Safe use of aluminium in marine multi-material constructions

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Objectives

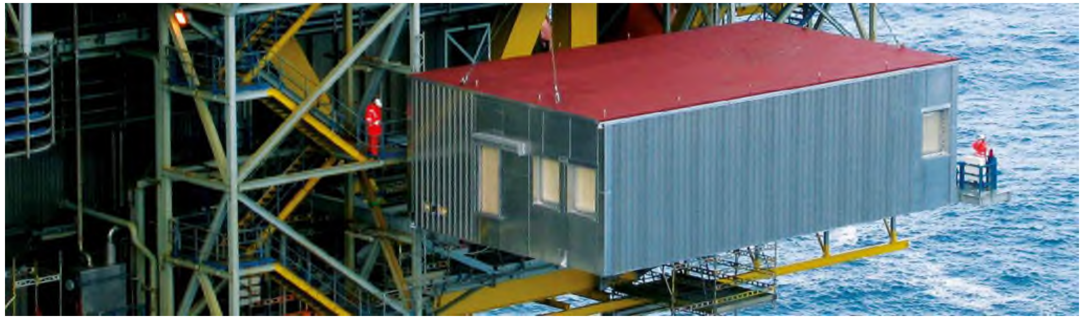
Main objective

- Extend the use of aluminium (Al) alloys in marine applications

Subgoals

- Designing against corrosion
- Fundamental understanding of corrosion mechanisms
- Parameters for marine corrosion protection methods

Marine applications of aluminium



- Both large structures and small parts
- Preferably not coated (costs), but can be
- Always connected to steel

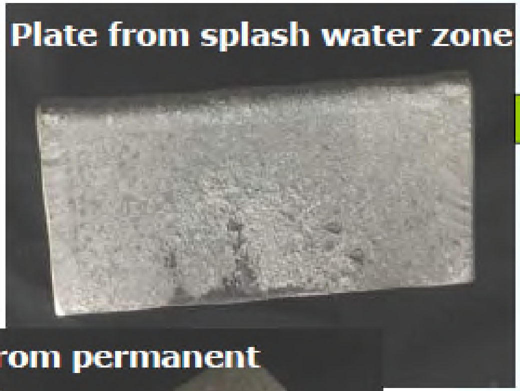
Photo: Marine Aluminium

Successful use of aluminium

Photo:
Roald Lilletvedt
NTNU

North Sea Buoy II

- Investigation of samples at Hydro R&D



- Constructed from AA5083 sheet and AA6082 extrusions
- No surface treatment
- Sub-surface corrosion protection by sacrificial zinc anodes
- Zinc anode consumption approx. 1/5 of that required for cathodic protection of steel

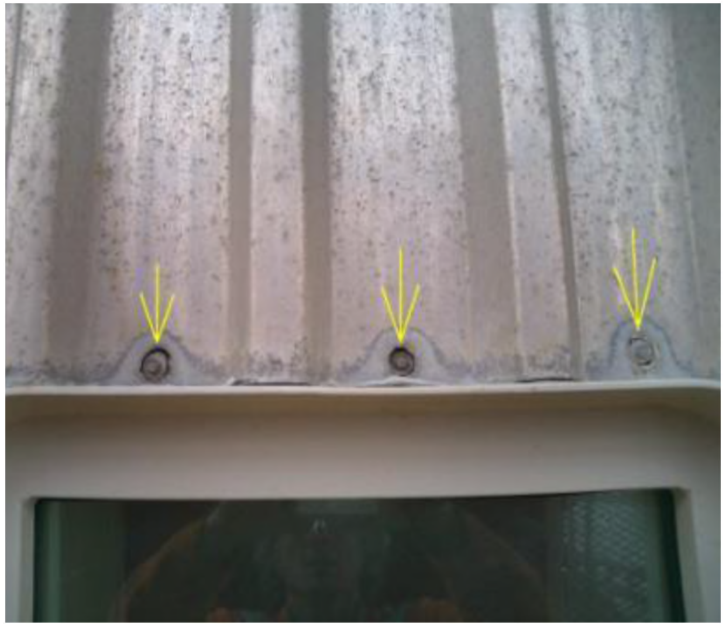
Technical survey after 30 years of service in open sea:

