POLISHED ROD FAILURE PREVENTION

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INTRODUCTION

The polished rod is the uppermost joint in the string of sucker rods used in a rod pump artificial-lift system. Almost without exception, the polished rod is the strongest component of the rod string. It has the largest cross-sectional area and its material strength is at least equal to that of the sucker rods. Yet in many cases, polished rods fail with regularity while the sucker rods do not. Polished rod failures are usually a symptom of a greater problem. Therefore, simply replacing one polished rod with another will most likely not prevent a similar failure in the future.

BENDING FAILURES

Almost all polished rod breaks are fatigue failures. Fatigue is associated with fluctuating loads which can cause failures even though the maximum stress resulting from these loads is less than the ultimate strength of the polished rod material. A fatigue failure is characterized by the initiation of a small crack at a point of high stress on the surface of a part. Under fluctuating loads, the crack opens and closes repeatedly and grows in a plane perpendicular to the axis of the stress. As the crack progresses, the effective cross-sectional area is reduced until insufficient material remains to support the load. While the entire string of rods is subjected to fatigue it is the polished rod that carries the highest load. That combined with the fact that the polished rod is subjected to bending is the leading reason for polished rod failure.
It is a common problem in the oil field to work under a reactive set of mind; Wait until a failure occurs and then address it instead of trying to avoid it from the beginning with an investment that is a fraction of a workover cost. This is true today more than ever with rising cost of workover rigs. While we can not minimize normal fatigue wear we can take corrective measures with regard to unnecessary bending and thus minimize polished rod failures.

Bending can be identified by a simple visual inspection with the aid of a carpenter's level or a plumb bob. Inspect the polished rod on the up stroke and down stroke from at least two different angles. Another symptom of bending is a stuffing box that requires frequent repacking.

There are several conditions that can cause bending.[1]
(1) Misaligned Pumping Units (Figure 1)**.** Unstable pumping unit foundations, bent structural members on the pumping unit, or improperly adjusted horseheads can cause misalignment. This misalignment will induce bending stresses in the polished rod and could cause premature polished rod failure. Check to make sure pad and pumping unit are level, unit bridle is centered on the horsehead, and head of unit for worn or unadjusted hinges.

(2) Misaligned Wellhead Assembly. The casing head, tubing head, flow tee, and stuffing box assembly should be vertical to allow alignment with the polished rod. API Recommended Practice RP 11 B suggests that the assembly be vertical to within 1 l/2 inches in 20 feet. Unless the polished rod happens to be misaligned the same amount and in the same direction, bending loads will be imposed on the polished rod. A string and plumb bob hung from the carrier bar down beside the tee and tubing can assist in alignment.

(3) Unleveled Carrier Bars (Figure 2)**.** Carrier bars must be level to prevent bending the polished rod. The load on the polished rod will force the bottom of the clamp flush with the top of the carrier bar and bend the polished rod. Leveling plates can be used to compensate for unleveled carrier bars.

(4) Uneven Surfaces on the Carrier Bar. Not only should carrier bars be level, but their top surfaces should be flat. An uneven carrier bar will bend the polished rod. A leveling plate can also be used in this situation to correct for the uneven surfaces. Otherwise, worn carrier bars should be machined flat or replaced.

(5) Uneven Polished Rod Clamps (Figure 3). The bottom surface of a polished rod clamp should be flat, in a common plane, and perpendicular to the axis of the polished rod. Otherwise, one side of the clamp will put more pressure on the carrier bar than the other causing bending.

All polished rod clamps have some end play between segments. Care should be taken to insure segments move freely on their hinges before installation and are even on the bottom after the clamp bolts have been tightened. Do not assume segments are even on the bottom just because they are even on the top.

OTHER FALIURES

While misalignment failures are the leading cause for polished rod failures there are other types of failures.

(6) Clamp on sprayed metal. Polished rod clamps should **NEVER** be installed on the hardened "spray metal" surface of a polished rod since they will damage the hard surface. These excessive radial stresses can damage the clamp as well as the polished rod. Stress buildup in the polished rod will be excessive which will quickly lead to stress cracking and premature polished rod failure. Spraymetal polished rods have an unsprayed portion for polished rod clamp placement.

(7) Clamps over torqued. Grossly overtightened polished rods clamps will lead to excessive stress on the rod and possibly failure. It is a good policy to always follow the manufacturer's recommended procedure and apply no more bolt torque than necessary to achieve the clamps rated load capacity. Never use extension devices to tighten clamps. In order to achieve correct torquing it is best use a torque wrench and after tightening, make sure both segments are still level on the carrier bar.

