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FACTORS DETERMINING HOISTING SHAFT ROPE DURABILITY

Michał Styp-Rekowski[1)], Eugeniusz Mańka[2]

[1)]University of Technology and Life Sciences
Prof. S. Kaliski Av. 7, 85-789 Bydgoszcz, Poland
tel.: +48 52 3408623, e-mail: msr@utp.edu.pl
[2)]Research and Supervisory Centre of Underground Mining Co.Ltd.
Lędzińska str. 8, 43-143, Lędziny, Poland

Abstract

The paper deals with factors determining the run and intensity of the wear-out process of mining hoist mechanisms. On the basis of the carried out experimental tests of a balance rope being a part of such a mechanism it was proven that conditions of the rope operation have a great influence on the kind and effects of its wear-out process. It was found that the basic cause of the rope strength features degradation is electrochemical corrosion and particularly – a chemical variant of this process. Of course, tribological wear is observed too.

Keywords: *rope, hoisting shaft, durability, operation environment*

1. Introduction

The wear process each of machine elements result in degradation of strength features of the material from which are made these elements or machines, generally referred to as technical objects. Exceeding permissible values of features which are significant in terms of the object operation (diagnostic symptoms) causes its transition from the fitness for use to unfitness for use state [2]. In case the fault is of permanent character the object life is affected, as well. Such a sequence of events and their results mean that the main goal of each technical object user is to reach the features boundary values over possibly the longest time, which means obtainment of its possibly longest life. The destruction process occurs in result of the technical object being influenced during its operation by different forcing factors such as: excitation forces, heat and chemical processes. In many cases, the listed above factors act simultaneously contributing to the wear-out process. Such a situation occurs when the object is used in a chemically active environment, for instance machines operating in mines. Tests proving rightness of this thesis were carried out with the use of a shaft hoist

In presented paper, tests of balance ropes of a mining hoist, shown in Fig. 1, have been discussed. The main practical aim of conducted research was to confirm the rightness of the decision concerning an exchange of a used rope for a new one, whereas the cognitive goal was to determine the causes of its accelerated wear-out. Achievement of both goals will be of great practical importance as the tests results will make up a database useful for making similar decisions in the future; besides, they may provide information for users how such mechanisms should be operated.

2. Object of investigations and its operation conditions

The durability of balance ropes operating in mining hoists depends mainly on synergy of such constructional factors as: material of wires and the rope core and characteristics of the used lubrication substances. Also, important are lubricants of the core and the wires used during the rope production process, the rope length of lay, its relief and untightness [1]. In case of mechanisms of ropes used in mining, especially underground, whose scheme is presented in Fig.1, a significant factor affecting their life is the environment in which they operate. For ropes operating in a strongly corrosive environment, this is the wire coating that is of primary importance, including: thickness, uniformity, and adhesion of the anti-corrosion coating to the wires throughout their length.

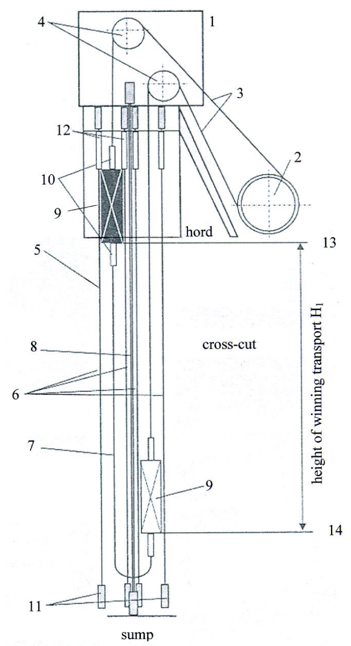

Fig. 1. Structural scheme of a shaft hoist: 1 – hoist tower, 2 – hoist wheels, 3 – lifting ropes, 4 – steering wheels, 5 – shaft, 6 – guide ropes, 7 – balance rope, 8 – fender rope, 9 – hoisting vessels, 10 – suspension gears, 11 – guide ropes weights, 12 – emergency breaks device, 13 – upper loading level, 14 – lower loading level

Confirmation of the influence of the work environment on the wear process intensity needs the tests of a mining hoist balance rope. Its basic, catalogue parameters are as follows:

- type (the rope marking): 45,0-33x7+A0-Z/z-n-N–G-1180-ZN-80/019-5021-170,
- the rope structure: 6x7x2,30+11x7x2,30+16x7x2,30,
- bearing cross-section: 959,80mm2,
- nominal mass of 1 meter: 8,9kg.

