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NEW CONSTRUCTIONS FOR NON-ROTATING HOISTING AND BALANCE ROPES FOR UNDERGROUND MINING

Summary. Trefileurope worked a lot, in the past twenty years, to develop new rope products for mine hoisting applications. However we also developped rope products for drum hoists, this presentation is focused on Koepe hoist, which are more common in Europe. The development of our dynamic ropes (head and balance ropes) for Koepe hoists has been done in close collaboration with some of our customers, operating very difficult machines, with the aim to obtain longer service lives with efficient easy-to-handle non-rotating products. This lead us to investigate for head rope products with high potential towards fatigue and tread pressure, as well as dynamic phenomenons.

NOWE KONSTRUKCJE NOŚNYCH I WYRÓWNAWCZYCH LIN NIEODKRĘTNYCH DLA GÓRNICTWA PODZIEMNEGO

Streszczenie. Firma Trefil Europe od przeszło 20 lat prowadzi prace dotyczące nowych konstrukcji lin przeznaczonych do górniczych urządzeń wyciągowych. Dotyczy to lin przeznaczonych do wyciągów bębnowych, a szczególnie lin dla wyciągów Koepe, szeroko stosowanych w Europie. Dynamiczny rozwój konstrukcji lin, szczególnie dla urządzeń wyciągowych Koepe, jest wynikiem ścisłej współpracy z użytkownikami naszych lin wyciągowych nośnych i wyrównawczych w bardzo trudnych warunkach eksploatacyjnych. Celem naszych prac było opracowanie lin konstrukcji nieodkrętnej łatwych w eksploatacji.

The qualitative analysis (given in Part 1) of the results obtained by four different types of head ropes on one of the most difficult existing Koepe hoists shows that the service life is closely linked to the structure and geometry of the ropes.

This mine hoist is one of the ones around which we developped the range of products we are presenting in this communication. We detail hereafter the working conditions of the ropes, as well as the characteristics of the installation.

The different types of head rope are evaluated by the comparison between the number of cycles before removal, asa well as the different tonnages of ore extracted.

The best results have been obtained by our Notorplast head ropes, in which each outer strand has a small plastic core, over a core specially desigh to have the best splitting of the inernal pressures.

We transposed the flexibility properties of this 12 outer strand geometry, over a 12 strand Warrington core, to design all-metallic heavy duty balance ropes, able to operate at high speed with extremely tight D/d loop ratio. These products are called NRHD24.

The service life of our head and balance ropes can still be improved by adapted protective coatings of the wires, either galvanising, or Galfan.

The Galfan coating (Zn 95%, Al 5%), which has a resistance to corrosion between two and three times greater that an ordinary galvanisation of equivalent weight per meter, is an interesting alternative to the heavy galvanising, as presented below.

Some elements about the NRHD24 balance ropes and about the Galfan coating will be found in the Part 2.

These developments have been operational for some years and fully experience-proofed, to the satisfaction of our customers. That is the reason why we are happy to present them in this communication.

Part 1

Notorplast long lasting heavy duty head ropes

This Part 1 introduces the results obtained with our Notorplast head ropes, based on comparative service lives on a particularly difficult hoist.

We also expose the way the different shaft parameters were taken into account when designing the rope.

1. Description of the hoist

This hoist is one of the most difficult machine we know, and has been one of these around which we developped the Notorplast ropes : our customer needed to improve substantially the service life of the ropes on this installation, which is a very importa production shaft.

We present hereafter the results given by four different types of ropes on this installation.

The mine hoist we consider is a single rope skip/skip Koepe with side-by-side sheaves, which is a very difficult geometry, due to the fleet angles combined with high speed and dynamic sollicitations.

The head rope has a length of 930 m. The Koepe and the sheaves have respective diameters of 8 and 7 m. The installation has been designed for a 70 mm dia. rope, on a minimal D/d basis of 100.

The static permanent load is about 30 tons, the skips have a 15 ton payload.

The unbalance on the head ropes is equal to 157 000 N, which is a very high value.

The shaft is dry, constituting an excellent working environment for the ropes.

