SUCKER ROD FAILURE DIAGNOSIS & ROOT CAUSE ANALYSIS GUIDE

This guide outlines an evidence-based approach for investigating failed sucker rods. It connects fracture location, visible damage, material condition, and operating history so that the failure mechanism and supporting root cause can be evaluated in a structured way.

PRODUCT AND FAILURE CONTEXT







FAILURE INVESTIGATION WORKFLOW

01
Evidence Preservation
Document the failed components

02
Failure Location
Identify the fracture position

03
Fracture Examination
Locate crack origins and propagation regions

04
Material Testing
Evaluate material and metallurgical condition

05
Operating Correlation
Compare findings with actual service loads

06
Root Cause Conclusion
Establish supported failure causes

THREE EVIDENCE CATEGORIES

Physical Evidence
Fracture surface, corrosion pits, deformation, wear marks and connection damage.

Material Evidence
Chemical composition, hardness, microstructure, inclusions and mechanical properties.

Operating Evidence
Rod-string configuration, pumping loads, stroke conditions, well trajectory and produced-fluid chemistry.

GUIDE APPLICATION

Application Area	Main Use
Field failure review	Rapid screening of failed rod evidence
Laboratory assessment	Correlation of fracture features and material condition
Engineering reporting	Structured root cause discussion and corrective direction

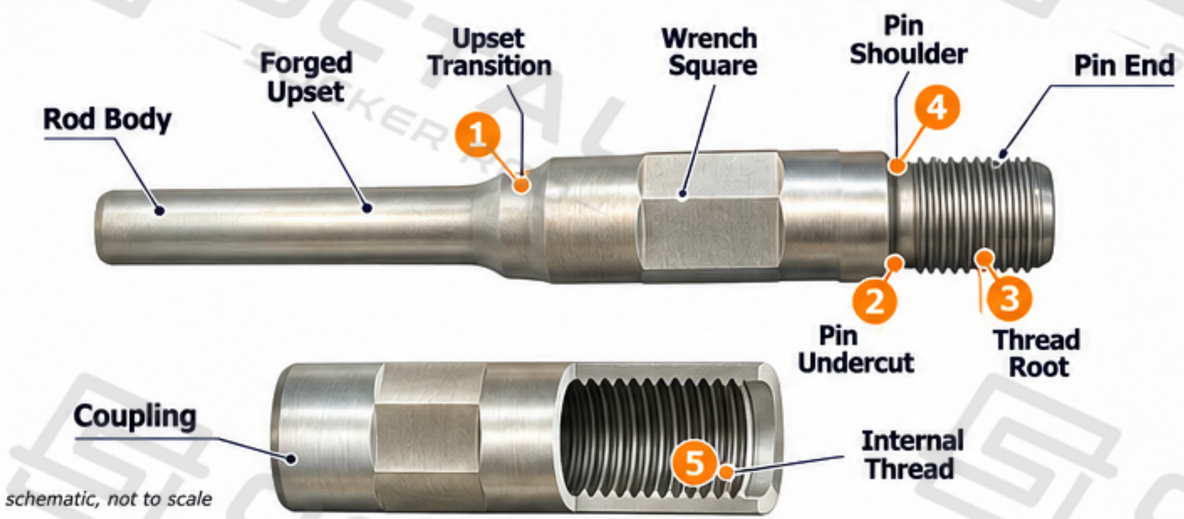
TECHNICAL NOTE

This guide supports engineering failure investigation. Final acceptance and material compliance should be assessed against the applicable API Spec 11B edition, approved purchase specifications, manufacturer requirements, and project-specific criteria.

SUCKER ROD FAILURE DIAGNOSIS & ROOT CAUSE ANALYSIS GUIDE

This page links common sucker rod failure mechanisms to actual structural hotspots so the likely crack origin, load path, and inspection focus can be evaluated together.

STRUCTURAL COMPONENTS & FAILURE HOTSPOTS



KEY HOTSPOT FOCUS

1	**Upset Transition**	Geometric transition zone; review surface condition and local cracking.
2	**Pin Undercut**	Local stress concentration near the threaded pin end.
3	**Thread Root**	Common initiation area for fatigue and corrosion-assisted cracking.
4	**Pin Shoulder**	Check seating condition, contact pattern, and load transfer.
5	**Coupling Thread Root**	Evaluate wear, corrosion, and connection-related fatigue.

