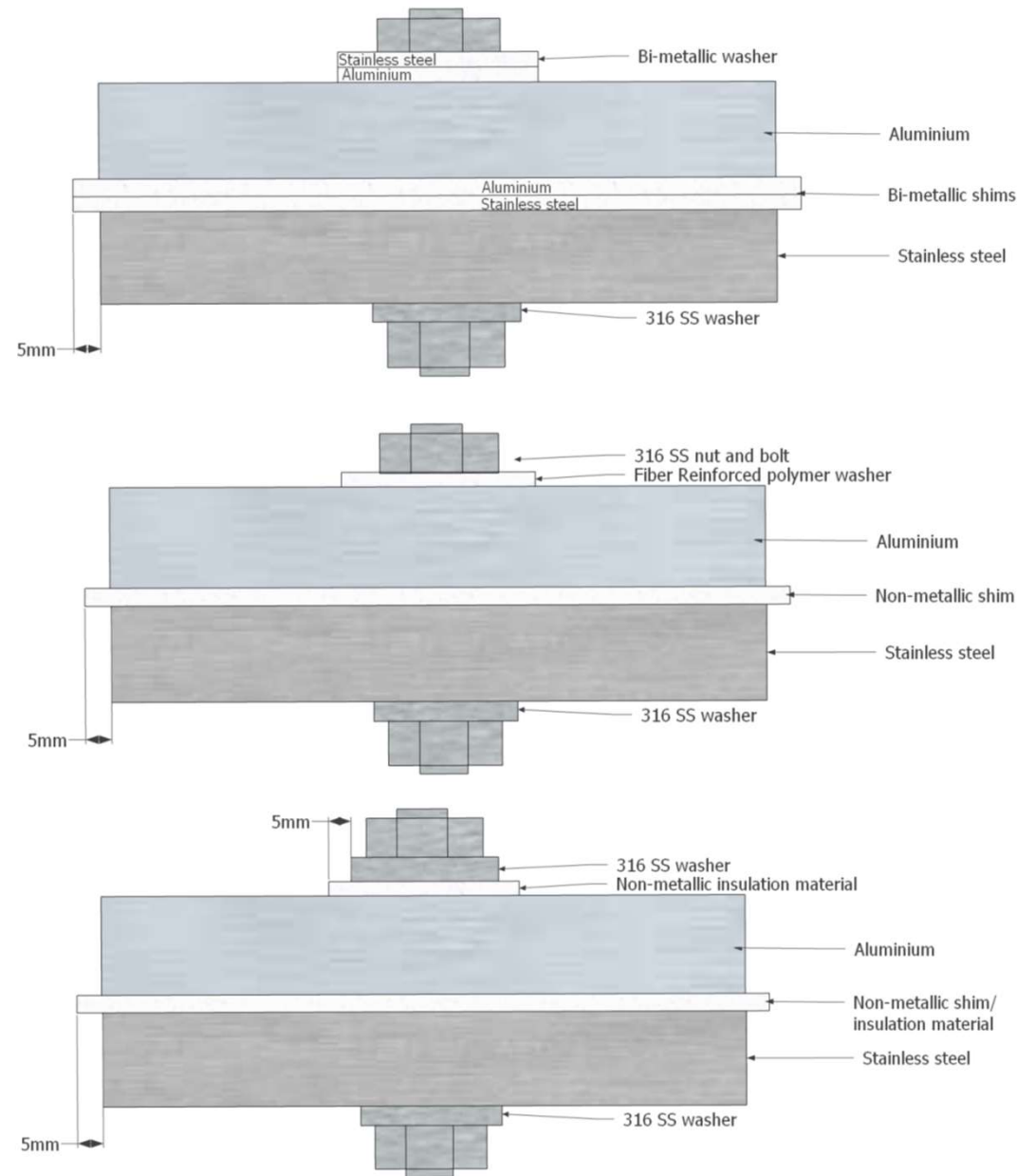
Failure due to mechanical loading of the polymer





