Innovative Magneto-Inductive Systems for Metallic Ropes

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Abstract

In this paper a survey on different system for the magneto inductive control of metallic ropes is presented. The fields of application regards cableway, cranes and elevators. After a brief introduction regarding the Magneto Inductive technique applied to the non destructive testing of metallic ropes, in the first part paper are presented the structures of detectors for different field of applications, together with their magnetic characteristics. Finally, the second part deals with the performance of the different detectors.

Keywords: Non Destructive Testing, Metallic Ropes, Cableway, Cranes, Elevator, Hall sensors

1 Introduction

The main technologies applied in the Non Destructive Testing (NDT) of ferromagnetic ropes [1-2] are based on the Magnetic Inspection (MI) and in particular on the Magnetic flux leakage (MFL) and the Magnetic Reluctance Variation (MRV) techniques. In the two techniques a magnetic flux produced by permanent magnets or currents is pushed inside the ferromagnetic parts to be tested. The presence of the flaw is detected by the measurement of a leakage flux in the MFL method and by the measurements of a variation of the magnetic flux in the MRV technique. The first approach allows only the identification of the flaw presence while the second one allows also a quantitative evaluation of the flaw volume. For these reason the first technique is called LF (Localised Faults) while the second one is called LMA (Loss Magnetic Area). The LF is usually efficient in the detection of broken wires even if the to part of the broken wire are very closed (narrow gap). The LMA is more reliable for the detection of flaw due to fatigue or corrosion because they can produce a generalised reduction of the wire cross section area.

The measurement of the magnetic field is usually provided by two main sensor technologies: coils and hall sensors. The coils are principally used when only the LF test is required while hall sensors are used when both LF and LMA are required. Many aspects influence a good flaw identification: detector topology, sensor technologies, magnetic saturation level of the body under test, position and dimension of the flaw, etc.

In the most countries of the world the NDT (LMA or LF) of ropes is compulsory only for cableways [3] but the demand in other fields of application it is increasing. It is worth to notice that NDT has been recently introduced for crane ropes [4], which are characterised by relative small diameters. Many plant managers of such plant are starting to requires today the NDT and the number of control requests are increasing dramatically. For such application the heavy and costly device adopted for cableway are non suitable. So the develop and market of lighter and cheaper devices is started for such field of application.

Another of the most promising sector of application for the NDT of ropes is represented by the elevators. The need is manly due to two factors. The first one regards the need of testing and maintainers staff to carry out and objective control. The second is linked to the technique tendency of going towards solutions characterised by ropes having an always inferior diameter (in order to reduce the hoisting dimensions) therefore in growing number. This second feature makes the visual inspection more complex and expensive in terms of time, as well as, less reliable. Similarly, the recent use of flat ropes (straps metal covered with plastic) in the elevator application makes the view examination impossible to perform and requires the use of a proper NDT technology.

In the paper, after a brief description of the magneto-inductive technology, a description of a wide range of innovative detectors for the control of several typology of ropes is presented. All the detector are developed at the Politecnico of Torino and are manufactured and delivered by its spin off AMC Instruments (www.aemmeci.com).

2 Magneto inductive principle

The NDT detector is based on a magnetic circuit closed to the ferromagnetic rope under test. The magnetic flux is produced with strong PMs (usually NdFeB) and is conducted to the ferromagnetic rope through a proper magnetic circuit made of high permeability massive iron (Fig. 1). When the rope
presents a discontinuity (as a broken wire) two magnetic effects occur: a variation of the main magnetic flux due to the reluctance variation and a magnetic flaw near the discontinuity (as sketched in Fig. 2). The exploitation of the two magnetic effects allow to obtain the two separate signal requirements:

a) Localised Fault LF

b) Loss Metallic Volume LMV

The magnetic sensors adopted for the revelation of two signals can be manly of two types: coils or hall sensors. The first kind of sensors behaviours are based on Faraday law and so give a signal proportional to the flux variation, on the contrary, hall sensors allow the measurement of the absolute value of the magnetic flux density (B).

Most of the commercial detector are based on coils. This is mainly due to technological-historical reasons. In fact the LF signal has been the signal required for the control rope since 50 years ago and, in the same time, coils are very sensitive to local flux variation produced by local flaws.

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years but in the same time the monitoring of the rope conditions is more and more required: people involved in maintenance of lifts today use the visual inspection but they require a more objective analysis.

