



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Failure Analysis and Prevention

General Procedure of Failure Analysis: Macroscopy of failed component I

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Fractography

- Failure: with or without fracture
- Without fracture failure like galling, fretting eventually can cause deformation or fracture
- Fractography: science of revealing load and environment conditions lead to fracture
- It uses 3D interpretation of appearance of broken parts
- It helps in identify loading events, how crack nucleate and propagate to cause bulk material fracture



How to Do it

- Commencing with visual examination followed by low to high magnification in the area of interest of fractured component.
- Naked eye, low magnification lens, stereoscopic microscope, SEM (1-100 X)

Purpose

- Determination of root cause of failure among the fundamental sources of failures
- Fractography determines potential casual factors
 - Whether a materials was used above allowable stress
 - Whether failed component had/had not properties assumed by design engineer
 - Whether a dis-continuity was critical enough to cause failure

Basic types of fracture

- In terms of fracture appearance
 - Ductile
 - Brittle
 - Fatigue
 - Creep
 - Environmentally assisted fracture SCC, H₂ embrittlement

Loading, Macroscale/Microscale

- Monotonic vs. fatigue fracture
Brach marks, striations
- Macroscale ductile vs brittle fracture
change in c/s and shear lip
- Microscale ductile vs. brittle fracture
Dimple-microvoid coalescence vs IG/TG cleavage facets



Inferences

- Stress state: plain stress/strain e.g. cup & cone
- Fracture initiation site:
- Crack growth direction: chevron marks
- Idea about crack growth rate
- Operational macro-scale fracture mechanism
- Extent fracture mechanism in cross-section: change in colour, texture, roughness



