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Online Condition Monitoring of Hydraulic Oils

Hydraulic oil is one of the most important components in mobile machinery. Excessive oil wear fatally effects machines and single components. For this reason the prescribed oil change intervals are calculated with a large safety factor, which often results in the oil being changed while it is still in a good condition. In order to create more flexible oil change intervals it only possible till now to detect unexpected deterioration by means of a laboratory oil analysis. A new type of sensor offers the possibility of online oil condition monitoring.

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The project "Development of an OCM-system to monitor the quality of biologically degradable hydraulic oils in mobile utilisation", is financially supported by the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung). This sensor has been developed in a joint research and development project between HYDAC Electronic GmbH, and both the Institute for Agricultural Machinery and Fluid Technology (ILF) and the Institute for Micro Technology (IMT) at the Technical University of Braunschweig.

Keywords

Online condition monitoring, hydraulic fluids, oil sensors

The influencing parameters which cause an ageing of fluids are as diverse as the applications of hydraulic oils (i.e. transportation of heat and materials, the transfer of productivity and signals, as well as lubrication and corrosion resistance). The expression ageing includes chemical and physical deterioration of the oil, which is caused by various stress factors. A quality deterioration is caused by the breakdown of additives and alterations in the molecular structure of the fluids. [1, 2]

It is almost impossible to ascertain the influence or importance of single stress factors, due to the magnitude of influences and their interdependence, in comparison between several machines. All knowledge about oil ageing is based mainly on empirical research, due to the non-existence of comprehensive physical and chemical models for these processes.

Based on this research, the most important factors for the deterioration in mobile hydraulics could be determined. These are oxygen, water and particles (particularly metal particles) as well as the temperature. Temperature is decisive for the speed in which the chemical processes take place and, particularly in the utilisation of mobile machines, the working temperatures are considerably higher than in stationary machinery.

The stability with regard to the ageing mechanism also depends on the basic oil used. Oils based on native raw materials, which are rapidly biologically degradable, are generally more liable to react with water and oxygen than mineral oils. On the other hand, rapidly biologically degradable synthetic esters have often proved to be much more stable than mineral oils. [3, 4]

Measurements

In order to fully characterise the state of the oil several measurements determining the properties, the mixture and the additives are required. Some of the most important are viscosity, additive content, the number of pollutants and expendable metals, the size distribution of the particles and the neutralisation value.

For the development of a completely new type of sensor it was most important to find a miniaturised and viable solution, which could also be utilised with mobile machinery.

The choice of measurements which characterise the ageing focussed on viscosity and the dielectric factor. The viscosity of the oil is a determining factor, which increases during ageing. The dielectric factor offers a good correlation to the neutralisation factor and can be relatively easily measured. The neutralisation factor provides information about the by-products and can only be determined in a laboratory by means of titration. Due to the fact that the viscosity and the dielectric factor depend on temperature, the sensor elements for both of these measurements have been integrated into a 16 mm² quadratic quartz substrate (*Fig. 1*).

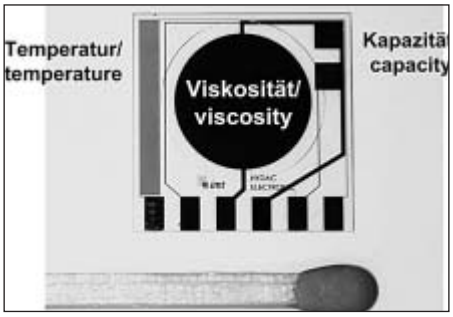

Fig. 1: Oil-multi-sensor (photo: IMT)

The temperature is measured by means of a conduction path resistance and the dielectricity by measuring the capacity between two capacitor plates lying on one level.

The thickness shear movement of the quartz is used to determine changes in the viscosity. An oscillator switch causes a shear movement through the quartz due to the piezoelectric effect, which is dependent on the mass of the quartz and adherences (*Fig. 2*).

When being used with fluids the density and viscosity determine these changes. Due to the fact that during ageing there are hardly any changes in the density, the viscosity is the determining factor for the measurement.

In addition to the quartz there is a further

sensor, which measures the relative moisture in the oil. This value does not enable any conclusions to be drawn as to the state of the oil, but is an important factor due to the fact that moisture accelerates the ageing process and can cause cavity creation. [5]

Tests

Various tests on stationary testing rigs were carried out for the development of the sensors in which the oil were aged in order to analyse the behaviour of the sensors. *Fig. 3* shows the standardised measurements of resonance frequency and dielectricity when testing with predominantly thermo-oxidative ageing. The variances at the beginning of the measurements are due to purposely initiated temperature jumps, which were required for the standardised function adjustment. Subsequent to the adjustment, the temperature was compensated. Thereafter the typical oil ageing process was clearly identifiable. The measuring records show that at the beginning of a phase hardly any changes in the oil occur. After about 450 hours an accelerated ageing takes place, showing a decrease in the resonance frequency and an increase of the dielectricity. Towards the end of the test, about 10 % fresh oil was twice added. It could be seen that the measurement varied accordingly. However, the ageing process cannot be halted by such addition, because the increases have practically no influence on the process. Due to the commencement and considerably advanced ageing there are many chemical by-products in the oil which themselves, have an accelerating and catalytic effect on the process. Therefore, once the ageing process has commenced, it can hardly be stopped.

