ROPE NDT AS MEANS TO RAISE SAFETY OF CRANE AND ELEVATOR USE

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Abstract: Steel rope NDT by magnetic flaw detectors is usual for mine hoist inspection through the world. But it is no ordinary by crane and especially by elevator inspection. However, magnetic NDT statistic data of 60 crane and 227 elevator ropes in use shows that about 23% of crane and 9% of elevator ropes should be discarded in accordance with actual discarding criterion in Russia. Russian State Rules for crane safe exploitation require the magnetic NDT while periodically inspection. But not all the inspecting companies meet it in Russia, contenting themselves by visual inspection only. This is not objective and does not provide rope inner faults detection.
That is a reason of rope break rather high percentage in general statistics of crane accidents and damages. Investigation of accidents with crane ropes in Moscow region in 2001 shows that they would de prevented by the magnetic NDT fulfilled timely. The elevator rope NDT problem is not so sharp but attention should de attracted to it to raise safety of elevators.

Introduction: Steel wire ropes belong to the basic elements of loading cranes and elevators. Safe use of the cranes and elevators depend on the rope condition. Deterioration of a rope during its lifetime leads to a reduction of the rope safety factor and to its possible destruction. There are rejection criteria for ropes in national and international rules on the safe use of cranes and elevators.
Rope condition must be checked yearly during crane and elevator periodic inspection according to the Russian national rules. The rope rejection criteria can be divided into qualitative and quantitative ones. The qualitative criteria are: various types of deformation; damage as result of a high temperature or of a flash influence; strand or metallic core break. The quantitative criteria are: diameter change; surface or inner abrasive wear and (or) corrosion of wires which lead to loss of metallic cross section area (LMA); quantity of breaks of outer and inner wires per definite length (usually per 6d or 30d, where d is a rope diameter). The last criterion belongs to the rope local faults (LF) whereas the first one (LMA) belongs to the dispersed faults. Evidently, the visual method of rope inspection is subjective and it allows one to define the rope condition relative to the qualitative criteria only.

Magnetic flaw detection is used to check the LMA and LF of a rope under test along all its length available for testing. The magnetic method of flaw detecting produces objective data about the rope LMA and LF independent of wire damage type (abrasive or corrosive wear, break or loss of wires) and of the damage location in the rope (outside or inside). It is possible to detect the rope section subjected to heating which leads to a change of the metallurgical structure. That means the magnetic flaw detection is available to define the condition of rope in use quantitatively, and to detect even hidden faults and their location.
The magnetic flaw detectors for steel rope testing are manufactured by many companies throughout the world. The University of Reading, England has surveyed them [1]. One of the most portable, light and advanced instruments, the INTROS was described on the 7th ECNDT in Copenhagen [2], on the 15th WCNDT in Rome [3], and on the 8th ECNDT in Barcelona [4]. More than 200 INTROS instruments were produced and delivered by the INTRON PLUS, Ltd. to Russian mining companies and crane inspection centres, and about 400 specialists have been trained and certified for instrumental rope inspection up to April 2004. There is a great deal of experience on magnetic rope testing in various types of machines, installations and constructions using ropes in the world. The technology is usual in the mining industry for inspection of mine hoist ropes, in rope airway transport and by guy rope inspection of guyed bridges and other guyed constructions. Unfortunately, the magnetic rope testing is used not everywhere and not every

time by technical experts of cranes. Specialists, responsible for the inspection, often restrict themselves to visual rope checking only. The magnetic flaw defectors are used for elevator rope testing rather seldom. The main reason is that the Russian national rules on safe use of elevators does not demand magnetic rope testing.
The visual method produces a possibility for inadequate inspection due to its subjectivity. Practically, it is hard and nearly impossible to review thoroughly a rope covered by lubricant and grime when a rope length is up to a hundred meters. Additionally, only surface faults of the rope can be detected and this is insufficient to define its condition correctly.

Results: The disadvantages mentioned above with the visual method lead to a rather high percentage of rope breaking in the total statistics of crane accidents. Thus, there were 120 crane breakdowns in Russia in 2001÷2003, 21 of them due to the rope breaking. Two accidents in Moscow region described below confirm the unfortunate situation in crane rope testing.
The tower crane POTAIN MD-185A failed in September 2001: a worker was killed. The reason for the accident was that the hoisting rope broke. The rope was 14 mm diameter, two-layer type; with construction 11x7(6/1)+6x7(6/1) with a metal core 1x7(6/1). Part of the rope, 380 m long was tested by the magnetic flaw detector INTROS after the break.
Figure 1 shows traces of the rope in two channels: loss of metallic area (LMA) and local faults (LF). The most worn section locates at distance (0-60) m from the place of the rope fastening. There is more than 6% LMA and many wire breaks.