The geometrical characteristics of this installation, its extraction capacity, as well as the load and working conditions of rope make it one of the most difficult in Europe : the side-by-side location of the sheaves, together with high speed (16 m/s), high acceleration and dynamic effects have a severe influence on the rope service life and endurance.

2. Rope design criteria

The performances of head ropes depend on the specific parameters of the hoist as well as on the general characteristics of the shaft.

It is necessary, when designing a rope for a given type of installation, to consider three main ideas :

- The suspended masses shall be balanced both sides of the installation : this dictates the weight per meter of the rope.
- The safety factors given by the hoist and shaft design and by national safety regulations is the basis of the required MBL of the rope.
- The shape of the Koepe and sheave grooves and the attachment design usually restrict the acceptable range for the rope diameter.

In the case which is presently under consideration, the adoption of a 1960 N/mm^2 grade impose a metallic cross section of approx. 1980 mm^2, and a rope diameter between 70 and 74 mm. This allowance offers many possibilities for the definition of the rope structure, the gap between the strands, the shape, size, and type of inserts between the various layers of strands.

If the clearances between the various strands and layers are important, the compressibility of the inserts greatly influences the rope elongation. This is associated with a decrease of the diameter.

The torsional behaviour of the rope is also of prime importance on single rope deep hoisting installation. High torques developped bt classical ropes can severely affect the guidance system, provocating excessive wear. These torques may also complicate the shortening the ropes. High torques can also lead to a rope kinking, during operation, due to dynamic effects on the ropes.

All these considerations eliminate any 6 strand design for this particular hoist, due to the high torque generated by these ropes.

The 8 strand semi-balanced constructions maybe suitable for deep hoisting as far as they do not induce problems on the guiding systems. They have been used by us as welle as by competitors on the considered shaft. However, and compared to 6-strand ropes, precautions are still required either when installing the ropes in the shaft, or when shortening them.

We have been convinced that, for these reasons, the best solution was to look for torque balanced constructions.

There are different solutions to achieve this. However, for safety and service life reasons, it is necessary to develop other solutions than the classical 17, 18 or 34 classes, which usually have internal wire cross nickings.

That is why we developped our Notorplast (head ropes) and NRHD24 (balance ropes) type of ropes, to associate high safety and service life (linear internal contacts between the outer strands and the core) with non-rotating properties.

This development has been made on the shaft and hoist which are pesented above, in close relationship with our customer.

3. Types of ropes tested

During the development of our Notorplast and NRHD series, four types of head ropes have been used on this hoist.

Rope Type 1 : It is an 8 outer strands, Right Lang lay, on 1+6 strand cross lay IWRC. Ropes with 37-wire and 47-wire outer strands have been tested, with respective outer wire diameters of 2,80 and 2,60 mm. However, the outer strand construction does not have any influence on the global behaviour of the rope.

Rope Type 2 : Multistrand rope Right Lang lay with flat strands. This rope has eight outer strands, a Left Lang lay 6-strand under layer, and a 5-strand center. The outer wires have a diameter equal to 2,80 mm.

Rope Type 3 : It is an Right Lang lay 18-strand rope, over a 6-strand cross lay under layer, over a 6-strand Right Lang lay mixed core. The outer wires have a diameter equal to 2,95 mm.

Rope type 4 : (Notorplast / Trefileurope) : 12 outer strands, Right Lang lay, each of these strands having a central pastic insert, over a Left Cross lay Warrington core. The four innermost strands are Right Lang lay. The outer wires have a diameter equal to 2,90 mm.

4. Endurance of rope types 1 to 4

We give hereafter, for each type of rope, average performances claculated on the three best service lives. The figures are given by number of cycles (one cycle being from the loading to the unloading of one skip), and tonnages extracted.

The discard criteria were those of the french RGEM (General Regulation for Mining Exploitation) national regulation.

Ropes	Number of cycles	Extracted tonnage (millions metric tons)
Type 1	286 000	4,3
Type 2	333 000	5
Type 3	120 000	1,8
Type 4	495 000	7,4

The best performances obtained are as follows :

Ropes	Number of cycles	Extracted tonnage (millions metric tons)
Type 1	326 000	4,9
Type 2	373 000	5,6
Type 3	120 000	1,8
Type 4	746 000	11,2

This last result, for rope type 4, constitute the longest service life never obtained on this installation.

