INTRODUCTION

The demand for cement production grows at exponential rates, accelerated by the growth of world population and urbanization. At the same time improving reliability, reduced operation and maintenance costs are the key priorities in the cement industries maintenance strategies. This document provides information about a novel online oil condition monitoring system to give a solution to the mentioned priorities. The WearSens® WS 3000 enables damage prevention of the gearboxes and indirectly the connected machines thereto, by an advanced warning time of critical operation conditions and an enhanced oil exchange interval realized by a precise measurement of the electrical conductivity, the relative permittivity and the oil temperature – setting new standards in terms of accuracy, sensitivity and resolution.

A new parameter, the WearSens® Index (WSi) is introduced. The mathematical model of the WSi combines all measured values and its gradients in one single parameter for a comprehensive monitoring to prevent gearbox from damage. Furthermore, the WSi enables a long-term prognosis on the next oil change by 24/7 server data logging. Corrective procedures and/or maintenance can be carried out before actual damage occurs.

LUBRICATION OIL CIRCUITS ARE USED IN THE FOLLOWING PARTS OF CEMENT PLANT:

1- Main Drive Gear of Grinding Mill
2- Main Drive Gear of Coal Mill
3- Main Drive Gear of Kiln
4- Main Drive Gear of Klinker Mill
5- Main Drive Gear of Roller Press

WearSens 3000 can be mounted on each of these oil circuits to ensure maximum protection and utilization of the lubricant, the gearbox, the connected machine and at the end the production line.

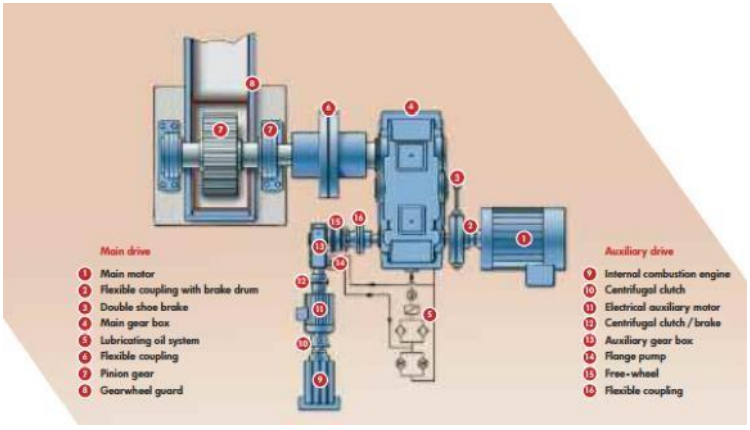


Figure 1: Typical Gear Drive Set Used in Cement Plants

CONDITION BASED MAINTENANCE

In general, the field of maintenance can be divided into three sectors: preventive (time-based), intelligent (condition-based) and reactive maintenance (run to failure), which show different dependencies between costs and number of failures. Figure 2 shows the costs associated with the different strategies.

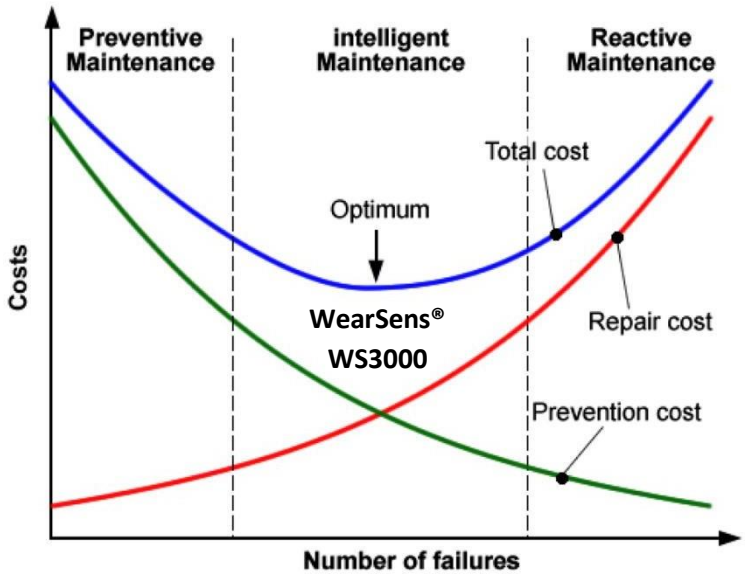


Figure 2: Costs associated with traditional maintenance strategies [P. Tchakoua 2014].

