ACCURATE & RELIABLE ROD CONNECTIONS

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ABSTRACT

A fully automated rod tong has been developed and deployed which significantly improves well profitability by increasing mean time between failures of sucker rod connections.

There is no other system available in the industry today that can automatically make sucker rod connections up to the manufactures' specifications.

The rod connection service provides reliable, long term connection performance by controlling the CD to within manufacturers' or API specifications for every rod connection. The system also reports the true torque [ft-lb] in each connection, ensuring that proper lubrication and tightness have been achieved. The paper will show that controlling both CD and torque on makeup connections is the best way to ensure that proper preload of the pin is being achieved.

This fully automated system eliminates the rod carding and tong calibration required by API 11BR recommended practice and the variations which can occur in the field due to uneven implementation of those methods. It also prevents damage of the rod pins and couplings due to cross threading, galled or stripped threads, dirt, debris and improper lubrication.

The system measures and reports on the quality of breakout connections while pulling out of hole so that damage to the threads or components can be identified and fixed as soon as possible during the well servicing operation. Numerous examples of both good and bad rod connections will be provided.

The system has been designed for reliable field use, including speed, quality, and ruggedness. It includes a stand-alone hydraulic power system, precision hydraulic and electronic components, and computerized reporting of every connection in the job. The job report includes specific results obtained for every connection and this can be stored in the producers' well file, for tracking performance over the life of the well.

1. The Industry Issue

The American Petroleum Institute recognizes that for optimum sucker rod performance it is imperative that all of the joints in a string of rods be made up to a given preload stress level in order to prevent separation between the pin shoulder and the coupling face during the pumping cycle[1].

From lubrication to inconsistent tong calibration, the majority of coupling failures are the result of fatigue damage – which is the direct result of improper joint makeup[2].

One oil company has stated that, "Over the last two years (2000-2001) sucker rod connections accounted for 53% of their rod failures"[3]. In fields with deep wells, deviated wells and high rod load wells, some engineers suggest the proportion of connection failures may even be higher.

Even with the introduction of calibrating hydraulic rod tongs using a pressure relief valve[1]; making up connections to the correct CD continues to be an issue.

To improve the reliability and performance of sucker rod connections in pumping service, Key Energy made a strategic decision to develop a technology solution known as SmartTong℠ with the following objectives:

- The system had to make up sucker rod connections consistently to the correct CD
- The system had to be computer controlled and automated to provide consistency
- The system had to be operationally efficient to allow its use on every connection and become readily adopted in the field
- The system had to provide a detailed post job electronic report to include the CD and Torque of every connection placed in the clients well

2.The Systems

The computer control system has two primary sensors on the tong, and others to monitor system operation. Signals from all sensors are fed into an embedded programmable automation controller (PAC). The controller monitors and logs all data and provides the output control signals to the hydraulic system. The system runs two software applications, one for calculating basic control parameters and the other to implement very high speed control for the hydraulics and the tong.

The tong system is similar to a commercially available rod tong, however with Smart modifications which allow precision computer control.

An encoder is mounted on the tong to precisely monitor both the position and speed of the rod as it turns. This allows the control system to determine the exact degree of rod rotation and control the CD to be within the manufacturers' or API tolerances.

The tong is designed to directly measure the torque applied to the connection, during both makeup and breakout directions. This assures the preload on the pin was at a level expected by the rod manufacturer.

Hydraulic pressure is not used to control the connections as it is with conventional power tongs. The hydraulic pressure is monitored to ensure the system is performing as expected but only as a performance check of the equipment itself, not the tightness of the connection.

The power system is a trailer mounted hydraulic power unit (HPU) which provides the clean, reliable hydraulic power and precision hydraulic control necessary to perform the rod connections. The HPU includes a 46 HP diesel engine for primary power, a 60 US gal. hydraulic fluid reservoir, a two stage hydraulic pump for multi-rate control, a high precision proportional electro-hydraulic control valve and the electronic control panel. The trailer provides transport and sufficient storage for the rod tong, all hoses, cables and all tools needed by the crew.

The SmartTong℠ system will operate worldwide, over the full range of ambient temperatures from -40 to 120°F. Hydraulic cooling is included and is used together with fluid pre-heating to ensure reliable, consistent properties for the hydraulic fluid in all operating conditions.

The diesel engine meets EPA requirements to operate in all jurisdictions. The trailer is constructed and tested to provide 110% containment volume for all fluids carried.

