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Effect of Protection on Guy Wire Related to Corrosion Defects

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Abstract: Guy wires are a powerful mechanical tool used widely in all industries. Most of the applications are employed in supporting tall structures such as antenna, communication towers, transmission lines, electric poles, and erecting flare stacks on an oil and gas platform or plant. Severe wind events such as tornadoes are the primary failure in transmitting line structure in many places worldwide. So, this research aims to investigate the effect of different types of guy wire on corrosion defects. There are many lay and strand design types in the production of guy wire. The two most common are the 7-wires and 19-wires lay. There are four samples with four conditions: the first sample is not protected with any material, the second is protected by lubrication using WD-40, the third is protected using rubber hose casing, and the last is protected by a combination of both lubrication and rubber hose casing technique. The result shows that the sample protected by a combination of lubrication and rubber hose casing has no corrosion defect.

Keywords: Guy wire, corrosion, protection, flare stack, forklift

1. Introduction

A guy wire is a tensioned cable, wire, or rope used to brace, guide, or secure tall constructions that are tall and not self-supporting in places such as ship masts, power poles, radio towers, or wind turbines. It was also known as strand wire, stay wire, guy strand, guy cable, and guy anchors when it came to any line required to hold something steady. Because the cables are subjected to significant stress, they are made of galvanised steel wires, which make the guy wires particularly sturdy [1]. Guy wire is a vital structure used for structural support [2,3]. Until now, guy wire is still being used to support tall structures as few alternatives are available. The benefit of using guy wire is that some of the structure's weight is transferred to the ground [4]. One end of the guy attaches to the ground, while the other connects to a high point on the structure. Guy wire is also standard, especially in the oil and gas industries. The most common application for guy wire is to support flare stack structures. A flare stack is a gas combustion device used in industrial operations such as petroleum refineries, chemical plants, natural gas processing plants, and oil and gas production sites with oil wells, gas wells, offshore oil and gas rigs, and landfills [5].

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Guy wire is taken more seriously in countries that face tornados and thunderstorms as it is needed to provide structural support to tall structures [6]. In Malaysia, the application of guy wire is at minimal risk due to geographic location. Mild turbulence may not cause tornadoes and affect structures. There are many lay and strand designs in the production of guy wire. The two most common are the 7-wires and 19-wires lay [7,8]. The Flare stack is stabilised using guy wires, and the cables can also be used to help move a load on a crane and forklift. However, multiple factors contribute to a defect or more in wire rope before, during and after its services—for example, broken wire, rope deformation and corrosion. Corrosion leads wire guys to degrade and lose their functioning capabilities in sedentary conditions. It is the breakdown of a substance because of chemical interactions between the material and its environment [9]. Corrosion can occur in a variety of ways in any material. So, in this paper, the different corrosion maintenance techniques for four types of guy wires will be discussed.

2. Materials and Methods

2.1 The Parameter and Materials

Four pieces of guy wire or steel cable wire are obtained from a refinery factory. Each two of the guy wire is from a different specific application in the industry. One type of guy wire is obtained from applying stabilising flare stack tower and the other for lifting load on a forklift. All four pieces of the guy wire are the same construction of 7x19 strands as depicted in Fig. 1. The diameter of the guy wire is 6.5 mm and 7.0 mm for each type. Four samples of the guy wire with three-technique are investigated. The first sample is not protected (Sample 1), the second sample is protected by lubrication using WD-40 (Sample 2), the third sample is protected using rubber hose casing (Sample 3), and the last sample is protected by a combination of both lubrication and rubber hose casing technique (Sample 4). The samples are left outdoors for three weeks in Parit Raja, Johor. The humidity in the three weeks is average at 75%. The average temperature is 32°C during the day and 26°C at night. After three weeks, the samples are taken to be observed under the Olympus SZH10 Zoom Stereo Microscope System for analysis. A Non-destructive test using Dye Penetrant Inspection (DPI) is done to test the effect of corrosion on all the samples. Three consumables are needed for this test: the solvent cleaner FLUXO S190, penetrant CHECKMOR 222 and developer LD7.

