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Fracture of a galvanized steel U-bolt stirrup of an overhead electrical transport line

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Abstract

Overhead electric transport lines, cables and support systems, experiment complex stress and environment requirements due to ice formation and release, wind exposure, temperature fluctuations and corrosion. The burst of any element in the chain brings the cables to the floor, cutting the transport of the current with important liabilities. This work reports the rupture of a galvanized U-bolt steel stirrup of a 60 kV overhead electric transport line of a Eolic Park in the North of Portugal. This component is subject to a complex load system and variable attack angles. Thus, the component is subjected to fatigue, wear, static crush and corrosion. The fractured stirrup was manufactured from a hot rolled C1- S235JRC steel rod with Ø 14.5 mm. The final component was hot dip galvanised and centrifuged according standard ISO1461. Fracture surface and multiple cross section microscopy and chemical analysis of the fractured stirrup as well as of new unused stirrups was carried out to identify the rupture mechanisms responsible for the collapse of the structure. Residual resistance of the broken stirrup was evaluated via dedicated designed tensile testing. The original steel has a wide number of big inclusions, same over 400 μm long, developed parallel to the axis of the rod. These inclusions intercept the surface of the rod, inducing surface indentations and cracking of the galvanised coating. Also a considerable number of pronounced notches are observed at the steel surface, at the steel/zinc coating interface.
The fracture surface displays two symmetrical glossy burnish areas, characteristic of the fatigue processes, separated by a central ductile central zone. In the fractured component several cracks due to inclusions are observed intercepting the fracture surface. Zinc and Oxygen were identified of all over the fatigue grown crack surface indicating that hydrolysis of the coating took place with continuous wet transport to the cracked surface with precipitation and oxidation.
The analysis carried out allows concluding that the failure of the component took place by fatigue. Fracture was initiated at the 1st/2nd thread of the component, close to the screw joint. The variable load acted perpendicularly to the plane of symmetry of the component. Corrosion took place simultaneously with fatigue crack propagation speeding the failure process. The inclusions

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present in the steel, mainly those that intercept the component surface, as well as the surface notches due to hot rolling, enhanced the disclosure of the fatigue process leading to premature failure of the component.

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Keywords: Fracture, Fatigue, Case Study, Corrosion

1. Introduction

Nomenclature

tcs	transversal cross section
lcs	longitudinal cross section
BS	Backscattered Electrons
EDS	Energy-dispersive X-ray spectroscopy
Etch	Etched with Nital 3%
FS	Fracture Surface
GC	Galvanized coating of the U-bolt stirrup
I	Steel/galvanized coating or oxide layer interface
OM	Optical Microscopy
S	Steel/burnish oxide layer interface at the fatigue fracture surface
S-Fr	Fractured U-bolt stirrup
S-Nw	New unused U-bolt stirrup
SE	Secondary Electrons
SEM	Scanning Electron Microscopy

Overhead electric transport lines, cables and support systems, experiment complex stress and environment requirements due to ice formation and release, wind exposure, temperature fluctuations and corrosion. The burst of any element in the chain brings the cables to the floor, cutting the transport of the current with important liabilities. Particular severe mechanical conditions develop in cold winter blizzard weather. Thick ice formation is probable during unload line periods when the cables are cold. High speed winds acting on a thickened cable induce considerable overloads on cable and support systems [Kiessling et al. (2003)].

This work reports the rupture of a galvanized steel U-bolt stirrup (Fig. 1a and b) of a 60 kV overhead electric transport line of an eolic park located in the interior North of Portugal where severe weather conditions can develop regularly. The rupture of the stirrup brought the line to the floor (Fig. 1c), cutting the transport of the current. This stirrup is a component of a line support system widely used in Portugal, particularly in Eolic Parks. The support system is composed (fig. 1d) by the U-bolt stirrup, a lifting eye and a ball socket. The ruptured component is subject to a complex load system and variable attack angles. Thus, the component is subjected to fatigue, wear, static crush and corrosion.

The fractured U-bolt stirrup was manufactured from a hot rolled C1-S235JRC (DIN St37-2K) steel rod with Ø 14.5 mm. Shaping was carried out by cold thread-rolling, cold bending, and deburring of the interior surface of the bent segment to remove surface kinks. The final component was hot dip galvanised and centrifuged according standard ISO1461.

2. Methodology

Fracture surface and multiple cross section microscopy, both optical (Olympus PMG3 optical microscope) and electronic (analytical SEM, Hitachi S2400), as well as EDS chemical analysis (Bruker Quantax with light elements detector) of both fractured U-bolt stirrup and new unused U-bolt stirrups was carried out to identify the rupture