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Monitoring of Mine Hoist Ropes at The Norilsk Nickel Company

Abstract

Monitoring of different kind of hoist ropes using magnetic non-destructive testing at the Norilsk Nickel Company is considered. The round cross-section ropes (inhaul, brake, guide) as like as flat steel and rubber-steel balance ropes have been testing by the magnetic rope tester INTROS continuously for years. Hundreds thousands meters of ropes at about 40 hoists are monitored. Non-destructive magnetic testing provides detecting of rope wear in proper time independently of it is outside or inside the rope. On the other hand, hundreds thousands dollars were saved due to ropes lifetime prolongation on testing result base.

Introduction

Safety of mine hoist use depends on many factors. One of the most significant factor is the hoist rope condition. Regulations set up requirements for steel wire mine hoist rope as like as steel rope flaw detectors used in Russia and Ukraine were reviewed in the report at the KOMAG conference in 1999 [1]. Real experience has been accumulated in non-destructive testing of hoist ropes and in monitoring of ropes condition since that time. The Norilsk Nickel (NN), one of the largest Russian mining company, has being using non-destructive testing of hoist ropes for many years. The magnetic flaw detector INTROS is a base for the rope condition monitoring at the company.

Description of ropes and testing instrument

There are about 270 steel wire ropes of more than 300 km total length at NN mine hoists in the city of Norilsk. The ropes are installed at 51 hoists of 27 shafts and include haulage, guide, brake and balance ones. The rope types are various: round strand ropes, half-locked coil ropes, locked coil ropes, flat steel wire ropes, steel-rubber flat ropes. There are ropes produced by Russian and foreign manufacturers. Diameters of the ropes lie in the range of 20…65 mm, while length (depth of shaft) varies in the range 300-1600 m.
The magnetic flaw detector INTROS has been used as a non-destructive testing instrument at the Norilsk Nickel since 1995. INTROS was originally developed and manufactured by Intron Plus, Ltd. according to the specifications of the NN Company. The instrument was described briefly in [1]. The new basic unit as like as new magnetic heads and a new version of software WINTROS were developed by the Intron Plus since that time. Fig. 1 shows the appearance of new basic unit. Unlike previous model the new one has two displays: large upper for on-line displaying LMA value, LF signal, some other useful information and the smaller lower display to show current rope distance. Data logger installed in the basic unit can store test data of rope with total length up to 32,000 m depending on settings of the instrument.

Fig.1. New INTROS basic unit

Fig. 2 shows the new magnetic head MH 233R for testing steel-rubber flat ropes of 233 mm width. Appearance of new magnetic head MH 450R for steel-rubber flat ropes of 450 mm width is similar. WINTROS 2.1 is advanced version of software for Windows. Disadvantages of previous version WINTROS 2.0 were minimized during developing of the new one. As the WINTROS provides archiving of testing data and comparing them in different manners, it is convenient for rope condition monitoring during rope life [2].

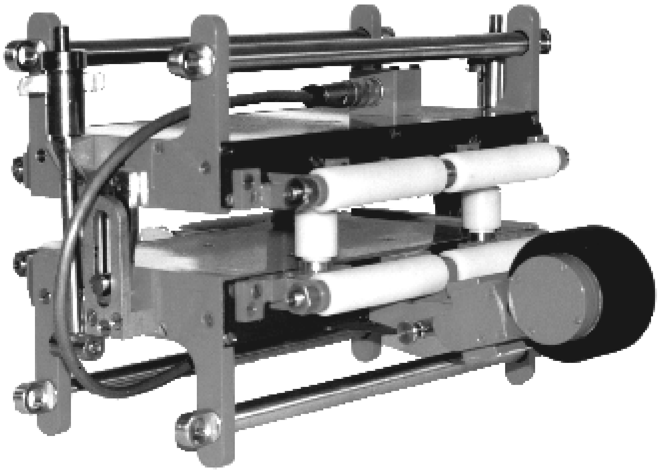

Fig. 2. New INTROS magnetic head MH 233R

Fig. 3 shows opportunity to compare results obtained in different time periods from the same rope. Brake rope 30,5 mm of cargo/man riding two deck cage of the “Scalistaya” shaft at NN have been tested with 10 weeks interval. LMA and LF traces obtained from those tests were processed with WINTROS for easier visual perception. The traces show that LMA at the most worn rope section (800-1100) m increased from 6,5% to 8,8% within 10 weeks. There is appreciable corrosion damage of the section too, as it can be seen on the LF traces. Considering above data, an inspector ordered testing the rope more often (monthly) and when LMA attained 10%, the rope was discarded.