5. Quantitative analysis

Rope Type 1 :

This rope has the smallest surface contacts with the Koepe and sheave grooves. The corresponding radial pressure is the highest, compared to the 3 other types of ropes.

Thanks to the mixed core, there is a good pressure repartition inside the rope. Furthermore, the contacts between the outer strands and the core are linear.

However, due to the compressibility of the core, the gap between the outer strands quickly diminish when operating, and is later reduced to zero. A deterioration process then begins, by contact between outer strands.

Despite of this, the first generations of this type of rope finally perished by core breaks and global deformations. From these facts, the designers of these products tried to obtain a better compromise between various parameters : gaps between outer strands, stranding angles, volume and compressibility of the core. The aim was to reduce the vulnerability of the core, and hence, to obtain longer service lives.

Rope type 2 :

This rope has a large surface of contact with the Kope and sheaves. The radial pressure on the rope is low , and the compressibility of the various inserts allows for a good pressure repartition of this pressure inside the rope.

However, for this type of rope as well as for type 1, the gap between the outer strands reduces notably during operation; indentation also appear between outer layer and under layer strands (Right Lang lay / Left Lang lay). The deterioration process generally begins on these contact points.

As a consequence, the performances obtained are only a little bit better than for rope type 1.

Rope type 3 :

It is with this type of rope that the worse fatigue life results are obtained.

Although the 12 outer strands allow for a better pressure repartition on the rope surface, and a good diffusion of this pressure inside the rope, the low compressibility of the steel core, associated with a low quantity of inserts between the various strands and layers do not allow for any radial displacement of any component.

Indentations on steel on steel contacts appear, and the degradation process quickly goes on.

Rope type 4 :

When designing this type of rope (Notorplast / Trefileurope), we tried to take into account the various input data.

The plastic inserts inside the outer strands give them a possibilty to deform when passing over the Koepe and sheaves, which optimizes their contact with the grooves, and lower the contact pressures as much as possible.

The core is based on a 12-stand Warrington construction. This allows for a very good repartition of the pressure inside the rope. This also allows for linear contacts between outer wires of anly layers of strands. There are no indentations or cross nickings.

Carefully chosen fiber inserts take place at the interface between the core and the outer strands, to lower the contact pressure in this area.

The follow-up of these ropes, as well as their careful dismantling and inspection after removal show a slow and progressive wear, with broken wires distributed on the various layers of strands, preferentially in the pick-up area.

During the developement of this product, the NDT inspection of the multi-layer stranded ropes has been carried out by the mine, with excellent results and reliability.

This helped also a lot in the promotion of this type of head ropes for Koepe hoisting, as tools for performance and cost efficiency.

6. Conclusion

In all cases, the fatigue life essentially depends on the geometry of the contacts between the wires inside the ropes, as well as on the distribution of the radial pressure.

The rope construction shall aim at the best pressure reduction and distribution.

The Notorplast head ropes give a very interesting answer to the rope service life and endurance problems, as demonstrated above.

Please find also hereafter some other results very recently obtained :

Location	Type of hoist	Tonnage extracted (metric tons)
Buchanan Mine Consolidation Coal, USA	**Ground mounted Koepe, superposed sheaves**	**22 400 000 tons** approx. 900 000 Skips
Agrium Potask Saskatoon, Canada	**Tower mounted Koepe, deflection sheaves very close to the Koepe**	**11 850 000 tons** approx 425 000 skips

Part 2

Further proposals by Trefileurope for mine hoisting

NRHD24 Balance ropes galfan coating

Although we worked a lot on the head rope geometries, we also tried to give proper answers for other aspects of mine hoisting.

The engagement we have had for years in this field also gave us many opportunities to work on balance rope design, and on the wire coatings.

1. NRHD24 balance ropes

We developed this type of rope, which is now the solution retaiend by our customer, on the same shaft than the one presented in part one.

On this shaft, the loop diameter is only of 1,1 meter. There is only one balance rope, nominal diameter 70 mm, the speed being equal to 16 m/s.

These very difficult conditions (loop D/d ratio as low as 15,7) lead to a lot lot of unstability of the loop as well as to reduced service lives when using standard balance ropes.