STRUCTURAL INTERPRETATION NOTES

- A failure location does not by itself prove the failure mechanism.
- The same hotspot may fail by fatigue, corrosion, overload, or connection problems.
- Pin-and-coupling failures should be evaluated as a mating system, not as isolated parts.
- Local geometry and surface condition often control crack initiation.

FAILURE MECHANISM CORRELATION MATRIX

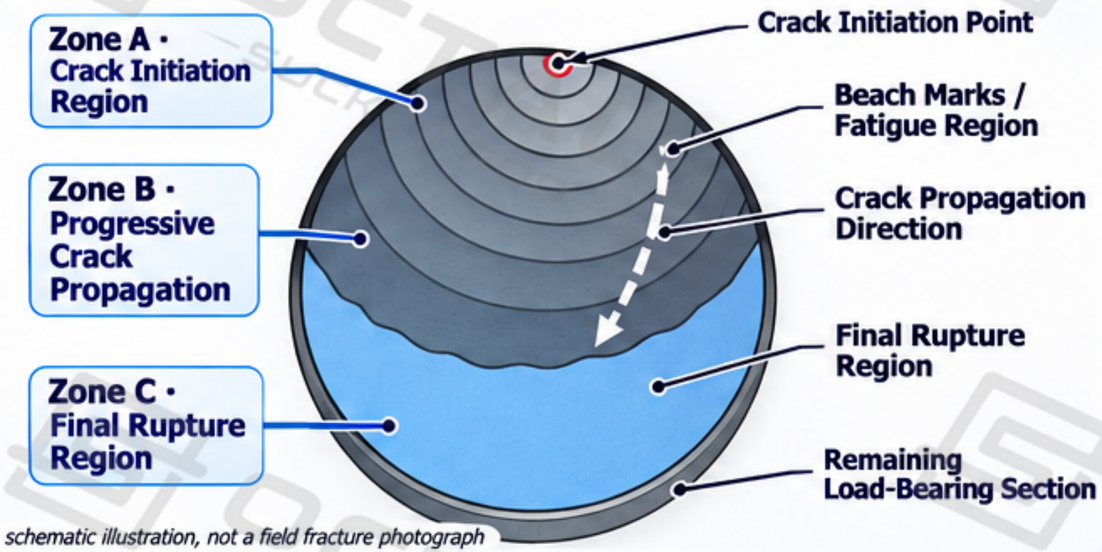
Failure Mechanism	Typical Initiating Condition	Investigation Focus
Fatigue Failure	Repeated axial stress cycles and local stress concentraitions	Crack origin, propagation region and cyclic loading
Corrosion Fatigue	Localized corrosion combined with repeated mechanical stress	Corrosion pits, crack origin and produced-fluid chemistry
Tensile Overload	Applied load exceeding the remaining section capacity	Plastic deformation, necking and load history
Bending-Related Failure	Transverse forces and repeated bending stress	Asymmetric damage, rod curvature and contact conditions
Mechanical Wear	Repeated contact, abrasion and surface damage	Material loss, wear distribution and tubing contact
Connection Failure	Thread damage, loss of intended shoulder contact or unsuitable make-up	Pin, coupling, thread roots and shoulder geometry
Manufacturing-Related Damage	Material discontinuities or process-related defects	Metallographic structure and production traceability

ENGINEERING NOTE Failure location does not independently establish the failure mechanism. Multiple mechanisms may act together, and the fracture origin must be evaluated against the material condition and actual operating history.

SUCKER ROD FAILURE DIAGNOSIS & ROOT CAUSE ANALYSIS GUIDE

This page explains how fracture-surface evidence is interpreted, from crack initiation and progressive propagation to final rupture, so that visible features can be linked to the likely failure mechanism.

