Cables for a moving world

TRATOS DEVELOPMENTS

OF HIGH LOAD, LOW SAG, HYBRID CENTRE OVERHEAD LINES

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Case Study: *TERNA, San Pellegrino Pass, Alps*

CONTENT

1.1. Introduction

In many countries the rapidly growing demand for electrical energy has led to the bodies responsible for electrical transmission systems to search for technical innovations which will increase the amount of power transmitted, with improved efficiency, within overall tight budgetary constraints.

There are not many solutions to this complex problem, the obvious ones being either the construction of completely new lines along the existing routes or the replacement of existing conductors with new more efficient ones, having a higher current carrying capacity without the usual corresponding increase in mass because the limiting temperature of traditional designs would mean an increase in size.

The attraction of simply replacing only the conductors in an existing line, lead TRATOS to draw upon its more than 40 years of experience and investment in R & D to develop a completely new, more efficient, hybrid load carrying conductor for overhead lines.

It would obviously be attractive to increase the current carrying capacity of a conductor whose mass is not very different from one of the traditional ACSR (Aluminium Conductor Steel Reinforced) types so as to maintain the same tension applied to the towers but this would lead to an unavoidable problem of increase in the operational temperature leading to damage to the conductor with also an undesirable corresponding increase in the sag.

As the use of traditional conductors is not possible it is therefore necessary to examine other potential solutions.

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1.2. New conductor materials

During the last few years metallurgists have introduced new innovative materials one of these materials is an alloy of Aluminium Zirconium (Al-Zr), this alloy is a high conductivity material with a maximum tensile strength comparable to pure aluminium, more importantly the maximum strength remains unchanged at high temperatures. Using this alloy it is possible to build a conductor with high thermal limits, working at temperatures not attainable with traditional conductors.

Four kinds of Al-Zr alloys have been developed, with the percentage of zirconium determining the thermal resistance. Of these four alloys the two most widely used are AT1, called TAL (Thermal resistant Aluminium alloy) and the AT3, ZTAL (Zirconium ultra Thermal resistant Aluminium alloy). These are included in BS EN 62004 Thermal-resistant aluminium alloy wire for overhead line conductor

Producing the optimum design of a high thermal capacity conductor depends not only on the use of innovative materials it also requires the use of a spatial distribution optimization technique. Spatial optimization consists of making maximum use of the conductive section of the conductor, by removing the free space between the wires in the conductor. This is achieved by using sector shaped wires, instead of traditional circular wires. Conductors made with these sector shaped wire have a naturally compacted formation, characterised by an electric resistance lower than that of a conventional compacted conductor of the same overall diameter.

The use of new innovative, heat resistant materials combined with detailed attention to the overall design is the best way to obtain the greatest increase in the current carrying capacity of a conductor. These can then be used to replace the existing conventional conductors in transmission lines using the existing pylons and towers with the added benefit of a reduction in sag.

1.3. New hybrid load bearing core

Not content with simply replacing the aluminium wires in conventional overhead line conductors TRATOS also considered how they could improve the reinforcing, load bearing core. In the new TRATOS conductor the optimum performance in terms of coefficient of thermal expansion, mass, mechanical strength within compact dimensions are achived by using a composite construction as a load-carrying core for the conductor.

During the four years between 2008-2011 an experimental design of innovative conductor based on thermal resistant aluminium alloy were developed and prototyped using a composite material core based on a special carbon fibre.

Extensive experimental research and development was carried out in order to identify and resolve any potential problems that could possibly arise due to the use of a non metallic material as a constituent part of a conductor operating at high temperatures as, in this field of electrical engineering, there are no existing Standards to refer to.

During this development, using conductors with a hybrid strength carrying core, TRATOS identified two essential limiting conditions; in the presence of humidity, the contact between the carbon fibres and the aluminium could generate an electromotive force that can cause corrosion of the aluminium; also at temperatures higher than 116°C the carbon fibres must be protected to avoid contact with oxygen, as the oxygen could degrade the resin used to bind the fibres, although the actual fibres themselves are not degraded.

Based on these considerations, TRATOS, devised, tested and manufactured the hybrid composites centre, consisting of a central core of pure carbon fibers and an outer layer of high modulus glass yarns applied to prevent any contact between the carbon and the aluminum.