From this graph, the optimal point in terms of costs and number of failures can be identified within the centre of the intelligent maintenance sector; intelligent maintenance (= condition based maintenance) is realized with the online oil condition monitoring solution WearSens® WS3000 by indicating critical problems of the gearbox or engine at an earliest stage. Due to the high requirements of the lubricant it is getting even more important to monitor the oil condition in real time to prevent the gearbox from damage and unplanned down times.

TECHNICAL OVERVIEW - BASICS

WearSens® WS3000 is an online, continuous system for oil condition monitoring. This permits the reliable detection of incipient damage and the early identification of critical lubrication conditions of bearings and other transmission elements in the gearbox.

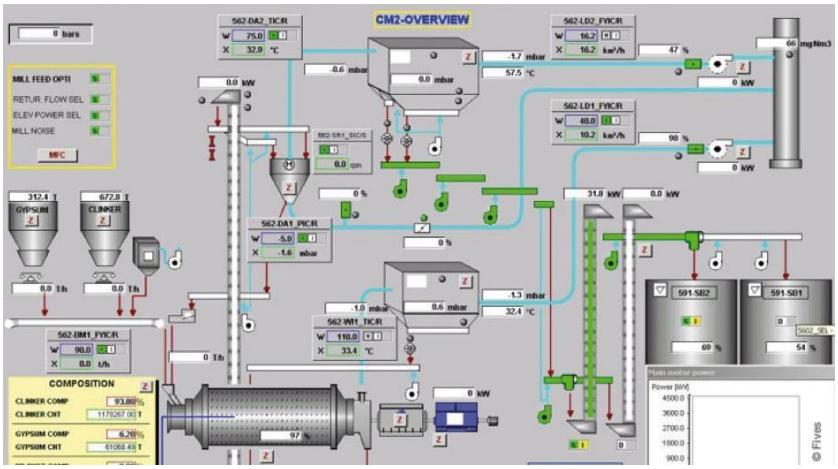


Figure 3: Process Visualization of a Typical Cement Plant

Wear of the bearing at touching contact surfaces, metal debris, foreign particles, suspended solids and chemically broken oil molecules, which forms acids or soaps all lead to an increase in the electrical conductivity. This increase directly correlates to gear wear and the degree of contamination of the oil due to the initial low conductivity of the oil and relatively high

conductivity of the contamination products. Ideally suited for the **early detection of damage**, it detects changes in the oil-machine system by measuring from the outset before any damage occurs (see figure 4). In addition, preventive maintenance measures are indicated. The sensor system increases the operational reliability, increases service life and reduces downtime periods. Oil change intervals are adjusted to actual needs and economic and ecological efficiency improvements are achieved.

