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Automated magnetic rope condition monitoring: concept and practical experience

Summary

Continuous rope monitoring is a new emerging application of rope NDT. It allows to increase safety of rope installations, that is especially important at dangerous industrial objects such as drilling rugs, hoists of steel mills, offshore applications. Design and implementation of rope monitoring systems has to solve several problems, which are not actual for common rope testing instruments. Firstly monitoring systems should be rugged designed and should be able to work in severe working environment (high and low temperatures, high humidity, dust, vibration action, explosive environment) and at the same time require minimum servicing. Secondly it should be automated and give clear and unambiguous indication, so that it can be applied by general machine operating personnel. To meet this contradictory requirements the monitoring system should be optimized for special rope application. Results of rope monitoring system Intros-Auto applied for drilling rigs will be discussed.

1 Introduction

In many industrial applications steel wire ropes are used for demanding jobs, when critical rope damage can cause heavy material losses or even fatalities. Such situations are common in offshore applications, oil and gas industry, heavy industry (mining, steel industry). To avoid accidents magnetic rope testing (MRT) is being applied, which enables forehanded detection of such rope defects as abrasion, corrosion, wire breaks in outer and inner layers [1]. MRT is proved to be efficient only if applied regularly, if time interval between inspections is not so long for rope deterioration to become critical. However intensification of equipment operation makes it in many cases difficult to apply common MRT regularly and increase its costs. Therefore last several years a new realization of rope diagnostics gains traction, this is continuous rope monitoring systems (CRM). Its significance was stressed also at the special IMCA workshop on 14 May 2015. MRT is a present state of rope NDT and CRM is its future.

2 Requirements for rope monitoring systems

Systems for rope conditional monitoring differ from common MRT instruments in many aspects. Such systems should have rugged design and be very easy to operate in order to ensure high reliability and robustness. Sensor should have high sensitivity for defects (wire breaks) and low level of maleficent influence factors. It should perform automatic data interpretation, results indication should be unambiguous and comprehensible. At the same time it should allow verification of this results. This implies storage of results over a considerable time and possibility to retrieve this results for external review. Automatically calculated rope discard criteria should comply with appropriate international norms such as ISO 4309 [2], so it should imply at least loss of metallic cross-section and number of wire breaks over fixed length (6*d* or 30*d*, where *d* – rope diameter).

3 Implementation of rope monitoring system

Complex of rigid requirements for monitoring system are possible to meet only in highly specialized implementations, designed for certain rope application. For example rope monitoring system Intros-Auto has several specific realizations: for hoisting block of drilling rigs, for hot-metal cranes of steel mills. Automatic system for monitoring of drilling rig ropes consists of a compact magnetic head (MH), placed on the rope (Fig. 1), connected with a control and display unit (CDU), placed at console of drill tower operator (Fig. 2) [3]. Monitoring system has explosive proof design, extended temperature range and IP 66 ingress protection, so it can be used in severe environment. The system provides two operation modes: continuous monitoring and periodical automated rope testing. Magnetic head shown at Figure 1 is designed for periodical (every shaft) rope testing. MH is located permanently near the drum in a winch unit, this enables quickly and easy mounting and dismantling of MH at/from the rope, no additional attachments are necessary.

Figure 1. Magnetic head of Intros-Auto at the rope

Figure 2. Control and display unit of Intros-Auto at operator console

Inspection procedure is fully automated, so the operator should switch system on and off and see results at the display. To make indication more understandable it conforms with traffic light principle. If some rope part with valuable deterioration passes through MH, CDU switch on yellow or red LED, depending of rope condition (yellow light corresponds warning condition and red light – critical condition). So far no valuable deterioration is found on the rope, green LED is lightning. In case the whole accessible length of the rope is checked it is possible to compare successive inspections with each other to find out, when rope begins to deteriorate intensively. At the end of inspection some additional information about found defects is being displayed at CDU to enable an operator to check defects visually if necessary. The system can store measurements of last several dozens inspection, this results can be send to some external computer via Wi-Fi or a cable. It is also possible to control inspection process from remote computer on-line. The system implements continuous and periodical monitoring modes. By demand inspection results can be analyzed by external expert so far measurements have the same representation as common LMA- and LF-traces. Speed of the rope during inspection can be from 0.2 to 5 m/s.

