Recording oil’s vital signs

On-board monitors are designed to take waste out of routine vehicle maintenance.

By John DeGaspari, Associate Editor

CHANGING THE OIL in an engine regularly protects the system and pays off in the long run. But it also involves throwing out a lot of serviceable oil from vehicles that see less strenuous use, and a schedule can’t predict when oil will break down ahead of time.

That’s why a number of efforts are aimed at developing on-board systems to measure oil quality in real time or, at least, to base predictions on specific, observable conditions.

A reliable means of monitoring the condition of engine oil will permit a new kind of just-in-time maintenance, and that, according to some forecasters, could save millions of quarts of oil a year.

Although industry-wide minimum standards exist for acceptable engine oil quality, engine oil performance can vary widely according to individual driving habits, driving conditions, and engine design. Acceptable oil performance specifications are based on standardized engine dynamometer tests developed by the American Society for Testing and Materials. Those tests are used to simulate a vast number of real-world variables, such as oil temperature, fuel flow, exhaust constituents, outside air temperature, intake air humidity, and engine loading, in a tightly controlled laboratory environment.

The bottom line when scheduling oil changes is to achieve the full design service life of the engine, according to Larry...
Bendele, director of the Engine Lubricants Research Department at Southwest Research Institute in San Antonio, Texas. Bendele's department runs tests of engine lubricants for industrial clients. Many factors affect engine oil performance in different ways, Bendele said. For instance, a vehicle used for short trips in cold weather never warms up properly, so its engine crankcase is subject to a hostile environment of condensed fuel and water vapor. On the other hand, a car that is driven across the desert, at or above the speed limit with a trailer in tow, will run at high temperatures, causing the oil to thermally degrade and thicken. Oil performance also can be influenced by ambient air conditions and fuel formulation, as well as by condition and type of engine.

Auto manufacturers recommend scheduled oil changes along very conservative timeframes, since driving conditions and other variables that affect oil performance and engine life must be taken into account. An effective schedule has to call for maintenance before signs of engine wear occur. "If you see signs of wear occurring, it's too late," Bendele said. "You've started the wearing process, which can affect exhaust emissions or shorten the overall life of the engine."

**SENSOR ON BOARD**

Strictly schedule-based maintenance has several downsides, according to some experts. One disadvantage is that it can be wasteful, requiring oil changes in many vehicles before they actually become necessary, according to Kyong Park, vice president of research and development at Kavlico Corp., the Moorpark, Calif., marketer of an oil monitoring device. In his view, scheduled maintenance also does not solve the problem of premature lubrication failure, which can result from the presence of engine coolant or fuel in the oil, nor does a schedule take into account specific operating conditions that may shorten or extend oil life.

Kavlico's on-board oil monitoring device has been commercially available for about two years. The sensor is designed to measure aging of oil by monitoring the dielectric constant, which increases as molecules break down and additives deplete with use. The dielectric constant correlates well with a total acid number and, according to Park, is easier to measure than other properties, making it suitable as the basis of an on-board sensing system.

The dielectric constant of oil depends on the length of the service period and the composition of the molecules. As friction and temperature cause the molecules to break down and as additives are depleted, the dielectric constant increases, measured by increased voltage. The sensor is a variable capacitor that consists of two parallel electrodes separated by a gap filled with oil. It consists of a sensing element that is in direct contact with oil; an electronic circuit that converts the signal from the sensing element to output voltage; a connector assembly that provides protection from electromagnetic interference; and the housing. The sensor measures less than 3 inches in height and weighs 3.5 ounces. The oil sensor can be located either in the output side of the oil filter or in the oil pan.

**TEMPERATURE SENSITIVITY**

One difficulty in measuring the dielectric constant is its sensitivity to temperature. As temperature rises, the dielectric constant also rises. To cancel out this temperature dependency, the sensor signal conditioner is designed with compensation circuitry. The circuit is mounted adjacent to the sensing element that is in contact with the oil so temperature can be accounted for.

In addition to measuring oil degradation by monitoring molecular breakdown, the sensor also can be used to detect the presence of contaminants such as water or coolant, each of which has a different dielectric constant, said Park. Water, for example, has a much higher dielectric constant than oil, so relatively small amounts can be detected.

The sensor has been installed on some large diesel engines. A potential application, suggested Park, is to detect seawater contamination in marine engines. Other places where the system could be useful would be hydraulic systems and compressors.
An on-board oil degradation monitor is also being developed by the Bio-MEMS Group at Ohio State University in Columbus. Marc Madou, a professor in OSU's Department of Materials Science and Engineering and OSU's Chemistry Department, has developed a sensor that uses iridium dioxide to monitor the condition of engine oil by measuring its pH.

"The key parameter that people are after is the total acidity number, and that relates to pH," said Madou. The sensor has three electrodes that are placed in a shielded alumina cell with a porous ceramic bottom that is filled with a polar solvent that does not mix with the oil. The design resists fouling and problems with results when the electrodes are exposed directly to oil.

Madou said that the iridium dioxide is a drift-free electrode featuring high sensitivity, long-term stability, and fast response.

"We optimized iridium dioxide as a pH sensor," said Madou. "We made it extremely robust so that it doesn't come off the iridium wire. It withstands very high temperatures, is extremely fast, and is a very good pH sensor."

The sensor uses two electrodes—one of iridium with iridium oxide, and the other of silver with silver chloride—to measure pH. The silver electrode works with a third, made of platinum, to gauge open circuit potential. The iridium and platinum electrodes work in tandem to measure the impedance of the oil.

The pH relates to the total acid number. Open circuit voltage gives information about antioxidants that might be present. Impedance, which is the resistance and capacitance of the oil, gives an indication of conductive particles, such as salts or metal particles.

Madou argues that a combination of measurements will present a truer picture of oil degradation than just one measurement.

So far, the sensor has been tested only under laboratory conditions. Madou said that he is negotiating with automotive companies to test the sensor under actual driving conditions.

The math model used by the Oil-Life System is based on millions of miles of driving tests and oil analysis results. "We have done a lot of homework in the past to get very good models relating to engine oil temperature and engine and vehicle speed," said Schwartz.

The Oil-Life System compensates for different driving styles and conditions. The math model involves computerized monitoring of engine revolutions, operating temperature, coolant temperature, oil temperature, and other factors to calculate the rate of engine oil degradation and predict when it should be changed. Rather than depend on fixed oil change schedules that may not be suitable for all situations, the monitoring system customizes oil change schedules based on the vehicle's engine and transmission type, as well as on an individual's driving habits.

GM predicts that its Oil-Life System will enable drivers to save 40 million quarts of oil annually, when it becomes equipment on most of the company's North American fleet.

A Dual Approach

A combined approach of monitoring driving conditions and using sensors has been taken by DaimlerChrysler of Stuttgart, Germany. The company has developed a passenger car maintenance system, called Assyst, for Mercedes-Benz vehicles. The Assyst system calculates oil change intervals based on driver-specific data, and supplements that information with a sensor that continuously monitors oil level, oil temperature, and the dielectric number of the engine oil.

The dielectric number can warn the driver that water is present in the sump or a coolant leak is occurring in the engine.

According to a paper presented last year to the Society of Automotive Engineers, DaimlerChrysler's Assyst system has extended oil change intervals by as much as 50 percent.