Uniform vs Tapered Sucker Rod Strings

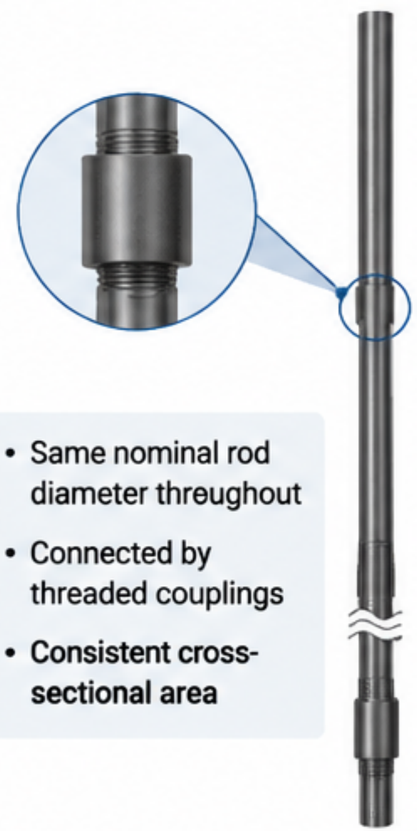
Engineering Comparison Guide



Overview

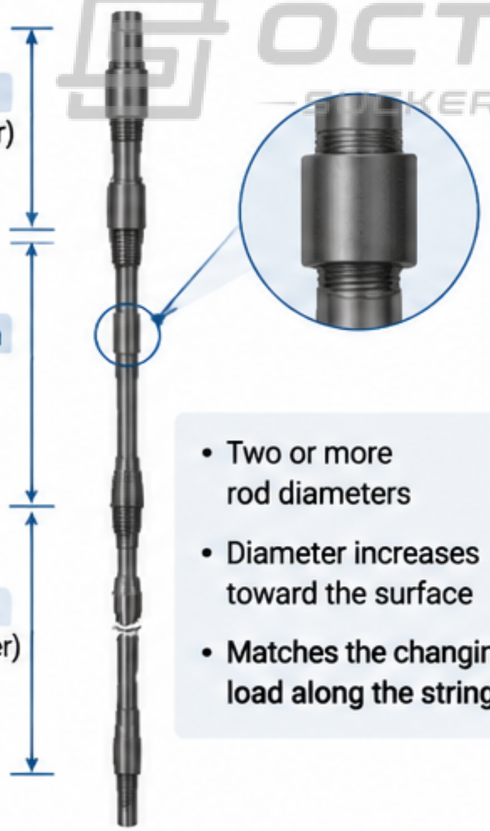
Uniform and tapered sucker rod strings are two common configurations in reciprocating rod-lift systems. Both transmit the surface pumping unit motion to the downhole pump through threaded rods and couplings, but they differ in how rod diameter and cross-sectional area are arranged along thie string.

Uniform Sucker Rod String



- Same nominal rod diameter threughout
- Connected by threaded couplings
- **Consistent cross-sectional area**

Tapered Sucker Rod String



- Two or more rod diameters
- Diameter increases toward the surface
- **Matches the changing load along the string**

Key Differences

Item	Uniform Rod String	Tapered Rod String
Rod Diameter	Single, constant diameter	Two or more diameters
Load Distribution	One size for the entire load profile	Diameters matched to section loads
String Weight	Generally higher (when sized for the maximum load)	Generally lower (without excess capacity)
Design & Assembly	Simpler	More design steps, multiple sizes

Guide Scope

This guide provides a practical engineering overview, including:

- ☑ Structure and configuration of uniform and tapered strings
- ☑ Rod load distribution and axial stress
- ☑ Advantages, limitations and application considerations
- ☑ Key steps for selecting rod diameters and taper lengths

