DELAMINATION OF THE ADHESIVE/STEEL INTERFACE DUE TO CORROSION IN ADHESIVE SHIP JOINTS

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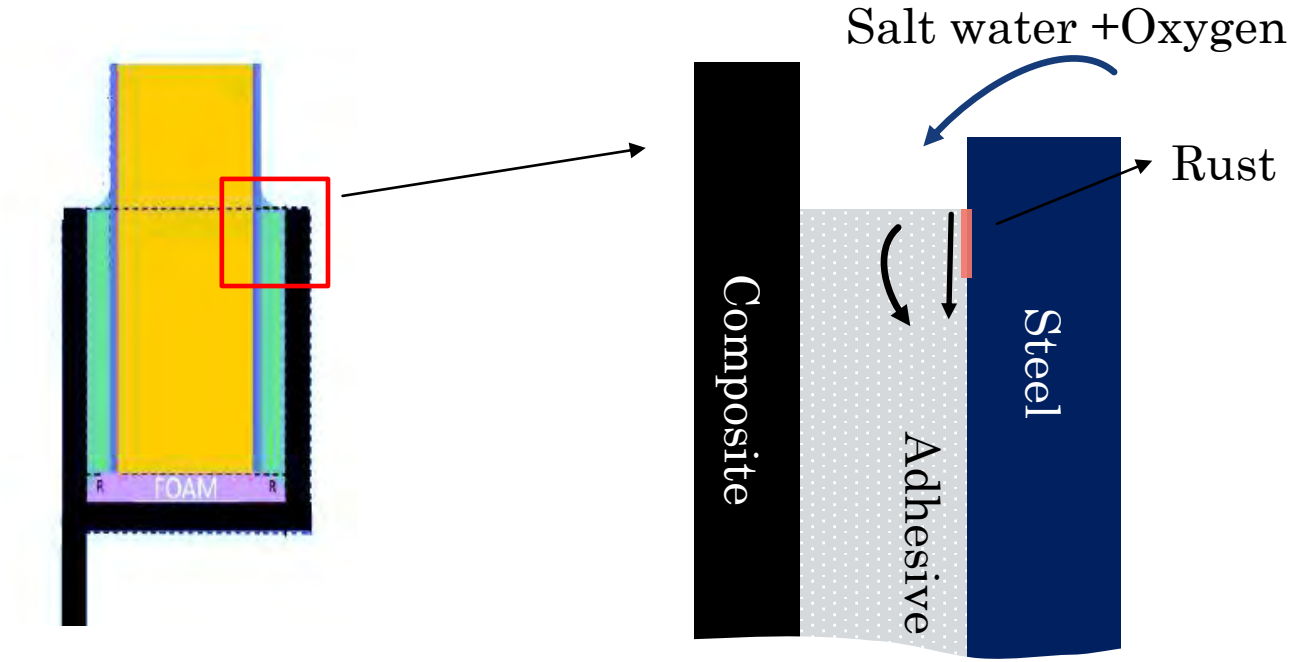
Outline

- Problem statement
- Experiments and the obtained results:
  - Gravimetric measurements of Scigrip adhesive at RT, 50 C, and 60 C.
  - Encapsulated steel experiment
  - Competing mechanisms in delamination of sandwich joints
- Delamination rate of steel/adhesive/steel sandwich specimens exposed to salt water and DI water, Experiments and FE simulations
- Summary and conclusions

Problem statement

- Adhesive joint in maritime industry are exposed to salt-water.
- Hydroxide ions and oxygen are deleterious to adhesive/metal bonds.



We have to understand:

(1) How fast the oxygenated water diffuses into the bulk adhesive?

(2) Is the adhesive/steel interface a fast path of diffusion?

(3) What is the role of salt?

(4) What is the role of temperature?

(5) What is the delamination mechanism?

Scigrip adhesive gravimetric measurement

Research question: What is the diffusion coefficient of water in Scigrip adhesive at RT, 50 C, and 60 C?

We follow the standard ISO 62: 2008 Plastics — Determination of water absorption for the measurement.

Materials and equipment needed:

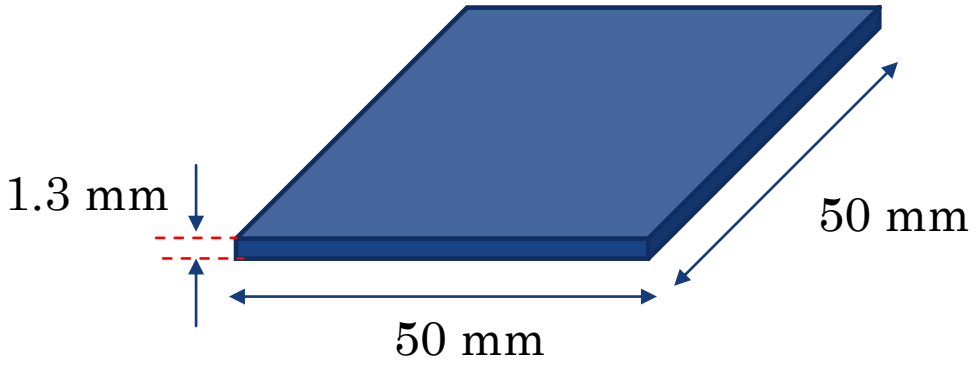
- 0.1 mg precision scale
- 5 specimens per exposure temperature.