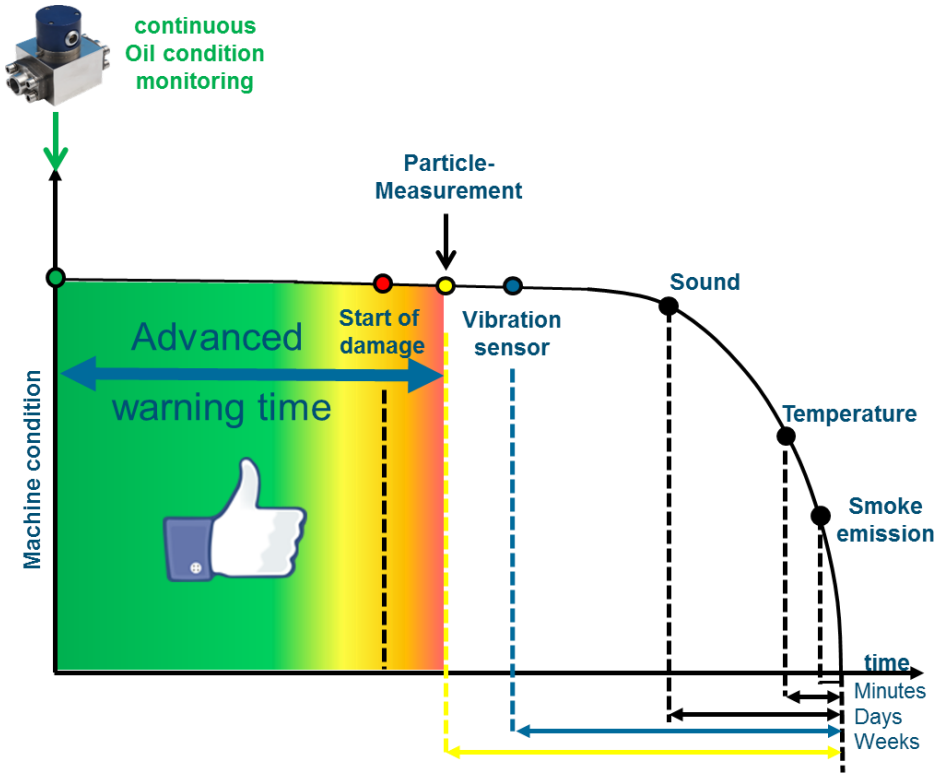


Figure 4: Existing sensor technologies such as optical particle measurement or vibration sensors can detect particles only **after** the occurrence of damage.

The crucial difference between the existing technologies and the state-of-the-art WearSens® system consists in the **damage prevention and wear limitation**, however, the particle counter **displays damage done**. The optical particle counter detects particles from a size of 4 microns. From the number of particles, it provides conclusions about the **state of wear or existing damage**.

The additive consumption in gearbox oils can be detected from the electrical conductivity changes and the additional high-precision measurement of the relative permittivity. Continuous evaluation of the chemical aging of the lubricant during operation opens up a new method for preventing premature bearing failures, occurring under stress conditions in gearboxes by timely implementation of appropriate corrective measures (oil change on demand).

Installation of the WearSens® WS 3000 Sensor System, Interfaces

The WearSens® WS3000 oil condition monitoring system can be easily installed into existing oil and fuel lines, either in the main line or in a smaller bypass line (see figure 5). A comprehensive list of communication interfaces to connect the sensor system to the existing data structure is shown below in figure 5 on the right side. Furthermore the recorded data can be transferred with high encryption to a cloud based SQL database with 24/7 full data access

and graphical data visualization. Alarm notification will be send automatically in case of a threshold violation of the incoming data.