3. Operation

The SmartTong℠ Rod Connection Service provides precise, independent control for both hydraulic flow rate and pressure so that the speed and torque available at the tong are always controlled. Pre-programmed CD set points and Torque profiles are used for every manufacturer, size and grade of sucker rod so that every connection is performed within specific control limits. SmartTong℠ is dispatched with a trained service specialist who operates the equipment and reports the job results. The system is designed to work in conjunction with service rigs and crews from any service rig contractor.

Once dispatched to the well site, the SmartTong℠ Specialist interfaces with the rig crew to review the job procedures and ensure that proper rod handling procedures[1] are adhered to. The rig crew's tong operator will operate the SmartTong℠ as he would a conventional tong. The rig tong operator starts the first two threads by hand, engages the tong power lever and then the SmartTong℠ Specialist sends the start command from his laptop to the tong to begin the process. Once the connection is completed and both the CD and torque are in tolerance, the system alerts the rig tong operator using a 100db horn to signal that the connection is good and OK to run it in the hole.

At the start of a makeup connection, the speed and pressure limits are set very low. This avoids any damage to the rod components in case they are cross threaded, galled or debris is present. After this initial engagement, the speed is increased to allow the connection to spin together at high speed. As the rod face approaches the shoulder face, the tong speed is reduced again so that at the point of shouldering the tong is turning at a controlled speed and pressure every time. This consistent condition at the shoulder point ensures that the control algorithms are able to deliver high accuracy and repeatable, reliable results.

After shouldering the controller continues to turn the tong head so that the precise CD set point will be reached. The software captures and records very high precision data on position and torque as the connection is made. Data acquisition is synchronized to the turns of the rod – approximately 40,000 samples are acquired from each sensor channel for every rotation of the rod. This high resolution data stream is what allows the system to deliver such precise CD makeup.

When the controller has stopped the rod at the appropriate CD set point, the software then verifies that the torque is within its profile for that connection based on the manufacture, size and grade of rod. The torque profile check on the tightness of the connection is critical to ensuring the connection is properly cleaned (no debris), lubricated and free of material defects or worn components.
Simply delivering CD to the correct value does not ensure that the connection will stay tight during loaded pumping cycles. The combination of both CD and torque is what determines that the proper preload has been established in the pin.

Throughout the makeup process, the SmartTong℠ software analyzes the CD and torque signals to determine if both are within allowable tolerances. The computer shuts the system down when the correct CD and torque are achieved. The software presents the full sensor data for every connection to the SmartTong℠ specialist who is running the equipment. The clear acceptance criteria, together with this graphical data display, allow the system to perform reliably without conventional rod tong calibration and rod carding processes[1].

The SmartTong℠ system also performs automated, controlled breakouts on rod connections. For each connection, the embedded controller delivers a pre-programmed curve of increasing pressure to the tong so that torque is applied uniformly and consistently every time. This allows for accurate, repeatable measurements of the breakout torque and an assessment of the tightness of each joint. Connections which show a torque level outside of the profile are visually inspected for wear or damage so mitigation steps can be taken (replace coupling, lay down rod). Identifying these connection problems while pulling out of the hole improves the opportunity for corrective action, since replacement materials can be delivered before the pressure becomes too intense to complete the job and bring the well back on production. Sensor data and connection results for each breakout operation are also logged and reported as part of the end of job report.

4. Results

SmartTong℠ ensures the connection is properly cleaned (no debris) and lubricated, ensures there are no material defects or worn components and then makes the connection up to exact CD and torque. If one or more of the above items are identified, the system shuts down and corrective action is taken. The client is assured that only properly made up connections are placed in his well.

One client had a high failure rate well (2.63) which had experienced seven pin and coupling failures during a 32 month period. After utilizing SmartTong℠ they did not experience any rod connection failures for the following 27 months.

The SmartTong℠ system has proven to be very reliable in performing rod connections in field operations. The system design allows for ease of transport, fast rig-up times, and reliable operation across a wide variety of operating conditions.

One of the most important findings to date is that the system correctly identifies connections with improper lubrication – such as no or insufficient lubrication, excessive lubrication and lubrication on the pin or coupling faces. This capability comes from measuring and analyzing the connection torque, both during spin-up of the threads, during makeup, and as the connection reaches correct final CD. Torque varies between lubricants; therefore using the same lubricant is critical. The quality of lubricant is also critical; "The correct choice of thread lubricant can enhance the load carrying capabilities of the rod string up to 40%"[4].

