Corrosion Behaviour of FLC Wire Ropes

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Abstract: *Steel wires are subject to corrosion when put in operation. It is important to analyze the wire rope condition time to time to prevent hazards in the work place. This paper reflects a process which can be applied in preventing wire rope failure by taking full locked coil sample of size 24 mm (in diameter).*

Keywords: Steel wires, Wire rope, Full locked coil rope, corrosion, corrosion on wire rope.

1. Introduction

Wire rope is an intricate device made up of a number of precise moving parts [1]. The moving parts of wire rope are designed and manufactured to maintain a definite relationship with one another. This relationship ensures that the wire rope has the flexibility and strength crucial to professional and safe hoisting operations.

According to shape, wire ropes are of following two types and shown in Figure 1 - Figure 3:

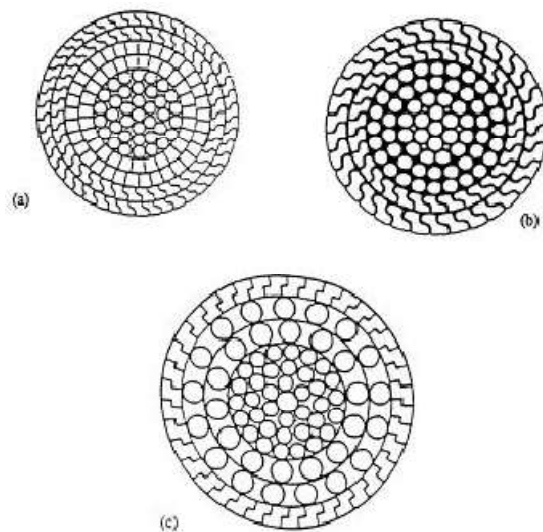a) FLC (Full Locked Coil)
b) HLC (Half Locked Coil)

Figure 1: Full locked coil (FLC) wire ropes
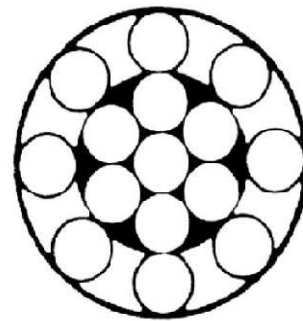

Figure 2: Cross section view of FLC

Figure 3: Half locked coil (HLC) wire rope

Locked coil wire ropes, by virtue of their unique design and construction have specialized applications in aerial ropeways, mine hoist installations, suspension bridge cables. In such specialty ropes, the outer layer is constructed with Z-profile wires that provide not only effective interlocking but also a continuous working surface for withstanding service wear.

Such ropes are comparatively more rigid than conventional wire ropes with fibre cores and therefore these ropes are more susceptible to the adverse effects of bending stress.

Advantages of Locked wire rope

The smooth outer surface of locked coil rope can withstand heavy wear, and because of the interlock, individual wire will not fly out of the rope if broken. The interlock also inhibits the ingress of moisture into the rope and the egress of lubricant from the rope, thus reducing the chances of internal corrosion. By virtue of their design, locked coil wire ropes have comparatively greater area of steel in proportion to their diameter than other types of wire ropes and hence have a higher breaking load-to-diameter ratio than any other construction.

Corrosion

The corrosion in steel can be described as a tendency of the material to return back to a more stable composition. In other words, the metal releases the energy it has accumulated in the steel making process. The initiators in this process can be gases, molten salts or other types of electrolytes, which create an electric gateway for the electrochemical phenomena taking place in a corrosive

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environment. If there is a way of preventing the electron exchange, the electrochemical corrosion may be stopped. In steel wire ropes, there is a difference between atmospheric corrosion (producing uniform rust), and more local forms of corrosion (creating deep pits areas) where the protective coating is damaged or missing.

Damage caused by Corrosion

Corroded steel wire rope will lose its strength and flexibility. Corroded wire surfaces will form fatigue cracks much faster than protected surfaces. If high local stresses help propagate these cracks, the mechanism is called stress corrosion.

Abrasive wear is also accelerated under such conditions. Wire and strand movement is restricted. This increases the risk of failure by bending fatigue. The reduction of wire area due to corrosion will lead to failure under tensile loads [2].

The amount of corroded metal is a function of the surface which oxygen can attack. Steel wire ropes have an exposed surface about 16 times larger than a steel bar of the same diameter and will therefore corrode correspondingly faster.

The amount of corrosion can be reduced by reducing the exposed surface. This can be done by galvanizing the rope wires. A steel core can also be protected by a plastic coating. An internal and external lubrication will also reduce or prevent corrosion. Steel expands when it corrodes. Therefore, sometimes an increase in rope diameter over time might be an indication that the rope is corroding internally. Static ropes (suspension ropes or rope sections lying over a saddle or an equalizer sheave) are more likely to corrode .faster than running ropes.

Case study [3]

Full locked coil (FLC) rope of 24mm diameter of 800HP friction hoist rope has been studied. Five samples from different ropes of same size in different locations of the same mine have been selected for the analysis of their corrosion behaviour using the reduction in diameter method. The steel wire ropes (FLC) have been thoroughly analyzed for each layer and core.

The samples of wire rope consist of five layers (outer, second, third, fourth and fifth) and the core. The common observations on each layer and core of five samples are given in Table 1.

Five wire samples have been collected from following location of 800HP Friction Hoist Rope:

(i)   Capple end near skip no. 1
(ii)   Capple end near skip no. 2
(iii)   Random place of winding rope
(iv)   Centre of rope at winding depth
(v)   Capple end near skip no. 1 rope no. 3

Observations on each layer and core of the above rope samples are shown in Table 2.