NORSOK M-001:2014 Annex A1

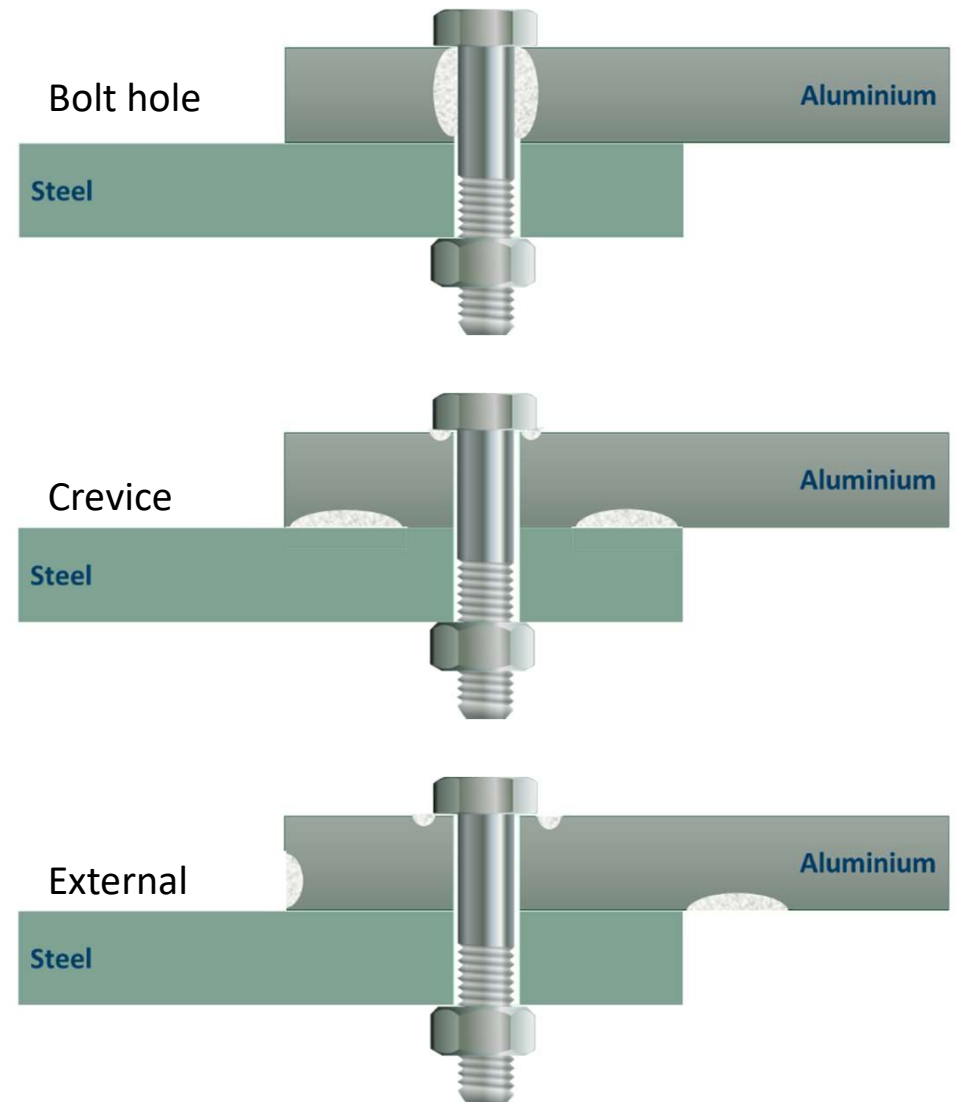
- Nonmetallic shim or bimetallic shim
- Nonmetallic, FRP or bimetallic washer
- Shims are to extend 5 mm beyond the aluminium