Another example of LMA determination during rope life is represented in Fig. 4. The results were obtained from Koepe hoist shaft of the main haulage plant of the DSK (German hard coal industry) [2].
These 3 traces were obtained under following conditions: the lower – after 109343 hoisting cycles; the middle – after 185879 hoisting cycles; the upper – after 202114 hoisting cycles.

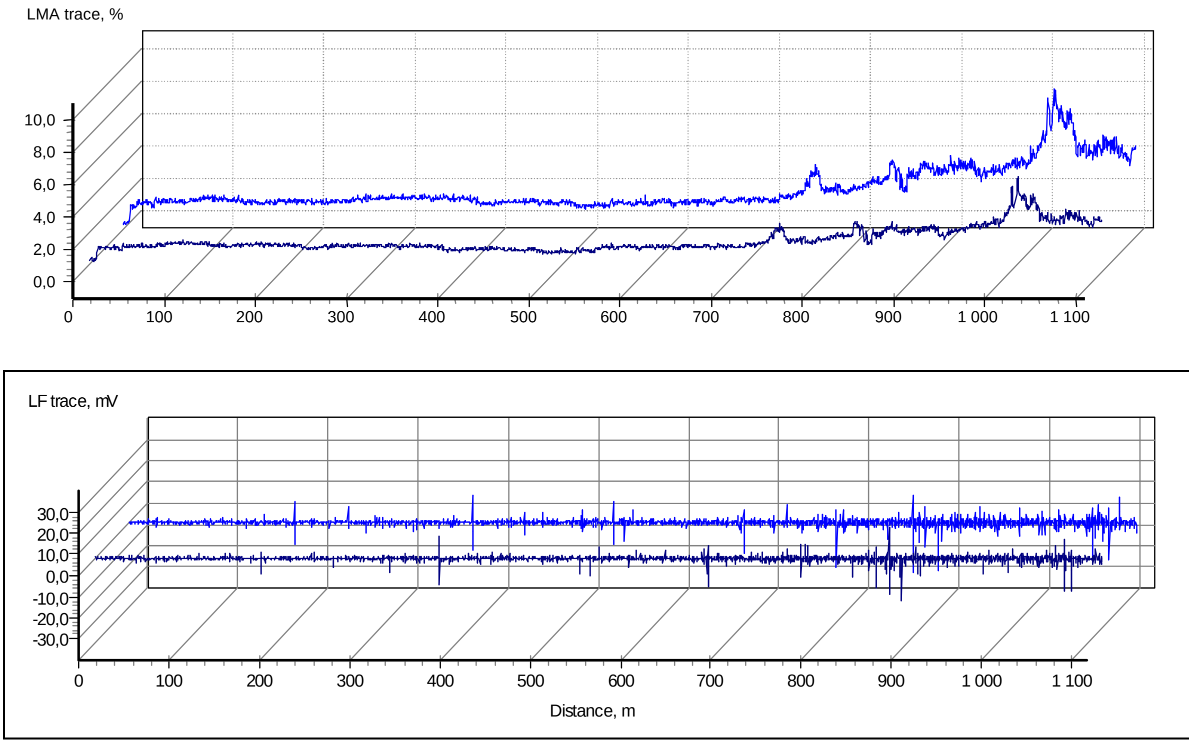

Fig.3. LMA and LF charts of brake rope 30,5 mm obtained by INTROS with 10 weeks interval

