FIELD EXPERIENCE IN ACHIEVING LOWER INTERVENTION COSTS

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INTRODUCTION

This paper describes how improved performance of rod strings in producing fields has been achieved, using a fully automated rod tong service to perform connections. The system has been in field use for four years and has led to dramatic reductions in connection failures and intervention costs for producers.

Four primary factors have been identified which contribute to the improved field performance. These are:

- Proper handling, preparation, cleaning, and lubrication of the connection materials
- Delivering accurate circumferential displacement (CD) in the connection
- Achieving proper torque in the connection
- Monitoring and controlling every connection in the rod string

Examples are provided which show why each of these four factors is critical in obtaining this significant improvement in performance.

ACHIEVING GOOD PERFORMANCE IN SUCKER ROD CONNECTIONS

API Recommended Practice 11BR Section 6.1 states "… for optimum performance it is imperative that all of the joints in the 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".

This principle has been validated over many years through theory, extensive laboratory testing and long periods of successful field operation. Our four years of successful experience also completely validate this principle – proper preload in the connection leads to good field performance.

API 11BR goes on to say that when a connection has good materials, good preparation and cleaning, and good lubrication, then achieving the proper CD will properly preload the connection. Our experience also proves that this statement is true. However, we see that during field operations there are many factors which can detract from this ideal state of affairs, and as a result a number of connections are made up without the proper preload stress. A rod string containing one or more of these "weaker" connections is much more likely to exhibit an early connection failure, and increase the intervention costs of the producer.

Using historical rod tong equipment and operating methods it is quite difficult to identify the individual connections which have lower connection preload due to these variations in materials or procedures. The SmartTong system uses tightly controlled operating practices together with new technology to identify any of these faults and correct them before the connection is run in the hole.

The first critical success factor is proper cleaning, inspection, and lubrication of the rod pin and coupling for the connection. The thread protector cap must be removed from new rods without mechanical damage to the threads – a hammer is <u>not</u> a suitable tool for this procedure. The crew must clearly avoid impact damage to the threads and faces, but there is also risk of broken plastic fragments remaining behind which will compromise the connection. Cleaning of the threads is done using a solvent and soft brush to remove the environmental corrosion inhibitor, oil traces, and debris. This is followed by a thorough degreasing and wipe down with a clean cloth to ensure the threads and faces are completely free of residue. Lubricant is applied to the pin threads furthest from the face and wiped down into the threads so that no lubricant will be transferred to the faces during assembly with the coupling.

Figures 1 and 2 show examples of the cleaning and lubrication techniques which are used with the automated tong. Using these specific preparations on every connection, it is possible to ensure that when the proper CD is applied to the connection, the pin and coupling will actually be preloaded to the desired amount. Using a conventional rod tong and only intermittent checks by rod carding, we know that these variations in the cleanliness, lubrication, or debris lead to variations in the CD which is obtained.

One of the operational benefits which has been seen to date is that the automated tong is delivered as a full field service rather than a product sale or rental. Having the trained specialist on site and actively managing each job provides full time effective supervision, so that these high quality standards are maintained even when changes occur in rig providers, rig crews, locations, and field supervisors.

The second critical principle is that delivering accurate CD will lead to proper preload in the connection. The automated tong delivers the CD for the connection according to the rod card value established by the manufacturer or API publication. It uses a sensor on the tong drive known as an incremental encoder to measure the precise rotation of the rod, and stop the tong when the rods have turned the desired circumferential displacement past the shoulder point.

Another source of variation which the automated tong eliminates is accurately locating the correct shoulder point for each connection. API and manufacturers' publications define the shoulder point for the connection as "hand tight", which is quite subjective. Variations which lead to improper hand tight condition include thread and face defects in the materials, parallelism of the faces, dirt or other debris, improper machining tolerances in the threads, and damage due to transportation or site handling. All of these conditions have been identified by the automated tong, and the conditions repaired or removed before the connection is run in the hole.

