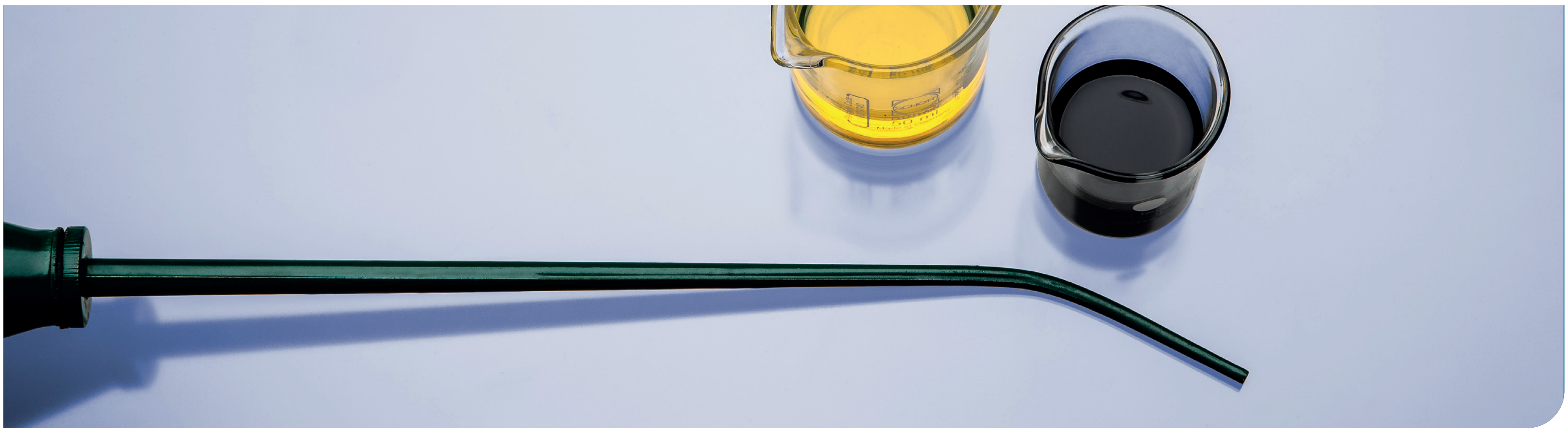
ADVANCEMENTS IN LUBRICATION OIL CONDITION MONITORING THROUGH FTIR SPECTROSCOPY



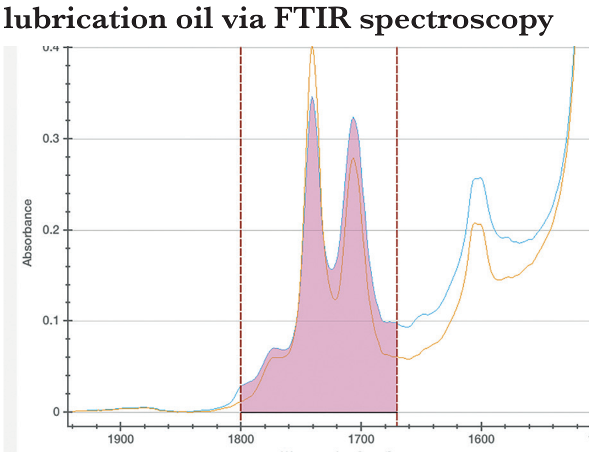
Lubrication oil plays a crucial role in the smooth functioning and longevity of machinery in various industries. Over time, the quality of lubrication oil can degrade due to factors such as contamination, oxidation, and wear particles. Traditional methods of oil analysis have limitations in providing real-time and comprehensive insights into the oil's condition. However, Fourier Transform Infrared (FTIR) spectroscopy has emerged as a powerful and versatile tool for monitoring the condition of lubrication oil. This article explores the principles of FTIR spectroscopy and its applications in lubrication oil condition monitoring, highlighting its advantages over conventional methods.

Understanding FTIR spectroscopy

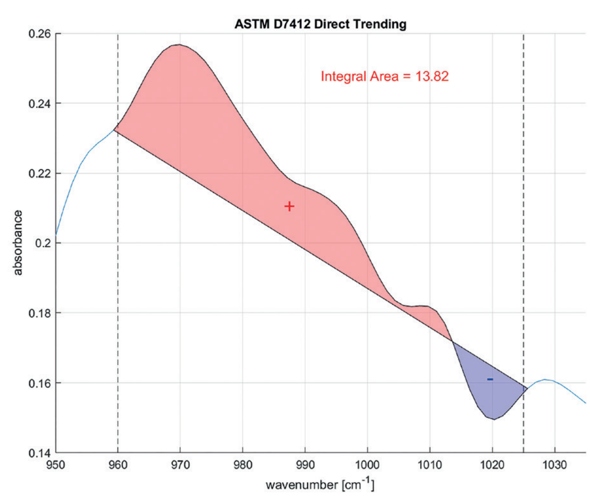
Fourier Transform Infrared (FTIR) spectroscopy is a non-destructive analytical technique used for identifying and quantifying chemical compounds in a wide range of materials. In the context of lubrication oil analysis, FTIR spectroscopy is employed to analyze the molecular composition of the oil sample, providing valuable information about its chemical and physical properties.

