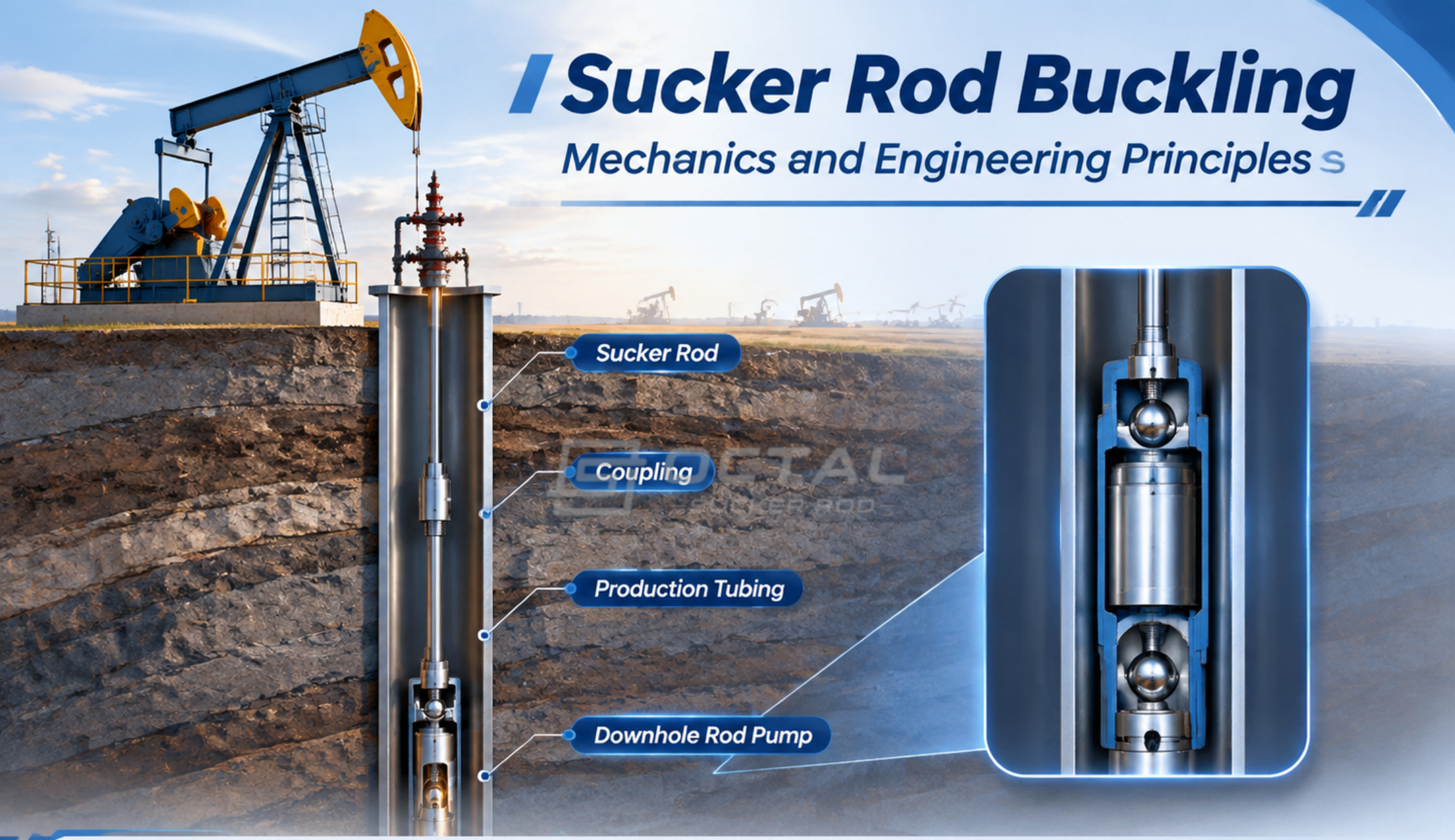
Sucker Rod Buckling

Mechanics and Engineering Principles s



Load Formation
Sources and distribution of rod loads

Neutral Point
Position and significance

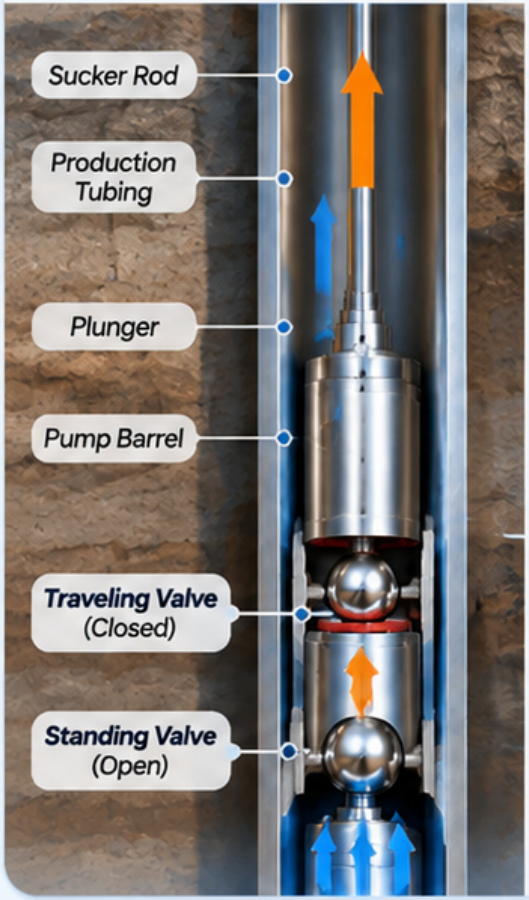
Buckling Modes
Forms and characteristics

Stability Assessment
Evaluation methods and criteria

02 Sucker Rod Pumping Cycle and Downstroke Compression

Upstroke

Rod string moves upward and mainly carries tensile load.



