technical bulletin 027

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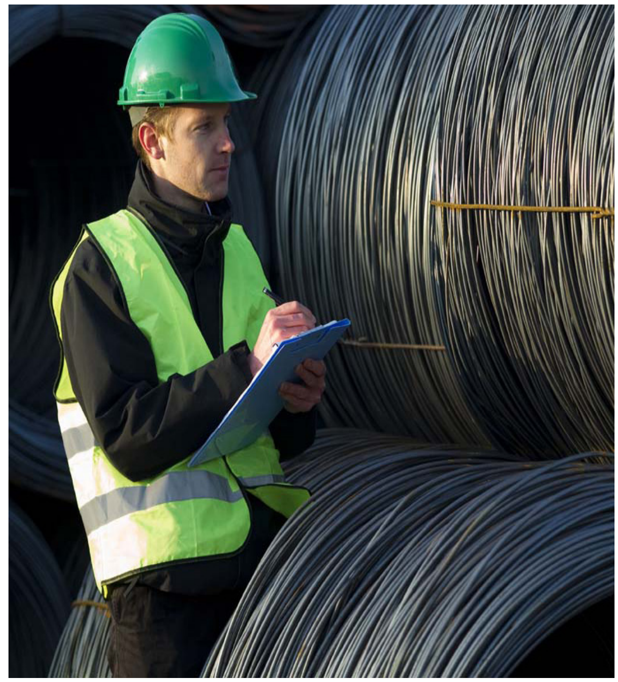
Wireline Cables Forensics 101: A review of how forensics is used to determine the cause of wireline failures.

Forensic Analysis of Wireline Cables

Failure analysis of electromechanical cable or wireline is in many ways similar to investigating a crime scene. There are a number of clues that must be considered when examining the damaged wireline when attempting to determine the reason of a failure. The well conditions, operating procedures, and review of maintenance records and line record book are some of the crucial pieces of information during the investigation of a failure.

Wireline failures are usually classified as either mechanical or electrical and each requires an experienced investigator to determine what has caused the damage to the cable. This article is the first in a series that will outline how engineers at Camesa systematically examine damaged wireline cables and shed light on the telltale clues that help them diagnose how a cable has failed. In this technical bulletin, we focus on wire breaks seen mainly in the outer steel armor wires of the cable.



Armor Wire Failures

Mechanical failures mostly affect the outer steel armor wires and usually result in a wire break causing the cable to strand on top of the lubricator or tangle in the sheaves. The most common causes of this are simple mechanical wear against a derrick leg or casing, jumping a sheave wheel, tensile overload, or a combination of axial loading and perpendicular compression. Another common cause of armor wire failure can be traced to the well environment and corrosive fluids that can cause corrosion of the steel armor, causing them to become brittle and fail under reduced loaded conditions. One such problem arising from galvanic corrosion has been discussed in the Camesa April 2014 Technical Bulletin. While locating a mechanical failure is usually obvious to the casual observer, determining the root cause of the damage requires microscopic analysis of the break surface of the steel armor wire, also in most cases examination of the steel microstructure by a metallurgist and the expertise of a knowledgeable investigator.

The type of wire break in steel armor wires can provide a great deal of information about the circumstances and manner in which a wireline failure occurred. By analyzing the wire break under a microscope, it can be determined whether the wire was exposed to mechanical damage, high heat, corrosion, fatigue, overloading or even wire drawing problems. By understanding the way steel reacts and breaks in each of these situations, the investigator can get closer to the probable cause of the failure. Examples from case histories are used below to explain these occurrences. A high magnification stereomicroscope was used in examining these wire breaks.

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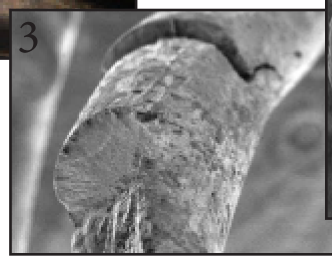
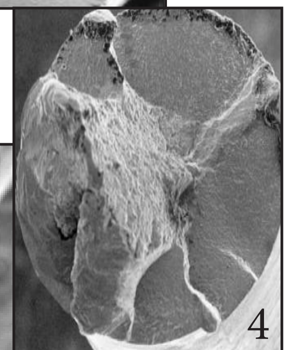
Fatigue Breaks

Bending fatigue can be caused by running over sheaves or on and off of a wireline drum. A fatigue crack normally starts at the points of contact between the outer wires and the sheave or drum surface or at crossover points between individual wireline wires. It then proceeds with increasing number of bends, finally creating a fracture which is perpendicular to the wire axis.

