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ZINC INJECTION IN LIGHT WATER REACTORS TO MITIGATE STRESS CORROSION CRACKING OF ALLOY 182 AND COLD-WORKED 316L STAINLESS STEEL

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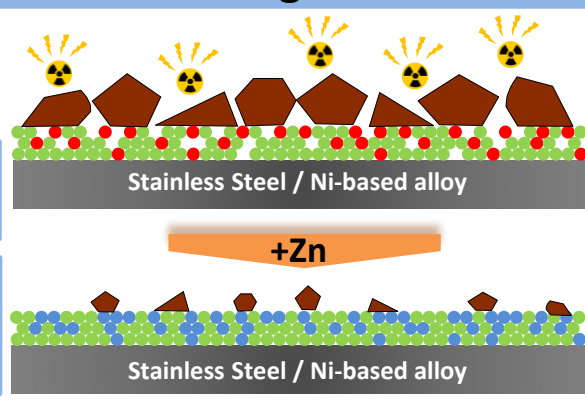
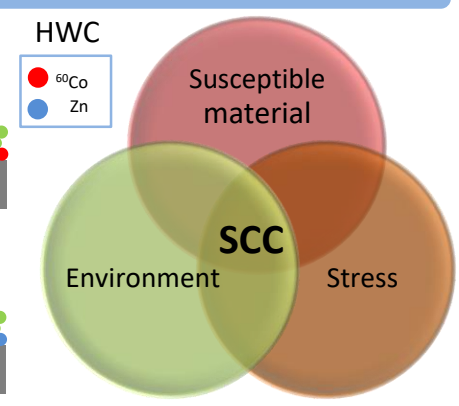
Background

Radioactive build-up in oxide films of light water reactors.

Reduction of radioactivity by Zn-injection.

Potential side effect: stress corrosion cracking (SCC) mitigation.





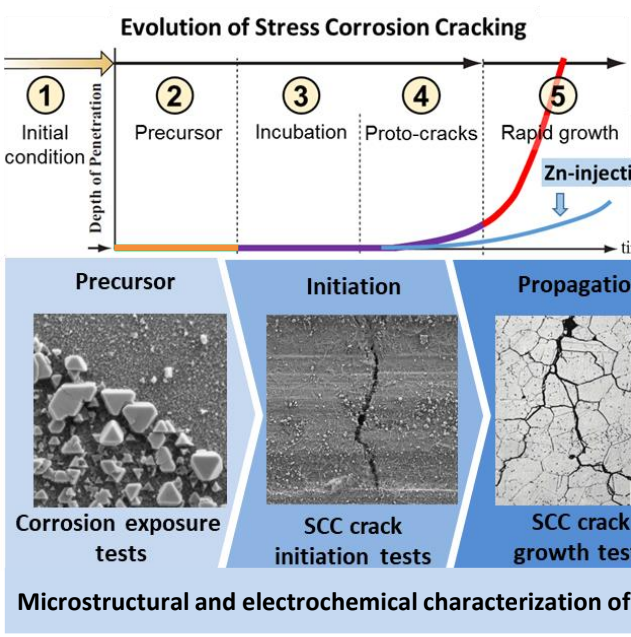
Objectives

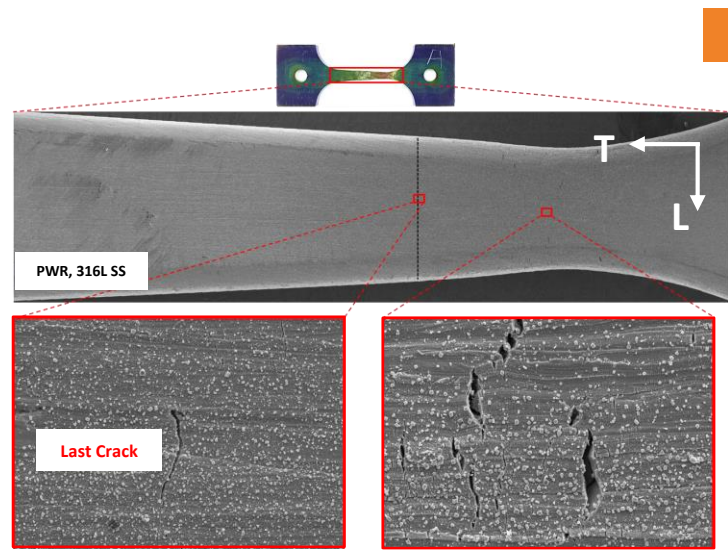
1. Quantification of the SCC mitigation effect by Zn.
2. What is the mechanism behind the mitigation effect of Zn-injection?
3. What is the role of Zn in corrosion kinetics?