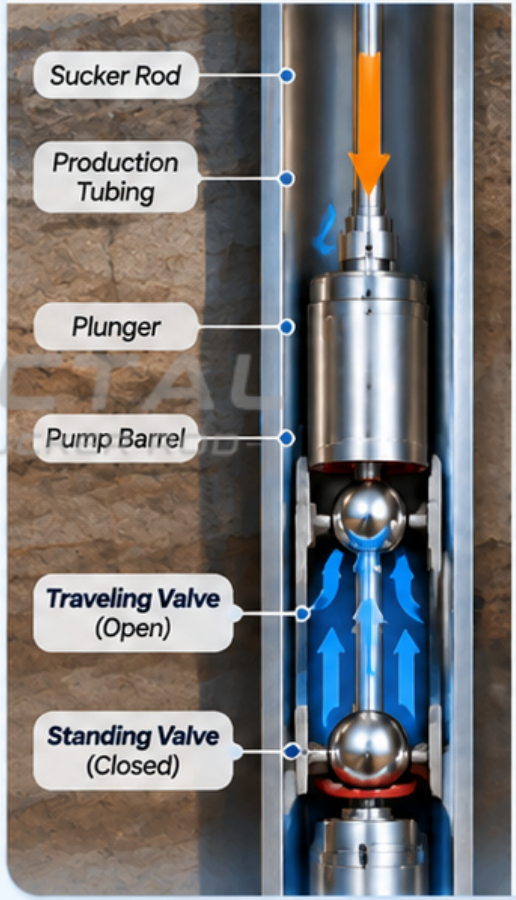
- The surface unit lifts the rod string and the produced fluid.
- Rod string is under tensile loading.
- The plunger moves upward, closing the traveling valve and lifting fluid above the plunger.



Traveling Valve (Closed) — Upstroke

Downstroke

Rod string moves downward, and resistance in the pump can cause compression in the lower rod sections.



Main Resistance During Downstroke

Hydraulic Resistance
Pressure difference across the traveling valve.