The tested rope was characterized by the below strength features:

- tensile force the whole rope: 1009,00 kN,
- tensile force wires according to the manufacturer: 1286,23 kN,
- tensile force wires according to the user: 1273,47 kN,
- safety coefficient for start of operating: 13,23.

Conditions in which the tested rope operated is defined also by the below, selected operation values:

- the rope maximum static loading: 76,256 kN,
- the rope length from the upper location of the vessel to the return: 870 m,
- kind of grease used for maintenance: Nyrosten N113.

In the presented case, the rope was operated in a medium – wet, downcast shaft, used both, for transporting materials and people. The torsion transmission drive was provided by a double rope lift machine situated on the hoist horst. In order to balance the static moment on the machine shaft, two round balance ropes were applied ϕ 45 mm. The hoist depth was 850m. whereas the rope maximum length, from the rope wheel axles to the head of the cabin on the coal pit, was 883 m. After about 32 months of operation with an average work intensity, about 200 extractions per 24 hours, the rope executed approximately 64000 cycles and due to the safety factor decrease by approximately 29,5%, it was exchanged.

It should be mentioned here that the mean operation time of previously used ropes was 42 months, which was about 30% longer than the operation time of the research rope.

3. The experimental rope investigations

The standard procedure concerning research of ropes consists of three kinds of tests: organoleptic, magnetic and fatigue ones, and this is the order in which they will be discussed in this paper.

Fatigue tests results are of special practical value, as being of destructive character – they can be carried out only on a rope which had been removed. On the basis of their results it is possible to define explicitly and undoubtedly the degree of its destruction and its strength features decline which is a criterion important for making decisions on further destination of the hoist critical element. The above listed factors make the fatigue tests the most informative [5, 9].

3.1. Organoleptic tests

As the result of a carried out inspection, there was found a deep corrosion of the external layer wires spreading onto the inner layer wires, especially on the return sections – when the hoist cabins were at the level of 850m. below the vessels. Traces of the corrosion related wear-out process are shown in Fig. 2, where a fragment of a partly unlaid rope has been presented.

Fig. 2. Some fragment of the rope before the tests with visible corrosion

After being dismounted, the rope was found to have local losses and losses in solding, though on not more than three wires of the external and internal layers, at the length equal to the rope seven diameters (~270mm.). Material losses in the wires due to friction and dents at the place of the layers contact, were not found.

After being cleaned, the broken wire of the external layer had a diameter about 2,0 mm. which means a decrease in the wire diameter by 13% compared to new wires and respectively, 24,4% decrease in their cross-sections. However, a visual examination revealed that the discovered loss was not caused by a friction wear-out but rather by corrosion whose effects were partly removed by cleaning.

3.2. Magnetic tests

Magnetic tests are not of destructive character and therefore are especially advised in cases when it is necessary to make a decision on the rope mechanism further operation. Places of the rope biggest weakening and their intensity can be indicated with high precision (of course accounting for the object size) [3,7,8].

A fragment of the test result records has been presented in Fig.3. The record concerns the rope sections in the places of its returns (from 10 to 30 meters) under both cabins.

