Originally appeared in World Oil® JUNE 2016 issue, pgs 51-53. Used with permission.

PRODUCTION TECHNOLOGY

Sucker rod coupling material solves downhole wear economically

A new sucker rod coupling material enabled a more-than-threefold extension in run times in the Williston basin's Bakken shale, thereby eliminating significant workover costs for the operator and facilitating uninterrupted production.

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The cost of working over unconventional wells runs into the hundreds of millions of dollars per year. Therefore, there is a definite financial need to mitigate workovers as much as possible. The frequency of workovers conducted during the course of operations varies from operator to operator. Generally, a major workover may be required once every 12–18 months. However, there are also problematic wells that need to be worked over much more frequently. A significant number of shale wells in the Bakken fail approximately every six to nine months. Half of the failures in these wells are related to either tubing or sucker rod coupling failures, caused primarily by wear damage resulting from couplings contacting the inner tube wall.

Deviated wells can pose particular challenges, whether in unconventional or conventional applications. In the deviated or 'bent' section, an area is created, where the coupling and the tubing are subjected to increased contact, causing accelerated wear on both materials. These deviated areas are throughout the wellbore, but, due to cyclic load and rod string compression, the effects are much more detrimental in the lower section of the sucker rod lift system.

Sucker rod pumping in slightly deviated, 10,000-ft unconventional wells comes with unique challenges related to side-loading of rods. Rods in the lower section of the well are periodically put into compression due to unpredictable flow regimes. This compression in the rod string, accompanied by the deviated sections, creates tubing and coupling wear, significant workover costs and deferred production. Traditionally, rod guides can be deployed to prevent sucker rods from bending and maintain their centralized position in the production tubing. However, rod guides have poor durability, with a tendency to wear out quickly and become ineffective.

PROJECT METHODOLOGY

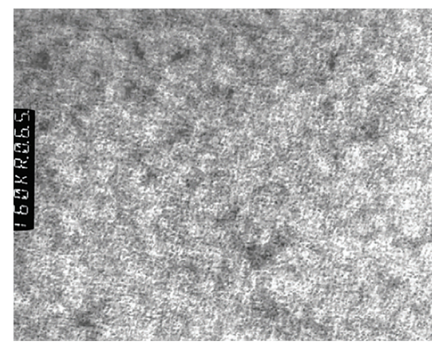
In Hess Corporation's North Dakota Bakken properties, this problem occurs frequently in the lower 1,000 ft of some wells, accounting for nearly half the failure rate in this region. The culprit behind the tubing wear is the SM (spray metal) coupling, made of a much harder material than the steel L-80 tubing. Over time, these couplings tend to wear the tubing down to the point of failure. The use of standard T couplings also can result in tubing wear by a galling mechanism.

Hess tasked Materion with identifying and quantifying the problem that they were experiencing in a number of wells, and developing a new base material for sucker-rod couplings. Materion went on to develop a coupling fabrication process and produce prototypes, using a production scale process. Hess investigated the torque/turn behavior relative to existing technology. Materion made modifications to coupling surfaces interfacing with the rod. The operator then validated modifications via additional torque/turn studies. Hess selected candidate wells, installed ToughMet couplings during workovers, and evaluated performance at six, 17 and 23 months.

CASE STUDY

In 2014, Hess determined to solve the problem of wear in deviated sections of wells with an alternate coupling material. The operator selected a CuNiSn high-strength spinodal alloy called ToughMet 3 TS95 to try as the new coupling material. The alloy was designed for bearing applications in both the oil field and aerospace industries. Due to its high strength; good corrosion and abrasion resistance; and non-galling qualities in sliding applications alongside other metals; it was an ideal match for sucker rod couplings, and compatible with the L-80 tubing. The nominal hardness of the CuNiSn alloy is HRC 20, compared to a maximum hardness of HRC 23 for L80 tubing. The alloy contains 15% Ni and 8% Sn, which improves the corrosion resistance compared to other bronze alloys.

Fig. 1. Transmission electron micrograph (160,000 X), showing the spinodal structure in aged ToughMet 3.



