SPECTROGRAPHIC ANALYSIS OF LUBRICATING OIL

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Abstract – *Machine condition monitoring or predictive maintenance is the practice of assessing a machine's condition by yearly gathering data on key machine-health indicators to determine when to schedule maintenance. One of the keys to keep machinery operating at optimal performance involves monitoring and analyzing lubricant oils for characteristics such as contamination, chemical content, viscosity etc. Large amount of money is spent annually replacing machinery components that have worn out due to the inability of the lubricants to perform the required task. Knowing how to interpret changing lubricant properties can increase the life of critical equipment. The existence or amount of debris and particles from wearing parts, erosion and contamination provide insights about the issues affecting performance and reliability. Lubricant, fuel and other key fluid analyses provide critical early warning information indicative of machine failure. Analyzing and trending the data means you can schedule maintenance before a critical failure occurs. The result of which is higher equipment availability and productivity, lower maintenance cost, optimal equipment performance and a greener operation. Each application has distinct lubricant requirement necessitating a suitable product and system which must perform their intended function under varying operation and climatic conditions. Satisfactory and trouble-free performance largely depends upon the selection of suitable lubricant.*

*Key Words***:** Spectroscopy, contamination, infra-red.

1. INTRODUCTION TO SPECTROSCOPY

Yuegang Zhao explains in his book that Spectroscopy is a technique for detecting and quantifying the presence of elements in a material. Spectroscopy utilizes the fact that each element has a unique atomic structure. When subjected to the addition of energy, each element emits light of specific wavelengths or colors. Since no two elements have the same pattern of spectral lines, the elements can be differentiated. The intensity of the emitted light is proportional to the quantity of the element present in the sample allowing the concentration of that element to be determined. The light has a specific frequency or wavelength determined by the energy of the electron in transition. Since many transitions of different energy are possible for complicated atoms which have many electrons, light of many different wavelengths is emitted. If this light is dispersed by using a dispersing element such as a prism, a line spectrum will result. These spectral lines are unique to the atomic structure of only one element. For the hydrogen atom with atomic number 1, the spectrum is fairly simple as illustrated in Figure 1.
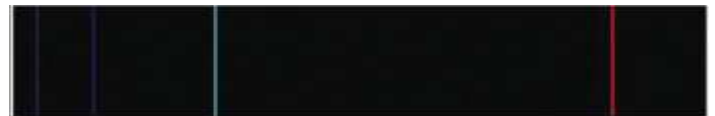

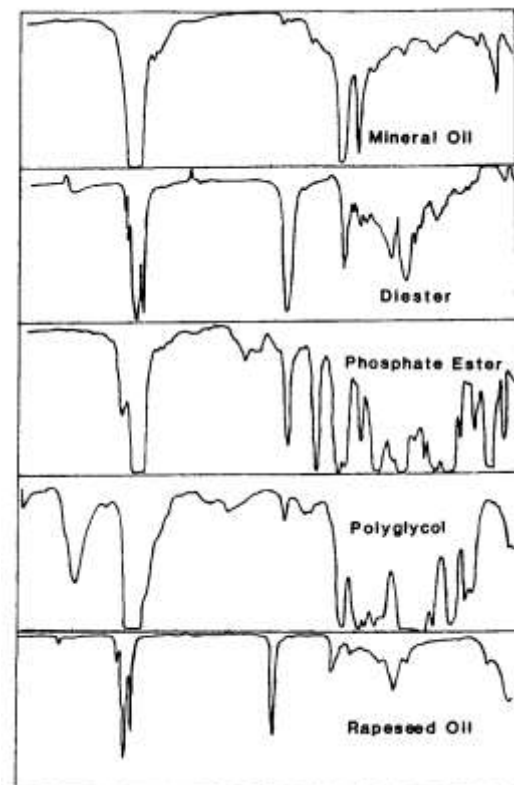**Fig -1**: Emission Spectrum of Hydrogen

Fig -2: Infra-red spectra of different base oil

More general information about the composition of the base oil is easily obtained by the technique called infra-red spectroscopy, and its more modem version FTIR (Fourier transform infra-red) spectroscopy. This is a cheap technique

requiring only a tiny sample, and will distinguish all the types of synthetic oil and the main composition types in mineral oils, but it requires specialist knowledge to carry it out. Some examples of infra-red spectra of different base oils are illustrated in Figure 2.

1.1 Monitoring oil degradation

Harish Hirani in his paper deals with online condition monitoring as an essential component of Predictive Maintenance which helps in determining the condition of in-line service equipment in order to predict when maintenance is required. Once a defect has been identified, the failure has already commenced, a planned cost effective maintenance strategy can be framed than allowing the machinery to fail. In other words the main aim of online condition monitoring is to detect the presence and the type of fault at an early stage of development and to monitor its evaluation, in order to choose an adequate plan of maintenance.

