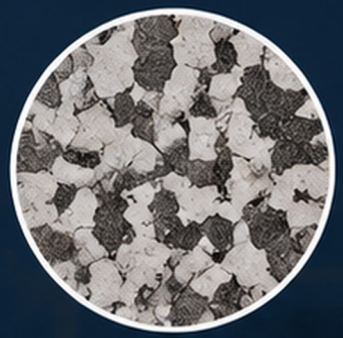
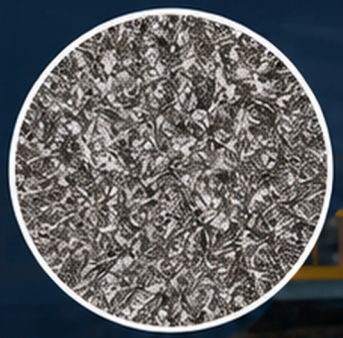
Sucker Rod Heat Treatment & Microstructure Guide

Understanding Normalizing, Quenching, Tempering and Their Effects on Steel Microstructure



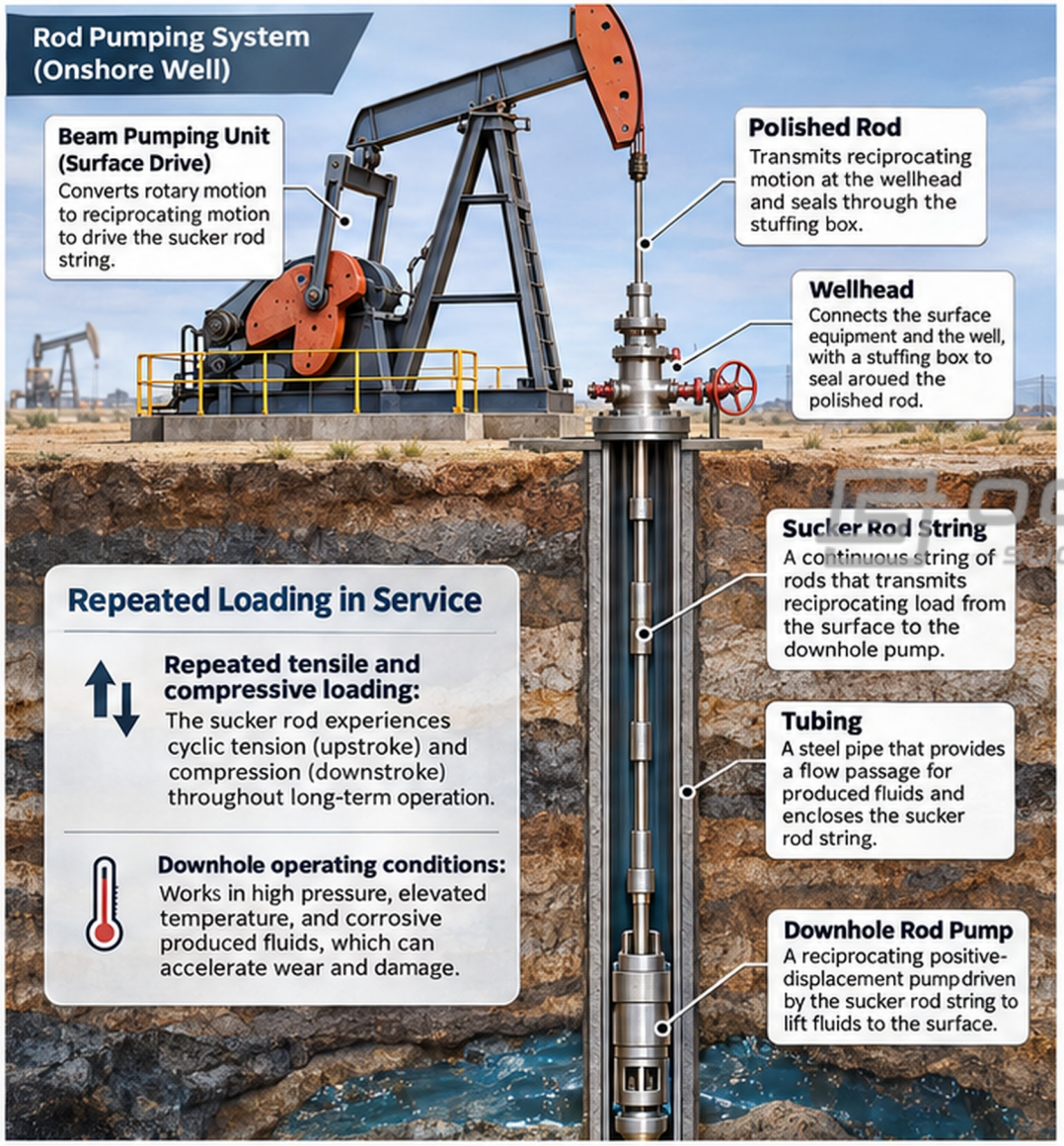
Ferrite-Pearlite



Tempered Martensite

Why Heat Treatment Matters for Sucker Rods

Heat treatment tailors the microstructure of sucker rod steel, delivering a balanced set of mechanical properties to withstand repeated loading, deformation and harsh downhole conditions in long-term pump operation.



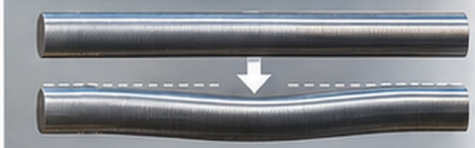
Tensile Strength



Resistance to tensile loading/fracture, ensuring the rod can withstand the repeated tensile load in service.

Withstands repeated loading (tension)

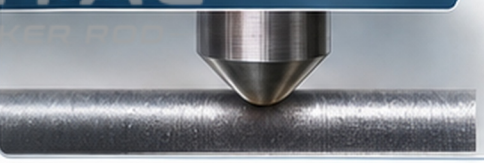
Yield Strength



Resistance to permanent deformation, helping the rod maintain its shape and load-carrying capacity under repeated service loads.

Prevents permanent deformation under load