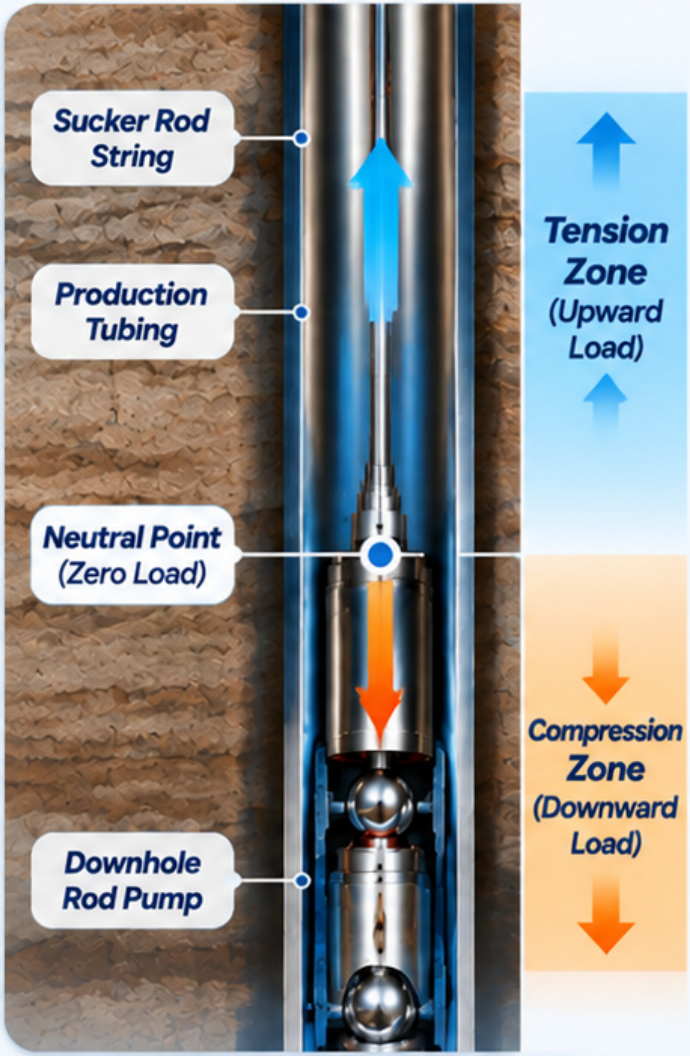
Plunger Friction
Mechanical friction between plunger and pump barrel.

Fluid Resistance
Flow resistance related to fluid viscosity and pumping speed.

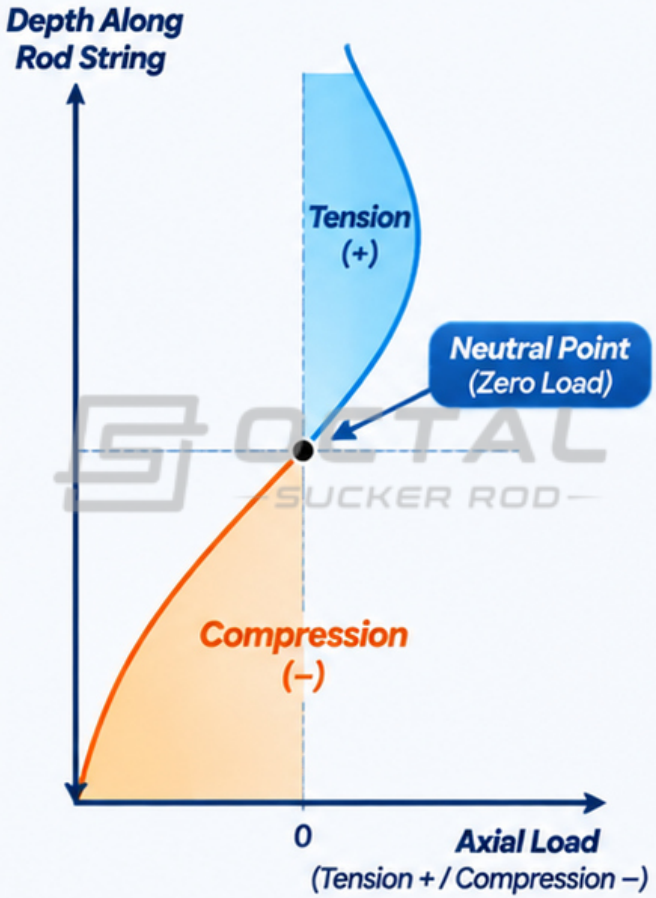
These resistances can generate an upward reaction at the lower end of the rod string, contributing to axial compression in the rod sections above the pump.

Compression is not necessarily uniform along the rod string. Its distribution depends on the pumping cycle, pump conditions, rod-string configuration and the forces acting near the downhole pump.

03 Neutral Point and Axial Load Distribution



Conceptual Axial Load Distribution

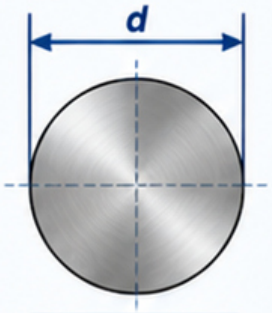


Term	Engineering Meaning
True Load	Mechanical axial force under the selected calculation convention.
Effective Load	Load adjusted for applicable pressure and buoyancy effects.
Maximum Load	Highest tensile load during the pumping cycle.
Minimum Load	Lowest load during the pumping cycle.
Neutral Point	Position where calculated axial load changes between tension and compression.

The neutral point changes with operating conditions and the selected load calculation method. It should not be treated as a fixed location along the rod string.