Procedure:

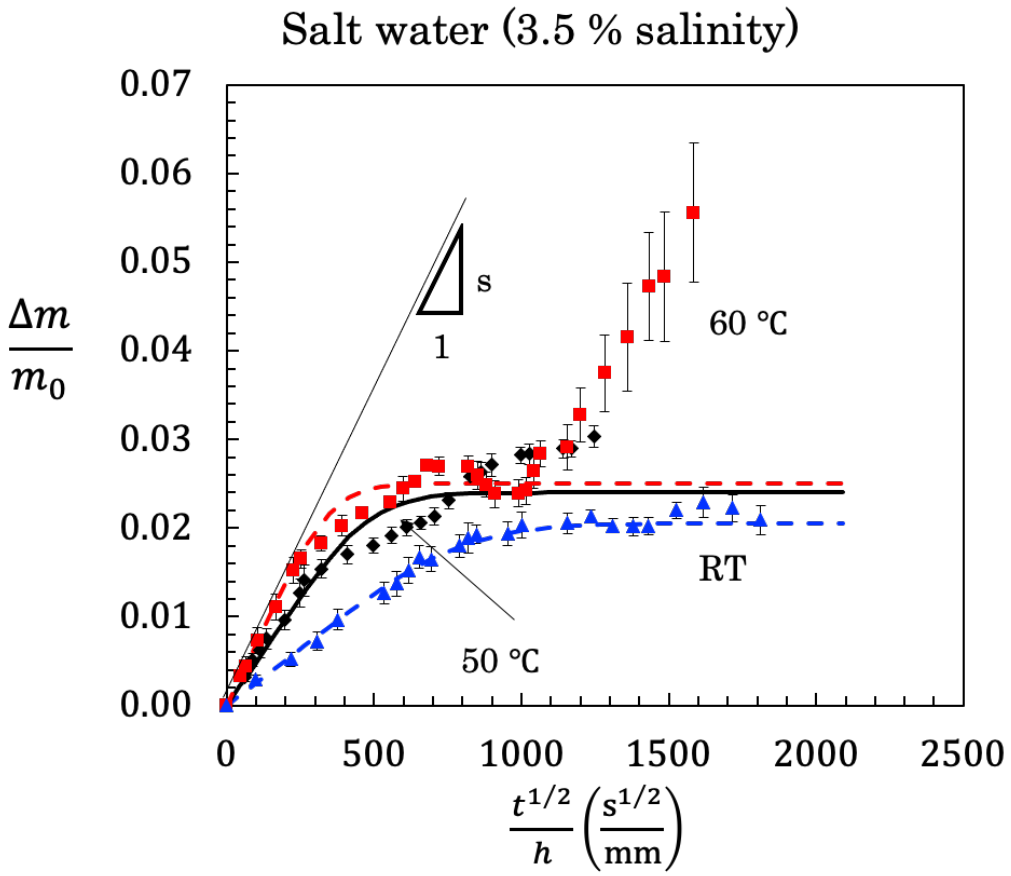
•Allow diffusion from all sides of the specimen

•Gravimetric measurements at regular time intervals to determine the water uptake

•Extraction of D



Diffusion coefficient of scigrip, effect of temperature and salinity



	Salt water		DI water	
	D ($\times 10^{-13}$ m^2/s)	Cs (%)	D($\times 10^{-13}$ m^2/s)	Cs (%)
RT	3.1 ± 0.3	2.1	7.0 ± 0.5	3.0
50 C	9.6 ± 0.8	2.3	23.2 ± 1.9	8.1
60 C	14.8 ± 1.9	2.4	24.3 ± 2.1	11.0

Encapsulated steel experiment

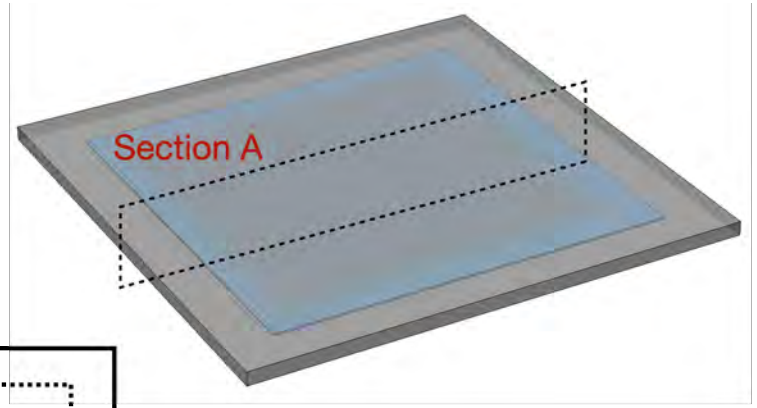
Research question: What is the rate of corrosion in presence of adhesive?

Material and equipment needed:
- 0.1 mg precision scales
- Thin sheet of steel (As thin as 0.2 mm)
- Investigating the metal adhesive interface

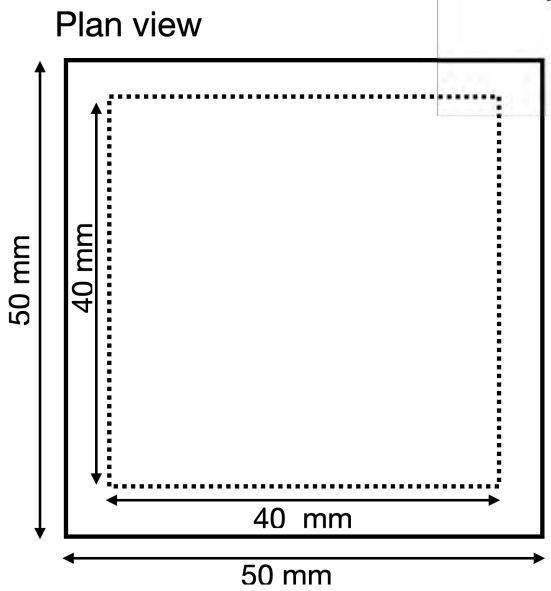
At various time intervals, weight measurements performed.

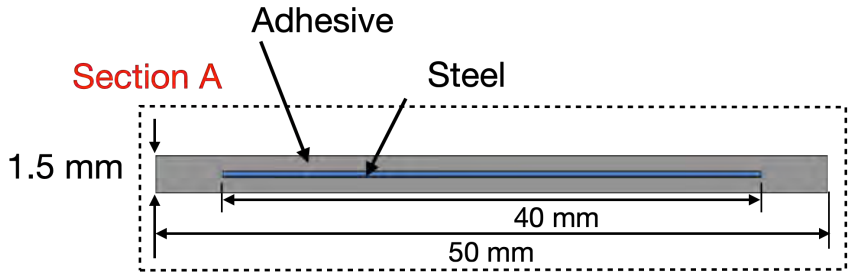
GOAL:
1- Measuring the rate of steel corrosion in presence of adhesive.

