LAB AT KEMPER 1120

1 Objectives

1. Explain stages of environmental fracture
2. Explain mechanisms of crack growth in SCC
3. Explain mechanisms of crack growth in HIC
4. Explain stages of Creep
5. Identify creep fracture surface features
6. Use creep deformation map to Identify the dominant creep mechanism
7. Predict creep failure time using Larson-Miller Parameter

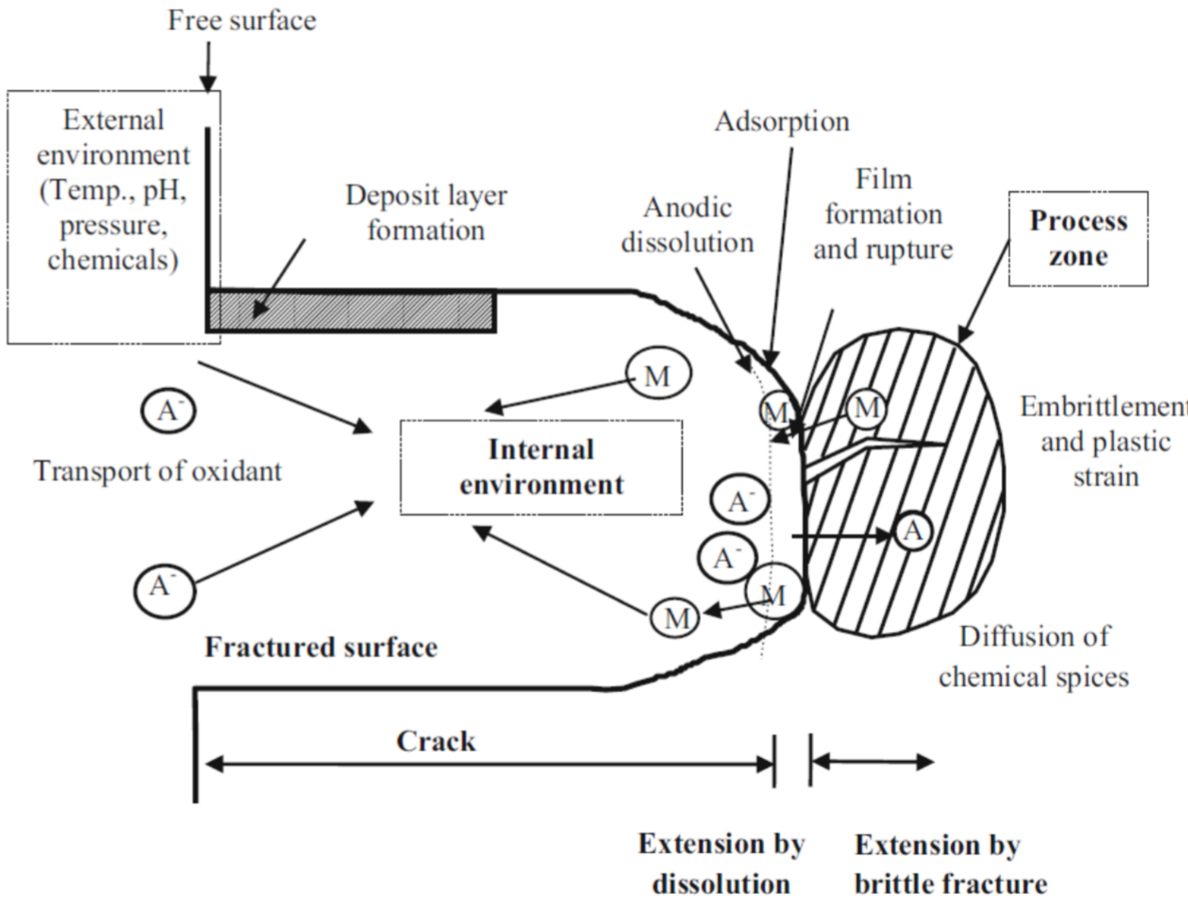
1.1 Stages of environmental fracture

A slow or stable fracture due to combined action of loads and the environment in a susceptible material