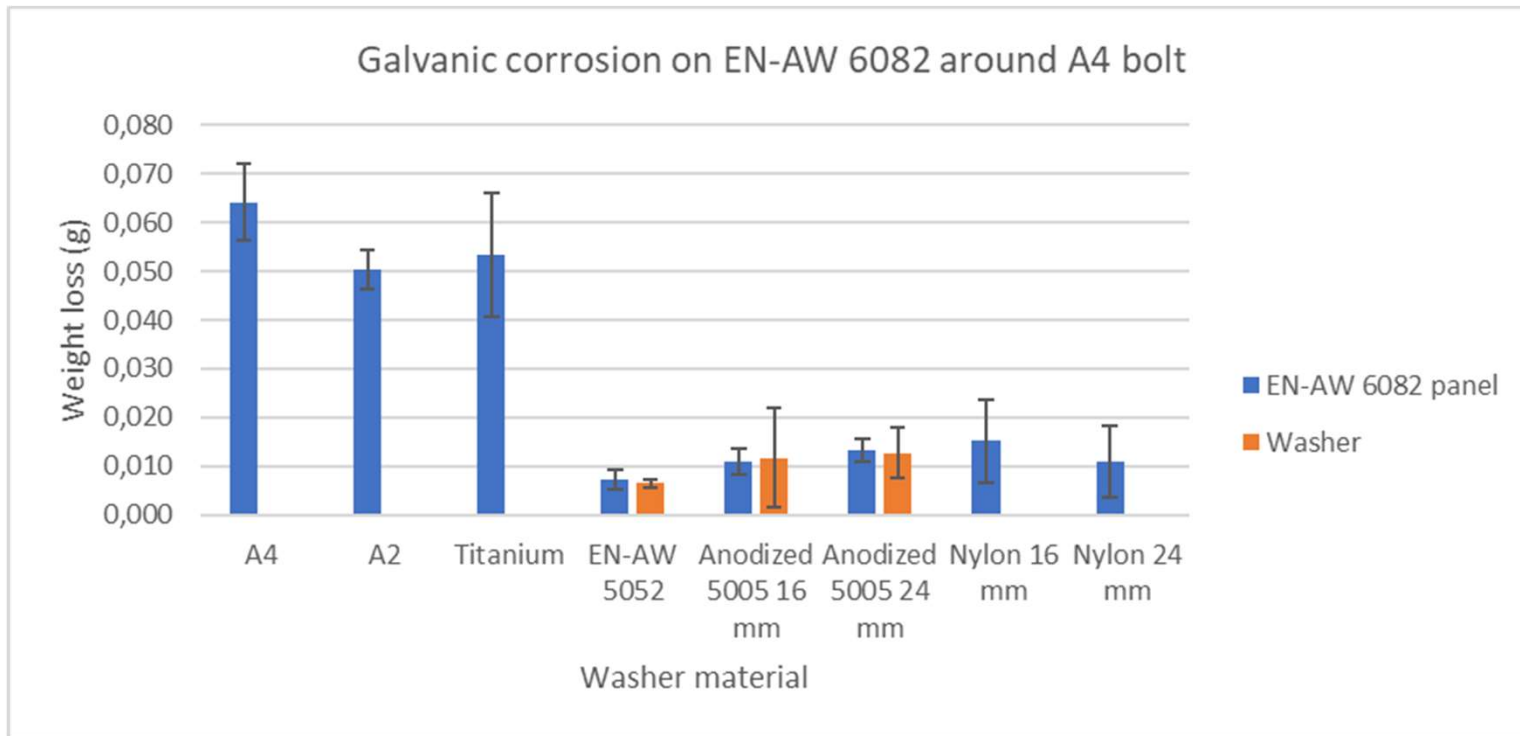
Locus of attack

- Somewhat different corrosion attacks in the three cases
- Prevention may be different