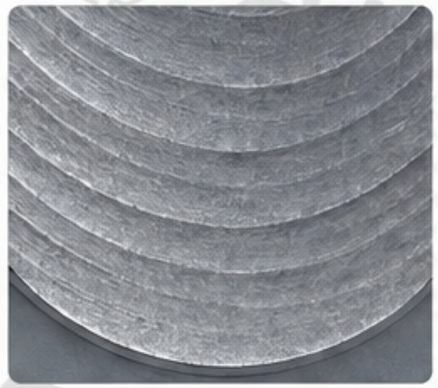
FRACTURE SURFACE ANATOMY



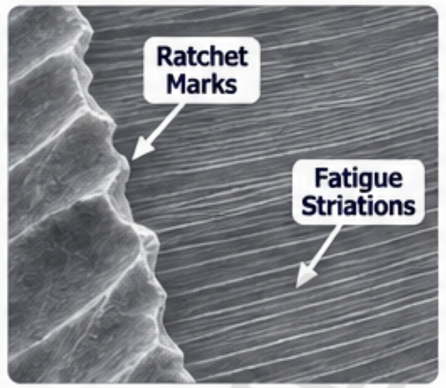
schematic illustration, not a field fracture photograph

REPRESENTATIVE FRACTURE FEATURES

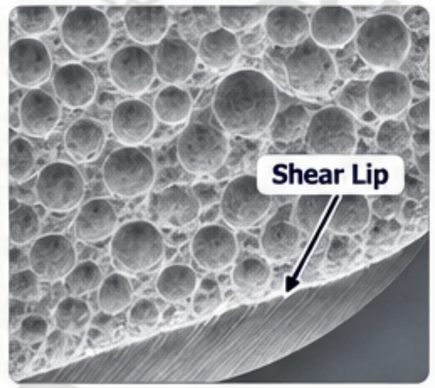
Beach Marks



Ratchet Marks / Fatigue Striations



Final Rupture / Overload



Representative visual cues should be interpreted together rather than used in isolation.

IMPORTANT INTERPRETATION NOTES

Beach Marks vs. Fatigue Striations
Beach marks are macroscopic progression markings, while striations are microscopic features typically confirmed under SEM.

Fracture Surface Preservation
Photograph and document the fracture before rubbing, cutting, cleaning, or mating the broken parts together.

Visual Evidence Limitations
Not every fatigue fracture shows clear beach marks or ratchet marks. Absence of a feature does not eliminate a mechanism.

Evidence Correlation
Fracture features must be evaluated with geometry, material condition, and operating history.

FRACTOGRAPHIC FEATURES AND INTERPRETATION

Fracture Feature	Typical Appearance	Engineering Interpretation
Beach Marks	Macroscopic curved or concentric progression markings	May indicate changes in crack-front position
Ratchet Marks	Ridge-like features between adjacent crack origins	May indicate multiple fatigue initiation sites
Fatigue Striations	Microscopic, relatively parallel markings	Can support fatigue-crack propagation identification under SEM
Dimples	Microscopic cup-shaped depressions	Commonly associated with ductile microvoid coalescence
Shear Lips	Inclined regions near the final fracture boundary	May indicate localized shear deformation
Corrosion Pits	Localized cavities on the steel surface	May act as fatigue-crack initiation sites
Rubbed or Smeared Areas	Flattened or mechanically disturbed regions	May result from contact after fracture or during handling

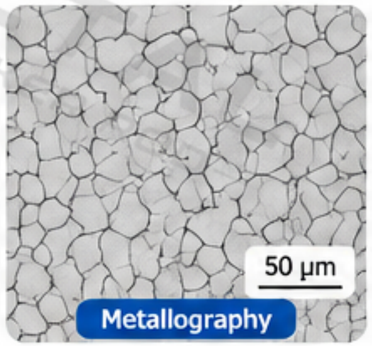
ENGINEERING NOTE Visible fracture features alone do not conclusively establish the root cause. Interpretation must be correlated with material condition, component geometry, and operating history.

SUCKER ROD FAILURE DIAGNOSIS & ROOT CAUSE ANALYSIS GUIDE

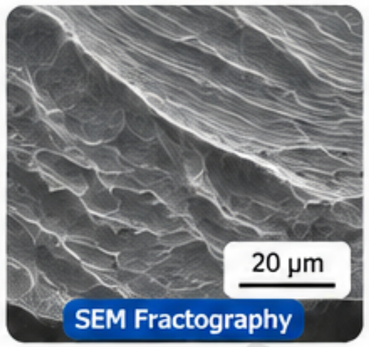
This page introduces key laboratory testing methods and engineering assessment approaches to verify material condition, characterize damage, and evaluate the service load on failed sucker rods.