1. Crack nucleus formation
   - mechanical strength reduction(Temperature dependent)
   - formation of microstructural defects or surface micro-cracking
2. Nucleated crack turns into macroscopic crack
   - load opens the crack
   - corrosion is dominant
3. Fracture
   - not entirely mechanical
   - can happen at $K < K_{IC}$

1.2 Mechanisms of crack growth in SCC

Stress corrosion cracking causes:

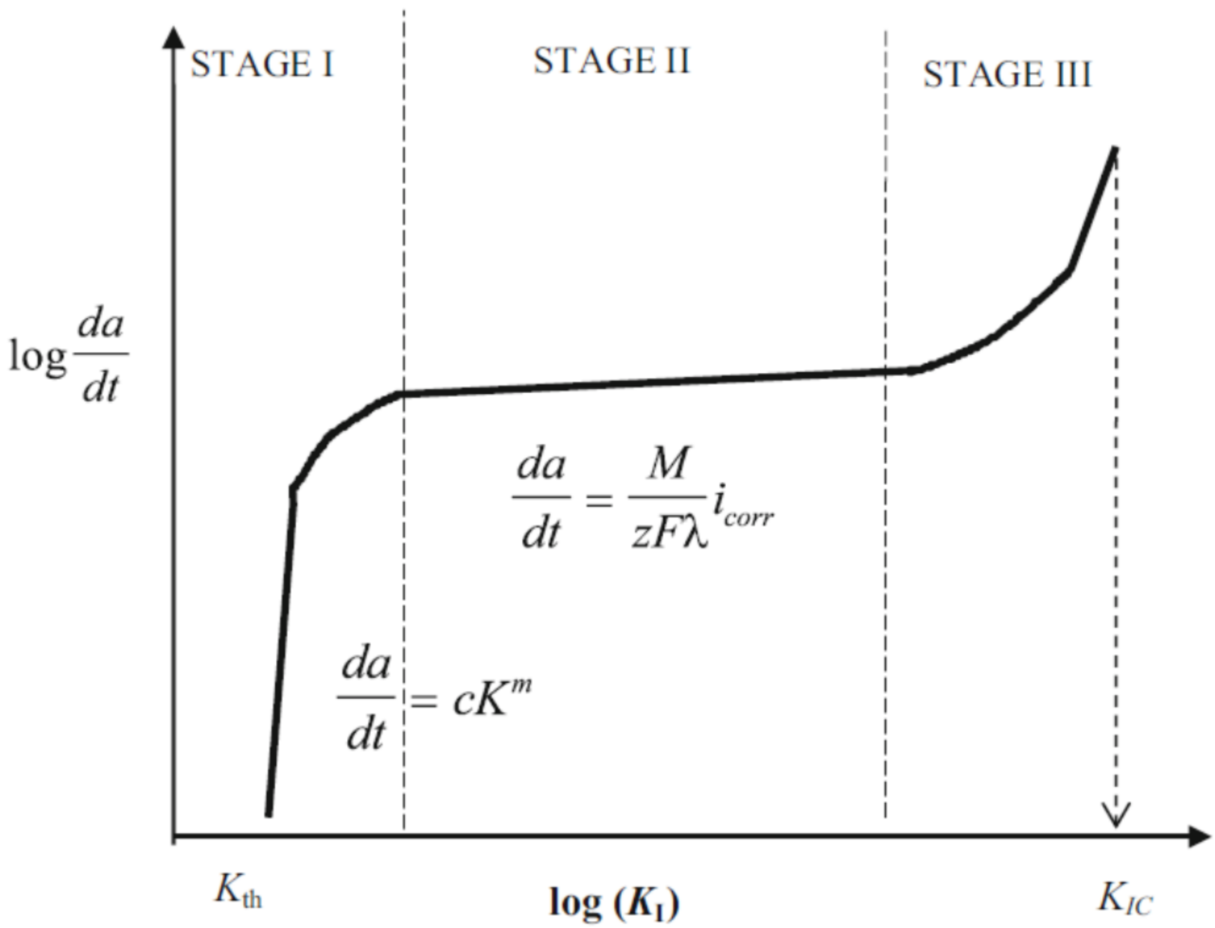


1. Slip
   -External stress causes dislocation and create slip steps
2. film rupture
   -Slip steps ruptures oxide film at the crack tip
3. anodic dissolution
   -ruptured oxide film causes exposes material to anodic dissolution (corrosion)
4. repassivation
   -new oxide film forms