- **No substantial wall thickness reduction**
- **No cracks** in base material or weld seams
- **Weldability** identical to new material
- **Joints with stainless steel screws fully intact** without galvanic isolation

S. Jupp and T. Hentschel, Hydro (2010)

Corrosion problems

Under/around stainless bolts

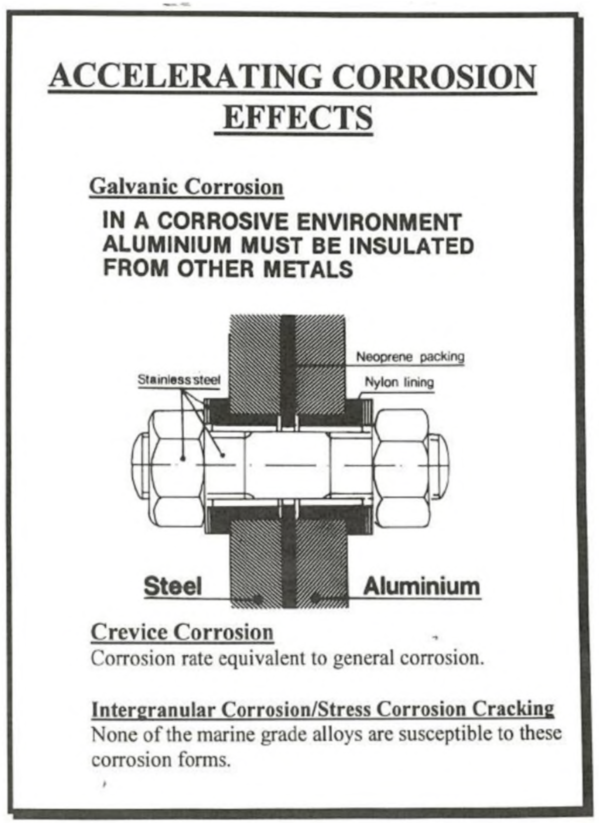


Steel-aluminium crevices

Steel-aluminium weld

Previously recommended designs

Electric insulation – difficult and weak



ACCELERATING CORROSION EFFECTS

Galvanic Corrosion

IN A CORROSIVE ENVIRONMENT ALUMINIUM MUST BE INSULATED FROM OTHER METALS

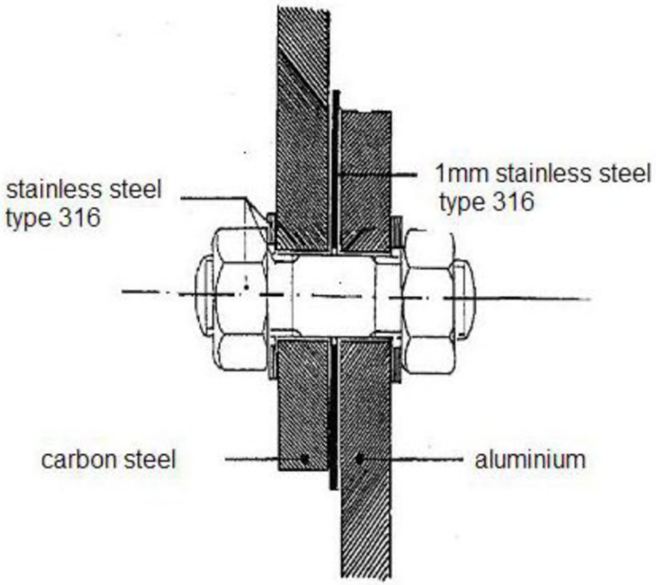
Crevice Corrosion

Corrosion rate equivalent to general corrosion.

