The Application of the Magnetic Method in Investigation of Ropes Used in Mine Pit Shaft Hoists

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Abstract: Hoisting ropes, depending on their destination, can be divided, among others, into lifting ones, balance ones, guiding-and-lifting ones, guiding ones, fender ones. Methods of assessment of the technical condition of steel ropes have been described in the paper. The results of investigations of the processes of wear of exploited ropes with using magnetic method have been presented. Complete or partial cracks of individual strands in the internal layer of the ropes were identifying.

Keywords: magnetic methods, steel ropes

1 INTRODUCTION

Many companies look for new, optimum technological solutions useful in designing large dimension constructions. Application of steel ropes used, for example, in mining pit shaft hoists, setting radio masts, forest observatories, suspension bridges, as well as production hall roofs are here useful. When selecting a steel rope for a given device, one should consider many factors, i.e. the kind and type of the device and the conditions in which the subject rope is to be exploited. The essential element of a rope is wires which, interwoven into strands and cables around the common root, make the proper rope. Due to their mass, flexibility, variety of designs, ropes made of steel wires have found application in many branches of industry. Those are, among others: underground mining (shallow pit shafts and the deepest ones in the world), drilling platforms and devices, harbours, conveyor tapes with steel ropes, building (cranes, elevators), even car tyres and dentures.

Hoisting ropes, depending on their destination, can be divided, among others, into lifting ones, balance ones, guiding-and-lifting ones, guiding ones, fender ones. Hoisting ropes do not have to be accepted by the Technical Supervision Office. Each hoisting rope should be in conformance with the documentation of the pit shaft hoist and possess its producer’s attest. A hoisting rope is a one used to pull hoisting vessels and counterweights in vertical and inclined pit shafts. The most commonly used ones are ropes with round or triangular strands. A balance hoisting rope is a one linking the bottoms of hoisting vessels (or of a vessel and counterbalance). Its destination is balancing the mass of the lifting rope. A guiding rope serves for guiding the vessels (counterweights) in the pit shaft. In auxiliary hoists, a rope of round strand, ordinary-lay design, stress relieved, can be used. A fender rope prevents the transverse motion of a vessel or counterweight in the pit shaft [3]. The most commonly applied designs of the steel ropes used as lifting ones in mining pit shaft hoists can be seen in Figures 1 and 2.

Fig. 1. Cross sections of Warrington-Seale design ropes: a) design 6x36WS – NFC, b) design 6x36WS – IWRC, c) design 6x36 Dyform – IWRC, d) triangle stand rope, design 6xV32 – NFC, e) oval strand rope, design 5Q + 6Q + 8Q – NFC

Fig. 2. Cross section of a multi-layer, round strand rope type NOTORPLAST, design 4x7 + 4x17 / 4x7 + 12(1 plastic core + 16) + NFC

2 METHODS OF ASSESSMENT OF THE TECHNICAL CONDITION OF STEEL ROPES

The assessment of the steel rope condition is performed by various available means. Mining companies, aiming at high production indices, keep the time necessary to assess the technical condition of ropes down to an inevitable minimum. That is why scientific entities perform experimental investigations to present the actual condition of a steel rope. There are several...
ways to assess the condition of a steel rope by non-invasive methods, e.g.:
- non-apparatus methods consisting in observation of the wear processes and measurement of the rope geometrical features which change in time,
- apparatus methods – by means of special diagnostic devices [3].

The apparatus assessment of rope condition is effected by means of magnetic defectoscopy. Magnetostatics is a part of the science of electromagnetism, concerning constant magnetic fields independent of time and their interaction with moving electric charges as well as with conductors with electric current.

The purpose of defectoscopy is to determine the rope condition by means of the signal recorded during testing relations taking place between physical magnitudes which are the object condition and the signal obtained from it. In magnetic defectoscopy, constant magnetic field generated in the measurement probe is used to generate the signal informing about the object condition (possible indications in the form of cracked wires). The magnetic field is divided into moving the rope in a constant magnetic field, recording the electric signal by means of the function of the change of the radial and axial component of the magnetic field as a result of a local rope defect and in calculation of the rope wear on that basis. Defects in the material (rope) located in constant magnetic field cause disturbance of the lines of the magnetic field forces. The magnitude of the disturbance is related to the occurrence of the defect. Detection of possible indications on a steel rope is effected by special measurement sensors consisting of an integral part of the measurement apparatus. The internal sensor (internal induction coil) is responsible for collecting information coming from the radial component of the magnetic field force lines. The sensor should be located at an optimum distance from the rope and should not be directly at the cramp. Information coming from the internal sensor is recorded on a diagram tape (defectogram). The internal sensor is a set of connected coils. Comparing the signals from the internal and the external sensors, it is possible to generate information on the defect location inside the rope. If the values of the signals from the external coil and the internal one are close to each other, it means that the defect is located deep in the rope. On the other hand, if the value of the internal coil signal is larger than that of the external coil, it means that the defect is located in the outer layer of the rope. Hall generator sensor is used to localise slow continuous changes of the rope cross section. It is responsible for collection of information from the axial component of the magnetic field force lines.

The magnetic flux flows through the magnetized rope with constant cross section, generates a homogenous magnetic flux (Fig. 3). A dissipation flux arises around the rope; it is disturbed when a defect appears in the rope and is proportional to the geometrical dimensions of the defect. In the middle part of the probe, there are sensors which transform the disturbance magnitude into an electric signal which is recorded by means of a recorder proportionally to the rope displacement. Measurement is performed during the probe movement in relation to the rope under examination or vice versa. The guiding systems mounted inside the probe allow for centric motion of the rope in relation to the probe. Various measurement sensors are applied depending on the way of transforming the measured magnetic induction $B$ [T] or the magnetic beam $\Phi$ [Wb] which are divided into induction ones $LF$, and Hall generator ones $LMA$ [3].