The automated tong uses a sequence of steps to determine the true shoulder point for every connection. All of these steps make use of the torque sensor which is located in the backup of the tong, and measures the actual torque occurring as the threads are first spun together, and then tightening occurs. When the threads are being spun together on a connection with good cleaning, good materials, and good threads, the torque will be very low – below 5 ft-lb. There is an initial torque threshold defined in the software which indicates the shoulder point has been reached, after which we expect the torque to rise rapidly due to the preload being delivered into the connection. Figure 3 shows an example of a torque curve where a proper shoulder point is visible.

What happens on some connections is that this initial torque threshold is reached, but then the torque does not immediately rise as expected – a "false shoulder" has occurred due to one of the conditions previously listed. In the automated tong system, the software recognizes this false shoulder condition, and begins to interpolate the torque curve and determine if a true shoulder point can be identified on which to measure and control the CD. In most cases, this interpolation in successful, and the correct CD is delivered based on this true (later) shoulder point rather than the initial false shoulder.

The third critical factor is the torque measurement and verification that the torque in the connection is correct. There is an important distinction here that checking the torque is a secondary check, after the correct CD has been established. Using a torque reading as the primary measurement of connection preload would not be appropriate. API 11BR Section 6.1 states that "… applied torque has not proven to be the most accurate nor the most practical means of measuring preload stress in a sucker rod joint". The experience of using our automated tong shows that this is partly, but not completely correct.

Measuring torque in a sucker rod connection is now very practical even in field conditions, using technology developed over the past 10 years. Sensors, data capture, and recording are readily available to enable this, and the automated tong has captured the very high resolution torque curve for every connection which has been performed both in the shop and on each rod string. This library of information is available for further analysis and could contribute to improvements in material quality, field procedures, and string design.

The reason that checking the torque is critical is that there are connections which do achieve the correct CD, but still do not have the desired preload in the pin and coupling. The preload will be low in a connection even with good CD when some defect causes the pin not to fully stretch to the same extent that it does in a proper connection. Examples we have identified which fall into this category are worn out threads, face defects, and parallelism in the faces. Similarly the connection can actually exhibit too high a torque reading at a proper CD, which indicates defects like thread interference, debris, or lack of lubrication and thread galling.

The level of torque for any one connection of a given rod type varies substantially. The range of acceptable torque values for good connections can be as much as ± 50% of the average reading for that rod type. To implement our solution, we use several statistical techniques which allow the specialist to implement proper torque limits for each specific rod string, and thus account for all of the variations which can occur in materials, site conditions, climate, and procedures.

A histogram graph is built into the control software which allows the specialist to implement high and low torque limits for the job, based on the population of previous rod connections, and also the specific results obtained for that string. Our successful experience has shown that along with the correct CD, a good torque reading indicates the connection has the correct pre-tension, and will hold the tight during extended pumping cycles.

The fourth critical factor contributing to our improved field performance is that every connection in the string is controlled, rather than relying on an intermittent check like rod carding. The industry does a good job of manufacturing, inspection, transport, handling, and running rods, so the actual number of defective connections is quite low. The challenge is that for the string to deliver superior life, it does rely on every connection being good. There are variable locations in each pumping rod string where higher stress loadings occur, and a weaker connection placed at one of these high stress locations has a much higher likelihood of premature failure.

The strength of the automated system is summarized in the following two points:

1. When the connection is made up every factor contributing to good preload is checked. In order for a connection to achieve both good a CD and a good torque level, all of the material characteristics, transport, preparation, and connection process itself must be good. A defect in any input or process will be identified, and the condition can be remedied before the connection is run in the hole.
2. Every connection in the string is checked, so that no weaker connections exist, and the entire string can carry the full pumping load as it was designed to do.

FIELD RESULTS AND OBSERVATIONS

The automated rod tong service has now been in active use for four years, and has made up well over 100,000 connections on rod strings in producing fields. Of this approximately 2/3 are on new rod strings, and 1/3 are rerun materials run from the rig derrick or picked up from the ground.

There have been zero reported connection failures for the connections made up on new rod strings. On rerun rod strings where the history of the connection quality and loading are much more uncertain, there have been a very small number (0.02%) of connection failures, however using the system does deliver dramatic performance improvement in reduced interventions. In one field the producer reported an improvement in failure rate from 1.0 to 0.44 in the 18 months after adopting the technology.