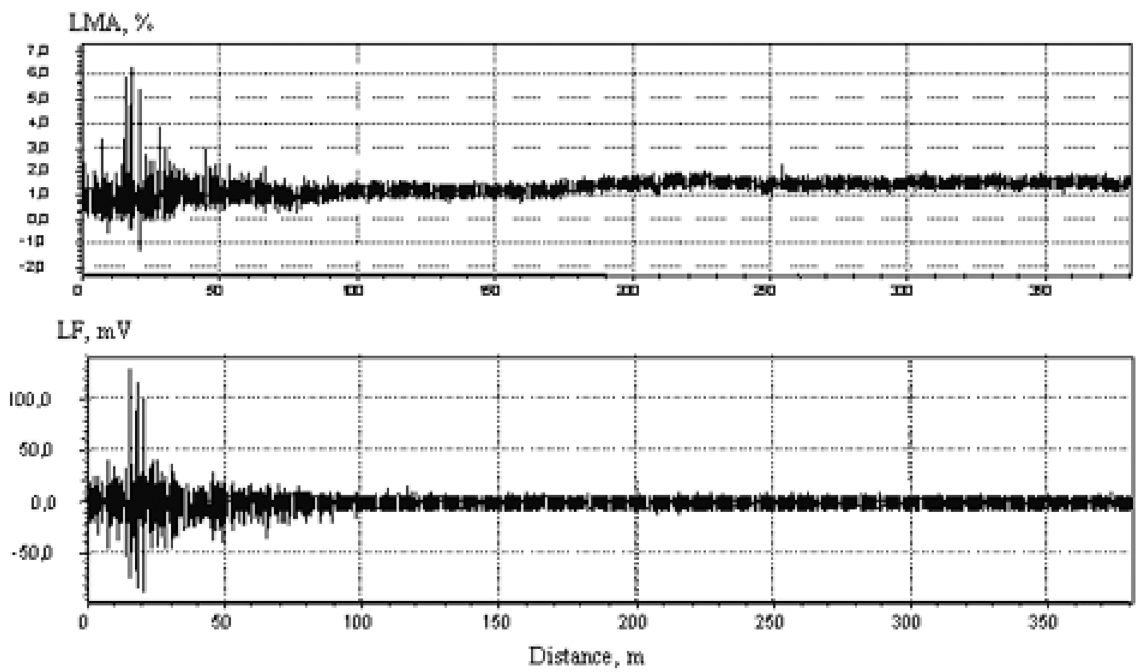

Figure 1: Data charts of the crane POTAIN MD-185A loading rope (rope A).
The traces of the rope section at distance (17-21) m are shown in Figure 2. The highest density of wire breaks is at (17.0-17.7) m and at (19.4-20.3) m. More than 35 wire breaks were identified the section 1 over a length 30d = 0.42 m at the location (17.0-17.7) m from analysis of the LF trace. This is significantly more than the discard criterion (8 breaks) in the length 30d. That means the rope must be rejected before it broke.

