A. BASIC CONCEPTS

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CORROSION BEHAVIOUR

ENVIRONMENTAL ASSISTED CRACKING PROCESSES

AGGRESSIVE ENVIRONMENT → **MATERIAL** ← MECHANIC LOADS

LOADING RATE

Static or Quasi-Sstatic → **Stress corrosion cracking (SCC)**

Dynamic → **Corrosion – Fatigue (CF)**

ENVIRONMENTAL ASSISTED CRACKING

ENVIRONMENT

Liquid or Gaseous Environments

Presence of damaging simple chemical elements or molecules

- Hydrogen — **Hydrogen assisted embrittlement**; **Hydrogen assisted cracking**
- Oxygen — **Intergranular corrosion cracking**

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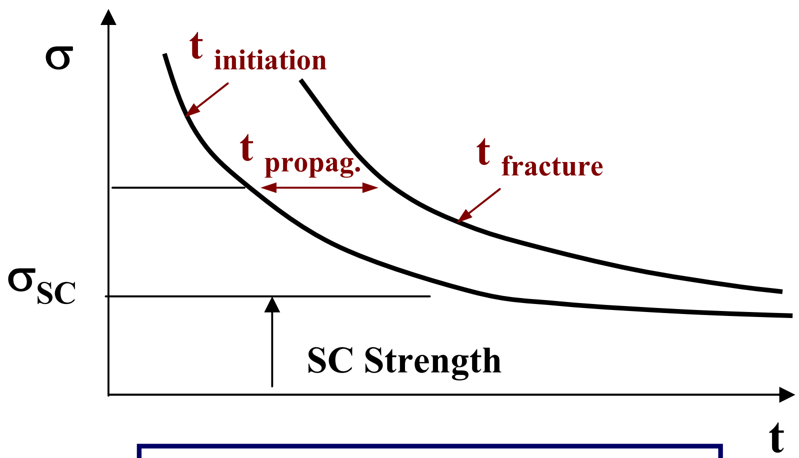
ENVIRONMENTAL ASSISTED CRACKING

Crack initiation processes

+

Propagation processes

FRACTURE



Safe Design: $\sigma \leqslant \sigma_{SC}$

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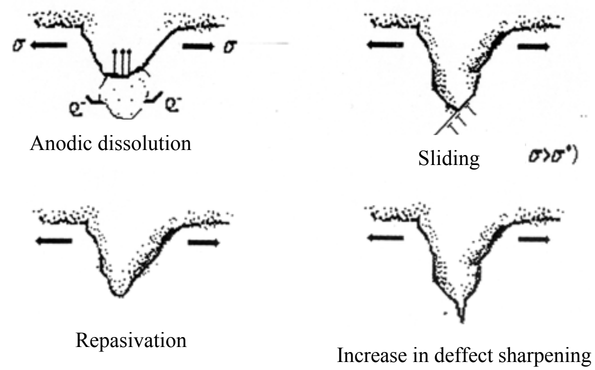

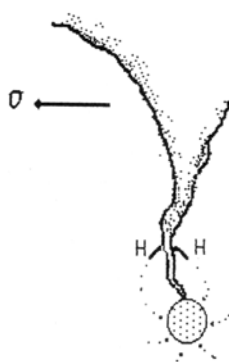

Catodic reaction

$H^+ + e^- \rightarrow ½ H_2$

Hydrogen embrittlement

- -Adsorption
- -Absorption
- -Diffusion
- -Local damage and failure
- -Crack advance

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ENVIRONMENTAL ASSISTED CRACKING

Life estimation (constant environment and stresses)

· Depends on initiation → material surface state
(roughness)
(surface defects) → inclusions ... / processing ... / recovering ...