To protect the composite hybrid fibre from premature oxydization, TRATOS has also developed a process of impreganating the fibres with a special, non-migrating, high temperature resistant compound which excludes oxygen from inside of the aluninium sheath. This aluminium sheath is extruded over the nucleus as a plastic material (high pressure, low temperature) in order to provide a tight protective layer.

TRATOS have also developed a range of accessories to be used when installing and terminating these new hybrid load bearing cores to ensure that this high level of protection is maintained.

By way of these solutions, to identified potential problems, TRATOS now have a 3 layer protection system which guarantees the integrity and longevity of the hybrid load bearing core:

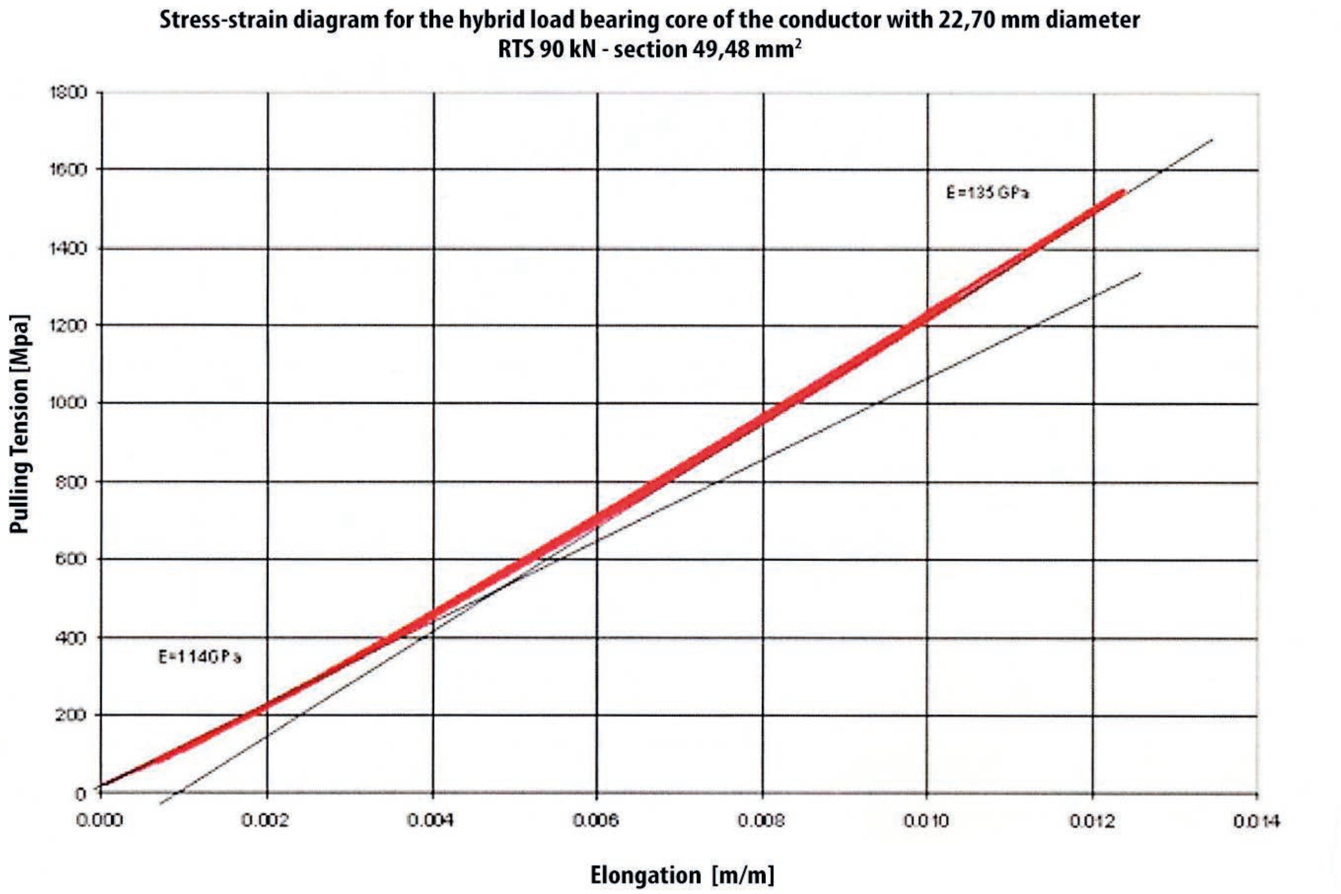
- **Glass fibre on the external layer of the hybrid carbon fibres**
- **A high temperature resistant, non-migratory impregnation**
- **A tight solid wall aluminium sheath**

