4/2014

Case Study: Forensic Analysis of a Corroded Wireline Data Logging Cable Sample with a Brass Rope Socket Cone

Galvanic corrosion could be a concern with brass rope socket cones, especially when used in an environment containing hydrochloric acid

Line Break Resulting in Dropped Tool

A 9/32 inch diameter (Camesa 1N29PTZ-EHS) wireline cable suffered a dropped tool incident while on location in the Midland Texas area. The incident was a result of the line breaking at the rope socket. The brass rope socket cone and adjoining cable sample were inspected and a metallographic examination was conducted to determine cause of failure. From initial observations it was seen that a significant amount of red rust covered the wires bent around the bore of the brass rope socket cone. It is apparent that the zinc has been sacrificed at both the top of the rope socket cone and also where the wire is bent to secure it to the rope socket cone but is intact where the wire does not contact the brass rope socket cone. It appears that corrosion contributed to the failures but concerns arise about the relationship between the brass rope socket cone and the galvanized wire as zinc and brass are on opposite sides of the galvanic table.

Initial observations of rust and loss of zinc layer around the point of contact with the brass rope socket cone raise concerns, since brass and zinc are on the opposite side of the galvanic table.

Examination of Wire Surface for Survival of Zinc

The photos to the right shows the progression of surface compositions of one wire starting with the failure, progressing through the top bend down the length of the rope socket cone to the point where it is bent and secured to the bottom of the rope socket cone. At the failure, all of the zinc and alloy layer have been sacrificed and a considerable amount of red rust is apparent. At approximately one inch away from the failure, the zinc is almost completely intact; at this point the wire does not contact the rope socket cone.

Progression of the surface compositions covering a wire length of 2 ½ inches from wire failure to the termination at the wire to rope socket cone.

The last photo (below) is the bent area that has been straightened to reveal bare steel where the zinc has sacrificed itself in contact with the rope socket cone. Brass transfer is also apparent at the bent wire contact area.

Brass transfer is apparent due to galvanic corrosion.

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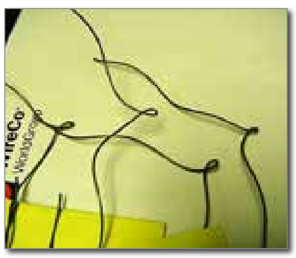
Mechanical Strength Tests

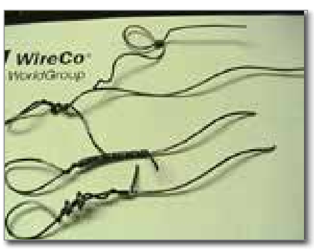
Six of the 18 outer armor wires from the adjoining cable sample were removed for physical testing. The breaking loads and torsion test results are listed below. Tensile failures were cup and cone with good reduction of area at the failure. The torsion failures were all square ended torsion fatigue. Both tests indicate acceptable ductility.

Breaking Load LBF	Torsion Test Twists in 100d
395	39
372	40
395	40
379	39
396	35
393	39

Strength tests on six outer armor wires show good results.

Four of these samples were also subjected to an e–kink test with no indication of brittle tendencies.





Wrap tests on four wire samples show no evidence of brittleness.

Hydrochloric Acid Test

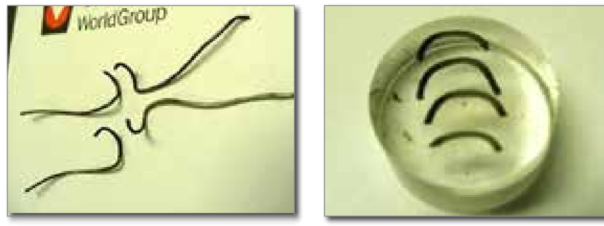
As previously noted, all wire failures were found at the entrance to, or immediately adjacent to the entrance bell of the brass rope socket cone. All twelve wires in the rope socket cone were parted in this immediate area. All twelve wires were removed from the rope socket cone for further examination. Eight were immersed in a solution of 50% HCl in water. A strong odor of sulfur was apparent possibly indicating that these wires were exposed to hydrogen sulfide.

Parted outer armor wires found at the entrance bell of the brass rope socket cone.

Metallographic Examination

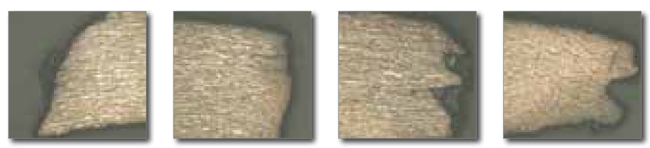
The other four wires were prepared for metallographic examination. All four were ground and mounted in the longitudinal plane.

