Sucker Rod Steel Materials and Alloy Composition Engineering Guide

Carbon Steel • Cr-Mo • Ni-Cr-Mo • Chemical Composition • API Grade Relationship





Sucker Rod Material Families



Different chemistry families, same finished sucker rod geometry.

	Carbon Steel	Cr-Mo Alloy Steel	Ni-Cr-Mo Alloy Steel	Fiberglass Composite
Material structure	Fe-C-Mn steel system	Fe-C-Cr-Mo alloy system	Fe-C-Ni-Cr-Mo alloy system	Reinforcing fibers + polymer resin with metallic end fittings
Density / stiffness concept	Conventional steel baseline	Steel density and stiffness range	Steel density and stiffness range	Lower density and lower axial stiffness than steel depending on design
Heat-treatment dependence	Properties depend on chemistry and processing	Strong heat-treatment response	Heat-treatment response and toughness control	Not heat treated; composite manufacturing controlled
Main selection variables	Finished grade, cyclic loading, corrosion exposure	Strength/toughness target, heat treatment, fatigue	Strength/toughness target, heat treatment, service environment	Tensile load, temperature, stiffness, end-fitting and fluid compatibility

Material family selection must consider finished grade, cyclic loading, corrosion exposure and connection design.

Common Steel Materials Referenced for Sucker Rods

AISI / SAE Material Designations and Engineering Considerations

Different AISI steel designations represent different chemical composition familles, while the finished sucker rod geometry and connection design remain the same. The selection of a specific material should be based on the required strength, toughness, fatigue performance and operating conditions.



AISI Material Classification for Sucker Rods

- **Carbon-Manganese Steel** (Fe-C-Mn system)
  - AISI 1541
- **Cr-Mo Alloy Steel** (Fe-C-Cr-Mo system)
  - AISI 4120
  - AISI 4130
  - AISI 4138
  - AISI 4140
  - AISI 4142
- **Ni-Cr-Mo Alloy Steel** (Fe-C-Ni-Cr-Mo system)
  - AISI 4330

Common AISI Steel Materials

Steel Designation	Alloy Family	Pricipal Material Characteristic	Main Verification Focus
AISI 1541	Carbon-Manganese	Medium-carbon manganese steel system	Chemistry, ductility, finished strength
AISI 4120	Cr-Mo	Lower-carbon chromium-molybdenum steel	Actual chemistry and heat-treatment route
AISI 4130	Cr-Mo	Approx. 0.30% carbon Cr-Mo alloy steel	Strength, toughness and heat treatment
AISI 4138	Cr-Mo	Higher nominal carbon Cr-Mo steel	Hardness, strength and fatigue-related properties
AISI 4140	Cr-Mo	Approx. 0.40% carbon Cr-Mo steel	Strength, hardness and toughness
AISI 4142	Cr-Mo	Slightly higher carbon Cr-Mo steel	Heat-treatment consistency and final properties
AISI 4330	Ni-Cr-Mo	Nickel-containing chromium-molybdenum steel	Toughness, strength and heat-treatment verification