It is clear that in these conditions, the 17 and 34-strand classical balance rope constructions are greatly handicapped towards fatigue life.

We tried, with the NRHD24 type constructions, to notably improve the flexibility and the service life of the ropes, ensuring at the same moment the stability of the loop.

This construction is based on a global geometry similar to the one of the Notorplast head ropes, but without plastic inserts in the outer strands : as the rope never goes on any sheaves, these would not be of any use.

The interface between the core and the outer strands is identical to the one of the Notorplast ropes described in part one, and is based on linear wire contacts. This interface is also protected by carefully chosen fiber inserts.

2. Individual wire Galfan Coatings

Both Notorplast and NRHD24 rope construction can be manufacured with Galfan coated wires.

This Zn95%/Al5% coating has a durability 2 to 3 times greater than a classical galvanising when the wires are exposed to normalised salt spray tests.

These allowed us to solve difficult corrosion problems for some of our customers.

General conclusion

We tried to give, in this presentation, an overview of the development we made in the last 15 years about mining ropes for Koepe applications.

During this time, we focused on the various qualities that make a rope user-friendly :

- Easy to handle and to operate
- Long lasting

We are happy to present you our experience about these products.

We think that, further than any detailed technical considerations, they fulfill the two major requirements of our customers.

Recenzent: Dr inż. Alfred Carbogno

Omówienie

Trefil Europe od przeszło 20 lat prowadzi prace dotyczące nowych konstrukcji lin przeznaczonych do górniczych urządzeń wyciągowych. Dotyczy to lin przeznaczonych do wyciągów bębnowych, a szczególnie lin dla wyciągów Koepe, szeroko stosowanych w Europie. Dynamiczny rozwój konstrukcji lin, szczególnie dla urządzeń wyciągowych Koepe, jest wynikiem ścisłej współpracy z użytkownikami naszych lin wyciągowych nośnych i wyrównawczych stosowanych w bardzo trudnych warunkach eksploatacyjnych. Celem naszych prac było opracowanie lin konstrukcji nieodkrętnej łatwych w eksploatacji. Trwałość lin zależy między innymi od konstrukcji lin. Zaprojektowano liny nieodkrętne o wysokiej wytrzymałości na zmęczenie i odporne na naciski w rowku wykładziny. Dobre wyniki osiągnięto przez zastosowanie lin typu Notorplast, w których splotki zewnętrzne posiadają rdzenie z tworzywa sztucznego i ułożone są na rdzeniu (wewnętrznej warstwie splotek) odpornych na naciski. Nasze liny nośne i wyrównawcze nieodkrętne wielowarstwowe charakteryzują się dużą giętkością, co sprzyja ich eksploatacji przy małym parametrze D/d, tj. na stosunku średnicy pętli liny D do średnicy liny d. Lina o tych cechach określona jest jako lina konstrukcji NRHD24. Trwałość lin można zwiększyć przez zastosowanie powłok ochronnych drutów liny. Może to być powłoka cynkowa lub z Galfanu (95% Zn i 5% Al). Doświadczenia wykazały, że powłoka z Galfanu zwiększa odporność drutów na korozję od 2 do 3 razy w porównaniu z powłoką cynkową.

This communication includes information about head ropes already published in the OIPEEC bulletin, N°70, 1995, by Jean-Pierre Damien, Trefileurope, and Prof. Jean-Michel Terriez, Université Joseph Fourier, Grenoble (France), notably the comparative data for head ropes.