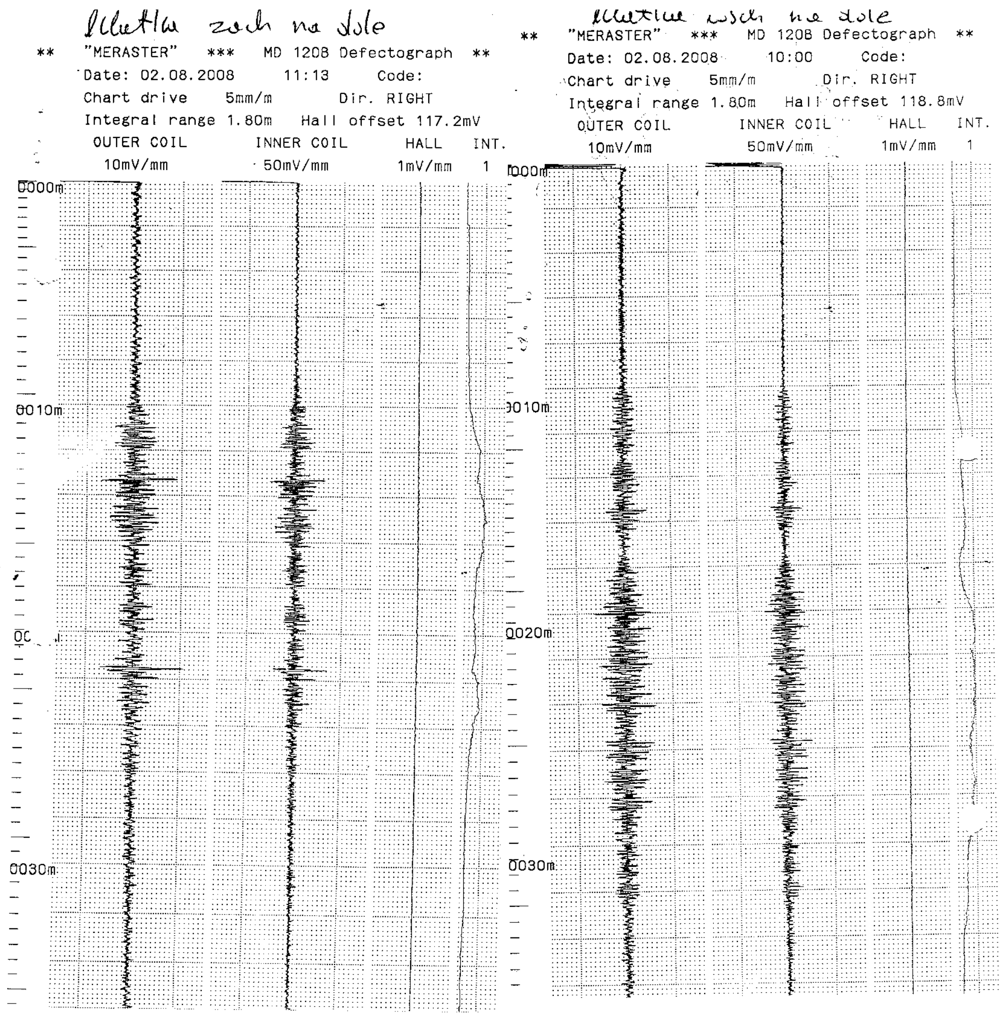

Fig. 3. Records of results of ropes magnetic tests n the place of the rope biggest weakening (the test parameters in the head of the record)

On the ground of the calculations using the indications of the internal coil integrator [3,10] it was found that losses of the metallic section (sum of cross-sections of particular wires) range from 15,1 to 29,5%, compared to a new rope. The rope changes (losses in the cross-section), found on the basis of magnetic tests, confirm the earlier observations – made during organoleptic tests.

3.3. Fatigue tests of the examined rope wires

The wires were tested in Non-destructive Research Laboratory of Research and Supervisory Centre of Underground Mining in Mysłowice. Break tests were performed on fatigue machines of the type FM - 1000 manufactured by Rauenstain Company and the type 10/Z1032 by Amsler. The range and methodology of the breaking, bending and torsion tests were carried out according to the binding norms, including [6].

