MEDIUM VOLTAGE CABLE WITH OPTIMIZED SCREEN SHEATH COMPLEX

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ABSTRACT

The use of polyethylene sheath has reinforced the robustness of the medium voltage cable. Nevertheless, some properties have become more sensitive, as the mechanical stiffness, the shrinkage, and the flame resistance.

In order to minimize these drawbacks, the authors propose to use blends based on specific polymers. As result, the shock resistance and the shrinkage are 2 characteristics of the cable particularly improved with these new compositions.

KEYWORDS

Medium voltage cable sheath shrinkage shock.

INTRODUCTION

Today, most countries tend, where possible, to build underground electrical distribution networks, instead of traditional overhead lines.
They have better reliability regarding the exceptional climatic events such as storms or periods of extreme cold weather, and require less maintenance due to the surrounding vegetation, etc..

The underground networks being more costly, utilities are looking for more reliable products, so as to reduce to minimum the maintenance, and increase the service life of the links

If we consider as example the medium voltage cable used in the french distribution network, it consists of an aluminum core, surrounded by a cross-linked polyethylene insulation. On each side of the insulation, there is a conductive layer, the external one being strippable.

The insulated core is protected from the external environment by a complex formed by an aluminium foil placed in long, looks like a continuous pipe, and stuck to the external polyethylene sheath.

POLYETHYLENE SHEATHING

The definition and quality completion of the screen-sheath assembly is essential for the life time of the product. The level currently achieved, with high quality materials and processes is quite satisfactory. In particular, the replacement of the PVC by Polyethylene has reinforced the robustness of the screen-sheath complex on the following aspects:

- Better protection against corrosion of the aluminum screen
- Higher adhesion of aluminum overlapping , and with the sheath.
- Lower sensitivity to moisture absorption
- Better temperature behaviour

The grades of polyethylene used for cable sheathing show common characteristics:

- A good resistance to stress cracking
- A high resistance against thermal ageing, by adding proper anti-oxidants
- A protection against UV, obtained with carbon black or specific agents
- Protection against termites or against the flame spread, by appropriate additives.

On the other hand some parameters have become more sensitive:

- the mechanical stiffness of the cable
- the shock resistance
- the shrinkage
- the flame resistance.

These drawbacks are well known to those who routinely use polyethylene. These materials are ready to use, and the cable maker hasn't all the freedom to reach an ideal compromise between properties, which may vary from one cable standard to the other.

The polyethylene are often characterized as a first approximation by the density and melt flow rate:

- The low density, high or low pressure, is interesting for the flexibility of the cable and withdrawal. On the other hand, its limited contribution to the impact resistance of the cable leads to increase its thickness.
- HDPE is interesting for shock and abrasion, but it leads to a shrinkage that may be detrimental to the accessories, and it adds rigidity to the cable, which doesn't facilitate the installation.

Some properties can be improved by adjusting either the type of PE (mono-modal, bimodal) or the extrusion (hot water throw, speed), but the leeway is relatively narrow.

BLENDS OF POLYMERS

In order to overcome these drawbacks, we have developed sheathing materials based on alloys (blends). These alloys contain different polymers in terms of crystalline structure, polarity and viscosity. It is necessary to ensure their compatibility, so that their entropy is not increased in an exaggerated way. To improve the compatibility, specific agents can be added.

These alloys can be manufactured in an internal mixer, which allows to mix thoroughly the different components, or in a continuous-type mixer. Various additives are also added to complete the formulation.

The following table compares the major characteristics obtained on plates with:

- 2 sheathing compounds from the market (LLDPE and HDPE)
- 2 polymer alloys prepared in the laboratory.

	LLDPE Sheath	HDPE Sheath	BLEND A	BLEND B
Tensile MPa IEC 60811-1-1	25.7	31.7	15.7	14.4
Elongation (%) CEI 60811-1-1	980	690	810	755
10d 100 °C ΔTS (%) ΔEB (%)	-10 +14	-17 -4	-12 +6.8	+22 -5
MFI (g/10 min) IEC 811-4-1	2.6	0.85	1.7	2.1
Stress Cracking IEC 811-1-4	Pass	Pass	Pass	Pass
Pressure at 90°C (%) IEC 811-1-3	7	2	6	10
Cristallinity (%)	38	52	28	25
Hardness (Shore D)	51	61	53	49
Water absorption 14 d at 85 °C (mg/cm²)	0.20	0.15	0.35	0.30
Water permeability 75 °C, 90% HR	4.4	3.7	3.8	4.3
Shrinkage on extruded tapes 6 h at 8°C (%)	2.9	4.1	1.1	0.8
Thermal Resistance at 70°C (K/m.W)	2.91		2.48	

