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Importance of rope NDT for safe lifting of loading cranes

Summary

Russian State Rules for the crane safe exploitation require instrumental testing of ropes by magnetic flaw detectors while periodical crane inspection. Unfortunately, not all inspection centres use the instrumental magnetic testing, contenting themselves only by visual inspection, which is subjective and does not provide inner faults detection. That is why the percentage of rope break is rather high in general statistics of crane damages and accidents. Analysis of two accidents in Moscow region with cranes in 2001 shows that both of them could be avoided if inspectors had used a magnetic flaw detector. Statistics of more than 50 crane rope inspections suggests that about 25% of crane ropes in use should be discarded.

1. Introduction: methods of rope inspection

Steel wire ropes belong to the basic elements of loading cranes. Safe use of the cranes depends 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 crane ropes in national and international rules on the safe use of cranes.

Rope condition must be checked during yearly crane 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.

2. Magnetic flaw detecting and visual method: a comparison

The magnetic flaw detectors are manufactured by many companies through-out the world. The University of Reading (2000) has surveyed them. More than 150 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. There is a great deal of experience on magnetic rope testing in various types of machines, installations and constructions using ropes. For example, Sukhorukov & Shpakov (2001) presented the practice for testing guy ropes of tower cranes.

Unfortunately, the magnetic rope testing is used not everywhere and not every time by technical experts of cranes in Russia. Specialists, responsible for the inspection, often restrict themselves to visual rope checking only.

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 metres. Additionally, only surface faults of the rope can be detected and this is insufficient to define its condition correctly.

3. Accidents with cranes because of rope breaking

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 45 crane breakdowns in Russia in 2001, 5 of them due to the rope breaking. Two accidents described below confirm the unfortunate situation in crane rope testing.

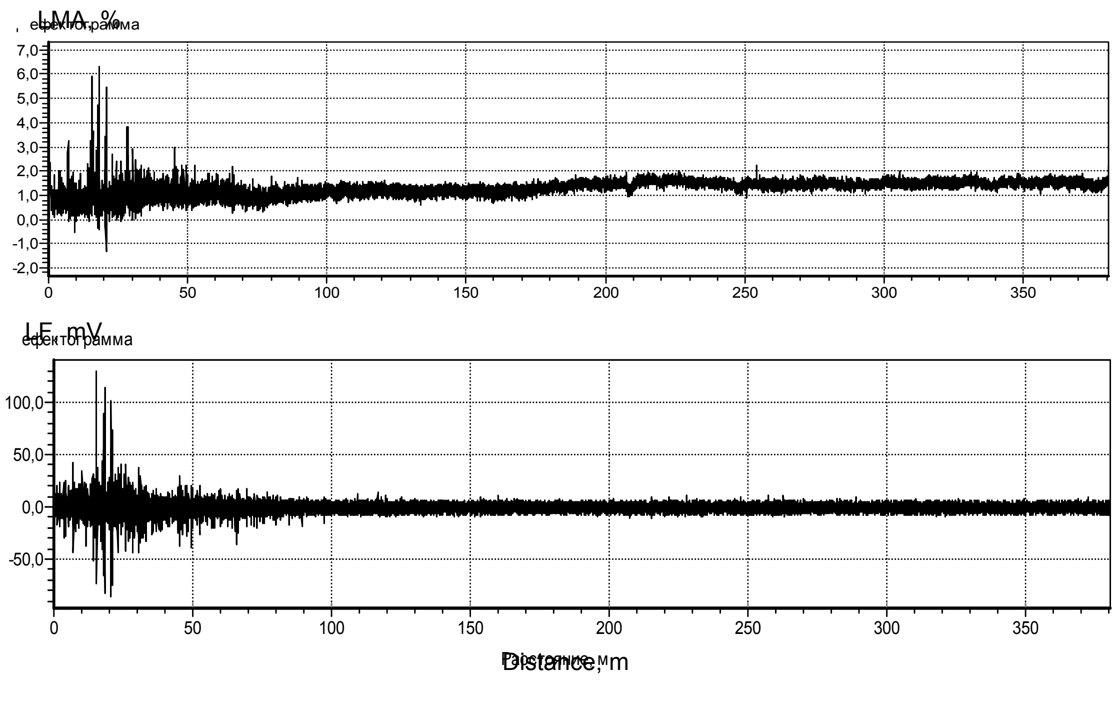

Figure 1: Data charts of the crane POTAIN MD-185A loading rope (rope A).

The tower crane POTAIN MD-185A failed in Khimky, a town in the region of Moscow 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: LMA and 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.

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.