Evaluation

In order to utilise the sensor in mobile machinery it is necessary to ensure an automatic evaluation of the data. The only problem is that a factor for the absolute determination of the viscosity of the oil is prerequisite. However, due to the fact that usually many

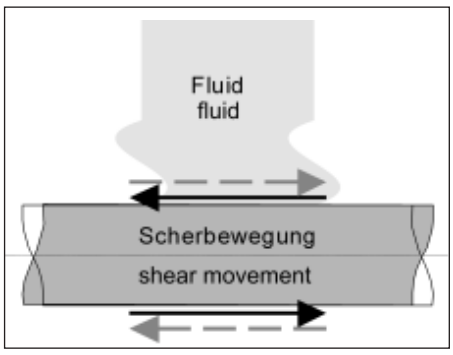

Fig. 2: Thickness shear movement [6]

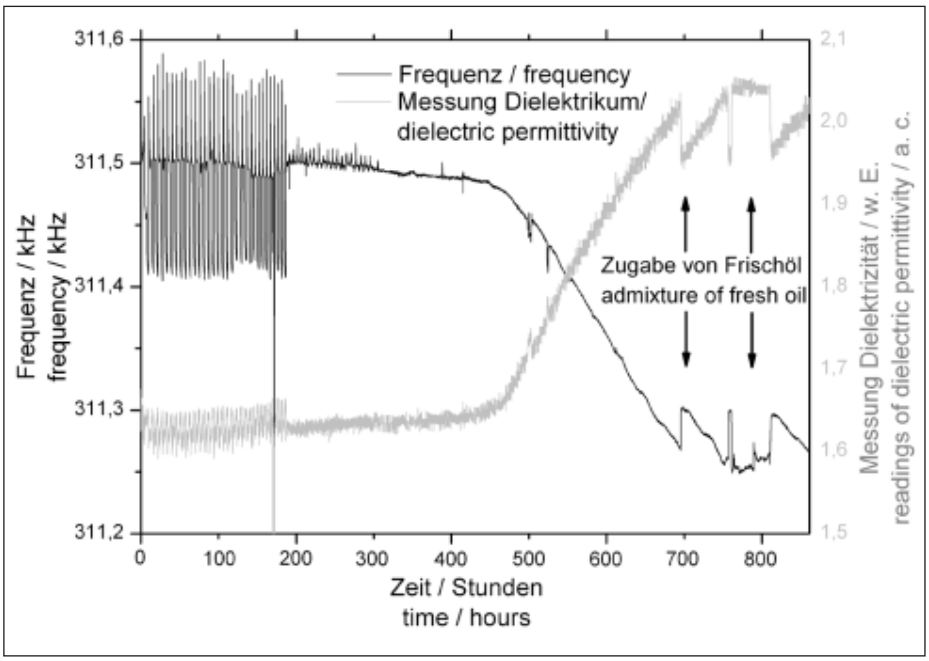

Fig. 3: Readings (Data: HYDAC Electronic GmbH)

varying types of oil are used, in which the composition also varies, this would incur considerable effort. Therefore the evaluation of this data can only be carried out based on measured data. The analysis of the ageing is by means of absolute changes of the frequency and dielectricity as well as their gradients. Several processes are taken into consideration for the evaluation. A classification is made according to various features, from good to bad. At the moment the method for classification is that of parametric templates and neuronal networks. Parametric templates divide the multidimensional feature space into various classifications which have to be predetermined. This method requires a lot of experience and knowledge, however it can be quite easily implemented. Neuronal networks implement the classification by means of the non-linear transformation of the distinguishing vectors. In order to use this method a sufficient amount of instructional data records, with which the network can be trained, is required. The advantages can be found in the automated creation of classification rules and a robust behaviour toward data records which do not lie within the recognised parameters. However, the independent creation of the rules means that the user has no possibility to detect the allocation logic of the classification [7, 8].

First Results and Outlook

First results of the online monitoring in the hydraulic system of a standard tractor clearly show that the sensor works reliably in a mobile location. These tests are still being continued.

Further goals for this project are the evaluation of tests on other research objects and the optimisation of automated data evaluation.

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