One surprising finding is that 10% of the connections exhibit some degree of false shoulder, where the system does not detect a clean sharp shoulder point, but has to interpolate that point in order to deliver a good CD value. This implies that conventional rod carding or other techniques based on the hand tight position will not deliver the consistency and repeatability that is expected.

What we observe in oilfield operations is that material suppliers, rig crews, and supervisors generally do a good job, but that there are no really robust field techniques (simple to learn, cost effective and fast enough) which identify and remedy the relatively small number of improper connections before they are run in the hole.

An example of this is in the cleaning process. On one job, the crew cleaning the connections was well trained and had substantial experience with running rod strings using the automated tong. The job started well and was progressing well until suddenly the torque readings indicated a big change, and would not reliably pass within established limits. Investigation by the specialist showed that the crew had changed from using the specified solvent and degreaser to using diesel fuel to clean the connections, simply due to availability and ease of use. This change in process was immediately identified by the system, and rectified so that every connection in the string had good preload and would give good performance.

An example of a connection where the correct CD would be difficult to obtain with a conventional tong is shown in Figure 4. This rod had significant damage to the pin face, likely created by impact during transport or site handling. A conventional rod tong will make up this connection with significantly less CD than target because a lot of the tong energy goes into overcoming the face damage – deformation of the defective area until the full face contact can be made. Figure 5 shows the result of making up this connection, then breaking it out and tightening it once again to the “hand tight” condition. The offset of 0.22 inches in the marking indicates how much error there would have been on the first connection. The face damage delays the true shoulder point where the faces really came together and the connection starts to build the desired preload.

Figure 6 shows the torque curve measured by the automated tong system when this connection was made up. The offset of 0.22” is clearly visible in the torque curve, and it is a good example of how the software interpolation picks the correct location as a true shoulder point, and can then apply the correct amount of CD.

Over the course of many field jobs it has become clear why CD alone is not sufficient to determine that a connection has the correct preload. There are a great many examples where a connection achieves the correct CD, but has a lower torque than expected. When these connections are broken out, cleaned and inspected, some defect or debris will be evident which kept the connection from being as tight as is should have been. In many of these cases, mitigating the fault before it is run in the hole prevents a subsequent premature connection failure with lost production and intervention costs.

An example of this from a rod job is shown in Figure 7. The middle coupling of the three shows dramatically different machining dimension than the two normal couplings on either side. Figure 8 shows the same three couplings in an end view, and here we can see that the machining results in dramatically different face area on the coupling.

Using a conventional tong to make up the connection with the larger face area would lead to dramatically less CD being applied, and a resulting connection with less preload which may be subject to early fatigue failure. This is a very intermittent occurrence, and so a rig crew has a major challenge to remain alert enough to spot this type of variation as they are running rods day after day.

Using the automated tong, the correct amount of CD would be applied to this connection, because that is the primary control variable which the system uses. However the torque reading will be substantially higher than the normal connection of this type, and so the specialist is immediately alerted to the material variation which has occurred and can correct the issue.

There are many other variances in materials, manufacturing, handling, connection preparation and usage which are identified by variation in the torque curve, which are mitigated before the connection is run in the hole. This leads to the summary statement which we believe describes the state of the art for today:

“Experience shows that connections must be properly prepared, made up with the correct CD, a that a good torque reading indicates the connection has the correct pre-tension, and will hold the tight during pumping cycles”

The last critical factor in the field success we have seen is the data collection and reporting of <u>every</u> connection which is performed. Parameters like rod size and grade, coupling type, actual CD and torque achieved are recorded and stored in the electronic well file, so that staff can be sure of the true work which was performed, and the actual service results which are being achieved. This is a major advance in record keeping and it allows long term tracking of rod string performance across all field conditions.

API RECOMMENDED PRACTICE 11BR

Four years of extensive work on improving the connection process in the field has validated that API Recommended Practice 11BR is very good, and covers many of the techniques which are required to obtain good rod string performance. The focus on rod handling, preparation, lubrication, and achieving accurate CD are well proven. What has been confirmed is that the proportion of connections with "faults" is relatively small, but this small proportion contributes significantly to rod string failures. Identifying and eliminating these few faulty connections has a very positive effect in lowing intervention costs.