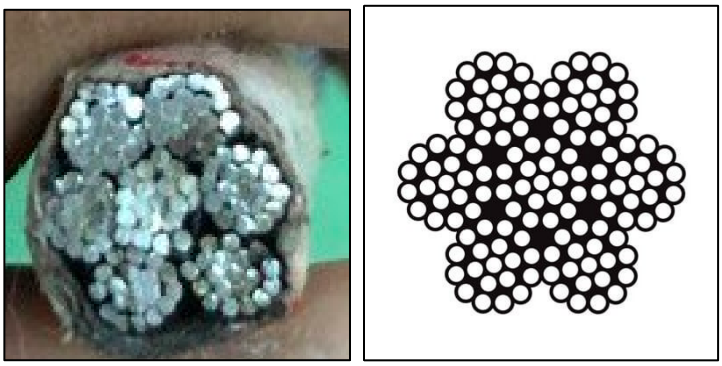


Fig. 1 - Construction of guy wire samples

2.2 Methodology

A tensile strength test is done to determine the tensile strength of the guy wires samples. The standard used is ASTM A931 Tension Testing of Wire Ropes and Strands Standard [10,11]. For the tensile test, the cable is categorised as Cable A1, A2, B1 and B2. The grinder machine is used to cut the guy wire sample to 1 meter each for tensile testing according to ASTM A931. The microscopic observation is done using Olympus SZH10 Zoom Stereo Microscope System.

3. Results and Discussion

3.1 Tensile Test

Fig. 2 shows the graph of load versus time for Cable wires A1 and B1. The load increase with the increment of time. Cable wire A1 (labelled red in Fig. 2) is obtained as a guy wire to stabilise the flare stack. It was measured to have a diameter of 6.5 mm using the vernier calliper. From table 1, the maximum force to be subjected to the cable wire is 29.2 kN, and its tensile strength for it is to be found at 760.0 MPa. While Fig. 3, the graph shows a gradual increase of load overtime during the tensile strength test for cable wire B1. Cable wire B1 (labelled green in Fig.2) is obtained from the application of using a forklift. It was measured to have a diameter of 6.5 mm using the vernier calliper. table 1 shows that the maximum force of cable wire can sustain 29.2 kN before it fails. In addition, its tensile strength for it is to be found at 878.9 MPa.

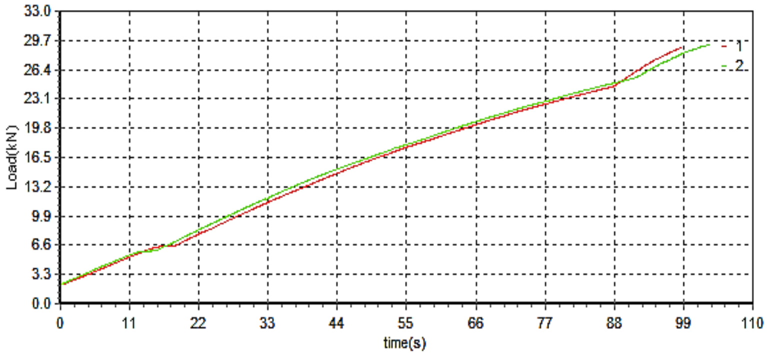


Fig. 2 - Load vs time result for guy wire A1 and B1

Fig.3 shows the graph of load versus time for cable wires A2 and B2. Cable wire A2 (labelled red in Fig. 3) is also obtained as a guy wire to stabilise the flare stack. It was measured to have a diameter of 7.0 mm using the vernier calliper. From table 1, the maximum force to be subjected to the cable wire is 30.0 kN, nearly the same amount of force subjected to cable wire A1 until it broke. In addition, the tensile strength is found at 780.1 MPa, which is higher considering the diameter is more than cable wire A1. Cable wire B2 (labelled green in Fig. 3) is obtained from lifting a load using a forklift. It was measured to have a diameter of 7.0 mm using the vernier calliper. From table 1, the maximum force to be subjected to the cable wire is 28.9 kN, slightly less than the amount of force subjected to cable wire B1 until it failed. In addition, the tensile strength for it is found at 870.2 MPa, which is lower even though the diameter for cable wire B2 is more than cable wire B1 at the difference of 0.5 mm. The result of the tensile test can be summarised in table 1. It can be concluded that cable B1 has the highest tensile strength and highest Elastic Modulus compared to other cables.