Rope condition is being estimated on the base of 3 different criteria – this are: LMA and number of wire breaks over two fixed lengths of the rope (for example, 6D and 30D), which can be combined to meet recommendations of ISO 4309. The main task of data processing consists in detection of wire breaks. To increase reliability of this two different LF-sensors are used: one sensor performs better sensitivity to outer wire breaks and another – better sensitivity to internal wire breaks. Special algorithm provides matching of appropriate LF-channels so that no double counting of the same wire break occurs. Figure 3 shows traces of two different LF-sensors, detected local faults are marked above the trace. To detect wire break signals at noisy background adaptive optimal filtering is being used. It should be also taken into account that one signal can correspond to several broken wires, so its magnitude should be considered in some statistical form to estimate number of broken wires.

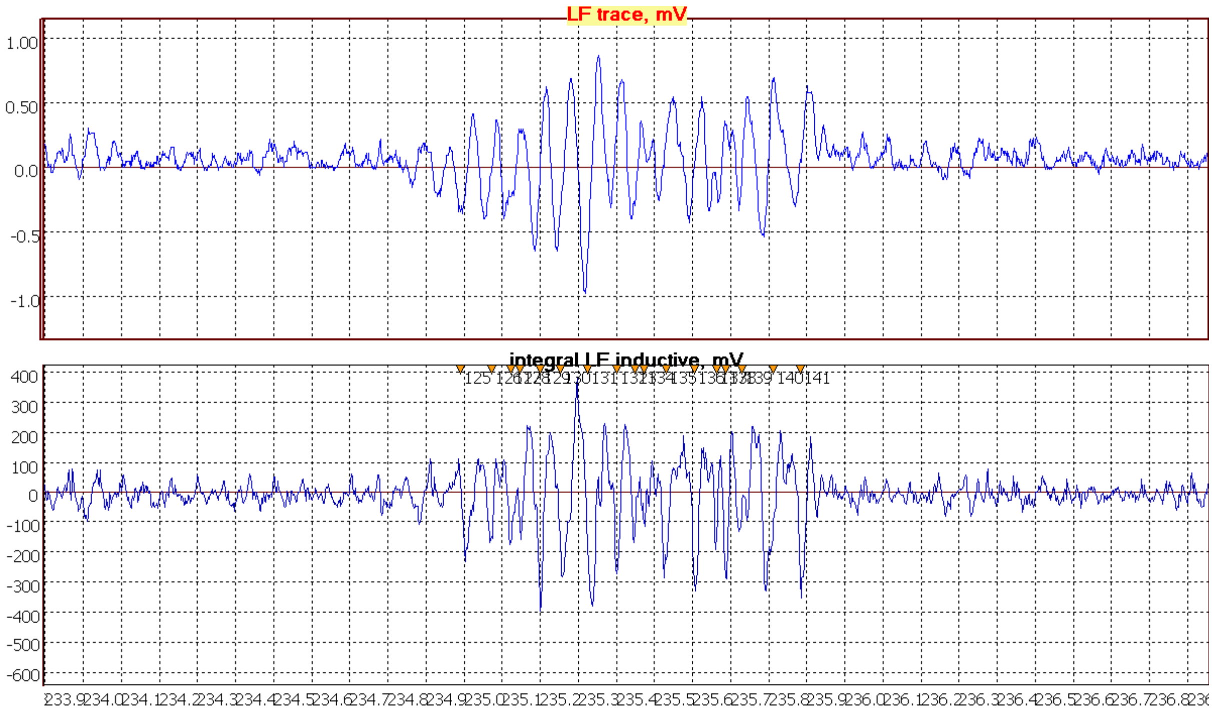

Figure 3. Two different types of sensors increase reliability of LF detection.

4 Case study

Results of calf line MRT, made by INTRON PLUS in 2010-2011, has shown that 25% of all inspected ropes had to be discarded before they reached ton-milage value, prescribed by rope service regulations. This demonstrates importance of MRT at drilling rigs.