04 Factors Affecting Sucker Rod Buckling Resistance

Rod Diameter and Bending Stiffness



Solid Circular Rod Section

Second Moment of Area

$$I = \frac{\pi d^4}{64}$$

I : Second Moment of Area
d : Rod Diameter

*For a **solid circular rod**, the second moment of area increases with the **fourth power of diameter**. A larger diameter therefore increases bending stiffness when the material and other geometric conditions remain unchanged.*



Effect of Rod Diameter on Sectional Stiffness

Rod Diameter d (Example)	16 mm	19 mm	22 mm	25 mm
Cross Section (Solid Circle)				
Second Moment of Area I (Relative Value)	**1.00** (Baseline)	**≈ 2.00** (2.0 ×)	**≈ 3.66** (3.7 ×)	**≈ 5.96** (6.0 ×)

Other Key Factors Influencing Buckling Resistance

Elastic Modulus (E)



Material property that determines stiffness and elastic resistance to bending.

Unsupported Length (L)



The axial length without effective lateral support. A longer unsupported length reduces stability.

Lateral Support



Constraints from rod guides or tubing contact that provide additional lateral support.

Tubing Clearance



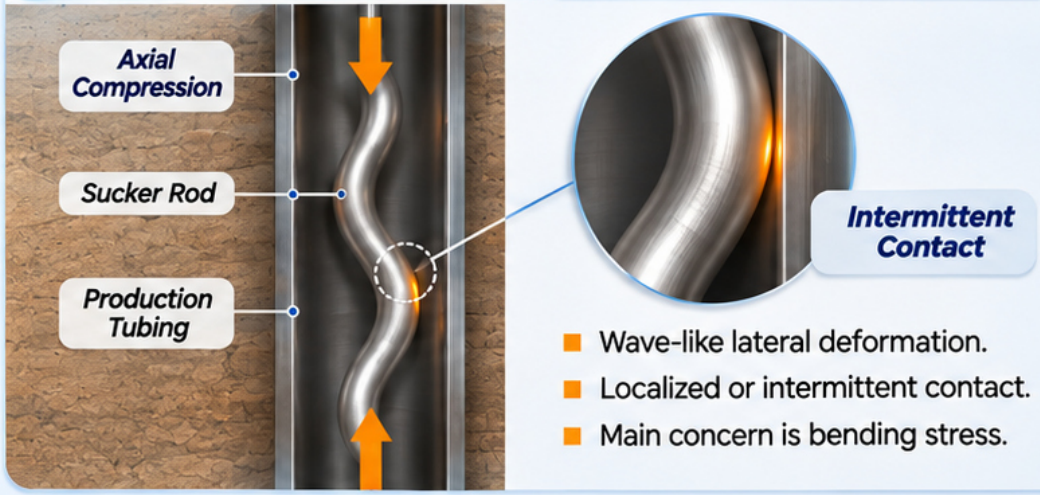
The radial space between the sucker rod (or coupling) and the tubing inner diameter, which affects lateral restraint and contact conditions.

A larger rod diameter increases buckling resistance, but it also increases the rod-string weight. Therefore, buckling risk should be evaluated based on the overall load condition, not rod diameter alone.

05 Sinusoidal and Helical Buckling of Sucker Rods

Sinusoidal Buckling

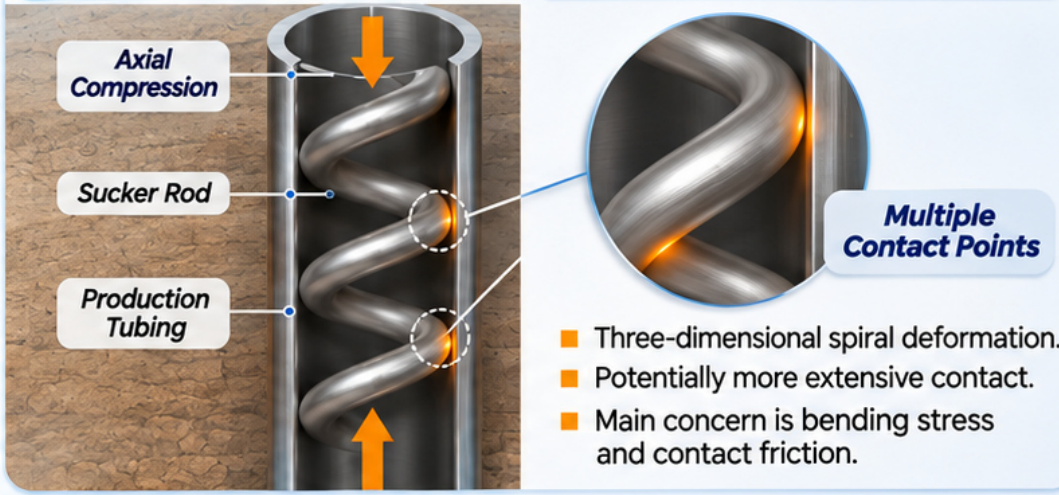
A wave-like lateral deformation under axial compression.



