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Permanently installed rope monitoring in conveyor systems

Dipl.-Ing. Ralf Eisinger[1*], Dr.-Ing. Gregor Novak[1**], Dipl.-Ing. Stefan Hecht[1]

[1] Institut für Fördertechnik und Logistik, Universität Stuttgart, Stuttgart, Baden-Württemberg, 70174, Germany
** Correspondence: ralf.eisinger@ift.uni-stuttgart.de; Tel.: +49-711-685-83799*
***former Institut für Fördertechnik und Logistik*

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ABSTRACT A permanently installed rope monitoring system can help to avoid unplanned downtimes and increase the safety level. The aim here is to set up a rope monitoring system that helps to monitor the hoisting rope as a critical component and to minimise downtimes in the context of "predictive maintenance". The already applied magnetic inductive rope testing can be used as a testing method. The paper deals with the topic of integrating such a permanently installed testing device, its use and evaluation strategies, and it identifies possibilities for new business areas for rope testing.

KEYWORDS Rope technology, conveyor technology, condition monitoring, magnetic inductive rope testing

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1. Introduction

The Institute for Materials Handling and Logistics (IFT) at the University of Stuttgart has been involved with ropes of all kinds, their application and their testing since its foundation in 1927.

The magneto-inductive rope testing devices developed by the IFT are used today in a wide range of applications. Today, magnetic induction rope testing is state of the art in many areas of rope application [1]. For example, this type of rope testing has been prescribed for decades in the field of ropeways and shaft hoisting systems, and in other areas, such as offshore cranes, it is recommended in order to avoid downtimes and dangerous conditions.

There are various testing devices on the market whose basic design hardly differs. Figure 1 shows an SMRT 25 (can be used for ropes with a diameter of up to 25 mm) distributed by the IFT with an SMRT 1.5 measuring box attached.

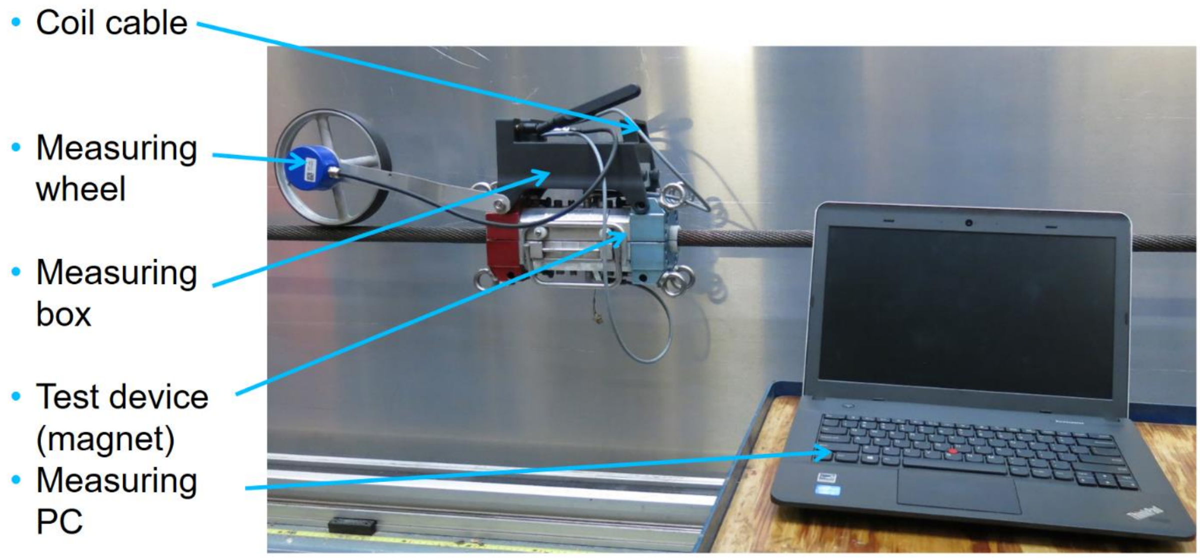

Figure 1: SMRT 25 with SMRT 1.5 of IFT

For magnetic inductive rope testing, the rope is magnetised to saturation. Nowadays, permanent magnets are used for this purpose and the changes in this magnetic field in the rope are measured by means of a coil or Hall sensors in the form of an output voltage. If a wire in the rope is broken, a change in the magnetic field occurs there in the form of a stray field, which is then detected by the coil or Hall sensor. Figure 2 shows the theoretical wire break signal of a measuring coil.