The infrared (IR) region of the spectrum lies to the right of the red end of the visible spectrum. We are unable to see this light although certain animals such as the pit viper can, enabling them to hunt at night. IR radiation was first described by William Herschel in 1800. He produced a solar spectrum by placing a glass prism in the path of the sun's rays and observed the changes, which took place when light of different wavelengths (different colors) fell onto the bulb of a sensitive thermometer. He noticed that the temperature increased as the thermometer was moved from blue to red, but he also found that the thermometer registered even beyond the red end of the visible spectrum. Subsequent experiments showed that this portion beyond the red was composed of a similar type of radiation to visible light, in that it could be reflected, refracted and absorbed by materials, which would reflect, refract and absorb visible light.
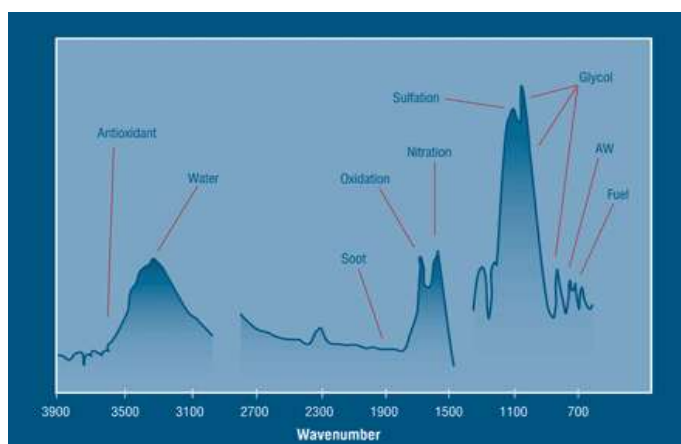

Fig - 3: FTIR Spectroscopy

1.2 Infra-red Working

N Robinson in his paper studied that all covalent chemical bonds such as those in organic molecules (CH_4 or methane) as opposed to ionic bonds, and those found in inorganic molecules (NaCl or common salt) absorb IR radiation, causing them to vibrate by stretching and contracting. The strength of the chemical bond between the atoms, which in turn is influenced by their atomic structure, determines which part of the IR spectrum the molecules absorb.

An analogous way of visualizing this phenomenon is demonstrated by Hooke's law of springs, where the amount of energy to start the spring oscillating is related to the strength of the spring and the mass on the end. In this case, it is the energy of the absorbed IR and the nature of the bond between the C and H atoms. The amount of energy in the IR beam is related to its wavelength; the smaller the wavelength the more energy. Although in this case only the exact energy required causing vibration is absorbed. All other energies both smaller and greater have no effect.

Therefore, for a molecule with several different kinds of bonds (for example, a C-H and a C=O), one would expect to see at least two different absorption bands. Chemical bonds within a molecule are therefore said to exhibit characteristic IR absorptions. It is this of waves in one centimeter. The final piece to the equation is how much of this radiation is absorbed. This is given by a simple law called the Beer-Lambert law that states the amount of IR absorbed is proportional to the concentration of the absorbing species and the distance the IR light has to travel through it.

2. FTIR SPECTROSCOPY

IR spectroscopy uses an electrically heated glow bar as the IR radiation source, and this radiation is passed through the sample to the detector. The chemical constituents of the sample absorb some of the IR light at reproducible and specific wave numbers.

The original method involved using a prism or diffraction grating to separate the individual wave numbers and then detect them, portions at a time, as they were passed through the sample, and plot the absorbance against the wave number. This process was incredibly slow and, depending on the accuracy required, could take as long as 10 minutes per sample.

Modern Fourier transform infrared (FTIR) uses the Michelson interferometer. This nifty device utilizes a moving mirror, whose speed is monitored by a laser, which also acts as a wavelength reference. The detector then measures the summation of all the frequencies over time resulting in a time-dependent interference pattern called an inter-Ferrogram. A computer algorithm called a fast Fourier

transform is then used to convert this signal to an absorbance spectrum. This is then radioed to a background spectrum of the empty cell to remove the contribution of atmospheric contaminants such as CO_2 and water vapor. This whole process takes as little as 1½ seconds per scan which allows for multiple scans on the same sample and for amplifying signal differences so that minute variations can be detected, giving greater accuracy.

Several years ago, Wear check purchased a new Glow bar FTIR. This represented two major changes in the methodology for determining oil degradation and combustion by-products.

- Spectral subtraction was replaced with computational interrogation of the IR spectrum and the resultant data trended.
- The horizontal attenuated total reflectance (HATR) cell was replaced with a 100-micron transmission cell.
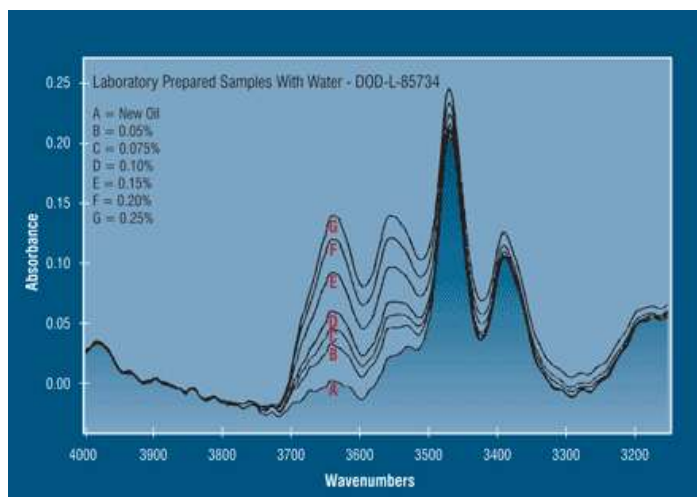

Fig - 4: Water contamination detection by FTIR

3. CONCLUSION

A well balanced oil analysis program can monitor machine wear condition, oil contamination and oil degradation at the same time. There are many different approaches to implement an oil analysis program, depending on the application and maintenance objectives. By analyzing this data we can schedule maintenance before a critical failure occurs which in turn will result in higher equipment availability and productivity, lower maintenance cost.

ACKNOWLEDGEMENT

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