Weight loss on 6082 sample and washers

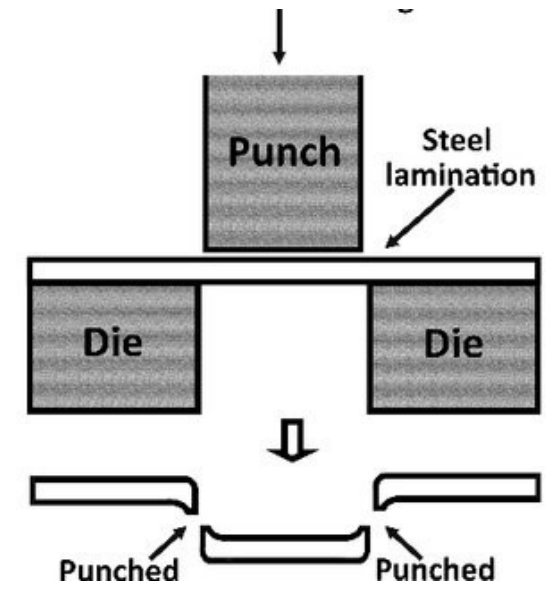




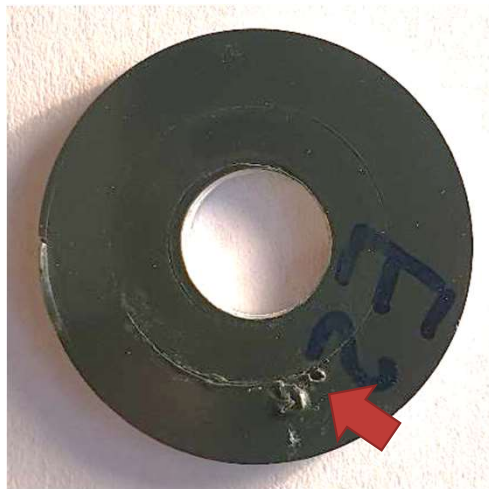
5083, 24 mm anodized washer



24 mm anodized washer



5083, 16 mm anodized washer



24 mm coated washer



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Galvanic corrosion test at Helgoland

Teknologi for et bedre samfunn

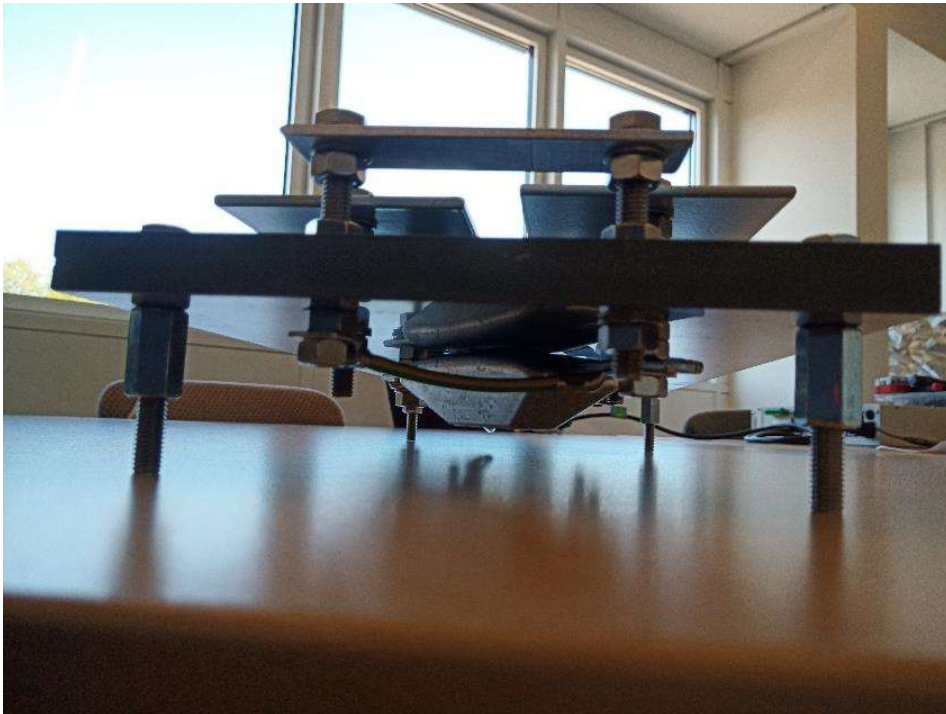


Test matrix

Atmosphere	Tidal (with CP)	Submerged (with CP)	Alloy	Geometry	Pre-treatment	Washer material	Parallels
U 1-3	U 21-23	U 41-43	6082	Flat	As received	A4	3
U 4-6	U 24-26	U 44-46	6082	Flat	As received	6060	3
U 7-8	U 27-29	U 47-49	6082	Flat	As received	Anodized 6060	3
U 10-12	U 30-32	U 50-52	6082	Flat	As received	Bimetallic	3
U 13-15	U 33-35	U 53-55	6082	Buttjoint, FSW	As received	Anodized 6060	3
U 16-18	U 36-38	U 56-58	5083	Flat	As received	A4	3
U 19-20	U 39-40	U 59-60	5083	Flat	As received	Anodized 6060	2
							20



Atmospheric zone





6082, A4 washers

"Out"