Hardness



Resistance to surface indentation/wear, which reduces wear at couplings and contact surfaces during repeated operation.

Provides surface resistance and wear durability

Ductility



Ability to deform plastically before fracture, providing deformation capacity to relieve stress concentration under cyclical loading.

Allows plastic deformation and reduces the risk of fracture

Impact Toughness



Resistance to sudden fracture and ability to absorb impact energy, helping the rod tolerate impact and load fluctuations during operation.

Resists sudden fracture and absorbs impact energy

Steel Composition → **Heat Treatment** → **Microstructure** → **Mechanical Properties**

Normalizing Process and Its Effect on Steel

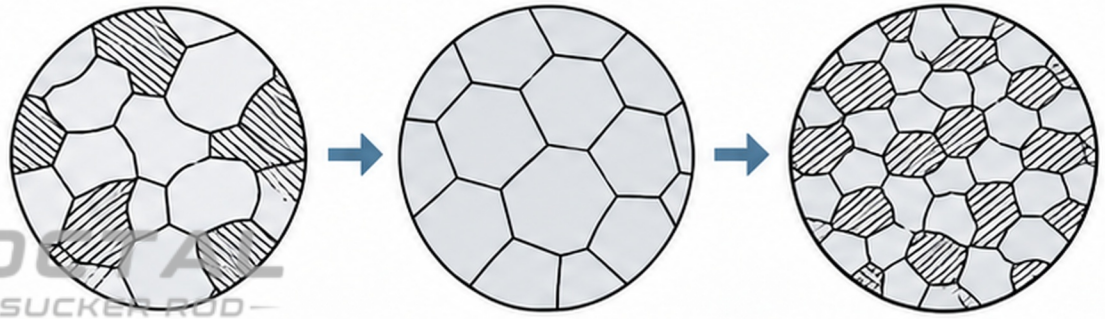
Normalizing is a heat treatment in which steel is heated into the austenite range, held to obtain a uniform austenitic structure, and then cooled in still air to refine and homogenize the microstructure.

