SENGENUITY
Sensor Engines by Vectron International

Rotating Pressure Vessel Oxidation Test Results For ViSmart™ Viscosity Sensor

Introduction

There exists a critical need in the mobile and fixed asset market to empower field units to determine oil quality on demand and provide complementary oil condition information that has been traditionally obtained from oil analysis labs. The current methodology of testing in off-site labs is non-optimal and costly due to the logistical challenges of shipping samples and the time delay in getting information back to personnel to be able to make quick and informed decisions. Determining oil quality in real-time with embedded and portable oil assessment devices operated by mechanic personnel provides the operational flexibility and rapid means of screening oil quality that is key to establishing a program to provide real-time condition based monitoring products for the care of all assets.

Measuring the viscosity of oil is a rapid method of determining oil condition, and is considered an important parameter in assessing asset readiness. The SenGenuity ViSmart™ viscosity sensor which can compliment IR spectroscopy and other bulk property sensors can provide instantaneous on-line viscosity and temperature data, has no moving parts with an extremely wide operating range and offers universal plug-n-play connectivity for integration with and into other handheld products. The sensors have been on the market to close to a decade and are currently installed in markets ranging from oil condition monitoring in machine tool and rotating equipment industries to process control in coating applications. It is in these rigorous environments where ROI benefits have been realized, and are now been evaluated for mobile and fixed assets where oil condition monitoring is of paramount importance.

SenGenuity's acoustic wave (AW) sensors offer a number of advantages over conventional mechanical and electromechanical viscometers as they are small solid-state devices that can be completely immersed in the oil providing an instantaneous viscosity data stream for embedded OEM or end-user spot-check applications. The sensors are unaffected by shock or vibration or by flow conditions so they can be used in harsh operating conditions to measure viscosity from 0 to 500 cP with a temperature range of -15˚C to 125˚C with a high degree of accuracy. At the same time, sensor measurements are not affected by particulates in the oil.

Conventional mechanical and electro-mechanical viscometers designed primarily for laboratory measurements are difficult to integrate into the control and monitoring environment. As a consequence, many companies rely on decisions based on intermittent "snapshot" data acquired from periodic sampling where conventional instrumentation can be affected by temperature, shear rate and other variables.

Given that contaminants in oil (water, solvents and fuel) are known to degrade viscosity and cause damage to internal components of diesel assets, whether they are trucks or construction equipment or military vehicles or power-gen equipment, it important to not just rely on snapshot data. High water contamination levels in diesel fuel have been shown to be the reason for corrosion and pitting leading to increased metal wear particle counts. The presence of residual cleaning solvents and fuel contamination has caused seals to swell and create less then ideal engine operating situations. Knowledge of viscosity in real time provide a significant benefit to measure aging of oil, ingress of contaminants during commercial operations and prevent incipient mechanical failure due to loss of oil lubrication properties.

Any sensor for these challenging oil condition monitoring environments has to demonstrate its reliability and longevity. This case study shows the SenGenuity ViSmart™ viscosity threaded bolt sensor (Figure 2) that is targeted at embedded integration to fixed and mobile diesel assets, pass the RPVOT tests, which is one of the industry benchmarks.

Product Technology

SenGenuity has developed a unique method to offer a viscosity sensor with a wide dynamic range (air to several thousand cP) in a single sensor (Figure 1).