The mechanical characteristics of these hybrid cores are extremely interesting, when compared to those of the steel or invar; the breaking load is of the order of 200-220 daN/mm2 , the elongation at break is from 1.6 to 1.8 %, the coefficient of linear expansion is 1.04 x10-6 1/ ° C, and the density is1.78 Kg/dm3. Table 1 gives a comparison of the properties of the TRATOS hybrid core with steel and invar.

The study then moved on to evaluate the elastic behavior of the hybrid core this proved that they are absolutely free of any hysteresis areas, behaving as a perfect elastic material.

Table 1

Characteristic	Measurement	TRATOS hybrid core	Galvanised steel	Invar
Breaking load	daN/mm^2	200-220	216	120
Elongation at break	%	1.6-1.8	1.5	1.5
Coefficient of linear expansion	x10^{-6} per ºC	1.04	11.5	2.4
Density (S.G.)	Kg/dm^3	1.78	7.8	8.13



1.4. Service Life

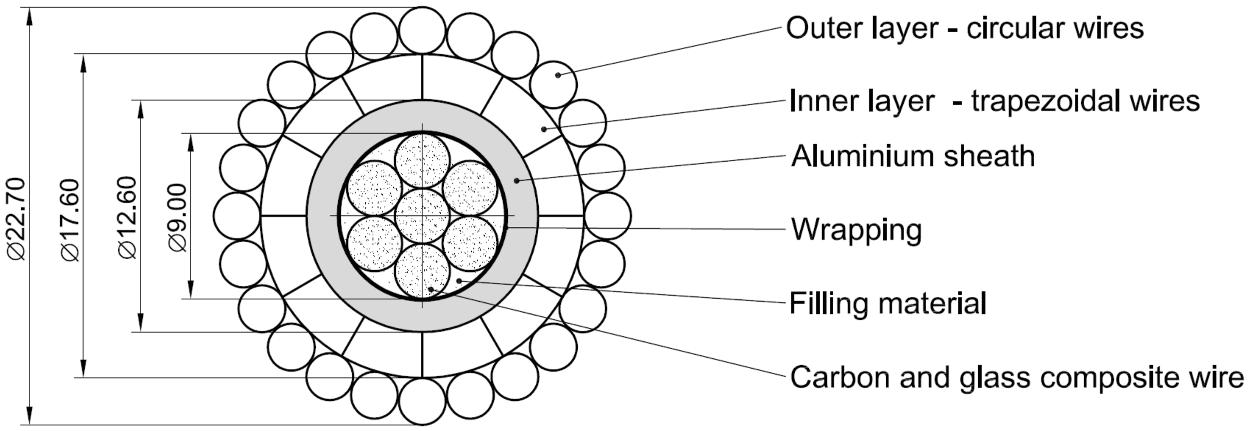
In order to identify the operating temperature corresponding to a continuous service life of 40 years, the long-term thermal aging for the determination of Arrhenius curves, was carried out at temperatures of 203 oC, 193 oC and 183 oC making use of research laboratories of Soficar.

This confirms a continuous service life longer than 40 years at 150 oC (153.5 oC)

1.5. First protype high load-carrying conductor

1.5.1. Design

7x3,00mm carbon fibre centre with a concentric layers of 12 sector shaped and 24 circular alloy TAL wires (d = 2,55 mm), having an external diameter of 22,70 mm