LABORATORY TESTING OVERVIEW

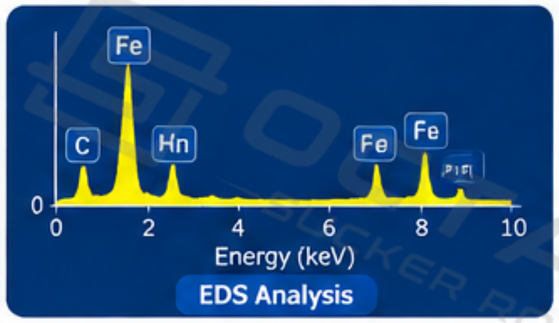

Hardness Testing



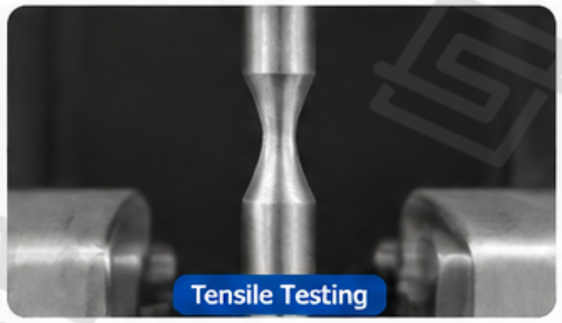
Metallography



SEM Fractography



EDS Analysis


Tensile Testing

EVIDENCE-BASED TESTING MATRIX

Examination Method	What It Evaluates	Diagnostic Value
Chemical Composition Analysis	Alloying elements and material chemistry	Checks material identity against specified grade
Hardness Mapping	Hardness distribution along the rod and forged regions	Identifies local variations that may indicate processing differences
Tensile Testing	Yield strength, tensile strength and elongation	Evaluates actual mechanical properties
Metallographic Examination	Microstructure, inclusions, decarburization and discontinuities	Identifies material and heat-treatment conditions
SEM Fractography	Fracture morphology, crack features and microscopic damage	Examines crack initiation and propagation characteristics
EDS Analysis	Local elemental composition	Helps characterize corrosion products and deposits
Dimensional & Thread Inspection	Rod diameter, pin geometry, thread profile and coupling dimensions	Identifies dimensional or connection-related discrepancies
Nondestructive Examination (UT/MT/PT)	Detectable discontinuities within the capabilities of the selected method	Assesses additional damage without sectioning the component

ENGINEERING STRESS ASSESSMENT

Nominal Axial Stress

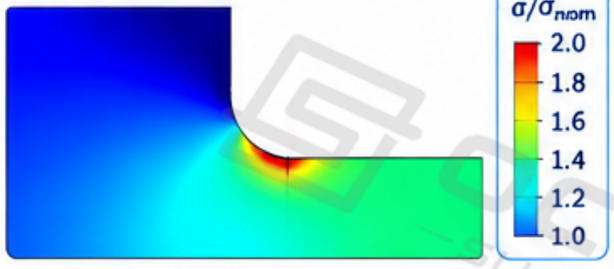
$$\sigma_{nom} = \frac{F}{A}$$

$$A = \frac{\pi d^2}{4}$$

Where:

- σ_{nom} : Nominal axial stress (MPa)
- F : Axial load (N)
- A : Cross-sectional area (mm²)
- d : Rod diameter (mm)

Geometric Stress Concentration



RECOMMENDED EXAMINATION SEQUENCE

Evidence Preservation → Visual & Dimensional Examination → Material Testing → NDE (UT/MT/PT) → Data Correlation & Assessment

ENGINEERING NOTE

Testing results should be interpreted together with fracture features, structural geometry and actual operating conditions. Use a comprehensive evaluation rather than a single test to establish the root cause and provide corrective actions.

SUCKER ROD FAILURE DIAGNOSIS & ROOT CAUSE ANALYSIS GUIDE

This page explains how to determine the primary failure cause by integrating fracture evidence, material testing and operating history, and how to translate the finidings into effective engineering actions.