· Depends on propagation → Local cracking mechanisms
(local fractures after restrained embrittlement)
(inherent mechanisms)

· If previous notches (stress concentration) or cracks exist → $t_{life} \equiv t_{propagation}$

Design $\sigma \leq \sigma_{SCC}$

σ_{SCC} is not only material dependent, it also depends in processing (surface finishing) and design (notches, welds,…)

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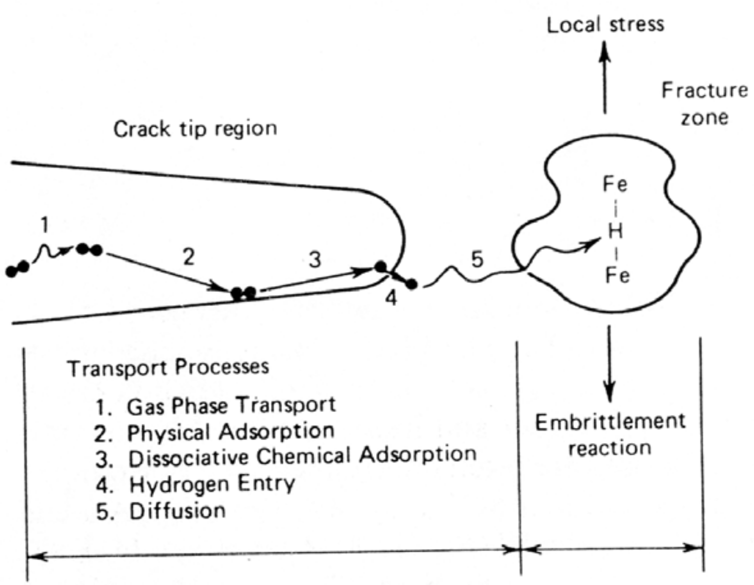
ENVIRONMENTAL ASSISTED CRACKING

Crack propagation rate; $\left[\frac{da}{dt}\right]$ is a characteristic of the material (for a given environment and local conditions).



Local mechanisms of material transport and embrittlement

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CORROSION BEHAVIOUR

ENVIRONMENTAL ASSISTED CRACKING

Material behaviour

- It defines the crack propagation process

- Stress state
  +
  Crack presence

↓

Application of Fracture Mechanics

Crack propagation rate as a function of the local stress state (K_I), that establishes, together with the environment, the cracking mechanisms

$$\frac{da}{dt} = f(K_I, \text{environment})$$

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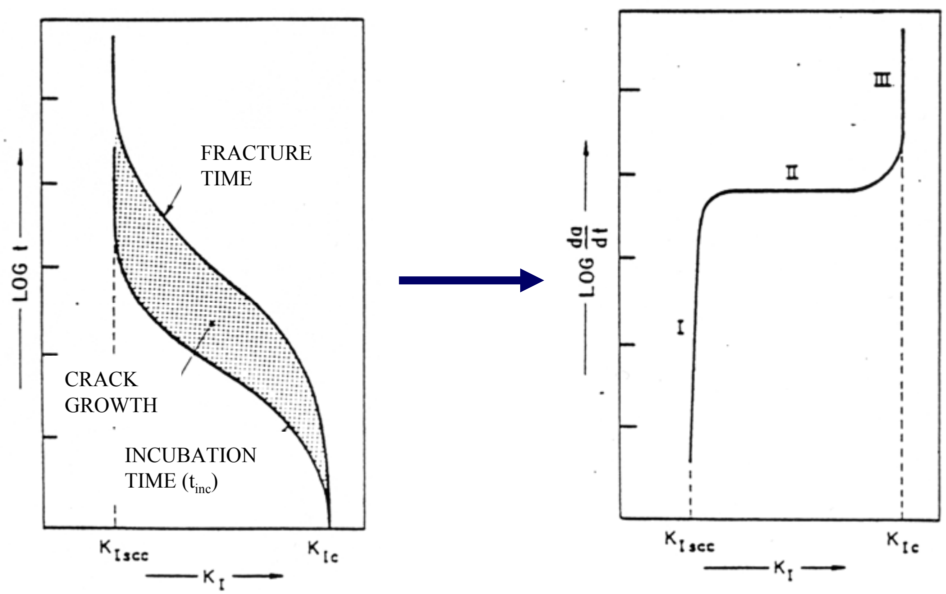
ENVIRONMENTAL ASSISTED CRACKING

