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Characterization of Residual Energy Loss and Damage Prediction of wire Rope wires Exposed to Sulfuric Acid

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ABSTRACT:- The Characterization of residual energy loss of wires extracted from wire rope of type 19x7 immersed in 30% H_2SO_4 was investigated in this paper. The results obtained from tensile tests on virgin and corroded specimens show a decrease in residual energy as function of immersion hours (8h, 16h, 24h, 32h and 40h). This progressive decrease of energy allowed us to develop a method to calculate damage evolution due to corrosion. Thereafter, and with the establishment of the damage, three stages of damage are distinguished and the value of the critical life fraction is identified, which predict the time of the damage and thus to intervene at the appropriate time before the risk of failure becomes risky.
Keywords:- Wire rope; wire; corrosion; residual energy; damage.

I. INTRODUCTION

Wire ropes are present in many areas of our daily life, in domestic and industrial lifting and pulling equipments and hoists, cable cars and ski lifts, cable railways, harbor cranes, and similar applications [1].
The base material of metal wires is typically a low alloy steel containing a carbon content close to eutectoid, with as main alloying elements manganese and silicon. These steels are formed by a drawing process [2].

A wire rope is generally constituted of many strands helically arranged around the central core in a layer or multiple overlying (Fig. I).

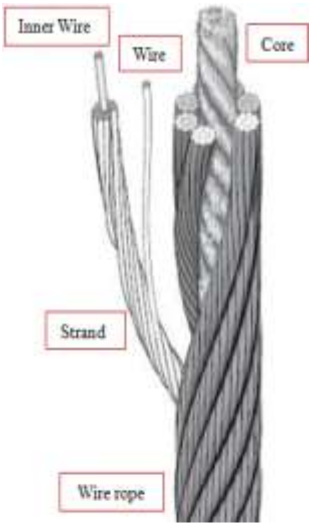

Fig.1: Basic components of a typical wire rope

The nature of a wire rope is such that there is an energy stored when it is in service. This introduces a potential safety issues due to an unexpected release of this energy. Therefore, regular, periodic and delicate monitoring and maintenance is necessary for personnel safety. Throughout the life of a wire rope, the wires and strands that make up this cable are subjected to several degradations indicating a loss of the original energy, which leads to very rapid deterioration leading to sudden and violent rupture [3].

The humid and oxygen-rich working environment of the wire ropes can cause corrosion. Corrosion reduces the cross section area of steel wire ropes as well as their flexibility and mechanical properties. Data shows that corrosion may cause the wire rope to lose more than 30% of its strength and even 50% in some cases. Besides, steel wire ropes become loose after intensive corrosion. This can be explained by the accelerating wear between steel strands by abrasion after rust has entered the wire rope core. As well, the condition of the oil will also be damaged when aggressive water enters the core, which weakens the lubrication and increases wear between the internal strand wires [4]. In this paper, the residual energy loss of wires under acid attack is studied, in order to predict the damage by corrosion of wires depending on the residual energy loss, based up on experimental tensile tests, and subsequently determine the critical life fraction β_c.

II. MATERIALS & METHODS

A. Materials

The tested specimens are strands extracted from wire rope of type 19x7 and antigyratory structure (1x7 + 6x7 + 12x7) 8 mm in diameter, composed of steel light greased, metal core, right cross, preformed, used especially in tower cranes and suspension bridges (Fig.2).

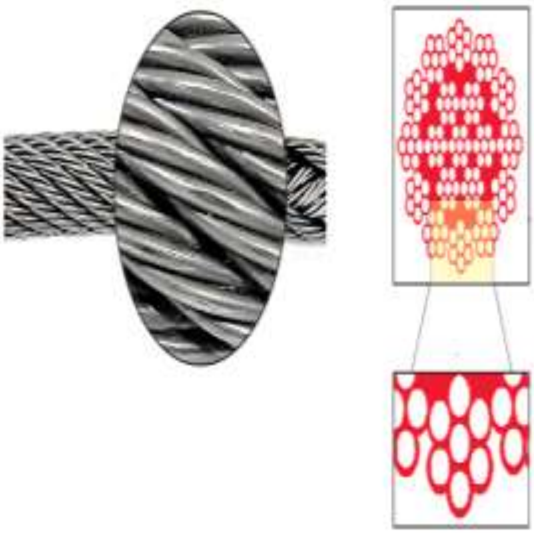

Fig.2: Cross section of a 19*7 “antigiratoire” wire rope

The mechanical characteristics of this cable are shown in Table 1, the ultimate Load is 41,14 KN (Table 1).