Table 1: Common observation on each layer and core of five samples

Outer Layer	Second Layer	Third Layer	Fourth Layer	Fifth Layer	Core
• Galvanized shaped steel wire • Revealed abrasive wear on its outer surface • Indentation marks on its inner surface at regular spacing • Intermittent corrosion pittings on the surface of the wire.	• Consist of rail section and round wires • Helical indentation marks and nicks • Intermittent corrosion pittings on the surface of the wire.	• Galvanized round wires • revealed light abrasive wear • helical indentation marks • Intermittent corrosion pittings on the surface of the wire.	• Consists of two wires of different diameter • revealed helical indentation marks • Intermittent corrosion pittings on the surface of the wire.	• Galvanized round wires • revealed helical indentation marks • Intermittent corrosion pittings on the surface of the wire.	• Galvanized round wires • revealed helical indentation marks along the surface of the wire

Table 2: Observation in rope samples*

Sample no.	Outer Layer	Second Layer	Third Layer	Fourth Layer	Fifth Layer	Core
1.	• Equivalent round diameter: 2.57mm	• Revealed light abrasive wear • Dent marks on the surface of the wire. • Max. percentage reduction of round wire: 0.80%	• Max. percentage reduction in diameter: 2.13%	• Diameter of two different wires are 1.91 & 1.42 mm respectively • Max. percentage reduction for 1.91mm diameter: 1.57% • Max. percentage reduction fot 1.42mm diameter: 1.41%	• Max. percentage reduction in diameter: 1.00%	• Max. percentage reduction in diameter: 0.66%
2.	• Equivalent	• Max. percentage	• Max.	• Diameter of two	• Max.	• Max.

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	round diameter: 2.63mm	reduction of round wire: 1.20%	percentage reduction in diameter: 3.83%	different wires are 1.95 & 1.45 mm respectively • Max. percentage reduction for 1.95mm diameter: 2.56% • Max. percentage reduction fot 1.45mm diameter: 2.06%	percentage reduction in diameter: 1.95%	percentage reduction in diameter: 2.37%
3.	• Equivalent round diameter: 2.58mm	• Revealed plastic wear also • Max. percentage reduction of round wire: 1.60%	• Max. percentage reduction in diameter: 2.13%	• Diameter of two different wires are 1.95 & 1.45 mm respectively • Max. percentage reduction for 1.95mm diameter: 2.56% • Max. percentage reduction fot 1.45mm diameter: 2.07%	• Max. percentage reduction in diameter: 3.90%	• Max. percentage reduction in diameter: 1.69%
4.	• Equivalent round diameter: 2.58mm • cut marks on its outer surface	• Revealed plastic wear also • Dent marks on the surface of the wire. • Max. percentage reduction of round wire: 2.40%	• Max. percentage reduction in diameter: 1.70%	• Diameter of two different wires are 1.95 & 1.45 mm respectively • Max. percentage reduction for 1.95mm diameter: 2.05% • Max. percentage reduction fot 1.45mm diameter: 2.06%	• Max. percentage reduction in diameter: 2.93% •	• Max. percentage reduction in diameter: 0.33% •
5.	• Equivalent round diameter: 2.65mm	• Dent marks on the surface of the wire. • Max. percentage reduction of round wire: 2.00%	• Max. percentage reduction in diameter: 2.98%	• Diameter of two different wires are 1.95 & 1.45 mm respectively • Max. percentage reduction for 1.95mm diameter: 3.58% • Max. percentage reduction fot 1.45mm diameter: 2.07%	• Max. percentage reduction in diameter: 2.46%	• Max. percentage reduction in diameter: 1.69%

* Percentage reduction in diameter is calculated as:

$$\% \text{ Reduction in available dia} = \%\text{RIAD} = \frac{\text{Maximum dia} - \text{Minimum dia}}{\text{Maximum dia}} \times 100$$

For shaped wires, the available equivalent round dia (AERD) is calculated as follows:

Available Equivalent Round Dia (AERD) = $\sqrt{}$ (Wt. in g of 150 mm length of wire sample X 1.08) mm

2. Result

From Table-1 and Table-2, following points have been noticed during study:

1. Outer most layer of the same type of wire rope has got shaped wire of equivalent round diameter ranging from 2.57mm to 2.65mm. All the wires are affected from abrasive wear and intermittent corrosion pittings on the surface.
2. The second layer of the wire rope comprises of two types of wires with a maximum percentage of reduction in diameter as 2.40%. The layer has got affected from abrasive wear and somewhere plastic wear, helical indentation and corrosion pittings.
3. Abrasive wear, helical indentation and corrosion pittings have also been observed in the third layer. The maximum percentage of reduction in diameter in the third layer is 3.83%.
4. The fourth layer of the wire rope has two round wires of different diameters. The maximum percentage of reduction in diameter is 3.58% with helical indentation and intermittent corrosion pitting.
5. The maximum percentage of reduction in diameter in the fifth layer is 3.90% along with helical indentation marks and corrosion pittings.
6. The maximum percentage of reduction in diameter in the core is 2.37% with helical indentation marks all through the wire.

3. Conclusion

The above results show that the fifth layer has the maximum percentage reduction of diameter among all the layers followed by the third layer. The fourth layer may also be comparable with the fifth and the third layer. The affect of corrosion is also comparable with the outer layer and the core. The condition of the wire ropes is in good health since it has maximum percentage reduction of diameter below 10%. These also suggest corrosion has affected more in the middle layer as compared to the outer layer though the middle layer is not directly exposed to the

environment. This may be due friction between the wires and lubrication prevail between the layers.

Acknowledgements

References

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Author Profile

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