STRESS CORROSION



Crack propagation happens over some characteristic threshold conditions, defining K_{ISCC} (da/dt = 0 for $K_I<K_{ISCC}$, Stage I)

- at a quasi-constant rate (da/dt = cte for $K_I>K_{ISCC}$, Stage II)
- loading to final fracture at stage III ($K_I = K_{IC}$)

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CORROSION BEHAVIOUR

DESIGN CONDITIONS AND INTEGRITY MAINTENANCE

- Guarantee maximum defect size ($a_0 \leqslant a_{Lim}$)

a_{Lim} → observable on reception

• Determine crack evolution

$$\mathbf{a_{calc}(t) = a_{Lim} + \int_0^t \left[\frac{da}{dt}\right] dt}$$

↑ **Material behaviour**

• Periodic and cyclic observations to guarantee

$$a_{real}(t) \leqslant a_{calc}(t)$$

when $K_I(a_{calc}) \leqslant K_{Ic} / F_{safety}$

• Repair, substitute or leave when critical security conditions are reached.

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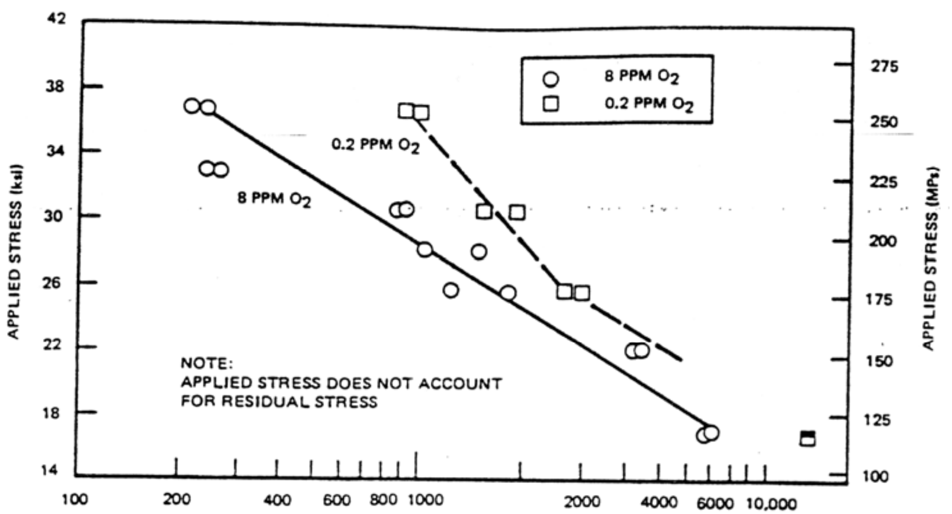
CORROSION BEHAVIOUR

STRESS CORROSION

Example: Intergranular corrosion on stainless steels.

• Conditions:
- Stress state greater than the threshold
- Aggressive environment [dissolved oxygen]
- Sensitized material



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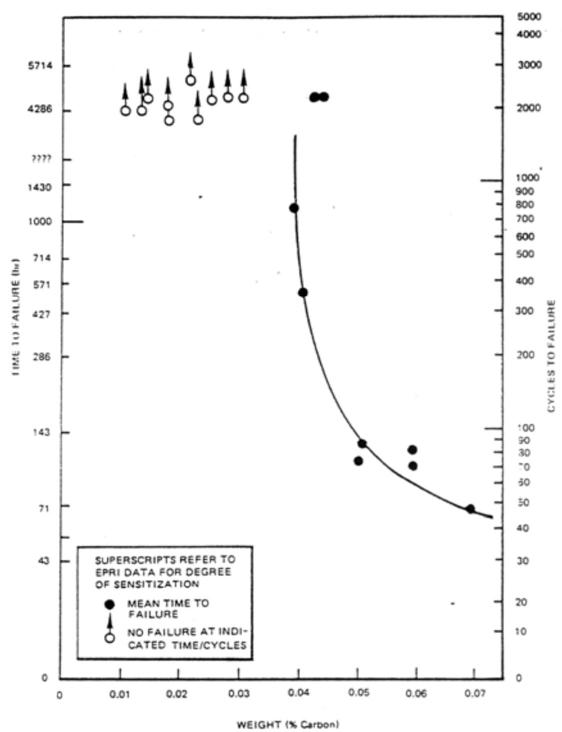