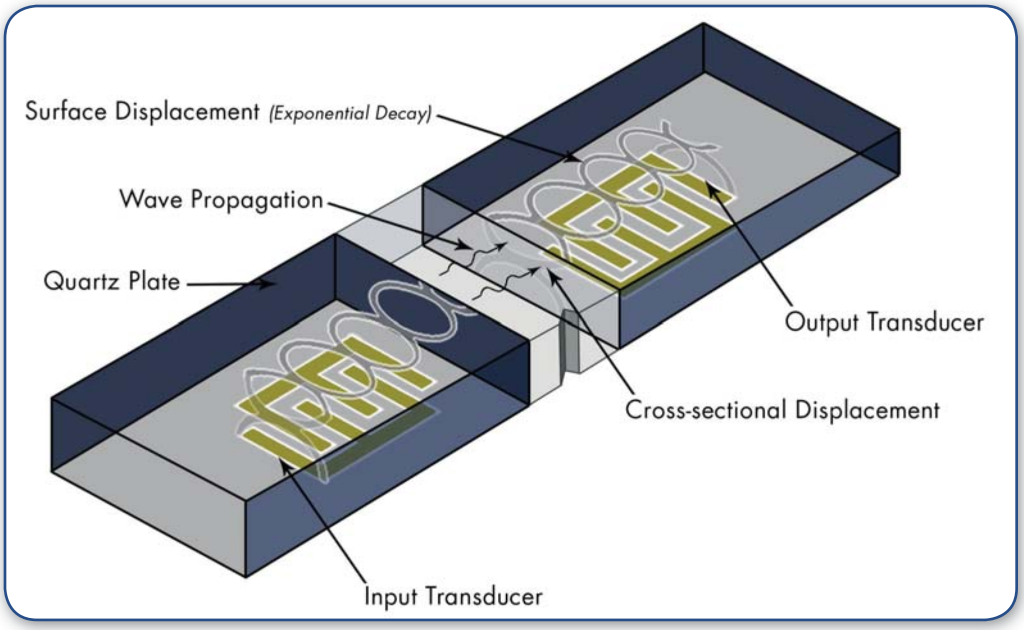

Figure 1. The SenGenuity sensor uses an acoustic waveguide with electrical transducers on one surface and being in contact with the fluid on the other surface.

Figure 2– SenGenuity solid-state low shear bolt viscosity sensor

The ViSmart™ is a commercially available, robust, reliable and cost-effective surface acoustic wave solid-state viscometer for integration into in-line, real-time monitoring and process control systems for scalable applications (Figure 2).

The sensor has no moving parts (other than the atomic scale vibration of the surface) and, due to the high frequency of the vibration, several millions of vibrations per second, is independent of flow conditions of the liquid and immune to vibration effects of the environment. High temperature electronics are utilized that allow a very wide operating temperature range for the sensor.

The importance of these acoustic sensors lies in the distinctly different measurement principle. Whereas one class of mechanical devices measures kinematic (flow) viscosity and the other class measures intrinsic (friction) viscosity, the acoustic wave (AW) sensors measure acoustic impedance, $(\omega\rho\eta)1/2$, where ω is the radian frequency ($2\pi F$), ρ is the density and η is the intrinsic viscosity.

The viscosity measurement is made by placing the quartz crystal wave resonator in contact with liquid. The liquid's viscosity determines the thickness of the fluid hydro-dynamically coupled to the surface of the sensor. The sensor surface is in uniform motion at frequency, $\omega=2\pi F$, with amplitude, U. The frequency is known by design and amplitude is determined by the power level of the electrical signal applied to the sensor. As the shear wave penetrates into the adjacent fluid to a depth, d, determined by the frequency, viscosity and density of the liquid as $d=(2\eta/\omega\rho)1/2$, as depicted in Figure 3.