1.5.2. Technical characteristics

Table 2

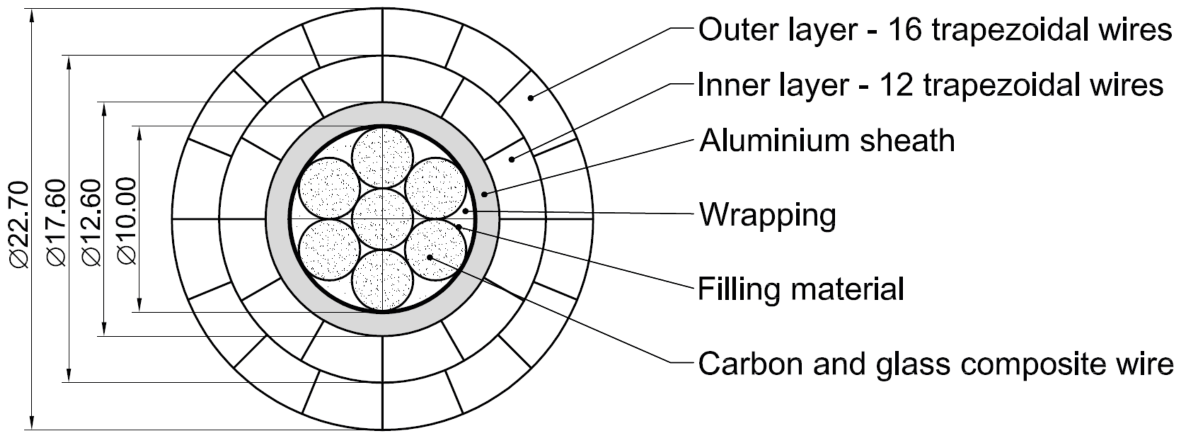
Overall diameter	mm	22,70
Mass	kg/m	0.88567
Load at break	daN	10500
Electrical resistance	Ω/km	0,0998

The conclusion of this development and the extensive laboratory scale testing was the trial installation of this first proptotype conductor on a section of 132 kV line for TERNA.

1.6. Second prototype high load-carrying low sag conductor

1.6.1. Design

7x3,30mm carbon fibre centre, with two alloy-TAL sector shaped concentric layers (12 +16), having an external diameter of 22,70 mm



1.6.2. Technical characteristics

Table 3

Overall diameter	mm	22,70
Mass	kg/m	0,9964
Load at break	daN	10500
Electrical resistance	Ω/km	0,095

In meetings with TERNA it was decided to install this cable in the San Pellegrino Pass in the Alps, on the 132 KV Moena-Cencenighe overhead line, the installation process being comparable with those of a traditional conductor of a similar size. This installation of a conductor at high altitude (2000 m) is a severe test for any conductor, in fact,

A report, prepared by the OEM, clearly states:

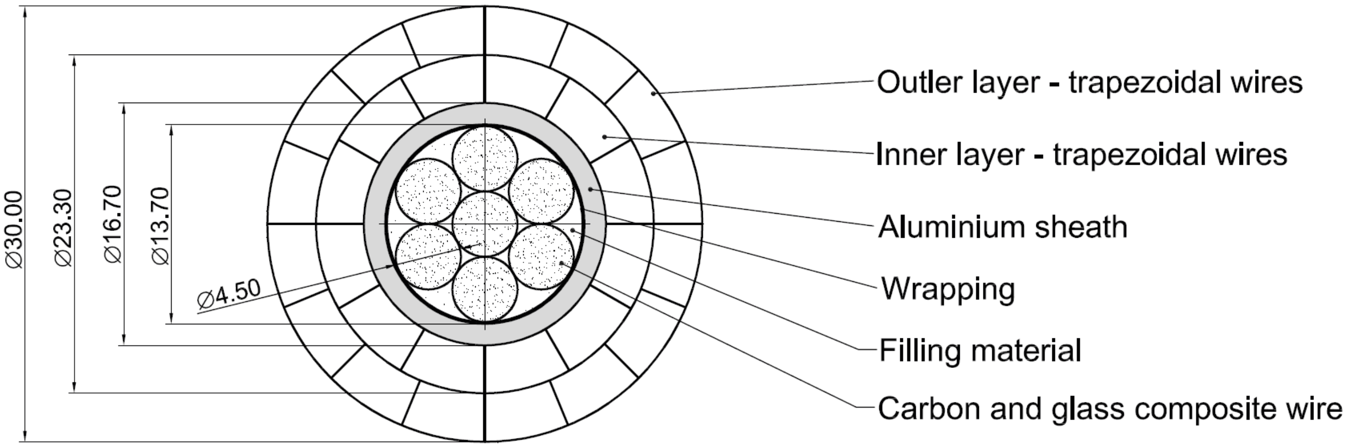
"The installation of the line at high altitude (2000 meters above sea level) is a severe test for the conductor: in fact, at low temperatures the mechanical load is transferred from the carbon core to aluminum alloy coats, determining a state of high stress for the latter. "

This conductor has operated successfully to date without problems.

