Sucker Rod Guides

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INTRODUCTION

The lifting of oil from wells by sucker rod actuation of bottom hole pumps, reciprocated from the surface, is as old as the oil industry.

Water well equipment and techniques were the practices turned to by oil men for the fundamentals upon which to found this new industry of artificial lifting of oil from wells. Much of what has been developed to date is an extension of the old art.

In the very early shallow wells drilled by cable tool rigs, little thought was given to the use of sucker rod guides as the well bores were rather straight and the rod strings carried relatively light loads. Also borrowed from the water well pumping industry was the wooden sucker rod, fashioned usually of Maple, or some similar hard, straight-grained wood, and provided with box and pin joints fastened to the rod by rivets therethrough.

Such sucker rods averaged 1-3/4 in. in diameter, with the box and pin connections being considerably smaller in diameter; hence, the wood portion of the sucker rod was the only portion that could come into contact with the well tubing. The rod acted throughout the major portion of its length as a guide and allowed very little wear on the tubing, and practically none on the rod connectors.

Wooden rods were superseded by metal rods, the boxes and pins of which, for strength considerations, were larger than the diameter of the rods. The resulting sliding metal-to-metal contact presented higher wearing factors, which were further complicated by rod stretch, corrosion, etc.

These difficulties were added to, during the same period, by the increasing prevalence of rotary drilling. Rotary drilling had admitted economy and speed over cable tool drilling methods, but the average well so drilled is not nearly so straight. Terrific problems were, and are, being caused by these deviate well bores. Of course, present day drilling is almost altogether accomplished by the rotary method. The problems encountered in sucker rod pumping of these wells depends in large measure upon the deviations and the abruptness of their occurrence within a given well.

To further complicate the picture, as wells have been drilled deeper throughout the years other problems have become more pronounced. Tubing buckling, stress reversals in sucker rods caused by high stroking rates, and stretch in rods due to high stresses, are some of these. It will be shown later herein how sucker rod guides, when properly used, can partially eliminate some of the effects of these factors.

Early thinking on the development of sucker rod guides was influenced by the recollection that, when wood was the material presented in sliding contact to the tubing, little wear was experienced. Quite naturally, then, the early sucker rod guides were of wood, usually the same familiar Maple or its equivalent.

Although the first U. S. Patent of record on a structure having some resemblance to a workable sucker rod guide dates back to 1864, the first modern wooden guide patent was issued to Dodson in 1925.

This wooden guide provided a slot that was fitted to the rod, had a longitudinal fluted body, and was secured to the rod by driving circular steel bands down on each tapered end of the guide. This guide was widely accepted as the most practical solution to many of the problems then begging attention, and enjoyed sales of several hundred thousand parts. They may yet be found in some supply stores, or even in use in an occasional well.

Had oil resistant rubbers, and other semirigid materials such as nylon, been available at this time it is likely that guide technology would have embraced their use. Since they were not available various guides were designed utilizing such other materials as hardened steel, bronze and, later, plastics. These designs all have their relative comparable advantages and disadvantages, revolving mainly around such considerations as original cost, methods of attachment to the rod string, useful life in the well fluids, and the efficiency with which they solve the problems for which they were invented.

TYPES OF GUIDES AVAILABLE

Basically, rod guides are used to center the sucker rod string in the tubing, so that wear on the rods, rod couplings, and the tubing is minimized. It is desirable to fashion the guide of a material that alleviates, rather than contributes to, this wear. Hardened steel has been favored, as has, in later years, sprayed coatings of extremely hard alloys such as Colmonoy.

Almost all of the guide structures presently available are designed to replace the standard couplings. These are of two general types. One type is not a guide in the sense that it provides any degree of lateral stabilization or centralization greater than that of a standard coupling, but is employed to prolong the life of the coupling itself, while lessening frictional drag. These are more or less standard couplings which are either hardened and ground on the outer diameter, banded adjacent either end with hard metal, or coated throughout their length by a hard metal.

Of course, the prolongation of coupling life is in itself a noble objective since, being the connector of the rod string, a coupling failure, by whatever means, results in a well out of production due to a rod parting.

The other popular type of modified coupling is more truly a guide, in the sense that it is capable of restricting lateral rod movement, at least at the coupling point where it is installed. It is of greater diameter than the standard coupling and is usually longer. It provides near contact with tubing walls on all sides, fluid passageway being provided by spirally disposed slots. These guides are offered by various manufacturers in many materials, ranging from bronze to hard alloy steel facings.