Conventional rod carding, rigorously applied, is a good start for obtaining good rod string performance. The challenge for field operations is that it can be time consuming to apply it rigorously, and in many cases crews and supervisors are not applying it to the full desired extent. A fully automated system like SmartTong delivers much better performance, because every variable is controlled on every connection in the string.

Several factors have been identified to date which may be worth consideration in future enhancements of Recommended Practice 11BR.

The difference between slim hole and standard couplings stands out clearly in the torque measurements during connections, with slim hole couplings creating measurably less torque in the connections. With further analysis this measured difference may be able to validate or guide the de-rating factors which are currently used for slim hole couplings in string design. We do not have enough data to report statistically sound results for many rod types, but this database of information is growing and available for future analysis.

We have also monitored and recorded the torque change which occurs when multiple remakes are performed using the same connection components. As expected there is initial seating and burnishing of the threads and faces during the first connection which results in a higher torque value. When the same CD is applied, the second connection results in lower torque and then as successive connections are made the torque readings begin to rise again. This may be useful in determining best practice for how many connections can be made with rerun couplings in varying operating conditions.

API Recommended Practice 11BR is currently being revised and updated, and will include initial recommendations for the use of automated tongs for rod strings. The draft revisions do include reference to the increased accuracy which automated tongs provide, and the observation that they are new and still not readily available in all areas.

SUMMARY

Using the automated rod tong service has reduced the connection failure rate and intervention costs significantly in fields where producers have adopted this new technology.

Sucker rod connections will give excellent service performance when the required proper steps of handling, cleaning, and lubrication are performed, when the CD is accurately controlled, and when the torque reading demonstrates that the preload has been properly developed in the connection.

When pulling rod strings out of the well, it is quite common to see wellbore fluid inside the connections, as shown in Figure 9. While this is a common occurrence, it is a sure sign of failure, and should not be accepted. In order for the fluid to enter the connection cavity, there must have been a point during the pumping cycles where a gap has opened up between the rod and coupling faces, and this indicates the preload has been lost in the connection. In this situation it is likely there has been excess stress applied to the connection materials, and subsequent early failure will occur.

Using best practices it is possible to avoid this condition and achieve excellent rod string performance.

Figure 1 – Proper cleaning of components is critical to obtaining good CD and connection preload

Figure 2 – Proper lubrication technique allows for consistent connection performance