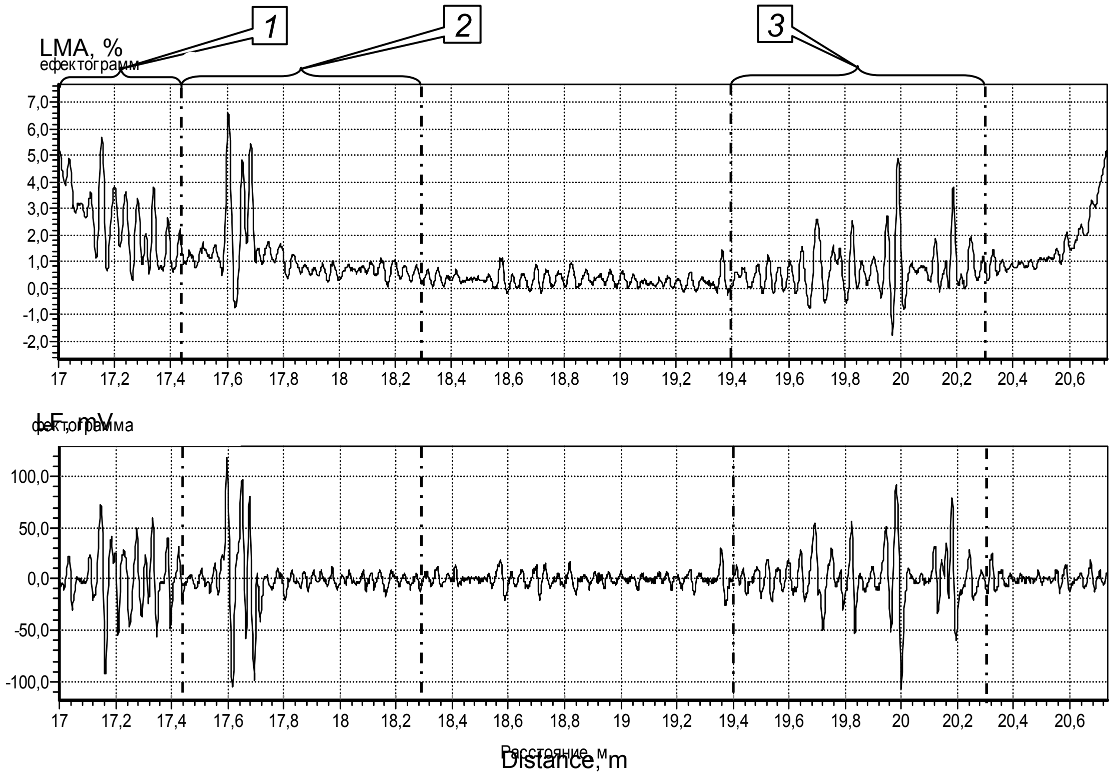

Figure 2: LF and LMA traces of the rope A, section 17-21 m.

The section 1 of the rope was unwound. The results were: 25 breaks in the outer layer, 88 – in the inner, 13 – in the core, total – 126 breaks. The significant difference in quantity of rope breaks detected by the instrument and visually by unwinding could be explained due to the following reasons. Firstly, part of inner layer wires breaks while the rope is dismantled, because the wires will have accumulated fatigue during rope use. Almost all wires of the inner layer in this rope section will have lost their bending resistance and practically crumbled while unwinding. Secondly, the rope section investigated (Figure 3) contains many breaks located very close each other and break signals are imposed each upon other. That is why the signal identification is difficult.

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.

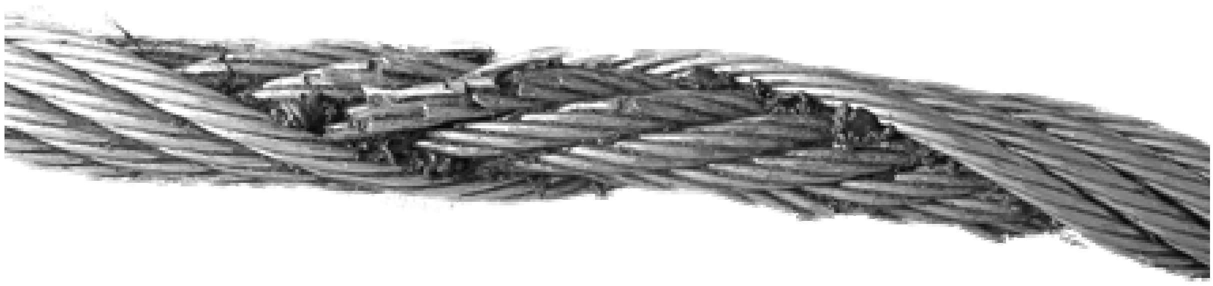

Figure 3: Section 1 of the rope A with outer layer strands partly removed.