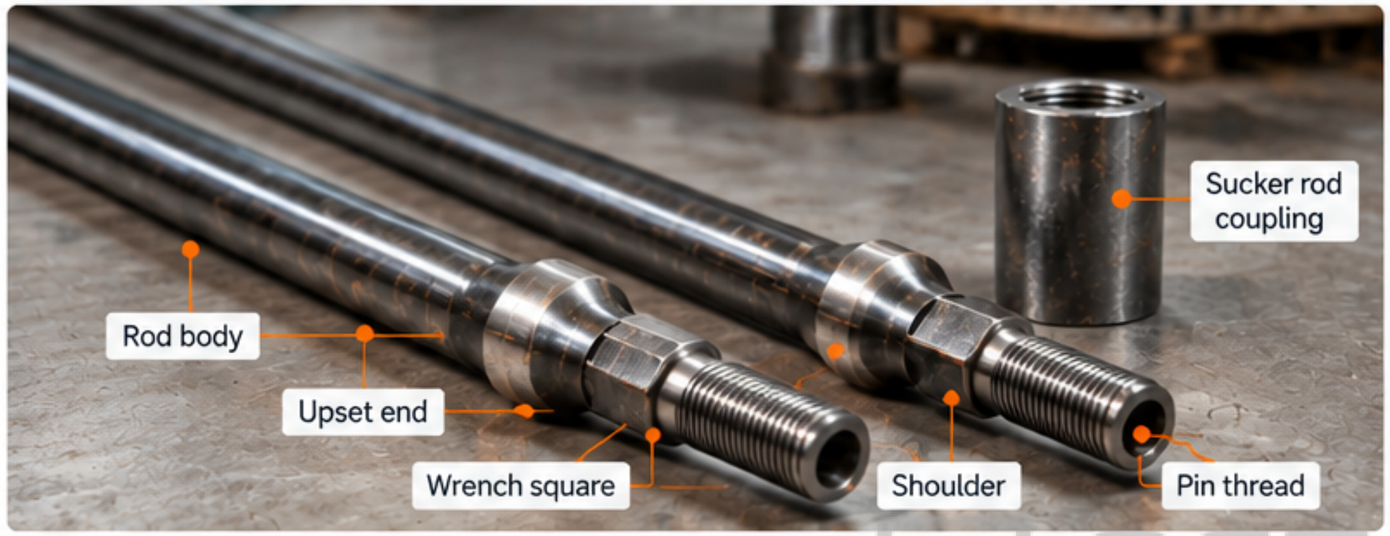
AISI steel designation identifies material chemistry; it does not automatically establish API finished-product grade.

The appropriate AISI material and finished sucker rod grade should be selected based on well conditions, required mechanical properties and applicable standards.

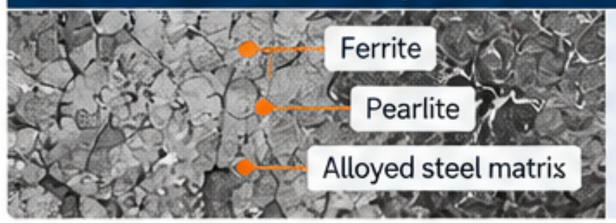
Sucker Rod Steel Chemical Composition and Alloying Elements

Carbon • Manganese • Chromium • Molybdenum • Nickel • Material Verification

Alloying elements control the hardenability, strength, toughness and heat-treatment response of sucker rod steels.
The appropriate chemical composition should be selected based on the required mechanical properties and operating conditions.



Steel Microstructure (Typical)



Sucker rod steels are typically low-alloy or medium-alloy steels with a ferrite–pearlite matrix. The addition of alloying elements such as Cr, Mo and Ni changes the transformation behavior during heat treatment, which influences the final strength, toughness and fatigue performance.

Main Alloying Elements and Their Influence

Carbon (C)
Controls hardness potential and strength response.
Influences heat-treatment response and final mechanical properties.

Manganese (Mn)
Improves hardenability and steel processing control.
Supports strength development and material consistency.

Chromium (Cr)
Improves hardenability.
Supports strength development after heat treatment.

Molybdenum (Mo)
Improves hardenability and high-temperature strength response.
Helps maintain toughness and strength balance.

Nickel (Ni)
Improves toughness and hardenability.
Supports strength-toughness balance in alloy systems.

Representative Chemistry Range of Common Sucker Rod Steels

Steel Grade	C (%)	Mn (%)	Cr (%)	Mo (%)	Ni (%)
AISI 4130	0.28 – 0.33	0.40 – 0.60	0.80 – 1.10	0.15 – 0.25	Not specified as principal alloy addition
AISI 4140	0.38 – 0.43	0.75 – 1.00	0.80 – 1.10	0.15 – 0.25	Not specified as principal alloy addition
AISI 4142	0.40 – 0.45	0.75 – 1.00	0.80 – 1.10	0.15 – 0.25	Not specified as principal alloy addition
AISI 4330	0.28 – 0.33	0.60 – 0.90	0.70 – 1.00	0.20 – 0.30	1.65 – 2.00