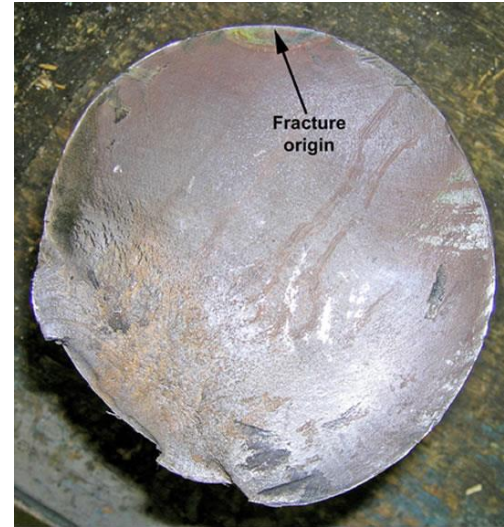
Visible distortion

- Plastic deformation(necking, buckling)
exceeded yield strength

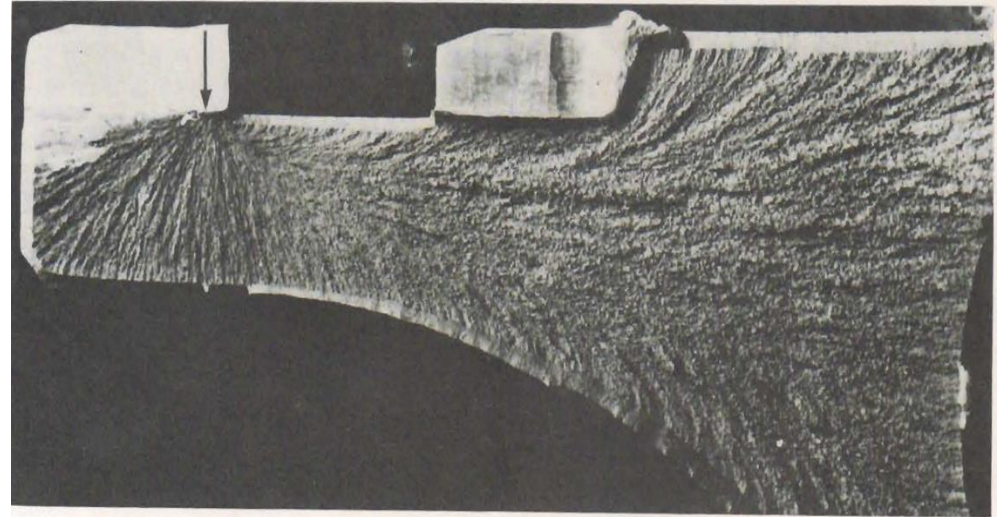
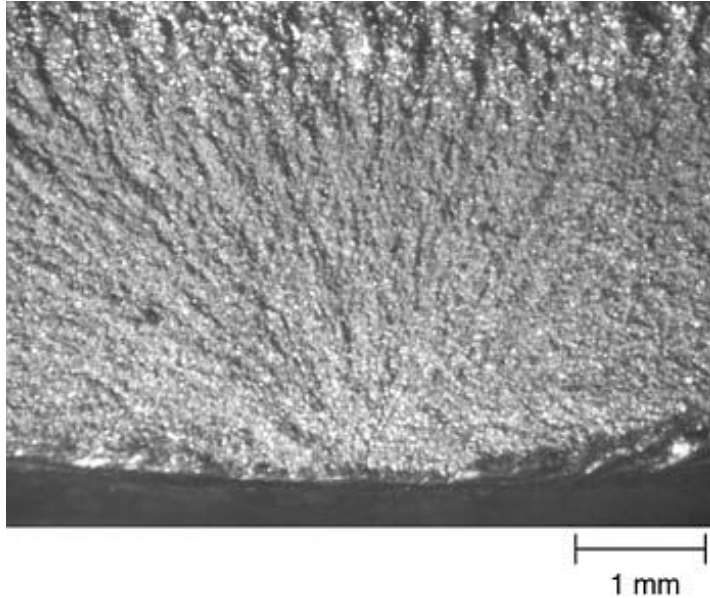