Since 2014 Intros-Auto automatic rope monitoring system was installed for pilot operation at several drilling rigs of 4 different companies in Russia. It checks steel wire ropes of 6-strand and 8-strand constructions with diameter from 28 mm to 35 mm. Monitoring is executed not continuously but in a periodical manner: the rope is to be checked before every shift, that is twice a day. During inspection the hook goes from the lowest position to the highest position to provide maximal rope length pass through MH. It is important that the rope during inspection has the same load, because results can differ depending on the load. The system was used for several whole cycles between calf line slip and cut operations, which lasts in that case from 1 to 2 months. Figure 4 shows LMA and LF traces of the rope after 30 days operation as it reached running of 4545 t-km, which exceeds cut and slip criteria by approximately 50% (3000 t-km): rope has no valuable deterioration. Only several stand-alone wire breaks are to be seen at LF-trace.

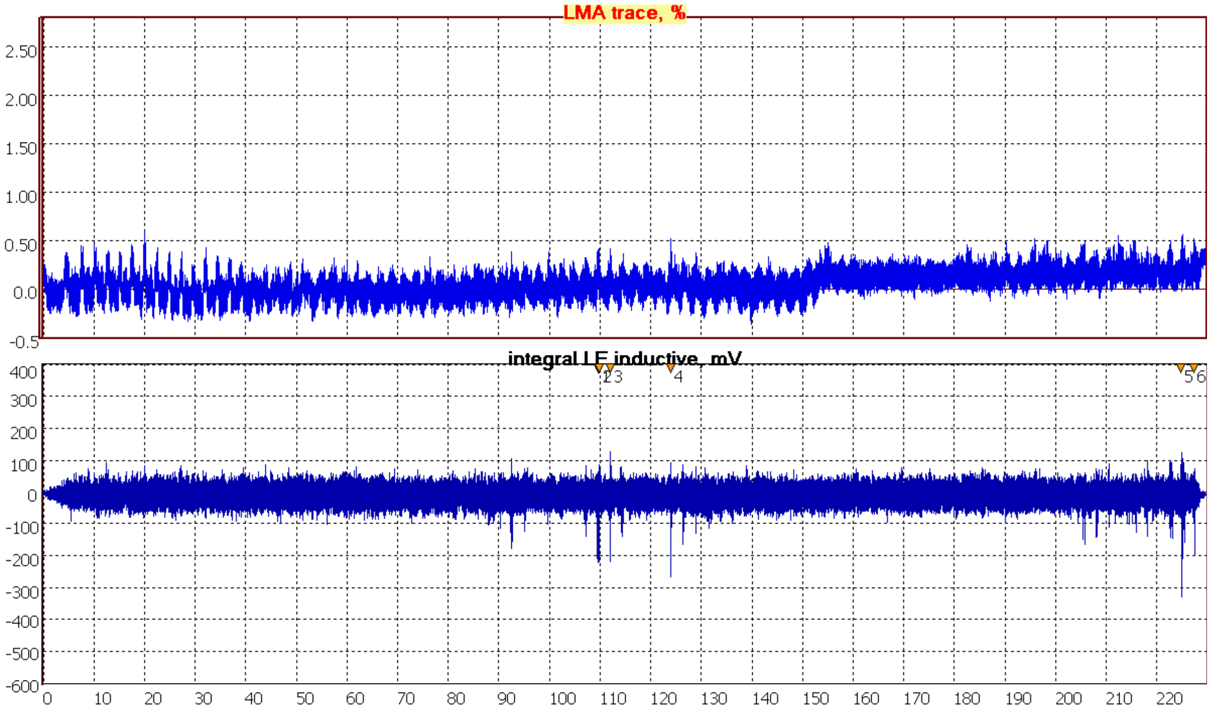

Figure 3. LMA and LF traces for the rope running 4545 t-km.

Figure 5 shows LMA and LF traces as yellow indication come; it was after 36 days of operation and the rope running achieved 5400 t-km. There are to regions with agglomerations of wire breaks: at the distance 90 – 150 m and at the distance 200 – 150 m; maximal number of wire breaks over the length of 30D at the second region is higher, than at the first, and it exceeds warning threshold, that was signalized with yellow light. Wire breaks locates in periodical groups that reflects peculiarity of rope deterioration on sheaves of this hoist.