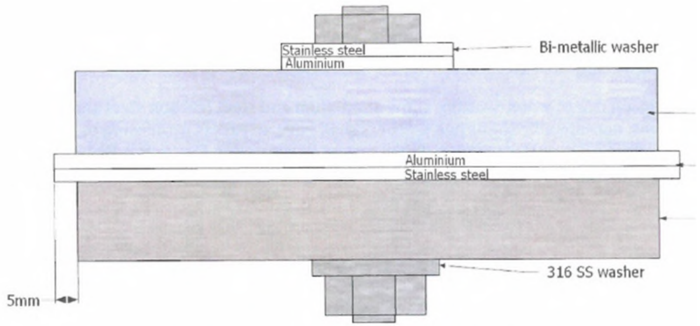
Intergranular Corrosion/Stress Corrosion Cracking

None of the marine grade alloys are susceptible to these corrosion forms.

Stainless steel shims – caused a lot of corrosion

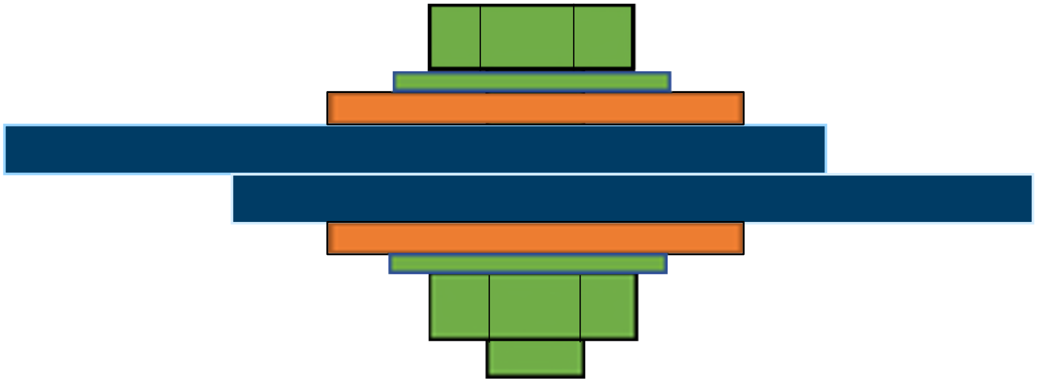


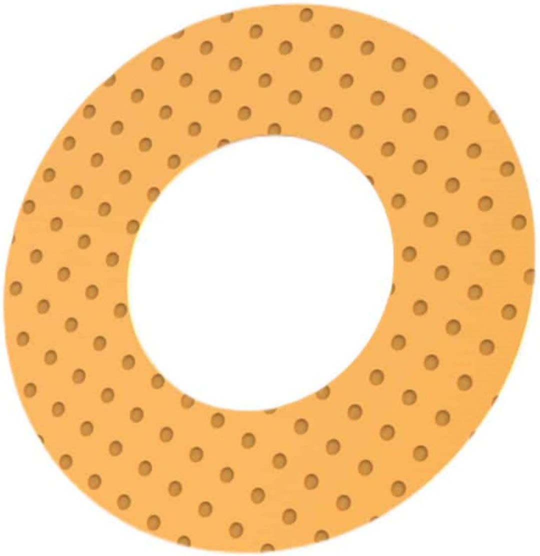
Bimetallic shims – commercially unavailable



Bolted joints – new NORSOK standard

- Polymeric washers have reduced galvanic corrosion
- 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





Coating aluminium for marine applications

- NORSOK M-501 standard for coating offshore structures

- Pre-treatment
  - Sweep blasting to roughness grad "fine"

Coat	Generic type	Thickness
Primer	Epoxy	50 µm
Barrier	Epoxy	
Top-coat	UV-resistant	
Total		225 µm

Cathodic protection of aluminium

- CP of steel: -0,8 to -1,2 V vs Ag/AgCl
- Happens to overlap with the passive range for aluminium
- Uncertainty: How many sacrificial anodes are required for CP aluminium ?