Nicks and gouges

- Possible crack initiation site

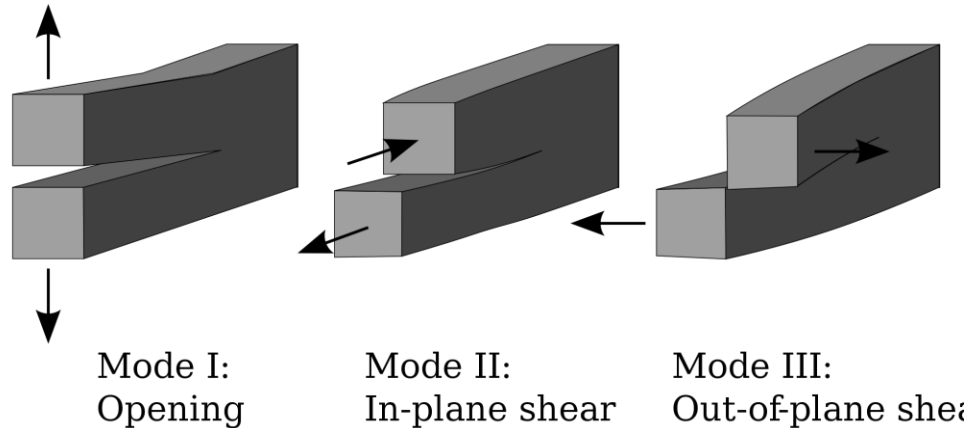


Fracture initiation

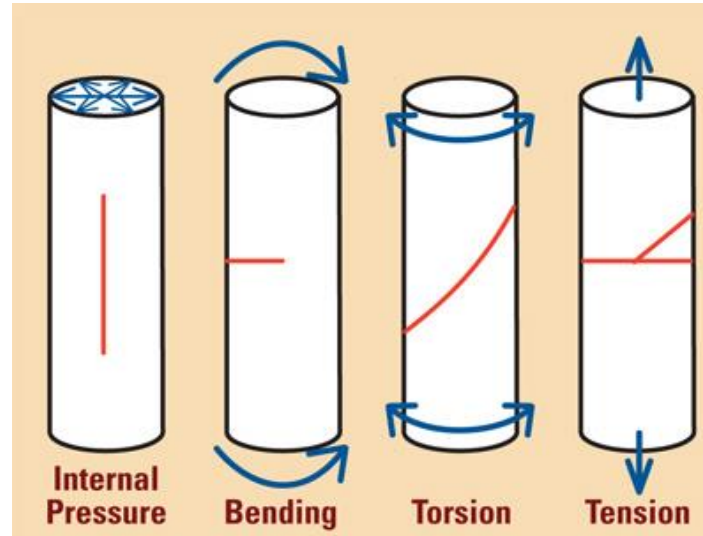


Fracture surface orientation w.e.t component geometry and loading

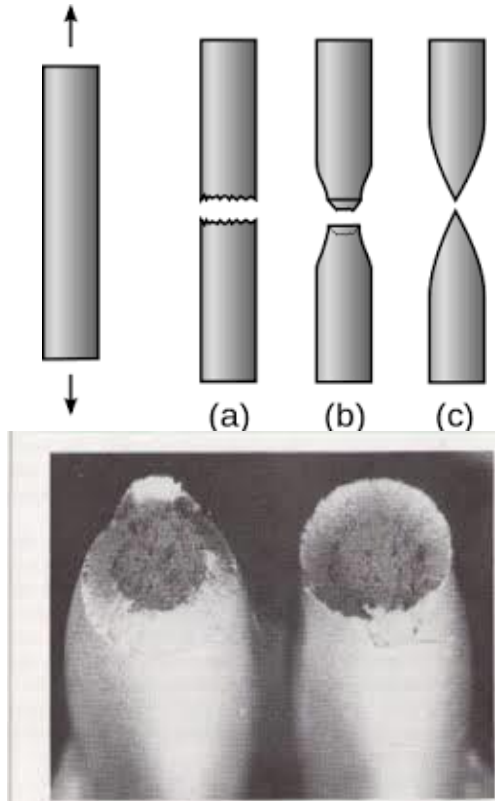
- Mode of loading: I, II, III
- Macro scale fracture: brittle/ductile



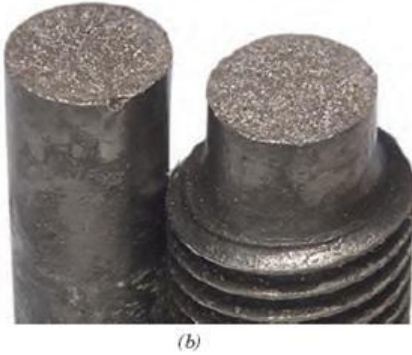
Type of load and fracture orientation



Macro-fracture: Ductile

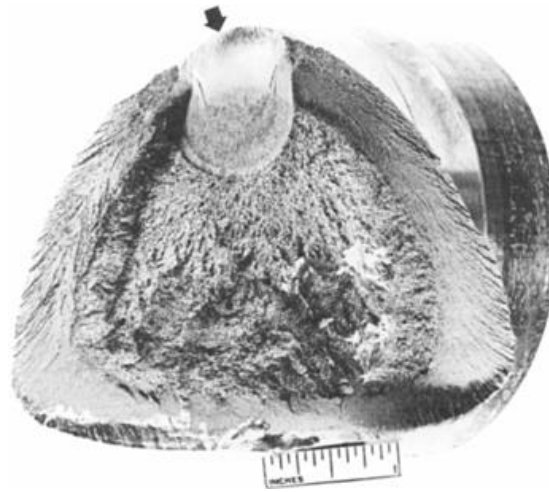


Macroscopic fracture: brittle

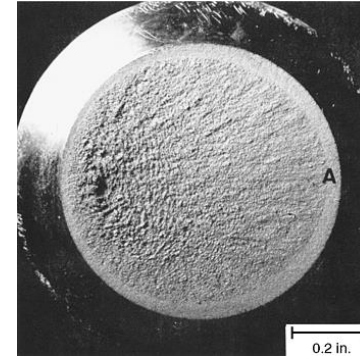
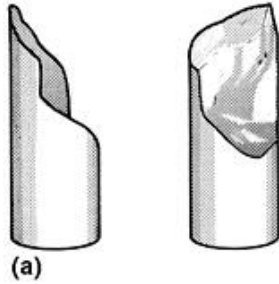


Both flat fracture and shear lips on fracture surface

- Incomplete constraint/mixed mode fracture
- Crack propagation direction parallel to shear lips