Table1: Properties obtained on blends A and B, in comparison with current materials

The results obtained with the two test mixtures show lower mechanical properties than conventional materials, but remain consistent with the values required by the standards. Other properties, like thermal aging, stress cracking and hot pressure test are practically equivalent.

On the other hand there are three properties, different on alloys A and B compared with conventional PE, which are the lower degree of crystallinity, the low shrinkage on extruded tape, and lower thermal resistance, which portends a more efficient cooling Cable. Despite the reduction of cristallinity, the hardness of the material don't decrease to much.

On the blend A, which seems to be very interesting, we have measured the dynamical properties, and observed that in comparison with a current LLDPE sheath,

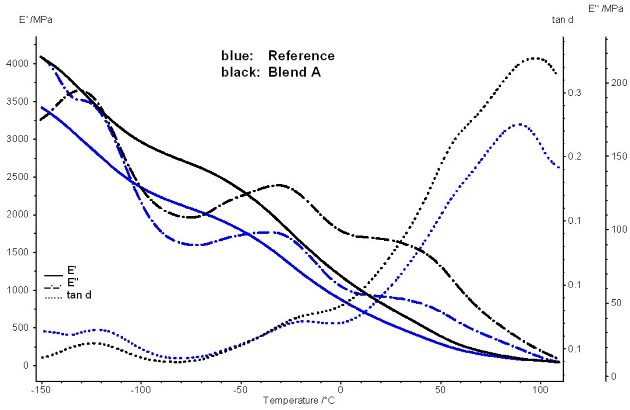

Figure 1: Dynamical properties of LLDPE sheath and Blend A

The elastic modulus E ' between -150°C and +50°C is higher for the blend A than for the reference one. This means that the new material is harder on a wide range of temperature.

- The viscous modulus "E" from -80°C to +70°C is also more important for the blend A than for the reference , indicating a higher mechanical damping for the blend A. This is confirmed by values of tan delta of the blend A which are more important between room temperature to + 100°C.
- No difference in the glass transition temperature is observed

PROPERTIES ON CABLE

For further comparison, we have manufactured 3 medium voltage (12/20 kV) cables to assess the impact of the screen/alloy A complex on the behavior of the product, in comparison with the 2 reference materials LLDPE and HDPE.

The cables are made of an class 2 aluminum conductor, with a section of 150 mm², which is insulated with a conductive layer 0.7 mm thick, an XLPE layer of 4.5 mm, and a strippable external conductive layer of 0.9 mm. The 3 layers are made simultaneously by an extrusion group equipped with a triple head, and then cross-linked by passing through a heated tube under nitrogen pressure.

After cooling and degassing, the insulated core is coated with a alu/PE screen of 150 microns, wrapped longitudinally and covered with a one of the 3 sheaths to be tested. The sheath is adherent to the aluminum screen.

Two different thicknesses were made for each type of sheath (2.2 and 2.5 mm) to check the influence of this parameter.

The most sensitive tests cable are described briefly below

Close and Return

Abrasion test:

A cable sample of 1.5 m is mounted on a rigid base. A metal cone shaped tool, of 90° angle, with a radius of curvature at the tip of 1 mm, and a mass of 12 +/- 0.5 kg is applied on the generating line of the cable overlapping. The tool performs two back-and-forth of amplitude 50 +/- 10 cm at a speed of 0.3 m/s. After the test, the metal screen must not be visible, and the overlapping must not be degraded.

Mechanical shock test:

- A weight of 6 kg drops on a cable sample, with a height of 27 cm.
- The tool has an angle of 90° with a radius of 1 mm.
- 4 shocks are made along the generating line on the overlapping of the screen, and 4 shocks at the opposite.

During the examination, there shall be no tearing of the metal screen and sheath. The deformation of the insulation doesn't have sharp angles.