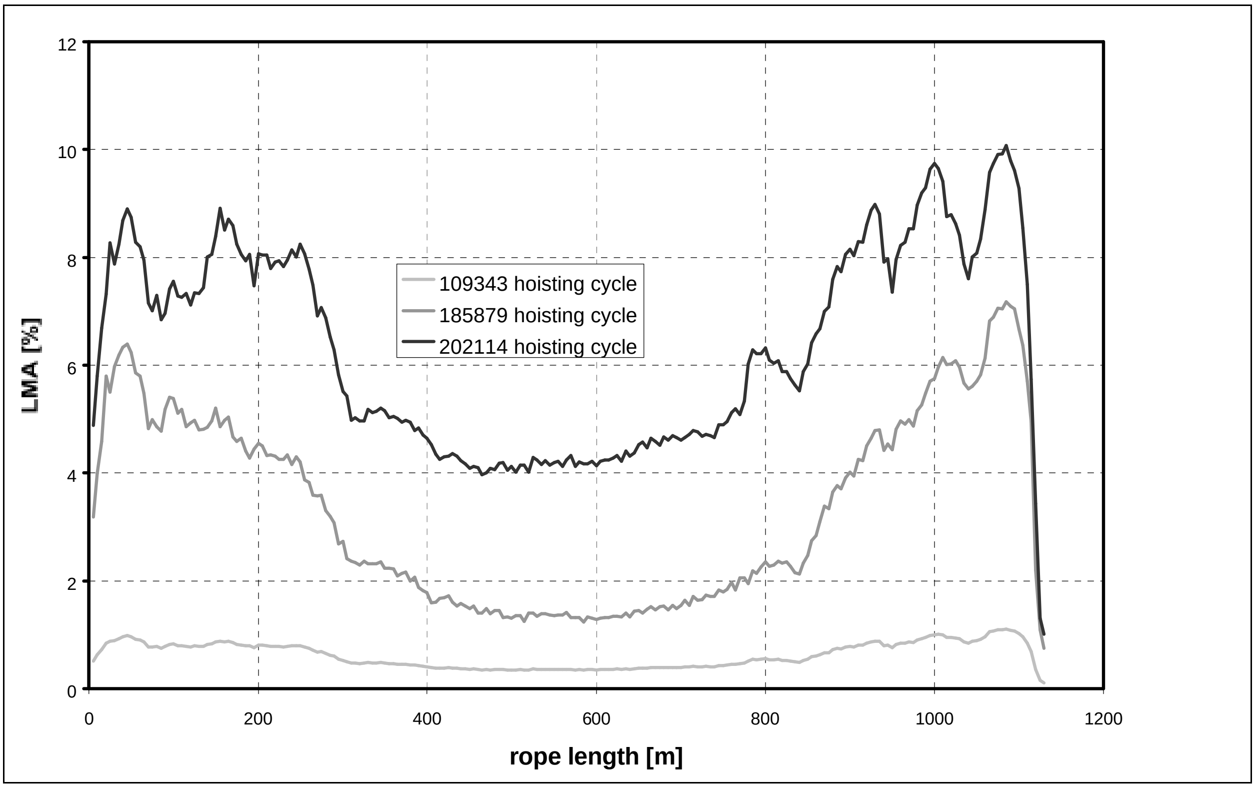

Fig. 4. LMA traces obtained from the rope after different hoisting cycles

Fig. 5 illustrates the rope wear during its life. Evidently that wear speed, defined as *d(LMA)/dc* (where *c* is hoisting cycles value) increases permanently. The speed increases dramatically in the last part of rope life. If an inspector could get data to draw a graph like the Fig. 5, he would appoint the next inspection in proper time considering the forecast of LMA raise in future and the rope discard criteria.

