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SPECIFIC ASPECTS OF INSPECTION OF LARGE DIAMETER STEEL ROPES

Summery

Problem of nondestructive inspection of large diameter steel ropes is especially important in offshore applications, where costs of potential lost are very high. In this aspect it is important based on computational simulations to find optimal magnetization conditions for LMA measurement and detection of internal and external local faults at multi-strand rope. Besides that it is essential for such ropes to enable detection of wire breaks clusters. For MRT instrument it is also important to realize not only one but two LF-channels with different spatial resolution. Near LF channels additional information about wire breaks can be obtained from local LMA behavior, upon conditiob that LMA measurement meets some rigid requirements. Nevertheless not all the cases can be identified by MRT so that additional visual inspection and result verification is necessary to solve such doubtful cases.

Key words: magnetic rope testing, wire ropes, MFL

1 Introduction

Large diameter (greater than 100 mm) wire ropes are used in a range of industries including offshore drilling, marine rigging systems, underwater exploration, stay ropes and open-cut mining. Most leading producers, including Redaelli, Bridon-Bekaert and WDI present such ropes in their product line. Most challenging from rope inspection point are offshore rope applications so they are the main purpose of this paper.

These ropes are often used in very adverse conditions, including seawater and continuous reverse loading, during pitching and other marine motion. This will inadvertently cause the ropes to deteriorate to their critical condition, requiring removal of the worn segment and/or complete replacement.

Such a rope can cost well over a million Euro ex-work, with the service costs of its replacing it can easily double if not treble. It is thus necessary that the rope is treated to accurate inspection of its condition at regular intervals. Magnetic rope testing (MRT) is the most precise inspection method, in particular of large diameter ropes [1, 2]. It should be mentioned that MRT inspection of such ropes is often very responsible, as there is no ability for its repeating, hence special requirements for equipment and personnel should be met.

2 Specific features of large diameter ropes and requirement for there inspection

Large diameter ropes are made to handle large loads, in excess of 5000 tonnes. In addition, such ropes must exhibit high axial and radial hardness and yet remain flexible.

Therefore rope design accounts for these requirements, and result in rope multi-strand construction with up to 300 individual wires, which relative cross-section is often less than 0.3%.

Large diameter ropes of multi-stranded design have got widespread use in the last time. The extra strength of these ropes comes at a cost, as they experience greater wear during spooling, with abrasive wear on external strands and frictional wear of internally. These effects can be reduced by using high density polyethylene sheathing for the strands and using plastic fillers for inter-strand space, that prolong operation life, but do not eliminate deterioration factors. In this case MRT becomes an important tool of rope condition estimation.

MRT of large diameter ropes require specialized equipment, such as the INTROS MH 100-175. (Fig. 1 — rope tester placed at the rope sample). Inspection is often carried out at the industrial site, where the rope is used. It should be mentioned that MRT instrument to magnetize such a rope is rather heavy (over 100 kg) and induce strong attractive forces so it is complicated to handle. Large rope diameter and specificity of offshore lifting operations determine requirements for MRT:

- Accurate adjustment of magnetic head (MH) at the rope is necessary to ensure correct inspection results;
- Special actions should be taken to exclude influence of external ferromagnetic parts of construction (crane's structural elements for example);
- Ensure correct odometer operation;
- LMA calibration should be performed at the less wear-prone rope part, which can be used for subsequent calibration during next inspection; preferable for MRT instrument to have automatic calibration procedure, because of a fair potential measurement error (for example, while calibrating with additional rods of 1% rope cross-section and typical LMA background noise of 0,2-0,3% at rope section with 10% LMA it gives an error of 2-3%).

Figure 1. Intros MH100-175 at the rope sample.

3 Physical aspects of magnetic inspection of large diameter ropes

During MRT it is very important to achieve magnetic saturation of rope material, as it is also stated in IMCA LR004/HSSE 023/M197 [3]. It ensures follows advantages:

- Increase detection probability of wire breaks especially for internal rope strands;
- Reduce LMA measurement error, caused by previous rope magnetization;
- Increase signal/noise ratio for LF and LMA traces due to reduction of influence of material properties' inhomogeneity.