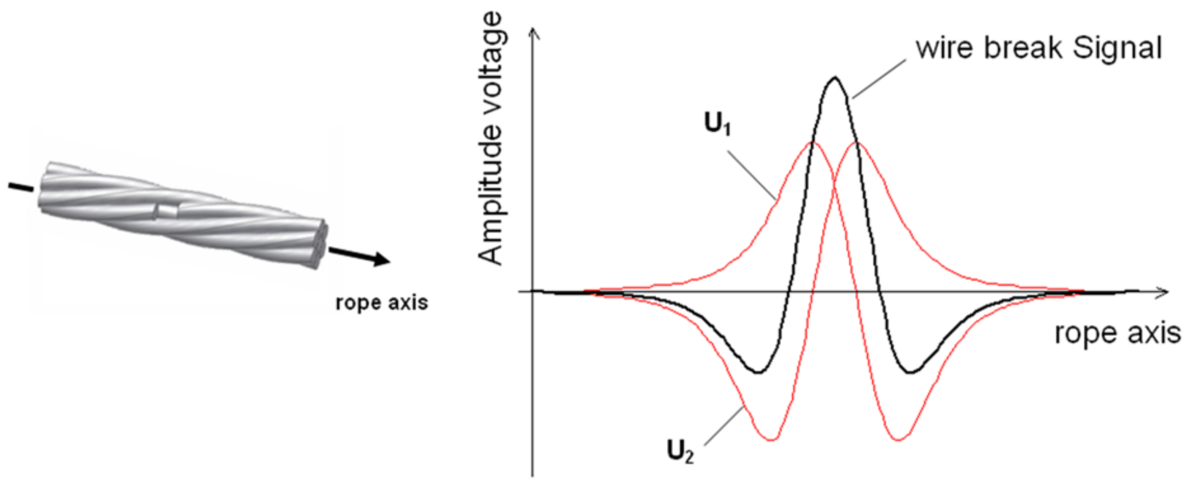

Figure 2: Theoretical wire break signal of a measuring coil

The measurement data is transmitted live to a measuring computer, usually by means of a data cable. In the case of the SMRT 1.5 measuring box developed by the IFT, the transmission takes place via a WLAN connection. The WLAN connection makes it possible to dispense with the measuring cable, which usually represents a high safety risk with regard to the risk of tripping, entrapment and cable breakage. The live transmission of the measurement signal makes it possible to detect and mark abnormalities during the measurement and to visually check them immediately after the measurement.

Conveyor systems in intralogistics, such as storage and retrieval machines or process cranes, are nowadays operated with ever higher utilisation and shorter downtimes. The wire rope is still the most commonly used load-bearing material and is normally subject to continuous wear in the form of wire breakage. In addition, other damage mechanisms such as corrosion, twisting, etc. can occur during operation, which can be detected with magnetic inductive rope testing devices under certain conditions. However, wire breaks as described are the primary type of damage in wire ropes and are most suitable for quantitative detection and monitoring.

The risks associated with the use of materials handling equipment are primarily unplanned breakdowns and the associated loss of production and delivery capability and the possibility of material damage and personal injury [2]. Therefore, regular inspection of the load-bearing equipment is necessary, whereby it is a problem with wire ropes, as well as with wire rope-reinforced belts, that only external wire breaks can be detected during a visual rope inspection carried out in accordance with the regulations. However, internal wire breaks can occur even in cross lay ropes, especially when plastic deflection sheaves are used. To counter this, a single steel sheave is often used in the rope drive in the area of most bending changes. For example, in a stacker crane with double reeving, a steel sheave is used at the front of the load handling attachment, with the disadvantage that to a certain extent the maximum payload is reduced due to the higher dead weight of the steel sheave.