Materials

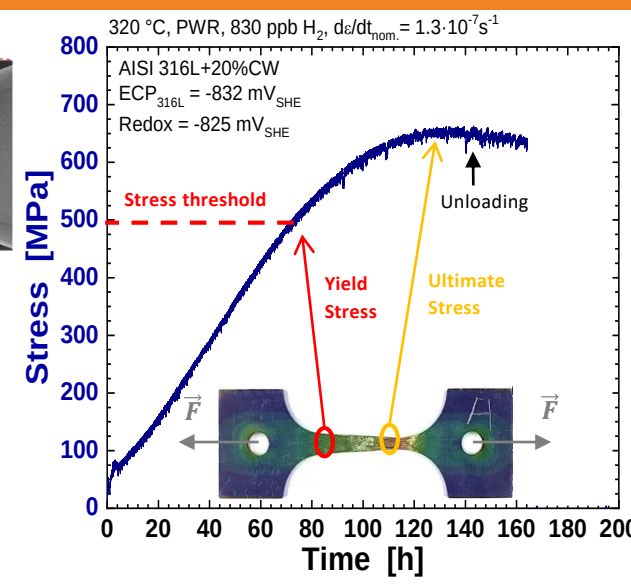
1. Ni-based weld metal Alloy 182.
2. Cold-worked 316L stainless steel.

Methodology





Slow strain rate test with flat tapered tensile specimen

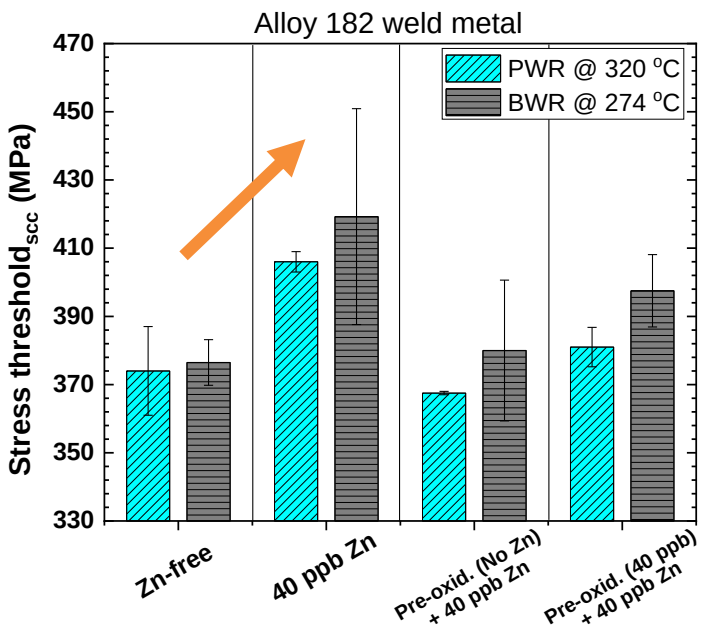


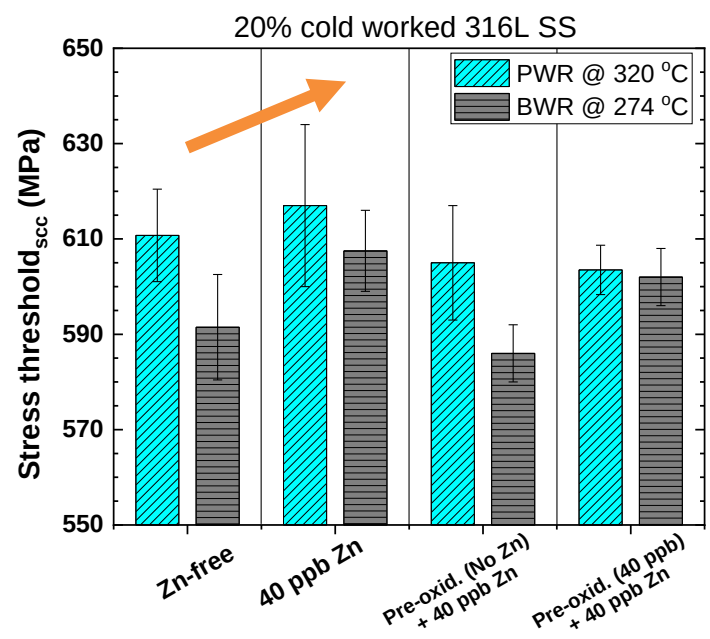
Water chemistry	Temperature [°C]	Pressure [bar]	Dissolved H_2 [ppb]	B & Li [ppm]	Zn injection [ppb]	pH_T	ECP conditions
BWR	274	90	253	-	0 & 40	5.6	Ni/NiO transition
PWR	320	130	830	600 & 2.25		7.5	

Strain rates (dε/dt):
$5x10^{-7}$ s^{-1} for Alloy 182
$1.3x10^{-7}$ s^{-1} for CW 316L SS