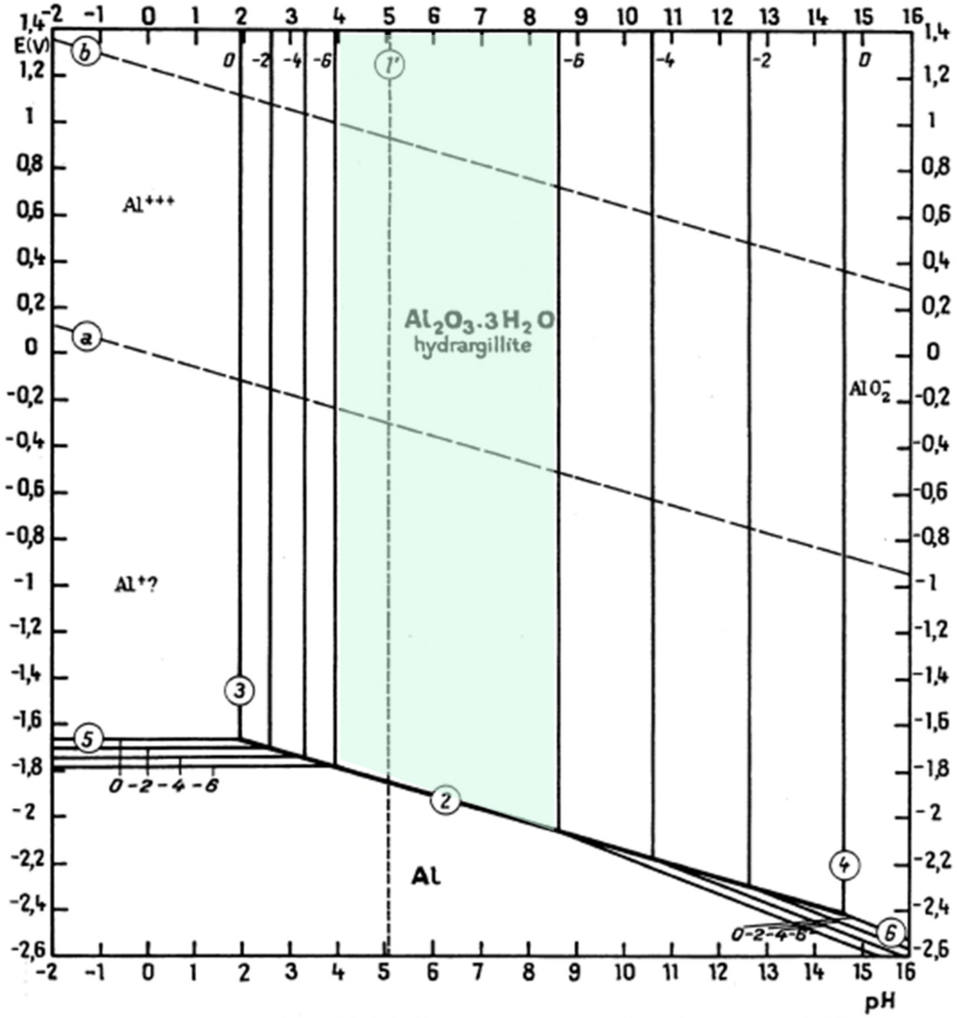
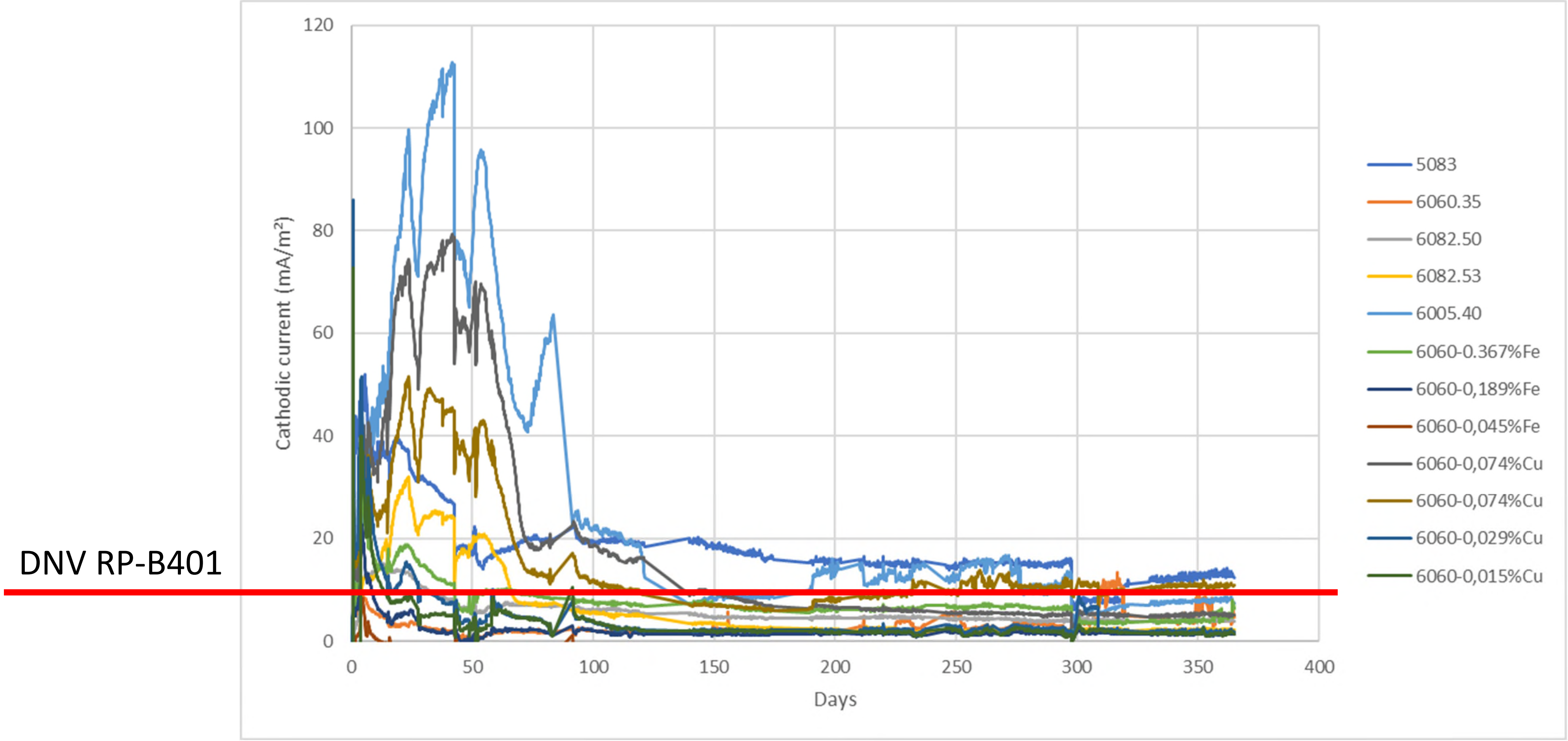