Process Flow

Heating → Austenitizing → Holding → Air Cooling



Microstructure Evolution During Normalizing



Original Steel Microstructure

Ferrite (light) and pearlite (hatched) with relatively coarse and non-uniform grains.

Austenite (During Heating)

Single-phase austenite with equiaxed grains after sufficient heating.

Ferrite–Pearlite Structure (After Air Cooling)

Refined and more uniform ferrite (light)–pearlite (hatched) structure.

Key Effects of Normalizing

Grain Refinement

Forms finer austenite grains and, after air cooling, a finer ferrite–pearlite structure.

Improved Microstructural Uniformity

Reduces segregation and structural differences, giving a more uniform ferrite–pearlite structure across the section.

More Consistent Mechanical Properties

Provides more stable and consistent strength, hardness and toughness, and reduces property variation.

Note: *The final structure depends on chemical composition, section size, temperature and cooling rate.*

Quenching and Tempering: Developing Strength and Controlling Toughness

Quenching and tempering (Q&T) is a heat treatment route used to increase the strength and hardness of sucker rod steel while maintaining sufficient ductility and toughness. It involves austenitizing, rapid quenching and tempering.

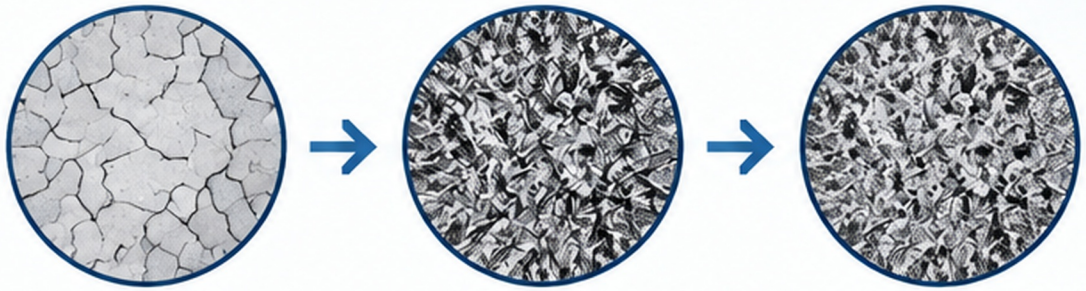


Heat the steel to the austenitizing temperature range to form austenite.

Rapidly cool the steel in a suitable medium (e.g., water or oil) to obtain a predominantly martensitic structure.

Reheat the quenched steel to a temperature below Ac1 and hold for a period to relieve stress, redistribute carbon and precipitate carbides, resulting in a tempered microstructure.

Microstructure Evolution (Schematic)



Austenite (during heating)

Martensite (after quenching)

Tempered Martensite (after tempering)

Quenching

Develops high hardness and strength through the formation of martensite.

