

Application of MFL nondestructive testing for automated rope condition monitoring

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Abstract

Continuous rope monitoring is a new emerging application of rope NDT. It allows increasing safety of rope installations, which is especially important at dangerous industrial objects such as drilling rigs or mining shafts. At the same time their design and implementation makes to solve several problems, which are not actual for traditional MFL equipment. First of all monitoring systems should be rugged designed and be able to work in severe working environment (high and low temperatures, high humidity, dust, vibration action) with minimum servicing needed. Secondly it should give a maximally easy to interpret condition indication, for example, as traffic light indication, so that it does not claim some special qualification of service personnel. Thirdly it should be based on automatic processing of representative measurement data. There is a row of some additional features, which distinguish MFL equipment for continuous rope monitoring. These questions are discussed in the report in general and for the case of drilling rig rope monitoring.

Keywords: magnetic flux leakage (MFL), Electromagnetic Testing (ET), rope, wire, condition monitoring

1. Introduction

Non-destructive testing of steel wire ropes plays very important role in safety assurance of different lifting machines and mechanisms and allows reducing of costs of possible incidents; it also helps to reduce operating costs due to planning of rope replacement [1]. The most informative method of non-destructive rope testing is MFL (magnetic flux leakage) [2, 3]. It enables to locate and numerically estimate two main deterioration factors of wire ropes, these are loss of metallic cross-section area (LMA), caused typically by corrosion and abrasion, and localized faults (LF), caused by wire breaks both outer and inner. This type of rope inspection is recommended by different international codes, such as ASTM 1571: Standard Practice for Electromagnetic Examination of Ferromagnetic steel Wire Rope, BS EN 12927-2004: Safety requirements for cableway installations designed to carry persons — Ropes, ISO 4309: Cranes — Wire ropes — Care, maintenance, installation, examination and discard. Effectiveness of non-destructive testing depends on the regularity of rope inspections during the whole lifecycle of the rope. Regularity of inspection depends on several factors, first of all from availability of qualified personnel with special equipment at place. There are many rope applications with remote location, such as oil and gas drilling rigs or offshore platforms and vessels, which are hardly accessible for external NDT experts but do not have their own specialists. Automatic rope testing system offers a reasonable solution for such rope application.

2. Requirements for rope monitoring system

Design of such a system should be aimed on a solution of somehow contradictory problems: the system should ensure high reliability and robustness, be easy in use, do not assume special qualification of service staff. It should also admit a permanent installation at the hoist. To ensure high reliability mechanical effect of the rope on the sensor should be minimized, at the same time the sensor should have high sensitivity for defects (wire breaks) and low level of maleficent influence factors. This leads to some conflicting requirements. High sensitivity to

wire breaks presume a small gap between the sensor and the rope, but a small gap results in intensive mechanical effect on the sensor as the rope moves, which brings about a reduction of mechanical robustness. One of the possible solutions is presented in [4].

On other hand the system should perform automatic data processing to give an operator resulting rope condition estimation only, but this estimation should have rather high reliability. To enable verification of data processing results these should be storage over a considerable time, for example, several months, and be easily accessible for some external expert or supervisor (by wireless data transmission).

3. Realisation of rope monitoring system for drilling rigs

Inspection of 53 drilling rig calf lines in Volga federal district made by INTRON PLUS have resulted in discarding of 13 ropes according to Safety Norms for Gas and Oil Industry, but none of that has reached the end of its service life according to Technical Rules of Calf Line Operation (according to tonn-milage). These results roused INTRON PLUS to develop an automatic rope diagnostic system – Intros-Auto.

Above-mentioned requirements are taken into account in automatic Intros-Auto system. It utilizes compact sensor (magnetic head), fixed on the rope, so it can be mounted at place with intensive transverse moving of the rope. The system is designed for monitoring of drill tower ropes (Fig. 1) and first batch of Intros-Auto instruments is already installed.



Figure 1. Drilling rig, where rope monitoring system is installed

Intros-Auto consists of the magnetic head and control and display unit connected by means of a cable. Magnetic head locates just above a winch (Fig. 2a). It is not fixed on the rope permanently, but locates near the winch and can be put on the rope easily for the daily rope check. Result of the inspection appears on the display (Fig. 2b), which locates at the console of drill tower operator. Inspection procedure is fully automated, so the operator should switch system on and off and see results at the display. If some defect part of the rope passes thought the sensor, it lights yellow or red LED, depending of rope condition (yellow light corresponds

warning condition and red light – critical condition). So far no valuable defects are found on the rope green LED is burning. It is important that every time the whole length of the rope being checked, because it makes possible to compare successive inspections with each other to find out a moment as a rope begins to deteriorate intensively.