"In"





6082, anodized 6060 washers

"Out"



"In"





6082, bimetallic washers

"Out"



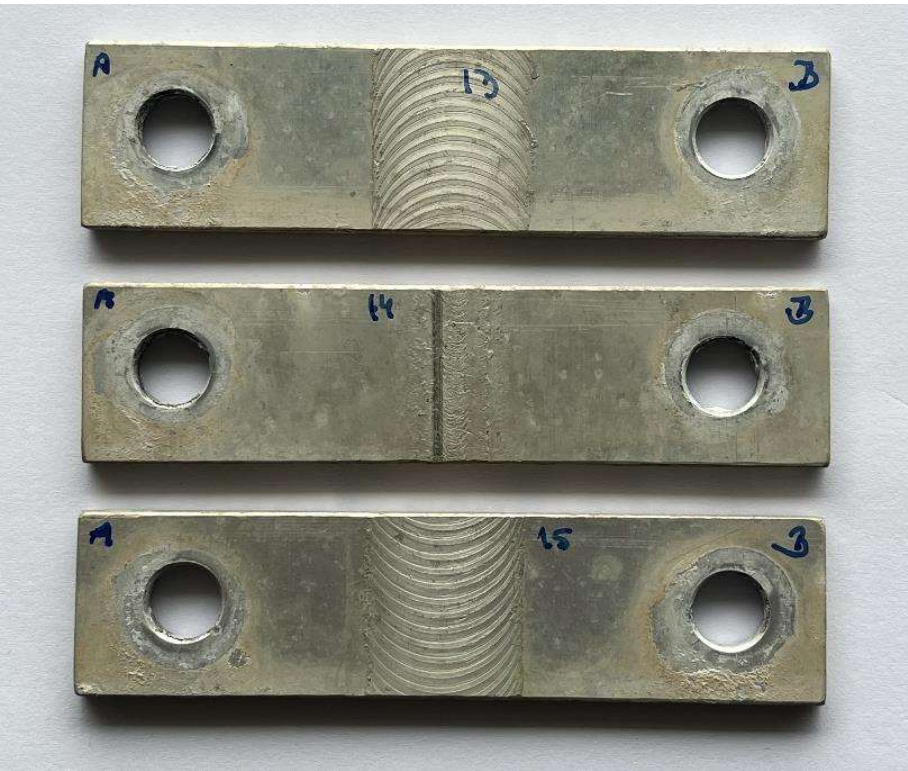
"In"





FSW 6082, anodized 6060 washers

"Out"



"In"





5083, A4 washers

"Out"



"In"