3.2 Detector: AMC_LIFT

The use of ropes for lifts is one of the biggest field of application of ropes. The rope technologies and performances has been strongly improved in the last
an always inferior diameter (in order to reduce the hoisting dimensions) therefore in growing number.

For all this reasons, the regulatory bodies are therefore considering the introduction of magneto inductive control in the field of vertical lifting of people. The control technologies can be adapted from the ones already developed for ropes of big cableways but they require some critical changes. For such application the heavy and costly device adopted for cableway are non suitable. So the develop and market of lighter and cheaper devices is started and this market is more close to the elevator market. Moreover, it is worth noting that the major part of actual devices is based on coil technology: the need to reduce device size calls for the use of other technologies, such as those based on Hall effect probes. Such technique is already adopted by AMC, which have a specific know how, in all the other instruments. AMC has developed in the last year a first product series of a device for the contemporary control of the set of lift ropes.

In Tab. 2 are reported the main technical information regarding the AMC_LIFT detectors.

In Fig. 7 and 8 are reported the two devices for 4 and 6 ropes and in Fig. 9 and 10 are reported the magnetic flux density in the different hole of the detector without the ropes. The magnetic induction in the centre of the detector is about 500 Gauss for the AMC_LIFT4 and about 1000 Gauss for the AMC_LIFT6. More technical details about the devices are reported in [8].

Table 2: Detector device

<table>
<thead>
<tr>
<th>Detector name</th>
<th>Signal</th>
<th>Range (mm)</th>
<th>Detec. Hole (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMC_LIFT4</td>
<td>LF</td>
<td>4-12</td>
<td>13</td>
</tr>
<tr>
<td>AMC_LIFT6</td>
<td>LF</td>
<td>6-13</td>
<td>15</td>
</tr>
</tbody>
</table>

Figure 7: AMC_LIFT6: open and closed position

Figure 8: AMC_LIFT4: open and closed position

Figure 9: Magnetic induction measured in the different channel of the detector AMC_LIFT4

Figure 10: Magnetic induction measured in the different channel of the detector AMC_LIFT6

Finally, it should be noted that for all the detector for lift application there is the limitation to the LF control (LMA sensor are not present). It is considered sufficient since the cables are typically installed in a place protected from weather (since the signal LMA is particularly effective in relief of defects as corrosion). It is not excluded in the future to provide a configuration also having a control type LMA. If now people involved in maintenance are ready to accept a technology as LF, is necessary to proceed by degrees in innovation, considering that until now the rope control was based on a visual inspection characterised by a high degree of empiricism.

3.3 Detector: AMC_BELT

The increase of the use of power transmission belt in particular in the lift application introduce the need of a NDT control. In fact, the internal rope of the belt can not be control by visual inspection. A proper device for the control of belt with different number and size of metallic ropes and so different width of the belt has been developed. In Fig. 11 is reported the device AMC_BELT designed for belt from 30 to 55 mm.
3.4 Sensor array

The electronic developed for the sensor head is made by two electronic parts: the sensor array and the conditioning one. Boards change with instrumentation depending on number and diameter of plant’s ropes.

The sensor array board for the AMC_ROPE detectors is made by two half crowns of hall sensors, as reported in Fig. 12. The number of hall sensors depends from the size of the crown and so from the size of the detector. The crown is the transducer elements that get the information about the rope state in the magnetic domain and put it on the electric domain. The signals of the two half crowns are added and the total signal, through a conditioning circuit, is send to the stage of the acquisition system.

Fig. 12. Sensor array for AMC_ROPE detectors

The sensor array board for the detectors AMC_LIFT is made by a number variable from 4 to 6 crowns of hall effect sensors. Each crown has dedicated conditioning circuitry. A conditioning board is also present and made by three blocks. A first sum block, that output the total sum of the signals of each crowns, a second low-pass filter stage and a final gain stage. The sensor array for the AMC_BELT detector is made by a simple linear array of Hall effect sensor, with the same conditioning circuit of the others detector.

3.5 Acquisition System

After the instruments head comes the acquisition system. The purposes of this element is to power the electronics of the sensor head, to acquire and memorize the signals that indicates the rope status and, after the acquisition, to post process the information acquired, in order to give to the operator a complete diagnostic tool.

