ANALYZING SUCKER ROD MAKE UP QUALITY AND ITS EFFECT ON WELL FAILURE RATES

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ABSTRACT

The questions and issues surrounding sucker rod connection integrity and their effect on well failure rates have been around as long as the sucker rod itself. The standards set by the manufacturers of rods and couplings, the service rigs that run and pull them, and rod tong use in the field will be discussed and explored, looking for methods of improving the reliability of the connection, thereby reducing failure rates in beam pumping wells.

Data gathered from a computer coupled to a high speed data acquisition system to analyze the rod connection both in the disassembling process as well as the makeup process is presented. A discussion of curve fitting is central to identifying poorly made up connections as well as connections pulled from the hole that should not be reinstalled.

INTRODUCTION

On any given day, the domestic well servicing industry will make up or break out somewhere between 70 and 100,000 rod connections. Over 30 percent of beam pumping well failures are attributable to rod pin failures, coupling failures, or rods backing off during pumping operations. The focus of this paper will be finding ways of reducing the likelihood of failures in beam pumping wells and thereby reducing lifting costs.

An informal survey of pumping well operators revealed that 7/8 and 7/8 HS rods have a disproportionately high failure rate. The paradigm: operators in general feel the connection design of that rod is lacking. In reality, the 7/8 rod is the rod that is stressed to near maximum; perhaps the improvement opportunity is not to redesign the 7/8 connection, but to be more precise in making of high stressed connections and learning to work with closer tolerances.

The practice of "buying a good failure rate" by replacing entire high failure rod strings is an option often exercised by some operators. This practice is expensive and most likely indefensible. The decision is normally made based on limited knowledge of which rods are failing and is certainly made without any predictive analysis of individual rods or sections. Understanding rod pulls and breaks might help predict which rods will likely fail and with this information, replacing damaged sections or individual bad rods without incurring the expense of a total string replacement has the potential of huge savings to the operator.

Unfortunately, the industry is still making rod connections using a set of manually manipulated rod tongs or hand rod wrenches, methods which are imprecise, repetitive, and have not been improved upon over the past 40 years. Reducing the number of pin and coupling failures can save the industry millions of dollars each year.

PROJECT OBJECTIVES

1. To develop a system of quality assurance wherein the service rig crews can tighten rods as closely to manufacturers' specifications as possible. Current industry standards are based on Circumferential Displacement (CD). To insure well service perfection, real time measuring, monitoring, and feedback to the crew of the CD during and after make up would be the prime and foremost objective.

2. To develop a system that would identify and / or flag potential failures both during the make up and disassembling process. Determining thread, mating face, or parallelism (alignment or straightness) problems before a connection is sent back into the hole saves time and money.

3. To use breakout information obtained while tripping rods out of the hole to identify and study well bore dynamic problems like fluid pound, slippage problems, rod slap and a host of other dynamic issues that directly affect failure rates and well bore economics.

4. To determine how many times a connection can be properly tightened before distortion takes its toll. Previous work has suggested that a rod pin or coupling has a finite life, which might be determined by total life cycles or applied stress during pumping, but using captured data from the DAQ system, this new information could potentially lead to a study of the cumulative effects of thread and coupling fatigue on the rod string.

5. To educate the industry regarding the importance of adhering to close tolerance work.

ROD TONG DYNAMICS DURING MAKE UP

The dynamics of a proper rod make up are illustrated in Figure 1. Courtesy of Sandia National Labs, Figure 1 shows the stress changes involved in a rod pin coupling interface during three stages of a pumping cycle. At stage one (left), the rod is properly tightened with no applied load. The shaded areas at the pin-coupling interface, in the first three engaging threads, and immediately next to the neck of the rod illustrate the ideal stressed areas of a rod connection. Stage two (middle) is when the same connection has compression applied to it, which might depict the downstroke of a pumping well. The shaded areas change, indicating the application of downward forces. The greatest changes are in the thread and neck region. Stage three (far right in Figure 1) shows the stress realignment when an applied load is placed on the connection. Note the increased stress in the neck area including the first three engaged threads, and the decreased stress at the coupling-pin interface as the rod coupling is exposed to forces trying to pull them apart as in an upstroke.

Figure 1 illustrates one point: the rod connection is meant to be fluid tight (hydraulically sealed), tight enough to hold during the cyclic pumping of a well and at the same time not so tight that it exceeds the yield of the threads or the tensile stress limits of the stress relief neck.

PHYSICS OF PROPERLY TIGHTENING A CONNECTION

Applying some basic physical principles to a service rig making up a rod will help to fully understand the variables encountered and addressed later in this discourse. The kinetic energy (W) of a moving body is defined as a body of (m) pounds having a velocity of translation of (v) feet per second. Calculating this energy is Equation 1:

(1) $$W = mv^2/2$$

The equation above applies to a body moving in a straight line and can be used to illustrate the effects of velocity and mass on energy. A derivative of this equation can be developed for rods rotating in a derrick, but the principle is unchanged. In other words, the more it weighs and the faster it is moving, the more energy the moving body contains.