These devices, while long lived, are relatively expensive, provide stability only at rod coupling points and add length to the rod string since they are longer than the standard coupling. Also, the introduction of a dissimilar metal into the well in intimate contact with both rods and tubing is of suspected disadvantage from a galvanic corrosion standpoint.

Another guide offers a replaceable plastic element. In past years this was supplemented by still another structure of plastic molded onto a pony rod section designed to be introduced into the rod string.

One guide on the market is capable of being installed at any point on the rod string, both adjacent coupling points and at all other points in the "run" of the rod. It is available in two materials: oil resistant synthetic rubber or nylon. The rubber type has an internally molded spring steel clip, protected by the rubber, which provides the necessary grip onto the rod.

The nylon guide, recommended for special purpose installation in high salt water and/or hydrogen sulfide producing wells, has no steel insert, the "memory" of the nylon being sufficient to retain it in place on the rod. Either of these structures provide the desired flexibility of installation and are cheap enough (less than a replacement rod coupling) to be used in sufficient quantity to give adequate protection throughout the rod string.

USES OF GUIDES

It is popular to visualize the rod string as perfectly centered within the tubing, and the tubing centered within the casing. This condition seldom exists. More often deviation in the bore hole is reflected in less abrupt deviations in the casing, which are reflected as even less extreme deviations in the tubing, and likewise with the rod string. On the upstroke the rods tend to pull along a straight line, while the tubing tends to buckle; on the downstroke the rods tend to buckle and the tubing string tends to straighten as it assumes the weight of the fluid column.

"For all practical purposes the motion imparted to (the) polished rod by surface pumping mechanisms is a simple harmonic motion. — The resulting pumping cycle is characterized by the transfer of fluid loads from tubing to rods on the upstroke and from rods to tubing on the downstroke." [1]

The dynamic, frictional, and shock loads are all superimposed to complicate the problem. The interrelationships of these movements cause sliding frictional contact between rods and tubing. In wells of minimum curvature this may cause wear only on the couplings of the rod string. In wells of more abrupt and extreme deviations wear will occur also at the mid-sections of the rods.

That the effects of tubing buckling in pumped oil wells is deserving of further study is set forth in a paper published in 1957 by Lubinski and Blenkarn. [2]

" - - - the force is large enough to buckle the tubing in all wells except those with a very high working fluid level - - -. Therefore the tubing buckles into a helix which contacts the rod string over its entire length below the neutral point." The neutral point is defined as the point in the tubing string with neither compression nor tension.

This treatise minimizes the effect of crooked holes as the major single factor in rod and tubing wear, and maximizes the effects of the tubing buckling described as a causitive factor. Further, it proposes that rod guides can profitably be used in any well to alleviate the effects.

In summation, the case for the use of sucker rod guides has many facets. Sucker rod guides, when applied properly, secure for the user the following results:

1. Center rods in tubing
2. Save rod, rod coupling, and tubing wear
3. Reduce friction, thereby reducing horsepower input required to pump the well
4. Lower polish rod peak load
5. Assist in damping vibration
6. Lengthen effective plunger travel
7. Decrease pump plunger wear
8. Minimize rod fatigue by decreasing bending stresses
9. Decrease the effects of corrosion of rod couplings and rods
10. Cut operating costs by accomplishing the above, which allows all equipment to run longer between "rod" jobs and replacement of rods, tubing, and couplings.

Because of the interrelationships of various conditions in a pumping well, all of the above mentioned benefits may not accrue to the operator in a given installation. As illustrated later herein, apparent effects the reverse of those claimed may be obtained. It is when the overall net effect is evaluated that the worth of the guides becomes evident.

"Sucker rods are designed to operate only in tension. However the effect (in pumping) is to cause repeated bending stresses in addition to normal tension stresses. This action is similar to bending a piece of wire back and forth until it fractures. Repeated bending causes the outer fibers of the sucker rod steel to separate, thus forming small transverse cracks - - - that grow rapidly until failure occurs. A rod string pumping at 20 strokes per minute is subjected to 28,800 reversals of stress in one day's operation." [3]

Rod guides can be profitably employed in any well to minimize this bending, or spurious transverse motion, by their centralizing and stabilizing effect. This is especially true in wells using fast pumping rates and/or plunger type pumps of the Martin type. In these installations, actual or relative compression in the rod string may result in forcing the pump downward. By keeping the rods acting more or less in a straight line, not only is rod damage and fatigue decreased (lessening corrosion tendencies), but the effective stroke length of the plunger is increased and pump efficiency goes up.