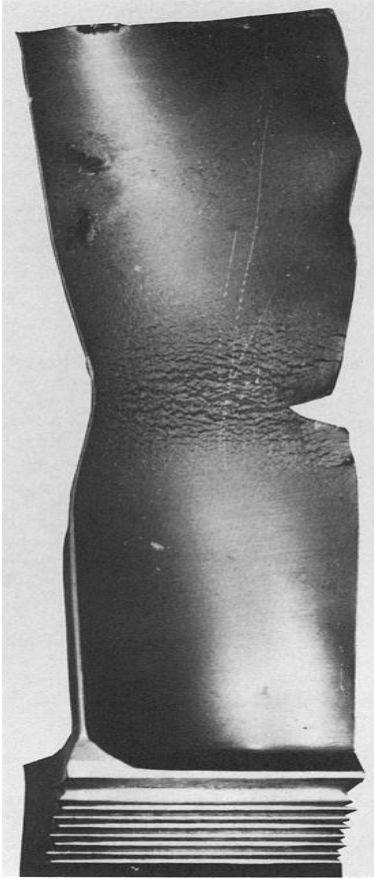
Stress state



Macroscopy: beach marks



Macroscopy : creep

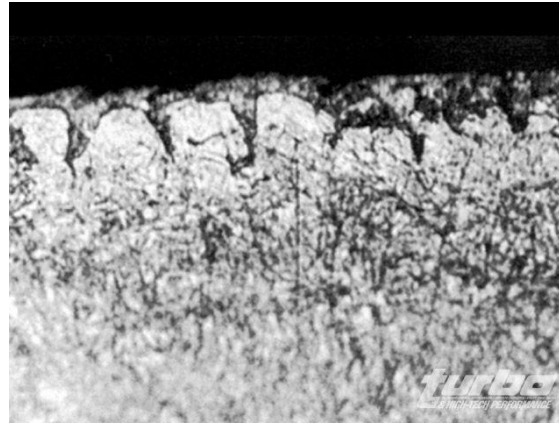
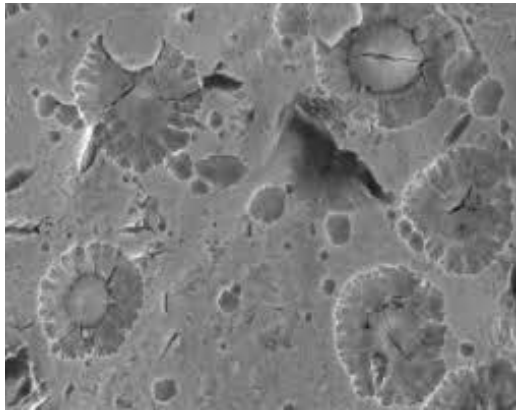


