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# New oil condition monitoring system, WearSens® enables continuous, online detection of critical operating conditions and wear damage

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**ABSTRACT** – A new oil sensor system is presented for the continuous, online measurement of the wear in turbines, industrial gears, generators, hydraulic systems and transformers. Detection of change is much earlier than existing technologies such as particle counting, vibration measurement or recording temperature. Thus targeted, corrective procedures and/or maintenance can be carried out before actual damage occurs. Efficient machine utilization, accurately timed preventive maintenance, increased service life and a reduction of downtime can all be achieved.

## 1. INTRODUCTION

The oil sensor system measures the components of the complex impedances X of the oils, in particular the electrical conductivity, κ and relative dielectric constant, $\varepsilon_r$, and the oil temperature T. The values κ and $\varepsilon_r$ are determined independently.

Figure 1 Sensor with triple plate design.

Inorganic compounds occur at contact surfaces from the wear of parts, broken oil molecules, acids or oil soaps. These all lead to an increase in the electrical conductivity, which correlates directly with the wear. In oils containing additives, changes in dielectric constant infer the chemical breakdown of additives. The determination of impurities, a reduction in the lubricating ability of the oils, the continuous evaluation of the wear of bearings and gears and the oil aging all together follow the holistic approach of real-time monitoring of changes in the oil-machine system.

## 2. PRINCIPLE OF OPERATION

With the WearSens® unit, components of the complex impedances *X* of oils, in particular the specific electrical conductivity κ and the relative permittivity $\varepsilon_r$ as well as the oil temperature *T* are measured [1-3]. The values κ and $\varepsilon_r$ are determined independently of each other. Figure 1 shows the sensor with its triple plate design. Oils are electrical non-conductors. The electrical residual conductivity of pure oils lies in the range below 1 pS/m. Figure 2 illustrates conductivities of various materials.
The conductivity range of the WearSens® sensor system is marked in green. It starts below the conductivity of the distilled water. For comparison, the electrical conductivity of the electrical non-conductor distilled water is larger by six orders of magnitude.

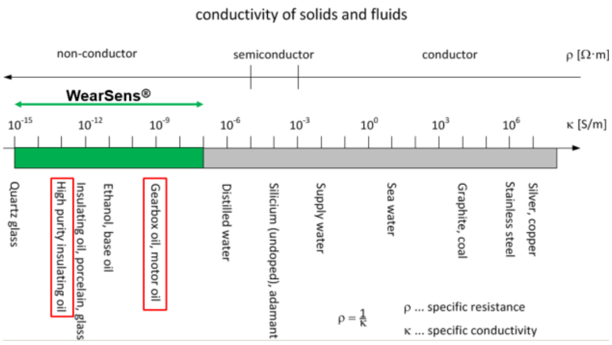


Figure 2 Conductivities of liquids and solids, measurement range of the presented sensor system is marked in green.

Abrasive (metallic) wear, ions, broken oil molecules, acids, oil soaps, etc., cause an increase of the oil conductivity κ. It rises with increasing ion concentration and mobility. The electrical conductivity of almost all impurities is high compared with the extremely low corresponding property of original pure oils. A direct connection between the electrical conductivity and the degree of contamination of oils is found. An increase of the electrical conductivity of the oil in operation can thus be interpreted as increasing wear or contamination of the lubricant. The aging of the oil is also evident in the degradation of additives. The used additives reveal high conductivity compared with the oil.

Ion mobility and thus, electrical conductivity κ are dependent on the internal friction of the oil and therefore, also on its temperature. The conductivity κ of the oil increases with temperature. The type of contamination and its temperature dependence cannot be assumed to be known. To improve the comparability of measurements, a self-learning adaptive temperature compensation algorithm is necessary. A change of the oil quality can then be assessed by the temperature compensated conductivity value, even though the specific contamination is not determinable. The relative permittivity is measured with the same basic sensor arrangement as used for the determination of the electrical conductivity.

Figure 3 shows the effect of temperature compensation.

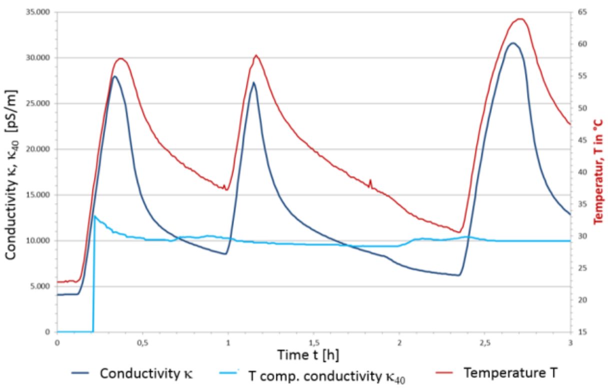


Figure 3 Temperature compensation algorithms.

While the conductivity κ changes significantly with temperature, the temperature compensated conductivity, $\kappa_{40}$ stays nearly constant.

## 3. CONCLUSIONS

The online diagnostics system measures components of the specific complex impedance of oils. For instance, metal abrasion due to bearing wear at the tribological contact, broken oil molecules, acids or oil soap cause an increase in electrical conductivity that directly correlates with the degree of pollution of the oil. The dielectrical properties of the oils are especially determined by the water content, which, in the case of products that are not enriched with additives, becomes accessible by an additional accurate measurement of the dielectric constant. In the case of oils enriched with additives, statements on the degradation of additives can also be deduced from recorded changes in the dielectric constant.

Indication of damage and wear is measured as an integral factor of, e.g., the degree of pollution, oil aging and water content, acidification and the decomposition state of additives or abrasion of the bearings. It provides informative data on lubricant aging and material loading as well as the wear of the bearings and gears for the online operative monitoring of components of machines. Additional loading, for instance, by vibration induced mixed friction in rolling-sliding contact (rolling bearings, gears, cams, etc.) causes faster oil aging. Verified in roller bearing rig tests, the oil suffers from incipient resinification and significant acidification, as proven by infrared spectroscopy of used lubricant.

For an efficient machine utilization and targeted damage prevention, the new WearSens® online condition monitoring system offers the prospect to carry out timely preventative maintenance on demand rather than in rigid inspection intervals. The determination of impurities or reduction in the quality of the lubricants and the quasi-continuous evaluation of the bearing and gear wear and oil aging meet the holistic approach of a real-time monitoring of a change in the condition of the oil-machine system.

The measuring signals can be transmitted to a web-based condition monitoring system via LAN, WLAN or serial interfaces of the sensor system. The monitoring of the tribological wear mechanisms during proper operation below the tolerance limits of the components then allows preventive, condition-oriented maintenance to be carried out, if necessary, long before regular overhauling, thus reducing outages caused by wear while simultaneously increasing the overall lifetime of the oil-machine system.

The oil sensor system was installed into an oil circuit of a hydraulic actuator system for ground resonance excitation performing a long term analysis of the hydraulic oil quality. The functionality of the introduced electric online condition monitoring sensor system is tested successfully. The evaluation of the experiment is presented.

## 4. ACKNOWLEDGEMENT

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