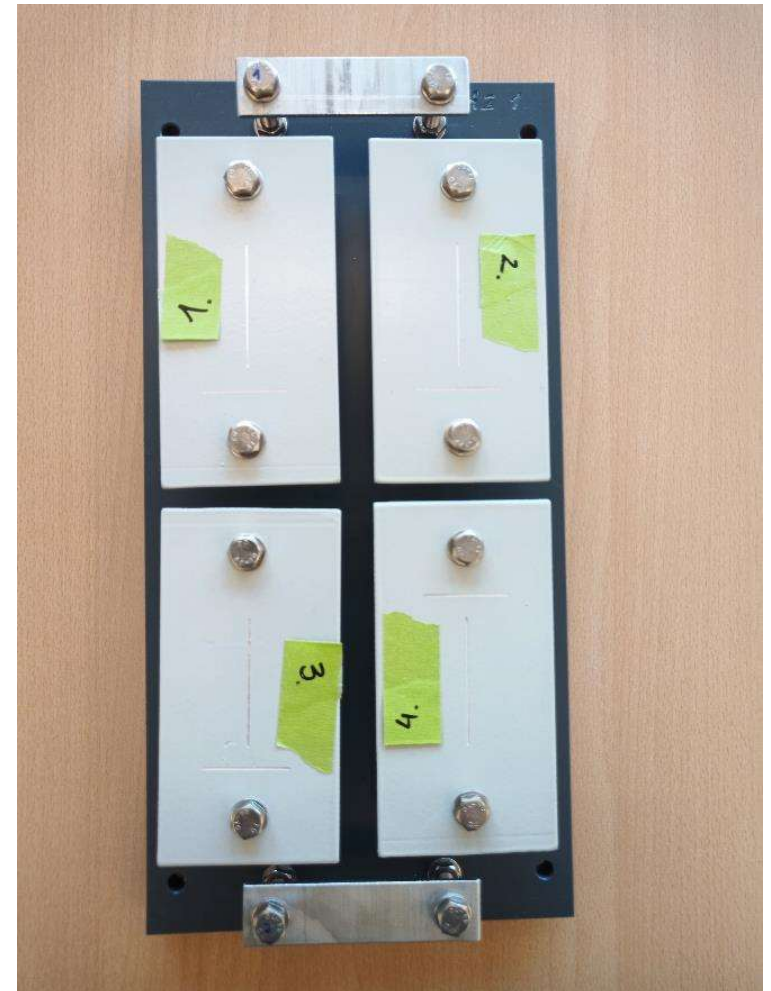
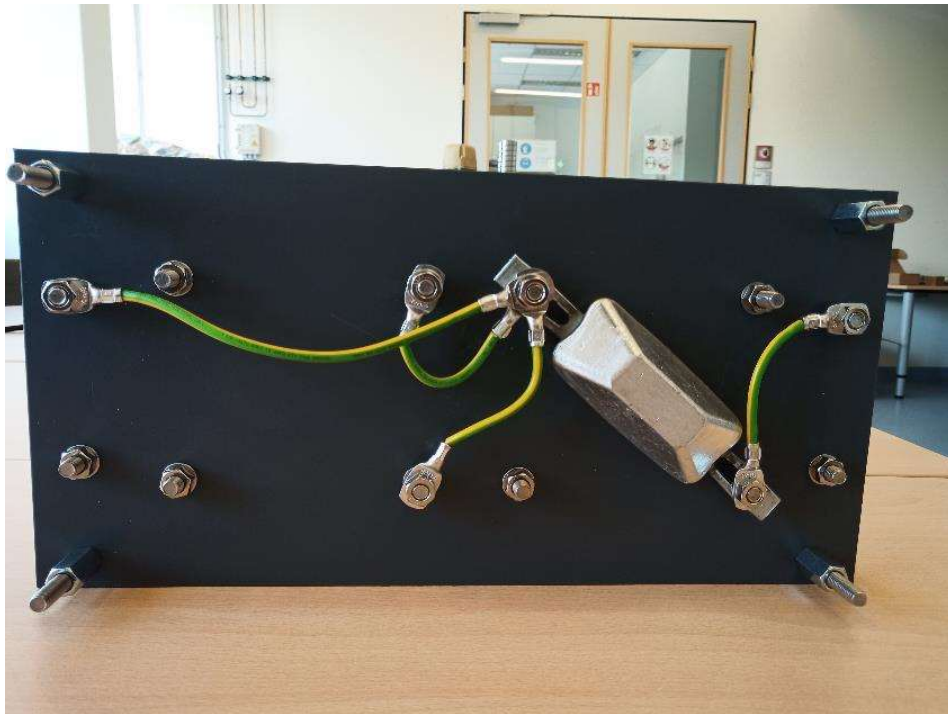
Atmospheric zone

Summary of observations

- Corrosion attacks:
 - In crevices between washer and aluminium
 - Pits outside the crevices
 - In bolt holes
- Anodized washers got damaged during mounting, so protection was lost
- Anodized washers reduced corrosion on the substrate, but the washers corroded correspondingly more
- Bimetallic washers had little effect
- Backside more attacked. No sunshine and slow drying?



Tidal zone





6082, A4 washers

"Out"



"In"





U 37 and 38 5083, A4 washers

"Out"

"In"