The system is designed to be portable and fully integrated. The project choose was to make a PC based system, with an external acquisition board, all integrated inside a single case (Fig. 13).

Figure 13: Acquisition system for AMC_BELT and AMC_LIFT family

The board used is a NI USB-6008 (for AMC_BELT and AMC_LIFT family) and a NI USB-6009 (for AMC_ROPE family), 8 channel USB multifunction DAQs and a commercial Windows based laptop is used to carry the software. The use of a laptop with an external acquisition board simplify the design of the acquisition system and give more flexiblity to the system

The acquisition and post-processing software was developed using Labview 8.6. The use of Labview and G-language make the software easy to test and upgrade. The software interface (Fig. 14) is made by an acquisition software and a post-processing tool.

Figure 14: Acquisition and post processing software written in Labview 8.6

The acquisition software can acquire up to 6 channel simultaneously (to cover the case of AMC_LIFT6, that have up to 6 analog outputs), and offer a real-time visualization of a single selectable channel. During the acquisition process some basic diagnostic feature are available (crown status, battery
status, real time filtering, etc.). The post-processing tool offers the possibility of loading a saved trace, filter, zoom and put marker, in order to separate the signal from the background noise. Another useful tool is the report generation toolkit, that allow the generation of a multipage report with trace (separated in strip) and plant information.

4 Detector performances

4.1 AMC_ROPE

The performance of the system can be shown considering the signal indicated in the certification procedure. Not in all the application fields there is a standard that define the required system performances. In particular, only for detector employed for the control of cableway installations designed to carry persons there is a proper standard reference (4). According this standard the detector should be able to pass a test on a proper laboratory test rope where artificial faults have been realised.

The results and the detectors installation during the test on the two detectors AMC_ROPE26 and AMC_ROPE35 are shown in Fig. 16 and 17. The test is positive when the amplitude signal included in the dotted circle is more than twice of the trace noise.

In the control of ropes of the other sectors (e.g. cable cranes, etc.) the system certification is non compulsory but the certification according the EU standard allow to guarantee the reliability of the test results.

4.2 AMC_LIFT

The low size of ropes for elevator do not allow to test the detector according the CEN -EN 12927-8:2004. For this reason a test procedure has been created, in order to define some important parameters in NDT as tolerance band (width of the background noise) and consequently the signal to noise ratio.

In all NDT based on magneto-inductive technique the signal is obviously affected by a noise linked to the rope trefoil and his swing and the presence of a defect is highlighted by a peak that exceeds a tolerance band. This approach is used in the performance evaluation of NDT device for cableway ropes. For example, in the follow (from Fig. 17 to Fig. 19) are reported some tests on ropes of different diameter: from 9, 10 and 11 mm, composed of 114 wires, of which only one wire has been broken and the ends are 5 mm close. From the experimental results show that for the device to the range of tolerance varies between 70 mV (9 mm cable) to approximately 100 mV (11 mm rope). When the signal exceeds the range of tolerance, so evident (eg 25% above) is certain that a broken wire in the rope.

A significant number of tests on field have been provided in collaboration with ICEPI Notified Body by the Ministry of Industry. About 15 plants were chosen to ensure that the sample was as representative as possible. Details about all the other analysed plant are reported in [9].
4.3 AMC_BELT

If in the case of detectors for lift the standard of certification cannot be applied even more so in the case of belts. In order to create also in this case a benchmark for the evaluation of the detector performances, a set of artificial faults have been realised in a 30 mm belt, with 12 small ropes inside; each rope has a diameter of 2 mm. Fig 20 shows the trends of the LF signal detected in the presence of:

1) defects distributed;
2) localized fault ~ 25% of a single rope
3) localized fault ~ 50% of a single rope
4) localized fault ~ 75% of a single rope

In all cases is clear visible the presence of the defect and obviously it increases with increasing its entity.

5 Conclusion

The present paper deals with the possibility to employ the magneto-inductive (M-I) technique for the non-destructive control of metallic ropes adopted in different field of application.

In the paper is shown how the use of the hall sensor technology allows to realise detectors for several size ropes and able to control simultaneously more ropes (lift application).

The possibility to create innovative detectors, besides to the reduction cost of such devices, open new field of application of the Magneto Inductive testing and allows, for example, to introduce the control in the huge word of elevators.

6 References