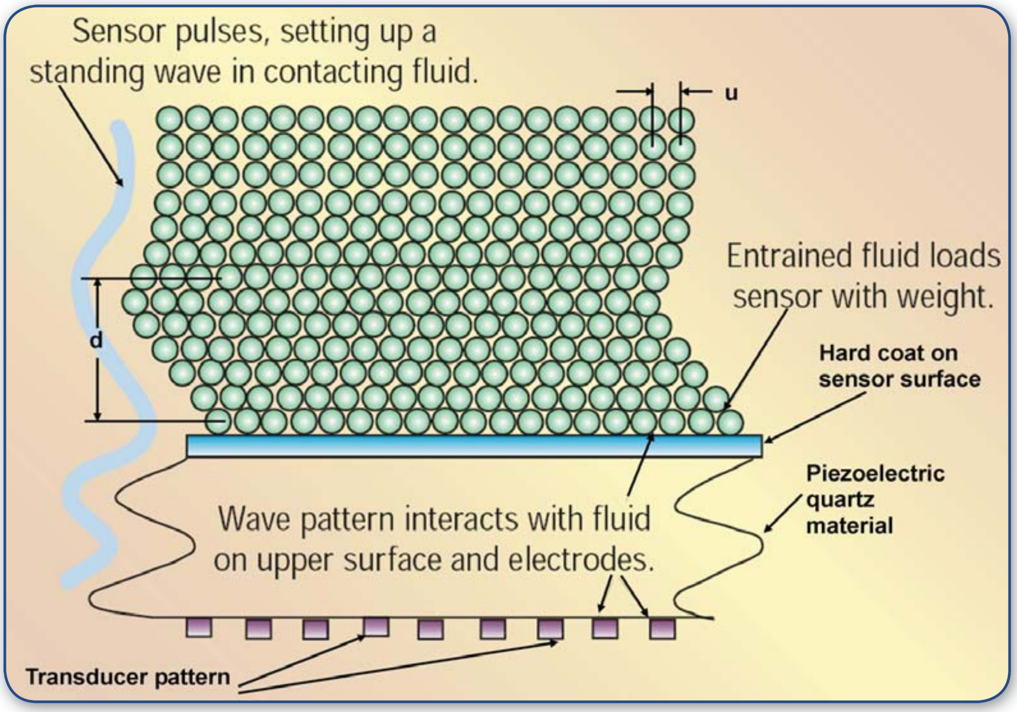

Figure 3. Cross section of the sensor showing transducers on the lower surface and liquid molecules (gold balls) on the upper surface.

Acoustic viscosity is calculated using power loss from the quartz resonator into the fluid. The unit of measure is acoustic viscosity (AV) and is equal to ρη, (g/cm3 • cP) (density times dynamic viscosity).

The acoustic wave resonator supports a standing wave through its thickness. The wave pattern interacts with electrodes on the lower surface (hermetically sealed from the liquid) and interacts with the fluid on the upper surface. The bulk of the liquid is unaffected by the acoustic signal and a thin layer (on the order of microns or micro inches) is moved by the vibrating surface. Also present is a proprietary hard coat surface that is scratch proof and abrasion resistant which allows the sensor to be operable in extreme environments and enabling the ViSmart™ sensor to be a suitable candidate for oil condition based monitoring applications in mobile and fixed asset markets.

RPVOT Test and Data

ViSmart™ viscosity sensor element has been successfully tested for Rotating Pressure Vessel Oxidation Test (RPVOT) for applications in engines for continuous, real-time monitoring of oil condition. The RPVOT is an ASTM 2272 test, which oxidizes the oil heavily, and is used to test the sensor's capability to survive oxidized oil conditions (see Figure 4 for effects on a copper coil); these conditions are reflective of actual operating conditions in engines.

Figure 4: The effect of RPVOT testing on the copper coils

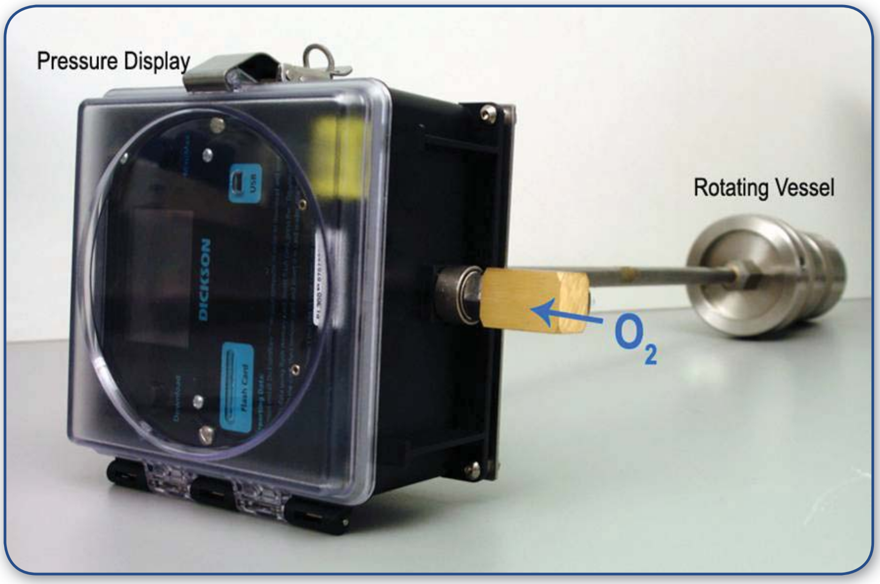

Figure 5: The RPVOT vessel

The procedure is as follows: Oil (high quality API CF-4 multi-grade engine oil which is used mainly for diesel engines as they are used in trucks) quantity is approximately 55 ml in the vessel and the ViSmart™ sensor element manufactured in accordance with standard semiconductor practices and packaged in a standard T0-8 housing is placed in the vessel (see Figure 5).