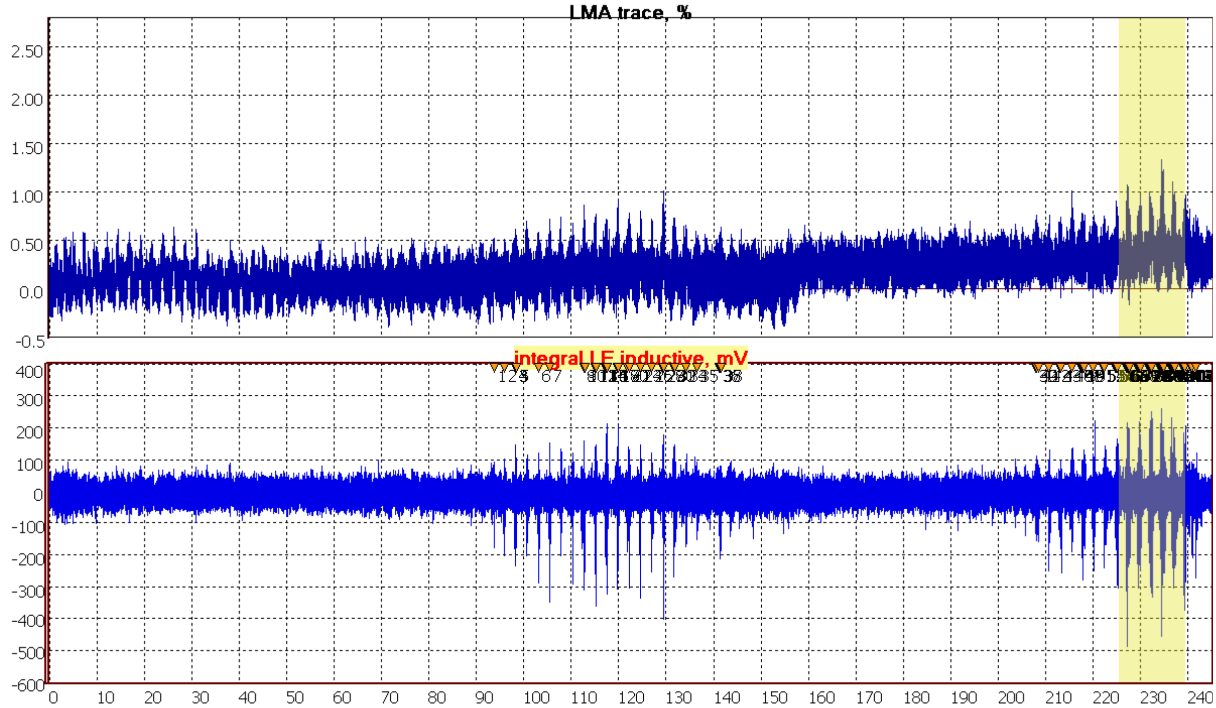

Figure 5. LMA and LF traces for the rope running 5400 t-km.

Figure 6 shows LMA and LF traces as red indication come; it was after 38 days of rope operation, rope got a running of 5900 t-km. Maximal number of wire breaks over 30D length at the distance of 200 – 150 m exceeded rope discard threshold. It should be stressed that it occurred only in 2 days after the yellow indicator. After the beginning of rope degradation it goes fast. The end rope running in this case is nearly two times higher, than prescribed criteria for cut and slip operation, so the rope was used notably longer, that means measurable cost reduction.

