Electron Spin Resonance (ESR) Provides a Useful Tool for Assessing the Lifespan of Engine Oil

The lubrication of an engine allows it to work efficiently and undergo minimal wear, translating to lower running costs as fuel economy and engine lifespan are optimized. Maintaining the engine lubricating oil is a vital part of ensuring that a vehicle continues to run smoothly throughout its lifetime. It is essential that the lubricating oil is changed once it becomes degraded. During its use, the oil undergoes degradation through oxidation, thermal decomposition and mechanical abrasion processes.

Such processes lead to the formation of residues that can alter the viscosity of the lubricating oil resulting in blockages of oil filters and other engine components. This impairs the lubricating function of the oil and puts the engine at risk to excessive wear and a reduced lifespan.

Although special formulations and chemical additives help reduce oxidative degradation, an oil's lubricant properties will inevitably diminish over time. It is important to know when an engine oil has reached the point where its protective properties are no longer sufficient to protect the engine. At the time when protection is lost, the used engine oil is removed and replaced. The used oil is considered hazardous waste and must be handled and disposed of accordingly.

Knowledge of a lubricating oil's condition is important for providing guidance on oil change intervals to maximize engine protection and minimize the hazardous waste contribution. Here we discuss a novel new technology for assessing more accurately when an engine oil needs to be replaced.

The degradation of lubricant oil proceeds primarily by way of a free radical oxidation process. The rate and level of free radical formation provides a useful indicator for how well a particular engine oil will perform under real driving conditions. The current work investigated the use of electron spin resonance spectroscopy (ESR; aka EPR) for measuring free radical formation during the lifespan of an engine oil under typical driving conditions.

The ESR technique is the only direct measurement for free radical formation in materials. The proposal here is to determine if a correlation exists between the free radical ESR signal from an oil and its time of driving use. Since free radicals are the initial product of oxidative degradation in engine oil, the ability to monitor their concentration is useful for determining the present performance condition of a particular oil type or formulation.

An ESR spectrometer was used to analyze free radicals in samples of lubricating oil taken from the dipstick of the same engine after every 1000 km traveled by the vehicle. Figure 1 shows a typical ESR spectra measured from a X-5W40W engine oil after typical usage The bottom spectrum is the fresh oil; the top spectrum is following 10100 km of use.

Figure 1

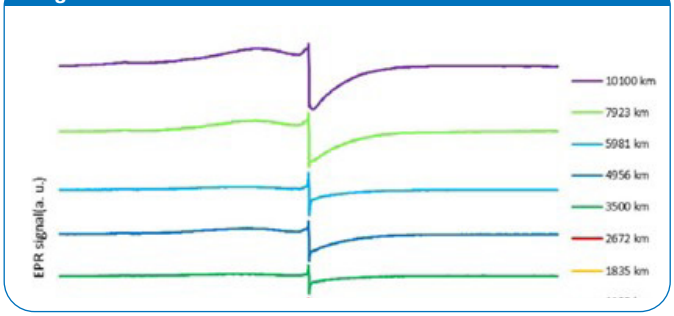

Figure 1. ESR spectra from a X-5W40 engine oil at increasing usage (in kilometers)

The ESR signal increases in a manner proportional to the distance driven. Measuring the central peak intensity of these ESR spectra in three different oil types revealed an almost linear correlation between the concentration of free radicals and the oil's degradation condition; expressed in the number of kilometers traveled by the vehicle (see Figure 2.)

Figure 2

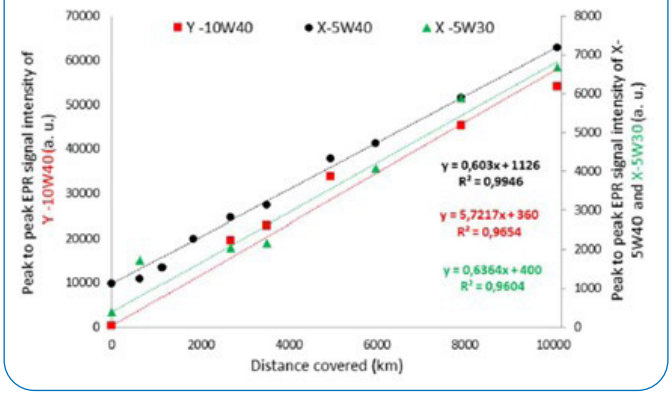

Figure 2. Relationship between the ESR signal intensity and the engine oil usage (in kilometers)

It was concluded that ESR provides a valuable new method for assessing oil degradation as it relates to usage in distance driven. The method can provide a tool for optimizing engine protection while also minimizing unnecessary disposal of oil before its actual protective properties have expired.

Bruker's unique EPR instrument platform portfolio ranges from easy-to-operate benchtop systems with high-throughput sample automation to high-resolution floor-standing and imaging systems. The EPR solution portfolio includes push-button quality control tools for a straightforward monitoring and tracking of material changes.

For more information on Bruker's new line of portable ESR spectrometers that are ideally suited for this method, click the following link: https://www.bruker.com/en/products-and-solutions/mr/epr-instruments.html.

References

All ESR data were obtained from:

[1] Zzeyani S, et al. Spectroscopic analysis of synthetic lubricating oil. Tribology International 2017; 114:27

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