OIL CONDITION

BY RAJ SHAH AND PAUL VOELKER

Lubricant formulators and their additive suppliers are being challenged to develop new formulations for passenger car engines and heavy-duty diesel engines, in response to U.S. Environmental Protection Agency directives requiring reduced vehicle emissions and customer demands for better fuel economy.

Starting this summer, the new ILSAC GF-4 passenger car engine oil category will be expected to maintain catalytic converter efficiency for 120,000 miles. At the same time, these oils must reduce by 20 percent the current level of phosphorus the contain[1]. Phosphorus is a proven component in antiwear protection but known to slowly poison the catalytic converter in the exhaust system.

On the heavy-duty diesel side, the proposed new PC-10 engine oil category is under rapid development, driven by the EPA's "2007 Rule" mandating an additional 90 percent reduction in nitrogen oxides (NOx) and particulates. The on-board equipment that will make this possible will further load increasing levels of soot into the crankcase[2].

Achieving low emissions while maximizing fuel economy is a particular formulation challenge for diesel engines. Older and rebuilt diesel engines running with retarded fuel ignition timing to satisfy proposed emission requirements force higher soot loading, causing poorer fuel economy. Newer engines equipped with cooled EGR systems allow more advanced fuel injection timing for better fuel economy — but they introduce corrosive acids (from sulfur in the fuel) into the oil, which leads to damage in cylinder liners, rings and bearings.

To minimize abrasive and corrosive engine wear under the PC-10 specification, new dispersants and detergents will be needed to manage soot, which is expected to reach levels in the oil of up to 8 to 10 percent/wt., approximately 50 percent above previous requirements. Another unknown is how very high soot loading will affect the oils' antiwear performance. The lubricant industry relies on phosphorus- and sulfur-containing additives for antiwear protection but with a mandate scheduling their reduction, new chemistries for replacements and supplements will soon be needed.

All of this is putting heavy demands on the engine testing facilities which demonstrate lubricants' compliance and additive packages' sustained performance over time. However, testing an oil sample during an engine sequence test usually requires two steps, sampling then analysis. These steps must be repeated at frequent, consistent intervals for the duration of the test, slowing down the flow of information and introducing the possibility of error.

A BETTER WAY

As an alternative to this laborious process, the Oil Insyte Monitoring System uses an in-line sensor that continuously measures additive package performance in oils. A proprietary technology eliminates the two-step process of sampling and analysis and provides fast results by measuring oil breakdown as it happens — independent of base oil type or additive package, and collected under actual test conditions and temperatures.

The Oil Insyte System provides a method for directly comparing additive package performance by measuring the leading indicators of oil wear under actual test conditions without operator intervention. Specifically designed to fit test-facility engines, the system provides easy set up and operation. The methodology does not require external standards or calibration, is independent of an oil's viscosity, and is compatible from 70 degrees C to 150 C (as measured in the reservoir).

The Oil Insyte design actually comprises two separate systems. An Oxidation System independently measures additive depletion and oxidation, while a Soot system determines soot contamination. The components include a sensing element, a mechanical interface (that secures to the oil reservoir) and a signal-conditioning unit with an easy-to-read LCD that displays the condition of the oil. (See Figure 1.)

Values for oxidation, additive depletion, and temperature are displayed on the Oxidation System. Soot and temperature are displayed on the Soot System.

METHODOLOGY

Oil Insyte uses a patented technique that employs a polymeric bead matrix held between two conducting permeable surfaces. This bead matrix contains charged groups that serve as a conducting medium for measuring the solvent properties of oil. The method operates by correlating a relative change in the electrical properties of the beads with a relative

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change in the solvent properties of an oil, i.e., the interactions between the charged groups adjust as the oil moves from a nonpolar (clean) condition to a polar (oxidized or soot-contaminated) condition. (Figure 2, page 20)

Taking a relative ratio of the conductivity of the beads to the conductivity of the oil (bead chamber to open chamber) determines the oxidation state of the oil. A ratio of the two signals effectively subtracts out additive effects and provides a unique method for measuring oxidation in isolation.