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.

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 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 the town of Domodedovo, also in the region of Moscow 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 fibre 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. 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). 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 Sukhorukov *et al.* (2001) 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.

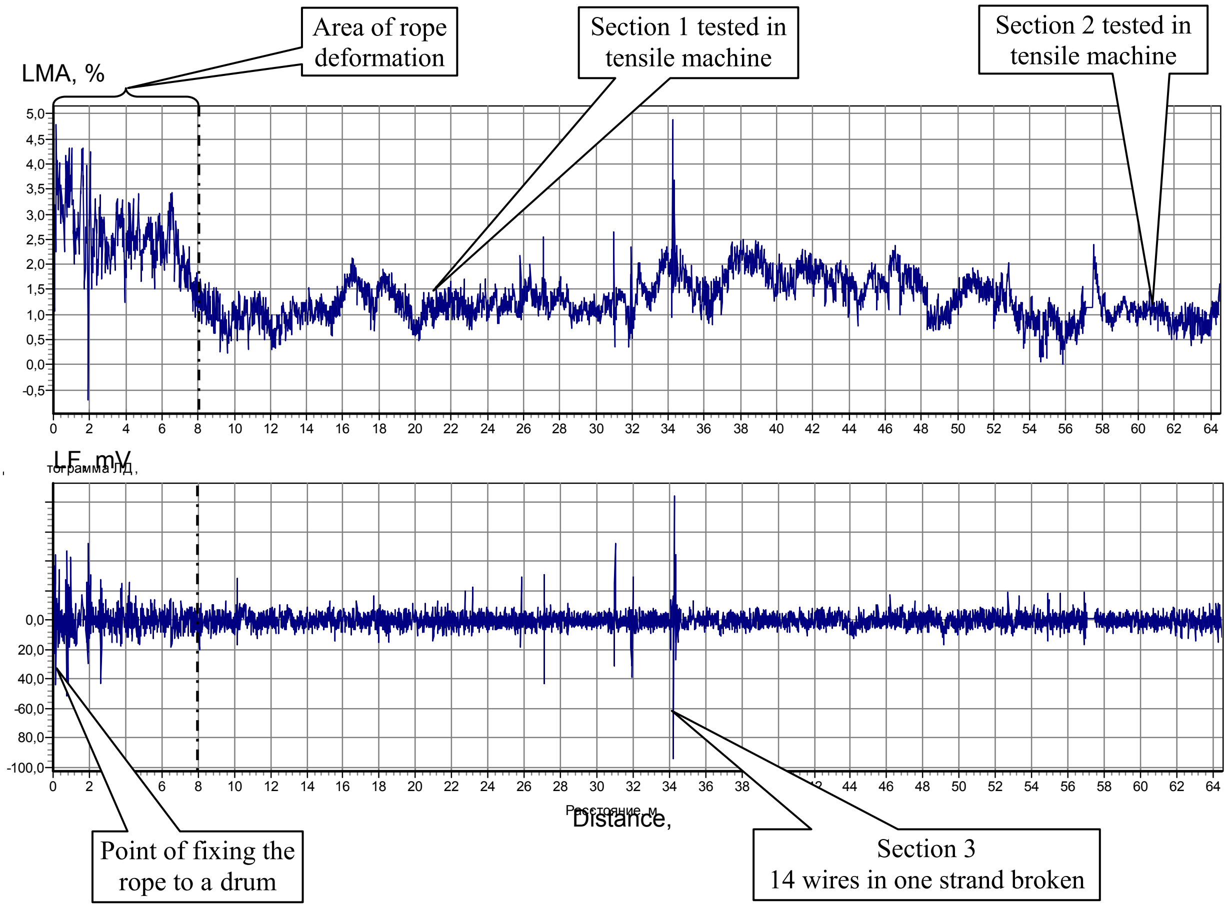

Figure 4: Data charts of the crawler crane DEK-251 boom rope (rope B).

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

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 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 (Snezhinsk).

4. Conclusions

Magnetic non-destructive testing allows an increase in the safe use of cranes due to objective, reliable and documented evaluation of the real rope condition and by ensuring timely rope replacement.

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 limit himself by a subjective conclusion on rope condition while using magnetic defectoscopy, such as is possible with a visual inspection, because the instrument submits a document in view of a standard report. On discovering any 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 inspection.

The statistics of rope inspection described in the frame of this report is rather eloquent: ¼ of all the ropes inspected 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.

5. References

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