2. Magnetic inductive rope testing in intralogistic applications

When wire ropes are used in materials handling systems such as storage and retrieval machines or process cranes, maximum service lives are often specified based on the machine hours. These in turn are based on experience, tests or estimates [1, 3], but these can only reflect the actual service life to a limited extent, as the actual load spectrum is almost never known. Due to this fact, the wire ropes must be inspected regularly by an expert, whereby, as described above, only a small part of the rope is actually inspected. Furthermore, the maximum service life of the ropes specified by the machine manufacturer precludes further use of the ropes until they are ready for discard, even if they are still in good wear condition. A loss of warranty would possibly be the consequence.

Premature wear of the rope can and does lead to dangerous conditions when "sudden" rope breaks occur because no externally visible wire breaks or no full inspection of the ropes took place and the ropes were used for longer than technically possible. The failure of a storage and retrieval machine, for example, can mean an immense monetary loss, especially during peak periods, such as the time before Christmas. Although today's storage strategies take into account the most even distribution of stored goods possible, bottlenecks can still occur during the loading and unloading of trucks. This in turn leads to delays in the supply chain, which in turn affects the delivery to supermarkets, for example. This circumstance can be countered by regular magnetic inductive rope testing of highly loaded rope drives (Figure 3).

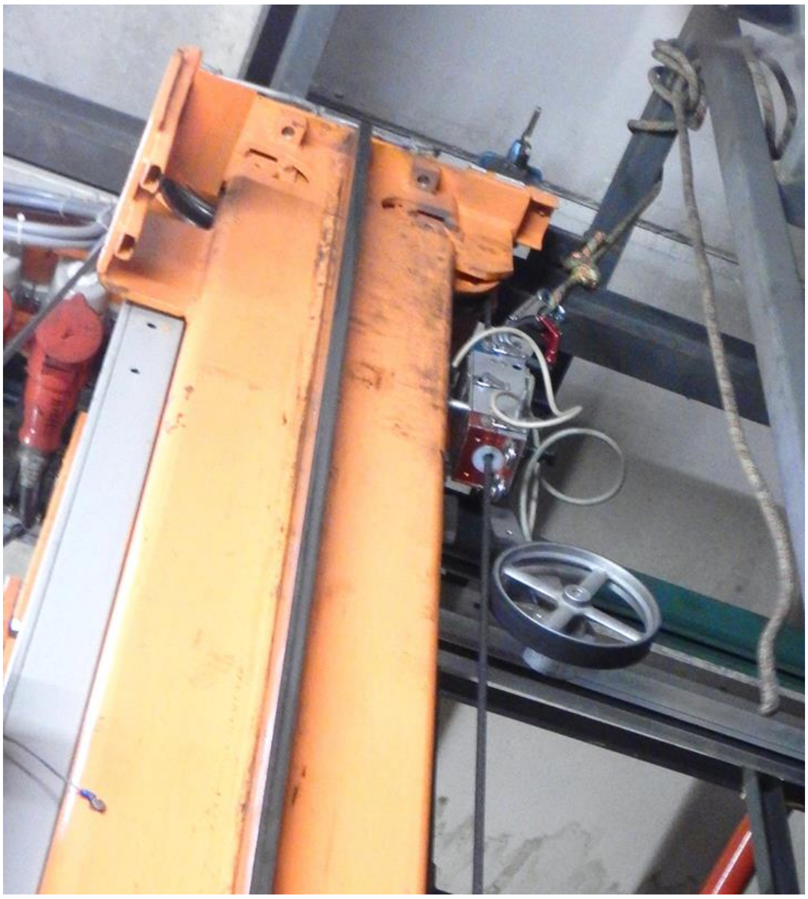

Figure 3: Magnetic inductive rope test on a storage and retrieval machine

This type of inspection has the following advantages with regard to its use in intralogistics systems:

- Fast execution
- Traceable results
- Testing of the complete rope cross-section

The magnetic induction rope test can usually be carried out in a short period of time. It takes about 10 minutes to set up and dismantle the testing device, and the test itself can then be carried out at full lifting speed. In addition, there is the access to the test point(s), which must also be carried out with manual testing. This means that a rope test can be carried out in a minimum amount of time, so that the hoist is available for normal operation again within a short time.