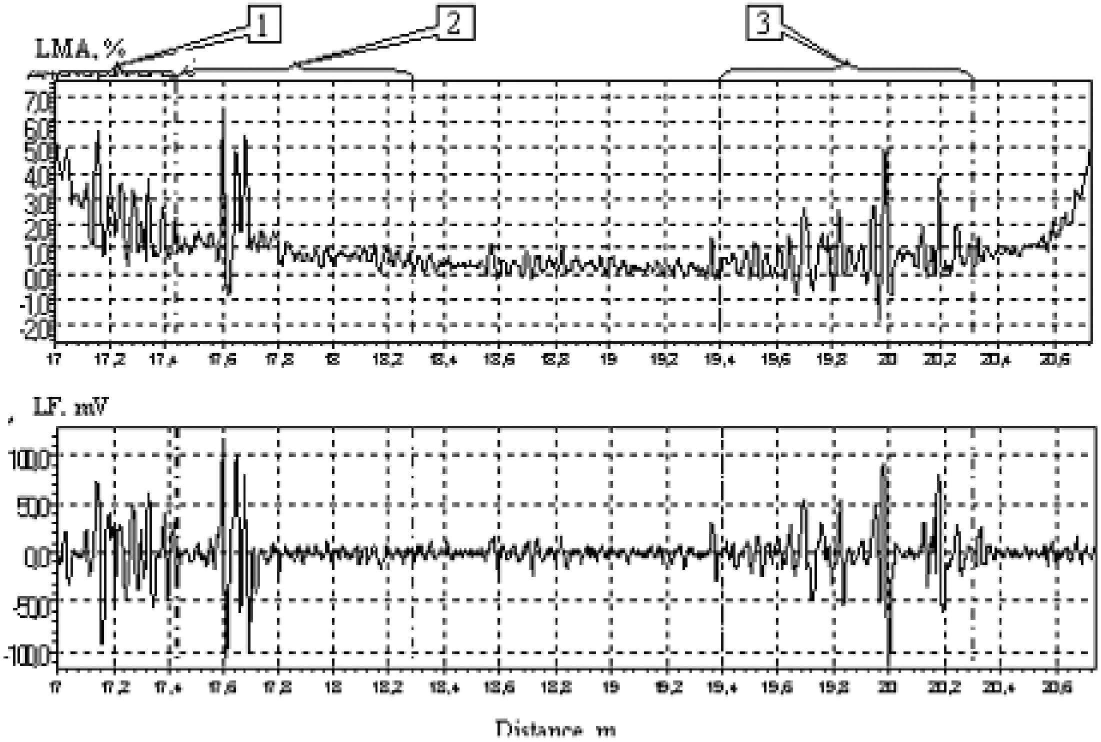

Figure 2: LF and LMA traces of the rope A, section (17-21) m.
The section 1 of the rope was unwound. Figure 3 indicates many broken wires in the inner layer. The sections 2 and 3 of the rope were tested in a tensile testing machine. The breaking strength of the section 2 had fallen 61% and that of section 3 by 49% relative to the certificate value. These sections were worn at approximately the same level as section 1 because the traces of all of them are similar.

Figure 3: Section 1 of the rope A with outer layer strands partly removed.
Visual checking of the rope sections (364-380) m upon dismantling of the sections confirms the magnetic testing data (Figure 1): there are no LF and considerable LMA. Certified data on the breaking strength of two rope fragments taken from the section (364-380) m differed from the data of tensile test machine by no more than 3% and 5% respectively. This confirms good correlation between INTROS readings and real rope condition.

It was determined by visual checking that there are group of wire breaks in the outer rope layer. The breaks could have been detected by visual rope inspection while the rope was in use. But this did not happen because a detail visual inspection of the 400 m length rope takes too much time and the inspector's attention inevitably wanders. It was determined also that the most worn sections of the rope worked on the crane pulleys. The rope length between (364-380) m was located near a drum and did not go over the pulleys.

Thus the rope was broken due to inadmissible rope wear, which could be detected by magnetic testing in proper time, and the accident would be prevented. On the basis of the results of this accident investigation, the Russian State Supervising Committee on Mining and Technology (GOSGORTECHNADZOR) demanded two layer ropes to be replaced by single layer ropes on all the POTAIN MD-185A cranes used in Russia. The reason is that wire breaks occur typically in an inner layer and in the core of a two-layer rope due to the high bending load at crane pulleys.

Another accident happened in December 2001. A crawler crane type DEK-251 was smashed because of boom rope failure: a person was killed. The rope is 20 mm diameter; its structure is 6x36(14/7+7/7/1) with fibber core (GOST 7668-80). The rope was broken at the distance 57 m from the point of its fixing to a drum.

The charts covering two fragments of the broken rope (0-52) m and (58-64) m are shown in Figure 4.