The basic principle of FTIR spectroscopy involves passing infrared light through a sample and measuring the absorbance of different wavelengths. Each type of molecular bond absorbs infrared radiation at characteristic frequencies, producing a unique spectrum for the sample. By analyzing the resulting spectrum, it is possible to identify the molecular components, contaminants, and products of degradation present in the lubrication oil.

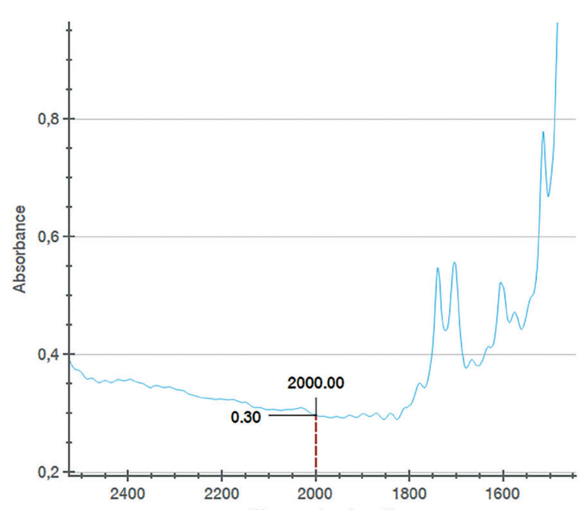
ASTM-compliant analysis of lubrication oil via FTIR spectroscopy



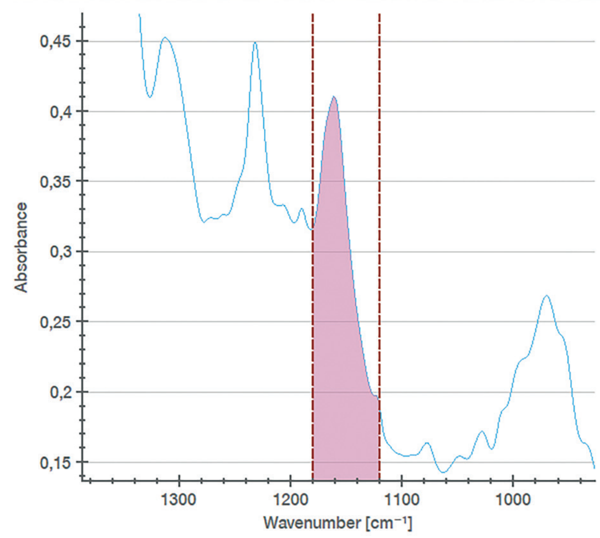
Monitoring oxidation according to ASTM D7414: Oxidation of lubrication oil is a common issue that can lead to the formation of sludge, varnish, and acidic by-products. FTIR spectroscopy is highly sensitive to chemical changes in the oil, allowing for the monitoring of oxidation and degradation processes. By tracking specific spectral bands related to oxidation products, such as carbonyl compounds in the region of 1800 cm-1 - 1670 cm-1, FTIR enables the assessment of the oil's resistance to oxidation and how much oxidation has already occurred. This information is crucial for predicting the remaining useful life of the lubricant and determining the optimal oil change intervals, thereby improving overall maintenance planning and cost-effectiveness.



Monitoring of phosphate antiwear additive depletion according to ASTM D7412: Over time, lubricants can undergo degradation due to factors such as temperature, oxidation, and contamination. Phosphate antiwear additives protect the oil and moving parts from degradation, but they are susceptible to depletion as a result of their chemical interactions within the lubricant. Monitoring their levels helps identify lubricant degradation and potential issues related to wear and friction.