Nowadays, magnetic induction rope testing is computer-aided. The measurement data is transferred to e.g. a notebook and evaluated there. This has the advantage that the measurement and its results can be saved and called up later for comparison during further measurements. If a rope does break, the results of the rope tests carried out can be called up to determine the cause of the damage.

In contrast to a manual visual rope inspection, not only the rope surface (approx. 20% of the rope cross-section) is inspected, but the complete rope cross-section. This means that internal wire breaks can also be detected and a complete analysis of the rope can be carried out. Furthermore, it is advantageous that the range of the highest rope damage can be determined with the help of the displacement measuring system of the testing device and can be visually inspected separately in case of critical conditions, as it is also required in the standard ISO 4309 (2017) [4].

3. Permanently installed rope testing devices and their use

In addition to the use of mobile magnetic inductive rope testing devices, it is also possible to use permanently or semi-permanently installed rope testing devices. The test devices are installed in the area of the highest-loaded rope area, for example, at the mast head of a storage and retrieval machine. Due to the permanently available test device, a rope test can be carried out at any time when required, in the case of a storage and retrieval machine, for example, during the night when only relocations are carried out. In this way, the operating sequence does not have to be interrupted and service technicians do not have to work a night shift as the system can carry out the test fully automatically. Permanently installed test equipment is already available for offshore and cableway applications [5, 6]. In principle, permanent monitoring by means of a permanently installed test device would be possible, but this would generate a relatively large amount of measurement data. This measurement data would always have to be analysed and evaluated, and due to the relatively slow development of wire breaks, there are no advantages compared to a regularly performed measurement.

Such a permanently or semi-permanently installed magnetic inductive rope testing system was developed by the IFT for the rope manufacturer Fatzer AG and is already being used in the field of ropeways, especially for urban ropeways [5, 7]. The test device is permanently installed in one of the cableway stations (Figure 4) and can be operated independently of the system control.

Figure 4: Permanently installed rope tester Fatzer Truscan [7]

Like the mobile rope tester, the test system consists of the test magnet with sensor head and a displacement measuring device. The data is transferred to a compact control cabinet from where it is loaded into a database or cloud via an internet connection. Here, the measurement data can be automatically evaluated in a first step and, in the case of gross abnormalities, analysed and evaluated again separately by an expert. At the same time, this database functions as a portal for the operator or customer where they can, for example, call up the condition of their ropes.

In the semi-permanently installed version, a bracket is permanently installed in the cableway station to which the test device can be attached in a defined manner. Furthermore, there is a plug connection to the electronic unit described above, one unit of which is always permanently installed. After the rope test has been carried out, the test device can be taken to the next installation. In this way, acquisition costs can be reduced. In the case of the permanently installed rope testing device, a rope test can be carried out at any time, this is of course not possible with the semi-permanently installed device variant. However, the use of the semi-permanently installed testing system is otherwise the same as for the permanently installed variant.

Both systems can be calibrated on site using a special calibration procedure that meets the requirements of EN 12927 (2019) [8]. This is particularly interesting for installations outside Europe, as it eliminates the need for a return transport to the institute and the test system can be used without interruption.

For these rope tests, the IFT carries out the so-called official evaluation including the expert opinion as a service within the scope of the accreditation as a recognised expert body for ropeways.