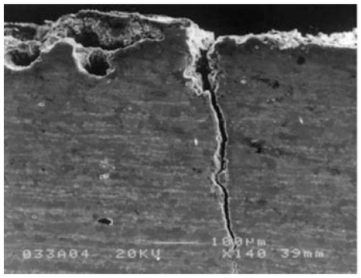
1.2.1 Two types of SCC Mechanisms

1. Controlled by Environment:
   - Predominant mechanism is anodic dissolution
2. Controlled by Stress:
   - Predominant mechanism is brittle fracture
   - Thin film of corrosion products

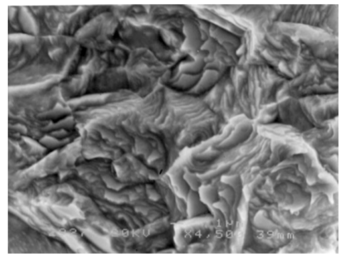
1.2.2 Stages of SCC

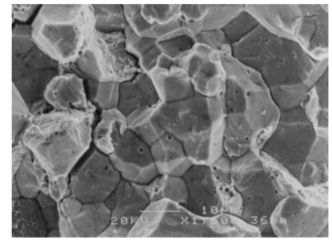


1. Formation and rupture of passive layer
2. crack tip anodic dissolution
3. Static fracture

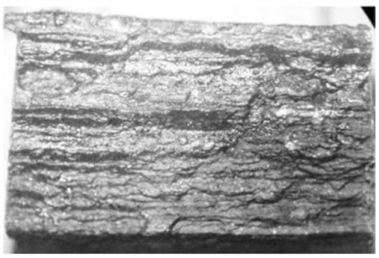


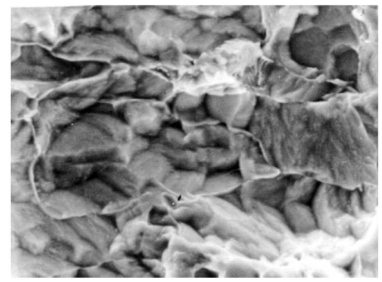
SCC cracks nucleated at corrosion pits





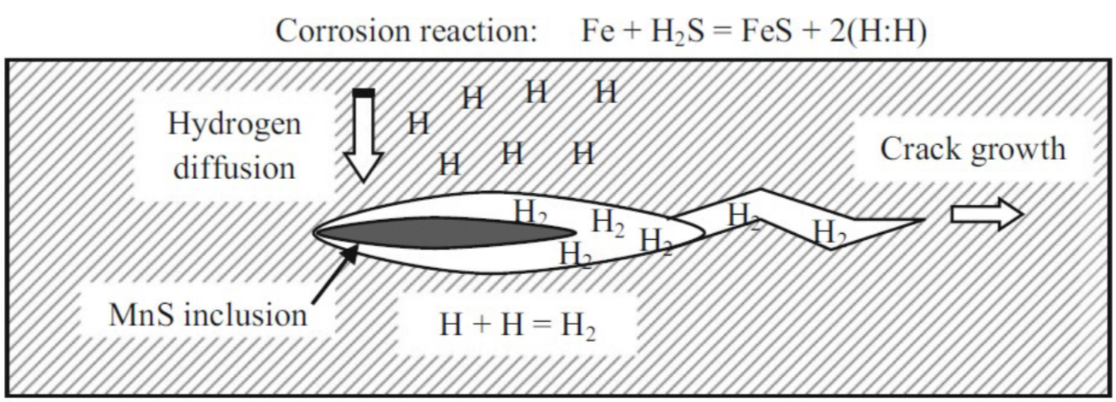
Crack can be IG or TG, or mixed.
It depends on which being anodic.