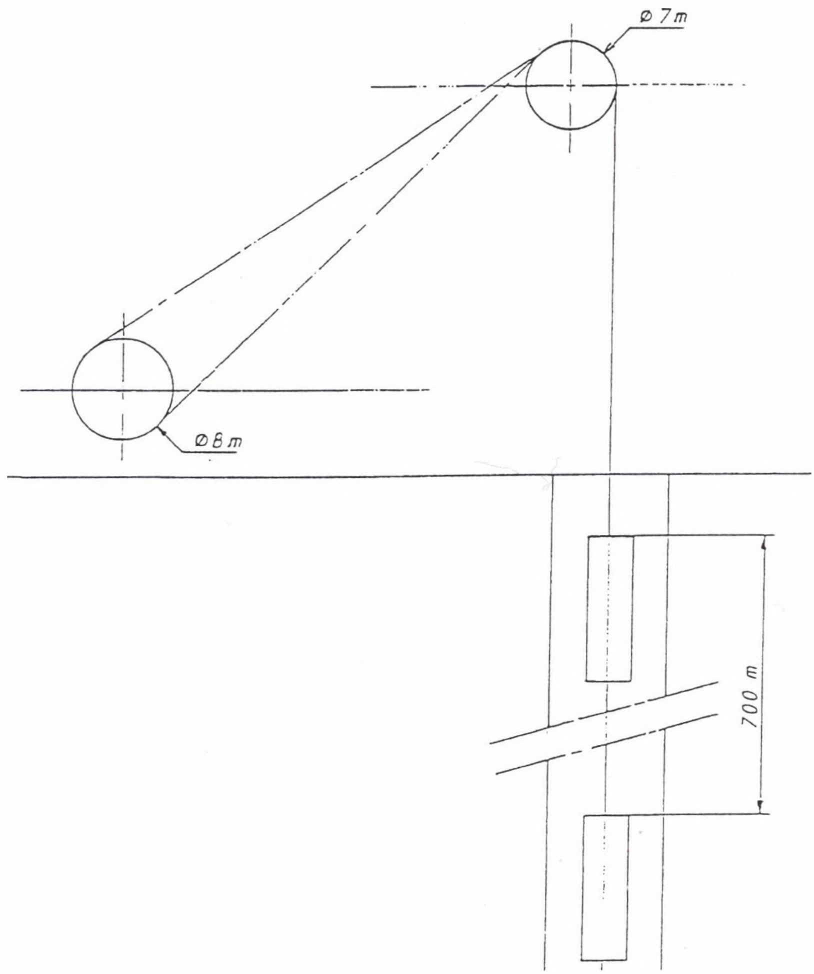

Fig.1. Two identical hoists in the same shaft
Rys.1. Schemat urządzenia wyciągowego

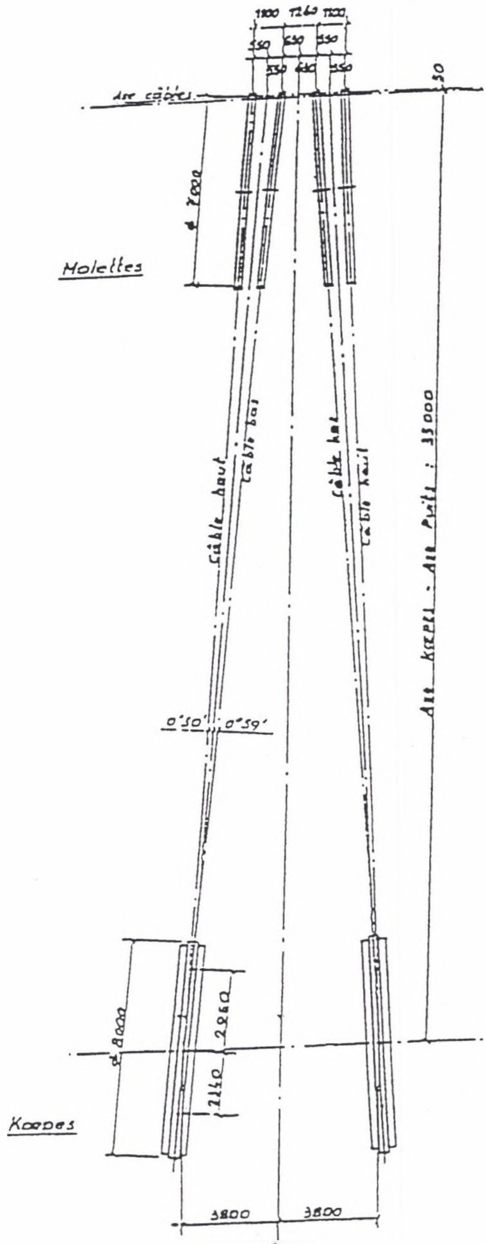

Fig.2. Two identical hoists in the same shaft
Rys.2. Usytuowanie kół zębatych względem szybu