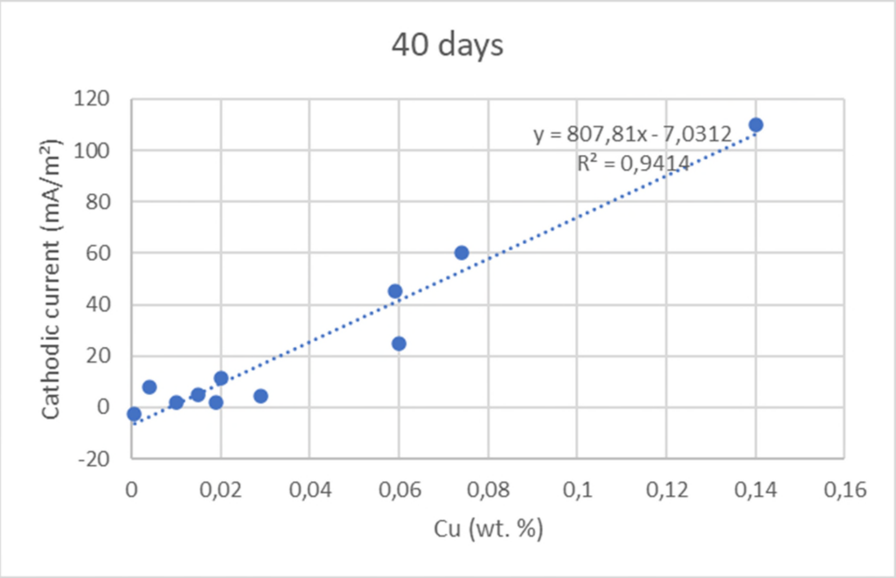