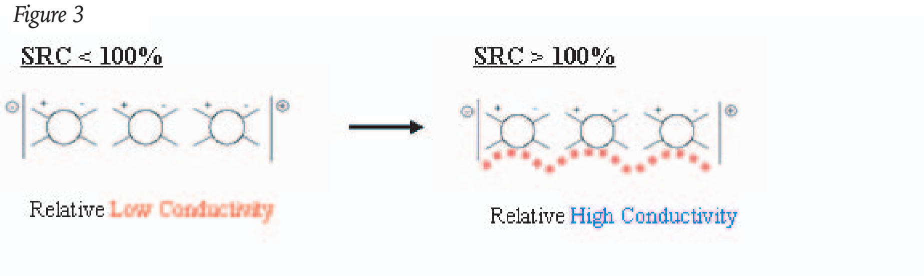
Alone, the open chamber independently measures additive depletion by a relative change in the oils conductivity. The sensor is operational for oxidized oils measuring from 10 to 50 OD per cm by infrared spectroscopy. (OD stands for units of optical density.) On an overall scale of 1 to 33 OD/cm, a measurement of 20 to 26 OD/cm typically is considered the optimum oil change interval for automotive oils.

Soot measurements are based on a percentage of the

Figure 1

Figure 2

Figure 3



For clarity, only a single monolayer of the charged bead matrix is shown

saturated relative contamination (SRC), i.e., the amount of freely available soot in the oil. Here's how this works:

Like water, a percentage of soot is normally contained by an oil's additive package. When that threshold is exceeded, soot is available for coming in contact with the sensor and triggering a response. The free soot (composed of carbon) sticks to the surface of the beads forming a "bridge" across the chamber and providing a relative increase in conductivity. (Figure 3)

Depending on the oil's additive package, the same amount of free soot can be present at 1 to 2 percent contamination (for base oil without additives) to greater than 7 percent for fully formulated oils.

COMPARING RESULTS

The following plots provide results of soot contamination and oxidation/additive depletion with the Oil Insyte System. Results are compared with standard laboratory techniques.

Figure 4 illustrates the performance of the Oil Insyte Soot System in detecting soot contamination in diesel engine oil and in oils treated with weighed samples of activated charcoal (powdered) to simulate contaminated conditions.

The line graph at left in Figure 4 shows the sensitivity of the Oil Insyte at detecting soot from oil sampled from diesel engine test stands. Soot detection is correlated with laboratory weight percent measurements. Weight percent measurements however, may not be the best indicator of additive package performance.

The figure at right in Figure 4 demonstrates the principle of SRC from adding known quantities of charcoal to base and formulated oils. In base oil (no additives) the percent charcoal detected by the Oil Insyte equals the amount of charcoal added, i.e., 2.5 percent. Results in formulated oil show a relatively higher percent charcoal concentration is needed to provide a comparable response, i.e., an 8 percent treatment correlates with a 2.5 percent response. The results for the formulated oil support the principle of SRC by detecting free soot only. Additives in the formulated oil are suggested to bind the remaining 5.5 percent soot.

Figure 5 illlustrates the performance of the Oil Insyte Oxidation System in measuring oxidation/additive depletion and compares the results with infrared spectroscopy (IR) and dielectric analysis measurements. Oils were sampled from automobiles during the course of normal driving. Data were measured using two formulated oils, SAE 30W and SAE 10W-40.