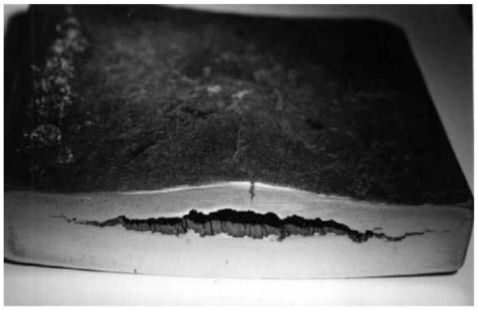


Brittle appearance, and there is clear evidence of corrosive attack on the fractured surface

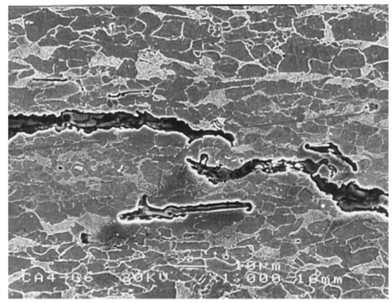
1.3 Hydrogen induced cracking (HIC)



- Reported in low and medium carbon steels exposed to sour environments
  - Sour environments contain hydrocarbon H_2S, carbon dioxide, and water(l).
- atomic hydrogen dissolves in material
- gashouse hydrogen inside the metal, near the inclusion is formed and creates stress concentration at the edge of the trapping creating cracks

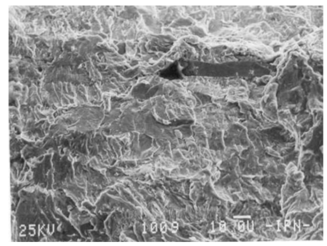


Near surface: Blister



The cracks move toward each other.

In the midlle: Lamination



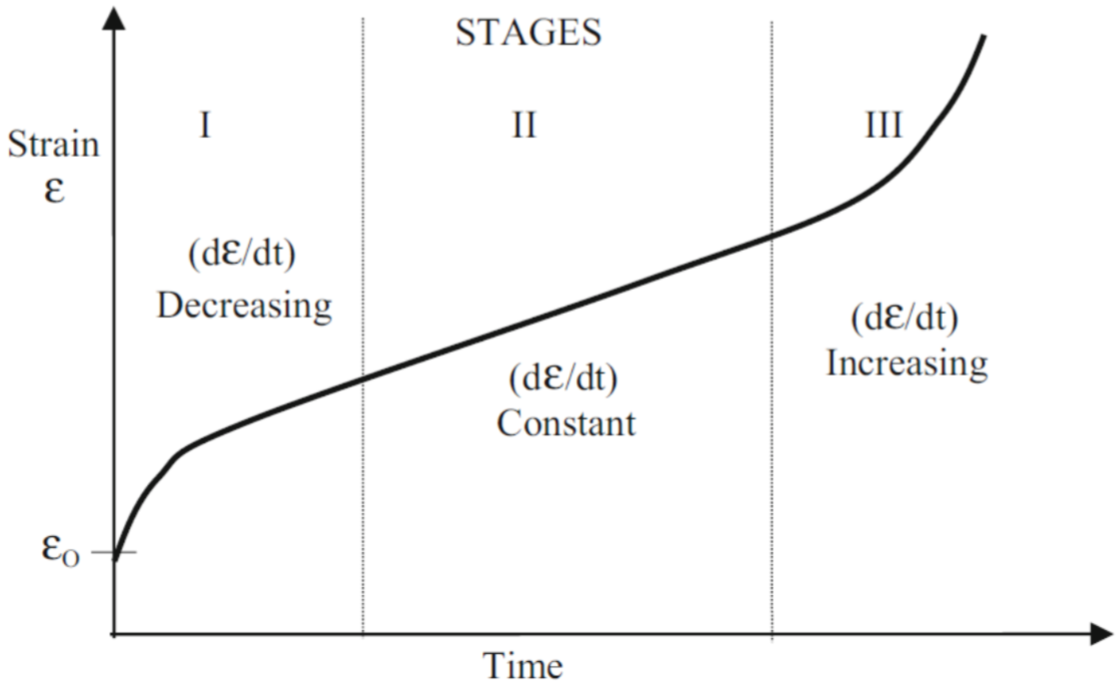
Brittle appearance.