1.7. Third Development high load-carrying conductor

1.7.1. Design

Single hybrid high load-carrying core of 7x4,50mm carbon fibre centre, with two alloy-TAL sector shaped concentric layers (12 +16), having an external diameter of 30,00 mm



1.7.2. Technical characteristics

Table 4

Overall diameter	mm	30,00
Mass	kg/m	1,74484
Load at break	daN	22000
Electrical resistance	Ω/km	0,054364

1200 metres of this experimental size has already been made and tested successfully in the laboratories of TRATOS and Gorla Morsetterie. In September 2012 it was sent to the Institute Erse for official tests in their System Research Department.

When tested the actual breaking load was equal to 24,000 daN, and in order to provide a solution for higher loads, TRATOS has developed a variation of this rope reinforcing the main core and bringing the outer diameter to 31,50 mm.

This variation has advantages compared to the conductor with load-carrying in ACI, with an outer diameter of 31,25 mm. The most important advantages are the lower ohmic resistance, the higher breaking load and the tension transfer point.

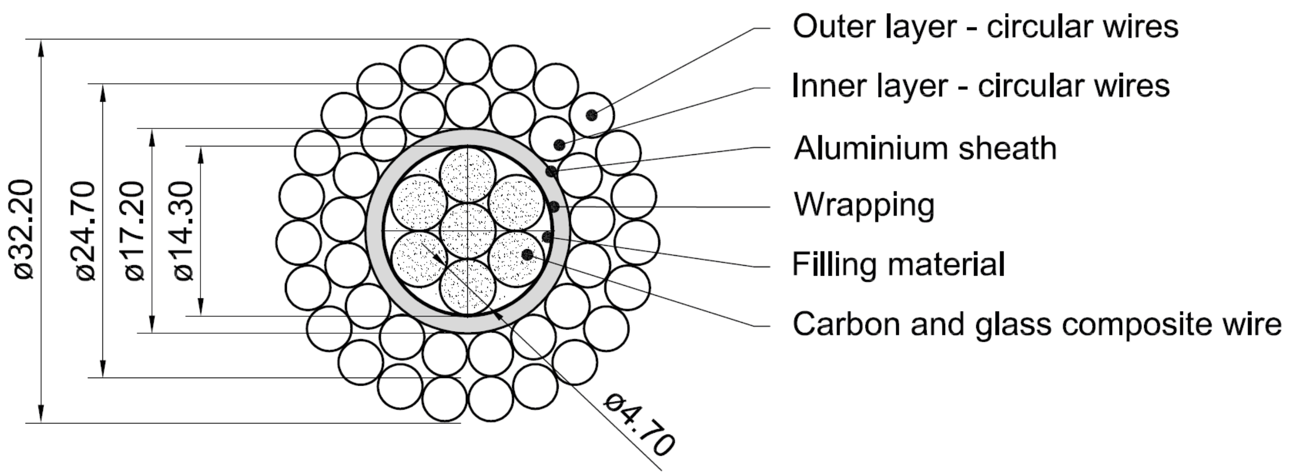
These kinds of ropes are very interesting, allowing a considerably decrease in sag, as from the temperature of 30 -35 ° C the coefficient of expansion passes from the global average value of 14,7 x10-6 to that of the central nucleus of 5.8 x10exp-6.

This conductor could be considered as an alternative to both of the conductors presently used by TERNA, type ACSR, external diameter 31,50mm and type ACI 20 SA core, external diameter 21,25 mm (TACIR)

1.8. Fourth high load carrying conductor

1.8.1. Design

Single supporting hybrid load-carrying composite core of 7x4,70 mm, aluminium sheath and 2 concentric layers of (13+17) circular wires of 3,75 mm, having an external diameter of 32,20 mm



1.8.2. Description of the conductor

This conductor has been ordered by one of the major companies in the overhead cable sector and will be installed over a section of 4.66 km in a 380 kV line, with three conductors in each phase, the total quantity ordered is 42 km.

