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Stiffness characterization and residual strength loss evolution applied to twisted aluminum wires destiny to overhead low voltage cables

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Abstract

In the modern era, overhead transmission lines become irrelevant in the development of new cities as becoming mandatory. Nonetheless, it is crucial to understand overhead line technology in order to model the next generation of power networks, as most of the power networks still comprise overhead lines.
This field of study was exposed to methodical and thorough research; there is a common perspective which is shared amongst multinational power engineers and researchers, that overhead transmission cabling bestows mammoth improvements and benefits when compared to its predecessor technology of overhead lines. However, the overhead technology is still dominating and is in use all over the world.
Our goal is to establish the mechanical behavior of overhead power cables BT based on aluminum, by uniaxial tensile characterization tests.
Coupled traction tests are preceded by chemical characterization tests to determine the boundaries of the material as its tensile strength and stiffness.
In this context we will treat the results of mechanical and chemical testing applied to stranded overhead electrical conductors different in nature, including the twisted aluminum. All trials are conducted under guidelines prescribed by the appropriate standards for each type of test.

Key Words: Overhead lines; aluminum cables; chemical characterization; stiffness; tensile test; standards.

1. Introduction

The transport of electric power since the production centers is ensured by overhead lines and underground cables. These latter undergo a fast evolution imposed by the increase in the urban zones and by a better quality of service and environment required by electricity consumers (Figure 1). Moreover, the recent technological developments have supported the choice of the overhead cables by the adoption of new materials (synthetic insulator, aluminum sheath…) and new installation methods that reduce the capital costs [1].

The increase in electricity consumption, high loads, aging; harsh environments and density of residential areas make it increasingly important to be able to locate quickly and prematurely the defects arising in underground cables [2].

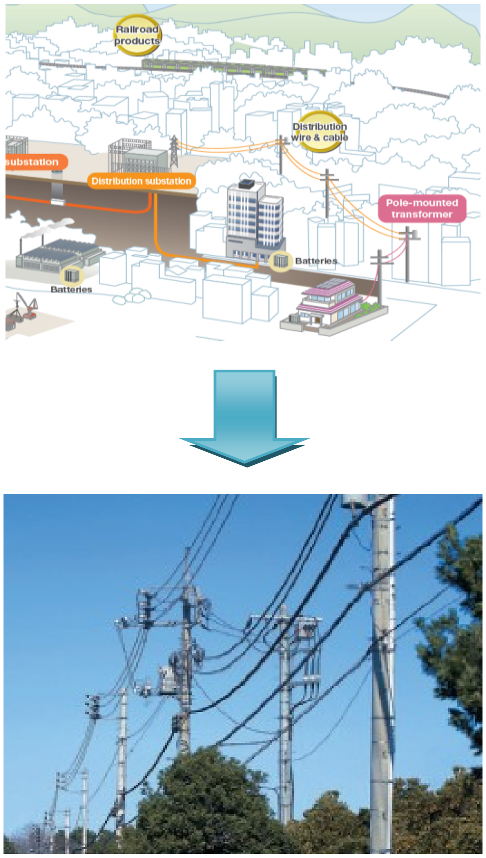

Figure 1: Distribution of overhead cables installing pylons

Even if the investments related to their installations are prohibitive, their environmental and aesthetic impact is greater. The structure of cable tested in this study is shown in Figure 2.

This cable consists of aluminum conductors strands identified by black insulation and a neutral conductor. The outer sheath of these conductors is composed of polyvinylchloride (PVC) and a thin galvanized steel metal screen. Every conductor strand is made up of several wires wrapped in successive layers around a central core wire.