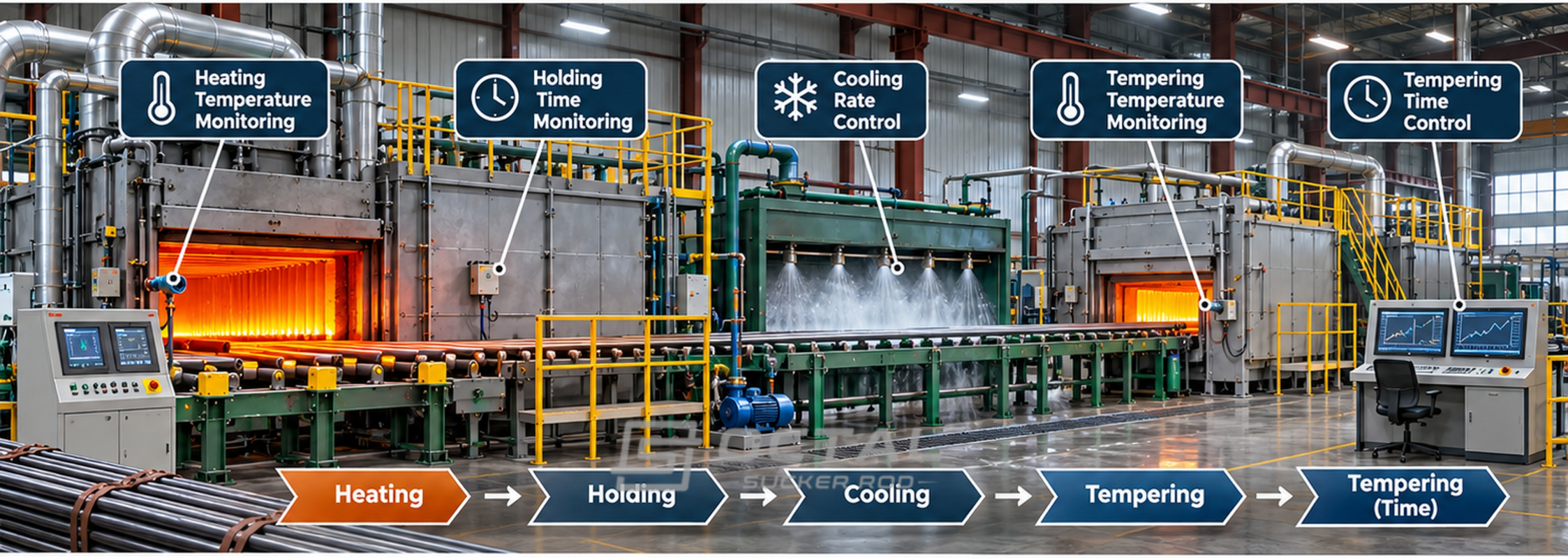
Tempering

Adjusts hardness and strength, improves ductility and toughness, and relieves internal stres

Key Takeaway

Q&T enables a balanced combination of strength, hardness, ductility and toughness for sucker rods. The final properties depend on the steel composition, quenching method and tempering conditions.

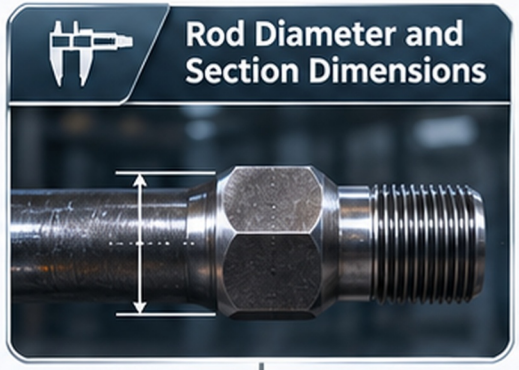
Key Heat Treatment Controls in Sucker Rod Manufacturing

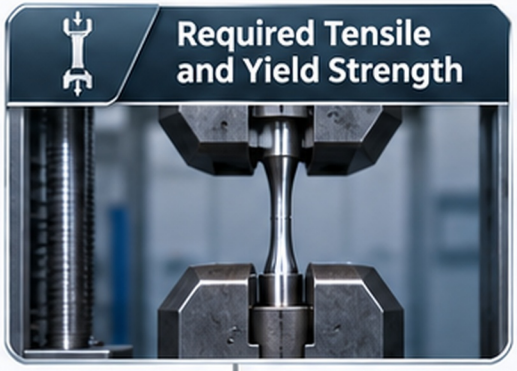


Key Control Parameter	Engineering Purpose
Heating Temperature	Ensures the required phase transformation
Holding Time	Allows sufficient and uniform heating throughout the treated section
Cooling Rate	Controls microstructure formation and hardening response
Tempering Temperature	Adjusts the final balance of strength, hardness and toughness
Tempering Time	Ensures consistent tempering throughout the treated section

Selecting and Controlling Heat Treatment Conditions









MATERIAL SELECTION AND PROCESS DEVELOPMENT

Material Selection



Process Development

MUST BE CONSIDERED TOGETHER









Mechanical Testing → **Product Verification**