

Study of specific energy in elastic phase of the different elements of a low voltage underground power cable.

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ABSTRACT

Elements that constitute electric cables require a compromise between mechanical and electrical characteristics to achieve the desired functions, the choice of materials constituting each element involves economic and technical factors and requires a broad knowledge of materials to choose from. Unfortunately, by the external environment and operating conditions of these cables, the insulation material is subjected to various kinds of stresses, without forgetting the moisture effects that could not be prevented on the other elements of cable despite the presence of peripheral protective sheaths. The aim of this work is to study the mechanical behavior of underground electrical cable components. For this reason, a comparative study between the different specific energies in elastic phase of cables elements is performed. We concluded that the outer sheath has a specific energy in elastic phase considerably higher compared to the other elements energies, this elastic energy is extremely important for the used material, it increases the level of its performance and its endurance against mechanical stress. Therefore, it makes the material more reliable and increases its availability as well as its mechanical life time.

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Introduction:

Electrical cable has experienced intrinsic modifications to adapt it with the mechanical, physical and environmental constraints more and more severe. The increase in electricity consumption, high loads, cables aging make the comprehension of mechanical behavior of underground electrical cable and all its constituent elements an issue extremely important.

The specific energy in elastic phase is a mechanical property characterized by the intrinsic characteristics of the material: Young's modulus, yield strength and density. This energy represents the ability of a material to withstand the mechanical stresses without undergoing irreversible damage.

The aim of this paper is to study the mechanical behavior of different underground electric cable elements and a comparative study between calculated specific energies in elastic phase of cable constituents is performed.

Experimentation: Studied specimens:

The underground electrical cable that is the subject of our analysis is: Low Voltage Cable BT AS H1 XDV 3×240 ALU + 95 (figure 1).

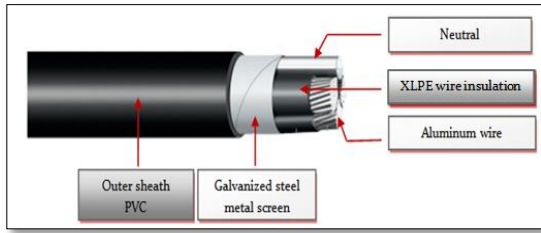


Fig. 1: Underground electric cable BT H1XDVAS

The studied cable is made up of three essential materials:

- The plasticized PVC: material of the outer sheath ;
- Wire insulation polyethylene XLPE (inner sheath)
- Aluminum wires.

The sample preparation is done through several steps [1]. We have obtained the following final test pieces (figure 2 and figure 3)

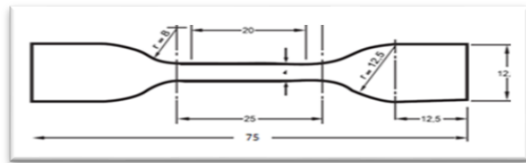


Fig. 2: Standardized specimen for outer sheath and wire insulation

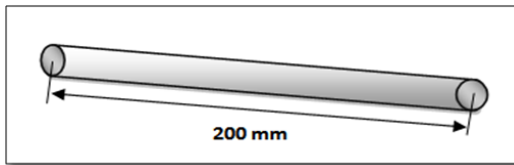


Fig. 3: Schematic of aluminum wire specimen [2]

Mechanical characterization:

In order to characterize mechanically this material, a tensile test is applied to 5 specimens according to the standard for each material.

Figure 4, figure 5 and figure 6, illustrate the stress-strain curves of the outer sheath, the wire insulation and aluminum wire.