This type of conductor, using round wires, has been selected from several proposed designs having outer diameters of 30,0 mm and 31,50 mm respectively, for the following reasons:

- **Smaller mass**
- **Reduced corona effect**
- **Reduced sag but with the same tension applied to the pylons**

1.9. Comparison of current ratings, (Calculated using Shurig & Frick formula including solar irradiation)

1.9.1. Comparison of current ratings of the following conductors:

- Hybrid core 7x4,50mm , 2 layers of trapezoidal TAL wires (12+16) , overall diameter 30,00 mm.
- Hybrid core 7x4,70mm , 2 layers of 40 circular TAL wire (17+23) x 3,75 mm overall diameter 32,20 mm
- ACI core 20 SA, 19x3,25 mm, overall diameter 31.00 mm
- Steel core, 19x2,10mm, 3 layers of circular wires 54x3,50mm, overall diameter 31,50.

Table 5

Conductor Diameter mm	30.00		32.20		31.25		31.50	
Core type	Composite core 7x4,50mm		Composite core 7x4,70 mm		ACI 20SA core		Steel core (ACSR type)	
Conductor type	2 layers of sector shaped TAL wires (12+16)		2 layers of circular TAL wires (17+23) x 2.75mm		19x3,25 mm		19x2,10 mm	
Electrical Resistance Ω/Km	R=0,054364		R=0,05712		R=0,06857		R=0,05564	
Temperature of conductor °C	Current (A)							
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
	10°C	30 °C	10°C	30 °C	10°C	30 °C	10°C	30 °C
35	614		363		554		1260	1076
90	1257	1075	1061		1132	968		
130	1521	1391	1504	1376	1371	1255		
150	1630	1516	1612	1500	1470	1368		

Calculated using the following parameters :

Solar radiation	*1000W/m2*
Coefficient of emission	*0,5*
Wind velocity	*2 Km/h*
Atmospheric pressure	*1 Atm*
Coefficient of absorption	*0,5*

1.9.2. Comparison of the sags of the following conductors:

- Hybrid core 7x4,50mm , 2 layers of sector shaped TAL wires (12+16) , overall diameter 30,00 mm.
- Hybrid core 7x4,70mm , 2 layers of 40 circular TAL wire (17+23) x 3,75 mm overall diameter 32,20 mm
- ACI core 20 SA, 19x3,25 mm, overall diameter 31.00 mm
- Steel core, 19x2,10mm, 3 layers of circular wires 54x3,50mm, overall diameter 31,50.

Table 6

Conductor Diameter mm	30.00	32.20	31.25	31.50
Core type	Composite core 7x4,50mm	Composite core 7x4,70 mm	ACI 20SA core	Steel core (ACSR type)
Conductor type	2 layers of sector shaped TAL wires (12+16)	2 layers of circular TAL wires (17+23) x 2.75mm	19x3,25 mm	19x2,10 mm
Pulling load, daN	3539	3539	3539	3539
Pulling load/load at break	0,197	0,192	0.1361	0.2100
Mass, kg/m	1,74484	1,676762	2,240	1,953
Pulling load/mass, m	2030	2110	1586	1812
Span, m	400	400	400	400
Temperature of conductor °C	Sag (m)	Sag (m)	Sag (m)	Sag (m)
15	9,67	9,30		
75	10,24	9,99	14,10	13,31
95	10,43	10,16	14,51	14,07
105	10,52	10,24	14,44	14,44
115	10,62	10,33	14,81	14,81
125	10,71	10,41	15,17	15,17
135	10,81	10,50	15,52	15,52
155	11,03	10,67		

1.10. The Future

The new hybrid load bearing core developed by TRATOS can easily be modified to match the installation conditions, the desired current carrying capacity, the geographical and climatic location, allow an increased span with reduced sag, give a greater margin of safety for wind and snow loads or simply replace existing designs of all metallic conductors with a conductor of reduced mass.

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