2- Time required for full delamination of adhesive from steel substrate

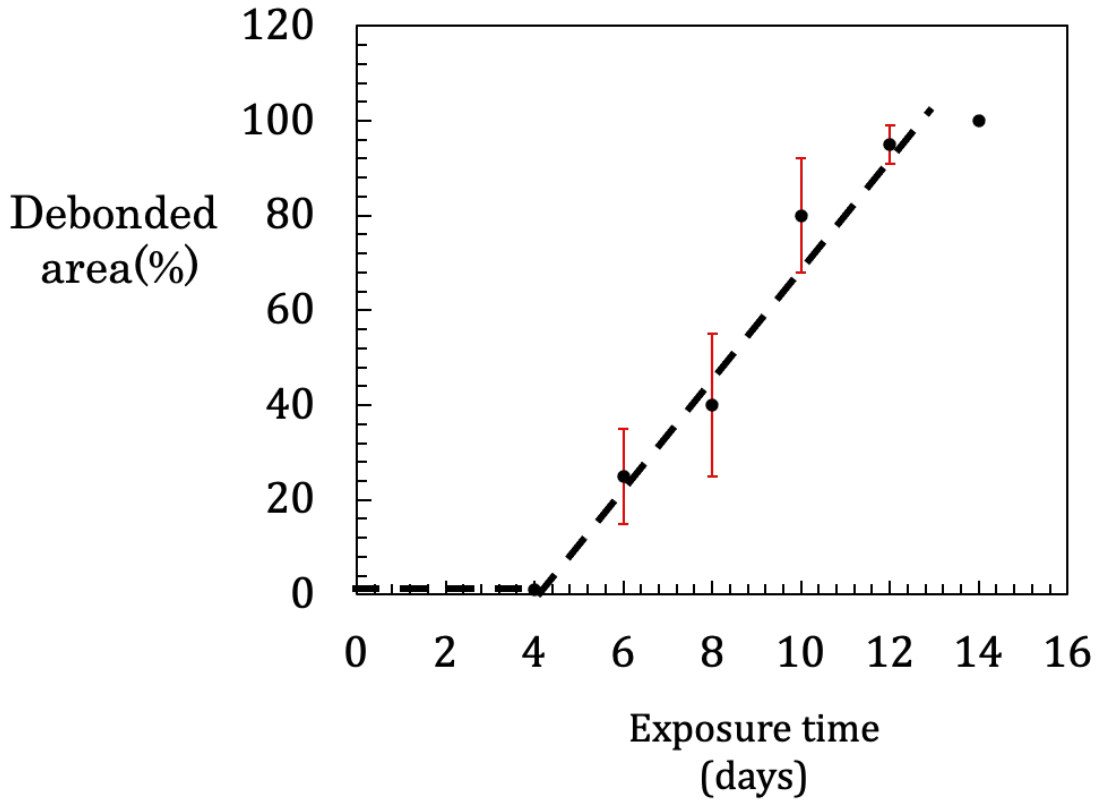


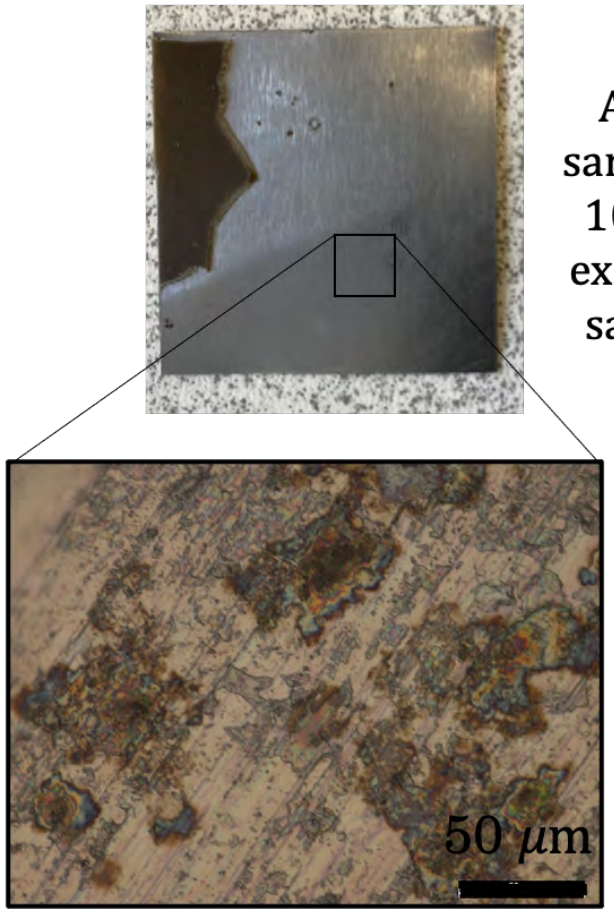
Steel thickness=0.2 mm





Delamination of encapsulated steel specimens

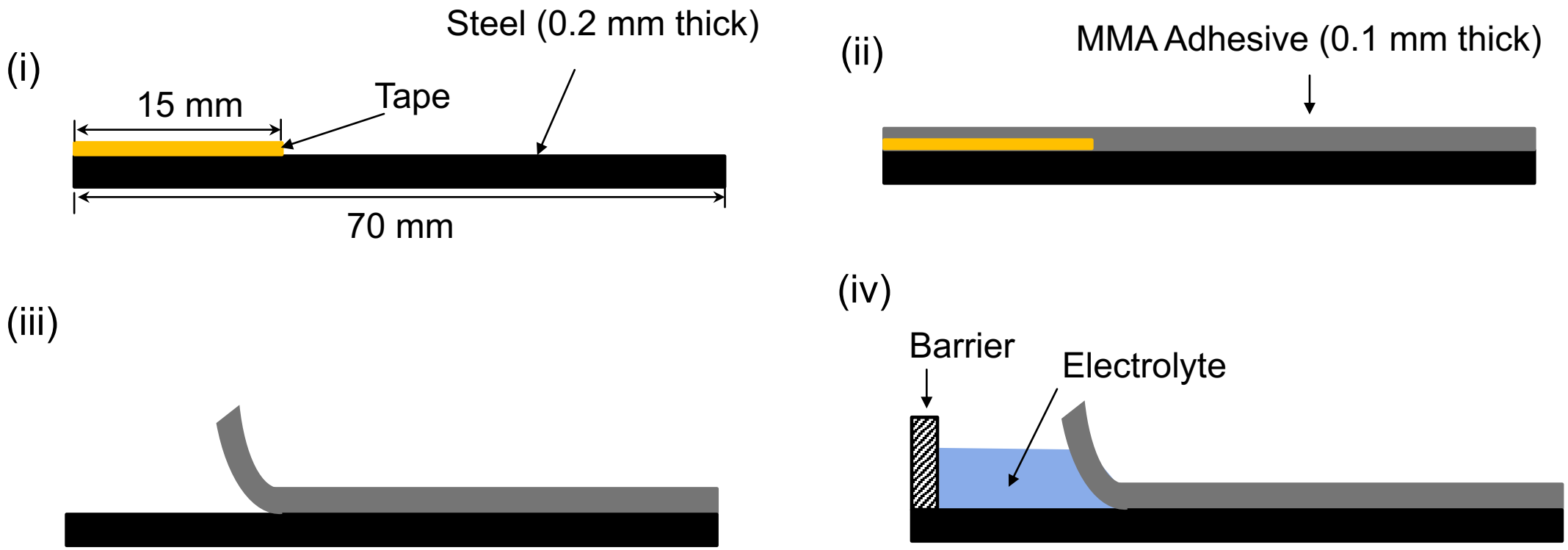




A typical sample after 10 days of exposure to salt water.

Orange and black rust is visible on steel surface in optical microscopy images.