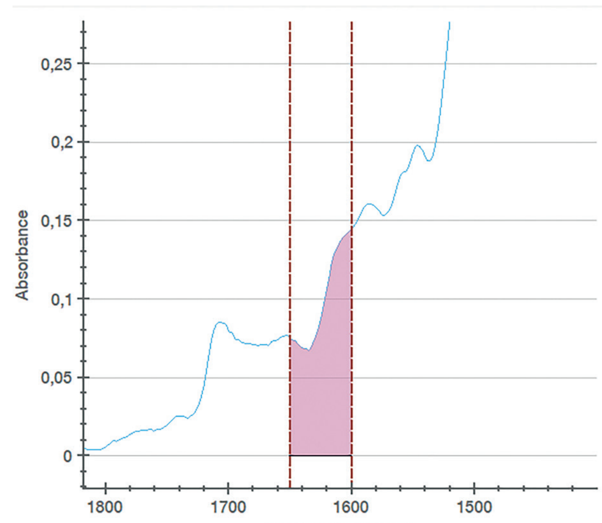


Monitoring of soot according to ASTM D7488: Soot is a by-product of incomplete combustion in diesel engines. Monitoring the level of soot in lubrication oil provides insights into the combustion efficiency of the engine. Elevated levels of soot may indicate problems with combustion, such as incomplete fuel burning or engine wear. Soot does not exhibit a characteristic peak but shifts the baseline of the FTIR spectrum upwards. Therefore, when analyzing the soot content of an in-service oil, the baseline shift at 2000 cm-1 in the FTIR spectrum is measured. This measurement value (Abs/cm) is often converted into soot as a percentage (%) in order to make the results more comparable.



Monitoring sulfate by-products according to ASTM D7415: Sulfate by-products in lubricating oils can result from the use of certain additives or can be formed during the combustion process in engines. Sulfuric acid, formed from the combustion of sulfur-containing fuels, can react with metal surfaces in the engine, leading to corrosion. Monitoring sulfate levels provides information about the quality and condition of the engine oil.

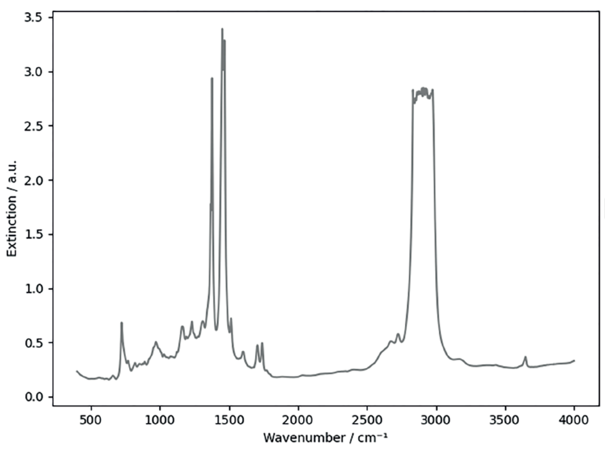
Sulfate by-products exhibit a peak at around 1160 cm-1; the peak area is calculated from 1180 cm-1 - 1120 cm-1 and is plotted over time to depict the increase of sulfate.



Monitoring nitration according to ASTM D7624: Nitration occurs when nitrogen oxides (NOx) produced during combustion react with the oil, leading to the formation of nitrocompounds. Nitration is often associated with oxidative stress on lubricating oils. High temperatures and the presence of NOx can initiate oxidative reactions, leading to the breakdown of oil molecules. Nitrate compounds exhibit a peak at 1630 cm-1 of which the peak height is measured to assess the current nitration level. Monitoring nitration is crucial for understanding the extent of oil degradation in internal combustion engines.

Further applications of FTIR spectroscopy in lubrication oil analysis

FTIR spectroscopy provides a comprehensive chemical analysis of lubrication oils, allowing for the identification of various molecular components. This includes the assessment of oxidation by-products, degradation products, and the overall chemical composition of the oil. The ability to analyze multiple aspects of the oil's chemistry in a single test provides a holistic understanding of its condition.



Peak analysis: Peak intensity analysis in FTIR spectroscopy involves measuring the height or area of specific peaks in the spectrum. Each peak corresponds to a molecular vibration, providing a chemical fingerprint of the sample. In engine lubrication oil analysis, peak intensity analysis makes it possible to quantify the concentration of various components, including contaminants and additives.

For instance, the presence of water in lubrication oil can be identified by analyzing the intensity of peaks associated with water molecules in the range of 3,550 cm-1 - 5,100 cm-1.

Moreover, peak intensity analysis facilitates the monitoring of additive concentrations. Lubrication oils often contain various additives to enhance their performance, and deviations from the expected concentrations can impact the oil's effectiveness. ASTM standard methods are only available for phosphate antiwear additives; however, many more types of additives are used in the formulation of lubrication oil. FTIR spectroscopy is able to evaluate levels for various additives simultaneously, ensuring that the lubricant maintains the desired formulation for optimal engine protection.

Identification of contaminants: FTIR spectroscopy allows for the identification of contaminants in lubrication oil, including water, fuel, and coolant. As an example, water contamination can lead to reduced lubricating properties and increased wear. With their high infrared signal intensities, the presence of water molecules can be easily detected via FTIR analysis, enabling timely corrective actions.

Verification or comparison to reference spectra: Verification in FTIR spectroscopy involves confirming the identity of the sample oil by comparing the obtained spectrum with spectral data of a reference sample. This spectral comparison excels at fast verification of samples by identifying these oils based on their unique spectral signatures. By establishing a reliable reference library, technicians can swiftly and confidently verify not only the oil itself but also components present in the oil sample.