With the temperature of the oil bath (for tightly controlled temperature environment) at 150°C (see Figure 6), introduction of 10 ml water takes place. The copper coil in test beaker is together with ViSmart™ sensor element. Pure pressurized oxygen 180 psi (12.5 bar) is then introduced to the rotating vessel in which the test beaker is placed for 24 hours. As the oxygen under pressure reacts in the rotating vessel catalyzed by a copper coil the pressure reduces. The oil becomes more acidic through oxidation processes. The test is normally finished after a pressure reduction of 25 psi (1.75 bar) according to the maximum (ASTM 2272).

Figure 6a: Water bath for the RPVOT vessel.

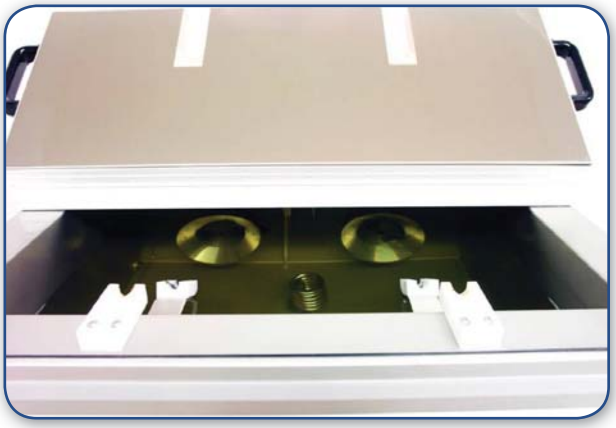

Figure 6b: Water bath with lid open for the RPVOT vessel.

Figure 7: ViSmart™ sensor element at the start of the RPVOT test

The sensor was analyzed at 4 hour intervals for surface coating integrity and packaging robustness. A photograph of the sensor element at the start of the test is shown in Figure 7.

Elemental analysis conducted to determine if there was any degradation of the sensor element itself, and if particulates or other matter were released during the test. Photograph of the sensor, taken at the conclusion of 24 hours, shows no issues with sensor element reliability or robustness (see Figure 8).

Figure 8: ViSmart™ sensor element at the conclusion of the RPVOT test showing full reliability and robustness

The RPVOT test was conducted by OELCHECK GmbH (www.oelcheck.de), the world leader in lubricant analysis and related consultation. This activity is part of the working partnership between SenGenuity and OELCHECK. Under terms of that partnership, OELCHECK, as part of its overall oil condition monitoring and data analysis services, is conducting tests of the ViSmart™ sensor supported by their deep knowledge in tribology for customers in Europe.

The report issued by OELCHECK stated that the RPVOT results show that the SenGenuity ViSmart™ viscosity sensor element itself can withstand the conditions of excessively aged modern engine oil without significant formation of deposits on the sensor surface. The report went further on to say that the ViSmart™ sensor element is also not getting damaged at atmospheric pressure conditions at temperatures up to 150°C.

The successful test outcome clearly demonstrated that no significant sensor element surface degradation or material buildup had occurred in the excessively aged engine oil.

Benefits

The commercially available ViSmart™ viscosity sensor can be readily applied in field operations or installed directly on the equipment for continuous monitoring of viscosity to enable the mechanic personnel to test the oil in minutes. It would be complementary to lab oil analysis test burden by providing real-time viscosity data and would enable streamlining of logistic costs. And given no calibration is required for the rugged vibration and shock proof sensor, once it is installed in a harsh industrial environments, maintenance costs are extremely low.

The sensors are currently used in 24/7 applications in the commercial sector, with real-time data transfer for decision making abilities. The real-time in-line threaded bolt sensor can be fully immersed in the oil or be simply used for spot-checking or continuous monitoring. Providing real time viscosity data and using the sensor continuously would provide the necessary information to personnel to make critical decisions in actual field applications leading to extension of machine life and maintenance schedules while complimenting the other oil quality parameter data stream obtained from the labs.

Contact Information

If you would like to learn more about our sensors, the markets we serve and customer applications we strive to address, please do not hesitate to contact our Application Engineering group at support@sengenuity.com.

SenGenuity • 267 Lowell Road, Hudson NH 03051, USA • Tel: 1.603.578.3025 • Fax: 1.603.578.4060 • www.sengenuity.com