Wires of an untangled, two meter long section of the rope, coming from the return under the eastern case, were tested. The tests covered 100% of the wires which had been straightened, cleaned from the lubrication and partially, mechanically- from corrosion products – Fig.4.

a)

b)

c)

d)

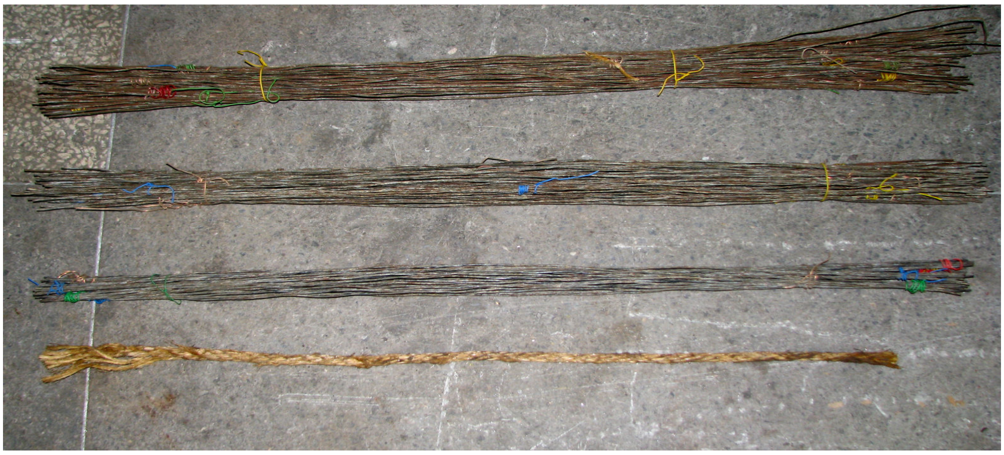

Fig.4. Prepared for tests segments of wires of the rope layers: a) external, b) central, c) internal and d) core

Tensile Tests

Describe below tests, like the following ones (bend, and torsion ones) were conducted on samples which came from different layers of the rope: external, central and internal.

The tensile tests carried out in particular layers of the rope revealed that only 16 wires of the external layer did not meet the requirements of the standard on the minimal tensile force. The total tensile force for the old (used) rope, obtained during tests, was 1 220 490N, whereas this force for the new line was 1 286 230 N. Thus, the difference in values (loss) accounts for 5,11% of the initial value.

The total tensile force, according to the manufacturer's certificate, is a value calculated from the formula:

$$P_{zr} = \frac{\sum_{i=1}^{i=99} P_{zri}}{99} \cdot n_d \ , \qquad (1)$$

where:

P_{zr} – the rope tensile total force, N,
P_{zri} – tensile force of individual wire, N,
n – number of wires in the tested rope

The average value, determined from a 99 element sample is consistent with requirements of the standard for ropes of II class [6].

Bend Tests

In a two direction bend test, the minimal number of bends for all wires is 12. The conducted tests showed that not all of the represented layers fulfilled the fatigue criterion, whereas changes which occurred in particular layers were of diversified character:

- from 112 wires of the external layer, 26 (23,2%) did not meet the required criterion,
- from 77 wires of the central layer, 21 wires (27,3%) did not withstand the required number of bends, for the internal layer – only 5 (11,9%) in 42, did not meet this criterion.

Overall, 52 wires out of 231 wires making up the whole line did not meet the standard requirements, which accounts for 22,5% of all wires.

Torsion Tests

The required number of torsions for a standard torsion test, for wires of all the layers, is 16. Like for the bend tests, the number of wires which did not meet this criterion was different for each layer. The results of these tests were as follows:

- in the external layer none of the 112 wires completed the required number of torsions,
- from 77 wires of the central layer , 67(87,0%) met the criterion,
- in the internal layer 10 wires, out of 42 (23,8%), did not meet this criterion.