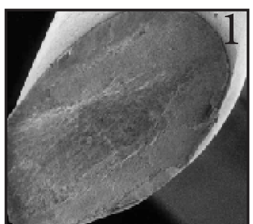


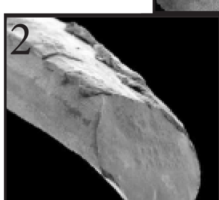


Types of bend fatigue break: Fig. 1: A fatigue crack starting at the point of contact with a sheave. Obviously the crack propagated concentric to its point of initiation. The crack only becomes visible after destroying the strand in a pull test; Fig. 2: The fatigue break seen here is due to a crack generated when the wire was subjected to local bending and compression. This can be due to using an improper diameter sheave or even a wireline jumping a sheave; Fig. 3: Two adjacent fracture cracks. This kind of failure can often be seen if wires are subjected to local bending and compression; Fig. 4: Wire fatigues in a rotary bending test. The cracks initiate from all around the circumference.

Shear Breaks

Shear breaks are caused by high axial loads combined with perpendicular compression of the wire. Their break surface is inclined at about 45 degress to the wire axis. The wire will fail in shear at a lower axial load than a pure tensile overload.





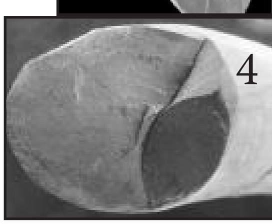
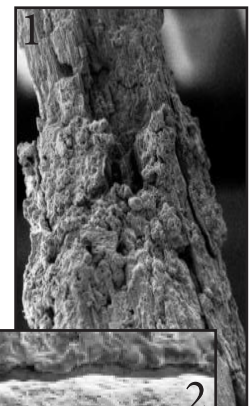


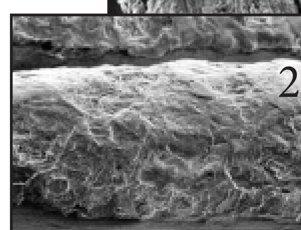
Fig. 1: A typical 45 degree shear break. Note that there is a small reduction in diameter at the edge of the fracture surface, but it is small compared with the necking associated with the ductile tensile cup and cone failure. Fig. 2: High transverse loading initially caused severe plastic wear. Finally the wire failed in shear. Fig. 3: A typical 45° shear break is seen here. This type of break is commonly seen when the wireline breaks as a consequence of jumping a sheave or being wedged in. Fig. 4: A fatigue crack has propagated to a critical level before the remainder of the wire failed in shear.

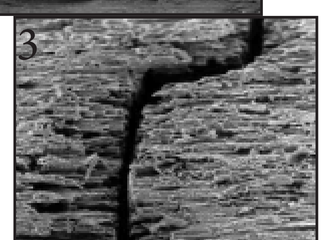
Corrosion Fatigue Break

Corrosion is the reaction of metal with oxygen. In steel wire ropes, we distinguish between atmospheric corrosion (producing uniform “rust”), and more local forms of corrosion such as pitting corrosion (creating deep pits in areas where the protective coating is damaged or missing). Corroded steel wire rope will lose its strength and flexibility. Corroded wire surfaces will form fatigue cracks much faster than protected surfaces.

The galvanizing on Camesa’s wireline products helps reduce the amount of corrosion on their wirelines by reducing the exposed steel surface with zinc coating. The plastic insulation on the copper conductor also serves as a corrosive barrier for the copper conductor.







PHOTOS ON RIGHT Fig. 1: Severe uniform corrosion (atmospheric corrosion). Static ropes and ropes operating in a marine environment should be galvanized and well lubricated. A plastic coating between the steel core and the outer strands will protect internal rope elements. Fig. 2: Surface corrosion. Please note the increase in the effective diameter of the wire. Fig. 3: Stress corrosion crake. Tensile stress help propagate a crack initiated by corrosion. Fig. 4: A corrosion fatigue break is seen here. As can be seen in the examples photos, the highly oriented striations in the steel wire become apparent in the corroded state.

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Tensile Overload Break

Tensile overload breaks are created when the axial load in the individual wire exceeds the wire's breaking strength. Tensile overload breaks are generally associated with a ductile wire diameter reduction at the point of break and the formation of the typical "cup and cone" ends.