Historically, the service industry has only measured and / or controlled one component of the tong make up process, applied pressure. Actually, there are two energy related components that control the final CD achieved during the rod make process which might be expressed by the following equation:

(2) *Final CD = f {tong rotating Energy} + {final applied energy (hydraulic pressure)}*

First we must consider the energy contained within the rotating mass (tong table mass, rod mass, and angular velocity as shown in Equation 1). As illustrated in Equation 1, the larger the mass and the faster it turns, the greater the energy contained in that rotating mass. Taking Equation 1 to extremes, one could suppose that if the tongs rotate so fast, they would twist off the pin of the rod should a sufficient speed (energy) be obtained during the turning process. An analogy to this phenomenon is a tire shop mechanic who changes tires with an air wrench. That guy, who we all call various names when we have to change a tire in the field late at night and twist off a lug nut, can literally spin that torque wrench so fast it will strip the threads on the hub or even break off the stud.

The second component to consider while obtaining the proper CD is the applied hydraulic force or resultant torque from the tongs. The crew normally adjusts the hydraulic pressure based on the size of the rod and the desired CD. As one increases the rod size, the intrinsic rotating energy becomes less of a factor as it takes more final hydraulic energy to obtain the desired CD. As the rod size decreases, the rotating energy becomes a larger factor and the final hydraulic pressure less of a factor. The two equations above add variables to the process of a rig using the tongs to make a rod connection.

To the eye, the progression appears to be quite simple but to a computer, it is a complex relationship involving momentum, thresholds, applied torque, and the slope of lines. The tong operator engages the tongs and starts the rotation by pulling the trigger. This rotation engages the heads with the rod flats and the whole mass (tong head plus rod mass) starts to turn.

Normally, a connection takes about six turns from start to stall and the tongs obtain maximum RPS after one full turn, so the tongs are almost always turning at maximum momentum when the shoulder point is reached, provided of course, the fluid flow rate is being generated by the engine driven pump and the trigger handle is fully engaged.

The tong operator has presumably set the rig pressure bypass valve to some predetermined pressure needed to properly make up that rod connection and the rotational process continues until the tong operator sees a stall (tongs quit turning). At the stall point, in his mind, the process is complete and the connection is made. If he is conscientious, he will verify that connection with the card. It is important to note the tong operator does not nor can he look at the hydraulic pressure gauge during or after the make up; he must rely solely on the stall to indicate the process is complete.

Going forward, for the purpose of illustration, let us presume the proper CD was achieved and the pressure was properly set for that particular set of circumstances. We need to examine the variables affecting proper make up.

CREW AND RIG VARIABLES CONTRIBUTING TO THE ROD CD

Items Fixed for a Given Rig

1. Tong size and design.
2. Motor.
3. Rig hydraulic system capacity design.

Momentum Variables Controlled by the Task and Crew

1. Engine speed during the make up process, which governs total fluid flow, which governs the momentum (Equation 1 via v^2).
2. Tong trigger handle position in full open, full closed, or partially open which governs the velocity and thereby the momentum of the rotating body (v^2).
3. Mass (weight) of the rod or rods being turned (single, triple, or pony sub). Weighing factor of three.

THE TRIGGER HANDLE VARIABLE

The primary variable to investigate using the above scenario involves the rotating speed of the tongs. There are many varieties of tongs available on the market today and with each set of tongs, a variety of drive motors, all of which contribute to different turning speeds. A rig field study found that tongs can turn from zero to 3 ½ revolutions per second, provided the rig's hydraulic system is furnishing sufficient hydraulic fluid flow. Additionally, the tongs have a manually operated trigger handle and maximum turning velocity is dependent upon full deflection of that trigger handle, allowing for full flow of the hydraulic fluid. The manual compression of the handle is then a variable in make up. It is highly unlikely that this trigger handle will be depressed equally and fully during every rod connection, especially if it is done by humans 70,000 times per day.

ENGINE RPM EFFECT ON TONG ROTATIONAL SPEED AND STALL PRESSURE

A typical service rig has a direct coupled, engine driven hydraulic pump. Since the rig hydraulic pump is directly coupled to the engine, logic dictates:

1. The rig engine RPM controls the hydraulic pump RPM and
2. The pump RPM controls the fluid output, which
3. Directly controls the turning speed of the tongs, which
4. Directly controls the energy in the rotating mass (Equation (1), which
5. Directly affects the obtained CD of the connection (Equation 2).

The conclusion: the engine RPM must be stable and consistent for each rod connection throughout the rod run. This is true for the first make up when the card is used for pressure verification as well as all subsequent makes.

The hydraulic pump RPM via the engine RPM also affects the rod connection in another way as illustrated in Figure 2. Rigs use gear pumps for their hydraulic supply, and a characteristic of gear pumps is fluid slippage. In fact, a new pump right out of the factory might have an efficiency number of 80%. As the pump wears with time, its efficiency goes down and more fluid passes between the gears and the walls of the pump. The result of this phenomenon is apparent in Figure 2. If the pump RPM is high, the tongs stall at the desired pressure as there is plenty of hydraulic energy to operate the tongs and the proper CD is obtained. If however, the pump RPM is too low and excessive fluid bypass is occurring within the pump, the tongs will still stall (this is what the tong operator is looking for), but at far less pressure and the rod will be under-torqued.

In the real world of running rods, the operator is watching the blocks and the tong man is watching the tongs. That leaves no one to monitor the torque gauge. Rods are being made on the transfer line while the blocks are ascending during the make up process. If the operator is still raising the blocks when tong stall occurs, normally there is sufficient engine RPM to obtain the proper CD. If however, the blocks arrive at the top of the derrick prior to tong stall, the engine would likely be at an idle or at least falling and there would be a deficiency in hydraulic energy, which would result in an under torque situation.