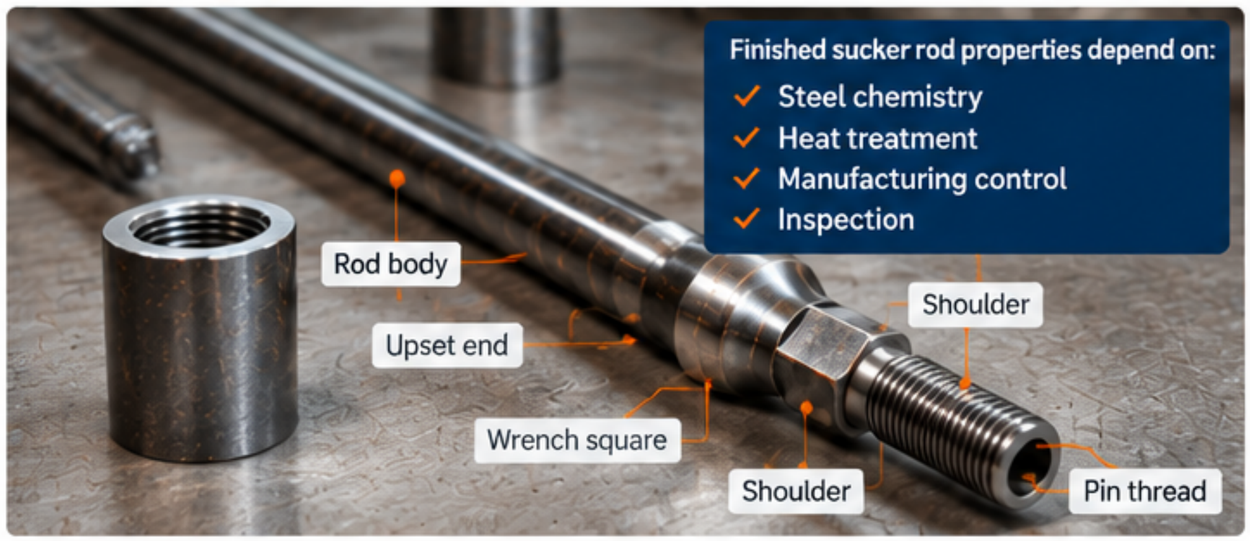
Note: The values above are representative reference ranges only. Actual chemical composition shall be verified by the applicable material specification and Mill Test Certificate (MTC).

Chemical composition identifies the steel system, but finished sucker rod performance also depends on heat treatment, manufacturing process, dimensions, inspection and operating conditions.

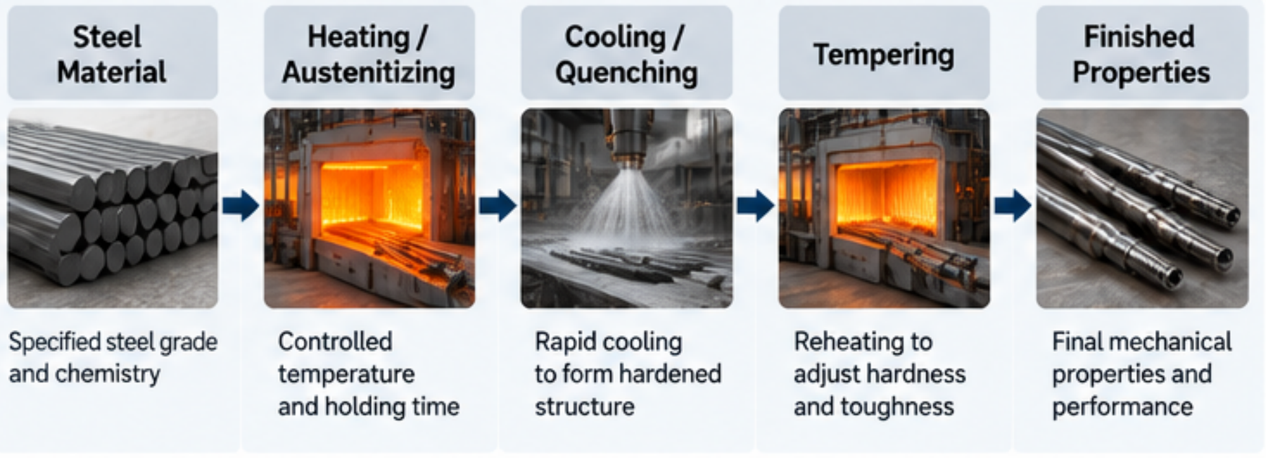
Heat Treatment and Mechanical Property Development of Sucker Rod Steel

Normalizing • Quenching • Tempering • Stress Relieving • Final Property Verification

Heat treatment transforms the microstructure of sucker rod steel and controls the final mechanical properties.
The appropriate heat-treatment route should be selected based on the steel material, required performance and operating conditions.