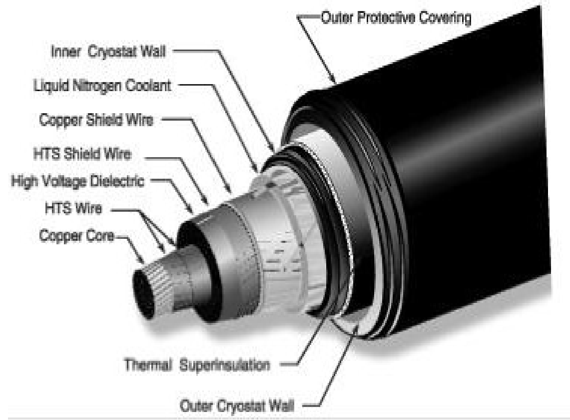

Figure 2: Constitutions of overhead power cables

Thus, their wires require a detailed study because of the harmful effects of their failure on the entire electrical system. The purpose of our work is to treat the results of mechanical tests and chemical composition applied to aluminum wires of overhead electrical conductors.

All trials are conducted under the guidelines prescribed by the appropriate standards for each type of test [3].

2. Distribution of overhead cable failures

Among families of causes of failures of overhead cables come first surge of cables and connection problems (cable clamp bolt). Statically, the share of these causes in all causes of failure is 43% for the faults of voltage and 40% for those due to connections in the year 2011.

Furthermore, we noticed that most other causes of failures leading to an increase in temperature (Figure 3) [4].

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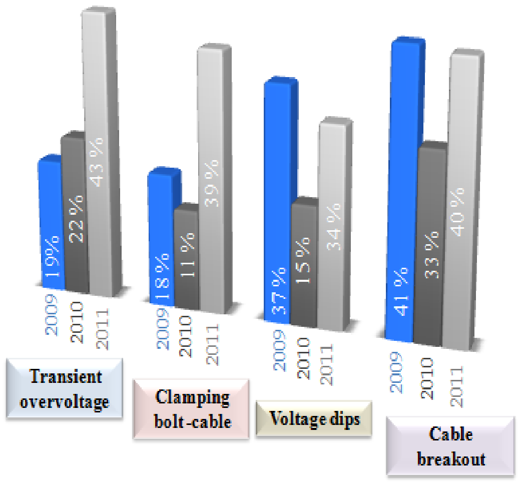


Figure 3: Distribution of causes of electrical networks

Indeed, aggressive environments or defects in connections result in a degradation of the electrical contacts. This result is an increase of the contact resistance resulting in a local heating by Joule effect to current flow. The cable clamping bolt defects are likely to cause an abrupt break overhead cables.

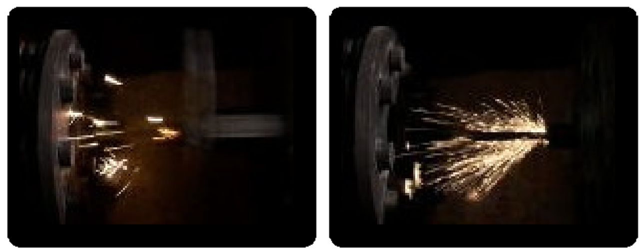
The temperature seems to be a physical quantity to oversee a significant portion of failure causes.

Among the causes breakaway cables or electric wires, there is the connection defects leading to local heating of the connection and can degenerate into a boot (Figure 4) (Figure 5). Most other causes of failure (power surges, harmonics), also lead to a rise in temperature. Therefore, the temperature seems to be a physical quantity that could help detect and diagnose an important set of failure modes of electric cables.

The breakout cables also affect the causes of failures related to the environment that surrounds the components of the electrical network.

a) Virgin specimen b) Damaged strand specimen

Figure 4 : Different forms of breakout cable strands



a) Start of sparks b) sliding sparks

Figures 5: Sparks caused by friction between cable and clamp bolt

Humid environments promote the oxidation of metal parts of the cables [5].

Dusty or corrosive environments, such as those found in paper mills, for example, attacked the electrical contacts. This increases the electrical resistance of contaminated touch [6] [7].

The intrusion of animals in the cables (insects, birds) is a cause of stripping strands.