VARYING MASS OF THE TURNING RODS AND TONGS

The kinetic energy varies (Equation 1) with the mass of the rotating body. If the tong pressure is set for running triples out of the derrick versus picking up the same size single off the ground, we have a change in the mass and therefore a change in the amount of energy. While tripping out of the derrick, the rig is making up triples (each triple of 7/8 rods weighs 165 pounds). Conversely, when picking up rods from the ground, the single turning rod weighs 55 pounds (one third the mass). Improper make up will occur if the tong operator (taking into account Equations 1 & 2) sets the pressure equally for a triple (165 pounds at one RPS) and a single (55 pounds at one RPS). He must remember to add pressure or final torque to lighter turning loads and subtract pressure for heavier loads.

Another factor that affects rod make up and possibly even thread wear and tear is centrifugal force. The faster the tongs turn, the farther out the center of gravity of the moving mass moves as shown in Figure 3. At a tong speed of three or more revolutions per second, the threads must withstand enormous forces. Two analogies to this might be an airplane in an uncontrollable spin or a bucket of water on the end of a rope. If the rope is long enough and the bucket is swung in a circle fast enough, the water will stay in the bucket, but at some speed, the rope will break or the airplane's wings will be ripped off. The applicable lesson: slow down the tongs and control the momentum.

Taking all of the above into account, the computer model which accounts for varying speeds of the tongs is far too complex for the current rod tong work. For our purposes, the speed variable has been eliminated by holding the tong speed constant.

Objective 1: To develop a system of quality assurance wherein the service rig crews can tighten make up rods as closely to manufacturer's specifications as possible.

COMPUTER ANALYSIS OF A ROD MAKE UP

Figure 4 illustrates the computer plot and analysis of a sucker rod make up. The abscissa in this case plots the applied hydraulic pressure of the rod tongs at any given point along the ordinate, which can be scaled in time or position. In Figure 4, the ordinate is scaled in time and the encoder pulses are plotted on the ordinate. Each pulse is a gear tooth passing and the closer the encoder pulses, the faster the tongs and the more space between each encoder pulse represents slowing of the tongs. Also plotted on the ordinate is the backup wrench Hall Effect information. The backup switch (normally closed) will open the circuit when a predetermined threshold torque, or shoulder point, is obtained by the rod tongs. Normally, this switch is set at 40 foot pounds of torque. The backup wrench senses the 40 foot pounds of torque right at the time the pressure encoder pulse slope changes. This makes sense as the tongs are moving from a nearly friction free thread make to a friction tight face make up.

The region from A to B is representative of the tongs turning prior to the shoulder point. The pressure / encoder pulse count slope is almost flat, indicating friction between the coupling and pin is minimal (which is normal). Point B is where the rod pin and coupling faces meet, or the shoulder point. The pressure curve, both in the slope and in the absolute value, makes a drastic change as the tongs encounter the face mating friction. At point B, the backup threshold torque is obtained, opening the sensor. From B to C, the pressure moves steadily upward, increasing in value until the tongs stall out (at C as noted by the absence of encoder pulses). When the computer senses the absence of encoder pulses for ½ second, a stall is presumed and the calculations begin.

Calculations can be made at the following points:

- The slope from A to B, which relates to the threads and their condition.
- The total pulse count between B and C, which can be transformed into CD information.
- The slope from B to C, which is indicative of the mating surface condition. A broken or two stepped slope is a telltale sign of alignment problems.
- The final pressure at C, which is the final input parameter to rod tightness.

Using these calculations, we can now write a set of rules that govern and standardize a good connection that can be run into the hole with reasonable expectations of a long life. In essence, we are defining a target based on torque, final CD, and two slopes. The resulting rules are the following and are portrayed in Figure 5:

1. Threaded Region: The slope from A to B must be neutral or very slightly positive, which is the result of little or no friction while making up the threads. Damaged rod or coupling threads will cause an upward slope in the line.

2. CD: The encoder pulse count from B to C can be measured and displayed in inches. Since CD is a direct reflection of pre-stress, obtaining the manufacturer's suggested CD is essential to proper make up of a rod.

3. The final pressure at C must be compared to a unique tong-based norm.

There are of course, some expected variances in each connection and the computer can be set to accept tolerance levels of errors of 5% or more if desired. If the target is obtained, an audible horn or light signals the operator that all is well and go on into the hole. Likewise, if one of the parameters is out of tolerance, he is notified to take a look as something is wrong. The rigs have a human machine interface or HMI screen and the actual curve can be displayed and with a bit of training, an operator can see if he needs to look at his pressure, or the rod threads or coupling-rod face.

If one only used target pressure as the sole criteria, then a rod with bad threads could strip and stall the tongs prior to reaching the proper CD. In some cases, if the threads are bad enough, the tongs might even stall prior to reaching the shoulder point. Therefore pressure alone does not serve as an accurate indicator of quality, but it is certainly better than nothing a good start to quality control.

Objective 2: To develop a system that would identify and / or flag potential failures both during the connection and disassembling process.

Using a hand wrench and a cheater pipe (snipe if you work in California) to disassemble a tight rod, when the mating surfaces disengage, it snaps and the operator holding the wrench best be holding on. That snapping action is the connection giving back its stored energy. Then, as the rod is continually rotated, there is little or no friction if the threads are good. If you watch a floorhand using hand wrenches pulling rods, he will snap-snap, then let the hand wrench by its own weight and angular velocity back the rod out. Often, a rig using hand wrenches daily will have a rod coupling welded on the end of the wrench, which gives it a bit more inertia (weight) while spinning the rod out by hand.