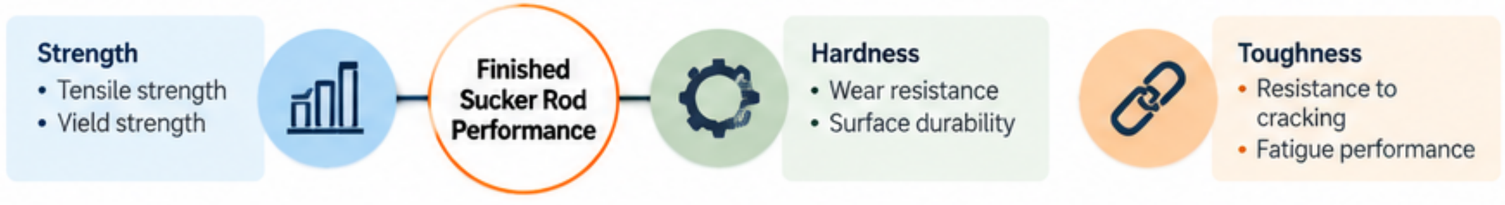
Sucker Rod Steel Heat-Treatment Process (Typical Route)



Common Heat-Treatment Processes for Sucker Rod Steel

Process	Main Purpose	Effect on Steel	Key Control Factors
Normalizing	Refines and controls steel microstructure.	Improves structural uniformity before further processing.	Heating temperature, holding time, cooling condition.
Quenching	Rapid cooling after heating.	Develops hardened microstructure.	Cooling rate, hardenability, distortion control.
Tempering	Reheating after hardening.	Balances hardness, strength and toughness.	Temperature and holding time.
Stress Relieving	Reduces residual stress.	Improves dimensional stability.	Temperature and previous processing condition.

Key Mechanical Properties and Their Relationship



Higher hardness or strength does not automatically mean better fatigue performance.
The appropriate balance of strength, hardness and toughness should be based on the actual operating conditions

Heat-Treatment Verification Points

Steel heat number	Traceable to the material production batch.
Processing record	Heat-treatment parameters and route.
Mechanical test results	Verify strength, hardness and other properties.
Finished product identification	Link to inspection and final product records.

Heat treatment must be evaluated together with steel chemistry, rod dimensions, manufacturing process and service conditions.
The appropriate heat-treatment route and final properties should be selected based on the specific steel grade, well conditions and design requirements.

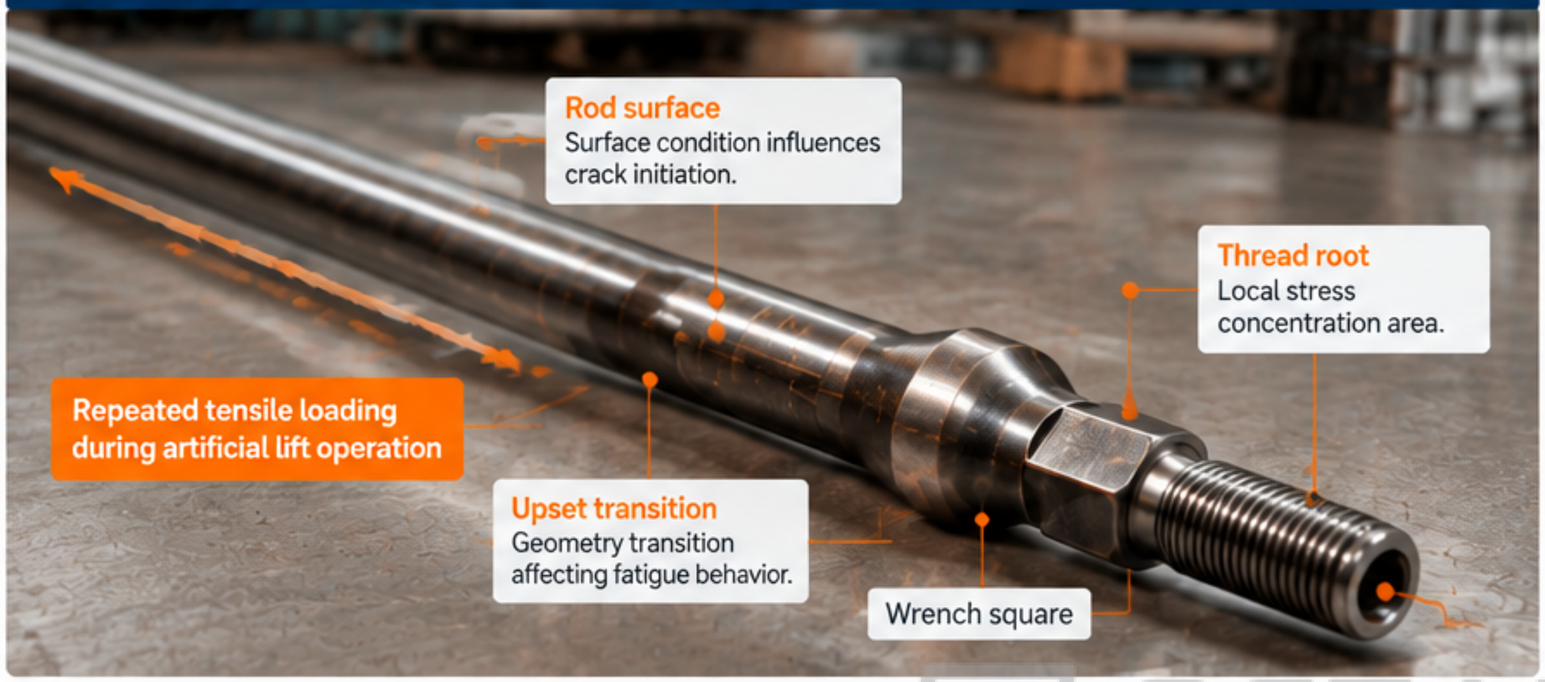
Mechanical Properties and Fatigue-Critical Areas of Sucker Rod Steel