Typically, in this type of investigation, the zinc is chemically removed from the wire prior to grinding and mounting samples for metallography by placing the samples in a solution of 2% nitric acid in methanol. This is done to properly etch the microstructure for evaluation. If the zinc or residual iron/zinc alloy layer is present, the samples will not etch properly.



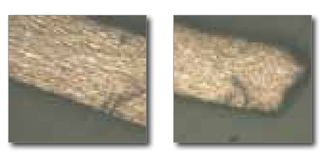
Preparation of samples for metallographic examination

Due to the appearance of red rust on all four samples, it was chosen not to use the zinc stripping solution. When these samples were final polished and introduced to the etching solution, all etched properly. This indicates that there was no residual zinc and that both the zinc and iron/zinc alloy layer had been sacrificed to some corrosive or galvanic environment.



The armor wire ends going into the rope socket cone.

Secondary cracking was found in the failures from the cable side of the failure but not on the rope socket side. In general, the metallography revealed a typical, moderately cold worked pearlite structure. Light pitting from the surface oxidation was apparent.



The armor wire ends from the cable side of the failures.

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Hydrogen Embrittlement

The question was raised about the possibility of Hydrogen embrittlement. In moderately to heavily cold worked high carbon steel wire, the effects of hydrogen embrittlement would be seen through longitudinal splitting, following the paths of the elongated pearlite from wire drawing. There was some evidence of this type of behavior being observed in two or three of the failures, but it was not a common aspect in all of the wire failures.

Fatigue break due to hydrogen embrittlement

General Observations

- All 12 wires attached to the brass rope socket cone parted either at the top of the rope socket cone or immediately adjacent to the bend going into the bell of the rope socket cone.
- All wire failures exhibited a complete absence of zinc or zinc/iron alloy layer. This was isolated to a length of approximately 1 inch.
- Wires on the outside of the rope socket cone and on the cable side of the failure retained varying proportions of zinc, but none were found to be completely devoid of zinc other than the immediate area of the wire failures.
- Physical testing of wires removed from the cable side of the failure immediately adjacent to the wire failures showed acceptable breaking load strength and no apparent loss of ductility in the torsion, bend or wrapping tests.
- Metallography revealed a typical microstructure for this product with no irregularities found in the base structure that would contribute to these failures.
- Secondary surface cracking, thought to be associated to the surface corrosion, were found on the cable side of the wire failures
- The brass rope socket cone and zinc wire are opposites in electromotive force and some galvanic corrosion should be expected.

Summary

There is little doubt that the wire failures in this investigation were precipitated by some sort of oxidation/galvanic corrosion but the affected length of this phenomena was too small (approximately 1 inch), to effectively evaluate the physical aspects of the immediate area of the failures. Wires that were bent at a 45 degree angle approximately ¾ inch from the failures exhibited no evidence of brittleness. Physical testing of wires with failures from the cable side exhibited normal characteristics as did the microstructural analysis.

As these wire failures are isolated to a very short length immediately adjacent to the bend through the bell of the brass rope socket cone, it is recommend to review the procedure for cable re-heading with focus on how to modify the procedure or what might be added to the procedure to provide additional protection against corrosive/galvanic attack in the immediate area of the bell of the brass rope socket cone.

Galvanic corrosion would occur due to physical contact of the brass fitting (rope socket cone) and zinc which are opposites in electromotive force in the galvanic chart, in the presence of any trapped fluid within the interstitial spaces of the wires in the rope socket. The rate of galvanic corrosion would be highly accelerated if this fluid is acidic in nature and exposure times are high.

It was also noted that these types of failures were more common to just one part of the US and outside of this area these types of rope sockets are operating without issue.

To help prevent premature pullout during acid operations, Camesa recommends:

- Limiting exposure time to hydrochloric acid.
- Pack rope socket with nonconductive grease.
- If exposure to hydrochloric acid is expected, rinse rope socket with fresh water after exposure and re-head as often as possible.
- Alert oil & gas operation supervisors to the hazards associated with exposing wireline cables to high concentrations of acid prior to staging and perforating in acid operations.
- Alloy metals that are resistant to Hydrogen Sulfide are not necessarily resistant to Hydrochloric acid and may not protect from wire embrittlement.

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