1.4 Stages of creep

Creep refers to plastic deformation leading to fracture of a material under stress when subjected to high temperature. $T > (0.3 \text{ to } 0.5)T_{melting}$
Creep leads to loss of tolerance and component/structural failure.
Used in engine components, turbine blades, Boilers, pipelines, etc.

Effect of high temperature:

- Reduction of yield and tensile strength
- increase in dislocation mobility(diffusion)
- Recovery and recrystallization and grain growth.
- Dissolution and precipitation of second phases



Stages of creep:

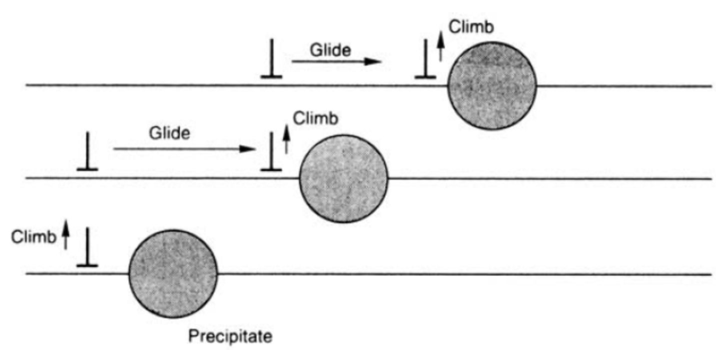
1. The strain decreased due to work hardening phenomena associated to dislocation density increase
2. Strain rate is constant due to balance between hardening and recovery or softening mechanisms
3. The strain rate increases due to onset of creep damage, characterized by microvoid nucleation and growth mechanisms

1.4.1 Dislocation-controlled Creep mechanism

- Creep rate in climb:
  - Independent of grain size
  - Dependent on the stress

$$\dot{\varepsilon}_{ss} = \frac{AGb}{kT}\left(\frac{\sigma}{G}\right)^n$$

G: Modulus of rigidity
B: Burger's vector
K: Boltzmann constant
A: Constant



2 Wear

2.1 Three types of wear

2.2 Abrasive Wear

1. Occurs when a harder material is pressed against a softer one
2.

2.2.1 Abrasive wear mechanisms

1. Plowing
2. Cutting
3. Fracture

2.2.2 Types of Abrasive Wear

1. two body
2. three body
   -Occurs when theres a particle involved in between two podies