Macroscopy: High temperature: thinning and tube busting

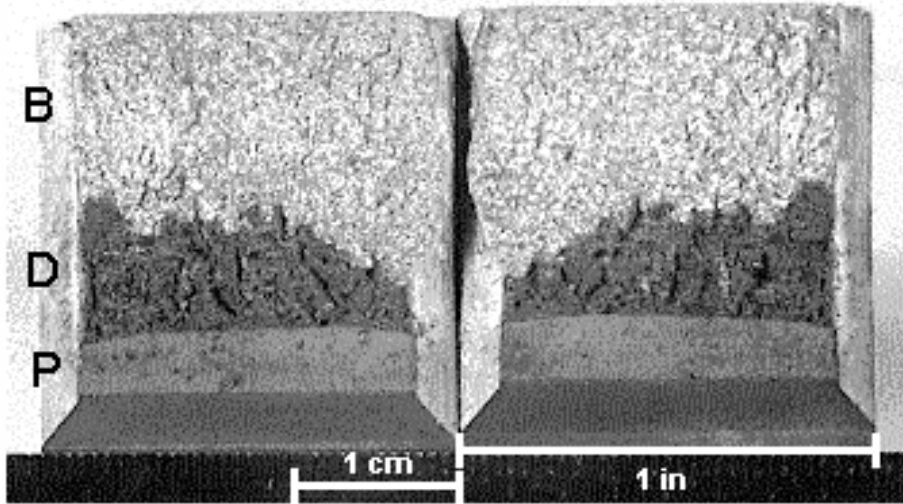


Tightly closed cracks

- Cyclic loading
- Surface imperfections: quench cracks, shot peening

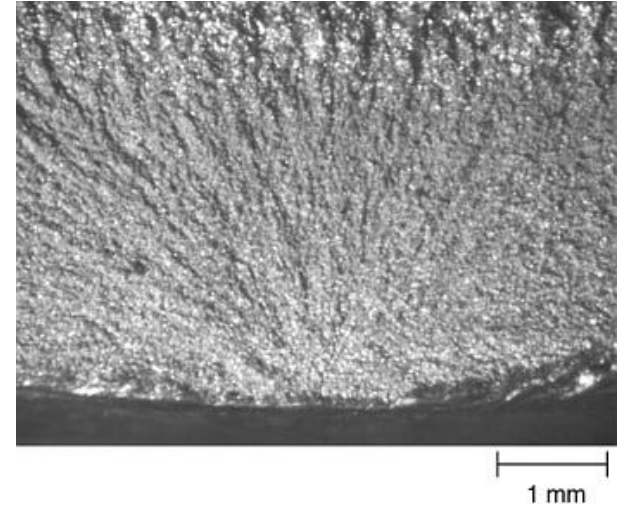
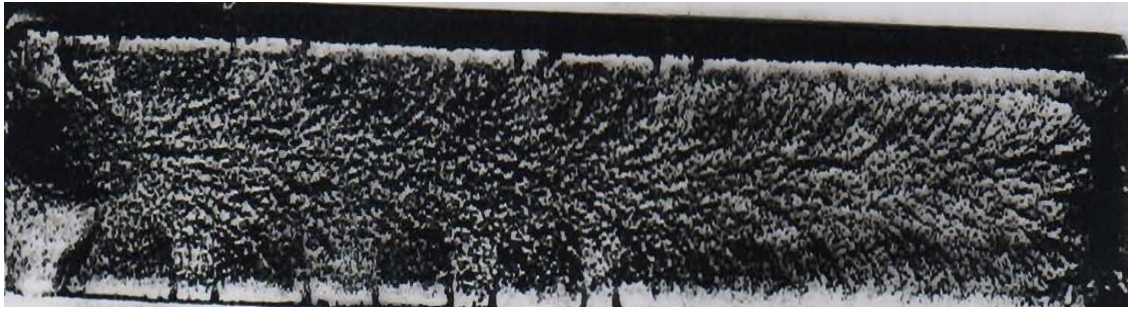