Increase In Pump Efficiency

This increase in pump efficiency in a large number of guide installations is fact, not theory. Dynamometer tests have shown that the installation of guides in many cases results in higher polished rod loads and increased horsepower required to pump the well. This, on the surface, refutes the value of the guides when considered alone; but sufficient increases in fluid production per unit time, brought about by improved volumetric efficiency of the pump, far offsets the increased loading. In fact, the increased loading is a direct result of the increase in volumetric efficiency. Indeed, rod guides have often allowed the adjustment of pumping cycles and plunger sizes downward, while keeping the well on the same production rate.

A somewhat atypical installation is recalled in a well near Cement, Oklahoma, that was causing a great amount of difficulty in the gear box of the pumping unit. Stress reversals in the gear box, brought about by severe sucker rod whipping, were causing teeth to chip from the gear train. Dynamometer cards showed not only a violent stress reversal cycle, but the existence of a greater torque on the gear box than was recommended by the manufacturer. Yet, calculations based on the engineering considerations of the well indicated that the pumping unit was installed within its capacity.

Rod guides were installed, with the results that torque was decreased 12 per cent to a point within the capacity of the pumping unit, gear tooth chipping was ended because no stress reversals at an excessive torque loading were present, and, although peak and average loading on the polished rod decreased in this case, fluid production of the well increased measurably.

Users of sucker rod guides often report such dramatic economy as that experienced by one large independent operating a 30 well lease near Smackover, Arkansas. Before the institution of the guide program this operator was using three rod pulling crews, and they were not keeping up with the wells that were continually going off the pump for various reasons.

Since the launching of a planned program of guide usage, one crew handles this entire lease on a part time basis. In this field, producing about 1600 barrels of fluid daily per well to obtain 25 to 40 barrels of oil per day per well, the average rod pulling job represented a direct cost of $75.00 plus, of course, the lost production. This operator estimates that the net savings gained by the use of rod guides on this one lease approximates $2000 monthly.

All too often the decision to run guides or not to run them is made by a person in an operating level that either does not have the facts on guides, or does not know how to evaluate them. By far the large majority of guides are used solely to prevent rod coupling wear. This is a good reason, but almost the least important one for installing guides. It certainly represents only a small portion of the benefits that could be realized by their proper use.

Even where hardened and ground couplings are used they somewhat reduce friction; but, in addition, they mainly shift wear from the coupling, where it is visible, to the inner wall of the tubing, where it is not visible to the eye. And, of course, wear to the tubing is more damaging and expensive. There is one guide on the market today that stands in basic difference to all the others. These guides

1. Are made of oil-resistant synthetic rubber, to take the wear and not merely transfer it,
2. Are capable of being installed anywhere on the rod string and not just at coupling points,
3. Are movable and salvable at any time while the rods are out of the well,
4. Are possessed of extremely low coefficient of friction to provide maximum freedom from friction. (Everyone knows how slippery a rubber shoe heel is on a wet deck plate.)
5. Provide electrical insulation to minimize electrolytic corrosion.

The nature of rubber in abrasive wear is that particles of the carbon black, used as a reinforcing pigment for the rubber compound, are bared at the wearing surface by erosion of the rubber matrix. So, the carbon black particles themselves resist abrasive wear and contribute largely to the low frictional coefficient of the material.

"Because of the softness of the rubber compound, hard particles - - - make impressions for themselves instead of cutting into the metal - - - . When an unyielding non-rubber is used under similar conditions, sand or other abrasive particles are not able to make room for themselves and therefore actually become tiny cutting tools - - - thus causing rapid wear."[4]

The suitability of rubber in low-friction bearing applications where abrasive laden fluids are present is admirably attested to by its wide acceptance for many years in outboard marine bearings. These are used to support propeller drive shafts in seagoing ships of all sizes, including launches and harbor tugs operating in the shallow, disturbed sandy waters of lakes and harbors.

Not only do rubber bearings outlast all other types, the coefficient of friction is in the order of .020, as compared to the range of .030 to .120 that can be expected with the various materials offered in metal rod guides in sliding contact with tubing walls. Too, quite often a pumping oil well's produced fluid may be mainly water. This works to the better performance of rubber guides since water is an excellent lubricant for rubber, which is not true for the metal guides.

CORROSION

Many observers contribute a great portion of rod and tubing wear to corrosion, or at least a combination of corrosion and abrasive wear. One reporter observes, "Failures due to rod wear are usually the result of both rod wear and corrosion. The sucker rod (or rod coupling) rubs the tubing and removes corrosion products that could stifle the corrosion reaction, thus allowing corrosion to proceed."