Figure 7 shows the torque curves overlaid for three different connections. The blue torque curve was acquired for a connection performed with the manufacturers recommended amount and placement of lubricant (on the threads). The red upper torque curve shows the torque curve for the same components, but with all lubricant removed using solvent and rags. For this connection, the torque curve rises higher as expected and the peak torque is higher than the acceptable level, which alerts the operator that the connection is faulty, and needs to be broken out, inspected, cleaned and re-lubed. The lower red line shows the torque signal for the same components with excess lubricant applied; not only on the threads, but also the pin and coupling faces. Here the torque falls below the acceptance range and once again the operator will be alerted to take corrective action before running the connection in the hole.

Figures 8 and 9 show examples of connections where excess lubricant would cause less than desired friction to be obtained on the rod faces and the potential for backing off during cyclic loading.

Experienced field staff will observe that this variation in lubrication can be a major source of connection failures when operating a conventional rod tong. Using a conventional power tong with intermittent rod carding is today's accepted industry "best practice". However, problems can develop when the degree of lubrication varies on the connections made up between the carded connections. A conventional tong is set to deliver a "set" level of pressure to each makeup connection and when the lubrication varies, the friction forces in the connection vary substantially and the amount of rotation (CD) will vary accordingly.

Figure 9 shows the torque curves from the same three connections as Figure 6, overlaid once again on top of each other. In this case the curves have been extrapolated to show what would happen if all three stop at a fixed torque (pressure) rather than at a fixed CD. It is clear that in both the under-lubricated and over-lubricated cases the connection will fall outside the acceptance range for CD.

Another condition that the SmartTong℠ system readily identifies is material defects. Rod and couplings are subject to wear, fatigue, damage, and debris due to the extreme conditions in may field operations. To assure good performance under high rod loadings and heavy pumping, the materials must be maintained in optimum condition.

Figure 11 shows a coupling that was identified (and replaced) during a connection on a field job. The connection result indicated a lower torque value than target for the amount of CD applied and so the operator was alerted that the connection was faulty. Inspection of the coupling showed a very minor amount of metal missing from the machined face on the coupling – barely noticeable by eye as shown on Figure 11, but enough to be measurable to the SmartTong℠ torque sensor. This reduced surface area would also reduce the friction forces which are required to keep the connection from backing out under repeat load cycles.

Defects such as worn threads on the rod or coupling are also identified by reduced torque. Abnormal increases in the torque signal are seen due to material defects such as nicks, pitting, galling, corrosion, or out-of-round threads, and when debris is present in the connection.

5. Reporting

For every connection performed the SmartTong℠ system records the summary data regarding the time, materials (manufacturer, size and grade), rod string, environmental variables, and the actual connection results, into a master database on the PC. In addition to the database of results, high resolution sensor data for every connection is stored in a binary file format, for graphical replay (as shown in this paper), detailed analysis and ongoing development.

At the end of each job a report is generated that details the location, personnel, equipment and other job details, together with the connection results for every connection on the job. Figure 13 shows the report summary page, Figure 14 is the table of results for the connections performed.

Following the results table in the report is a specialized graph, as shown in Figure 15, which has been created specifically to show the SmartTong℠ connection results. The vertical axis is the connection number, starting at the top with the first connection within the job, and progressing downward to the last connection. The black line running vertically down the middle represents zero CD and zero torque. For each connection, the CD value is shown by a bar towards the left side, and the torque value is shown by a bar towards the right side.
The lower and upper acceptable limits for CD and torque are shown by the green and red vertical lines.

Looking at the tabular connection data, Figure 14, we can see that the torque was 482 ft-lb, which is 113 ft-lb below target, and therefore less than the lower limit. The connection data in the table is color coded red to highlight the incorrect value, and the corresponding bar on the graph is also color coded red to show this same effect.

This report is forwarded to the client and can be stored in the electronic well file, in order to track specific rod string performance over time, and objectively measure the value created by using this technology.

Conclusion

- SmartTong℠ is the only technology that can consistently makeup rod connections to manufacturer's or API specifications
- Simply delivering CD to the correct value does not ensure that the connection will stay tight during loaded pumping cycles. The combination of both CD and torque is what determines that the proper preload has been established in the pin.