Such a permanently installed or semi-permanently installed test system can also be used in conveyor systems. In this case, the test system is installed in the same way as the mobile test device in the area of the most heavily loaded rope zone, or in the case of the semi-permanently installed variant, a holder is provided. In this way, even complex rope drives can be tested with the advantage that the data is immediately available in a database or cloud. The evaluation can then be carried out automatically in a first step, as in the case of the cableway system, and in a further step by an expert for an official test report. The advantage of using such a test system is that it can be specially adapted to the rope constructions used and thus the quality of the measurement data can be increased. Many ropes used in conveyor systems consist of a large number of individual wires with a metallic cross-section of less than 0.1% of the metallic rope cross-section. The magnetic induction method is here physically in the limit range of the reliable detectability of a single wire break. However, such a single wire break does not play a significant role for the discard maturity of the rope. However, many such single wire breaks on a short section of the rope can endanger the safety of the operation. Figure 5 shows the result of three measurements staggered on the y-axis, where the detection of single wire breaks and thus the reliable detection of discard maturity is not possible. In this case, however, the measurement is helpful in greatly reducing the time required for a visual rope inspection, as only the severely damaged areas of the rope need to be inspected. In this case, however, it is not possible to make an exact statement about the discard maturity of the rope.

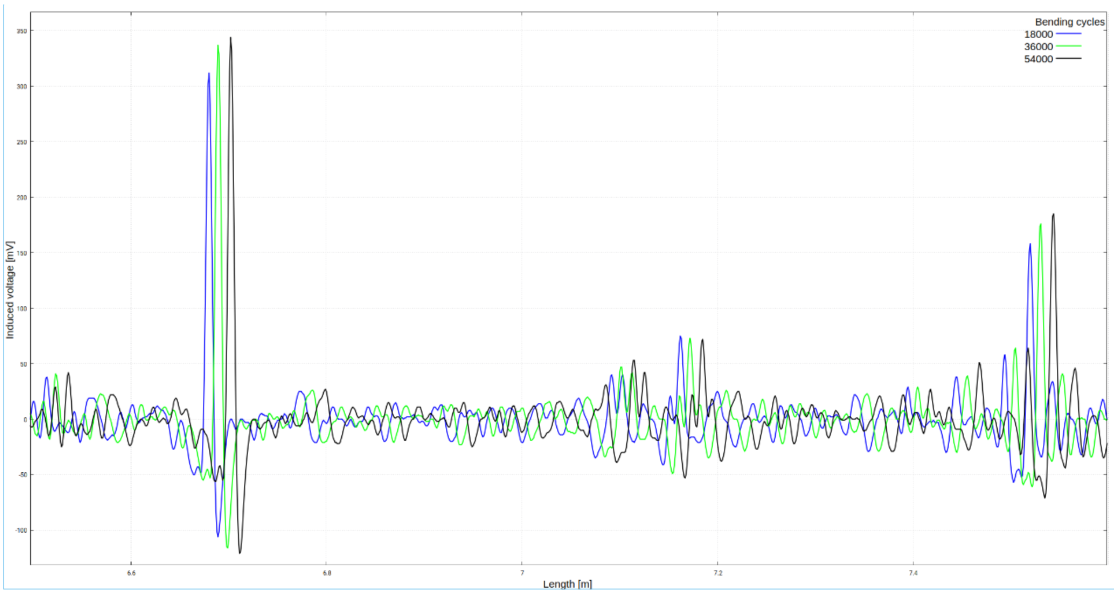

Figure 5: Section of the results of an MRT rope measurement of a conveyor systems

Currently, research is being carried out at the IFT on methods to not examine the measurement data from the magnetic inductive measurement for individual wire breaks, but to transfer the data obtained into a damage graph. Figure YY represents a possible solution. On the one hand, due to the regular measurements, the temporal growth of the damage graph can be used as a criterion for discard maturity. At the same time, however, the elongation of the rope (and thus the reduction of the diameter) can also be used as a possible discard criterion. Investigations are also currently underway to determine whether possibilities from the field of fuzzy logic can be used to provide a reliable discard criterion despite the non-recognition of individual broken wires.