Schematic of the MMA-coated steel specimen manufacturing.



Steel/Adhesive/Steel sandwich experiments

Research question: Is the corroded interface create a fast path of diffusion in adhesive-steel interface? What is the speed of corrosion front penetration (L_c vs t) for different temperatures?

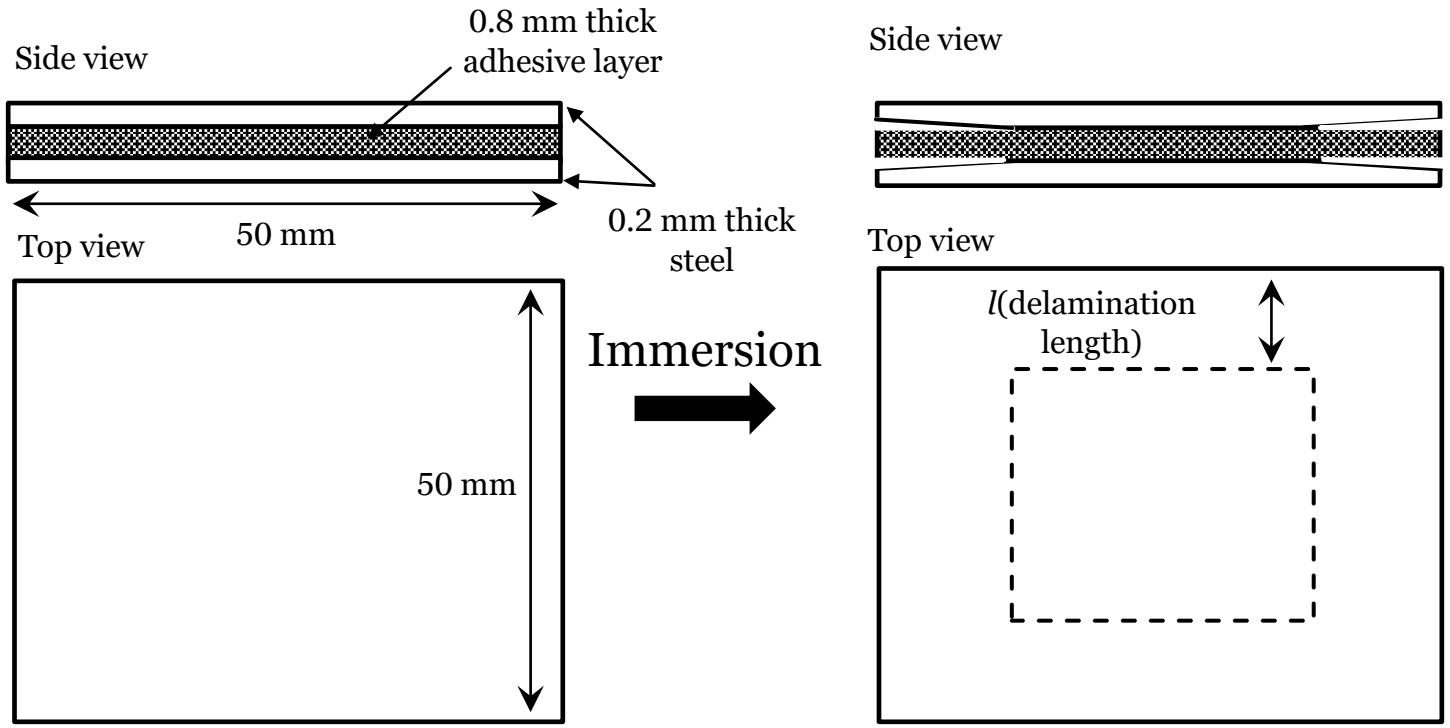
Test:

A layer of adhesive joining two steel sheets

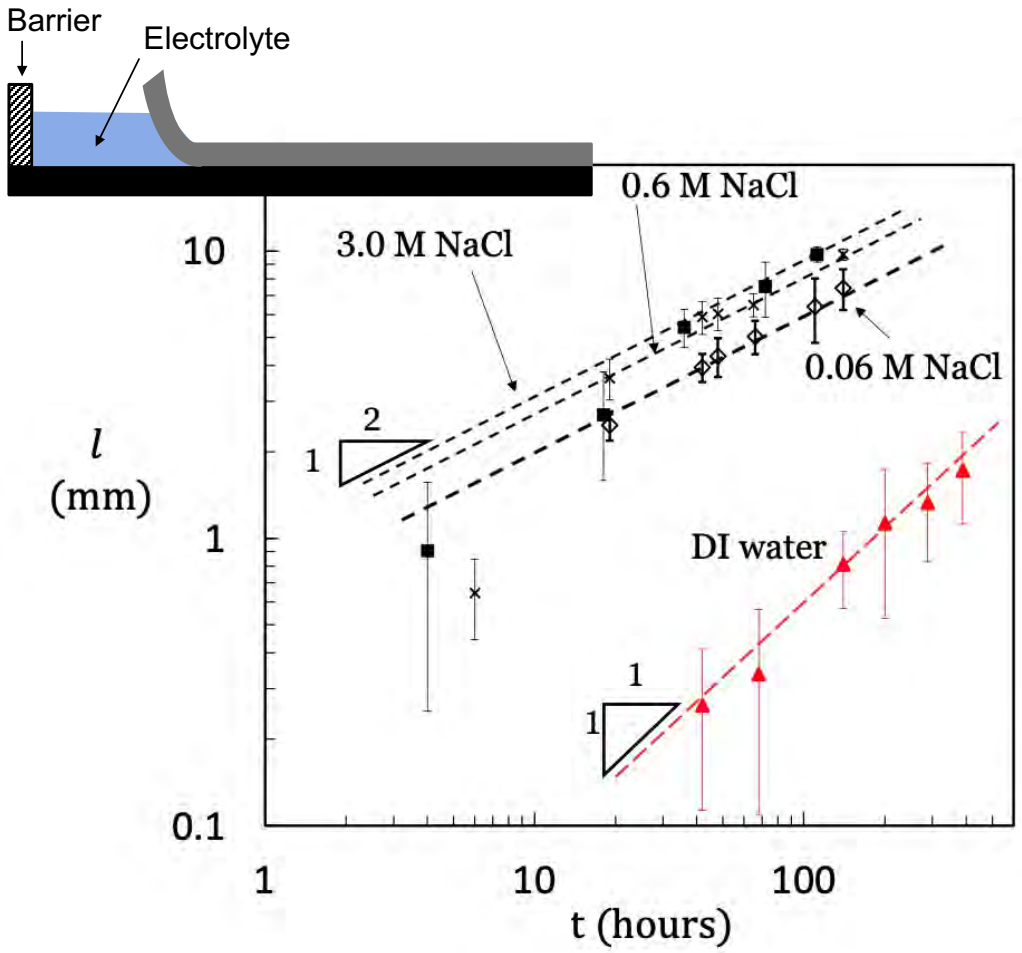
Material and equipment needed:

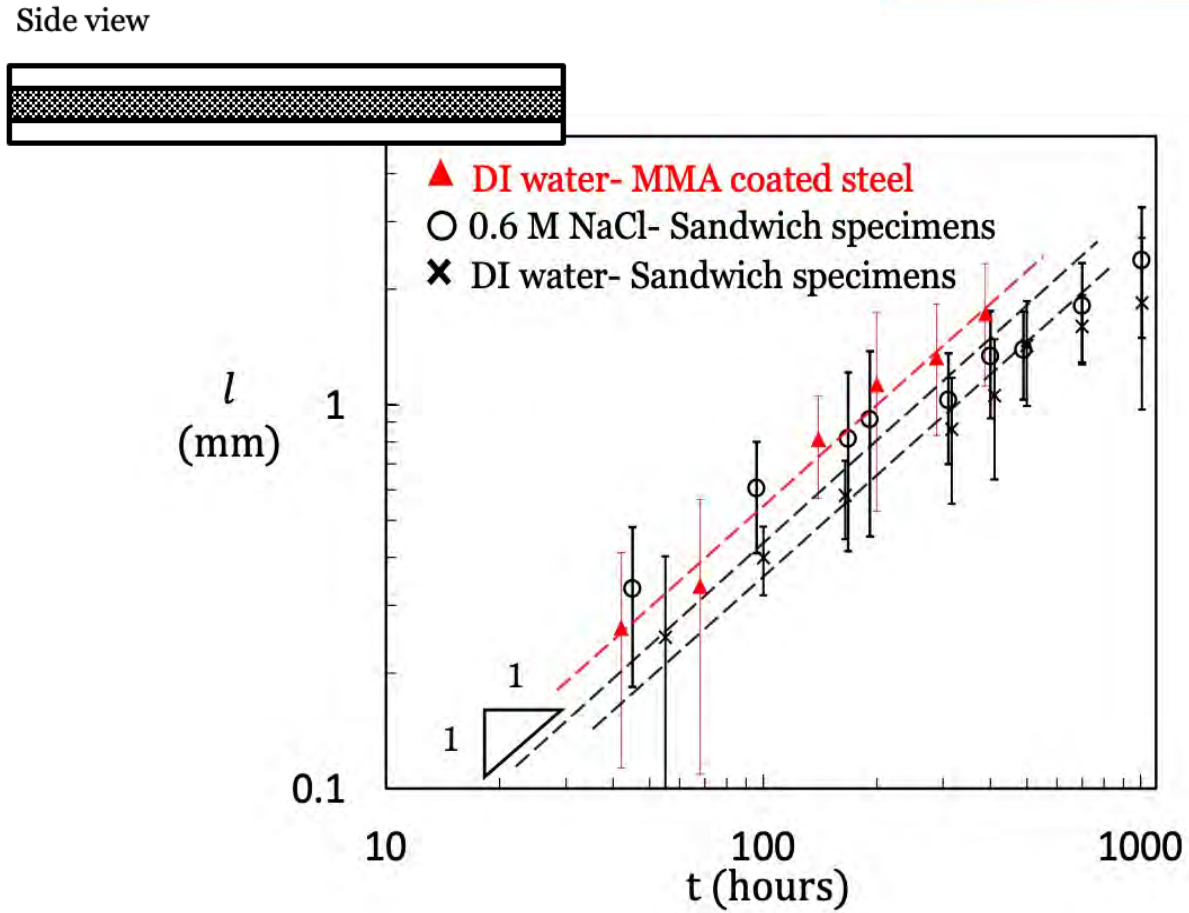
- Thin sheet of steel (As thin as 0.2 mm)

- We can use the results of this experiment to calibrate the FE model.