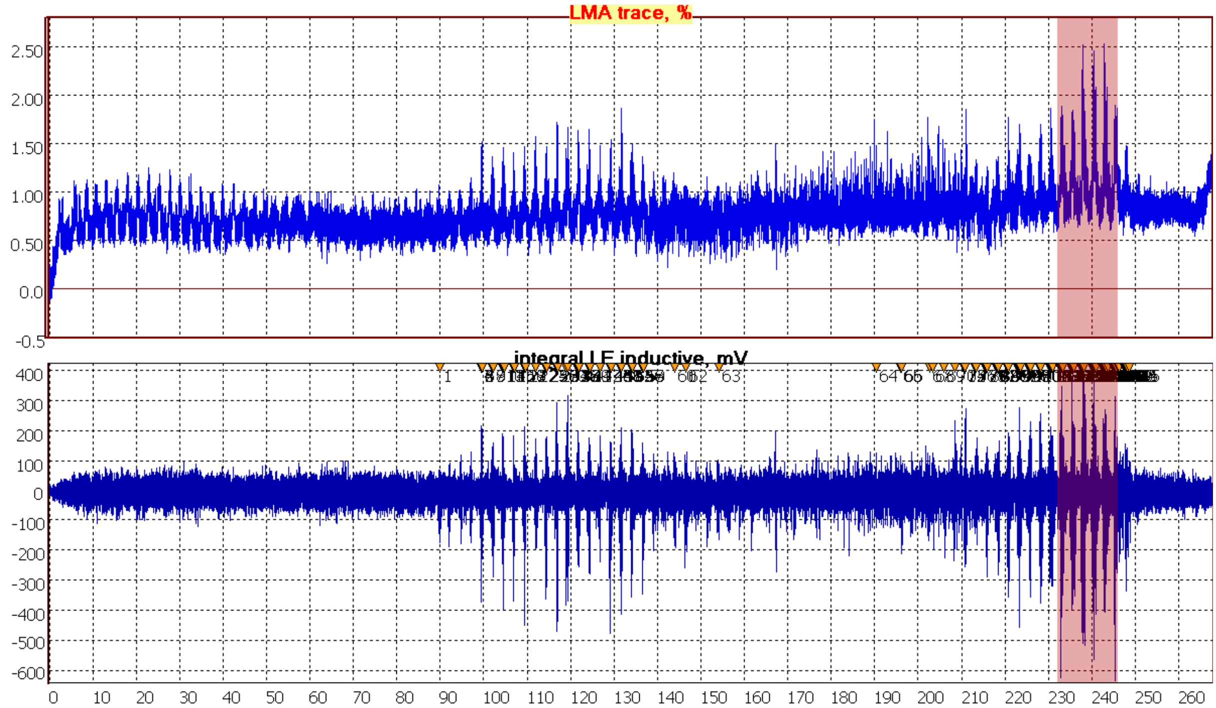

Figure 5. LMA and LF traces for the rope running 5900 t-km.

Rope discard criteria for red indicator correspond to breakage of 10% of wires at one lay length (corresponds to 6*d*). In this case this means breakage of 21 wires. Most deteriorated section of the rope was cut out and disassembled to count real number of broken wires. Figure 7 shows separate wires of one strand after it was unstranded. Maximal number of wire breaks at the lay length put together 27. So system indication was correct. It should be mentioned that it is complicated to count exact number of broken wires in wire breaks agglomeration, so only statistical estimation can be done. Unstranding of most deteriorated rope section was repeated after the next cycle of operation and it also confirmed correct rope condition estimation, made by Intros-Auto.

Figure 6. Broken wires of one strand after its unstranding.

5 Conclusion

Concept of periodical automatic rope condition monitoring was developed and implemented in Intros-Auto monitoring system. This system has proved to be appropriate for drilling rigs calf lines. It provides on-time detection of rope deterioration and at the same time gives an advantage of condition-based rope operation that can result in cost reduction. Operation of Intros-Auto rope monitoring system in industrial conditions have shown its reliability, simplicity in operation, validity of inspection results. This concept will be extended to another important rope applications.

Reference

[1] Sukhorukov V., Slesarev D., Vorontsov A. Electromagnetic Inspection and Diagnostics of Steal Ropes: Technology, Cost-Effectiveness, Problems. – Materials Evaluation, 2014, №8, pp. 1019-1027.

[2] ISO 4309:2010 International standard. Cranes – Wire ropes – Care and maintenance, inspection and discard.

[3] Slesarev D., Sukhorukov D. Automatic monitoring of hoisting steel wire rope: practical approach. - OFFSHORE CRANES & LIFTING CONFERENCE. 2014.