Changing mechanisms: shade, texture, colour, roughness



Chevron marks/ Radial Marks

- Pointing toward crack initiation site
- Crack propagation direction

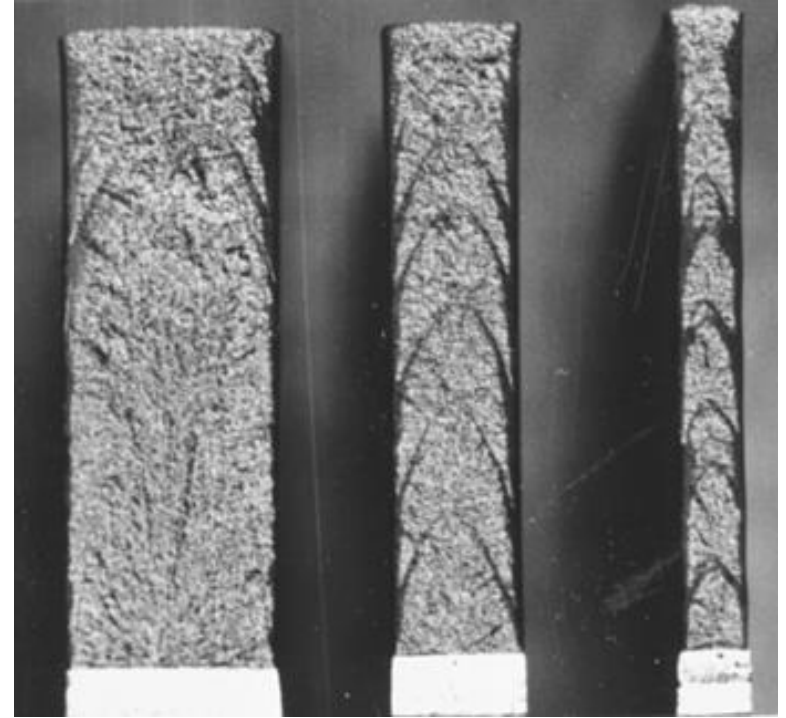


Radial marks



Crack arrest line

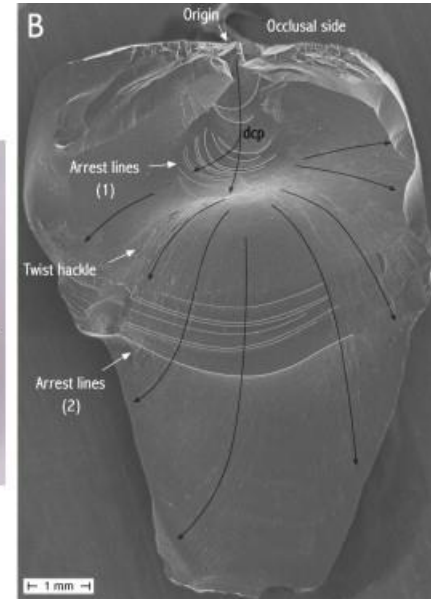
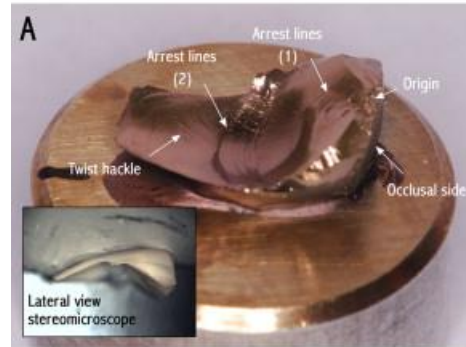
- U shape monotonic loading
 - Lines point in the direction of crack propagation
 - Incomplete constraint