(8) Wrong coupling. Polished rod pin failures generally occur due to the installation of sucker rod couplings instead of polished rod couplings. Polished rod couplings have a shallow counterbore and a 9° taper that conforms to the profile of the polished rod pin. Sucker rod couplings have no taper and a deep recess (Figure 4). These differences lead to two common failures:

Sucker rod coupling failure - The 9° polished rod pin creates excess residual hoop-stress during makeup on the inside diameter of the sucker rod coupling near the coupling-shoulder contact face. The stress crack initiates on the inside diameter of the sucker rod coupling and propagates longitudinally, with each applied load, until the crack reaches the area with the highest tensile stress (Figure 5).

Polished rod pin failure - The deep counterbore of the sucker rod coupling fails to engage the last one or two threads of the polished rod pin. Unengaged threads are areas with increased local stress intensity and may lead to failure. Polished rod couplings' shallow recess to the first thread allows every polished rod pin thread to be engaged (Figure 6).

The solution to this problem is simple and cheap; **ALWAYS** use a polished rod coupling. Most polished rod coupling manufactures label the coupling in order to differentiate it from the sucker rod coupling, however the couplings can be easily distinguished by a visual inspection of the counterbore.

SUMMARY

Polished rod problems are easy to overlook. Hanging the polished rod on the carrier bar is among the last actions for a workover rig just before they get off the well site. This leads to rushed operations and careless decisions. Furthermore, the result of these decisions can manifest itself a long time after the well was returned to production, so it can create the illusion that nothing wrong was done by the rig. It is our responsibility to insist that proper alignment takes place. Make it a habit to examine all possible misalignment sources and always insist on proper installation.

Attached at the end of this paper is a troubleshooting guide for polished rod failure that was written by Mike Borden[2] and presented in the Southwestern Petroleum Short Course in 1997. It is a very handy tool to identify potential root causes for a failure and the recommended fix.

REFRENCES

1. Angelo, Larry. HOW TO MINIMIZE POLISHED ROD BREAKS. J. AU. Huber Corporation. Southwestern Petroleum Short Course, 1994.
2. Borden, Mike. NEW INNOVATIONS IN POLISHED RODS, POLISHED ROD LINERS AND THEIR IMPACT ON COST AND THE ENVIRONMENT. Hasco Manufacturing Company. Southwestern Petroleum Short Course, 1997.
3. "Failure Analysis." Norris Products. 2005. 20 Jan. 2008 <http://www.norrisrods.com/failure_06.asp>.

Table 1
TROUBLESHOOTING GUIDE FOR POLISHED RODS[2]

PROBLEM	REASONS	SOLUTIONS
Polished rod pin breaks	Using a sucker rod coupling. A polished rod pin should be connected with a polished rod coupling because a polished rod thread has a 9.0 degree taper.	Install a polished rod coupling.
Polished rod breaks just above or in the stroke area.	Fatigue caused by bending due to misalignment between the pumping unit and the stuffing box.	Align unit and stuffing box by hanging a plumb bob from the carrier bar to the stuffing box.
	A polished rod clamp may have been placed on the hard surface area of the polished rod, which will cause the thin layer of coating to crack resulting in fatigue failure.	Never install the polished rod clamp on the hard surface of a hard faced polished rod.
	Hard surface area of polished rod may have been damaged when delivered to well location causing the thin layer of coating to crack resulting in fatigue failure.	When transporting polished rods to the well site, the same procedures used in transporting sucker rods should apply.
	Pumping unit may not be level causing unwanted bending or flexing of the polished rod.	Level pumping unit and maintain a level pumping unit foundation.
Polished rod breaks between or below clamp or carrier bar.	Fatigue break caused by uneven segments of the polished rod clamp, also bent hinges or bolts could cause unwanted bending or stress.	Replace polished rod clamp. (Make sure to check for uneven segments).
	Carrier bar has worn top surface.	Replace or recondition carrier bar.
	Carrier bar is out-of-level due to the bridle not being centered over the horses head.	Center bridle over horses head by placing a torpedo level on the carrier bar.

	Pumping unit may not be level causing unwanted bending or flexing of the polished rod.	Level pumping unit and maintain a level pumping unit foundation.
	Clamp was not properly installed on the polished rod.	Clamp bolts should be tightened to the manufacturers recommended torque. Do not over tighten polished rod clamp.
Hard surface flaking off polished rod.	Pinholes started from electrolysis which will undermine hard surface.	Use lubricator with grease to help insulate polished rod.
	Polished rod may be worn out allowing corrosion to attack the base material.	Replace polished rod.
Hard surface worn only on one side of the polished rod.	Hard surface of polished rod rubbing against stuffing box when stroking.	Re-alignment of pumping unit required.
Hard surface of polished rod grooving vertically.	Excessive wear from packing being too tight.	Use lubricator with grease to reduce friction.
	Polished rod stroking against stuffing box.	Realignment of pumping unit required.
	Foreign abrasive material imbedded in stuffing box packing.	Remove foreign object or replace stuffing box packing.
Not satisfied with length of polished rod run.	Stuffing box packing too tight, causing friction and excessive wear (abrasive material in fluids).	Use lubricator with grease to reduce friction and pressure on stuffing box
	Blowing dirt, salt or sand sticking to polished rod and the stuffing box.	Use lubricator/wiper to seal stuffing box from environment,
	Excessive strokes per minute.*	Slow down strokes per minute.