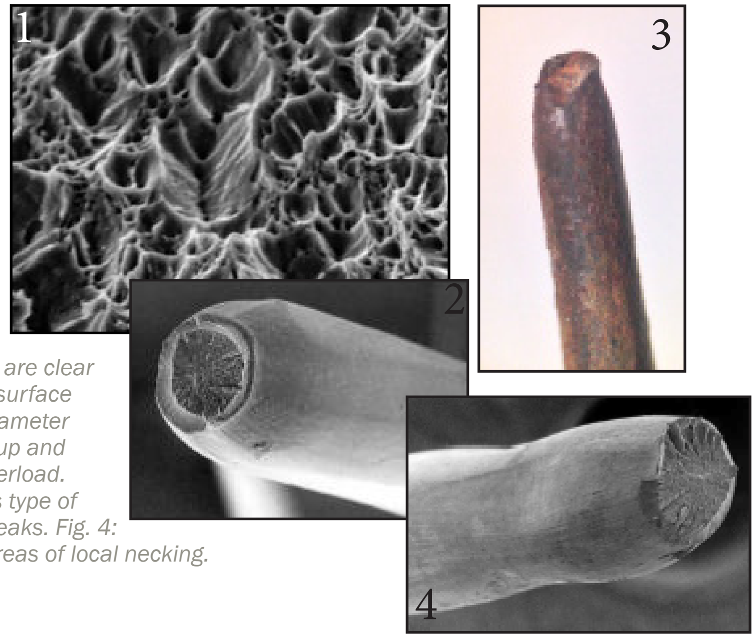

Fig. 1: Ductile dimple formations in the steel microstructure are clear indication of a tensile overload (enlarged view of the break surface of a cone center). Fig. 2: A classic cup and cone fail. The diameter reduction at the fracture is clearly visible. Fig. 3: A classic cup and cone failure (possibly at a crossover point) due to tensile overload. The diameter reduction at the fracture is clearly visible. This type of break is also seen in combination with other type of wire breaks. Fig. 4: Before failing by tensile overload, this wire developed two areas of local necking.

Mechanical Wear and Damage

Mechanical wear in steel cables is the removal of material due to mechanical abrasion. Due to wear against sheaves, drums or neighboring cable wraps, a wireline diameter will initially reduce at a high rate. With increasing wear, however, the bearing surface of the wireline will increase and the cable diameter reduction will slow correspondingly. Mechanical damage can also be caused by the impact of a hard surface such as closing a valve on the cable or hitting it with a tool.

Given the amount of information that can be obtained by examining a broken armor wire, it becomes important to have this as evidence while investigating a wireline failure. If both ends of the broken wires are available and matched, one can more easily find answers and come closer to knowing the cause of the failure.

One of the next steps after identifying the wire breaks type would be to examine the region of the cable surface surrounding the break to look for any evidence of mechanical damage, abrasion, impact, corrosion or exposure to heating. We shall continue this series of Forensic Analysis of Wireline Cables in our next issue to look at such examples.

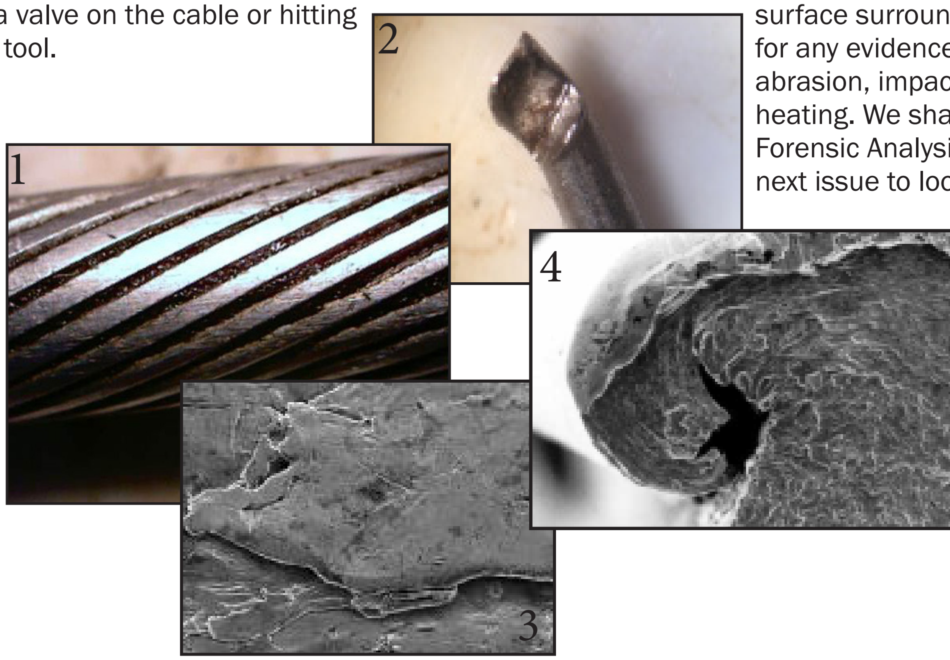

Fig. 1: Mechanical wear of the outer wires can be seen. Fig. 2: The wire break seen in this picture has broken due to an impact with a tool or harder object. Some plastic deformation is visible. Fig. 3: Wear surface of an outer wire of a steelwire rope. Fig. 4: Plastic wear on the surface of an outer wire. The material displacement is very visible.

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