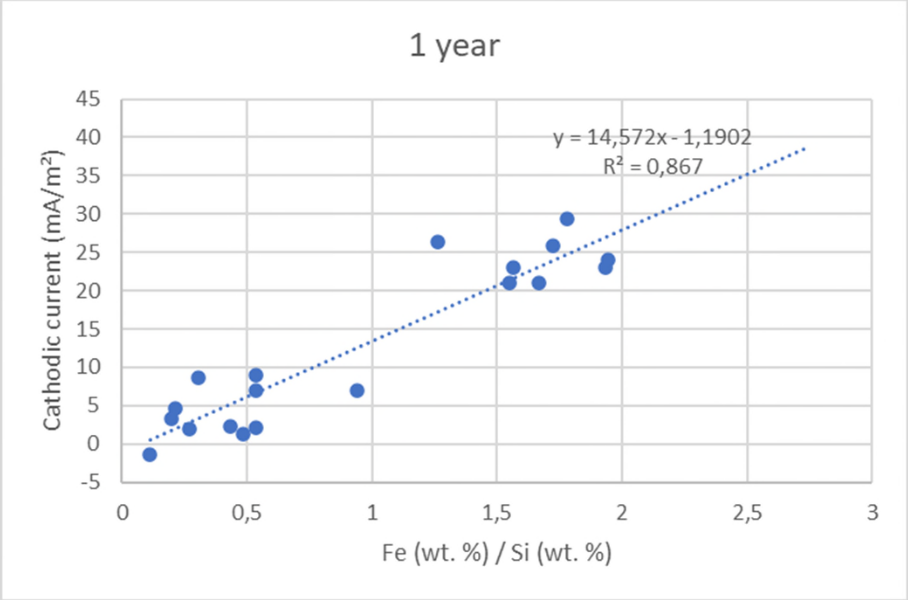
FIG. 1. Potential–pH equilibrium diagram for the system aluminium–water, at 25°C.