References

1. API Recommended Practice 11BR
2. Society of Petroleum Engineers, paper 3429, “Fatigue of Threaded Sucker Rod Couplings”
3. Southwestern Petroleum Short Course - 2002, “Modified Internal Chamfer Coupling”
4. Southwestern Petroleum Short Course - 2008, “Lubricant Selection Using Circumferential Displacement of Sucker Rods”

Figure 1 – Electronic Control Enclosure

Figure 2 – SmartTong℠ Rod Tong

Figure 3 – SmartTong℠ System Trailer

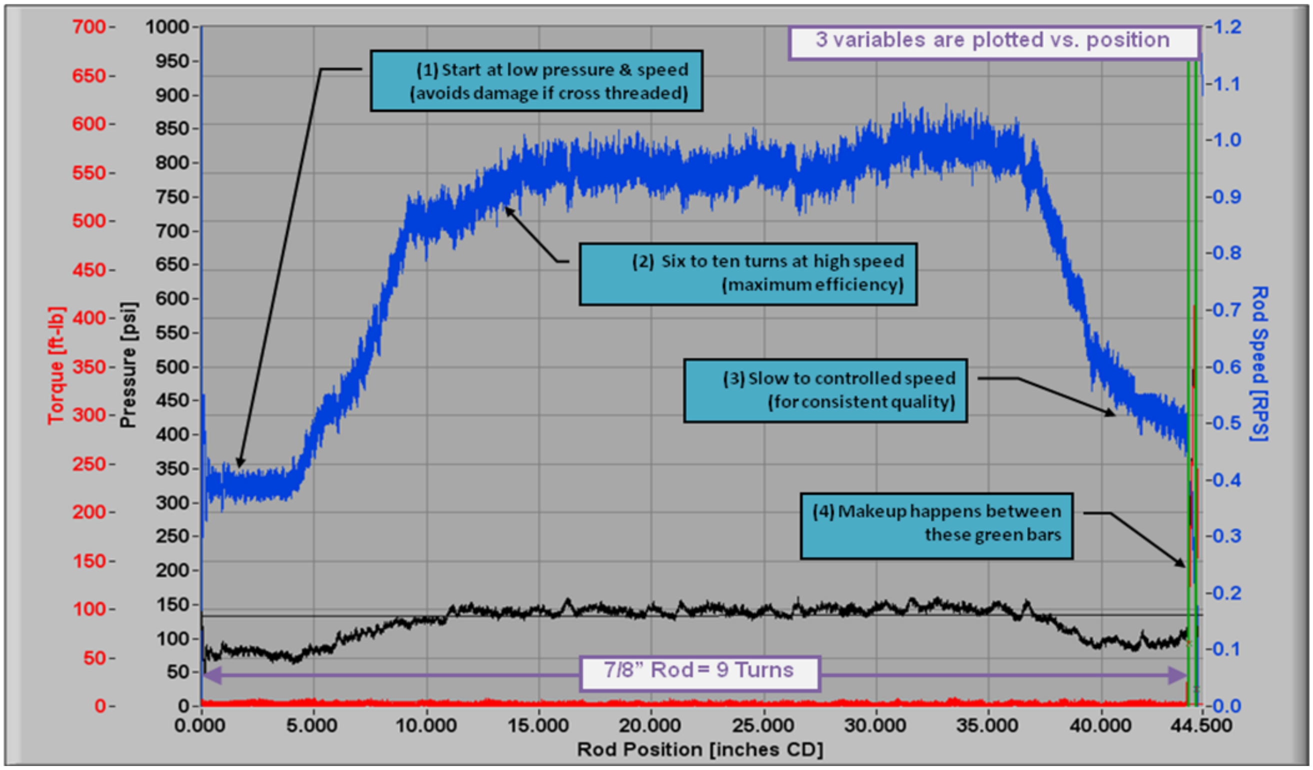

Figure 4 – Variable Speed Rod Makeup (9 turns)