Figure 2a. Magnetic head of Intros-Auto at the rope



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

Current rope condition is estimated according to 2 main criteria: loss of metallic cross-section area and amount of wire breaks at the defined rope length (for example $30D$, where D – rope diameter) – wire break density. Additionally the system considers increasing of wire break density. Whereas loss of metallic cross-section area can be indirectly measured by the sensor on the base of magnetic flux leakage, estimation of wire break density is based on detection of wire breaks. Consequently detection of wire breaks plays a key role in automatic rope diagnostic system. This defect detection procedure is based in a proper processing of LF signals, which typical shapes are shown on the Fig. 3 (the appropriate rope section has critical amount of wire breaks, so that rope was discarded by the system). Reliability of defect detection depends on different factors including signal-to-noise ratio, distance between distinct defects, and defects location at rope cross-section. To increase detection reliability two different sensors are used to generate two LF traces: Hall sensors (“LF trace” on the Fig. 3) and inductive coils (“integral LF inductive” on the Fig. 3). There signals are to be processed together with consideration of different spatial resolution and some distance shift of defects pulses: it is important that one defect will not be counted twice.

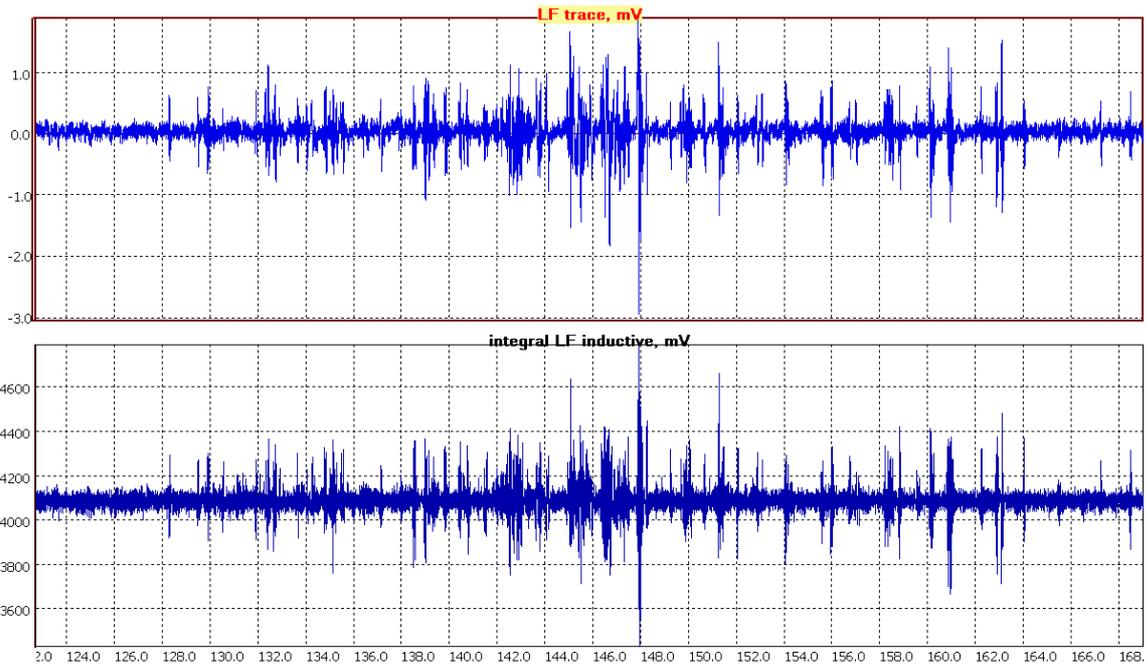


Figure 3. LF traces of discarded rope

Decision of an automatic system has statistical nature, so it can be a mistake in some specific cases. To make possible analyze and solve such specific cases the system should provide a possibility to store inspection data for a quite long time and upload it from a system in external computer for the further analysis by an expert. This data should be represented in some conventional form, such as LMA and LF charts.

Conclusion

The developed automatic rope diagnostic system can be used for rope condition monitoring on drilling rigs and in other similar rope applications. However, wide implementation of rope monitoring systems requires development of appropriate rope condition criteria for warning and critical level. Obviously it should be based on rope residual strength calculation with respect to rope construction and load conditions. Furthermore it should concern probability of defect detection (POD) for the specific rope monitoring system.

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