Strength • Toughness • Cyclic Loading • Rod-End Stress Concentration

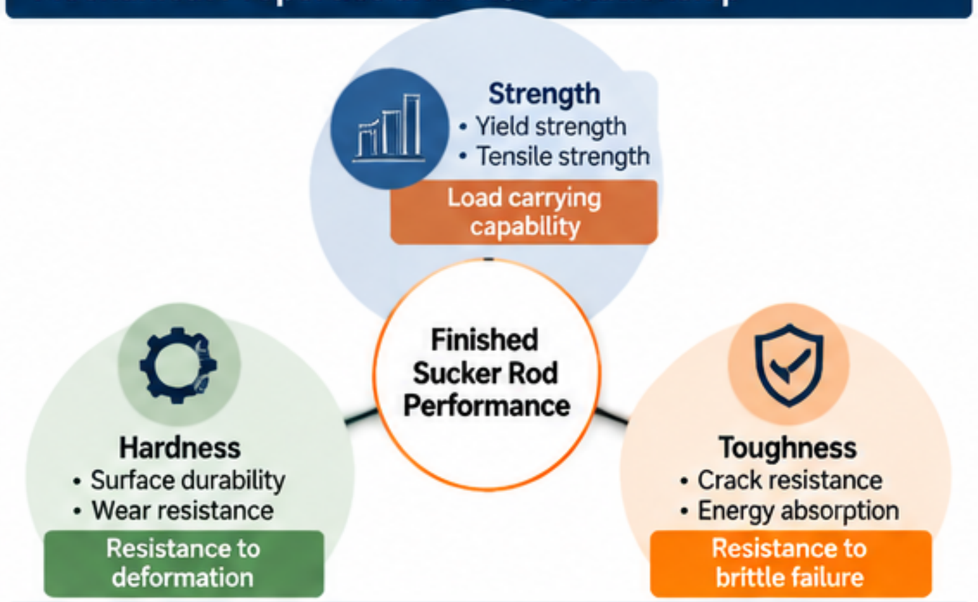
Sucker rod performance depends on the balance between mechanical properties, rod geometry, surface condition and operating conditions.
Proper material selection, heat treatment and quality control help improve fatigue resistance and service life.