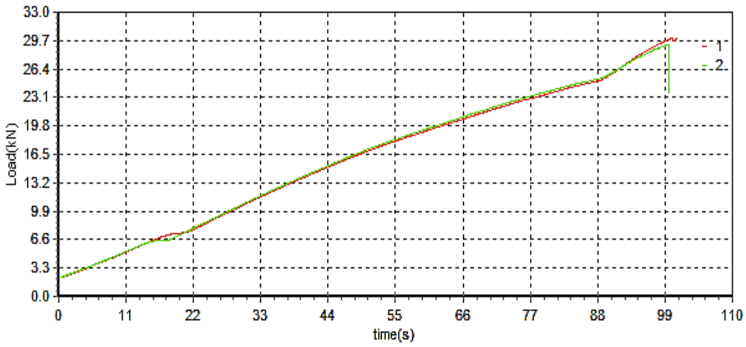


Fig. 3 - Load vs Time result for guy wire A2 and B2

Table 1 - Tensile test result for guy wires

Cable	A1	A2	B1	B2
Maximum Load Force (kN)	29.2	30.0	29.2	28.9
Tensile Strength (MPa)	760.0	780.1	878.9	870.2
Yield (kN)	24.83	24.62	23.81	21.93
Elastic Modulus (GPa)	24	23	28	27

3.2 Observation Condition for The Cable Wire

Table 2 shows the condition for each tested sample for microstructure observation. There are four conditions: sample 1 did not apply for any protection, sample 2 was coated with lubrication using WD-40, sample 3 was protected using a rubber hose cover, and sample 4 was protected by lubrication using WD-40 and rubber hose cover.

Fig. 4 shows the microscopic observation of the internal condition of the cable wire structure without protection after being left to corrode for three weeks at 15 times magnification. Fig. 4 shows that the internal structure of cable wire sample 1 is heavily corroded. The condition of the wire strands is severe, with the corrosion deepening each of the individual wires. According to [12], lubrication is critical in moving parts that work under frictional conditions. No significant effect of time and temperature was detected on the coating thickness in the black coating. While Fig. 5 shows the microscopic observation of the internal condition of the cable wire structure that is protected with lubrication after being left for three weeks at 15 times magnification. Fig. 6 shows the microscopic observation of the internal condition of the cable wire structure that is protected with a rubber hose after being left to corrode for three weeks at 15 times magnification. It can be observed that the sample has a good condition of its internal structure. Only a tiny amount of corrosion occurred in the sample compared to the condition of cable wire protected with lubrication. The individual wire strands look great but still look new after being cut in half to show the internal structure of the cable wire shown in sample 3. Fig. 7 shows the microscopic observation of the internal condition of the cable wire structure that is protected with a rubber hose and lubrication after being left to corrode for three weeks at 15 times magnification. It is observed that the best condition of cable wire internal structure. The condition of the construction of wire strands that make up the cable wire is in a good state.

Table 2 - Condition for sample microstructure

Sample	Condition
Sample 1	Not applied for any protection
Sample 2	coated with lubrication using WD-40
Sample 3	protected using a rubber hose cover
Sample 4	protected by lubrication using WD-40 and a rubber hose cover