Figure 6 is a high speed (1000 hertz) picture of a rod being disassembled by the computerized rod tongs. Point (A), where the peak pressure starts to drop, is the point where the rod pin coupling mating surfaces disengage. When the makeup pre-stress is relieved suddenly, the tong table kicks around and, causing the tong motor to become a pump for just an instant, creates a negative dip in the hydraulic pressure at (B). When this surge dissipates, the pressure curve then reverts to unscrewing the rod.

The components that can be analyzed for useful information in Figure 3 are as follows:

- The peak pressure (A) at the start of the breakout process indicates tightness. The peak pressure needed to start the rod moving in the disassembling process is quite predictable and will normally be about 200 psi above the make up pressure. A normal breakout curve (seen in Figure 6) is so predictable that one could develop a new physical law called the "Freddie's Law of Rod Disassembling Pressures." This law behaves much like the law of conservation of energy: *If it is done right to start with, you get back what you put into it unless it is acted on by an outside force*. While pulling out of the hole and disassembling rods, if the pressure required to "break" the rod is too high, something is wrong.

- The slope from A to B indicates mating surface condition. The slope from A to B, on a sound connection, is always instantaneous, drastic, and nearly a straight line. Breaks or slope changes may be indicative of facial problems and are normally followed by a zero BC/AB ratio. A long extended slope is seen in a connection that has bad threads or corrosion. Corrosion is hard to break loose but once it moves, it moves only with more applied force from the tongs.

- A high ratio of BC to AB indicates the snapping effect indicative of all good rod connections. A high ratio means you're recovering the energy you put into it during makeup. A low ratio or nonexistent one normally should be interpreted in conjunction with the peak pressure at A. Low pressures at A combined with a low ratio normally indicate looseness. The connection has lost the stored energy due to some well bore dynamic irregularity or it was simply not made right to begin with. More often than not, when you see this in the field, the connection spits fluid at you upon breaking. A high pressure at (A) combined with low or no BC/AB ratio is indicative of bad threads and a damaged connection.

- The line between D and E is representative of the thread region, and the slope should be neutral.

Figure 7 is a example of a rod break with bad threads. Note the increasing slope from D to E. As the tongs turn the rod out of the coupling, the required pressure is increasing and there is no question, this rod should be laid down and not rerun.

Figure 8 is an example of what a wet connection looks like. The tightness (A) appears to be normal, but note the BC/AB ratio (slap back) is nonexistent and the slope from A to B does not exhibit the drastic straight line attributes seen in Figure 6. When one interprets this chart, note the encoder pulses which indicate a fast moving table.

Figures 9 and 10 are real well examples of tight rods identified while pulling out of the hole. Note the near perfect uniformity of the break pressure with the exceptions circled.

Objective 3: To use breakout information obtained while tripping rods out of the hole to study and identify well bore problems.

Figure 11 is a specific example of how failure rates on a beam pumping well can change overnight and how money was spent due to the lack of detailed data. This 8,000 foot well historically had a failure rate of about .3 (failing every third year) and most of the failures were only pump changes. Like a light switch, the failure frequency jumped to 2 (failing every six months), mostly due to 7/8 pin failures. The engineer instructed that on the next failure, the complete rod string would be replaced. In his defense, when the engineer made his call, he did not have detailed data on individual rods and did what was best for his company, he purchased 8,000 feet of rods and all new couplings.

The rig moved on the well, fished the deep pin break, and as instructed, started pulling out of the hole and laying down the rods. Every third connection being broken had an extremely high torque requirement to unscrew the rod. Two at normal torques and then one high, two normal, one high was the pattern coming out of the hole (Figure 11). Be mindful that a rig runs and fishes rods making every third connection, but backs out each connection in singles when they are being laid down. This explains the 2-1 phenomena seen while laying the rods down. With this data in hand, the engineer then went back into the well files and found that the rig that ran these rods back into the hole was the same rig the company released for poor work performance. He concluded the rig that ran these rods back into the hole severely over tightened his rods and this must have been the reason the failure rate jumped.

Most rod manufacturers want their rods tightened to 70% of yield at the neck. The manufacturer's design and specifications mandate 70% of yield tightness to be 1) tight enough to stay tight during the cyclic life, 2) not so tight as to yield the threads or neck, and 3) water tight. Theoretically, if these parameters are met both at the time of running the rods and during life cycle of the rod, then the connection should last forever. Running loose rods or over torqued rods is certainly an issue in the oilfield. Loose rods might cause a back off and a well failure. The severely over torqued rods documented in Figure 11 caused multiple failures as well as the discarding of the whole string. This was truly a very expensive mistake.

Objective 4: To determine how many times a connection can be properly tightened before distortion takes its toll.

Texas Tech University, in conjunction with several companies, is currently conducting pump tests to verify slippage equations used in beam pumping wells. This test well (The Texas Tech Red Raider #1) will afford many opportunities to the industry, both the oil companies as well as the service companies. This 4,000 foot slippage test will be pumped under very controlled conditions and the pump will be pulled as many as ten times over the next year.

Norris Sucker Rods, Inc. has furnished a new string of ¾, 7/8, and 1" rods for the test, and these rods will be run and pulled under very tight controls using computer driven tongs. We will be studying any changes in pin coupling characteristics and measuring the makeup and breakout characteristics on each trip. Assuming these new rods are properly assembled and properly used, the next year should yield significant data of what ideal breaks look like and the long term strength of the connections.