Under MFL testing magnetic flux Φ is induced in the rope part under the test. In the case that rope material was fully demagnetized before test and the magnetic field is homogeneous across rope cross-section, magnetic induction will achieve a value corresponding to some point *a* or *b* at initial magnetization curve (Figure 2): – *a* corresponds to magnetic saturation, *b* – undersaturation. In the typical case that rope material has some initial residual magnetization *Br*, under saturation conditions magnetic induction achieves same point *a*, while with undersaturation it comes not to *b* but to some area around *b* (marked as red ellipse). In the last case LMA value of MRT instrument will have variation depending on the size of this ambiguity area. Magnetic saturation of the material under test results in reduction of magnetic background influence, as well as reduction of the influence of material inhomogeneity, which appears because of thermal and mechanical impact during rope production or operation.

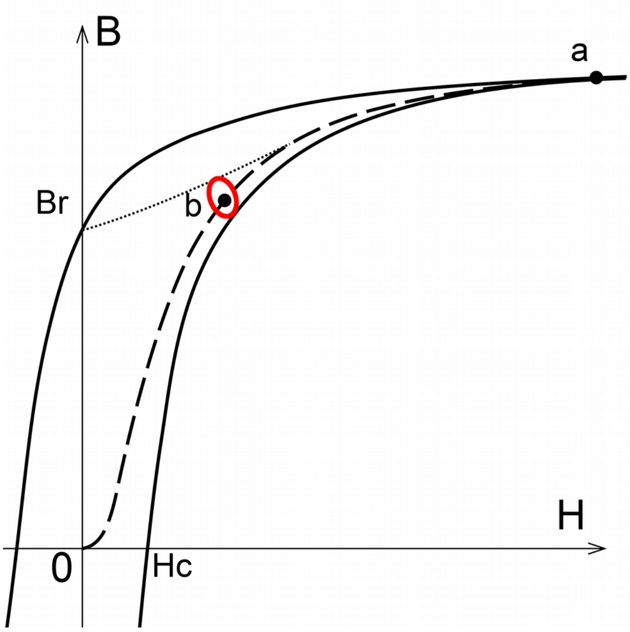
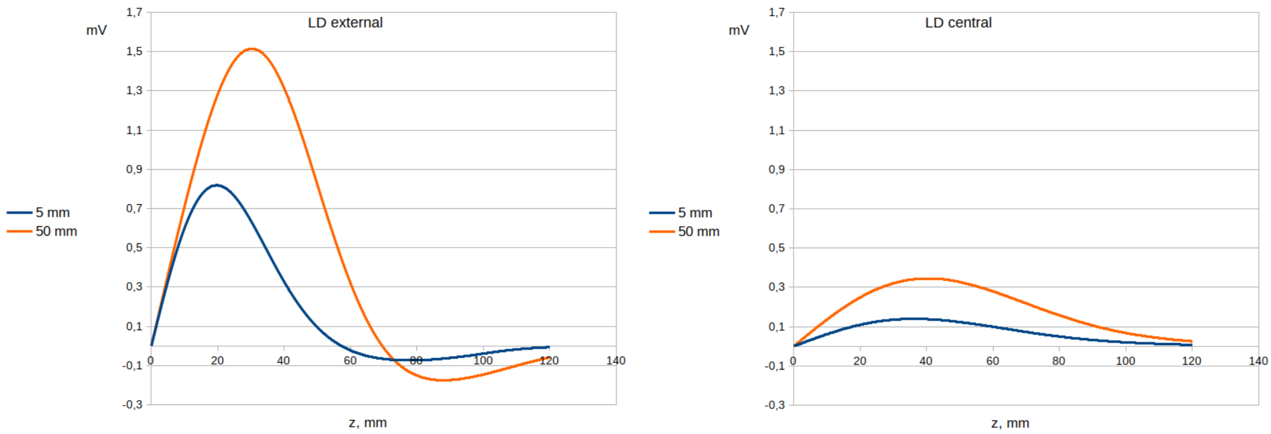