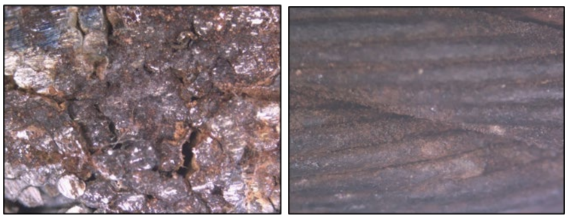


Fig. 4 - Rust formation of cable wire at x15 magnification without protection

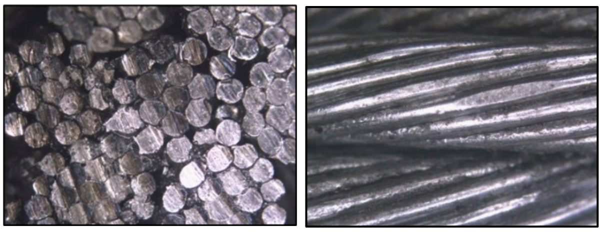


Fig. 5 - Condition of cable wire at x15 magnification protected with lubrication

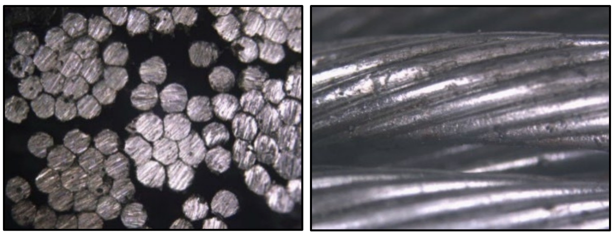


Fig. 6 - Condition of cable wire rubber hose protected at x15 magnification

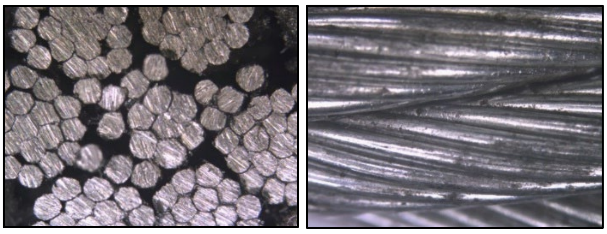
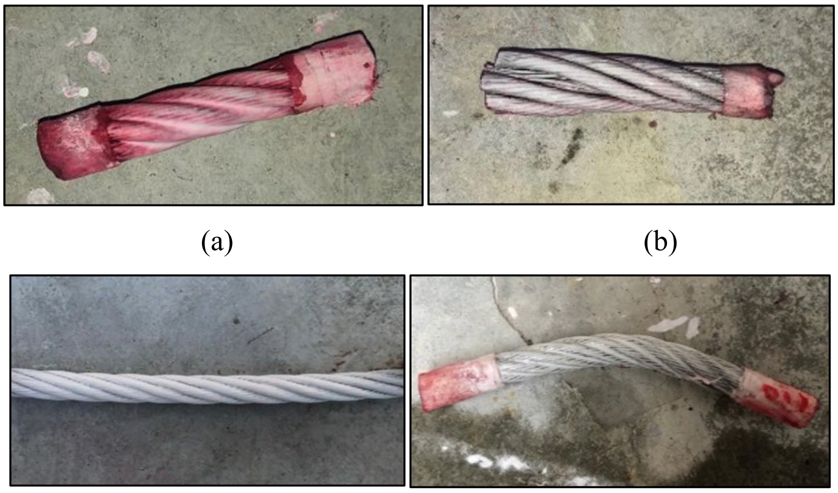


Fig. 7 - Condition of cable wire protected using rubber hose and lubrication at x15 magnification

3.3 Dye Penetrant Testing Result

Fig. 8 (a)-(d) shows the result of Dye Penetrant Testing on cable wire Sample 1, Sample 2, Sample 3 and Sample 4. As predicted, cable wire sample 1 (as shown in Fig. 8(a)), which is the most corrode, will have many defects. Sample 2 (Fig. (b)) defects are much less compared to the condition in Fig. 8(a). The lubrication has successfully reduced moisture from causing corrosion to the steel wire strands. Fig. 8 (c) was also in good condition as Fig. 8(b). It is predicted that cable wire Fig. 8(d) to produce the best result as the combined protection method was used. As shown in Fig. 8(d), the cable wire had both regular lubrication and a rubber hose cover to protect it from the environment. Previous studies also highlight that the typed lubricant with a large particle causes the retardation of full lubrication on the entire contact surface and the local delamination of the coating layer on the wire surface [13]. The result agreed well with the current results.



(a) (b)

(c) (d)

Fig. 8 - Result of dye penetrant testing

4. Conclusion

Three methods of corrosion prevention using lubrication, rubber hose cover and combined both ways were done, and the experiment lasted for three weeks. It has been found that no protection on sample 1 causes severe corrosion. Protection using lubrication is slightly better than a rubber hose cover. Lastly combined method of lubrication and rubber hose cover provided the best result to protect the steel wire cable from corrosion. Defects and flaws on the surface and sub-surface of the cable samples are detected using a non-destructive testing method, Dye Penetrant Testing. It can be concluded that sample 1 is the most corroded and has the most defect and flaws. Sample 4, protected using a rubber hose and lubrication, gives a better result with no defects than samples 2 and 3. Lastly, the combined protection method that applies lubrication and rubber hose cover gives the best result with nearly no defects and flaws.

Acknowledgement

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