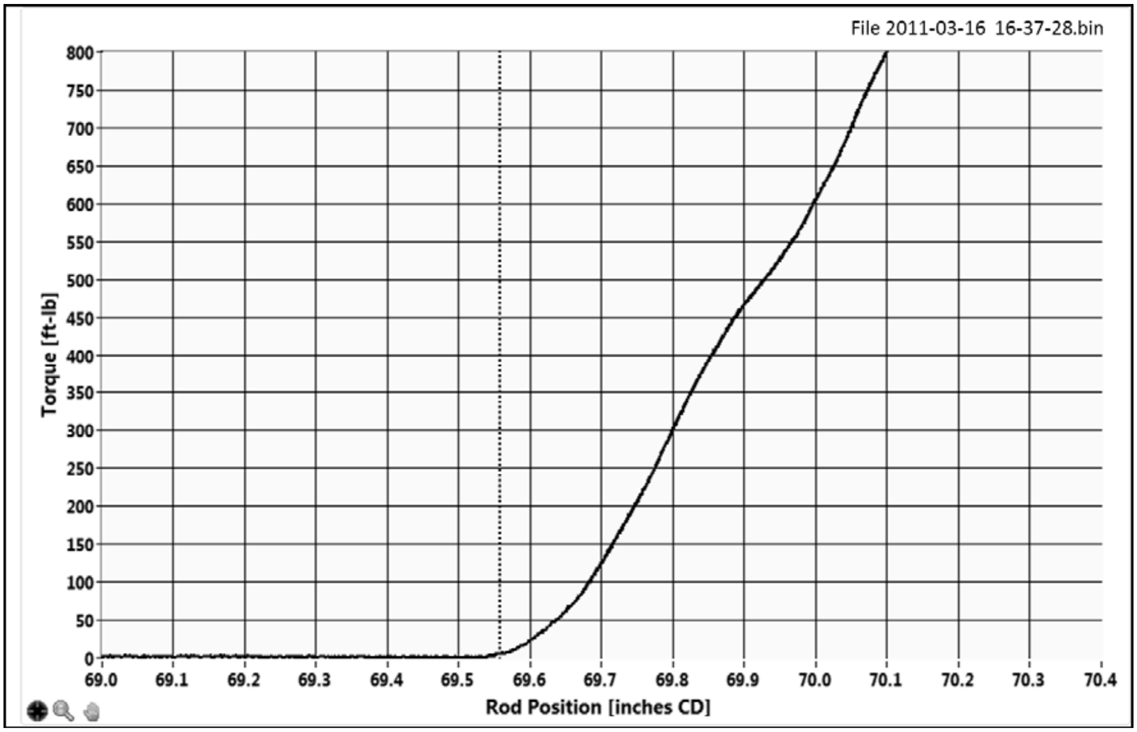

Figure 3 – connections with proper dimensions and tolerances exhibit a shoulder point with a sharp inflection in the torque curve as they are made up. Using the "hand tight" definition is satisfactory in this case.

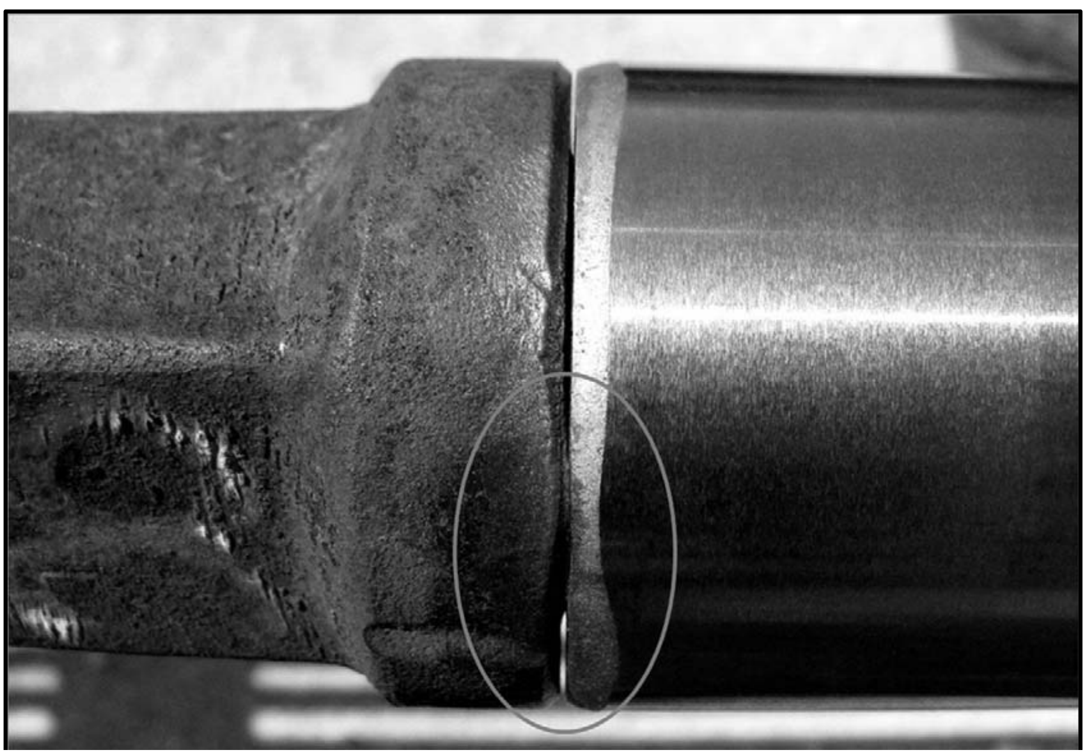

Figure 4 – Connections with face damage have very different positions for hand tight vs. the true shoulder point