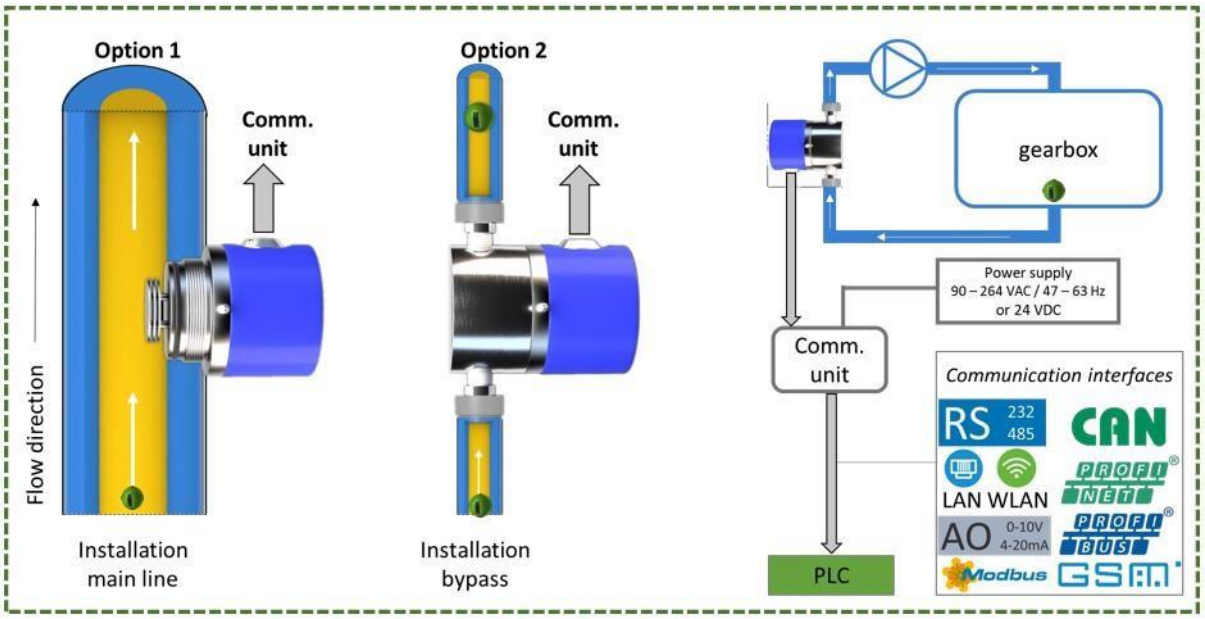


Figure 5: Installation scheme of the WearSens® WS 3000 sensor system.

BE PREPARED FOR INDUSTRY 4.0

The cement industry is strongly working towards solutions for the technological advancements currently reshaping the industrial world: what is called Industry 4.0. Industry 4.0 is the fourth industrial revolution, where the brainpower that has gone into creating apps for smartphones is creating applications for smart factories (see figure 6).

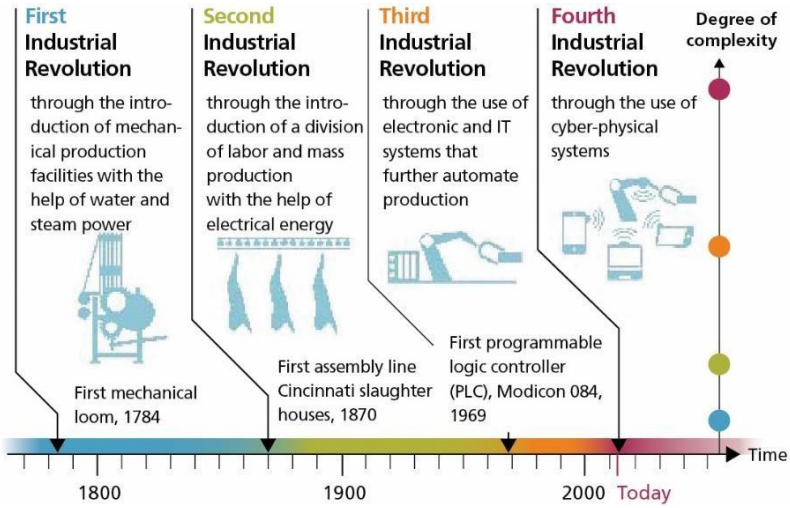


Figure 6: Development towards Industry 4.0 (Source: DFKI, Saarbrücken 2011).

Big data networks connecting people, machines, correlated sensor systems, processes, plants, and customers – are enhancing competitiveness globally and meeting rapidly changing customer demands. This process of digitalization and the growing requirements of correlated data sets new challenges for the condition monitoring in the cement production sector as well.

By combining the continuous oil condition monitoring with WearSens® together with online vibration monitoring it is possible to get a more comprehensive picture of the actual machine and oil condition in real time based on a correlated and connected data base, indicating offline laboratory check-up's – condition based. Identify problems much earlier and react in time. Have a closer look into your oil when it is performing abnormal. With WearSens® WS 3000 you are prepared for the industry 4.0.

WEARSENS® INDEX WS_I

The WS_i model considers short, mid and long-term changes in the lubricant by continuous monitoring of the conductivity, relative permittivity and temperature over a time of several years with a high time resolution of < 45 seconds. Because of the measurement sensitivity and the high time resolution, critical operation conditions can be identified much earlier and a damage can be evaded with short term analysis.
The stress of the lubricant and the monitored machine itself is based on the environmental condition, machine fluctuation and settings resulting in instantaneous changes of the conductivity and relative permittivity and their gradients. Critical operation conditions result in an increased charge carrier generation and will change the conductivity and its gradient significantly. A big change in a short time period in the measured values leads to a high WS_i signal; for example, a significant increase in the electrical conductivity in a short time period is an indication of an abrupt high load or depending on the increase in the conductivity a critical operation condition. Frequent critical operation conditions lead to faster degradation of the oil additive complex. An example for the time course of the WS_i and temperature T of a gearbox is depicted in figure 7 below.

