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Sensors for Continuous Oil Condition Monitoring

There can be advantages of continuous oil condition monitoring alongside used oil samples being sent to a laboratory for detailed analysis ~ for example to learn of a water or fuel leak immediately, rather than waiting for a period of time before detection. Many different types of sensors using a variety of technologies are available on the market for internal combustion engines and this article concentrates on some of those mostly commonly in use.

<u>Dielectric Sensors</u>

These sensors will detect an overall change in oil condition; the principle being straightforward, in that the oil to be monitored fills the space between two parallel electrodes thus forming a capacitor with the oil functioning as a dielectric. The design of the electrodes can be of a cylindrical or other form depending on the application requirements.
In operation, any changes in the dielectric coefficient (relative permittivity) of the oil will lead to changes in the measured capacitance of the sensor.

The sensor can detect a change in oils used in engines because new oil largely consists of hydrocarbons that have low relative permittivity (of around 2 and described as “non-polar”), and small concentrations of various additives which may or may not be “polar”, e.g. the common antiwear family of Zinc Dialkyldithiophosphates (ZDDP) are weakly polar and have values around 4.

As the oil additive package is consumed or degrades from a fresh charge of new oil, the tendency would be for the relative permittivity of the oil to decrease back towards the base oil level. However, the ingress of contaminants into the oil, such as water or soot, together with a rise in oxidation by-products will tend to increase the relative permittivity considerably, as all of these species are generally more polar. The net effect is therefore much more likely to be a rise in relative permittivity over the service life of the oil. The rate and extent of this rise are the trend parameters to monitor and warning or alarm levels can be set in the light of operational experience.

Given the changes in permittivity are relative to the fresh oil, these capacity sensors should be baselined or zeroed for the particular oil in use. In addition, the relative permittivity of oil has temperature dependence and both the zeroing and subsequent trending are best performed close to the normal operating temperature of the engine.

The capacitance, and hence the relative permittivity, are generally measured by A.C. impedance techniques with varying effectiveness depending on the complexity of the measurement technique – which can be extended to determining impedance as a function of A.C. frequency rather than at a fixed excitation value. Multivariate modelling of this frequency dependence can enable an estimation of individual contributions of contaminants, such as water ingress, soot loading, fuel dilution, oxidation etc.

<u>Moisture Sensors</u>

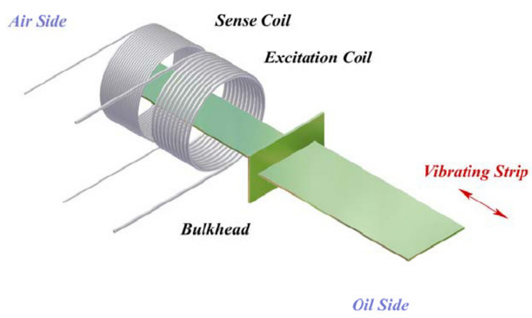
Moisture or relative humidity sensors are a variation on the oil quality sensors described above and focus only on water content. These are also a capacitative type, but the space between the electrodes is filled with a porous, polymeric material whose pore size and chemical composition ensures preferential diffusion of water molecules into its pores.

The measured capacitance of moisture sensors depends on the relative permittivity of the dielectric material between the electrodes which, in this situation consists of the polymer plus any water diffused into its pores and thus there is the ability to attribute the measurements more to water content. The operational range is from zero water content up to the saturation level of the oil beyond which no further water will diffuse into the polymer. The saturation level depends on the chemical properties and temperature of the oil but can be as much as a few thousand ppm. These sensors are thus best suited for low expected water contents.

To summarise; overall oil quality sensors which respond to changes in the dielectric properties can provide an indication in abnormal changes in the condition of the oil such as a faster rate of deterioration seen as oxidation due to engine problems, whereas moisture sensors respond mostly to changes in water content. Both however must be judged against reliable historical data.

Viscosity Sensors

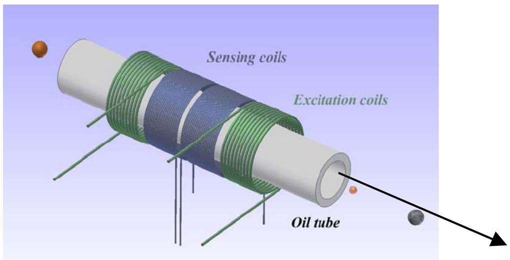
The effect of oil on a thin vibrating metal strip that is located in both air and oil is used to determine the viscosity of oil, as the greater the viscosity, the more the vibrations will be damped. Measurement is done by recording the vibrational profile following pulsewise excitation of the strip. Subsequent digital signal processing allows the decay rate to be determined and hence from previous calibration data, the viscosity.



From a measurement of the oil temperature, the determined viscosity can be corrected to a suitable reference temperature using ASTM, or similar, tables. An unexpected increase in viscosity when results are trended may be due to increased particulates (soot) from a worn or scuffed cylinder liner, or, in the case of a decrease in viscosity - fuel dilution caused by a fuel leak.

Particle Sensors

Metallic wear debris particle counters employing inductive technologies have been commercially available for some time.



Using a combination of balanced field coils and sensing coils, these devices are able to detect metallic debris and differentiate between ferrous and non-ferrous metals, due to the difference in mechanisms by which these two materials interact with the magnetic field. Particle sizes are related to the signal amplitude and material type to the signal phase. Current sensors are capable of resolving ferrous debris down to 40 µm diameter and non-ferrous to 135 µm diameter.

The foregoing information is very much “the basics”, although greater detail was provided by Kittiwake Technical Paper 580, presented to members of IDGTE 15th September 2011, which will be published in the March 2012 Journal.

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