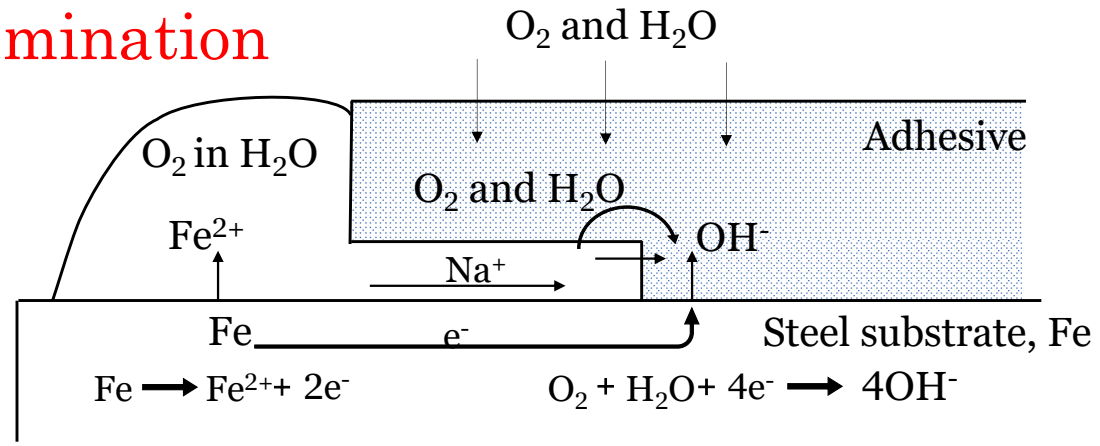
Delamination length against time in MMA-coated steel experiments



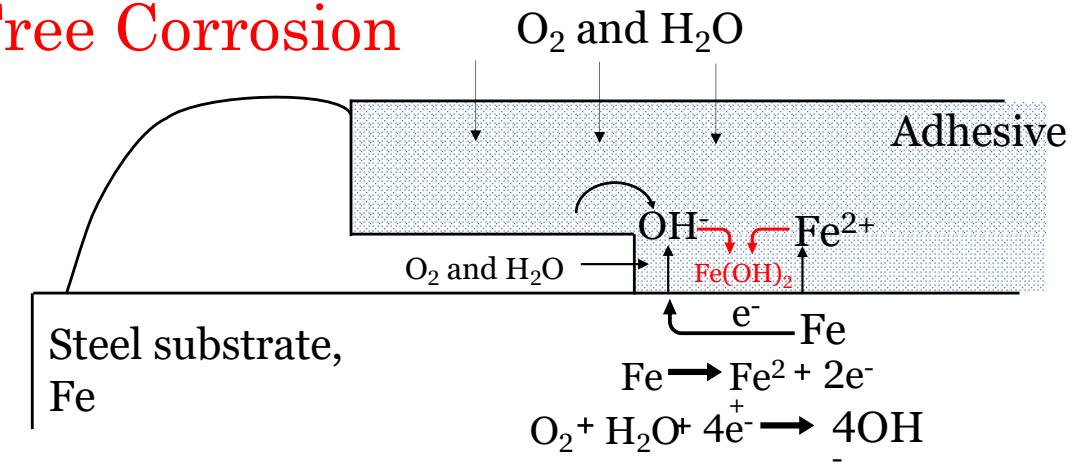


Competing delamination mechanisms

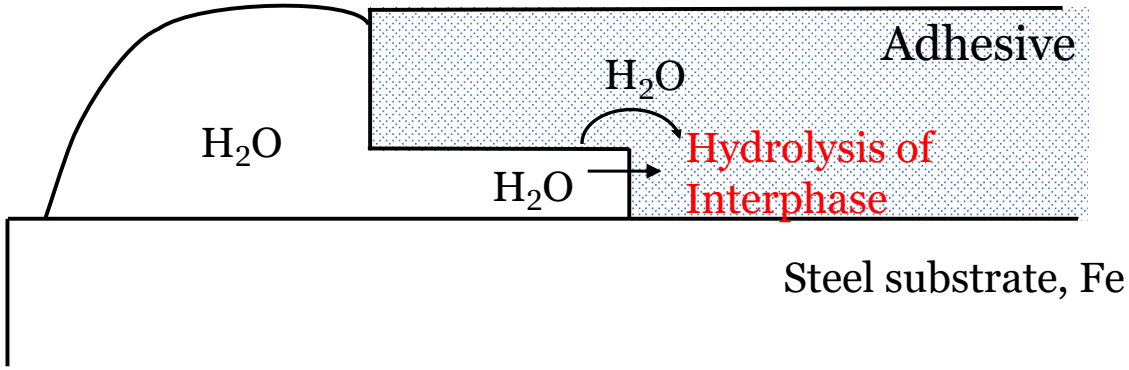
Cathodic Delamination



Free Corrosion



Hydrolysis

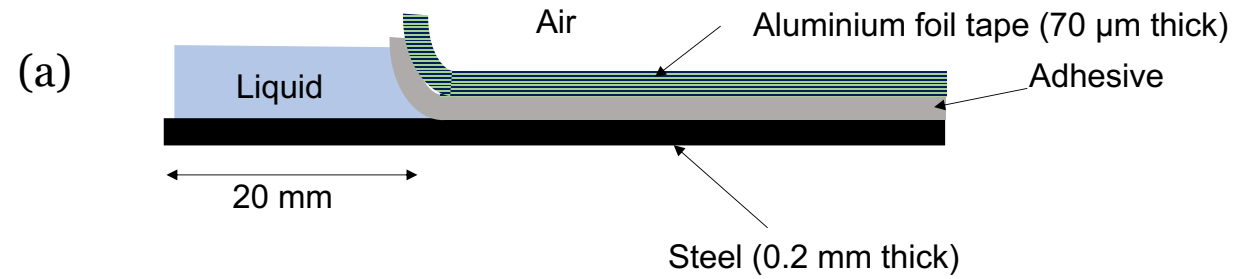


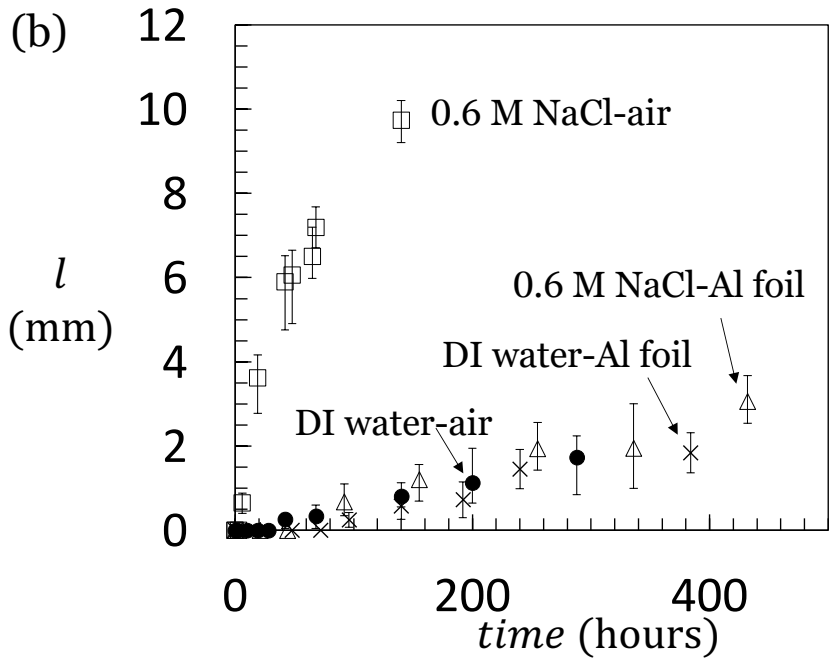
Fundamentals of the Competing Mechanisms