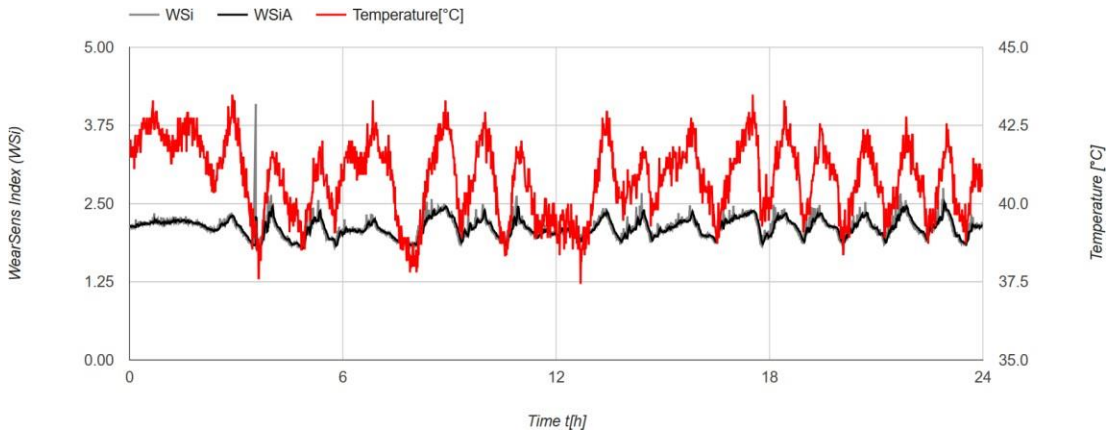


Figure 7: Time course of a measured WearSens® Index WS_i, temperature T over 24 hours.

By using the WS_i and the raw data as an indicator for the oil change on demand – condition based – the time interval of the oil exchange can be increased quite a lot due to the real condition of the oil: this will save money as a direct effect to the cement plant owner, preserve environment and resources. Furthermore, the short-term analysis can avoid critical operation conditions and prevent the gearbox from damage and unforeseen down times.

FIELD STUDY: FINGERPRINT OF THE OIL – OIL PARAMETERS COMPARED BEFORE AND AFTER AN OIL EXCHANGE

In this study, the measured conductivity and temperature was compared before and after an oil exchange. Figure 8 shows the two curves of the temperature dependency of the electrical conductivity κ before (red) and after (green) the oil exchange. The significant difference between these two curves indicates the aging of the lubricant over time: in this specific example the operation time of the used oil was already > 7 years. The two curves in figure 8 can be used as a "fingerprint" of the oil. When the parameter electrical conductivity is changing from the green to the red curve, the time for the next oil change can be planned accordingly.