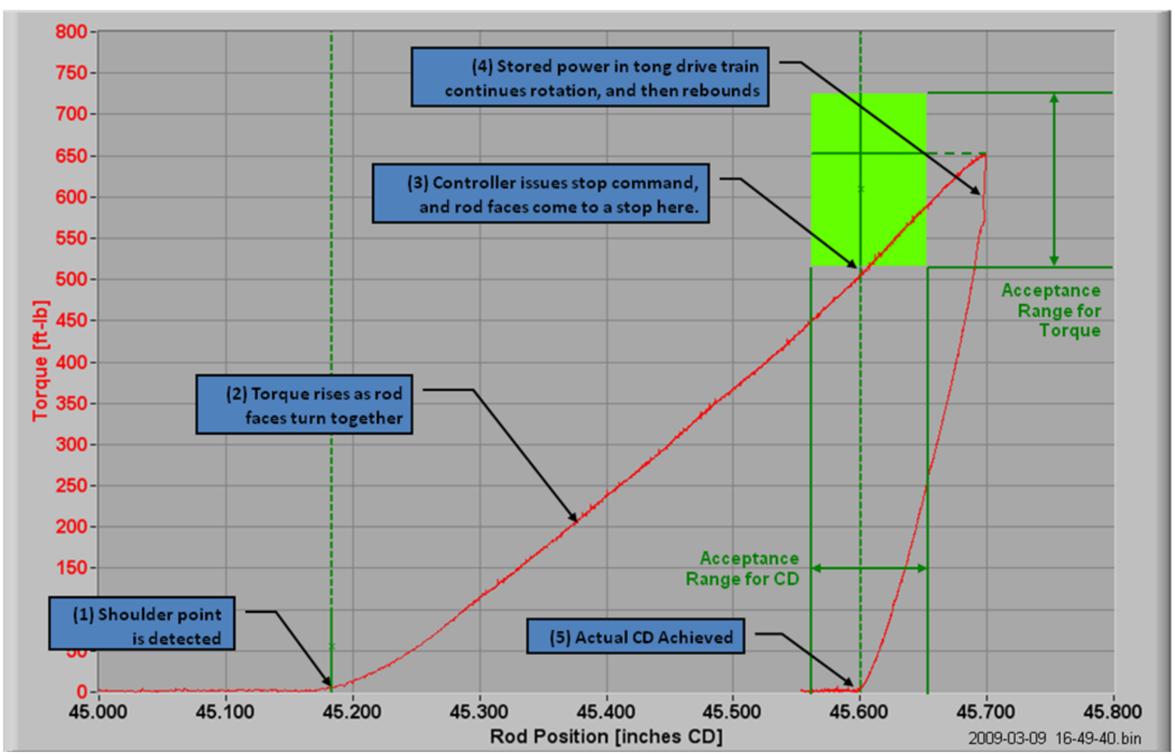

Figure 5 – Good Rod Makeup (CD and torque are both within tolerance)

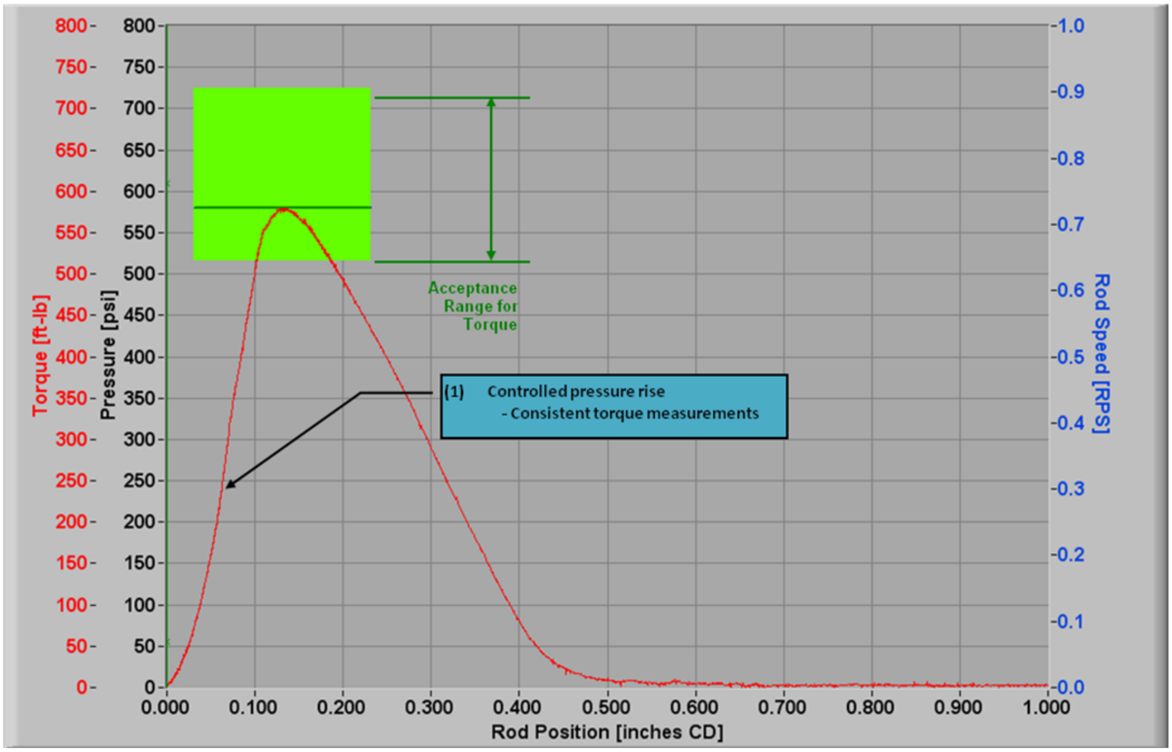

Figure 6 – Good Rod Breakout (Torque is within tolerance)