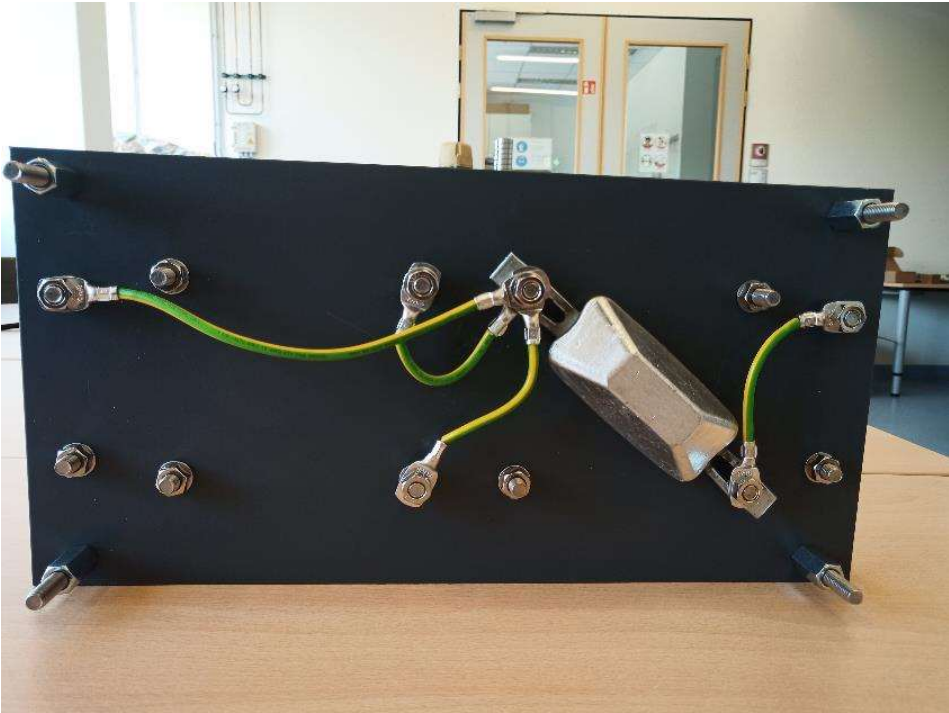
Tidal zone

Summary of observations

- Much less corrosion compared to atmospheric zone
- Little corrosion outside the crevices
- Corrosion in bolt holes
- Less corrosion also on Al washers



Submerged zone





6082, A4 washers

"Out"



"In"





5083, A4 washers

"Out"



"In"





