PUMPING UNIT SELECTION TO ENHANCE FIBERGLASS SUCKER-ROD

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INTRODUCTION

A 1985 survey of 123 oil operators across the United States by an independent market research company estimated that 8% of all sucker-rod purchases were fiberglass. That same poll estimated purchases in the West Texas and Eastern New Mexico region to be 18% of the share of all sucker-rod purchases for that area. Only 8% indicated they would never consider using fiberglass sucker-rod. The increased presence of this innovative product represents a significant change in an old system.

The need to eliminate corrosion, increase production, and reduce kilowatt consumption has always been a problem in our industry. The urgency of this problem received considerable attention after the Arab oil embargo of the early 1970's. The introduction of the fiberglass sucker-rod coincided with the times.

The resistance to corrosion was perhaps the primary purpose for many evaluations of fiberglass sucker-rod. Other initial tests were begun because of the need for well-load reductions that would result in lower gear-reducer torques, less structure requirements, and reduced kilowatt consumption. Lighter loads also allowed for longer surface strokes and consequently, more fluid. The advantages of fiberglass sucker-rod were recognized and documented to be a valuable addition to the artificial beam-lift. Today, this sucker-rod undoubtedly is a mainstay in our industry.

The widespread use and acceptance of fiberglass sucker-rod throughout the United States and particularly in West Texas is notable. The use, however, has been most often as a substitute for steel sucker-rod with few other changes in the rod pumping system. The advantages realized by injecting this new sucker-rod into the conventional pumping system can be increased even further by changing the conventional pumping unit into a more compatible machine. The scope of this paper is to review those changes that will enhance the use of fiberglass sucker-rod. The proven advantages already noted can be extended over and beyond with the careful selection of the pumping unit.

MODIFIED GEOMETRY

The term "conventional geometry" in this paper will designate any beam lift pumping unit that devotes 180 degrees of crank rotation in the 360 degree pumping cycle to the polished-rod upstroke. An equal 180 degrees would be devoted to the downstroke. "Modified geometry" or "offset geometry" will designate a beam lift pumping unit that devotes more than 180 degrees of crank rotation to the polished rod upstroke. The remaining portion or less than 180 degrees of rotation would be devoted to the downstroke.

To recognize the advantages of the modified geometry pumping unit a description of the conventional geometry is helpful. The rotating cycle of a conventional pumping unit is symmetrical. Half of the cycle is for upstroke. Half is for downstroke. The weighted crank is in the 12:00 position when the horse-head is at its lowest point. The horse-head is at its highest point in the cycle when the crank is at 6:00. Fastest pumping speeds occur at the 90 degree and 270 degree crank positions. Slowest speeds occur at 360 degrees and 180 degrees respectively. Greatest effective counter balance will be with the cranks horizontal in the 90 degree or the 270 degree positions. Zero counter balance is realized at 360 degrees and at 180 degrees. The symmetrical conventional pumping unit is a balanced machine.

The nature of the work to be done with the pumping unit however, is a job that can be described as unsymmetrical, unequal, and unbalanced. The upstroking of the pumping unit works to lift the sucker-rod string and a column of fluid. The downstroking of the unit carries only the weight of the rod-string. Each of these different functions is performed with equal speeds, equal counterbalancing, and equal available horse-power.

A modification of the pumping unit geometry to reduce gear-box torque can be accomplished by the manufacturer in several ways. A break in the symmetry of the unit will be effected by moving the gear reducer "in" or "out" so that the "bull-gear" or "crank" shaft is not vertically aligned with the tail bearing while the walking beam is level. The same misaligning effect can be realized by shortening or lengthening the distance between the center bearing and tail bearing of the walking beam. Obviously, the critical dimensions of the modifications will play an important role in the torque-factors of the modified geometry. The end result is an unequal symmetry to better match the unequal nature of the work to be done.

The modifications by most manufacturers will range from 185 to 195 degrees of crank rotation for the upstroke and from 165 to 175 degrees for the downstroke. As the rotating crank moves at a constant angular velocity on the upstroke it covers a greater percentage of the total circle. It spends more time covering this greater arc since it moves at a constant speed, consequently, the walking beam horse-head will move slower on the upstroke. The lesser percentage of the total circle will require less time so, the downstroke will be accomplished at a faster speed. The time factor in the crank rotation also means the prime-mover (electric motor or engine) will be devoting a greater percentage of its time or RPM's to lifting the upstroke of each cycle. The modified geometry units could be described much like a truck. They carry a heavier load at a slower speed going up a hill in a lower gear. The downhill is faster with less load in a higher gear. The engine speed of the truck is approximately the same.

The changing of crank rotation symmetry does not change everything. The gravitational effect of the counterweights will continue to be opposing and equal on each side of the concentric circle about the crankshaft. To match the maximum effective counterbalance to the maximum well load most manufacturers of modified geometries will "phase" or "offset" the crankpins to the centerline of gravity of the weighted cranks. This allows for a "lagging" or "leading" counterbalance that will coincide with maximum polished rod load. Some manufacturers provide adjustable phasing to meet specific well needs.