•Solution:

- Reduction of aggresive element concentration (↓O_2)
- Adequate material election
- Not susceptible to be sensitized

% C ↓ to avoid chromium carbides formation at sensitive temperatures and then the IG loss of chromium

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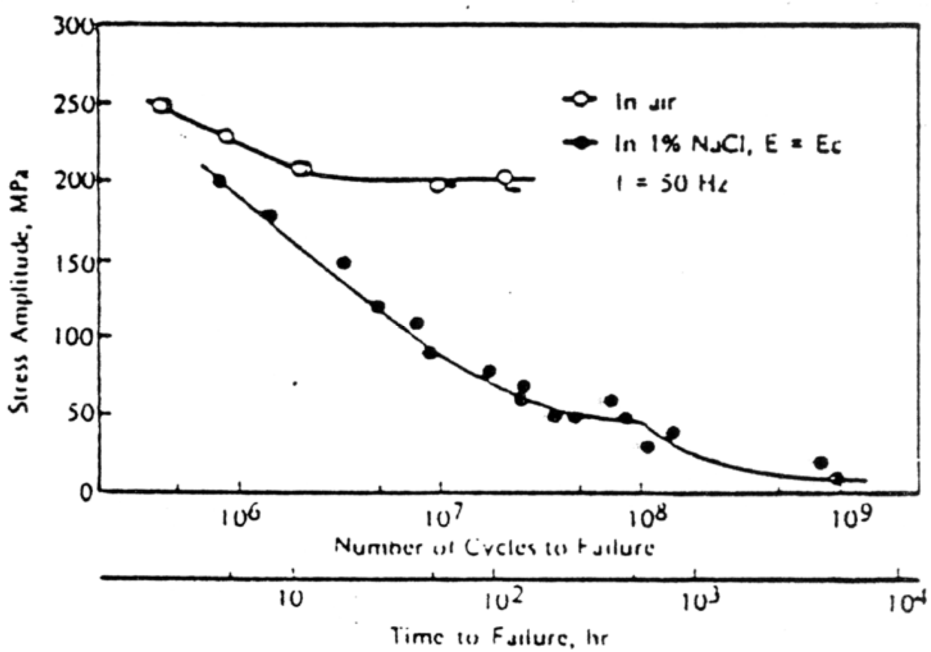
CORROSION BEHAVIOUR