The plot at left in Figure 5 shows a linear correlation with IR (left) measurements (scaled from 0 to 33 OD/cm). This demonstrates that the Oil Insyte is independent of oil viscosity, composition and temperature. Additive depletion results for the same samples at right

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Figure 4

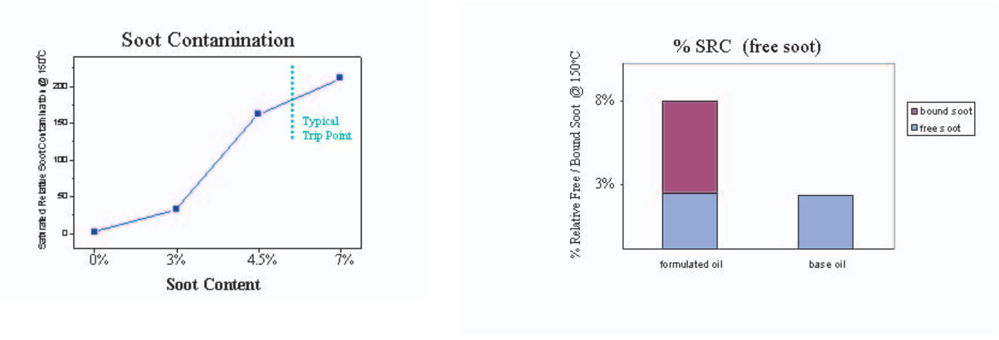
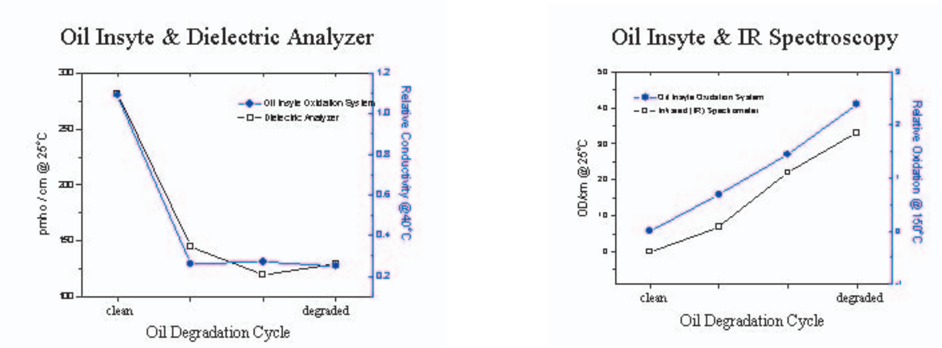


Figure 5



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show an initial decrease with wear and compare favorably with results from a dielectric analyzer.

SUMMARY

The Oil Insyte Monitoring System offers an in-line method for continuous oil condition monitoring, with an easy-to-read LCD display. The methodology measures the leading indicators of oil wear and allows the conventional two-step approach of oil monitoring — sampling and analysis — to be combined into a single, more efficient step. A common protocol allows for easy side-by-side comparisons for correlating oil type to driving environments and conditions.

The monitoring system's Oxidation System independently measures additive depletion and oxidation, providing the ability to examining the interdependence between the two for ensuring maximum lubrication performance.

The Soot System determines soot contamination and provides the ability to measure additive package performance by determining the amount of free soot present in the oil. This helps formulators to pinpoint how well the additive will protect engines and catalytic converters, ensuring compliance with tougher emissions standards and maximizing fuel economy.

The entire system can move outside the engine test lab as well, to serve as a useful tool where oil condition testing is performed in an on-site laboratory in the field, such as for stationary engines or mobile equipment.

Even where it is not feasible to integrate the sensor into the engine operating environment, the device provides an alternative to direct in-line oil measurements. In such cases, the sensing element may simply be immersed in a beaker containing a sample of the oil of interest and heated to the operational temperature.

Measuring additive package performance is of major interest to the lubricant, additive and automotive industries, which are tasked with producing cost-effective ways to satisfy new exhaust emission requirements. Testing is accelerating along with these demands. Quantifiable data on the behavior of oil wear based on changes in the additive package formulation need to be available fast, collected over the temperature range of the test, and easily interpretable. ▮

References

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2. McFall, D., "Diesel Countdown Begins," *Lubes'n'Greases*, February 2003, pp 12-17.

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