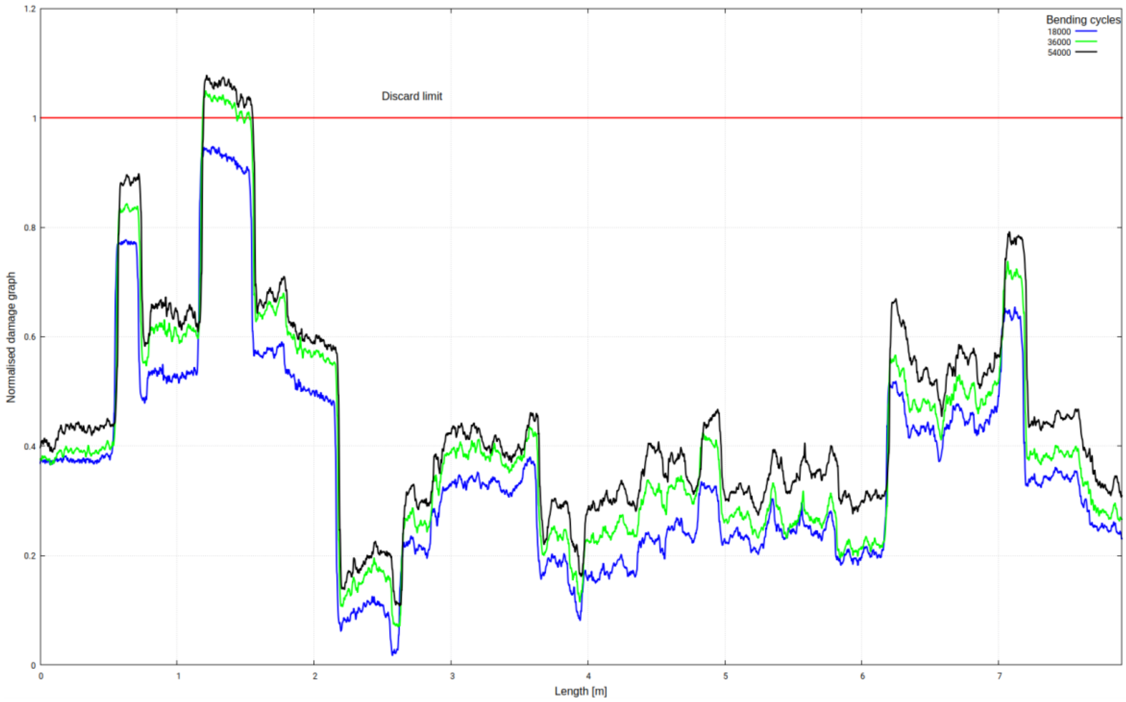

Figure 5: Example of a possible damage graph

In general, magnetic induction testing can greatly facilitate rope inspection in any case. With the use of such a testing system, manufacturers and suppliers of intralogistic systems can offer their customers the possibility to increase the safety level and build up new business fields by offering these tests.

4. Conclusion

The Institute for Materials Handling and Logistics (IFT) at the University of Stuttgart has been involved with ropes of all kinds, their application and their testing since its foundation in 1927. The magnetic inductive rope testing devices developed by the IFT are used today in a wide range of applications. The latest development is the use of permanently installed magneto-inductive rope testing devices for ropeways, which are particularly useful for highly used installations in large cities, the so-called urban ropeways.

Such permanently installed rope testing devices are not only interesting and useful for ropeways, but also for intralogistic applications such as storage and retrieval machines or highly frequented (process) cranes. Unplanned downtimes with regard to the ropes can be avoided and thus the system availability can be increased. Magneto-inductive rope testing is already being used in some cases in materials handling technology in order to be able to evaluate wire ropes more comprehensively. These mobile testing devices can be used for certified rope testing.

The evaluation of permanently installed rope testing devices can be carried out automatically online, whereby an expert can analyse and evaluate the measurement data again at any time. Thus, magnetic induction rope testing can be offered as a permanently installed solution as a service by testing organisations to enable the operator to increase plant availability and reduce unplanned downtime.

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