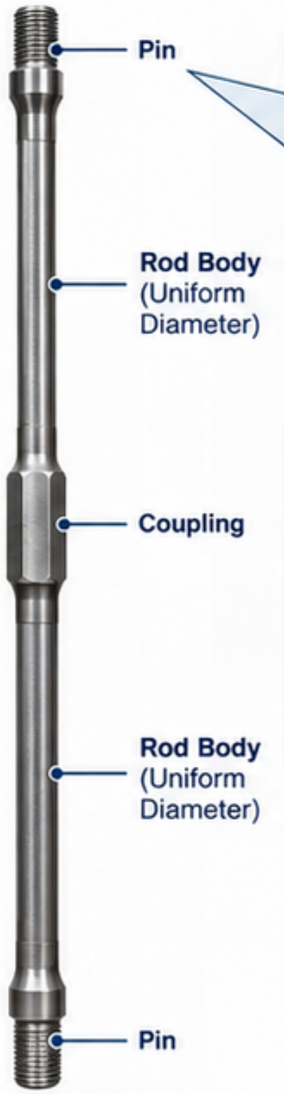
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Uniform vs Tapered Sucker Rod Strings

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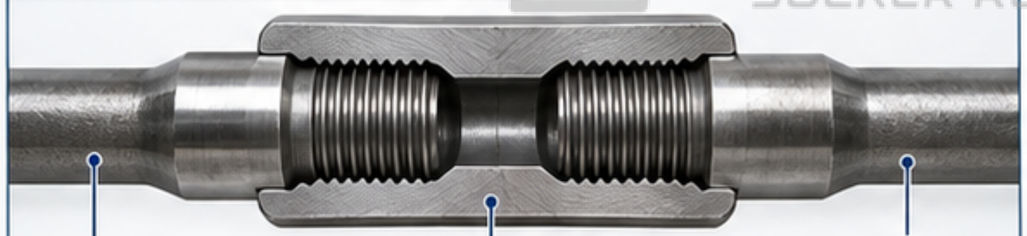
02 | UNIFORM SUCKER ROD STRING CONSTRUCTION



Threaded Pin End (Male Connection)



Coupling Connection (Sectional View)



What Is a Uniform Sucker Rod String?

A sucker rod string constructed with rods of **one nominal** rod-body diameter throughout the string, connected by threaded pins and couplings, to transmit reciprocating load between the surface pumping unit and the downhole pump.

Main Components

- **Rod body:** The main load-carrying section, with a consistent nominal diameter along the entire string.
- **Pin:** A male, threaded end (usually integral with the rod) used to connect to a coupling.
- **Coupling:** A female, internally threaded connector that joins two pins.

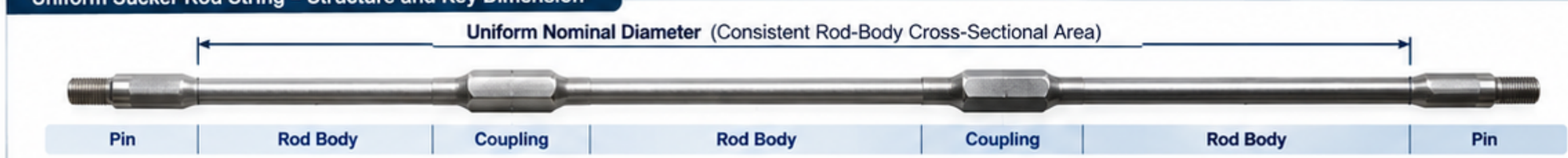
Structural Characteristics

- One consistent nominal rod-body diameter from top to bottom of the string.
- A consistent rod-body cross-sectional area along the string.
- The actual load varies along the rod string (e.g., higher near the surface and lower toward the pump), even though the rod-body diameter remains constant.

Assembly, Inventory, and Maintenance

- **Assembly:** Straightforward, using the same rod size and standard couplings.
- **Inventory:** Simple, with a single rod size and matching couplings.
- **Maintenance:** Convenient, with interchangeable rods and couplings that simplify replacement and field handling.

Uniform Sucker Rod String – Structure and Key Dimension



Structural Characteristics (Summary)

- Single nominal rod-body diameter throughout the string.
- Consistent rod-body cross-sectional area along the string.
- Load varies along the string, while the rod-body diameter remains constant.