Macroscopy: Fatigue crack arrest line: reverse cylindrical

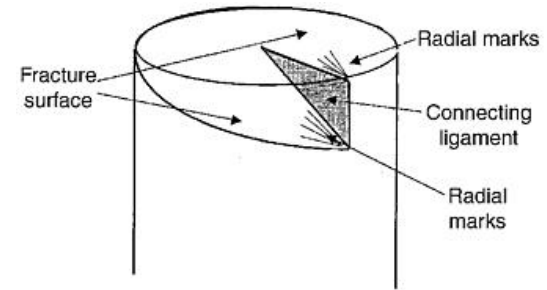
Cyclic loading

Propagation from centre of curvature

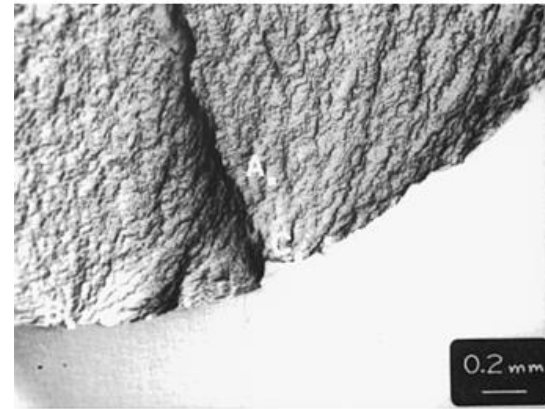


Ratchet Marks

- Mostly cyclic loading
- Indicating initiation site



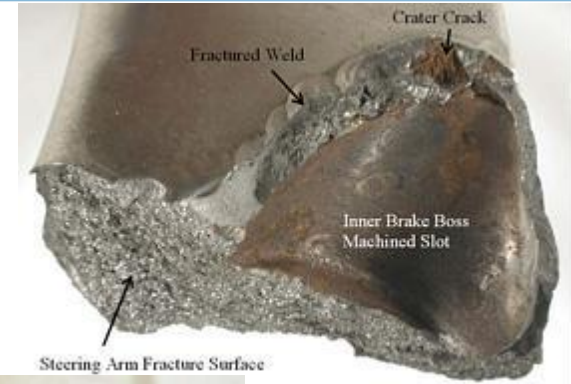
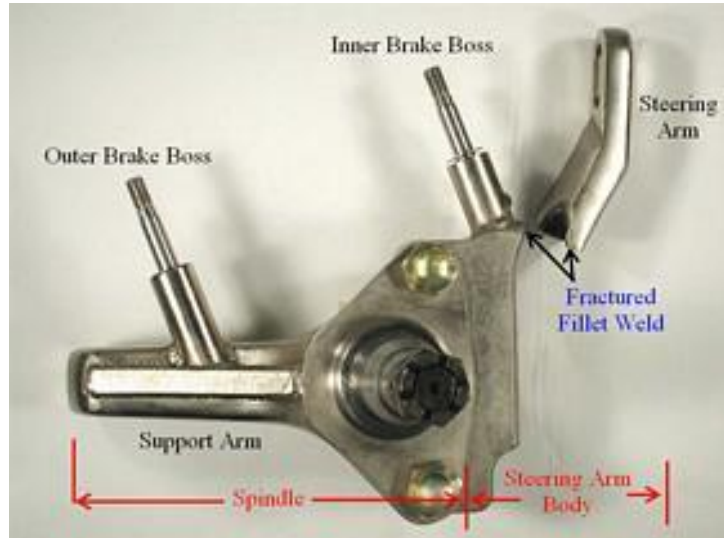
(a)



(b)