Totally, 189 out of 189 wires of the tested rope did not meet this criterion, which accounts for 81,8% of all the wires.

4. Analysis of tests results and their interpretation

Results of the tests described in the previous section are taken down in Table 1. They show the picture of strength features changes for wires making up a tested rope, and indirectly of the whole rope. Weakening of the whole rope strength features is mainly caused by the conditions in which the rope operates [4,10]. The places of the rope biggest weakening occur in its return points – when cabins are in the lowest or highest positions – see Fig. 1. In these places, during stops (loading or unloading) the rope stands still and is affected by environmental factors such as humidity getting through the hoist walls and gases contained in the resource. Chemical aggressiveness of gases which make up one of the rope environment elements, depends on the kind of shaft **,** whether it is a downcast or upcast shaft, and it is higher for the latter one. In these places ropes are exposed to mechanical damage by pieces of coal. The factors listed above, cause that the wear-out process occurs faster in such places than in others.

Table 1. Statement of strength tests results for the rope wires

Rope tested fragment	Total number of wires	Bend test		Torsion test	
		number of wires which do not meet the criterion	percentage of changes(losses) %	number of wires which do not meet the criterion	percentage of changes(losses) %
External layer	112	26	23,2	112	100,0
Central layer	77	21	27,3	67	87,0
Internal layer	42	5	11,9	10	23,8
The whole rope	231	52	22,5	189	81,8

Corrosivity of operating environment for mining mechanisms can be well reflected not only by rope but also by traces of corrosion on the hoist structure – see Fig.5. Thus, it can be said with high probability that one of the causes of the rope weakening is the influence of the environment factors. This can be proved by the fact that the external layer of the rope was more damaged that the other ones which results from its being more exposed to the environment components which appear in the form of moisture and gases.

Fig.5. Fragment of the shaft bearing structure with visible traces of corrosion

Analyzing forms and effects of the environment factors, it can be said that the products of corrosion observed on the surface of the rope and its particular wires are the effect of mainly electrochemical corrosion. Accounting for the operation conditions of the rope mechanisms it can also be stated that corrosion products occurred in result of formation of many oxygen micro-cells which appeared in places where water particles settled on the rope.

The fact that in the environment of mining machines operation (especially upcast shafts) there also occurred numerous elements which when mixed with air and moisture, created a reactive medium and generated chemical corrosion which undoubtedly intensified the corrosion process. In order to be able to estimate the share of particular kinds of corrosion in the rope destruction process it would be advisable to make a detailed chemical analyses, though their results would be of minor importance for the considered issue.

The influence of excitation forces, in case of balance ropes, is less significant in terms of their wear [4]. As observed earlier, the task of balance ropes is to balance the static moment coming from bearing ropes weight. The value of this weight, dependent on the rope length and unit weight, is rather small, compared to the loading (about a few percent), therefore, this factor contributes to the line weakening only insignificantly.

5. Closure

The carried out tests allowed to formulate a series of conclusions concerning the wear-out process of balance ropes used in a mining hoist mechanisms and discover the consequences of this process, the most important ones being:

- the wear process of the tested balance lines is of corrosive character, with the biggest share of electrochemical corrosion,
- forces acting on the ropes do not have a significant influence on the wear-out process intensity.

The observations made during the tests, concerning the wear-out process effects, are also results of the research, they include:

- corrosion traces are unevenly distributed along the rope: there are more on the external layer wires than on the internal and central ones,

- the rope biggest weakening was located in its reversal points – in these points destructive factors affect the rope most heavily.

Thus, the main goal of the research has been achieved, that is, it has been proved that the decision on the rope removal from operation was right as it lost its operational features to a degree which justified such a choice.

Another important effect of the carried out research on the rope methodology is a possibility of verification and comparison of results of different kinds of tests: organoleptic, magnetic and fatigue ones. The results of such actions can be used for informativeness improvement of noninvasive rope tests which, in turn, can improve safety of the mining rope mechanisms operation, even for an increased resurse [2].

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