EQUIPMENT USED

One governing factor in this work was to use as much readily available current rig equipment as possible in developing this technology. Designing a new high-tech rod make up device probably would have been much easier, but replacing all the rod tongs on service rigs would have been cost prohibitive to the service companies. Therefore, a conventional set of BJ rod tongs was modified for this work, although the modifications can be equally applied to Oil Country or Carter tongs.

Figure 12 is a view of the modified tongs used in this project. The motor (M) is coupled to the table (T) via a series of gear reductions. The motor / table ratio is 22:1, meaning the motor has to turn 22 revolutions to result in the table turning 360 degrees. In this project we were striving for maximum CD resolution, so we placed an 100 pulse / revolution optical encoder on top of the motor. This resulted in 2200 pulses per 360 degree rotation of the table. Since the arc of a 7/8" rod connection made to the proper CD is about 36 degrees or 1/10 of a circle, we were therefore looking for 220 pulses between shoulder point and stall for a rerun, 7/8 inch, type 97 rod. We were able to resolve the shoulder point and pulse count to within 3 pulses so the system resolution is within 2%. The DAQ system sampling rate had a frequency of one kilohertz.

The steps in the modification process were to:

- Regulate and control the tong speed to a manageable level, regardless of engine speed, to control momentum.
- Replace the motor from a high speed, low torque to a slow speed, high torque in order to manage and control the impact at shoulder point.
- Install two high speed transducers to measure pressures, one for make and one for brakes.
- Add a gear tooth counter to calculate rotation and angular displacement.
- Install a patented "torque sensing" backup wrench that would identify the shoulder point.

Two pressure transducers were installed very near the motor to measure the applied hydraulic pressure being exerted at any given time. One transducer can be used to measure make up pressure and the other for breakout pressure. To obtain the true torque output of the motor, the differential of the two would be used.

The backup wrench resembles in part, a regular torque wrench, but instead of getting a popping action when a predetermined torque has been reached, this wrench was configured with a Hall Effect sensor which sends an electrical pulse to the computer indicating that a shoulder point had been reached. The shoulder point can be set with an adjustment screw. The backup wrench had to be designed to minimize movement of the lower rod being held in place to avoid spinning of the lower rod in the elevators, causing damage to the rod neck. The wrench was also designed so that when the shoulder point had been reached, all movement of this backup wrench stopped and it became a rigid wrench capable of withstanding the output of the table.

The last major alterations on these tongs addressed the variable speed issues. After initially programming the computer to compensate for varying speeds, the speed was fixed to remove that variable. A pressure compensated flow control valve was placed in series with the hydraulic fluid supply flow, eliminating the engine RPM factor. The valve was designed to supply a fixed fluid flow at any required pressure. In the case of these tongs, we were using 10 GPM, which yielded a very consistent table speed of .8 revolutions per second. We found that as long as the engine was at 1200 RPM or above, we were able to obtain consistent speeds of the tongs.

OBSTACLES AND HURDLES

The Pena Syndrome

Art Pena of Yates Petroleum Corporation, a.k.a. The Make Yates Guru, along with Arturo De La Cruz of Weatherford ALS presented a paper to the 2002 SWPSC entitled *Modified Internal Chamber Coupling*. In this paper, the authors discussed the problem of a widely varying face width in groups of rod couplings. They predicted that the variances, which they found to be from .043 to .159 inches, might cause leaks or loosening over time for the thinner, smaller surface area connections. No doubt they are correct in their findings, but for the purposes of this paper, the problem of face width can be examined in a different light. Making up rods deals with the force and friction and pressures between two bodies. It is logical that as the cross section of the mating surfaces increases, the required torque to turn the connection to the proper pre-stress will increase.

Increased Make Up Time

Slowing the tongs down from 3 RPS to just under one adds time to the make up process. A rod needs to complete eight turns from start to finish, so making rods with these tongs takes 8 seconds from start to finish. In comparison, a fully engaged set of conventional tongs takes 3 seconds for the same task. Adding five seconds per connection adds five minutes for each trip on a 4,000 foot hole, and these five minutes will be an investment in well longevity.

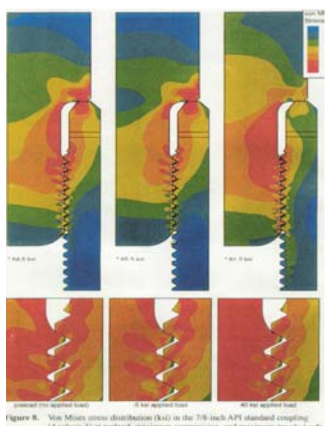
Lubrication

The work done thus far assumes clean and dry mating surfaces and the proper lubrication applied to the threads. Adding lubricant that reduces friction on the mating faces will alter the results.

Objective 5: To educate the industry regarding the importance of adhering to close tolerance work.

Data only has value when it is used to alter business practices. Eliminating failures will no doubt alter the bottom line of any beam pumping well operator. If even only 10 percent of failures can be eliminated by adhering to strict standards, the investment in data gathering and additional time spent achieving exact standards will be recouped repeatedly.

The technology described in this paper should be able to assure the well operator that each rod connection is tightened to exact standards, and this technology should also help identify either on the pull or the run which rods or couplings need to be replaced. It is both a quality assurance strategy as well as a proactive technology aimed right at 30 % of beam pumping well failures. If companies choose not to alter business practices, this data is useless.