Structural Advantages

- Simple and robust configuration.
- Straightforward assembly and field handling.
- Simplified inventory and supply management.
- Convenient inspection, replacement, and maintenance.

Design Limitations

- Does not match the decreasing load along the string, which can result in excess rod size (and weight) in the lower section.
- Generally less material-efficient than a tapered string.
- May be less suitable in applications where minimizing string weight or optimizing material use is a key design objective.

Uniform vs Tapered Sucker Rod Strings

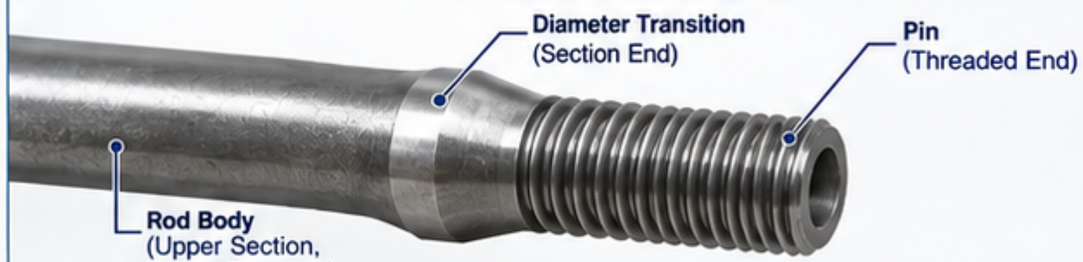
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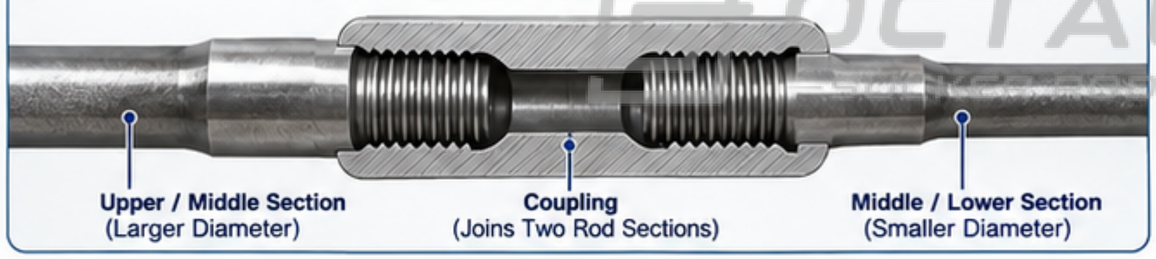
03 | TAPERED SUCKER ROD STRING CONSTRUCTION



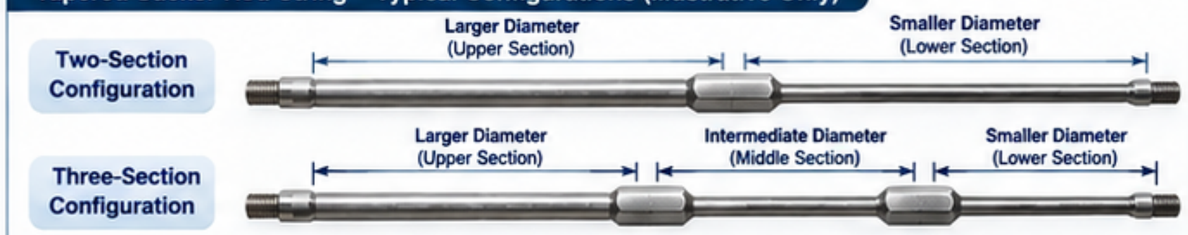
Threaded Pin End and Rod-Body Transition (Enlarged View)



Section Connection and Diameter Transition (Sectional View)



Tapered Sucker Rod String – Typical Configurations (Illustrative Only)



Note: The configurations, rod diameters, and section lengths shown are illustrative examples only, not universal recommendations. Actual design must be determined by engineering calculations and operating conditions.

What Is a Tapered Sucker Rod String?

A tapered sucker rod string is constructed by combining rod sections with different nominal rod-body diameters in series (e.g., two or three sections), with a generally larger diameter near the surface and a smaller diameter near the pump. Different rod diameters are selected according to the changing load requirements along the string.