Table I: Mechanical properties of the material

Cable diameter (mm)	8mm
Design	19*7 (1 * 7 + 6 * 7 + 12 *7)
Construction du toron	6 /1
Young modulus of the wire (MPa)	200 Gpa
Surface quality of the wires	Galvanized steel
Mass per unit length (kg/m)	0,272 kg/m
Minimum breaking strength	41,14KN
Poisson’s ratio	ν = 0,3

The chemical composition is obtained by spectrometric analysis using an advanced spark spectrometers for precise analysis of metals. The result is given in Table II.

Table II: The Chemical composition of the material

Composition	C	Si	Mn	S	P
Percentage	1,478	2,04	3	0,144	0,091

The minimum length of the specimens is equal to the length of the test 200 mm plus the necessary for the mooring. Therefore, a length of 300 mm is anticipated as the length of the test for the wires. The measurements tolerance in the length is ± a millimeter for all samples [5]. Dimensions of the wire are shown in Fig.3.

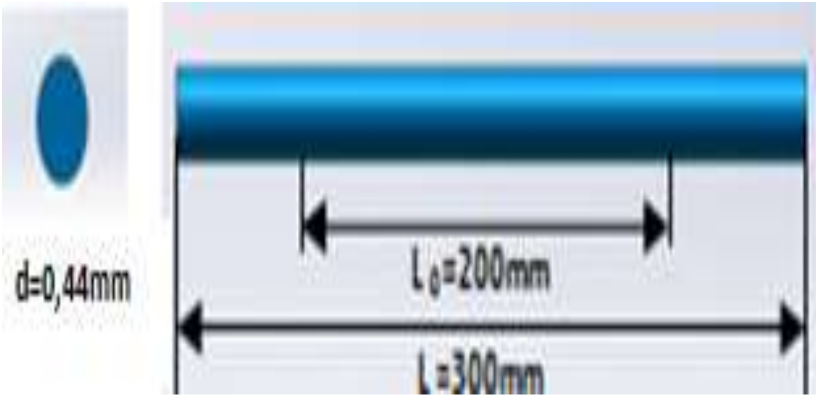

Fig. 3: Dimensions of the studied wire

B. Corrosion methods

The wires were cut at a length of 300 mm. The areas of 100 mm length were defined in the middle of the specimen (Figure 5), and then they were immersed in 30% H2SO4 solution at room temperature (Figure 6) [6].

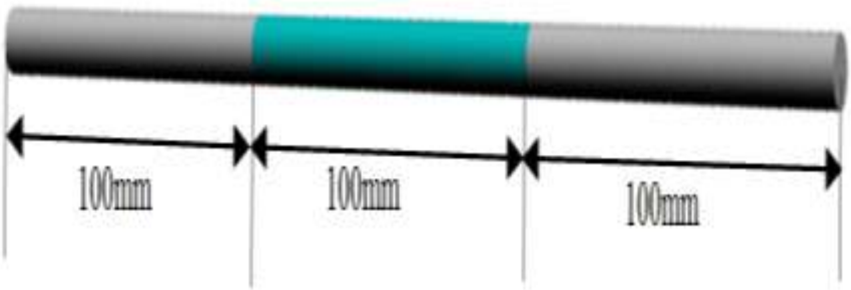

Fig. 5: Dimensions of the areas defined in the middle of the wire

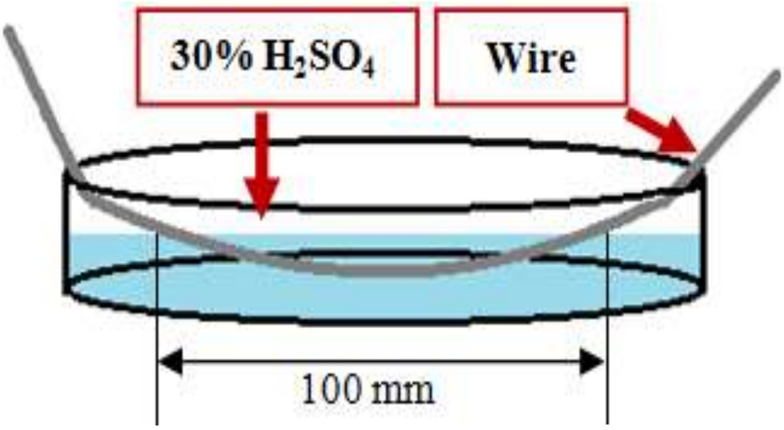

Fig. 6: Schema of accelerated corrosion testing

III. RESULTS AND DISCUSSION

A. Static tensile test on virgin and corroded wires

The curves of the applied force in function of the elongation of the corroded wires are given in figure 7. The mechanical tensile tests show only a little decline in the breaking force after 4 hours of immersion; this decline increases with the time of immersion. The breaking force decline is up to 80% for 40 hours of immersion.