The modified geometry pumping unit will operate at a lower peak torque. This reduction can be equated to a lower operating cost and frequently will allow the use of a smaller gear reducer to lower initial investment. A good rule of thumb is this: the change from conventional unit and steel rod to conventional unit and fiberglass rod is a reduction of one A.P.I. gear-box size.

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TAKING ADVANTAGE OF ELASTICITY

The pioneering of fiberglass sucker-rod was often a frustrating experience. Primary advantages that were expected was corrosive resistance and lack of weight. One major difficulty was elasticity. For many years the oil production industry was accustomed to using a somewhat rigid steel sucker-rod in the artificial beam lift. The very little stretch of steel could be engineered with predictability. The greater elasticity of fiberglass was looked upon as a disadvantage. One common way to eliminate elasticity was to pre-stress the rods with additional sinker-bars. Sinker-bars or steel sucker-rods were already necessary to keep the string in a state of tension. The reasoning was that much more weight would take the "stretch out" and render the rod-string rigid or in an extremely taut condition. Also, the additional weight would offset one of the original advantages - that of less weight.

Studies by several manufacturers and oil operators revealed the importance of pumping unit designs to take advantage of elasticity. As the human wrist synchronizes its movements in the operation of a child's yo-yo, the motion of a machine cannot only minimize the loss of net pump stroke but improve net pump stroke for additional production. Already mentioned, the conventional geometry pumping unit reached its maximum speed at 90 and 270 degrees of crank rotation or the half way point of the polished-rod going up or down. The various brands of modified geometry pumping units may reach maximum speed anywhere on the downstroke above or below the halfway point. The importance of maximum speed position on the downstroke will determine how much stretch or overtravel is attained. The greater the stretch on the downstroke - the less the stretch on the upstroke when the rod is lifting fluid. Additionally, the tightly stretched string will commence recoil to aid in the lifting of fluid. If the point of maximum speed occurs high in the downstroke, a deceleration will follow softening the stretch. The most desirable maximum speed is below the halfway point going down. In this condition the downstroke commences by accelerating all the way to maximum speed and then slows abruptly allowing the elastic string to continue falling to a maximum overtravel.

REDUCED KILOWATT CONSUMPTION

The harmonious combination of modified geometry to reduce gear-box loading and acceleration factors that produce more fluid will normally result in a lower cyclic load factor. A greater quantity of fluid lifted creates a greater imbalance between maximum and minimum loads. The previous mention of the imbalance of symmetry in the modified geometry more closely matches the imbalance between those loads. The greater downstroke speed in the geometry creates a greater torque on the lighter side while the slower speed under heavy load creates a lesser torque on the heavier side. The distribution of loading around 360 degrees of crank rotation is known as the cyclic load factor. The lower cyclic load factor is an indication of lower kilowatt consumption the combination has been proven in the field.

THE FINAL ANALYSIS

One operator in the Slaughter Field, Hockley County, Texas has been producing with fiberglass sucker-rod. The increase in his water injection over several years has caused his original, conventional 320 pumping units to become overtorqued. Most of his 320 units have been replaced with conventional 456 pumping units. The first modified geometry unit with favorable acceleration for fiberglass placed in this field was 228 unit. Several dynamometer tests verified gear-box loading of 72% of capacity. The unit achieved pumped-off condition in a 100" surface stroke. The 320 and 456 conventional units were run in 120" surface strokes to achieve pumped-off condition.

Another operator in Nolan County, Texas was producing 200 BFD with a conventional 160 pumping unit, steel string, and a 1.5" pump plunger. His old cut was 8%. An overloaded condition prevented a longer stroke or increased speed. To remedy a high fluid level and increase oil production his move was toward a 228 modified geometry unity with favorable acceleration, a fiberglass rod-string, a 2" diameter pump plunger, and a faster pumping speed. The total budget for all changes was approximately $50,000. Payback from increased production was netted in less than 90 days. A dynamometer test revealed incomplete pump fillage and gear-box torque of only 129,000 inch pounds. Daily production was 610 BFD. Later, downhole changes to eliminate gas interference increased production to 675 BFD with 54 BOD.

Each of these actual examples emphasises increased efficiency. One, to sizedown, reduce initial investment, and lower operating cost to move the same quantity of fluid. The other was an example of buying a complete new system with rapid pay-back and over 300% increased production.

The careful selection of the pumping unit can improve performance over and beyond advantages already realized with fiberglass sucker-rod. Modified geometry with phased counterbalancing will reduce gear-box torque, reduce cyclic load factors, reduce kilowatt consumption, and position the point of maximum acceleration of the horse-head to achieve maximum over-travel and move more fluid. The final analysis of the system efficiency is barrels per day/motor horsepower.