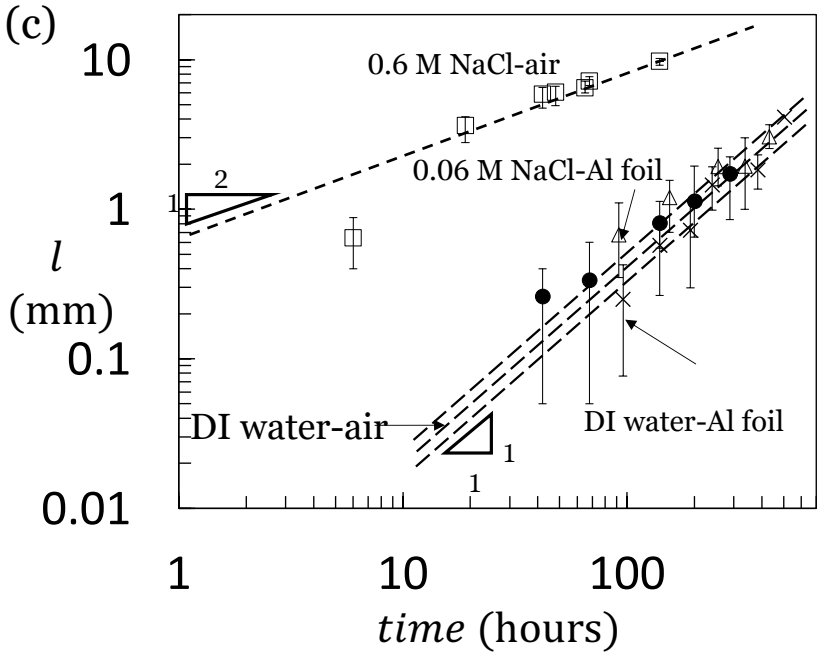
Decreasing oxygen supply

Mechanism	Fundamentals
A: Free corrosion	Production of both Fe^{2+} and OH^- at the crack tip. Needs O_2 supply
B: Cathodic delamination	OH^- production at the delamination tip from O_2, Fe^{2+} production remotely, Na^+ diffuses within the delamination crack to give charge balance.
C: hydrolysis	Water molecules destroy the bond between steel and interface.