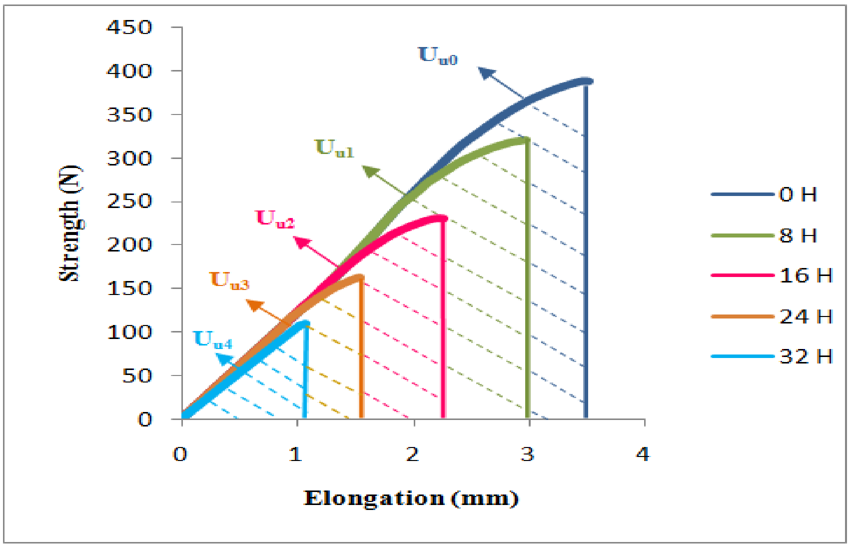

Fig. 7: Comparison of tensile curves of corroded wires

The values of residual ultimate energy and the values of the diameter loss rate reported in Table III.

Table III: Residual ultimate energy and the diameter loss rate as a function of the immersion time

Immersion time (H)	Ultimate energy (J)	Diameter loss rate (%)
0	0,9	0
8	0,69	15
16	0,42	25
24	0,25	35
32	0,057	50
40	0,01	80

B. Residual ultimate energy according to the diameter loss rate (%)

The figure 8 shows the change of residual ultimate energy as a function of the diameter loss rate.

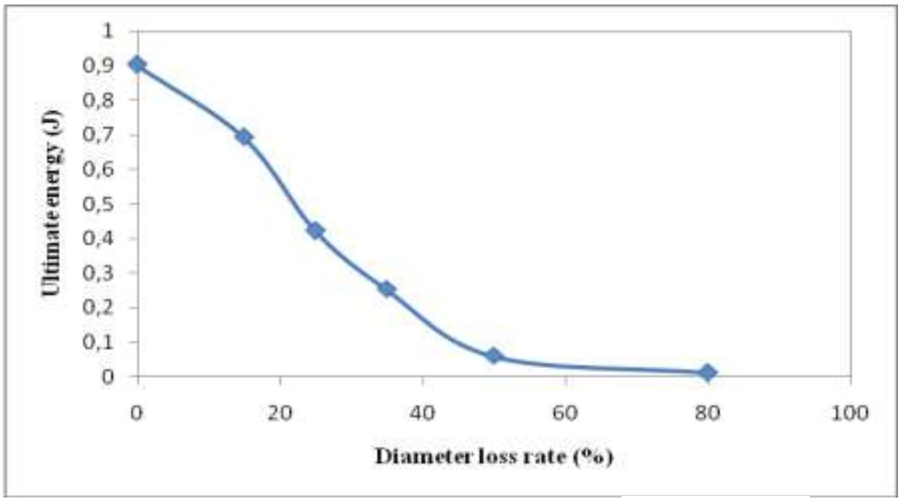

Fig. 8: Residual ultimate energy according to the diameter loss rate

A virgin wire has a residual ultimate force of 0,9J which fall gradually as the diameter loss rate increases, until the value of 0,01J. This can be translated by a loss of corroded wires resistance.