A project was initiated to manufacture 1-in. slimhole couplings. The new material was fabricated by a thermomechanical process. This resulted in a spinodal alloy structure made up of a homogenous single-phase mixture of regions having modulated solute concentrations. The spinodal hardening increased the yield strength of the base metal and added a high degree of uniformity of composition and microstructure, Fig. 1. A nano-scale mixture of very hard and soft regions in the metal results in the ideal structure for a bearing metal. Additionally, by way of its copper-based composition, any damage resulting from in-motion contact between ToughMet and the iron-based production tubing is reduced dramatically.

API couplings are furnished in two classes: T and SM. T couplings are manufactured from steel, which is a material similar to the production tubing, itself. This means that T couplings are very fast to wear in deviated sections of the well, and susceptible to corrosion. SM couplings are furnished with a hard nickel-based alloy coating, which serves to protect the coupling, but, in turn, damages the steel in the production tubing. Until now, operators have been faced with the dilemma of choosing which component to sacrifice: the coupling or the tubing. ToughMet's composition means that operators will no longer have to sacrifice either.

Materion manufactured prototype couplings, following the standard API dimensions for 1-in. slimhole couplings with rolled threads. Controlled make-and-break tests with strain-gauged rods were conducted to assess whether the standard makeup resulted in the required pin pre-stress compared to a T-grade coupling. Figure 2 shows both the new prototype couplings and the controlled makeup/breakout test setup. The standard circumferential displacement card value supplied by the rod manufacturer for the 1-in. rod size was determined to be sufficient to deliver good pin pre-tension. The lower elastic modulus of this alloy does not affect the makeup characteristics of this coupling. Subsequent breaks and re-makes of the material demonstrated a return to proper pre-stress levels. The efficient and inexpensive addition of copper plating on the threads and changing of the surface finish on the face of the coupling improved the overall makeup performance.

Fig. 2. New prototype couplings and a controlled makeup/breakout test setup.

PILOT TEST — PHASE 1

The operator tested the new couplings in two phases. Phase 1 of the pilot program began with four wells. Hess installed 1-in. slimhole couplings in two wells, experiencing tubing wear at a failure frequency rate of about six to eight months. In the other two wells, Hess installed couplings in the top section of the 1-in. sucker rod string, where deviated holes were causing wear. Since the installation nearly two years ago, none of the four wells have experienced a failure related to couplings, more than tripling the mean time between failures. The detailed history of four of these wells is discussed below.

Well 1: GO Elvin Garfield. The GO Elvin Garfield well was originally completed in September 2012. In April 2013, after only nine months of production, the well went down because of a suspected hole in the tubing. In May 2013, the operator pulled and examined the sucker rods, pump and tubing, discovering some wear on the ¾-in. rods. The operator changed 23 of the 24 couplings and replaced 34 of the ¾-in. rods, as well as 14 of the 1-in. rods. A small split was found in the sixth joint above the discharge, and 27 other joints were replaced that were worn beyond 35% wall loss. The sinker rod section also was extended by 250 ft. A total of 1,200 ft of the rods were guided (600 ft of the 1-in., and 600 ft of the ¾- in.).

In January 2014, the well went down again with a tubing split in Joint 310 caused by rod wear. The operator ran additional guided rods on bottom and laid down 18 joints as well. The operator also installed 1-in. slimhole ToughMet couplings in the bottom 1,000 ft of the well.

In June 2014, a tubing leak was discovered in Joint 295, and Joint 25 was found to be crimped. The ToughMet couplings were in excellent condition and were rerun. The operator removed one coupling for laboratory examination, and it did not show any signs of wear. The original dimensions were all intact.

In August 2015, after 17 months of production (the longest run time to date on this well), another tubing leak was suspected. The plastic-coated joint just above the pump had a hole. Repairs were made, and the well was put back on production. The operator reinstalled all the ToughMet couplings, with the exception of two for dimensional analysis. Figure 3 shows a cross-section of one these couplings. Figure 4 shows the mean time between failure versus total run time.

Well 2: Strahan 15-22 H. This well stopped producing in December 2015, because of a deep tubing leak above the

Fig. 3. A cross-section of ToughMet coupling.