ENVIRONMENTAL ASSISTED CRACKING

CORROSION - FATIGUE



Fatigue conditions

+

Aggressive environment

produce corrosion fatigue

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CORROSION BEHAVIOUR

ENVIRONMENTAL ASSISTED CRACKING

CORROSION-FATIGUE

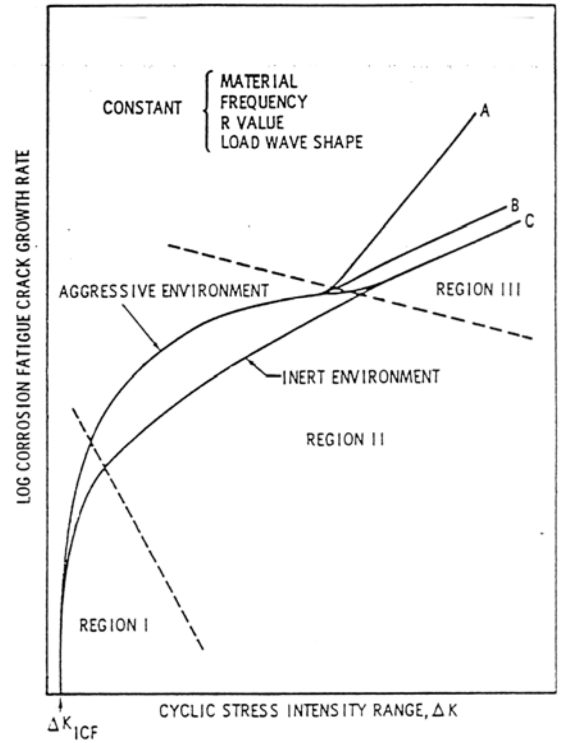
Similar behaviour than fatigue at inert environment

Threshold: ΔK_{ICF}

and crack propagation rate: $$\frac{da}{dN} = f(\Delta K_I)$$

The behaviour depends on:

→ Material (microstructure)
→ Stress condition (local)
→ Environment presence
+
Loading frequency
...



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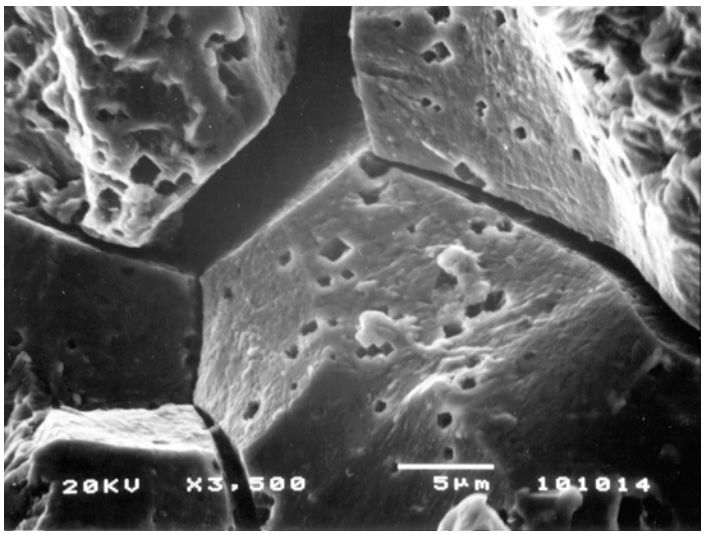
CORROSION BEHAVIOUR

ENVIRONMENTAL ASSISTED CRACKING

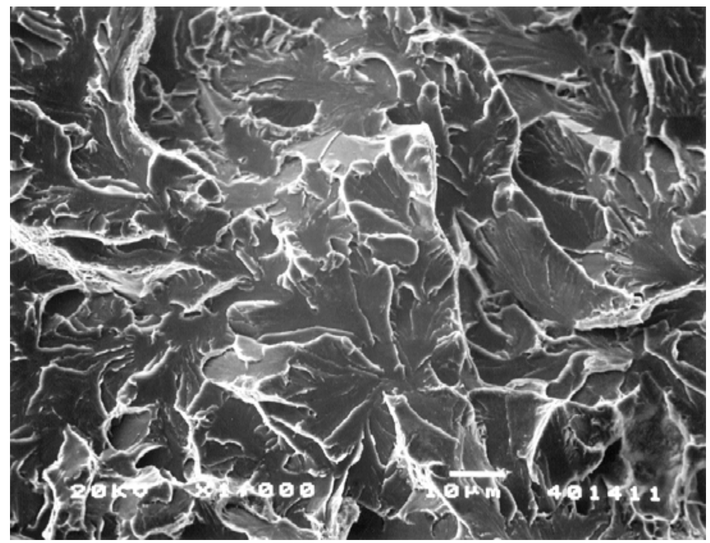
Mechanisms on metallic materials

SCC (metals) Crack advances generally by local fractures



Intergranular (IG)

or



Transgranular (TG)

Cleavages or tearing

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