- Wave-like lateral deformation.
- Localized or intermittent contact.
- Main concern is bending stress.

Helical Buckling

A three-dimensional spiral deformation under axial compression.



- Three-dimensional spiral deformation.
- Potentially more extensive contact.
- Main concern is bending stress and contact friction.

Comparison	Sinusoidal Buckling	Helical Buckling
Deformation	Wave-like	Three-dimensional spiral
Contact	Localized or intermittent	Potentially more extensive
Main concern	Bending stress	Bending stress and contact friction
Assessment	Compression and lateral support	Compression and tubing confinement

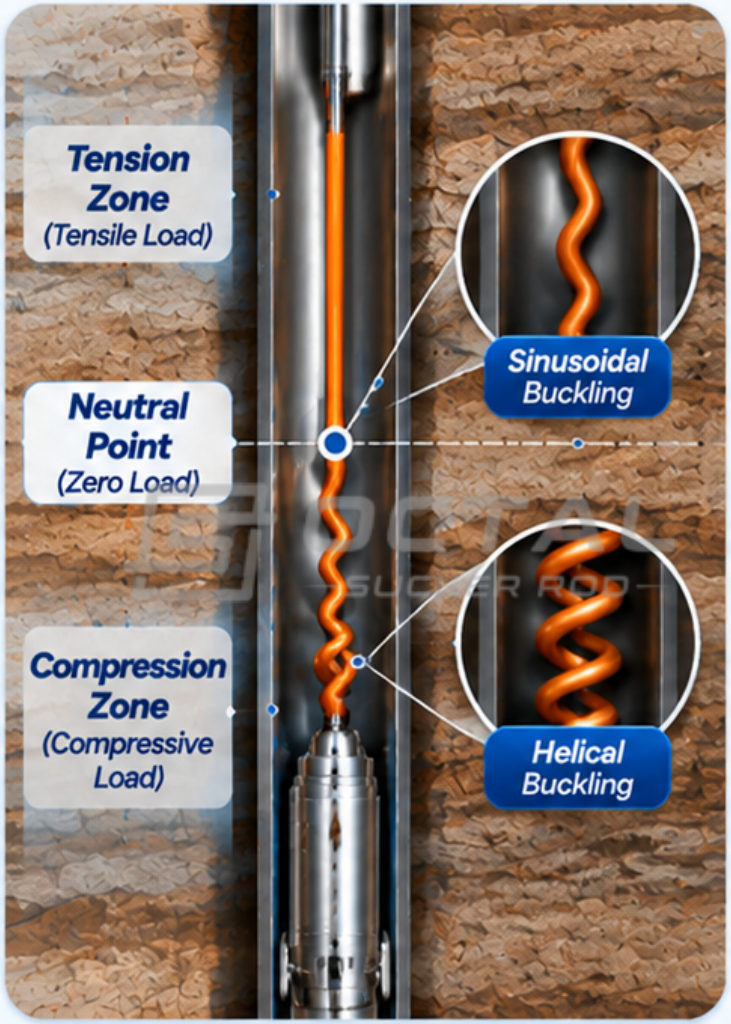
OCTAL SUCKER ROD

Sinusoidal buckling and helical buckling are different compression-related states of the sucker rod. Under idealized axial compression, sinusoidal buckling may develop into helical buckling. In actual sucker rod strings, the deformation pattern depends on axial loading, well geometry, and tubing constraint, and different buckling states may coexist along the string.

06 Engineering Interpretation and Key Conclusions

Engineering Analysis Process

- Axial Compression
- Neutral Point Identification
- Rod Section Stability Assessment
- Sinusoidal / Helical Deformation Evaluation
- Rod-to-Tubing Contact Assessment
- Engineering Design Review



Key Conclusions

- Axial compression is a primary condition associated with sucker rod buckling.
- Rod diameter, bending stiffness and lateral support influence buckling resistance.
- Well geometry, pumping conditions and tubing clearance must be considered together.

Sucker rod buckling assessment requires an understanding of the entire rod-string loading condition. A tensile-strength check alone cannot establish whether a rod section remains stable under compression.