Effect of reducing oxygen supply by a covering layer

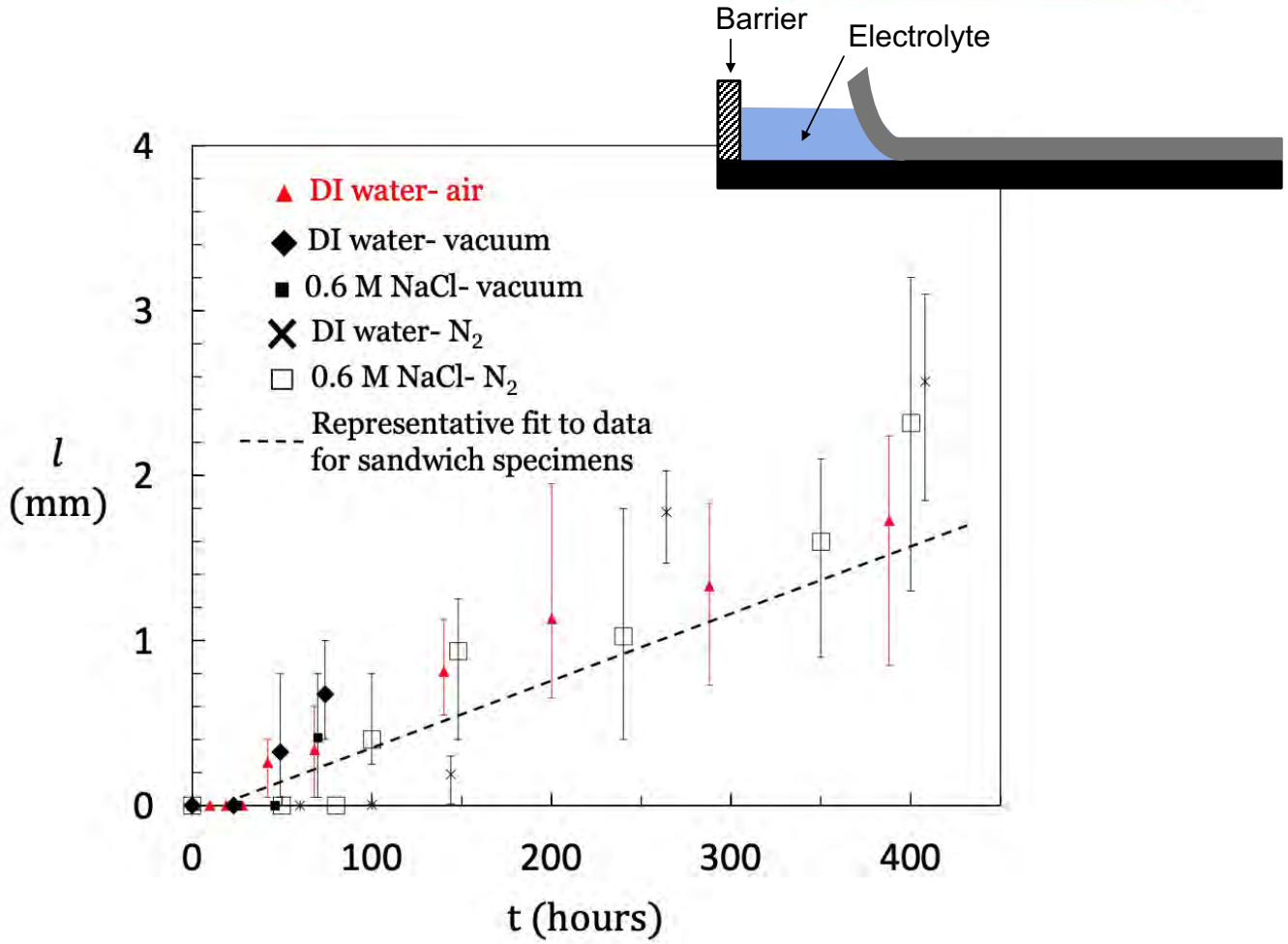






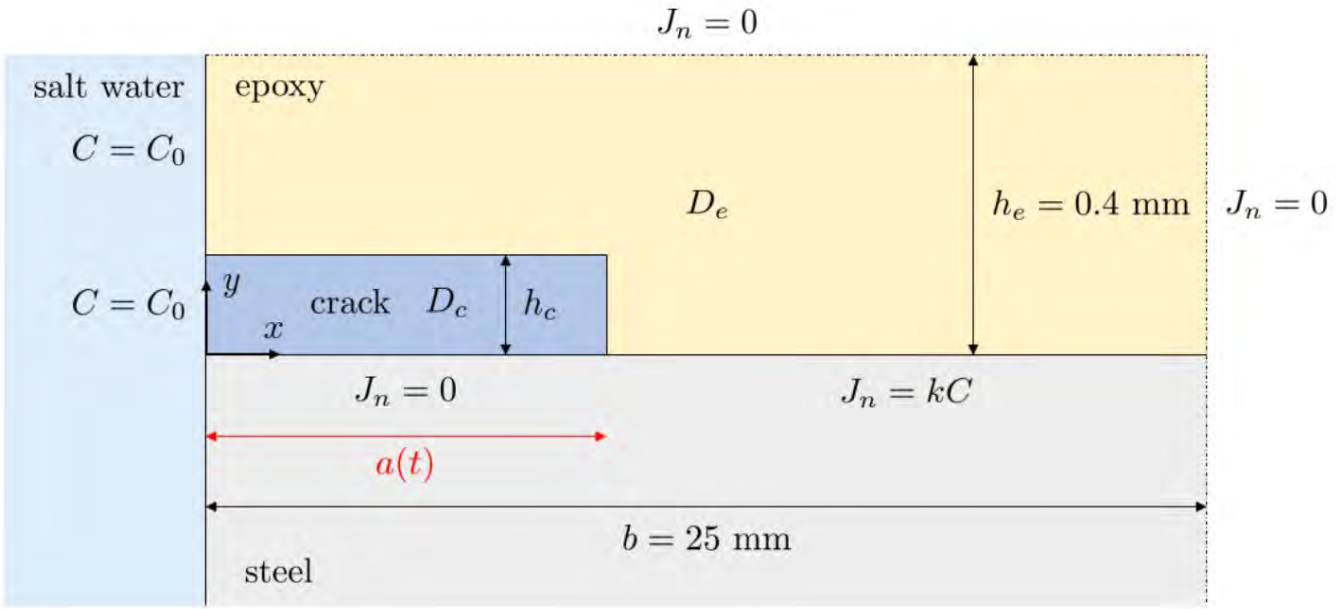
Delamination in Vacuum chamber and N_2 chamber

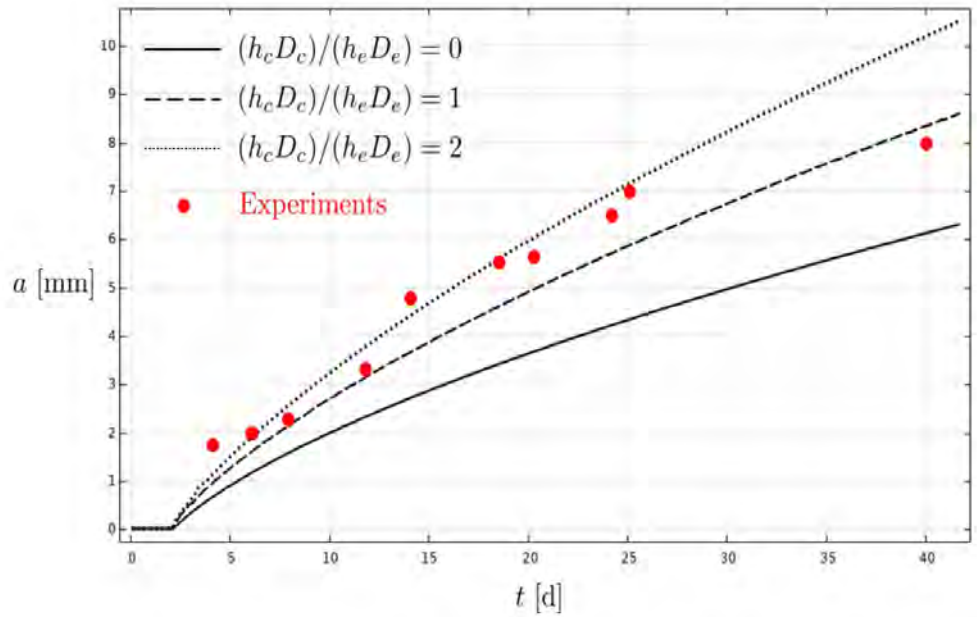
The fact that delamination is still happening in vacuum and N_2 chamber, and the similarity of delamination rate to sandwich specimens, suggest that oxygen supply is not controlling the delamination in sandwich specimens and the only mechanism that does not require oxygen supply to happen is HYDROLYSIS.



Finite Element Model

Geometry, material parameters and boundary conditions for the diffusion/corrosion model.





Conclusions and summary

- Delamination in closed joint configuration in which oxygen supply is limited is NOT governed by cathodic delamination.
- Finite element modelling was used to predict delamination rate using a diffusion of one species (oxygen or water)
- Insensitivity of delamination rate in closed joint configuration to salt concentration and oxygen supply suggest Hydrolysis mechanism rather than cathodic delamination and free corrosion.
- The linear dependence of delamination length to time also confirms the hydrolysis mechanism.

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http://www.interreg2seas.eu/qualify