Typical Configurations

- **Two-section configuration:** An upper section with a larger diameter and a lower section with a smaller diameter.
- **Three-section configuration:** An upper (larger), middle (intermediate), and lower (smaller) diameter section.
  The number of sections is selected based on well conditions, load distribution, and design objectives; a three-section arrangement is not always required.

Structural Characteristics

- Consists of multiple commercially available rod sections with different nominal rod-body diameters.
- Sections are connected by standard couplings at their interfaces.
- The rod diameter transitions at section connections to match the selected sizes.
- Load is higher in the upper portion and lower in the lower portion, and the tapered design matches this changing load distribution.

Design Requirements

- Determine the number of sections, rod diameters, and section lengths based on engineering calculations and operating conditions (e.g., load distribution, well depth, fluid properties, rowing equipment, and operating plan).
- Ensure reliable section connections and adequate strength for the expected loads.
- Select a structure that meets the well's operating objectives and overall reliability requirements.

Structural Characteristics (Summary)

- Composed of two or more rod sections with different nominal rod-body diameters.
- Includes upper (larger), middle (intermediate, if used), and lower (smaller) sections connected by couplings.
- The rod diameter decreases toward the pump, matching the changing load requirements along the string.

Structural Advantages

- Matches the load distribution along the string, improving structural efficiency.
- Reduces rod weight in the lower portion, which helps lower polished rod load and power demand.
- Provides design flexibility for different well conditions and operating objectives.

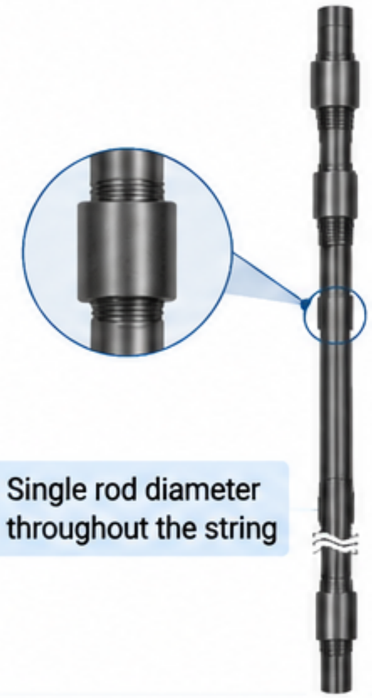
Design Requirements / Considerations

- Select the number of sections, rod diameters, and section lengths based on engineering calculations and operating conditions.
- Ensure reliable section connections and smooth diameter transitions.
- Verify that the overall structure meets strength, reliability, and operating objectives for the target well.