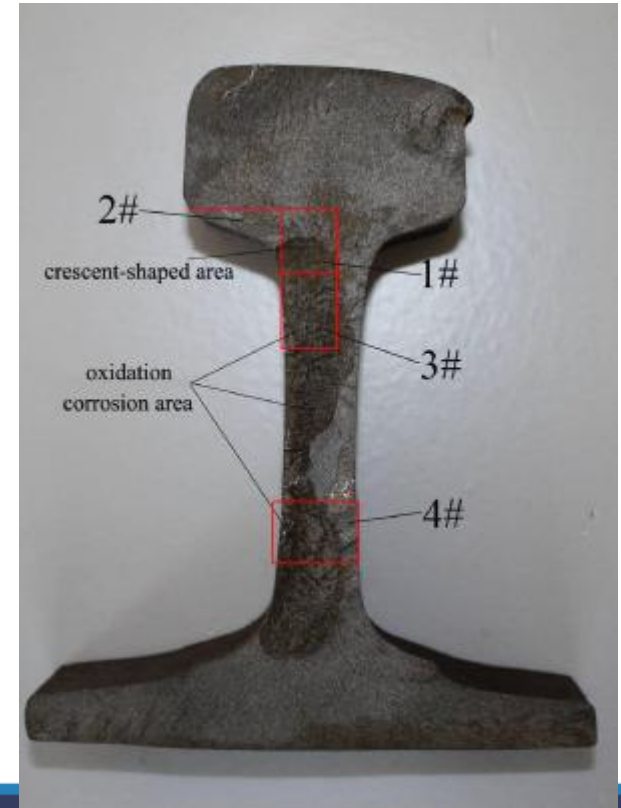
Decolorization

- Corrosion environment
- Possibility of elevated temperature



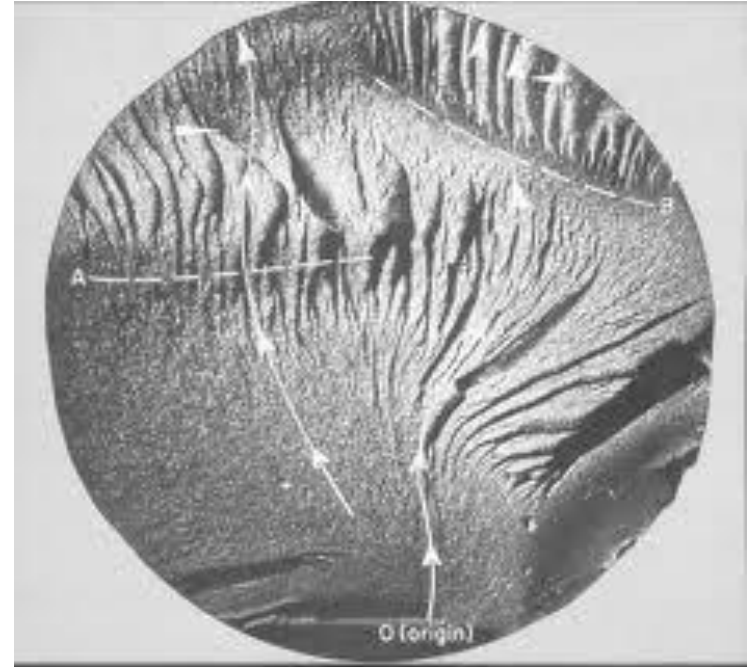
Oxidised fracture surface

- Possible crack initiation site



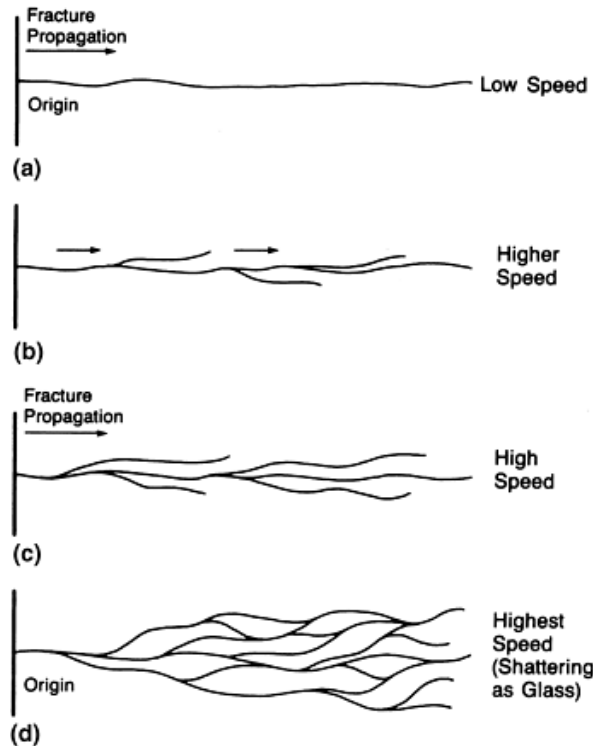
Reflectivity

- Matte: ductile fracture or cyclic loading
- Shiny: cleavage possibility
- Faceted (bumpy) shiny: intergranular with large grain size



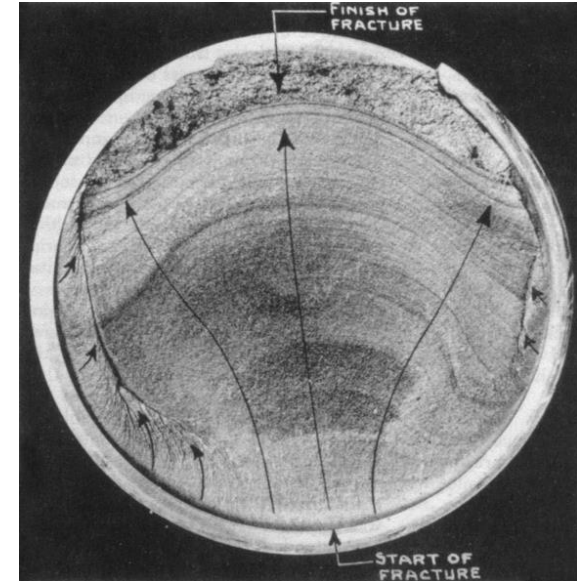
Surface Roughness

- Roughness increases in direction of crack growth (bending, compressive loading can affect it)
- Smooth plus rough region in direction of crack growth: cyclic loading
- Rough matte fracture: ductile
- Transition from stage II to stage III of fatigue fracture



Rubbing (general)

- May indicate vibrations
- May show final direction of separation
- Swirl pattern indicate torsional loading



Rubbing (localized)

- May indicate
 - crack closure in cyclic loading
 - Weak beach marks



Deformed draw marks, rolling scratch

- If twisted: torsional loading
- Variable roughness of fracture edge
 - In brittle bending, roughness in tension side