Key Areas Affecting Fatigue Performance on a Sucker Rod

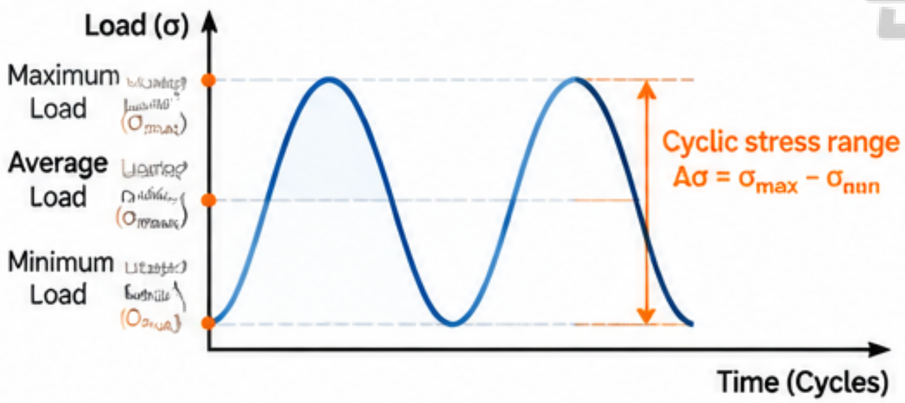


Mechanical Properties and Their Relationship



Higher strength or hardness does not automatically mean longer fatigue life.

Fatigue Loading and Stress Range



Repeated loading cycles create fatigue demand on sucker rods.

Actual fatigue life also depends on:

- Rod geometry
- Surface quality
- Connection design
- Corrosion environment
- Operating loads

Mechanical Property Verification

Property	Verification Method	Engineering Purpose
Yield Strength	Tensile Test	Confirms load carrying capability.
Tensile Strength	Tensile Test	Confirms ultimate strength level.
Hardness	Hardness Measurement	Checks heat-treatment consistency.
Dimensions	Dimensional Inspection	Confirms API 11B dimensional requirements.
Thread Geometry	Thread Gauges / Inspection	Confirms connection compatibility.

Fatigue performance is controlled by the combined effect of material properties, heat treatment, surface condition, rod-end geometry and service environment.
A balanced combination of strength, hardness and toughness is required to achieve reliable service life under cyclic loading conditions.

Steel Material vs API Finished Sucker Rod Grade

Understanding the Relationship Between Steel Chemistry, Manufacturing and Final Product Qualification

AISI steel designation identifies the chemical composition family, while the finished sucker rod grade is confirmed after manufacturing, heat treatment and verification according to product requirements.



1 Steel Material Designation

Identifies the chemical composition family.



AISI 4142

- Carbon content
- Alloying elements
- Material specification
- Heat-treatment response

2 Manufacturing Process

Develops the final material condition.



- Steel processing
- Rod forming
- Heat treatment
- Machining

3 Finished Product Verification

Confirms finished product requirements.



- Tensile test
- Hardness test
- Dimensional inspection
- Thread inspection
- Traceability

4 Finished Sucker Rod Grade

Product classification after verification.



API Grade D Alloy

- Finished product requirements
- Mechanical properties
- Dimensions
- Inspection acceptance

Steel Material Designation vs Finished Sucker Rod Grade

Steel Material Designation



AISI 4142

- Identifies chemical composition
- Material family
- Heat-treatment response
- Does not define finished product grade

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AISI material designation is not equivalent to API finished grade.

Finished Sucker Rod Grade



API Grade D Alloy

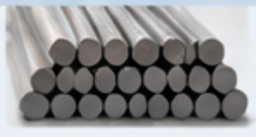
- Finished product requirements
- Mechanical properties
- Dimensions and tolerances
- Inspection acceptance
- Confirms product suitability for service conditions

Information Required for Sucker Rod Ordering

Item	Details
Material designation	AISI/SAE steel designation or approved modified chemistry
Finished grade	Applicable API 11B grade (e.g. Grade D Alloy)
Rod size	Diameter and length
Connection	Pin and coupling configuration (e.g, full-size or slim-hole)
Mechanical requirements	Strength and acceptance criteria
Service conditions	Load, temperature, corrosion environment and well profile
Inspection documents	MTC, mechanical test reports and inspection records

Material to Finished Product Traceability

Steel Heat → **Material Certificate (MTC)** → **Manufacturing Record** → **Heat Treatment Record** → **Mechanical Testing** → **Finished Rod Identification** → **Shipment Documentation**





Steel chemistry defines the material system; finished-product testing determines whether the sucker rod meets the specified grade.

Material selection should consider chemistry, heat treatment, geometry, inspection requirements and actual well conditions.