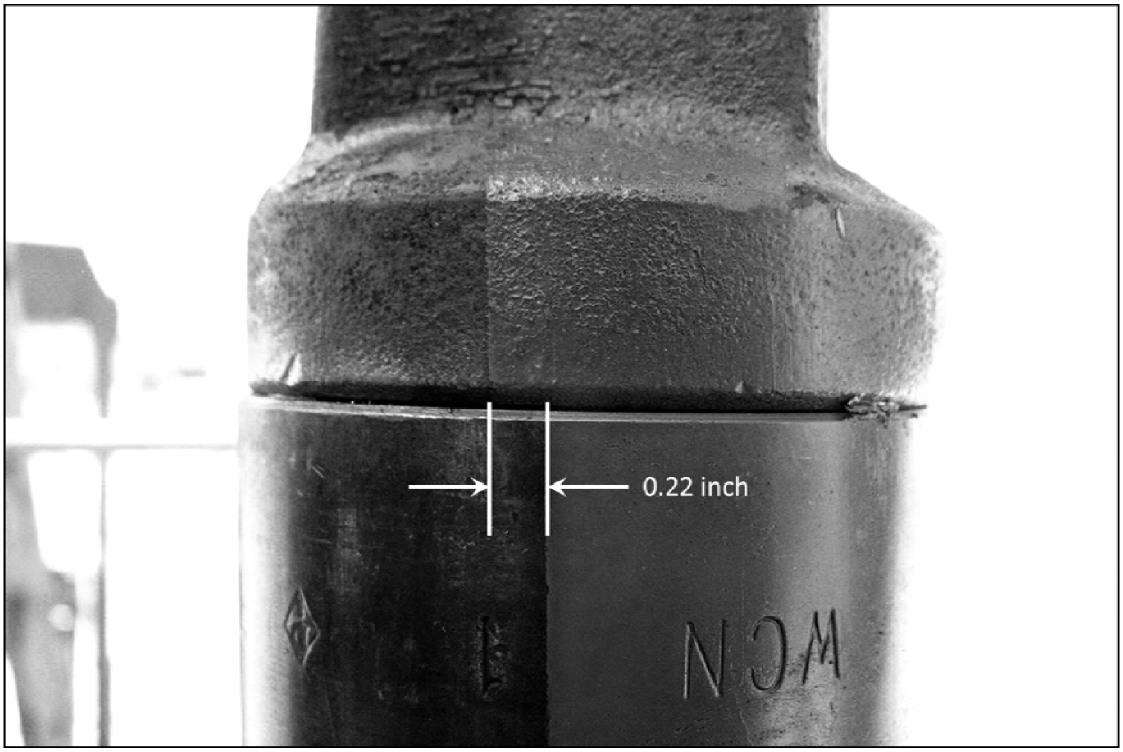

Figure 5 – After makeup and breakout then again hand tightened the “hand tight” position has shifted by 0.22 inches