ROOT CAUSE DETERMINATION PROCESS

Observed Damage
Fracture location, visible defects and condition

→

Failure Mechanism
Fatigue, corrosion, overload, wear

→

Evidence Correlation
Fractography, material testing and operating data

→

Root Cause Determination
Primary mechanism and verified contributing factors

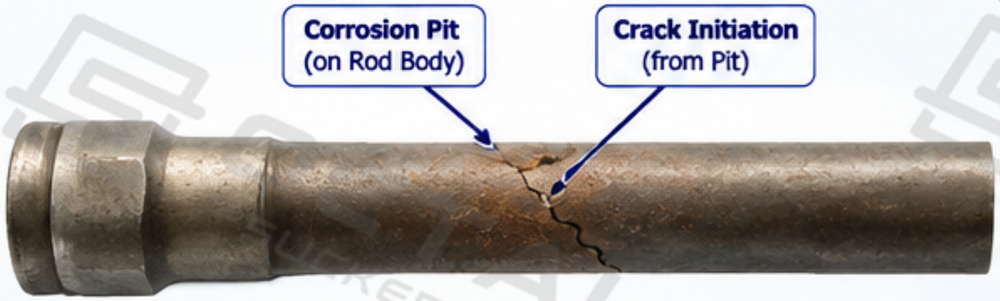
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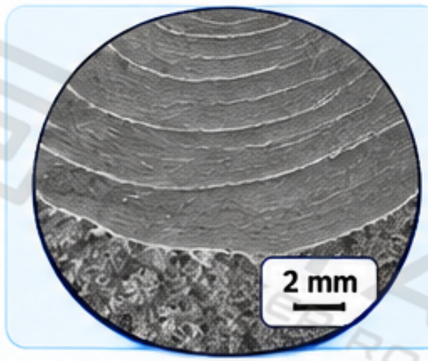
Engineering Action
Corrective measures and effectiveness verification

DISTINGUISHING KEY CONCEPTS

Classification	Meaning	Example (Sucker Rod)
Failure Mechanism	Physical process that produced the fracture	Fatigue cracking
Contributing Factor	Condition that accelerated or promoted the damage	Corrosion pitting or local stress concentration
Root Cause	Underlying condition supported by evidence and requiring correction	An established design, material, manufacturing or operating deficiency,

ILLUSTRATIVE FAILURE RECONSTRUCTION





Illustrative Scenario — Sucker Rod (Not a Field Case)

FAILURE INVESTIGATION REPORT TEMPLATE

Report Item	Information to Record
Failed Component	Rod body, pin, coupling or forged section
Fracture Location	Actual position and structural feature
Primary Failure Mechanism	Confirmed mechanism (e.g., fatigue, corrosion fatigue)
Crack Initiation Evidence	Fracture origion and related surface features (e.g., corrosion pit)
Material Findings	Chemical, mechanical and metallurgical results
Operating Conditions	Load history, pumping condition and service environment
Contributing Factors	Verified or suspected factors, clearly distinguished
Root Cause	Evidence-supported conclusion
Corrective Action	Engineering changes and verification plan

TYPICAL ENGINEERING ACTIONS

Identified Root Cause	Recommended Engineering Action
Corrosion-Assisted Fatigue	Control produced-fluid corrosivity, optimize inhibition, consider corrosion-resistant materials or coatings
Overload / High Stress	Review load design, stroke and pump operation; reduce peak load and improve rod-string matching
Manufacturing Defect	Strengthen material and process control (e.g., ultrasonic inspection, forging and heat treatment)
Connection-Related Failure	Verify make-up torque and shoulder contact, inspect pins and couplings; replace nonconforming components
Wear / Abrasion	Optimize centralization and wellbore condition, reduce side load and contact wear

ENGINEERING TAKEAWAY

Be Evidence-Based
A defensible root cause conclusion integrates fracture, material, geomtery and operating history.

Evaluate Systematically
Consider multiple mechanisms and their interaction, rather than relying on a single feature.

Implement and Verify
Take targeted engineering actions and confirm effectiveness through field monitoring or follow-up testing.

ENGINEERING NOTE

A visible fracture feature alone is not sufficient to establish the underlying cause. Root cause determination requires evidence correlation, mechanism analysis and actual operating history, followed by targeted actions and effectiveness verification.