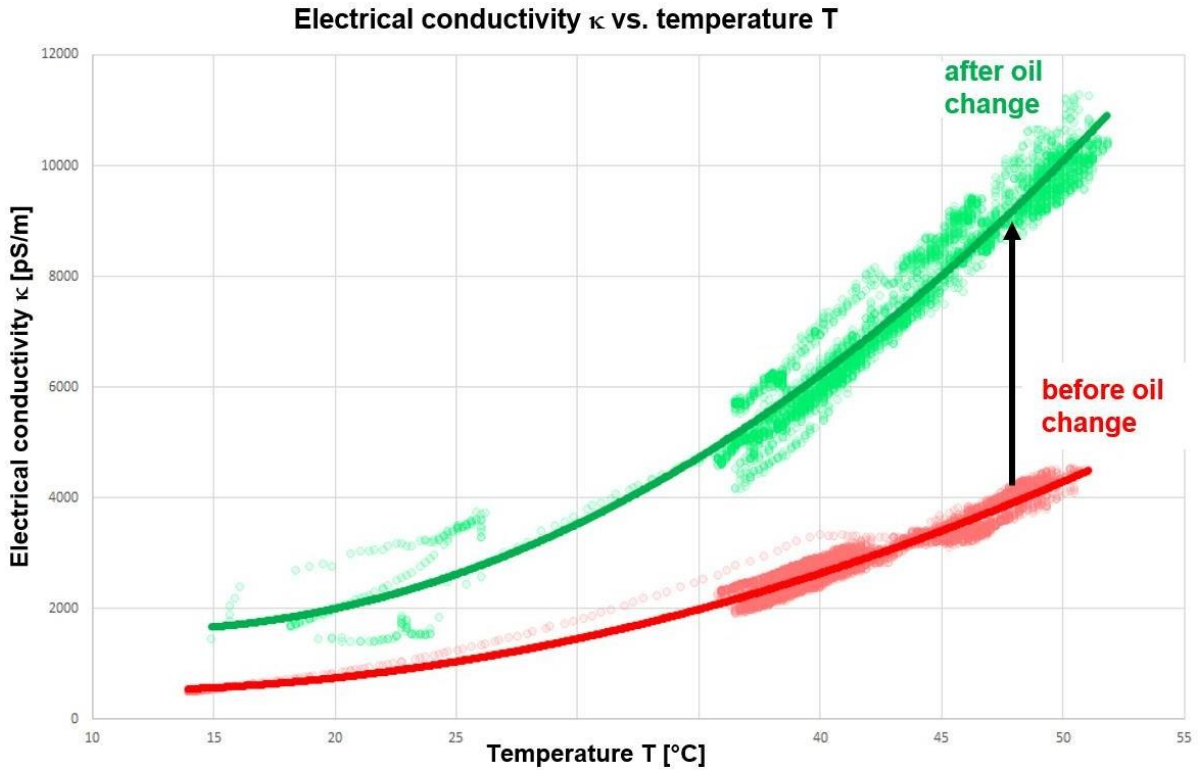


Figure 8: Temperature dependency of the electrical conductivity κ before (red) and after (green) the oil change.

The analysis of the historical data from day 1 up to the actual condition provides information about the oil performance 24/7/365 all-around-the-clock. Abnormal behaviour can be identified easily by cross-correlation with other turbines with the same operation time. The machine stress (low, normal, critical) will alter the oil due to the additive consumption at the different loads. Keep track on the oil parameters and assign an offshore oil sample analysis on demand.

THE BENEFITS

Prevent expensive downtimes and additional maintenance costs.

Comprehensive sensor analysis with cmc Instruments' cloud based condition monitoring solution, ready for industry 4.0.

Smart and proven tool for lower risk and more safety of the asset:

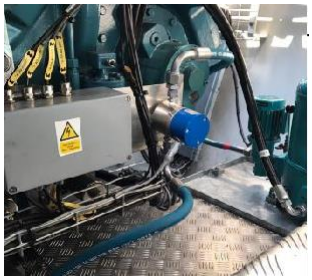
- Temperature-compensated measurement system with patented adaptive temperature algorithm
- More safety compared to the actual periodical offline oil analysis → Online oil monitoring enables offline lab reports on demand.
- Less risk for the end customer.

Extended oil change interval, first indication for an oil exchange on demand, condition based:

- reduce costs,
- increase life time,
- preserve the environment,
- protect resources.

Earliest identification of critical operation conditions (overload, contamination, …)

- Longer operation time,
- prevent damage and limit wear by early implementation of appropriate corrective measures,
- continuous evaluation of component wear, the degradation of the additives and tribological layers as well as the pollution and aging of the lubricating oil



In the test and development phase of the gears and bearings on test benches, the sensor supplies essential statements on wear mechanisms. Correlation of test protocols results in component optimization.

REFERENCES

The oil sensor systems from cmc Instruments GmbH have been tested and integrated by:

ABB	Lürssen GmbH
Addinol	Mann und Hummel
Arras Maxei S.A.	MINO Spa
Bosch	Pentosin GmbH
Bosch Rexroth	Repower
Caterpillar	RWE
Ceedee Vacuum	Schäffler AG
CJC C.C Jensen A/S Denmark	Schleich GmbH
Comet AG	Shell
CSO Energy GmbH	SIBCO Ltd.
Euca	SKF
Eurotech Italia	Speedwind
Evonik Industries	Speedwind Offshore
Frauenhofer Institute	Spinea
Fuchs	Starke & Sohn
GTS	Strama MPS
GE	Thyssen
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