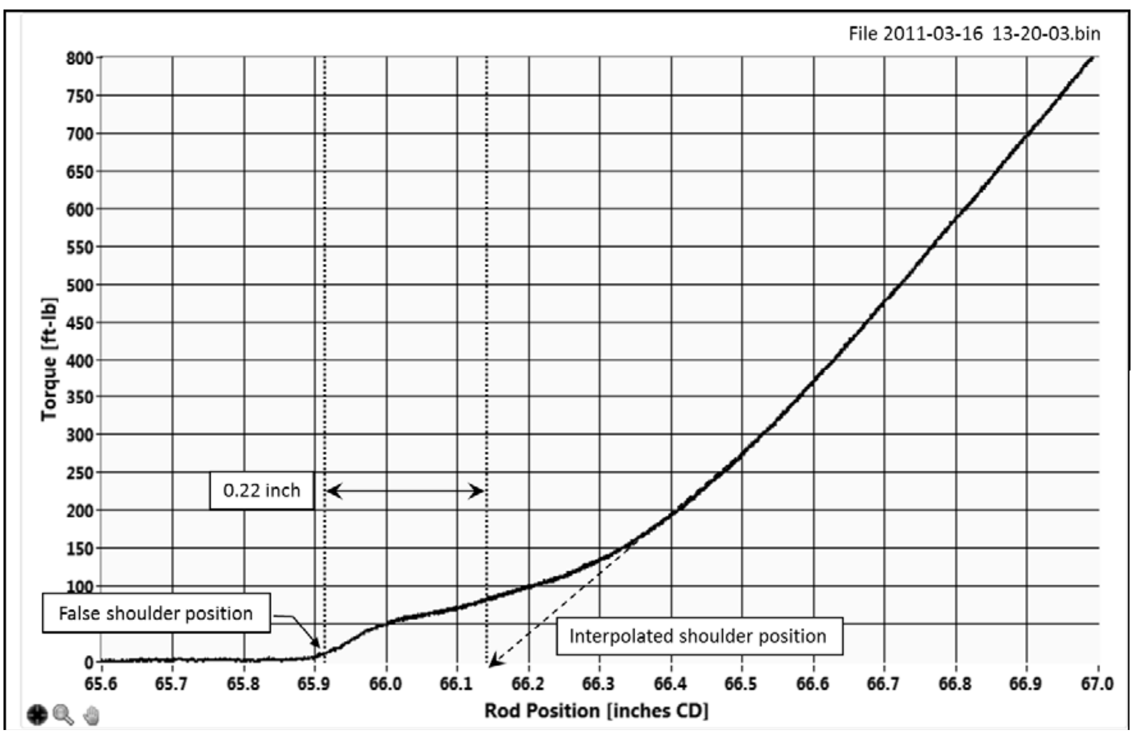

Figure 6 – SmartTong identifies the false shoulder position, and interpolates the correct shoulder position so that the CD is applied correctly and the proper preload is developed in the connection

Figure 7 – Materials with different characteristics lead to variations in applied CD and preload when using conventional rod tongs

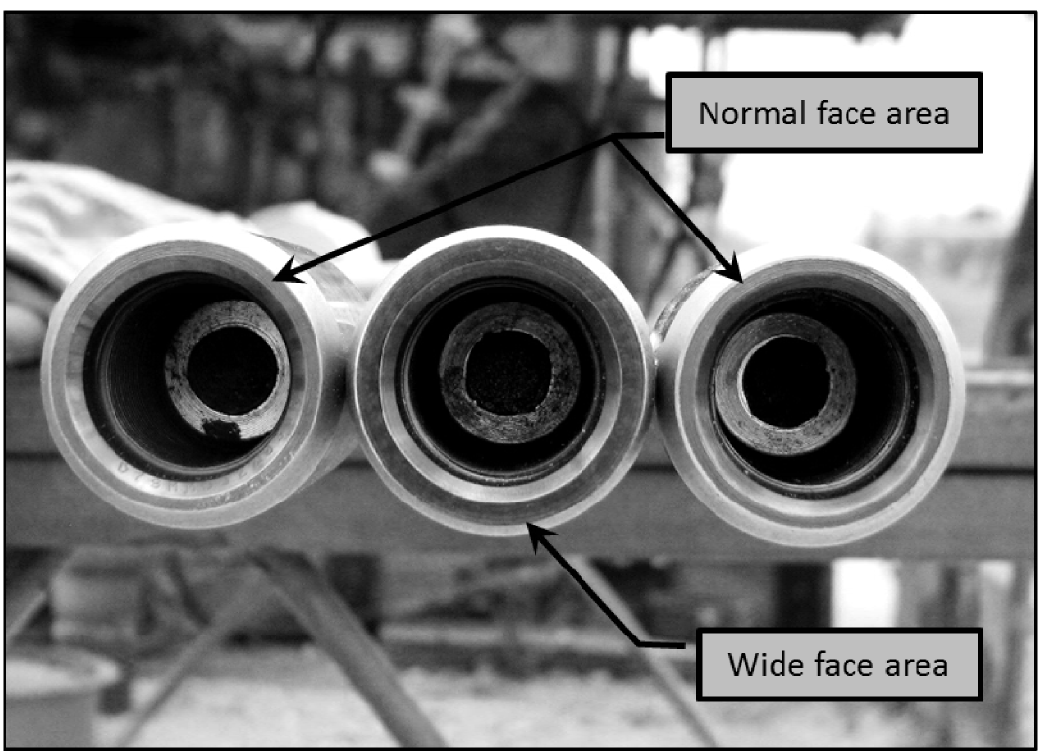

Figure 8 – large variations in face area are clearly evident, but smaller variations are harder to see during regular rig operations. API 11BR specifies a minimum, but not a maximum allowable face width on couplings.