2.3 Adhesive Wear

2.4 Fretting

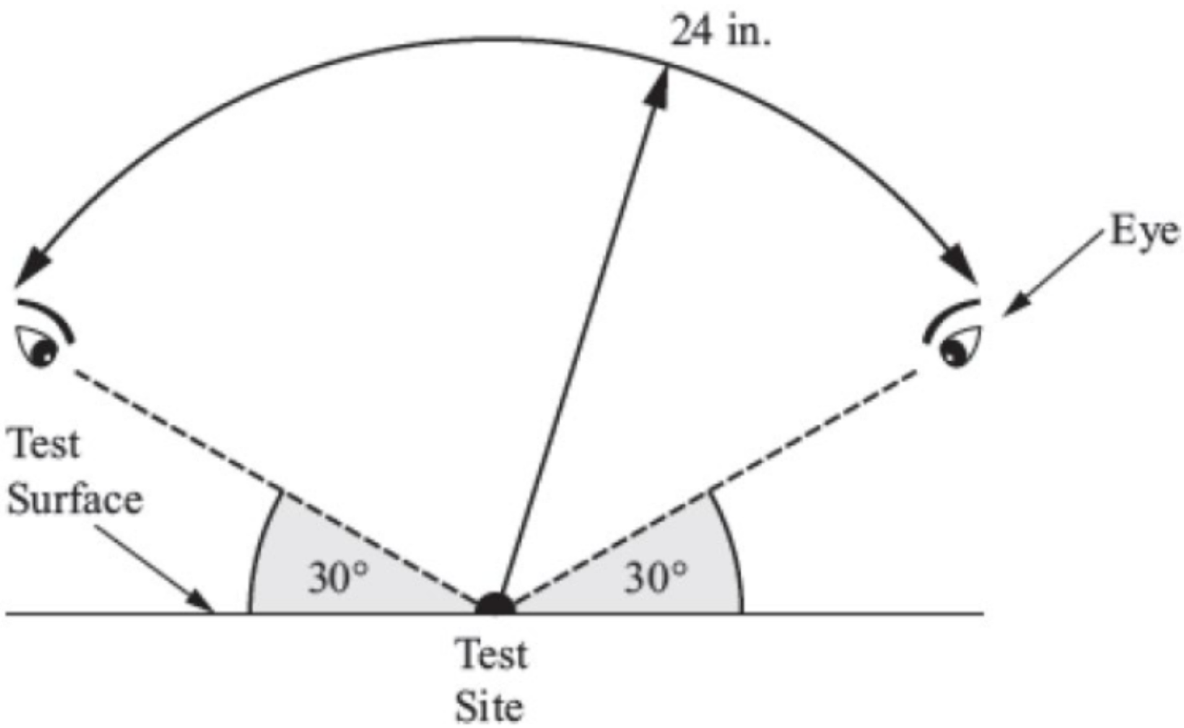
3 Non destructive testing(NDT)

Evaluation of an object without changing it or altering it in any fashion.

3.1 Objectives

1. Define NDT and name some NDT techniques
2. Principles and steps in penetrant testing
3. Principles of magnetic particle testing
4. Name advantages and disadvantages of NDT's

3.1.1 NDT Technique: Visual Inspection



3.1.2 NDT Technique: Penetrant testing (PT)

Take advantage of capillary action of Penetrant

- Good for surface discontinuities
- Can be used in production-type environment
- Flaws as fine as 1 micron can be detected
- Fluorescent dye can be used
- Portable

Advantages:

- Inexpensive
- Sensitive
- Minimal equipment
- Can be applied to irregular shapes
- Versatile and Portable
- Minimal training required
- Ease of interpretation

Disadvantages:

-

3.1.3 NDT Technique: Magnetic-Particle Inspection

Disadvantages:

- Crack direction matters

3.1.4 NDT Technique: Eddy-Current inspection

3.2 Destructive testing

Advantages:

- Generates useful data for design purposes
- Data can be used to establish standards and specifications
- Data achieved through ?destructive? testing ususally quantitative.
- Service conditions can be measured
- Useful life can be predicted

Disadvantages:

- specimens cant be used after testing
- expensive

3.3

4 Slide 1

1. Stages of environmental fractures
2. Creep
3. Third item

5 Slide 2 - Environmental Fracture

slow or stable fracture due to combined action of loads and the environmentin a susceptible material

5.1 example: Rolled up plastic hoses

6 Slide 3 - Stages of Environmental Fracture

- Stage 1: Accumulation of internal damage
- Stage 2: Nucleated crack turns into a macroscopic crack
- Stage 3: Rapid fracture, can happen $K < K_{IC}$

7 Slide 4 - Creep

8 Stress corrosion cracking (SCC) Mechanism

- Slip-dissolution mechanism involves 4 stages: slip, film rupture, anodic dissolution, repassivation
- External stress causes dislocations to move and create slip steps, increasing plastic strain, and breaking the oxide film at the crak tip.

9 SCC Mechanisms

9.1 Stress corrosion cracking SCC

For stage I: $log(da/dt) = cK^m$
For stage II: $log(da/dt) = M/(zF\lambda)i_{curr}$

9.2 SCC - Effect of Microstructure

9.3 Example problem

$PLM = (500 + 273)[17 + log(28 * 365 * 24)]$
$PLM = 17190$
using the graph, $\sigma = 400MPa$