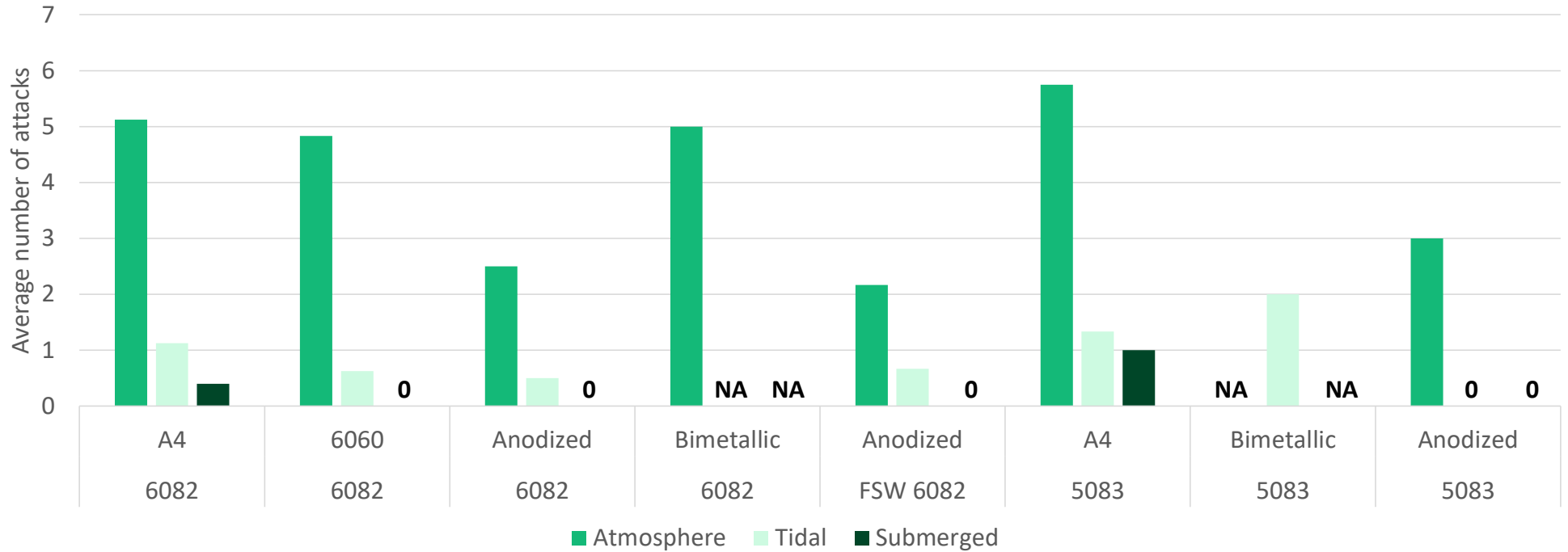
Immersed zone

Summary of observations

- Much less corrosion compared to atmospheric zone
- Less corrosion than tidal zone
- No corrosion outside the crevices
- The corrosion is mainly found in bolt holes
- Less corrosion also on Al washers



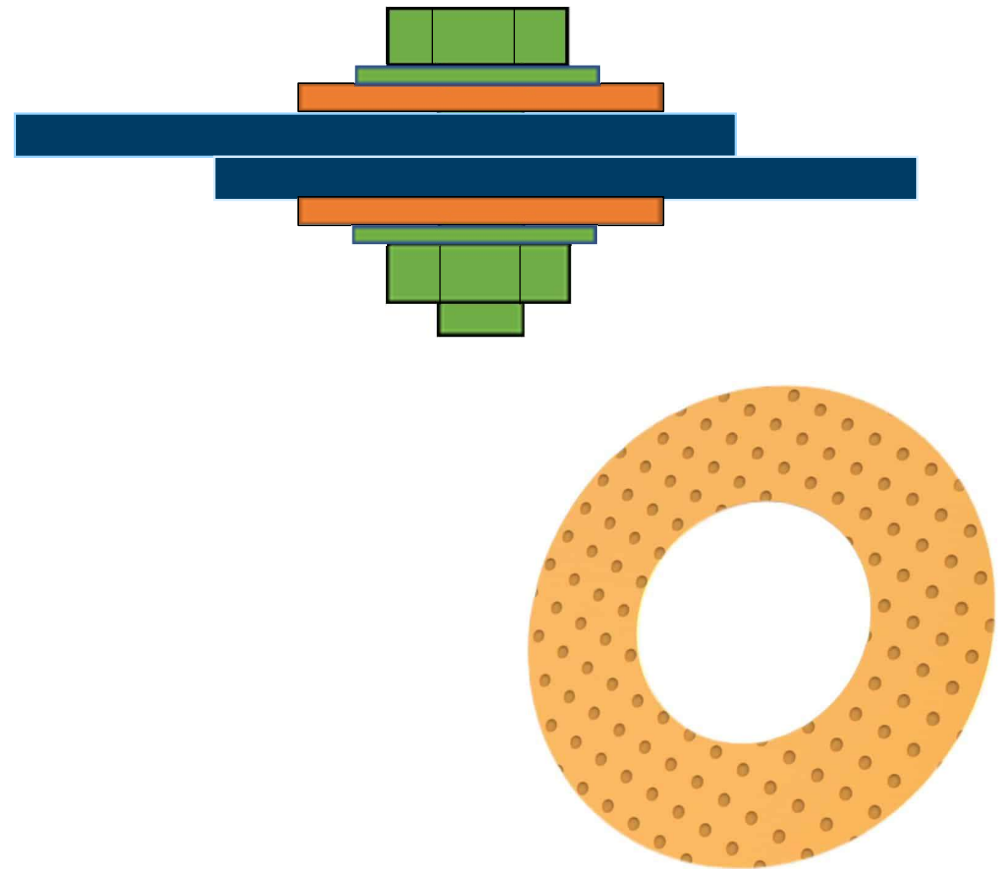
Average number of corrosion attacks





Bolted joints – what will work?

- New revision of NORSOK M-001 to be issued soon
- High strength composite washers
 - Prevent galvanic corrosion
 - Have compression strength comparable to aluminium
- The washer should extend beyond the steel to increase electrolytic resistance between aluminium and steel
- An additional stainless washer under the bolt will reduce risk for crushing the composite
- Sleeve or sealant inside the bolt hole





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