Uniform vs Tapered Sucker Rod Strings – Engineering Comparison Guide

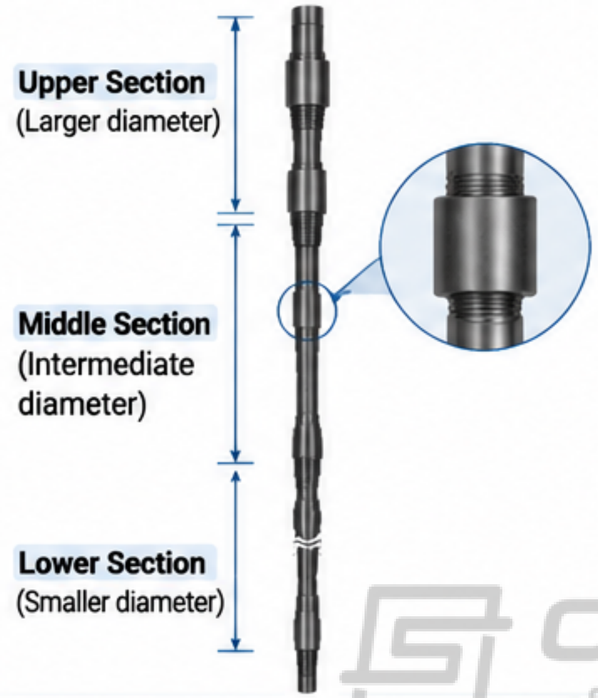
Technical Comparison

Uniform Rod String



Single rod diameter throughout the string

Tapered Rod String



Item	Uniform Rod String	Tapered Rod String
Rod Diameter	One diameter (constant)	Two or more diameters (stepped by section)
Cross-Sectional Area	Constant along the string	Varies by section (larger at upper, smaller at lower)
String Weight	Generally higher (when sized for the maximum load)	Generally lower (optimized by section)
Load Distribution	One size carries the entire load profile	Diameters matched to the changing tensile load
Connection Arrangement	Threaded couplings of the same size	Couplings matched to each rod diameter
Assembly & Replacement	Simpler, one size to manage	Multiple sizes, more planning during assembly and workover

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Key Advantages and Limitations

Uniform Rod String

✔ Advantages

- Simple configuration and assembly
- Easier inventory and spare parts management
- Fewer diameter transitions

✘ Limitations

- One diameter must meet the entire load
- Lower sections may carry excess capacity
- Can increase total suspended weight

Tapered Rod String

✔ Advantages

- Rod sizes matched to section loads
- Can reduce suspended rod weight
- More efficient use of rod strength

✘ Limitations

- More design steps and calculations
- Multiple rod sizes to manage
- Requires proper section length and transition

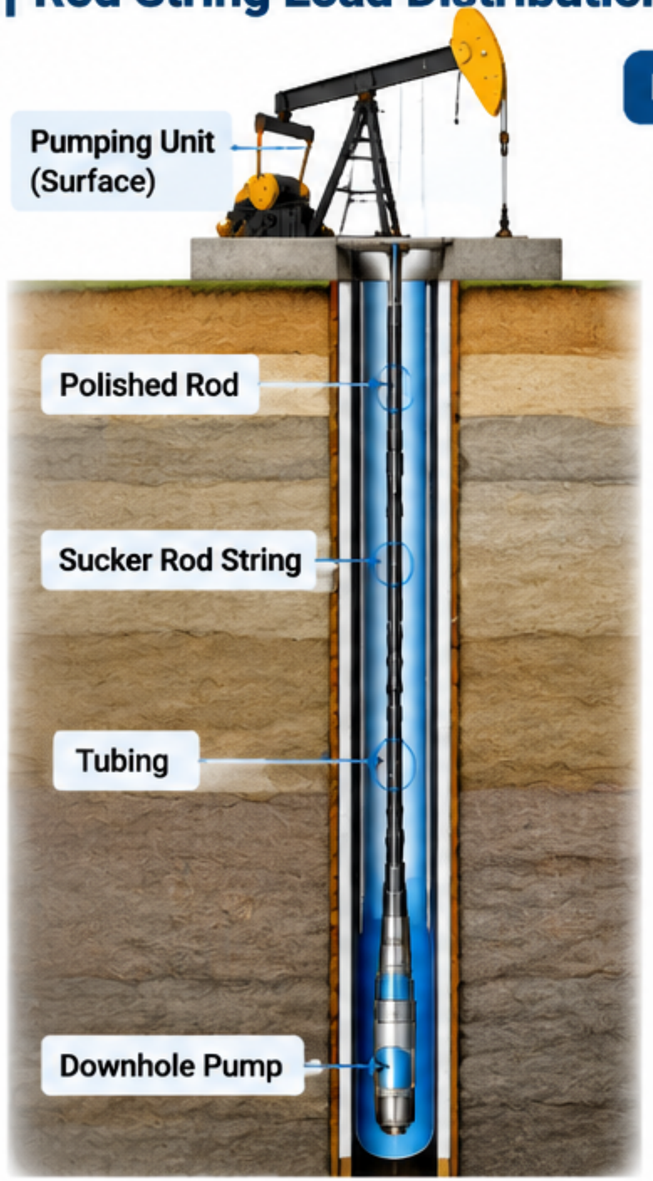
Engineering Considerations



- ☑ Confirm well depth and loading conditions
- ☑ Evaluate required rod size and material grade
- ☑ Check connection compatibility
- ☑ Assess string weight and pumping unit capacity
- ☑ Consider inventory and maintenance needs

Uniform vs Tapered Sucker Rod Strings – Engineering Comparison Guide

Rod String Load Distribution



Load Distribution Along the Rod String



Upper Section
(Higher tensile load)

Middle Section
(Intermediate load)

Lower Section
(Lower tensile load)

Main Load Components



Static Rod Weight
The suspended weight of the rod string, which accumulates toward the surface.