Far Left:

Rod made to ideal conditions. No load applied.

Middle:

Same connection with rods going into compression. Down Stroke Example

Far right:

Same connection with applied load on upstroke.

Figure 1 - Sandia National Lab Slide

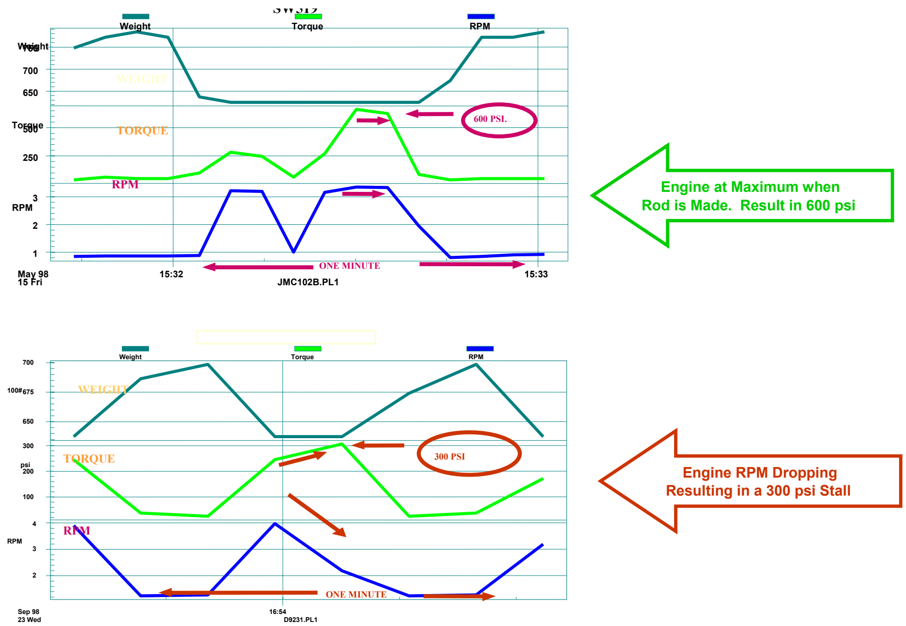


Figure 2 - Effect of Engine RPM on Rod Make Up

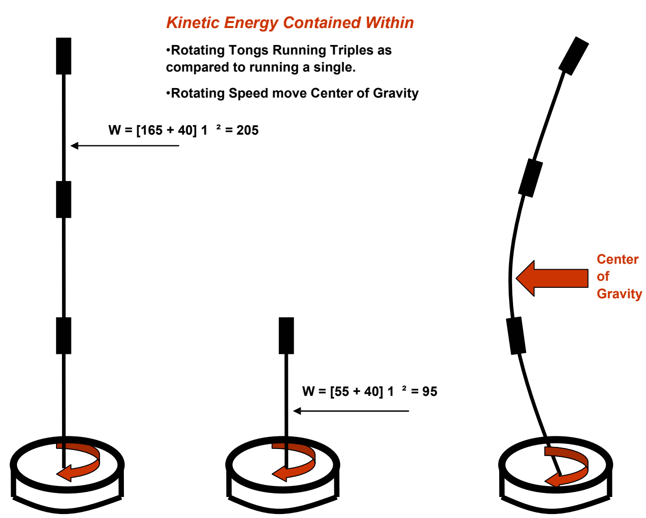
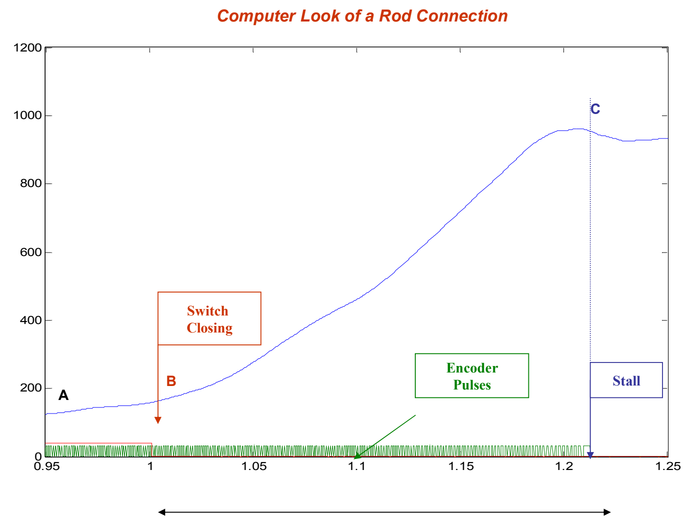