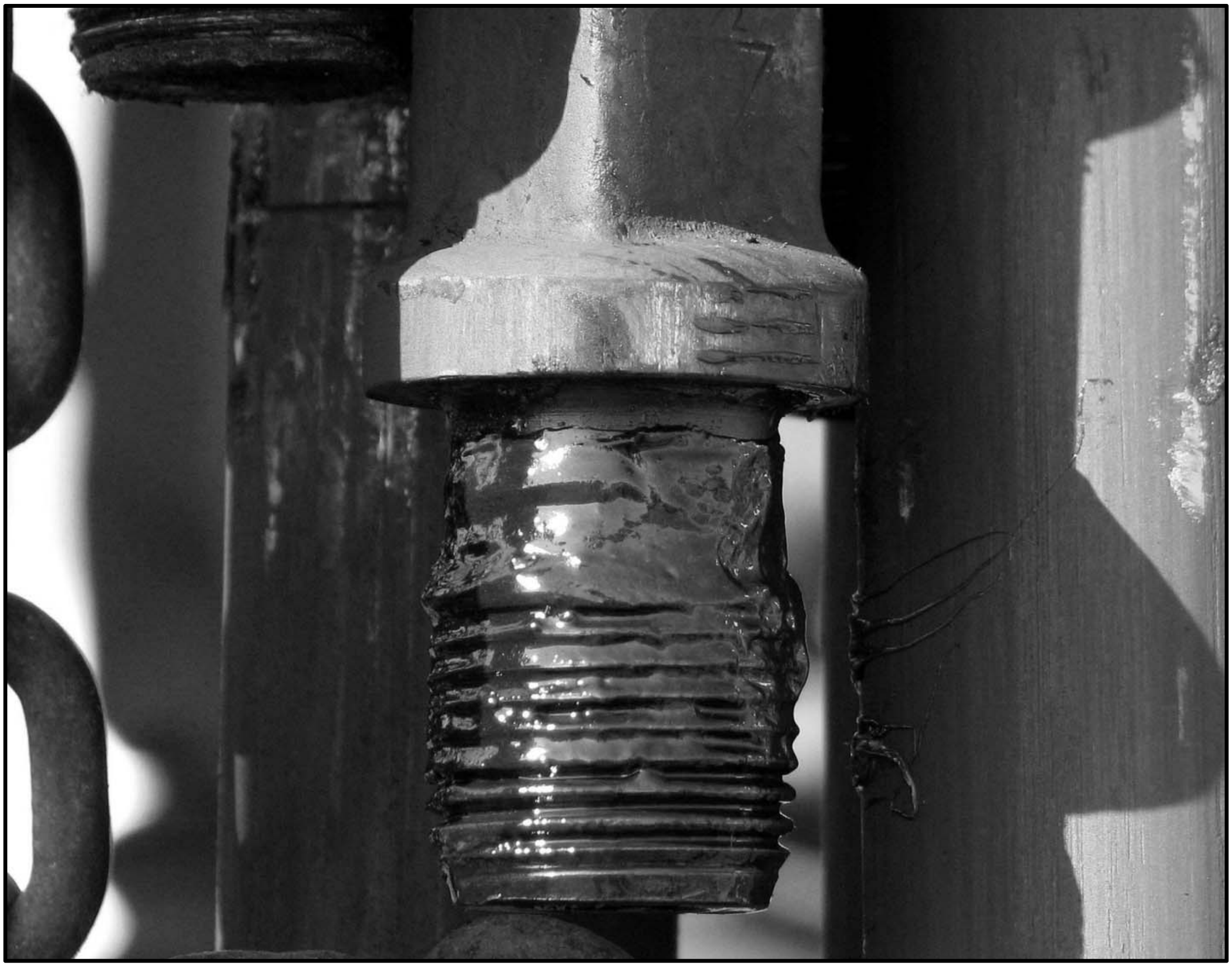

Figure 9 – Wellbore fluid inside the connection indicates separation of the faces and loss of preload. This is a failed condition and should not be accepted as normal.