Round vs. Semi-Elliptical Continuous Rod.

Continuous rod was originally developed in the early 1970s in the Rocky Mountains and still enjoys widespread use today.

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In the 1980's, progressive cavity pumps, or PCPs, were adopted as a viable form of lift for heavy viscous crude. Canada, California, and Venezuela quickly began to implement PCP's in these formations utilizing continuous rod to turn the pump.

Today, continuous rod is still predominantly used with PCP's in high viscous fluid formations and, to a lesser degree, with conventional rod pumping. Traditional sucker rods remain the primary form of conveyance in rod-pumped wells. There are two types of continuous rod shapes: round and semi-elliptical. The original continuous rods were semi-elliptical. The round cross-section continuous rods have become increasingly popular and are predominantly what Lightning Production Services recommends.

One of the main issues with semi-elliptical rods is that some portion of the minor axis will, most likely, be riding on the tubing wall leading to a smaller contact area and increased wear. The minor diameter of 1.0-inch elliptical rod is 0.74-inch, and the minor diameter of 0.875-inch elliptical rod is 0.7-inch. Semi-elliptical rods are designed to contact the tubing on the major side providing two points of contact to reduce side loading on the rod string. However, wells are not drilled perfectly straight, they tend to walk resulting in directional changes and doglegs. Generally, the major continuous rod axis will ride the low side of the tubing for most of the well, but if the well direction changes the minor axis will ride the low side causing a knife-like effect and increased wear. The most common cause of failure in elliptical rods is one-sided wear induced from corrosion and compression breaks. Round rod allows operators to utilize a rod rotator in rod pumping wells whereas elliptical rod does not. The use of a rod rotator helps disperse wear across the total circumference of the rod and helps keep the entire rod coated with corrosion inhibitors as the chemicals are not mechanically removed by wear action. Rotating elliptical rods defeats the purpose of their design, which is to provide two contact points as described above.

Continuous rods are designed to disperse side loads along the length of the rod, whereas conventional rod area of contact is primarily limited to the rod coupling. The decrease in sideloading pressure achieved by continuous rods significantly reduces wear and associated failures.

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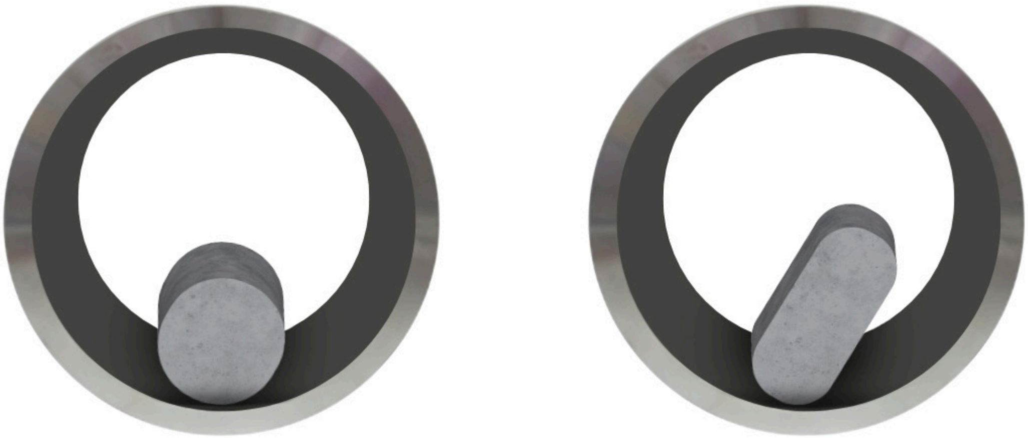

The equation for the normal force is given by:

$$F_N = L_r \cdot W_r(1 - 0.127 \cdot \gamma_F) \sin \alpha,$$

Where F_N is the normal force, L_r is the length of the rod string, W_r is the weight of the rod string, γ_F is the fluid specific gravity and α is the inclination. The normal force is proportional to the weight of the rod, therefore, the lighter the rod the smaller the normal force will be.

Pressure is defined as the results of a force acting on an object over a certain area. Wear is the direct result of the applied pressure to the rod or tubing. The equation for pressure is the force divided by contact area as given by:

$$\sigma = \frac{F_N}{A}.$$

From (2), it can be concluded that the pressure, or wear, is proportional to the normal force applied and inversely proportional to the contact area. The larger the contact area the smaller the pressure.

In the case of continuous rod, the contact area is spread over the entire length of the string as opposed to the small surface area of the coupling every 25 feet in a conventional rod string. Therefore, the resulting pressure is significantly less.

The area in contact with the tubing depends on the contact angle between the tubing and the rod or coupling. This angle is dependent on the radius of the rod and tubing used. It is somewhat difficult to estimate but without loss of generality an angle of 20° can be used for round continuous rods, 120° can be used for the major axis of semi-elliptical continuous rods and 15° for its minor.

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It is important to note that the contact angle will increase over time as wear patterns develop in the tubing. The contact angle described above is only meant as an initial starting point and will change over time.

The contact area is calculated as the length of the area times the arc length of contact, s, as in:

$$A_C = L_C \cdot s = L_C \cdot P \cdot \left(\frac{\theta}{360}\right),$$

Where A_C is the area of contact (ft^2), L_C is the length of the contact area (ft), r is the radius of either the continuous rod or the coupling (ft), P is the circumference of the rod and θ is the contact angle between either the continuous rod and the tubing or the coupling and the tubing (degrees).

For the round continuous rod, the circumference is given by $P = 2\pi r$, while the semi-elliptical continuous rod, the circumference is given by $P = 2\pi \cdot \sqrt{\frac{a^2+b^2}{2}}$, where a and b are the major and minor radiuses.

In the following table, circumference, arc length, area of contact, normal force, and the resulting stress are compared between a 1-inch round continuous rod, semi-elliptical rod – major axis, and semi-elliptical rod – minor axis at an inclination of 15 degrees.

Type	$L_{Contact}$ (ft)	Unit weight (lb/ft)	W_r (lbs)	Circumference (ft)	Contact Angle (°)	S	$A_{Contact}$ (ft^2)	F_N	σ (psf)
S-E Continuous Rod (Major)	25 ft	2.67	66.8	0.27	120	0.090	2.25	15.08	6.7
S-E Continuous Rod (Minor)	25 ft	2.67	66.8	0.27	15	0.011	0.28	15.08	53.8
Round Continuous Rod	25 ft	2.67	66.8	0.26	20	0.015	0.38	15.08	39.7

Table 1: Comparison of stress and related values for continuous rods, semi-elliptical rod (major axis), and semi-elliptical rod (minor axis).

As can be seen by Table 1, the advantage of using a semi-elliptical continuous rod lies in the reduced pressure from the extended contact area when its major axis is in contact. However, where the semi-elliptical rod contacts the tubing on its minor axis, the resulting pressure is over eight times greater. Also, as mentioned above, since a rod rotator is not recommended to use with the semi-elliptical continuous rod, only one side will wear until failure.

The round continuous rod, however, can spread the wear along the entire circumference of the rod as opposed to concentrating the pressure on one side of the rod leading to longer runtime. As can be seen by Table 1, resulting pressure is greater than the semi-elliptical major axis but smaller than its semi-elliptical counterpart minor axis.

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