Figure 3

Figure 4



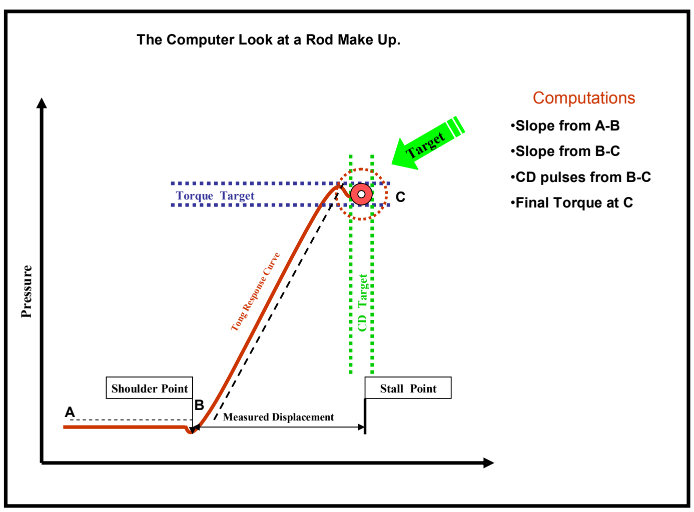


Figure 5

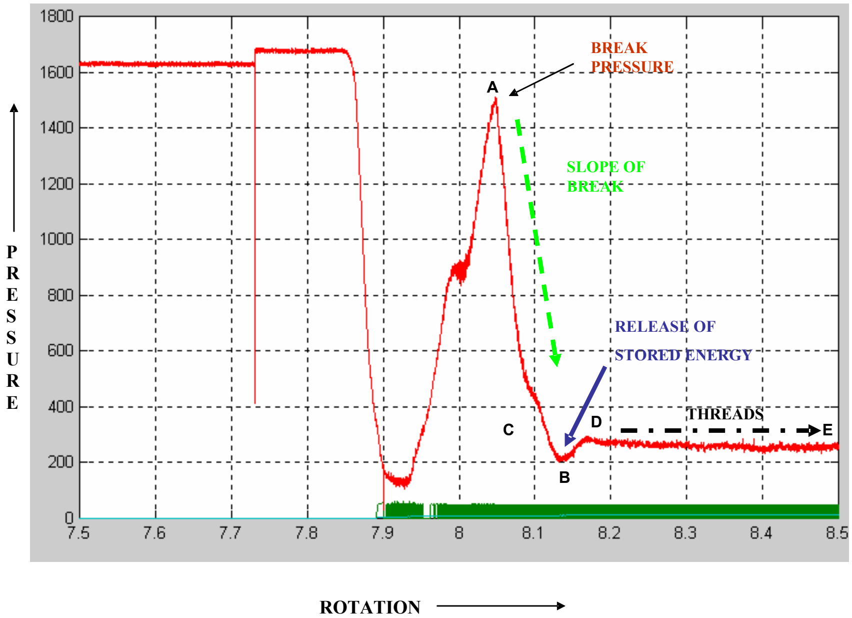


Figure 6 - Rod Break Out Curve of Good Connection

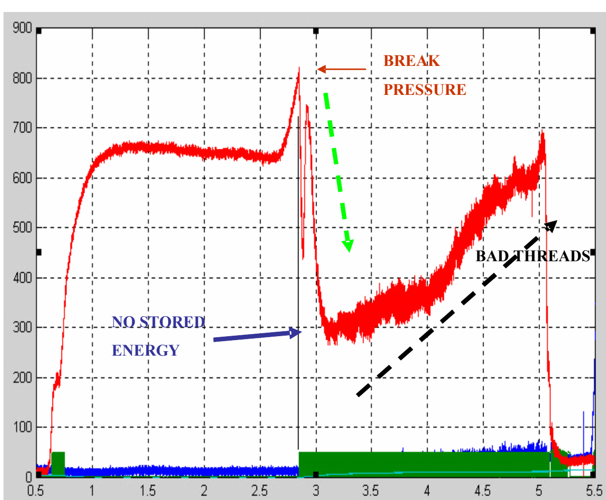


Figure 7 – Break Out Curve of Rod with Bad Pin Threads

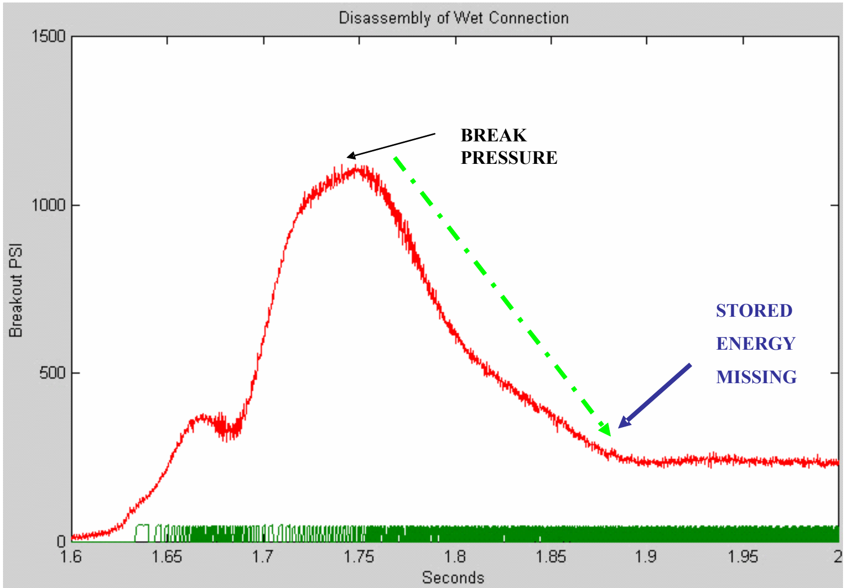


Figure 8 – Rod Break Curve of Wet Connection