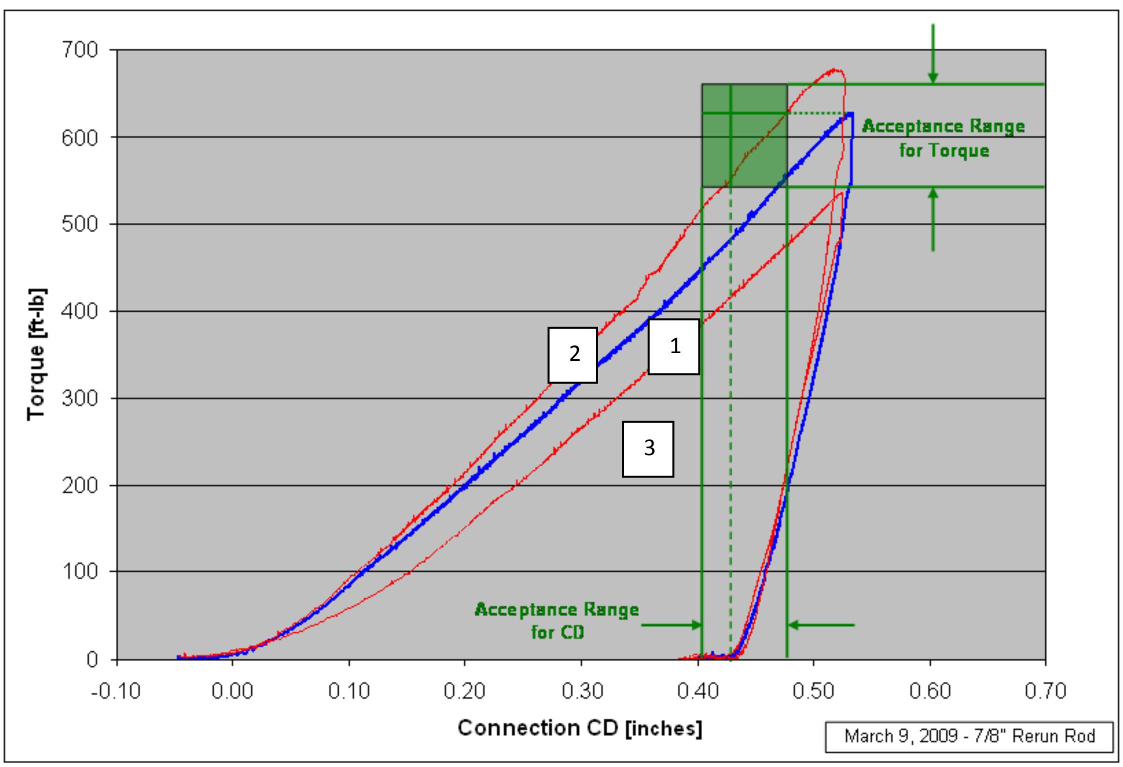

Figure 7 – Torque Signals Overlaid for Three Different Connections

1: Blue – correct lubrication

2: Upper Red – High torque due to under lubrication

3: Lower Red – Low torque due to over lubrication

Figure 8 – Field Connection before Cleaning

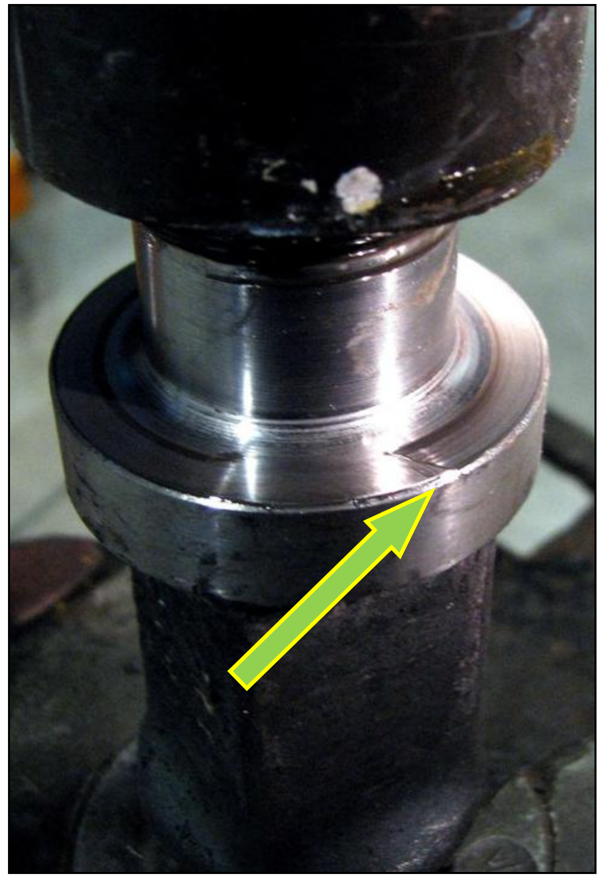

Figure 9 – Lubricant on Rod Face

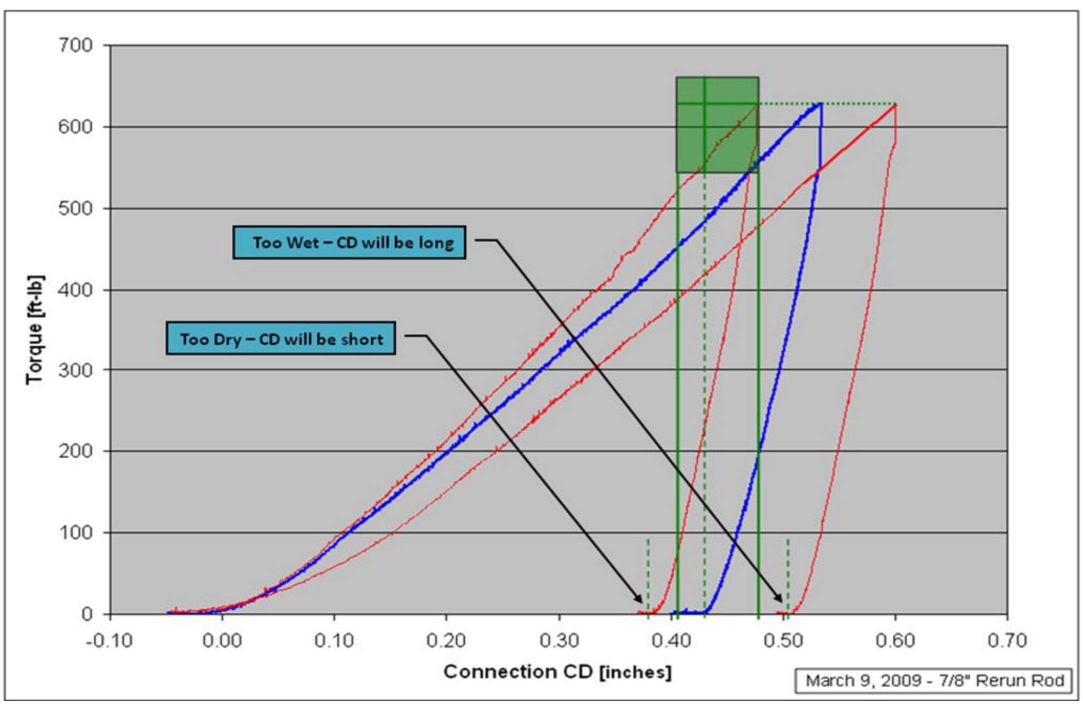

Figure 10 – Using a conventional rod tong with fixed pressure set point variation in lubrication causes CD to vary

Figure 11 – Defective Coupling Identified by SmartTong℠

Figure 12 – Coupling Face Defect highlighted

SmartTong

Rod Connection Service Report

Print this report

Job

General

Job #	Customer	Lease	Well	Rig #	Start	End
30	Profitable Oil Inc.	UTEX	94-3	Key 6004	19/03/2009 10:06:56 AM	20/03/2009 3:40:01 PM

Personnel

Customer Representative	Field Supervisor	Field Supervisor Contact	Field Technician	Rig Operator	Tong Operator
Willie Rodriquez	Cisco		David/Steve	Joel	Rudy/Alvaro

Miscellaneous

Tong Set	Previous Performance	Failure Rate	Notes
ST 1	Rod body break	0.80	Well File indicates 173 x 1", 145 x 7/8", 173 x 3/4", 7 sinker bars

Connections

Connection Types	
Total	210
Makeup	110
Breakout	100

Makeup Activity	
Makeups - Passed	100
Makeups - Rejected	10

Material Replaced	
Total Couplings	3
Total Rods	2

Breakout Activity	
Normal	94
Abnormal	6

Corrective Action	
Re-makes	*6*
Replace Coupling	*2*
Replace Rod	*1*
Replace Rod & Coupling	*1*