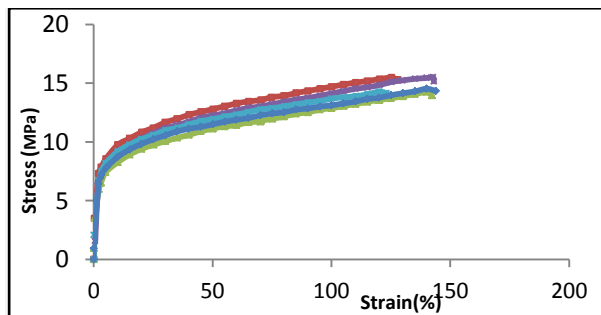


Fig. 4. Stress-strain curve of the outer sheath

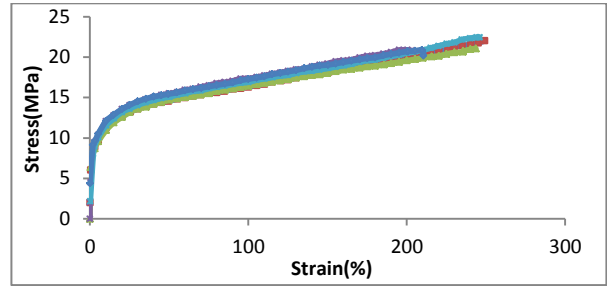


Fig. 5: Stress-strain curve of the wire insulation

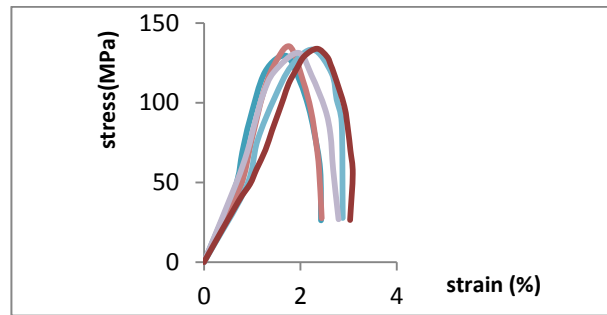


Fig. 6. Stress-strain curve of aluminum wires

Different mechanical properties extracted from stress-strain curves are summarized in the table 1, 2 and 3.

Table: 1. Mechanical properties of outer sheath [3] (cable H1XDV AS)

Elastic stress σ_e (MPa)	Breaking stress σ_r (MPa)	Strain ϵ (%)	E Young modulus E (MPa)	Maximum stress σ_u (MPa)
7.8	14	143	73.45	15.15

Table: 2. Mechanical properties of wire insulation (cable H1XDV AS)

Elastic stress σ_e (MPa)	Breaking stress σ_r (MPa)	Strain ϵ (%)	E Young modulus E (MPa)	Maximum stress σ_u (MPa)
10	24	237	70	22.91

Table: 3. Mechanical properties of aluminum wire (cable H1XDV AS)

Elastic stress σ_e (MPa)	Breaking stress σ_r (MPa)	Strain ϵ (%)	Young modulus E (MPa)	Maximum stress σ_u (MPa)
120	23	2.5	69	124.85

Specific energy in elastic phase calculation:

Energy of a system is the potential needed to perform works or produce heat. The specific energy in elastic phase is the energy associated to elastic deformation of materials[4]. The absorption capacity and the energy released per mass unit of a substance undergoing elastic deformation is expressed by the relationship:

$$\frac{w}{m} = \frac{\sigma^2}{2 \times \rho \times E} \text{ joule/kg}$$

with

ρ : the density in kg / m³

E: Young modulus in MPa

σ : maximum stress in MPa

For the different components of studied cable, calculated specific energy values are summarized in table 4:

Table: 4. Specific energy in elastic phase of different component:

Cable component	Specific energy(J/Kg)
Outer sheath	306.3
Wire insulation	744.2
Aluminum wire	3.8

We note that the specific energy in the elastic phase of underground electrical cable sheath is much greater compared to electrical aluminum wires, this difference is mainly due to the fact that the electrical sheaths are in direct contact with mechanical and environmental stresses while electric wires are protected and their role is the conduction of electric current.

On the other hand, the wire insulation has the highest specific energy and that is because of the huge thermal stresses related to the contact with electrical wires, the increase of the elastic energy more reliable and allows the material of the mechanically protected to withstand external and internal attacks.

Conclusion:

The mechanical behavior of electric cable constituents differ from one element to another and it

depends on functions nature associated to each component.

Indeed, the inner and outer sheaths have significant deformation and especially the inner sheath that could reach a deformation of 250% of its original length, this important deformation is explained by its direct contact with the electrical wires and thermal stresses that it should support.

A comparison of the specific energy between the various electrical cable elements is made, the results show that the wire insulation has a higher specific energy, which means that the material is mechanically more reliable and has the greater lifetime compared to the other components. It is also noted that the specific energy in elastic phase of aluminum wire represents the lowest value because of the fragility of aluminum material and its protection provided by sheaths (outer sheath and wire insulation).

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