![Fig. 3. Measurement probe, GP, with a rope located inside it: 1 – rope, 2 – path converter, 3 – magnetic circuit, 4 – measurement sensors, 5 – rope guide](image)

The measurement probe is a complex electromechanical device. It brings the running section of the rope into a condition close to magnetic saturation and provides signals from its sensors which detect the magnetic dissipation flux resulting from the external or internal lack of metallic section in the rope. The lacks can result from, among others, wire cracks, wear lands, deformations etc. The examination results are not influenced by plastics coatings.

A measurement probe should possess such features as:
- inbuilt magnetizing device, i.e. a permanent magnet (currently NeFeB material).
- $LF$ (local fault) sensor is used in detection of cracked wires (abrupt cross section changes).
- $LMA$ (lost material area) sensor is used in detection of gradual changes of cross section (continuous cross section changes).
- rope length transducer (measurement of the running rope length and motion speed).
- recording tape (defectogram) is moved out proportionally to the rope motion in relation to the probe (or the probe motion in relation to the rope); the curve obtained is synchronized with the rope speed at least up to the speed of 1 m/s.
- during examination, the rope must be situated centrically in the middle of the probe [3].

Examination with the use of a magnetic probe is performed by means of a recorder. The most commonly used recorder, due to its way of interpretation of results and reliability, is digital defectograph type MD120. It contains a portable recorder with a diagram tape and
3. INVESTIGATION OF THE PROCESSES OF WEAR OF NO LONGER EXPLOITED ROPES

In a pit shaft skip hoist, three-layer ropes type NOTORPLAST with the diameter of 52 mm made by TREFILEUROPE – Inspat INTERNATIONAL N.V. (Table 1) have been applied as the lifting ropes. In the final period of the ropes exploitation, notches have been found on the strand contacts, as well as increment of the phenomenon of wire cracking in the internal layers of the ropes (Fig. 5, 6).

Table 1. Design and strength data of the ropes under examination

<table>
<thead>
<tr>
<th>design</th>
<th>strength</th>
<th>cross section</th>
<th>structure</th>
<th>wire coating</th>
<th>mass of 1 running meter</th>
<th>grease used</th>
<th>$P_{\text{new}}$ [daN]</th>
<th>$P_{\text{total}}$ [daN]</th>
<th>safety factor acc. to $P_{\text{total}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>design</td>
<td>1770/1960 MPa</td>
<td>1181,13 mm$^2$</td>
<td>Z/z, S/s, S/s, Z/z</td>
<td>...</td>
<td>10,94, 10,92, 10,92, 10,94 kg</td>
<td>ELASKON II STAR</td>
<td>237 743; 231 439; 231 439; 232 743</td>
<td>193 700; 184 800</td>
<td>6,48; 6,70; 6,57; 6,39</td>
</tr>
</tbody>
</table>

From the rope under examination, a fragment corresponding to the occurrence of the impulse indicating faults of the rope internal structures has been selected.

On a section with the length of 2080 mm prepared for the examination, the following wire cracks have been found:
1. The external layer of strands 12 (1 plastic core + 8x 1.40 + 8x2.65) - the strands of the external layer have maintained adequate lubricant quantity inside. No wire cracks have been found, only small abrasion wear lands. No damage of sisal separators between the strand layers have been found.
2. Middle layer of strands 4 (1x2.35 + 8x1.40 + 8x2.65), number of cracked wires in section 40xØ2.65 - 17 pcs; Ø1.40 - 4 pcs; Ø2.35 - 2 pcs.
3. Middle layer of strands 4 (1x2.60 + 6x2.30), number of cracked wires in section 40xØ2.60 – 3 pcs.
4. Internal layer of strands 4 (1x3.05 + 6x2.50), number of cracked wires in section 40xØ3.05 – 3 pcs; Ø2.50 – 5 pcs.
Fig. 6. Views of a strand taken to examination; visible wear lands and wire cracks

4 CONCLUSIONS

The reason why the 52 mm dia. NOTORPLAST lifting ropes have been withdrawn from exploitation after 25 months of work in the skip pit shaft R-II, south section was a local rise of the record level on rope no.2 in the section of 55m to 70 m above skip “A”. The character of impulses indicated complete or partial cracks of individual strands in the internal layer of the rope.

In laboratory examination of the selected section of rope no. 2, basing on the defectograph record, the following results have been obtained:

- after unlaying the strands of the internal layer of structure 4(1x3.05 + 6x2.50) cracks of 3 wires Ø3.05mm and 5 wires Ø2.50 mm have been found;
- after unlaying the strands of the middle layer 4(1x2.35 + 8x1.40 + 8x2.65) numerous cracks of 17 wires Ø2.65 have been found, as well as cracks of 4 wires Ø1.40 mm; cracks of wires Ø2.35 have occurred in 2 wires;
- after unlaying the strands of the middle layer of structure 4(1x2.60 + 6x2.30) cracks of three wires Ø2.60 mm have been found;
- the summary force breaking the wires under laboratory examination was 196,274 daN while the summary force for a new rope was 231,439 daN, which means a drop of 15.19% as compared to a new rope;
- the average number of twists of the wires subjected to laboratory tests was 22 while the average number of twists for a new rope was 36, which means a drop of 38.89% as compared to a new rope;
- the average number of bends of the wires subjected to the laboratory tests was 10 while the average number of bends for a new rope was 16, which means a drop of 37.50% as compared to a new rope.

REFERENCES


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