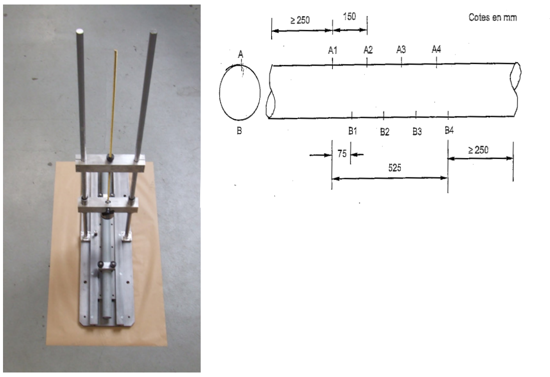

Figure 2: Shock test

Dimensional stabilization test on long sample

A sample of 5 meters is placed on a horizontal plane, one end is blocked, the other free. The sample undergoes cycles of heating 6 h at 105°C followed by 6 hours of cooling. At the end of the test, the shrinkage of the insulation must be less than 2 mm, and the withdrawal of the sheath has to be less than 10 mm.

Figure 3: Shrinkage test installation

Adhesion test between the metal shield and the outer sheath:

This test involves to measure the force required to remove a screen strip of 15 mm wide from the sheath, pulling it at 180° from its original position. No value of the force measured before aging or after compatibility test of 42 days at 100°C must be less than 20N.

Figure 4: Adhesion test

Radial leakage test and corrosion resistance of the metal screen

The sample of 8 meters is wind up, unwind and wind again in the opposite direction 3 times on a mandrel of diameter 20 (D + d).

After this test, four specimens of 1.5 m are cut, protected with caps at their ends, then immersed in saline water at 80°C and the pH is between 8.5 and 9. The test lasts 3000 hours.

Figure 5: Corrosion test

At the end, the cable is opened in 2 parts; the water should not have entered into contact with the three-layer insulation. The overlapping must remain sticked, and the metal screen doesn't present trace of corrosion in visible areas.

The characteristics have been verified on cable according to NFC 33 226.The following results have been obtained:

	NFC 33226	LLDPE		HDPE		Blend A	
Sheath thickness (mm)		2.2	2.5	2.2	2.5	2.2	2.5
Tensile strength (MPa)	>12.5	17.8	18.3	33.7	32.3	16.3	16.1
Elongation at Break (%)	>300	795	824	672	650	730	755
Ageing 42d 100°C ΔTS (%) ΔEB (%)	<30 <30		+12 -9		-14 +9	+9 -7	+17 +14
Sheath/aluminium screen adhesion, before ageing after 42d 100°C	>20 N >20N		31.6 24.5		35.2 28.7	31.5 29.1	32.1 26.3
Fire test 1kW burner			Pass		Pass		Pass
High and Low temperature installation ability			Pass		Pass		Pass
Shrinkage on 5 m cable sample (mm)	<10 mm	5.1	4.5	6.5	7.2	1.9	1.5
Shock test		Fails	Pass	Fails	Pass	Pass	Pass
Abrasion test		Pass	Pass	Pass	Pass	Pass	Pass
Radial water-tightness and metallic screen corrosion resistance			Pass		Pass		Pass

Table 2: Comparison of properties on cables sheathed with LLDPE, HDPE and Blend A

With the blend A, one found on cable a tensile strength lower than values usually encountered with polyethylene, but still very good compared to the standard.

Other characteristics obtained are quite correct, particularly the resistance to thermal ageing, screen-screen adhesion, adhesion between the screen and sheath, even after ageing. The 1 kW flame test and the radial water tightness test and corrosion resistance of the metal screen, are also essential for the durability of the cable.

Looking at the crash test and shrinkage, we see that the results obtained with blends provide an improvement in comparison with the usual PE sheathing, in particular it is possible to obtain a very low shrinkage, which will ensure a optimum behavior with accessories, and a shock resistance optimized, which will reduce the thickness of the sheath.

These results show that by using suitable alloys based on polymers, we can obtain a screen-sheath complex with improved characteristics compared to conventional LDPE or HDPE materials, including reduced thickness, and finally optimized solutions for the design of cables

CONCLUSION

Even if Polyethylene is well developed as sheathing material for underground cables, this study has shown that, by using blends of proper polymers, it is possible to improve the compromise of characteristics of the sheath, particularly on the point of view of shock resistance, and shrinkage behavior

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