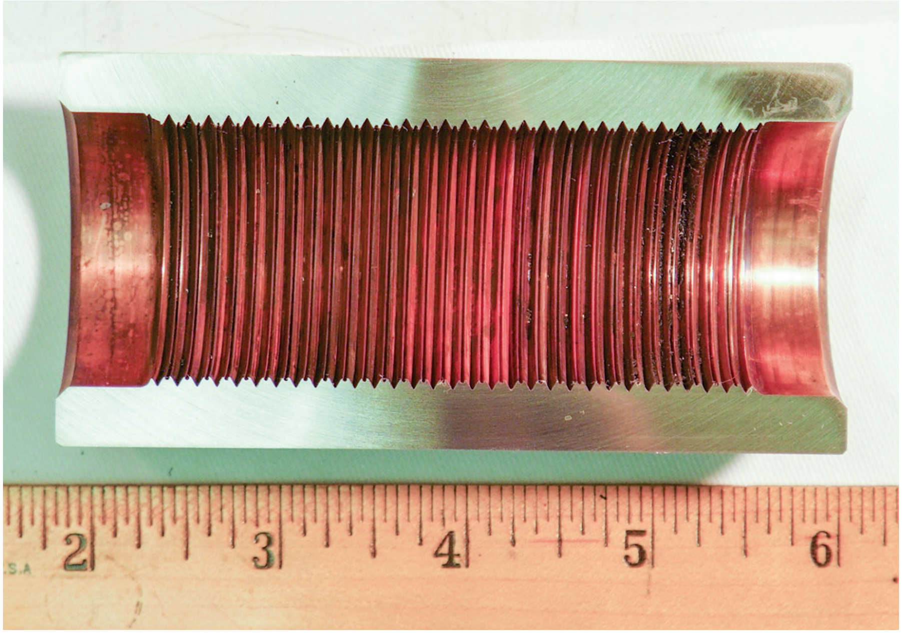
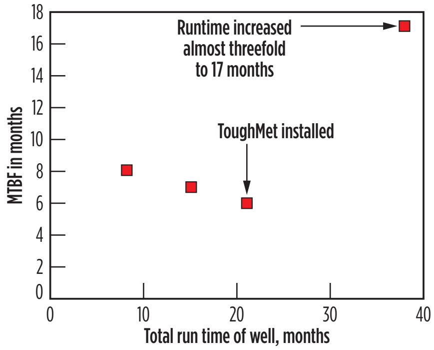


Fig. 4. Mean time between failure versus total run time.



pump (not in the vicinity of the ToughMet couplings). In this well, T couplings were alternated with ToughMet couplings at the bottom of 26 of the 1-in. guided sucker rods. The inspected tubing shows that there was no significant wear in the area covered by the 1-in. rod string. There was, however, more significant wear and corrosion, above and below the area covered by the ToughMet couplings. Figure 5 shows the ToughMet couplings after 20 months of service with no noticeable wear on the OD. The serial numbers are still clearly visible, indicating the corrosion and abrasion resistance of the material. For comparison, the OD measurements were taken on a new ToughMet coupling and one of the ToughMet couplings retrieved from the well after 20 months of service. The data show that the change in OD was only 0.020 in. or 10 mils per side. This equates to a loss of only 0.5 mil per month. As expected, the T couplings had a corroded surface and were worn with flat spots. Figure 6 shows a cross-section of one of the recovered ToughMet couplings.

Well 3: GO Braaten 156-97-3328H-1. This well ran for 15 months from the initial artificial lift installment date and required a workover in March 2013 because of a tubing leak. In May 2014, the well was again found to have deep tubing leak in a joint above the sucker rod pump. The operator removed Joints 287 to 306 because of excessive wear. ToughMet couplings were run in this area; however, they were alternated with SM couplings as a test. The well ran for 623 days versus the previous run time of 420 days—a 48% increase. In this instance, the crew found a hole in the tubing, two joints above the seating nipple. Root cause failure analysis for this well is still under investigation.