3. Materials and methods

3.1. Materials of physical and chemical characterization

Fatigue testing of all specimens cables are made on a universal machine, type "MTS 810", having a maximum capacity of 100 kN load (Figure 6).

The experiment is to submit samples of cables to test tensile and fatigue, after having established the adequate computer programs for machine control.

Figure 6: Fatigue Machine "MTS 810"

The apparatus used for mechanical characterization tests is a type traction machine "Zwick Roell" of a 2.5 kN load cell, which yielded more precision in the various tests, given the nature of materials used and the geometry of the sample ducts which have a small thickness (Figure 7).

Figure 7: Components of the traction machine

Chemical characterization is used to determine the complete primary chemical structure of an electric cable. It also leads to the identification of each of the chemical constituents and specifies its percentage relative to other elements. This characterization is performed by public laboratory tests and study with an advanced spark spectrometers for precise analysis of metals (Figure 8).

Figure 8: Spectrometer to acoustic emission (Bruker)

3.2. Sampling specimens

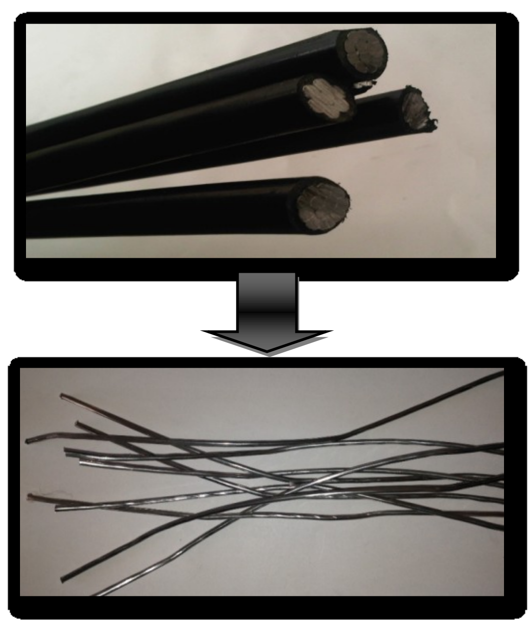


Figure 9: Test after separation of sheath and wires stranded in aluminum cable

The phase conductors and public lighting are twisted around the neutral conductor with a right-hand whose length is between 20 and 25 times the outside diameter of the beam (Figure 9) [8] [9].

4. Results and discussions

4.1. Chemical composition

The result of the chemical composition of various conductors constituting the twisted cable BT aluminum [10], are given in the tables (1 and 2).

Table 1: Chemical composition of the strands of twisted cable BT Aluminium (Aluminium conductor)

Element	Al	Fe	Si	Cr	Pb
(%)	99,84	0,05	0,02	0,01	<0,01

Table 2 : Mechanical statistics of a twisted cable strands BT Aluminium (Aluminium conductor)

σ_{max} (MPa)	**σ_r (MPa)**	**Wr (N.mm)**	**σ_{min} (MPa)**
325	301	37368	7,07

With:

σ_{max} : Maximum stress (MPa)

σ_r : breaking stress (MPa)

Wr : breaking energy

σ_{min} : Minimum stress (MPa)

4.2. Experimental results

After processing the curves in figure 10, a statistical study of the results was carried out; the average curve can be drawn as follows.

Thus, the evolution of the maximum stress versus deflection wires of aluminum is transferred to below, the curve has a decreasing pace, and the gap between the values is obvious.

The degradation of mechanical properties always proves remarkable; the resilient, the ultimate stress strain, stress at break and elongation are all increasingly decreasing values with increasing deflection, there is no longer a constraint stabilizing zone or elongation importantly, the rupture often precedes a local plasticizing and a sharp break thereafter.

Figures 10 and 11 postpone the development of ultimate stress and the stiffness as a function of deflection.