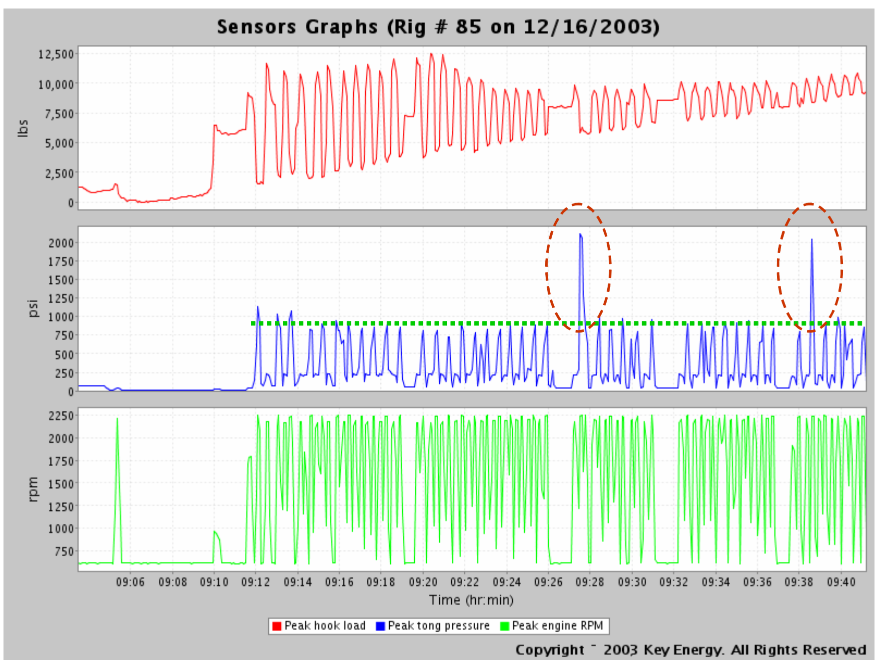


Figure 9

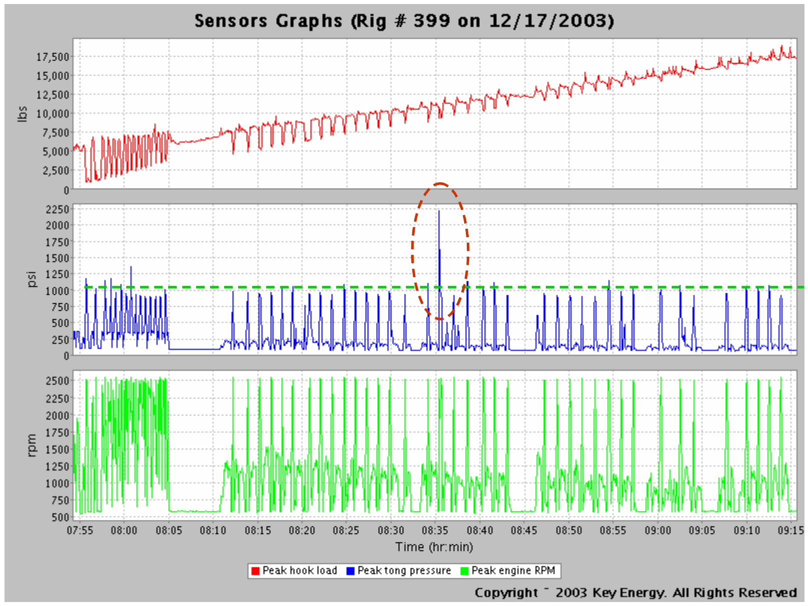
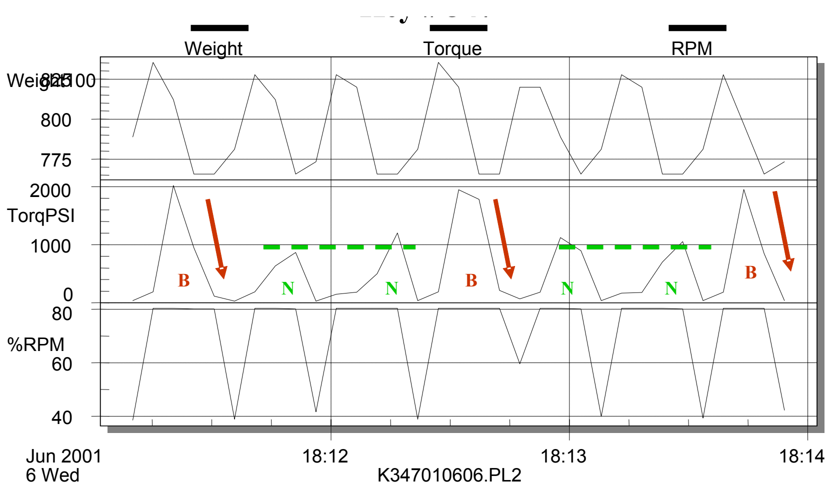


Figure 10



Laying Down a Rod String with high pin failure rate. Data suggest that the rod break out characteristics can identify damaged couplings or pins.

Figure 11

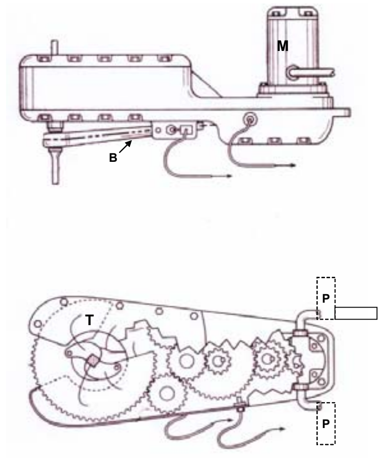


Figure 12 – Modified BJ Rod Tongs