Fluid Load
Axial load from the fluid column acting on the rod string, including the effect of produced fluid in the tubing.



Dynamic Load
Additional load from the reciprocating motion of the rod string, including inertial effects and cycle-related forces.

Well Trajectory Considerations

Vertical Well



- Simpler load path
- Axial load mainly from rod weight and fluid
- Widely used in rod-lift design

Deviated Well



- Additional friction between rod and tubing
- Higher overall load consideration
- Requires evaluation of well inclination and trajectory

Key Takeaways

- The upper sections of the rod string generally carry higher tensile loads due to the accumulated weight.
- Overall rod loading includes static, fluid and dynamic components that vary during operation.
- Well deviation can increase frictional loads and should be considered in the design.

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Rod Diameter and Stress Relationship

Key Formulas

Axial Stress:

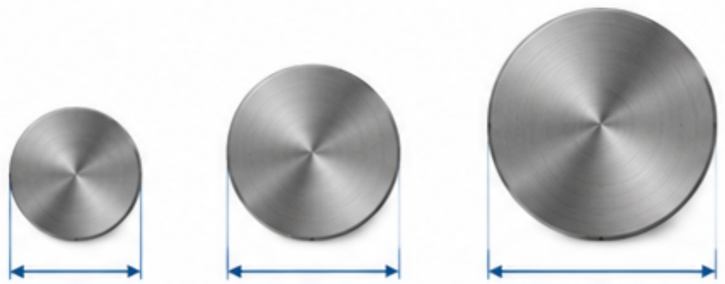
$$\sigma = \frac{F}{A}$$

Cross-Sectional Area (for a circular rod):

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

- σ : Axial stress (force per unit area)
- F : Axial tensile force on the rod
- A : Cross-sectional area of the rod body
- d : Rod-body diameter

Rod Diameter and Cross-Sectional Area (Comparison)



Larger diameter ⇒ Greater cross-sectional area
⇒ Lower nominal axial stress (for the same axial force)

Stress Evaluation Along the Rod String



Upper Section
- Highest accumulated load
- Larger diameter to reduce stress

Middle Section
- Intermediate load and stress
- Matching diameter and strength

Lower Section
- Lower accumulated load
- Smaller diameter can be used

Material Strength and Fatigue Considerations



- ☑ Select an appropriate material grade based on the maximum and minimum loads.
- ☑ Ensure the rod material has adequate yield and tensile strength for the design.
- ☑ Evaluate fatigue performance under cyclic (reciprocating) loading.
- ☑ Consider well conditions such as corrosion and temperature, which can affect fatigue life.

Design Implications

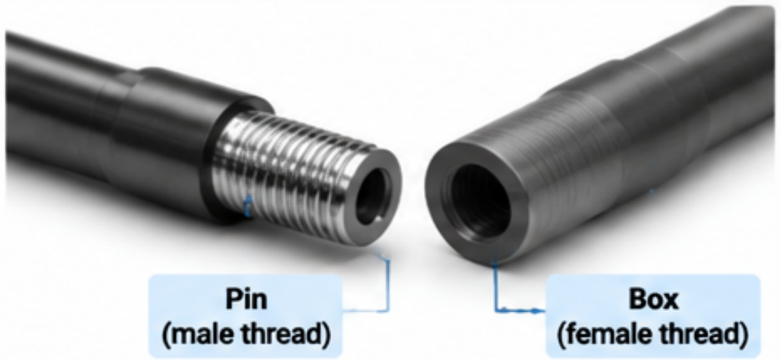
Consideration	Engineering Implication
Rod Diameter	Affects the cross-sectional area and nominal stress.
Section Design	Match rod diameter to the load profile along the string.
Material Strength	Must meet the required tensile and yield strength.
Fatigue Requirement	Evaluate the stress range and cyclic loading effect, especially at threaded connections.