Figure 13 – Job Report Header

Conn #	Rod Size	Rod Length	Rod Stand	Conn Status	Coupling Makeup	Depth (ft, approx.)	Time	CD (inch)	Torque (ft-lb)
1-M	3/4"	25.0'	S	N	D	0'	20/07/2009 11:16:34 AM	0.000 (+0.000)	0 (+0)
2-M	3/4"	25.0'	S	N	D	25'	11:19:34 AM	0.908 (+0.032)	496 (-99)
3-M	3/4"	25.0'	S	N	D	50'	11:22:32 AM	0.864 (-0.012)	653 (+58)
4-M	3/4"	25.0'	S	N	D	75'	11:24:59 AM	0.856 (-0.020)	637 (+42)
5-M	3/4"	25.0'	S	N	D	100'	11:26:32 AM	0.885 (+0.009)	595 (-0)
6-M	3/4"	25.0'	S	N	D	125'	11:27:34 AM	0.884 (+0.008)	578 (-17)
7-M	3/4"	25.0'	S	N	D	150'	11:29:48 AM	0.880 (+0.004)	632 (+37)
8-M	3/4"	25.0'	S	N	D	175'	11:31:06 AM	0.928 (+0.052)	510 (-85)
9-M	3/4"	25.0'	S	N	D	200'	11:31:55 AM	0.923 (+0.047)	552 (-43)
10-M	3/4"	25.0'	S	N	D	225'	11:33:01 AM	0.871 (-0.005)	586 (-9)
11-M	3/4"	25.0'	S	N	D	250'	11:33:47 AM	0.922 (+0.046)	507 (-88)
12-M	3/4"	25.0'	S	N	D	275'	11:34:41 AM	0.943 (+0.067)	482 (-113)
13-MR1	3/4"	25.0'	S	RR	ST		11:35:59 AM	0.398 (+0.023)	516 (-64)
14-M	3/4"	25.0'	S	N	D	300'	11:37:12 AM	0.918 (+0.042)	552 (-43)
15-M	3/4"	25.0'	S	N	D	325'	11:38:07 AM	0.884 (+0.008)	536 (-59)
16-M	3/4"	25.0'	S	N	D	350'	11:39:05 AM	0.891 (+0.015)	567 (-28)
17-M	3/4"	25.0'	S	N	D	375'	11:39:59 AM	0.886 (+0.010)	649 (+54)

Figure 14 – Connection Results Table

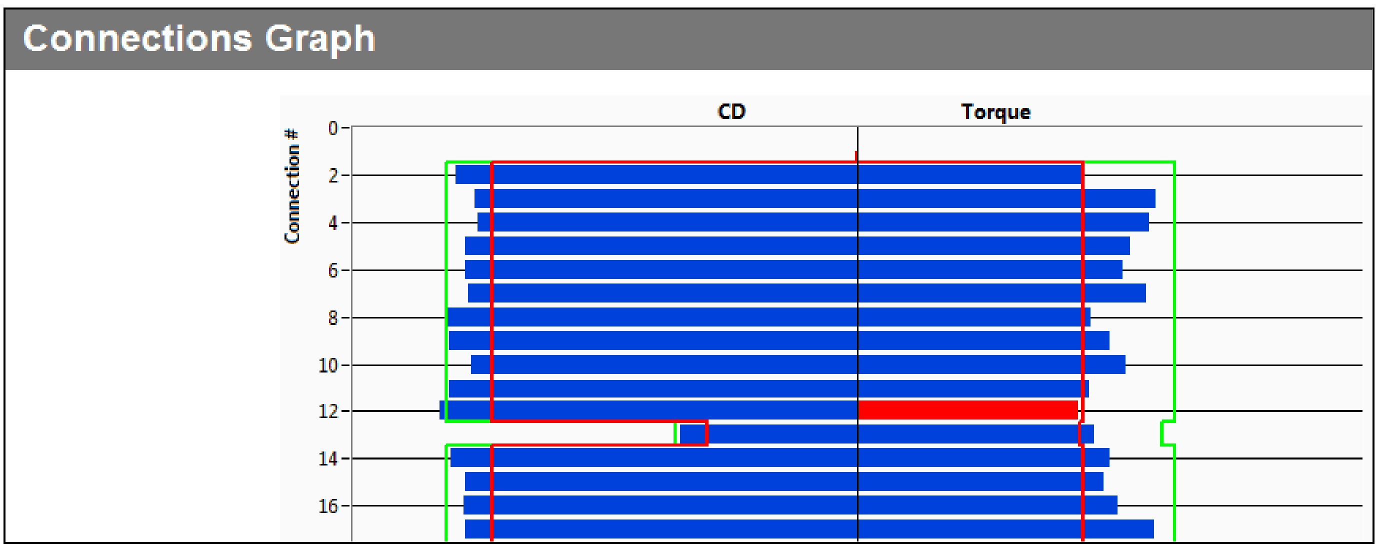

Figure 15 – Connection Results Graph