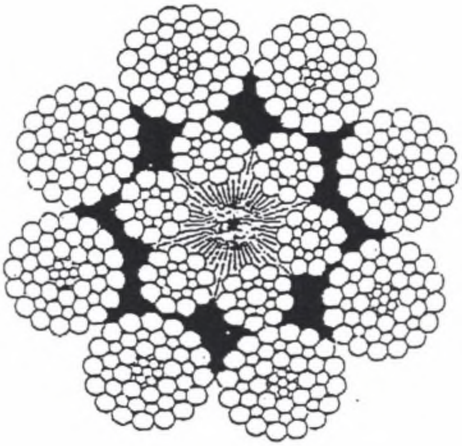

Fig.3. Part 1: Rope Type 1
Rys.3. Część 1. Lina konstrukcji nr 1

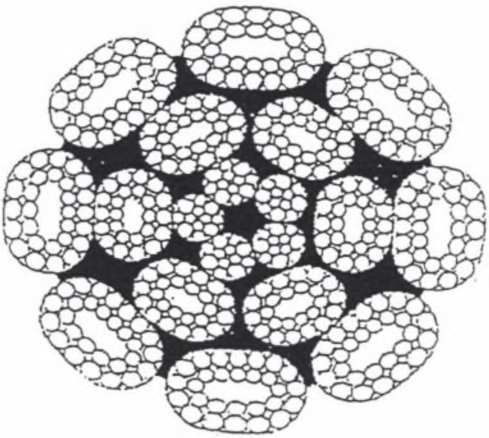

Fig.4. Part 1: Rope Type 2
Rys.4. Część 1. Lina konstrukcji nr 2

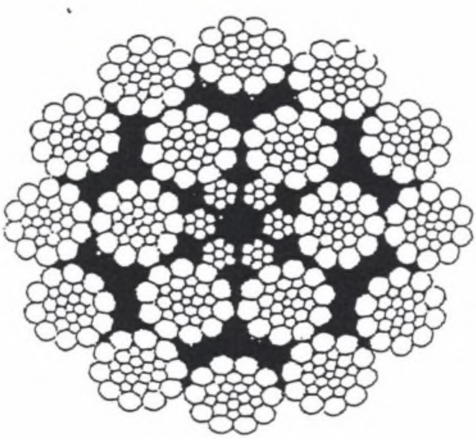

Fig.5. Part 1: Rope Type 3
Rys.5. Część 1. Lina konstrukcji nr 3

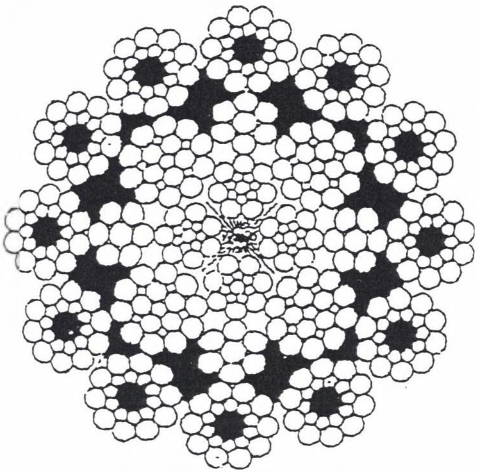

Fig.6. Part 1: Rope Type 4
Rys.6. Część 1. Lina konstrukcji nr 4

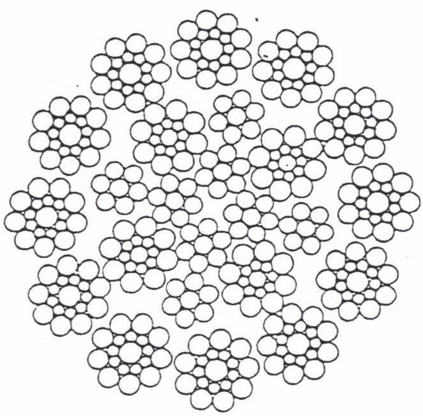

Fig.7. Part 2: Trefileurope NRHD24 Balance Ropes
Rys.7. Część 2. Lina wyrównawcza wielosplotkowa nieodkrętna konstrukcji NRHD24