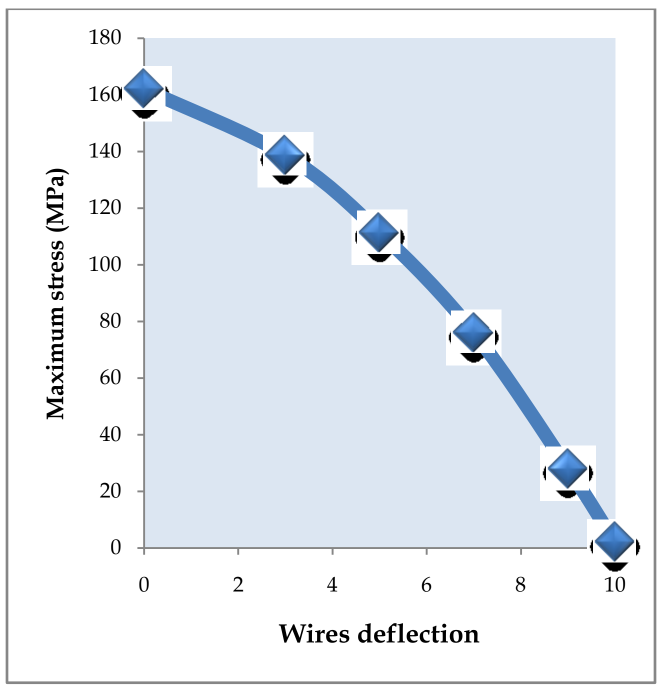


Figure 10: Maximum stress depending on the deflection of the twisted cable BT Aluminium (Aluminium conductor)

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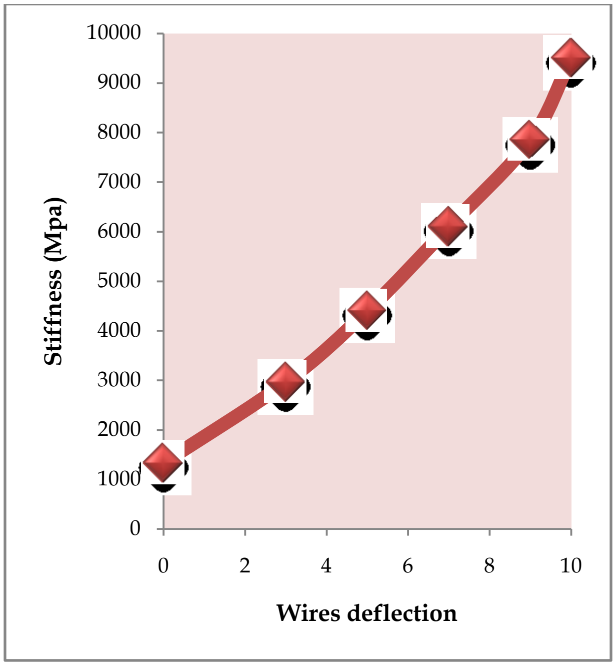

Figure 11: stiffness depending on the deflection of the twisted cable BT Aluminium (Aluminium conductor)

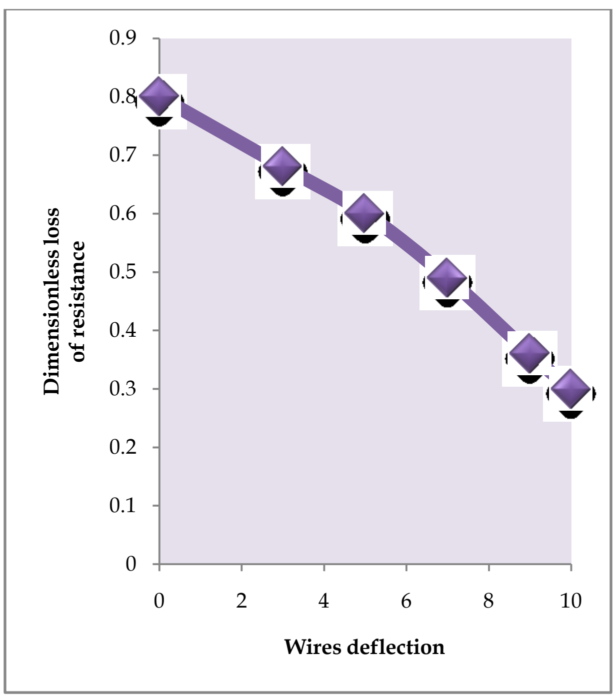

Figure 12: tensile strength loss depending on the deflection of the twisted cable BT Aluminium (Alu conductor)