Figure 2. Rope magnetization curve

Grade of magnetic saturation plays also important role in local fault detection ability. Being undersaturated outer wire layers bridge magnetic flux leakage from internal wire breaks so sensitivity to internal local faults goes down considerably. Finite element simulation was made for LF signals from outer and inner wire break for the rope of 162 mm diameter for two variants of magnetic system: 1. Standard magnetic system, which saturates internal wire layers; 2 Magnetic system with reduced weight (approximately 2 times lighter than standard variant). Figure 3 shows the signal (right part of it relative to the center of wire break) from broken wire with relative cross-section of 0,5% and air gap of 5 mm and 50 mm, located in the outer layer (a) and in the center (b) of the rope for standard magnetic system. Vertical axis corresponds to sensor output in mV, horizontal axis corresponds to a shift of sensor along the rope from the center of wire break in mm (sensor is located with a gap of several mm above the rope). Figure 4 shows similar signals for “reduced weight” magnetic system, amplitude of LF signal for internal wire break is about 0,0035 mV (for external – about 0,9 mV). Simulation gives relation of signal amplitude from outer wire break to signal amplitude from inner wire break of factor 5 for standard system and of factor 280 for “reduced weight” system. It is obvious from this comparison that it is not possible to detect internal wire breaks when using “reduced weight” system.



a b

Figure 3. Simulated signals from external and internal wire breaks for normal magnetization

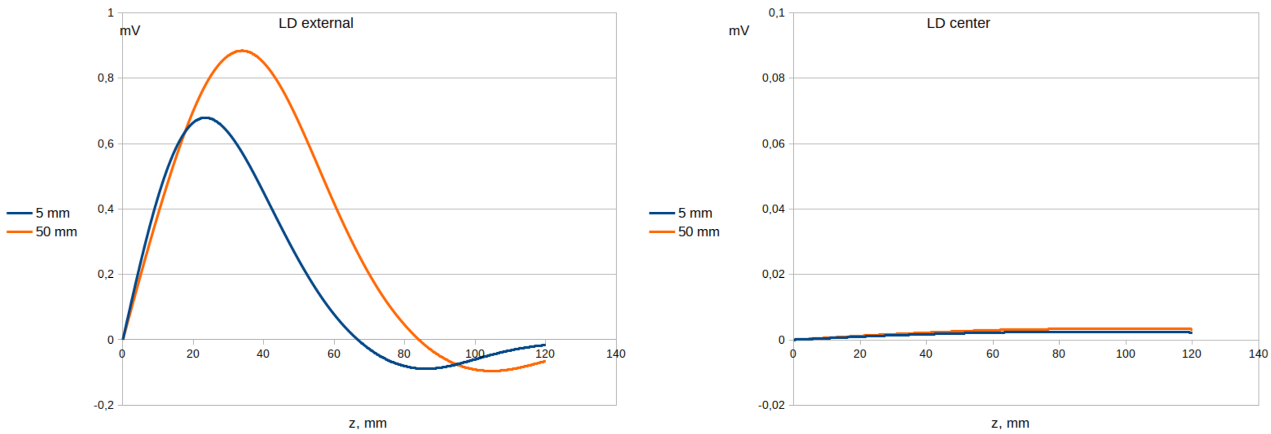


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Figure 4. Simulated signals from external and internal wire breaks for low magnetization

Signals for a standard magnetic system were also obtained experimentally. Experimental results (relation between signals from internal and external breaks and for different air gaps) differ from the simulation less than by 20%.

4 Aspects of LF detection reliability

Increasing of wire breaks detection reliability plays especially important role during inspection of multi-strand wire ropes. This is caused by two factors: 1. Internal wire breaks typical for such ropes emit significantly lower LF-signal, then outer wire breaks; 2. Often wire breaks appears not isolated but in clusters, which are especially hazardous, and signals of individual breaks overlap, which complicates trace interpretation and estimation of real beaks number. Reliability of wire breaks detection can be achieved by means of two methods.

To increase detection reliability two different LF-sensors can be used: one sensor with a better sensitivity to outer wire breaks and another – with better sensitivity to internal wire breaks [4]. Better sensitivity to internal wire breaks can be achieved by special sensor geometry. This is realized in some instruments. It should be mentioned that improving of sensitivity to internal wire breaks is being achieved at costs of increasing of disturbance from cross-axis rope moving during inspection. Correct trace interpretation in this case presumes consideration of rope movement information and high operator qualification.

