An Advanced Multi-Parameter Condition Monitoring System for Lubricants and Hydraulic Fluids

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Summary
A compact measurement unit for fluid monitoring based on simultaneous measurement of viscosity and density is introduced. It will be shown that measuring fluid parameters over varying fluid temperature provides additional monitoring parameters and enhances data consistency. Suitable temperature models are demonstrated. Measurement results are discussed, which show the potential of this approach and the applicability of the measurement system in an industrial environment.

Keywords: viscosity, density, tuning fork, oil sensor

Introduction
In order to reduce maintenance costs as well as the risk of unplanned downtimes, industry gradually adopts online condition monitoring (OCM) methods combined with predictive or proactive maintenance approaches. Enabled by the increasing level of automation, plenty of data can be made available to maintenance personnel and condition monitoring algorithms, and sophisticated evaluation methods can be implemented to assist in planning of maintenance actions. With the implementation of such data based decision methods, the reliability and precision of the collected data obviously has significant impact on the effectiveness of the maintenance actions triggered. Furthermore, the sooner a problem can be identified, the easier and cheaper the appropriate maintenance action will be. So in many cases, the benefit of a sensor increases over proportionately with its accuracy and long term stability.

In this contribution, we present an innovative method to increase data reliability, as implemented in a novel fully automated online condition monitoring system for hydraulic fluids and lubricating oils. The device continuously monitors the viscosity, mass density, and several other relevant parameters of the fluid. With the integrated active temperature control, measurement data can be acquired at any desired reference temperature and thus are independent of the operating conditions of the machine. By cyclic variation of the temperature, additional information is provided and used for validating the consistency of the data.

Monitoring System
Fig. 1 shows the compact OCM system. The temperature controlled measurement cell within the system, houses the vibrating quartz tuning fork sensor (QTF), a Pt100 temperature sensor and a capacitive relative humidity sensor as shown in Fig. 2. From the fluid induced resonance changes of the QTF, the viscosity and density of the fluid are determined [1,2]. As viscosity shows significant temperature dependence, it needs to be measured at well-defined temperatures. Therefore, a precise thermoelectric temperature controller is implemented which can be used to cycle temperature and to determine additional characteristic fluid parameters. These comprise the temperature coefficient of the density and various viscosity-temperature indices such as the VTC, the VI or the m-value [3]. Although not discussed in this publication, the system also provides the electrical fluid parameters [4] and the relative humidity, which, if measured over temperature, yields a true multi-parameter characterization of the fluid under test.
Results

A common model for describing temperature dependence, is the Vogel-Cameron model (VCM) [3] which we use in an adapted form (1) such that the model parameter $\eta_{40}$ represents the viscosity at the usual reference temperature for viscosity of $\vartheta_0=40$ °C. Parameters $A$ and $B$ are the slope of the normalized viscosity curve (see Fig. 3), and the original temperature offset variable of the VCM, respectively.

\[
\eta(\vartheta) = \eta_{40} e^{(\frac{(\vartheta-40°C)(40°C+B)}{B+\vartheta})} \quad (1)
\]

\[
\Delta\eta / \eta_{40}^{\vartheta=40°C} = A\Delta\vartheta \quad (2)
\]

\[
\rho(\vartheta) = \rho_{15} \cdot (1 + C \cdot (\vartheta - 15°C)) \quad (3)
\]

The viscosity vs. temperature curves for two oils (5W30 and HLP 46) and the heat transfer fluid Marlotherm SH (MT SH) are shown in Fig. 3. The curves differ apparently, but the slope parameter $A$ is very similar for all fluids (see Tab. 1). However, the $B$ parameter, characteristically around 110 °C for oils, is only 63 °C for MT SH. Standardized viscosity-temperature parameters such as VTC or VI-Index [2] are based on kinematic viscosity $\nu = \eta / \rho$, and therefore the density ($\rho$) measurements provided by the instrument can be used to calculate these values, as well. The density changes in Fig. 3 are linear over temperature and therefore the model in (3) can be applied. The temperature coefficient $C$ is therefore independent of the reference temperature, (usually 15 °C for density) and given in Tab. 1. The average fitting errors between model and data are approx. 0.2% for viscosity and 0.01% for density, which underscores the applicability of the models.

Conclusions

A novel measurement system for simultaneous measuring of viscosity and density over temperature was introduced. The suitability of temperature models which require only a minimum of parameters was verified.

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References