C. Residual energy damage

We have defined the static damage by the following equation:

$$D_E = \frac{1 - \frac{Uur}{Uu}}{1 - \frac{Ua}{Uu}}$$

Where D_E is the static damage using ultimate energy, U_u is the value of the total energy; Uur is the value of the residual ultimate energy and U_a the energy just before the final break. The variation of the static damage using ultimate energy according to the life fraction is illustrated by the curve with the following conditions (Fig. 9):

$$\beta = 0 \rightarrow \quad U_{ur} = U_u \quad \rightarrow D = 0$$
$$\beta = 1 \rightarrow \quad U_{ur} = U_a \quad \rightarrow D = 1$$

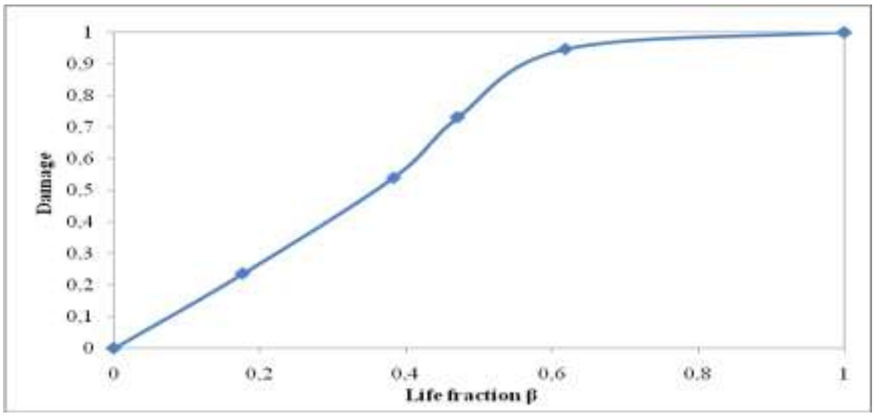

Fig. 9: Static damage diagram by residual energy

The increase of the damage means the loss in energy of static tensile strength; this loss evolves as the diameter loss rate becomes more important.

D. Relationship Damage –Reliability

When a system is in operation under static solicitations, its physical properties undergo a progressive degradation, so we often need to reduce the probability of sudden failure. The reliability theory permits to evaluate the probability of failure and considers the uncertainties associated with different variables. Reliability varies inversely to the damage [7]. Intuitively, there must be a relationship between these two parameters. This allows us to write:

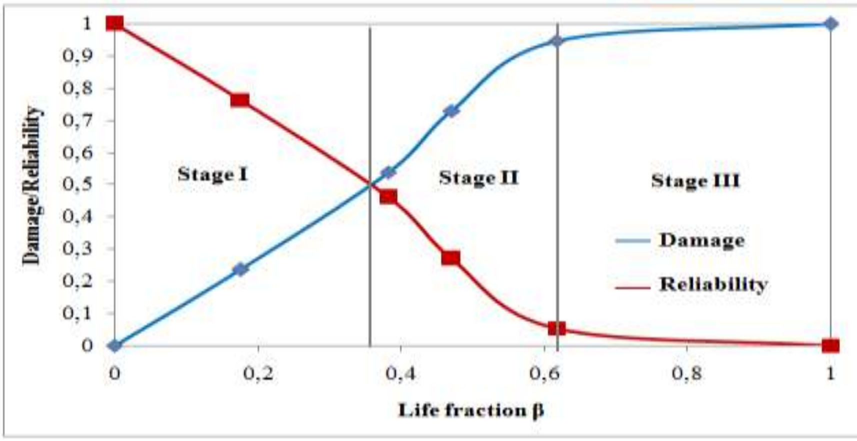

Fig.10: Superposition of static curves Damage –Reliability

The Increasing damage is necessarily accompanied by the decrease of the reliability (Figure 13). At the beginning, we have the damage initiation area (stage I), then specimens start to lose their internal resistance, it is the progressive damage zone (stage II) which requires maintenance. Starting from 80% of the damage (20% reliability) the specimens under tension are in the brutal damage zone. The advantage of determining the relationship between the damage and the reliability is that it allows, in particular, to know the values of life fractions when the damage becomes progressive and critical which corresponds in this case to $\beta_i = 0.35$ and $\beta_c = 0.65$ respectively.

IV. CONCLUSIONS

The primary objective of this investigation was to study the effects of corrosion on the energy of wires extracted from steel wire rope of type 19x7 with antigyratory structure. The tensile mechanical test showed a decrease in ultimate energy after only 8 hours of immersion. The secondary objective was to determine the three stages of damage due to corrosion (Stage I that corresponds to the initiation of an elastic damage, Stage II that corresponds to progressive damage and Stage III that represents the brutal damage), these stages predict the critical life fraction $\beta_C = 0.65$.

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