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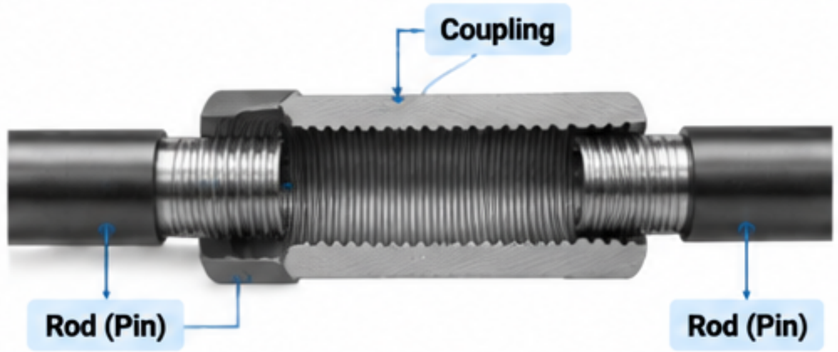
Connection and Operational Considerations

Threaded Connection



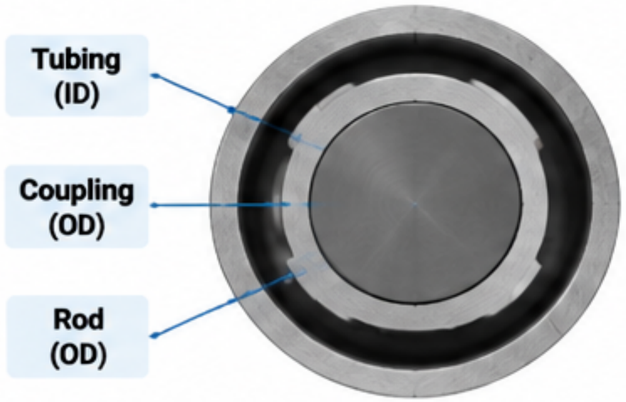
- Standard threaded connection used to join rod sections.
- Provides reliable tensile transmission under reciprocating load.
- Thread condition and cleanliness are critical for service life.

Coupling Compatibility



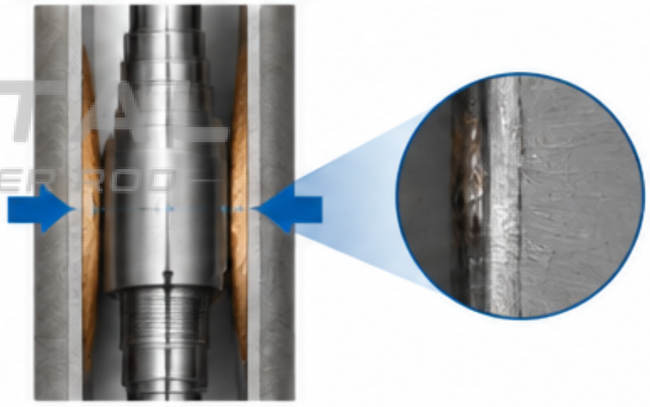
- Connects two rod pins of the same diameter.
- Ensure dimensional compatibility and thread fit.
- Use couplings of the corresponding rod size and grade.

Tubing Clearance



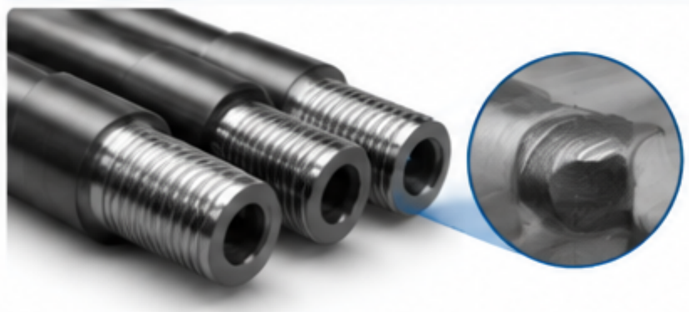
- Maintain sufficient clearance between the coupling OD and tubing ID.
- Consider tubing wear, scale and deformation in long-term operation.
- Insufficient clearance can increase friction and the risk of rod-tubing contact.