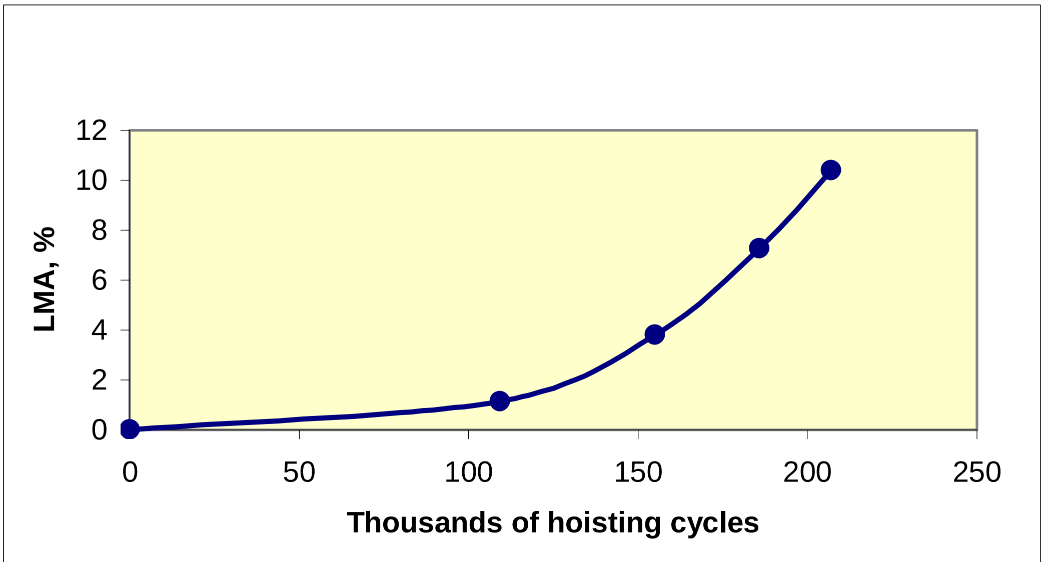

Fig. 5. LMA of rope depending on hoisting cycles

Rope monitoring experience

Large experience has been collected by personnel of NN in rope monitoring since 1995. During 1995 – 2003 more than 1,800 km of various ropes with total length about 328 km have been tested by INTROS. One example of the rope monitoring presented above (Fig. 3). Another is described in [3].
Russian mining safety regulations [4] state maximum duration of rope life depending on their particular application. Beyond this life duration rope must be discarded. Sometimes it is possible to extend rope use after rope instrumental inspection if test results are positive. Results obtained at NN after inspection by INTROS showed that many of ropes which life duration were expired were in good condition, i.e. did not reach retirement criteria. There was no sense to discard those ropes. About $130,000 was saved by NN due to life time prolongation of above ropes during 1995 – 1999. These funds did not include expenses, which could arise for delivery and installation of new rope.

Routine rope test procedures

Rope inspection in Russia is regulated by the National Rules on safety in mining industry [4]. There is the Standard Practice on magnetic flaw detecting of steel ropes as an official document of the GOSGORTEKHNADZOR [5]. It contents:

- short review of steel rope flaw detecting methods;
- requirements for steel rope flaw detectors;
- rope testing procedures;
- test result decoding methods;
- reference standard and calibration procedures description;
- requirements for rope testing work safety;
- definitions.

A routine test procedure consists of:

- instrument preparing for a work;
- instrument calibration by reference standards or by a rope section with no wear;
- choice of the instrument's magnetic head location when testing;
- magnetic preparing of a rope under test (by rope going through the instrument's magnetic head usually);
- rope testing when it go through the magnetic head;
- downloading the testing data to a computer;
- processing the data by WINTROS software and displaying (and printing) them (like chart records usually);
- decoding test results using calibration data and inspector's experience;
- checking test diagnosis visually on the rope under test;
- conclusion on a rope condition;
- test results and conclusion documenting.

The above rules state rope test methods and time intervals between inspections. The test methods are:

- destructive testing using tearing machine and checking flexural strength of rope wires;
- non-destructive testing by visual method and by magnetic flaw detectors.

Destructive testing of rope section must be done before rope hanging and then after each 3, 6 or 12 months depending on a rope application. This kind of testing presents a direct result, that means it define rope strength. Evidently, the result relates not to all the rope under test but only to its section destructively tested. Location of the section (with length not less than 1,5 m) is usually close to the end of the rope where it is not worn by friction. That is why the repetitive destructive tests do not present reliable data on all the rope condition. On the other hand, the multiple repetitive destructive tests can lead to the rope discard due to shortening of rope over the technological limit of length.