*Manufacturers recommend that the linear speed of a polished rod should not be more than 1400 inches per minute. The formula to calculate linear speed is: STROKE LENGTH X STROKES PER MINUTE = LINEAR SPEED

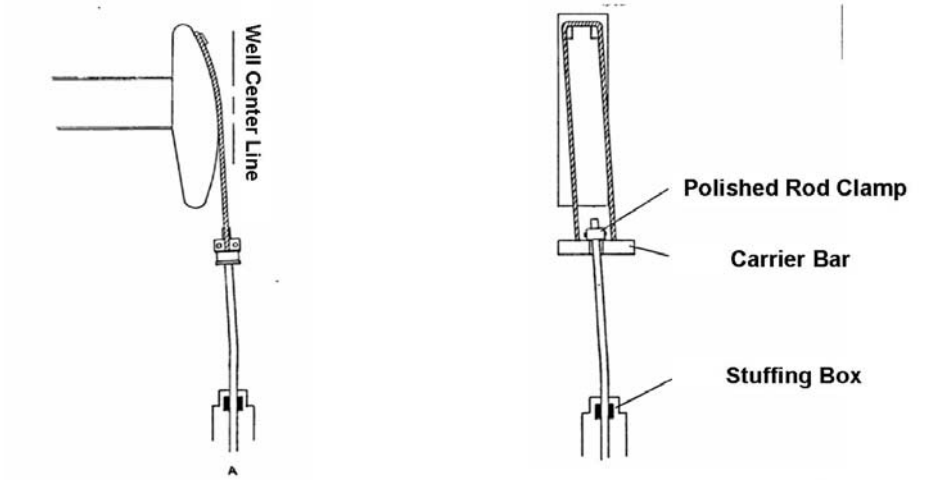

Figure 1 – Misaligned Pumping Units

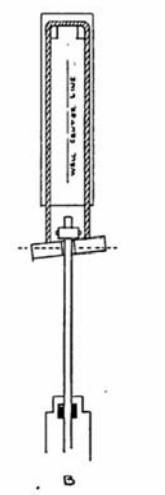

Figure 2 - Unleveled Carrier Bars

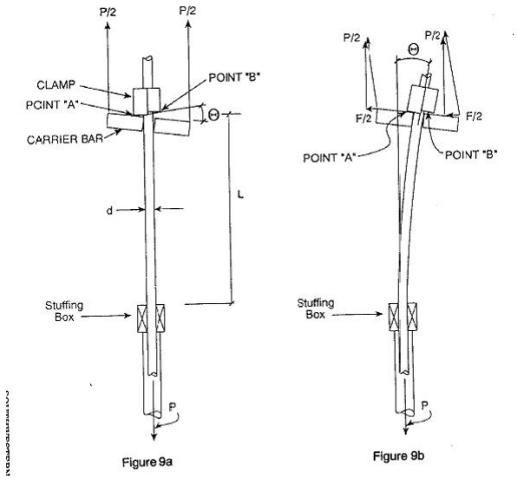

Figure 3 - Uneven Polished Rod Clamps

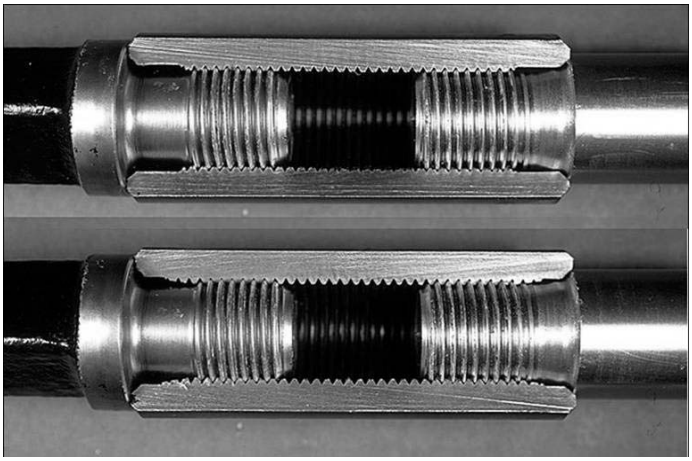

Figure 4 - Sucker Rods (Left) and Polished Rods (Right)
Engaged In a Sucker Rod Coupling (Up) and a Polished Rod Coupling (Bottom)

Figure 5 - Sucker Rod Coupling Failure

Figure 6 - Polished Rod Pin Failure