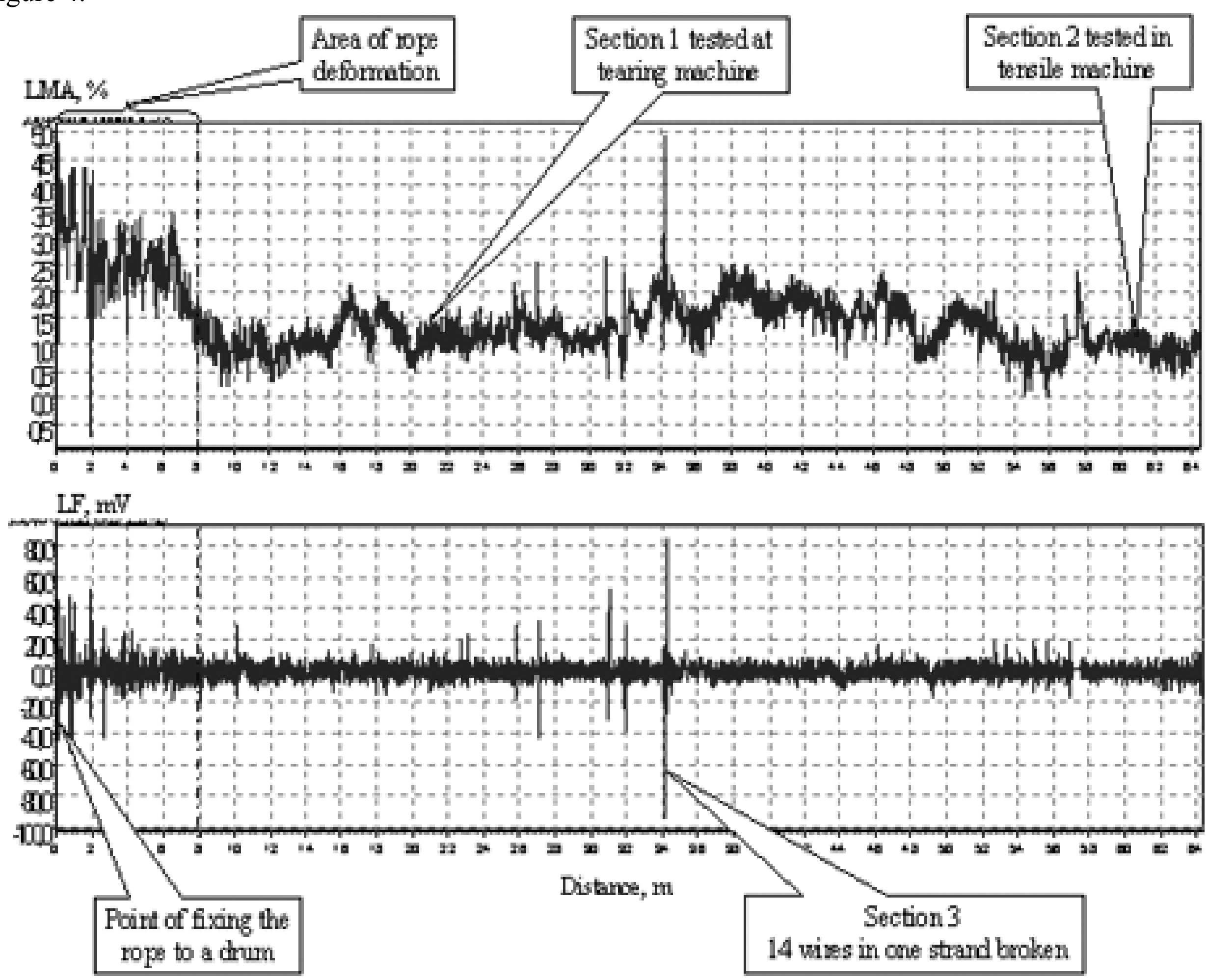

Figure 4: Data charts of the crawler crane DEK-251 boom rope (rope B).

The LMA is not over 5%, the most worn sections being at (0-8) m and at 34 m. Broken wires and strand deformation were detected by visual inspection in the section (0-8) m. There is significant signal at 34 m distance. The signal was identified as breakage of no less than 11 wires. Breaks of one to three wires were detected at distances 26, 27, 31 and 32 m. Visual inspection of the rope section at 34 m showed 14 wires broken over a 60 mm length (6d length) (Figure 5).