Another way to increase detection reliability consists in application of measuring system with high angular resolution [5]; this means decomposing of LF trace into separate measuring point lines (according to position of separate Hall sensors). It enables to localize wire break signal in angular position on the rope and therefore distinguish between breaks in different strands. But it is important to note that this representation is effective mostly for outer wire breaks. Interpretation of such signal representation is not a trivial task because of regular background component from a strand structure of the rope. Consequently this representation can be used only as additional to standard LF trace.

In particular should be discussed the problem of identification of wire breaks clusters so far as most of critical defect of large diameter wire ropes are of that type. Hard operation conditions cause development of wire break clusters at rope sections exposed to combination of high axial load and bending strain. Because of signal overlapping it is often not possible on the base of LF trace to estimate directly number of broken wires. As an example Figure 5 shows LMA and LF traces of a cluster with 13 internal wire breaks at some multi-strand rope. Some pulses at LF trace correspond to separate broken wires, but another correspond to 2 or 3 wires at once. Correct estimation of wire break number is based on joint analysis of LF and LMA traces and with consideration of previous inspection results of similar ropes. While overlapping LF-signals of neighboring wire breaks depending on their relative position can compensate each other and reduce signal magnitude, whereas LMA-signals from this wire breaks magnify each other. That is used for estimation of wire breaks number (under assumption of high accuracy of LMA measurement). However it is important to remember that LMA signal of one wire break depends not only from wire relative cross-section, but also from a gap between its ends.

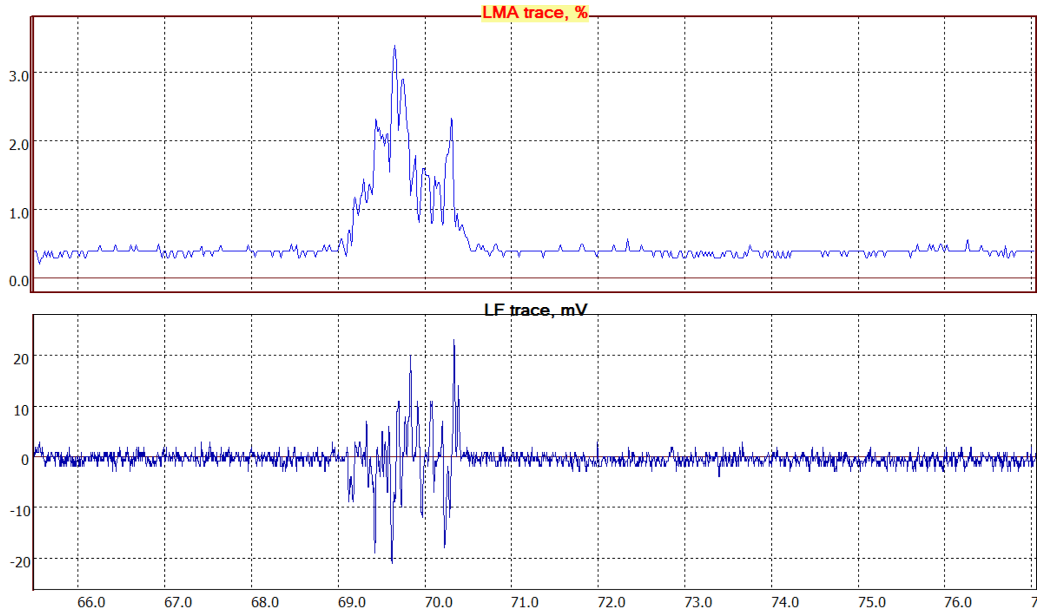

Figure 5. LMA and LF traces of a cluster with 13 wire breaks

It should be also said that deterioration of large diameter multi-strand wire ropes results some times in cracking of internal wires practically without a valuable gap between wire ends. So far as magnitude of LF signals depends significantly on the air gap, such defects can not be identified on the base of MRT trace analysis. Assuming this wires bear axial load they should go apart with a time, subsequently breaks should be detected by the next inspection, which should follow in a reasonable interval.

5 Conclusion

Valid inspection of large diameter steel wire rope on the base of MRT presuppose that the instrument provides magnetic saturation of the whole rope cross-section to enable detection of internal wire breaks and reduce influence of rope material inhomogeneity. To increase reliability of wire break detection LF trace should be complemented either with additional LF trace from the second sensor, or with expanded axial representation for the sensor with high angular resolution.

6 References

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