Current density for cathodic protection in seawater

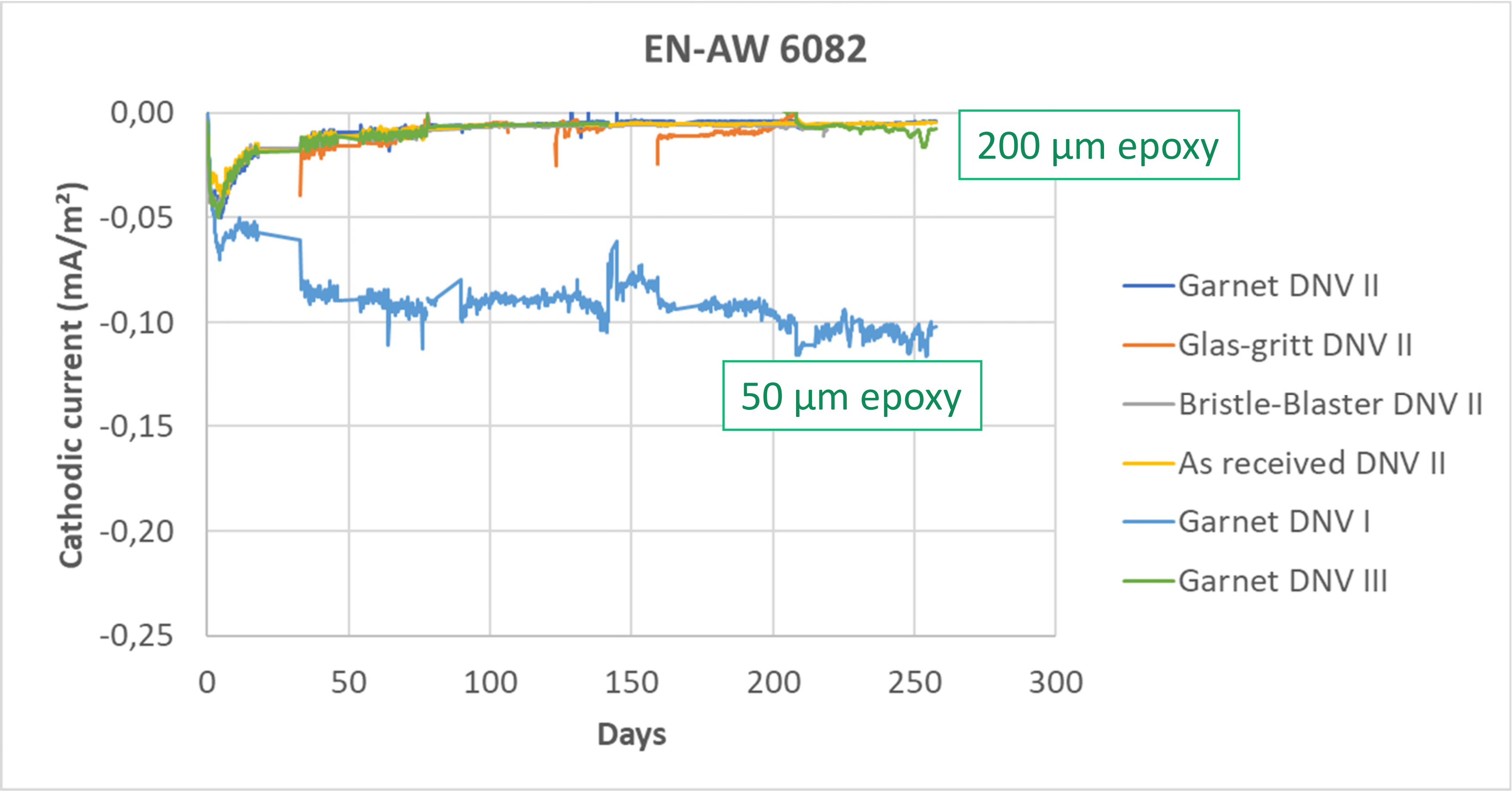


Cathodic current vs alloy composition





Coating degradation on aluminium in seawater with cathodic protection



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Conclusions

- Potential for more use of aluminium in marine and coastal constructions
  - Low weight, corrosion resistance, recycling, less coating maintenance …
- Lack of knowledge, standards and design codes for how to use aluminium in marine constructions
- Galvanic corrosion is a threat
  - Good design is key to success
  - Avoid Fe-Al crevices, avoid trapped water, surfaces must drain, bolt holes kept dry
- Coating
  - A wide range of pretreatment methods can be used
  - Less coating required compared to steel
  - Generally good performance of coatings on aluminium in marine environments, also subsea
- Cathodic protection
  - Same potential requirements as for steel
  - Current demand much lower than for steel, but current density values must be revised