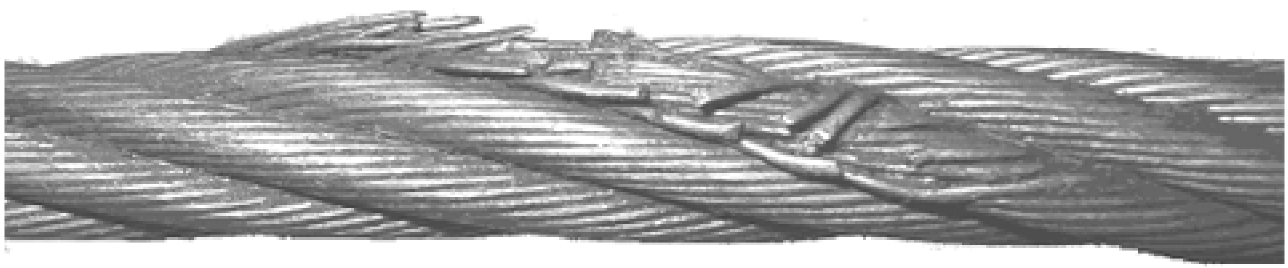

Figure 5: Wire breaks of the rope B one strand (section 3 in Figure 4).

The appearance of the broken wire ends indicates that the breaks appeared long before the rope failure. Taking into consideration that the rules permit not more than 14 breaks on 6d length, the rope must be discarded. Furthermore, according to [5] the breaks concentrated in one strand increase the fault hazard. However, the breaking strength of the unworn rope sections 1 and 2 (Figure 4) is only 7.5% less than nominal value. Visual investigation of the broken rope ends shows that only about 25% of wires broken at the rope failure location have needle-shaped ends indicating that they were broken by tensile stress. The ends of the remaining broken wires look typical of fatigue failure. Of course, the group of wires broken at the distance 34 m could be detected visually (Figure 5) but this does not happened while the rope in use: such as in the case mentioned above.

Instrumental inspection of ropes at 8 cranes was performed by personnel of INTRON Plus Ltd., TEKHCRANENERGO, Ltd. and VERTICAL Ltd. using the INTROS flaw detector in Moscow region in 2002 to get statistical data on rope in use condition. The cranes are various types: tower, bridge, jib and truck. Three of the 11 ropes inspected (27%) were discarded due to exceeding both the limit of broken wires per the 6d length and permissible LMA value. Other companies using the INTROS obtained statistical data close to that mentioned above. In particular, 11 out of 49 (22%) of ropes tested were discarded by TRANSENERGO, Ltd. (Snezhinsk).

Spot check of elevator ropes in use was undertaken to evaluate their condition. It was tested 68 elevators with 227 ropes by the INTROS instrument. The work was fulfilled by the Engineering Center NETEEL, Moscow; the SIBLIFTSERVICE, Ltd., Krasnoyarsk; Engineering & Consulting Center ALTON, Izhevsk; the INTRON RLUS, Ltd., Moscow.

The testing detected inadmissible defects of 21 ropes at 19 elevators. It means that 28% of the elevators and 9% of the ropes inspected do not meet the rules requirement.

Discussion: Visual inspection alone is inadequate to provide a real definition of the rope degradation level, even if the inspection is fulfilled conscientiously. An inspector cannot see any defect inside a rope under test without the rope dismantling. Besides, he cannot measure rope LMA value. As it is shown in the report, even many of surface defects like broken wires are not detected by inspectors. In any case the inspector’s conclusion on rope condition is subjective. On the other hand, an inspector has not to limit himself by a subjective conclusion on rope condition while using magnetic defectoscopy because the instrument submits a document in view of a standard report. On discovering any rope anomalies in the report and data charts, the inspector must describe them in detail after both instrumental and visual checking. Thus, defectoscopy

disciplines the inspector and decreases the human factor role in the technical crane and elevator inspection.
At present about 100 Russian manufacturing firms and organizations are involved in the magnetic rope testing by the INTROS, 45 of them are engineering centres. Unfortunately, only 4 centres inspect elevator ropes by the magnetic NDT. The level of efforts on crane rope NDT is raised several times in last 5 years in Russia due to energies of the GOSGORTECHNADZOR.
But elevator rope NDT is at a start position now. It is the option that the high margin of safety of elevator suspension allows to do without the magnetic NDT. However, if one takes into consideration that 28% of the inspected elevators in use are not meet requirements of the Safety Rules, it necessary acknowledge that the existent practice permits to use ropes with inadmissible wear.
Magnetic non-destructive testing allows an increase in the safe use of cranes and elevators due to objective, reliable and documented evaluation of the real rope condition and by ensuring timely rope replacement.

Conclusions: The statistics of rope inspection described in the frame of this report is rather eloquent: more than 23% of all the crane ropes inspected and about 9% of elevator ropes should be discarded. The two severe crane accidents in 2001 could have been be averted if the ropes were inspected by a flaw detector in proper time.

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