Quantitative additive analysis using integration: Lubrication oils often contain additives designed to enhance their performance. FTIR spectroscopy facilitates the quantitative analysis of these additives, ensuring that the specified concentrations are maintained. Deviations from the expected additive levels can be indicative of formulation issues or the need for additive replenishment. Next to peak analysis, evaluation of spectral integrals is an established quantification method in FTIR spectroscopy.

Integration involves calculating the area under specific peaks. This quantitative analysis is instrumental in determining the exact concentration of components in the lubrication oil sample. In engine maintenance, knowing the precise levels of contaminants, oxidation by-products, and additives is essential for making informed decisions about oil change intervals and maintenance schedules.

Advantages of FTIR spectroscopy in lubrication oil condition monitoring

1. **Real-time analysis:** One of the most significant advantages of FTIR spectroscopy in quality control is its real-time monitoring capability. Traditional methods may be time-consuming and require skilled laboratory workers or the sending of samples to a laboratory and a wait for results, leading to delays in decision-making. FTIR, on the other hand, enables on-site, immediate analysis. This rapid feedback loop allows maintenance professionals to make timely decisions and implement corrective actions promptly. The ability to address issues as they arise contributes to improved equipment reliability, reduced downtime, and overall operational efficiency.
2. **Early detection of issues:** The sensitivity of FTIR spectroscopy allows for the early detection of potential issues. Whether it's water contamination, oxidation, or abnormal wear patterns, FTIR can identify subtle changes in the oil composition that may precede more significant problems. Early detection enables maintenance professionals to address issues proactively, preventing extensive damage and minimizing the need for costly repairs.
3. **Comprehensive molecular analysis:** FTIR spectroscopy provides a comprehensive molecular analysis of lubrication oil. It can detect a wide range of chemical compounds, including contaminants, oxidation by-products, and additive packages. This holistic approach to oil analysis enhances the ability to diagnose various issues affecting the oil and the machinery it lubricates.
4. **Cost-effectiveness:** In the long term, the return-of-investment compared to traditional oil analysis methods is evident. The ability to perform on-site, real-time analysis reduces the need for frequent laboratory testing and the associated costs. Additionally, early detection of potential issues can prevent costly equipment failures and unplanned downtime.
5. **Reduced environmental impact:** On-site FTIR analysis reduces the environmental impact associated with sample transportation and centralized laboratory testing. The ability to perform analysis directly at the site minimizes the need for shipping hazardous materials and decreases the carbon footprint associated with traditional sample analysis methods.
6. **Combination of ASTM-compliant measurements with individual chemical analysis:** With modern FTIR spectrometers, like Anton Paar's Lyza 7000, the user can measure their oil sample once and receive analysis according to ASTM methods as well as individual chemical analysis. Lyza 7000's Used Oil Package contains all relevant test methods according to ASTM, and is equipped with a broad range of analytical tools to configure additional analyses for used oil. Combining those analyses types in one method results in time-saving, efficient measurement of used oil samples.

How Lyza 7000 solves challenges

While FTIR spectroscopy offers numerous advantages for lubrication oil condition monitoring, there are some challenges and considerations that should be taken into account:

1. Sample preparation: Proper sample preparation is crucial for obtaining accurate and reliable FTIR spectra. Contaminated or improperly handled samples can introduce artifacts and affect the analysis results. Training and adherence to standardized sample preparation procedures are essential to ensure the quality of data.

By using ready-to-use methods in Lyza 7000's software conforming to ASTM, lubrication oil samples usually only need to be filled into the sample cell – no dilutions are necessary.

When employing a horizontal attenuated total reflectance (HATR) cell with Lyza 7000, no sample preparation is necessary, further reducing user errors.

2. Data interpretation expertise: Interpreting FTIR spectra requires expertise in both spectroscopy and lubrication oil chemistry. Training personnel to accurately interpret spectra and make informed decisions based on the results is crucial for the successful implementation of FTIR spectroscopy in condition-monitoring programs.

The Lyza 7000 Used Oil package contains ready-to-use methods, which conform with ASTM. Measurement, spectral analysis and interpretation are performed in one run and yield one report containing all analysis results. The instrument can be used by untrained users after initial setup.

Conclusion

In conclusion, FTIR spectroscopy has revolutionized the quality control of lubrication oils by providing a powerful and versatile analytical tool. Its ability to offer early detection of contaminants, comprehensive chemical analysis, monitoring of oxidative stability, quantitative additive analysis, real-time monitoring, cost-effectiveness, and support for advanced data analytics makes it an indispensable technology in various industries. Lyza 7000 combines analysis according to standard methods with individual chemical analysis, taking FTIR spectroscopy in oil condition monitoring one step further than any other spectrometer.

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