Instrumental flaw detecting of ropes affords to increase test results reliability and to slow down expenses for testing procedures in compare with visual inspection. According to above rules, visual test, depending on rope application, have to be provided daily, weekly or monthly. Visual test takes appreciable time: 23 people are involved in visual inspection and about 25 thousands hours per year spend personnel of NN to check all the ropes at the facility. To increase reliability of obtained test results and to reduce costs it was suggested to increase the part of instrumental inspection comparatively to visual one. Experiment on the matter of partial substitution of visual inspection of ropes with instrumental was made at NN company in 2000 – 2002. This experiment was fulfilled under supervising of Russian Federal Mining Safety Department (Gosgortechnadzor). There were tested by INTROS 57 ropes of different types with afterward detail visual evaluation of the ropes. Five of them were discarded as they reached retirement criteria. Data of instrumental tests were properly compared with results of visual inspection and testing with tearing machine. It was confirmed that increasing part of instrumental inspection of ropes comparatively to visual inspection leads to higher reliability of test data and decreases costs.

Changes in the rope test procedures due to the INTROS instrument use

TALNAKHSERVICE, Ltd., as an independent expert company has been providing the rope non-destructive testing and the rope monitoring at all the mine hoists in Norilsk since 2003. The company defines possibility of safe use of the ropes monitored. There is a data bank on condition of every rope. The company follows and forecasts the rope wear dynamics and so can generate a plan for rope purchase in the nearest future. TALNAKHSERVICE utilizes INTROS instrument practically for all possible kinds of ropes: round, flat and flat steel-rubber.

After the experiment finished GOSGORTEKHNADZOR allowed to change routine procedures of hoist ropes inspection at the NN company. According to new authorization the ropes can be tested non-destructively by the INTROS more often than earlier:

- monthly for the haulage and guide ropes, if daily number of cycles is more than 100;
- one time per two months for all the ropes at auxiliary hoists and for steel balance ropes at multiple-rope hoists.

Earlier the time interval between non-destructive rope inspections was 12 or 6 months depending of the rope type and application.

Now permanent visual rope inspection along all the rope length is repealed. The visual inspection is obligatory now for the rope sections with abnormities detected by a flaw detector as like as for the sections unavailable for flaw detecting. According to the valid rules, the visual inspection along all the rope length must be fulfilled daily, weekly or monthly depending on the rope location and application.

Routine procedures of to the destructive rope testing at tearing machines were changed also. The time interval between the destructive testing of rope sections is increased from 6 or 3 months to 12 months for the ropes at the hoists with more than 100 cycles daily and for the ropes at the hoists with less than 100 cycles daily and for the ropes at the auxiliary hoists – to 24 months.

Calculation shows that potential profit due to increasing of time interval of rope destructive testing is about $1,000,000 for five years. Sources of the profit are:

- increase useful working time of a hoist due to inspection time shortening;
- decrease expenses for rope samples cutting off and for the destructive testing;
- saving funds for the new rope purchasing when a rope in use becomes too short because of cutting samples off.

The number of INTROS instruments has been increased up to 13 sets during 2003, which makes possible to provide instrumental inspections on regular basis. Each set includes 3 magnetic heads

(in average) for different rope types and sizes. The number of inspection personnel working with INTROS increased up to 16 persons.
The new rope inspection technology and procedures are rather effective. Here are two examples of rope non-destructive testing and monitoring.
Fig. 6 illustrates testing data of 38,5 mm locked coil type guide rope just after its hanging. The LMA and LF traces show 3 LF located at (240-360) m. The LFs were identified as inside wire breaks by rope manufacturer. Visual inspection of the places confirmed this: there were local diameter variations.
Another example: monitoring of the haulage 43,5 mm rope with 1250 m length. The total LF number increased since June, 17, 2003 to June, 27, 2003 dramatically: from 8 to 167. The maximum LF number per lay increased from 6 to 7. The rope was discarded. Reason of so quick rope wear was that lifting speed increased from 10 m/s to 14 m/s.