Thus, properly installed guides remove the harsh action, at least on the couplings, to prevent the protective corrosion coating from being removed from them. A like benefit will result on the "run" of the rods when guides are used.

If guides are installed to corrected "whip" or bending in the rod string, the resulting protection against fatigue failures pays double dividends, since fatigue failures seldom take place without being aided by corrosion. Fatigue cracking, once started, is a focal point for corrosion attack that will rapidly progress to sucker rod failure. It is generally understood that a sharp-bottomed corrosion pit could increase the normal sectional strett ten times or more.[5]

Corrosion Inhibitors

Since rod guides can accomplish certain desirable results in wells having corrosive tendencies, it is suggested that they be used in conjunction with other corrective efforts aimed at the reduction of corrosion's effects. The injection of corrosion inhibitors, for instance, is a long accepted practice which is daily gaining in widespread use. Rubber guides are compatible with popular inhibitors and, when used together, spectacular results are often obtained.

Placement

As previously stated, by far a large majority of guides are presently used merely to prevent rod coupling wear. To do this it is only necessary for a guide to be installed within a foot or so of the rod coupling affected, either above or below. It is usually more convenient to the installing crew to install above the coupling. If our only aim is the protection of the rod couplings it is evident that guides need only be installed adjacent to those couplings showing a degree of wear by visual inspection.

If the rods are then run back into the well in the same order that they were removed, as is most often the case, the couplings should be spaced in their original relationships to the well and be adequately protected. Often, however, a shifting of the wear pattern will result from installing the guides. Relocation, or the addition of guides, may be necessary at the next inspection of the rod string.

It should be kept in mind that the degree of protection obtained, and the service life of the guides, will depend largely upon the use of a sufficient quantity of guides to provide the bearing area necessary to protect the investment. Properly installed guides have been known to perform satisfactorily for periods in excess of three years, although, in some cases, a service life of as short as three months would have to be considered satisfactory when the specific rigors of the particular application are considered. Some operators, having extremely troublesome and expensive wells to produce, continue to use guides as an economical measure, even though a short life is experienced. Needless to say, this type application is the exception, not the rule.

When the production engineer, or other enlightened authority, desires to obtain the maximum benefits that that can be accomplished with the intelligent use of rod guides, their placement can be approached from a more theoretical standpoint.

By using the concept as advanced by Lubinski and Blenkarn, who define the neutral point in the tubing string as the point below which tubing buckling occurs, the location of the neutral point can be calculated for a given well. All guides, excepting those which may be indicated by observed wear on couplings, would be installed below the neutral point. Generally speaking, the guides are spaced adjacent to the pump, with the spacing width increasing upwards towards the neutral point.

This procedure can be accomplished by using the formulae developed by Lubinski and Blenkarn, or a very suitable approximation can be made. In essence, this would involve using two guides per rod, one adjacent to the coupling and one at the mid-point, for the first several rods above the pump. From there upwards, one guide per rod is adequate, to a point above the pump equal to 1/3 the well depth. In the middle 1/3 of well depth, one guide per each two rods; and the top 1/3 of the well will receive no guides except at indicated wear points.

The rubber guides for such an installation schedule in 2 in. tubing would cost $256.50, which is less than six cents per foot insurance premium, for protection of a much larger investment in rods, tubing, and production time - - - to say nothing of the cost of pulling machine time to service a rod parting.

SUMMARY

Almost at the outset of the oil well pumping industry, rod guides were visualized as a necessity to the solution of some important problems. Development of guides has been continuous since that time, involving guides made of wood, bronze, steel, nylon, synthetic rubber, and many other materials; many of these are still available in various forms from several manufacturers.

The placement of guides on sucker rods can result in full or partial solution of such pumping problems as frictional drag, wear on rods and tubing, corrosion, rod whip, plunger misalignment, etc.

The overall cost of a guide installation schedule is almost negligible compared to the results obtained.

BIBLIOGRAPHY

1. Zaba and Doherty, Practical Petroleum Engineer's Handbook, Third Edition, p. 400, Gulf Pub. Co., 1951

2. Lubinski and Blenkarn, "Tubing Buckling," Journal of Petroleum Technology, p. 75, March, 1957

3. Sucker Rod Handbook, Handbook 489, Bethlehem Steel Company, pp. 419, 21, 1958

4. Burton, Engineering With Rubber, First Edition, p. 408, McGraw-Hill Book Co., Inc., 1949

5. Corrosion of Oil and Gas Equipment, National Association of Corrosion Engineers and American Petroleum Institute, p. 13, 1958