PILOT TEST — PHASE 2

To further reduce friction in the bottom third to lower half of troublesome wells, a second phase of the pilot has been proposed. In this phase, the operator will install ¾-in. full-size couplings and 1-in. slimhole couplings in the bottom 4,200 ft of three wells. The purpose is to reduce friction in the lower portion of the string, thereby lowering the peak polished rod loads, lowering gearbox loads, reducing power consumption and increasing pump stroke length. This pilot commenced in first-quarter 2016.

Initial statistical analysis on output suggests it is producing, with a very high level of confidence, 8%–10% more oil than it did before. Production output examined prior to the installation of ToughMet couplings, and compared to stable production after the installation, strongly suggests that the change is due to the deployment of different couplings. Early results indicate that a move to ToughMet has the dual potential to solve a leading cause of well failure, while also improving overall well productivity.

Well 4: EL Cvancara H3. The EL Cvancara H3 well experienced tubing wear and pitting in 24 joints at the bottom of the well. There were 303 joints in this well above the tubing anchor catcher. Joint 300 experienced 99% wall loss. The operator installed 31 new 1-in. guided rods with 1-in. slimhole ToughMet couplings and 24 new ¾-in. guided rods with ¾-in. full-size ToughMet couplings. The goal was to place the ToughMet couplings in the part of the well experiencing the greatest side loading. The pump was also worn and replaced. The well was restored to a production rate of 120 bopd from the pre-workover rate of ~50 bopd. This well has a history of frequent workovers in the three-to-four-month average range. Success will be determined by the length of the extended run time between failures.

CONCLUSIONS

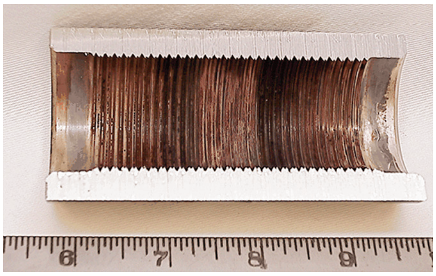
The operator has piloted ToughMet 3 TS95 couplings in 11 wells in its Bakken production unit for over two years now, to assess whether ToughMet couplings will eliminate the most common cause of well failure. Thus far, there have been no failures related to the couplings, and run times have improved up to three times over what they were previously. Material recovered from two wells after six months and 20 months shows the ToughMet couplings to be in almost-new condition. The pilot will be expanded to 75 wells this year.

The operator has launched a second pilot program, to assess whether ToughMet 3 TS95 couplings will reduce overall system friction and increase well production. Thus far, three wells have been put online in this pilot.

In financial terms, the results indicate that the ToughMet sucker rod couplings mitigate the most common cause of deviated well failure, thereby statistically reducing workover costs by $75,000 per well, per year. The net benefit of one year's uninterrupted production from a well producing 100 bopd at $40/bbl is $130,000 to $200,000 of pre-tax cash flow, depending on how long the well is typically down for a tubing failure workover. The return on investment is high, and the payback is quick.

Fig. 5. ToughMet couplings after 20 months of service.

Fig. 6. A cross-section of recovered ToughMet coupling.



The marginal cost of installing a larger number of ToughMet Couplings in a manner consistent with Phase 2 of the pilot is $11,000. This investment has the potential to deliver $100,000 more in annual oil production per well, in addition to the savings provided by eliminating workover events related to coupling and tubing wear.

Well failures are a significant expense to operators, not only in financial terms, but in risks posed to their workers, who are required to perform workover tasks in hazardous environments. It is a problem that operators have endeavored to solve for decades. With the advent of ToughMet couplings, Materion has introduced a solution that will both eliminate the technical cause of a recognized well problem, and help the whole system perform in a more efficient, revenue-generating fashion. WO

ACKNOWLEDGEMENTS

The authors would like to thank both Hess Corporation and Materion Corporation for the opportunity to publish this work. The authors also appreciate the efforts of Charles Panzer (Hess) for assisting with the workover jobs at the well sites and analyzing the well operating data. They also appreciate Dr. Robert Kusner (Materion) for conducting the analysis of the recovered couplings and Chad Finkbeiner for his statistical analysis of well production data.

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