A decrease in the ultimate stress versus deflection is noticed, but a significant increase of the stiffness is observed, this increase continues up to reach values close to those given by the standard specimens (Figure 11).

The figure 12 shows the evolution of the dimensionless loss of resistance depending on the deflection of wires.

The loss of strength is remarkable and decreases progressively approaching a critical value, this curve allow us later to determine the limit load - below which we estimate the damage sustained to the material is acceptable.

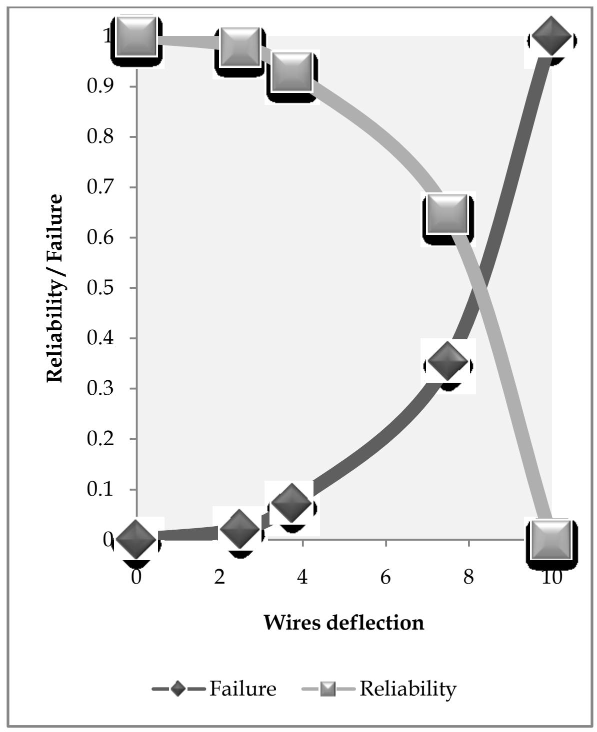

Figure 13: Estimation of reliability based on the damage to the twisted cable BT Aluminium (carrier neutral)

The damage keeps a virtually linear course; at initiation, the damage is negligible (D≈0) for the virgin cable and here is the mechanical characteristics are highest, then accelerates in a way increases with increasing deflection until it reaches its maximum value is D = 1, where the break occurred, and there is a progressive and remarkable degradation of mechanical properties (Figure 13).

5. Conclusion

In the programs of improvement of transmission and distribution of electric energy, particular emphasis is reserved to the activity of treatment and prevention of failures. Thus, determine and know the critical life of strands of electric cables is one of the essential elements in the activity to diagnose the degree of degradation of distribution system of electricity. In this sense, knowing the damage level is an important factor in determination of the state of aging and degradation of the strands of electrical equipment.

An electrical conductor is never perfect. Not only, there are faults which are derived directly from the output of the cable but also the passage of electric current can develop several failures especially in its structure with an applied load. When a cable is in use, the strands are the seat of thermal, electrical, mechanical and finally to constraints related to the environment, making the study of drivers essential for the reliability of the electric cable in general.

Often, knowledge of an overhead cable requires a thorough understanding of each of its essential elements, the aim is firstly the mechanical characterization of virgin electrical conductors to complete the mechanical characterization of the distribution cables and then we opt for characterization through a mechanical tensile test on faulty elements and therefore the full cable.

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