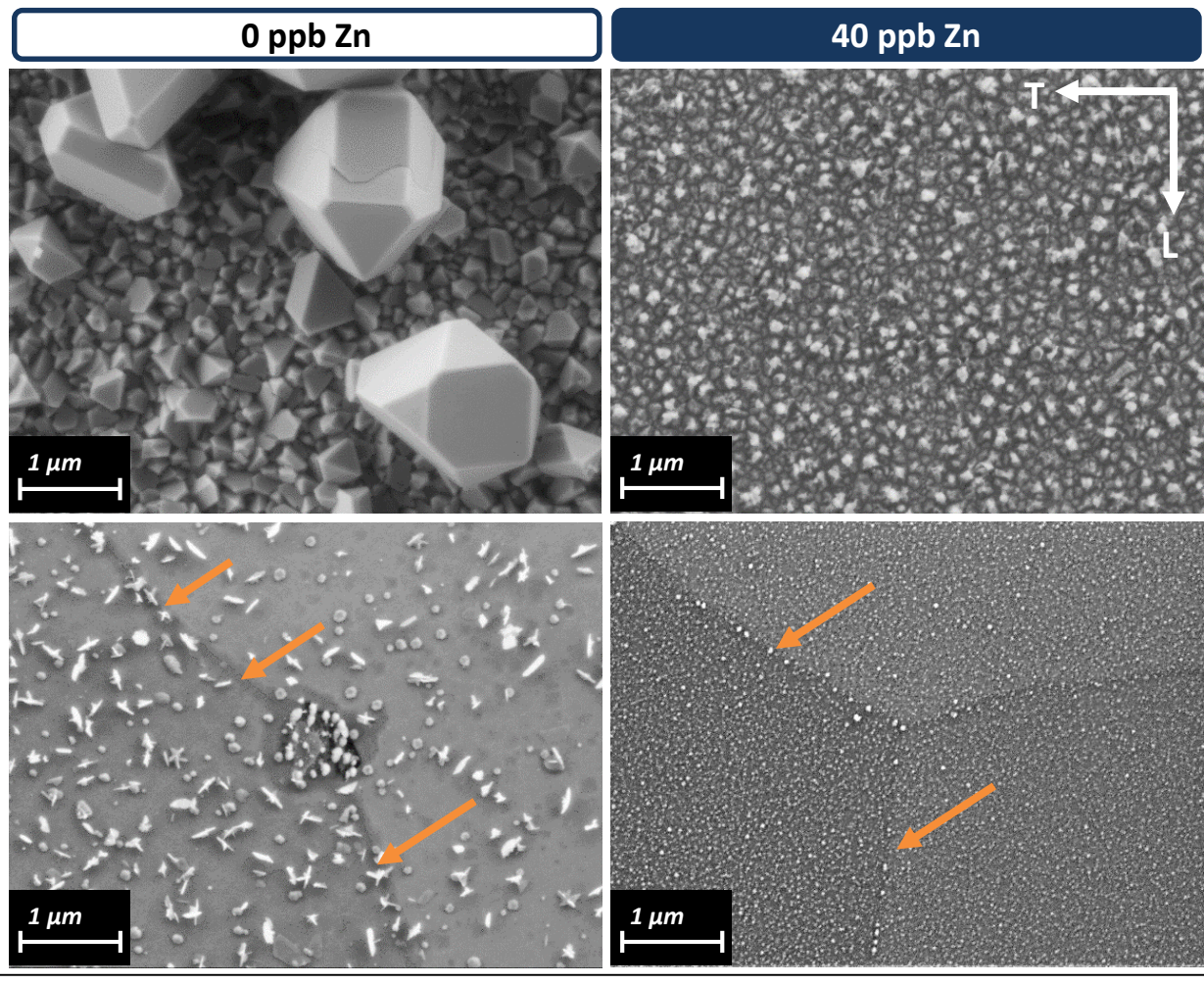
SCC Initiation Susceptibility

Higher stress threshold → Lower SCC susceptibility





Oxide Film Formation under BWR Conditions



SEM:

Field emission gun SEM – Zeiss ULTRA™ 55

Secondary electron (SE) images

Exposure time: ~350 h

OPS 0.02 µm polished surface

Grain boundaries (GBs) preferential oxidation

TAKEAWAYS

Preliminary results revealed a tendency towards a higher stress threshold and thus lower SCC susceptibility with Zn injection in both materials under BWR and PWR conditions.
These observations still need to be confirmed with e.g., constant load tests.

If the oxide film is formed without Zn, the SCC mitigation effect seems to disappear.

The oxide film on Zn-treated specimens appears to be more uniform with smaller oxide crystals.

Hypothesis: Cr-rich inner oxide layer limit diffusion of Ni and Fe ions, that contributes to the oxide growth. They are known to occur through a solid state process. Zn-treated surface seems to have less vacancies in the inner Cr-rich layer.

Preferential oxidation of the GBs is visible on the OPS polished surfaces.

OUTLOOK

Further investigations are planned: SCC growth tests, analytical electron microscopy (TEM, HR-STEM), X-ray photoelectron spectroscopy (XPS), electrochemical characterization, etc.

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