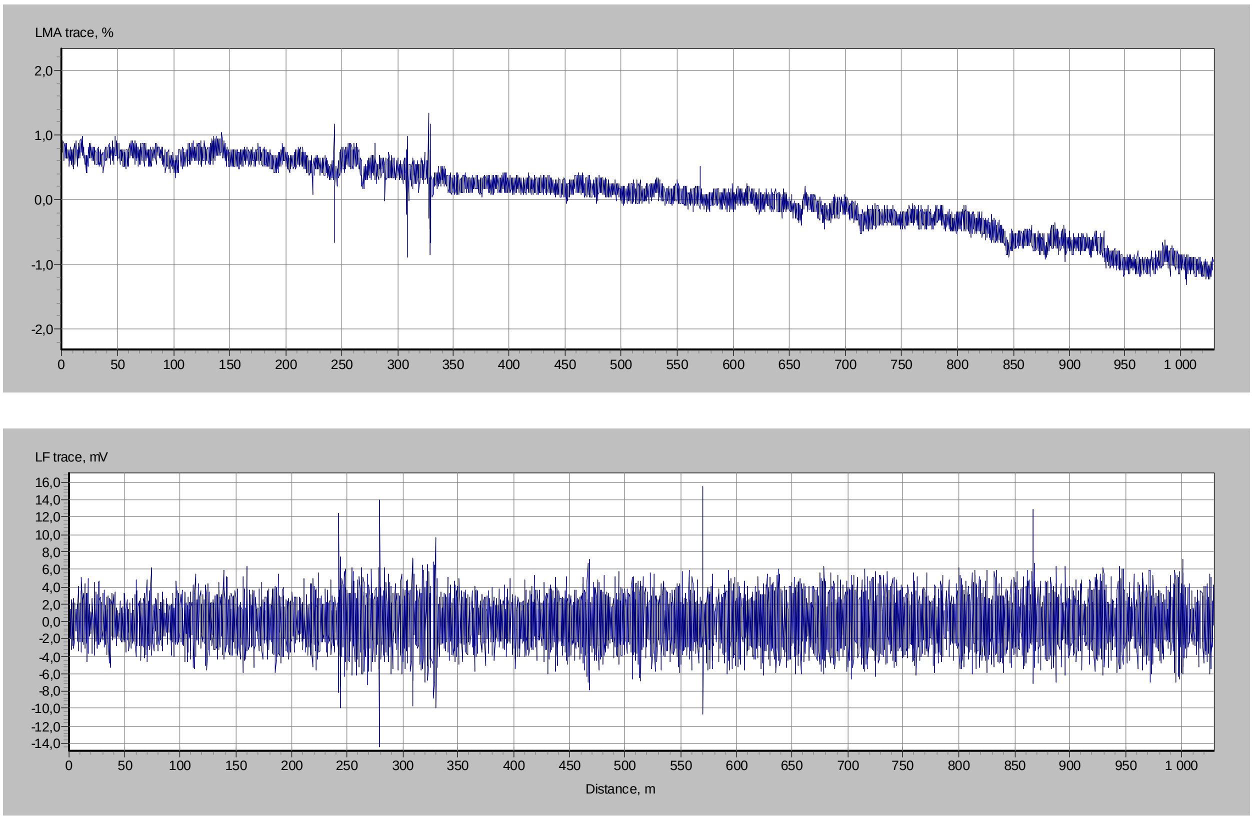

Fig. 6. LMA and LF charts of rope 38,5 mm. Charts obtained by INTROS rope tester.

The rope condition monitoring at NN mine hoists makes possible to analyze rate of rope wearing. The average wear speed defined as the LMA value per time period is about (0,05-0,1)% per week.

Conclusion

The experience of hoist rope non-destructive testing and monitoring is very effective: higher level of hoist use safety is provided. On the other hand, non-destructive testing and monitoring bring a real profit due to decrease of destructive testing scope and due to release of 23 people of inspection staff involved in visual inspection.

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