Rod–Tubing Contact



- Can occur in deviated, curved or high-friction wells.
- May lead to tubing wear, rod damage and higher operating load.
- Proper rod size, coupling OD and well trajectory design can help reduce the risk.

Fatigue and Wear Risks



- Reciprocating loads can cause fatigue damage, especially at threaded connections.
- Rod-tubing contact and abrasive fluids can lead to surface wear.
- Regular inspection and replacement based on well conditions help maintain reliable operation.

Engineering Considerations

Item	Key Consideration
Connection	Use standard, compatible threads and couplings.
Tubing Clearance	Ensure adequate clearance considering field condition changes.
Rod-Tubing Contact	Evaluate based on well trajectory, rod size and operating conditions.
Fatigue & Wear	Monitor thread and rod body condition; replace when necessary.

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Uniform vs Tapered Sucker Rod Strings – Engineering Comparison Guide

Engineering Selection and Specification Checklist



Selection Guide: Uniform or Tapered?

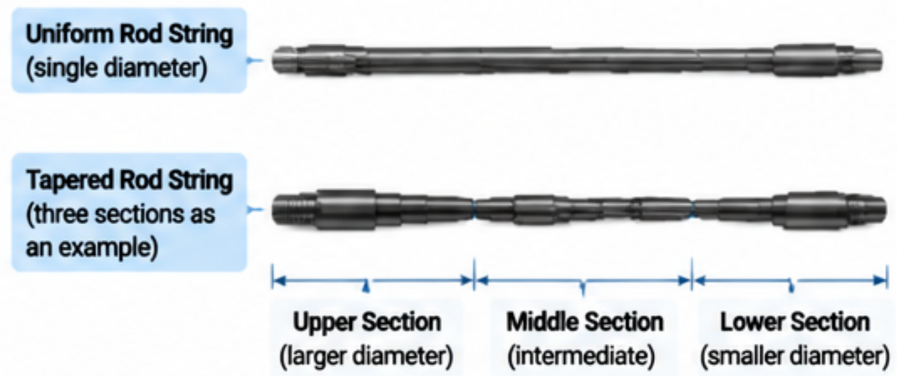
Choose Uniform Rod String When

- ☑ The well depth and load level are within a manageable range.
- ☑ A simpler configuration and easier inventory management are preferred.
- ☑ The operating conditions are relatively stable.

Choose Tapered Rod String When

- ☑ The well is deeper or the total rod weight needs to be reduced.
- ☑ A more balanced load distribution along the string is required.
- ☑ The design calls for higher operating efficiency svid longer service life.

Rod String Configuration



Key Specification Considerations

Rod Diameter	Select the appropriate diameter(s) based on well depth, load profile and pumping conditions.
Material Grade	Use a grade that meets the required tensile and yield strength for the design.
Section Length	Define the length of each section, especially for a tapered configuration.
Maximum / Minimum Load	Confirm the expected maximum and minimum rod loads under operating conditions.
Connection Compatibility	Ensure the pin, box and coupling are compatible in size, thread and material.
Tubing Clearance	Verify sufficient clearance between the coupling OD and tubing ID to reduce contact risk.

Final Technical Specification Checklist

- ☐ **Rod string type** (Uniform or Tapered)
- ☐ Rod diameters and section arrangement
- ☐ Material grade and applicable standard
- ☐ Section lengths and total string length
- ☐ Design maximum and minimum loads
- ☐ Thread type and coupling specification
- ☐ Tubing size and clearance confirmation
- ☐ Operating conditions (well type, depth, deviation, fluid)
- ☐ Special requirements (coating, corrosion control, etc.)



Key Takeaway

Select the rod string configuration and specifications based on a comprehensive evaluation of well depth, load conditions, tubing size and operating environment to achieve safe and reliable rod-lift performance.