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Spectrophotometric Oil Analysis: An Untapped Resource for Condition Monitoring

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Abstract
Gear oil is a fluid lubricant used in gears (gearboxes) for reduction of friction and wear of the gear tooth surfaces, removal of the heat generated by the operating gear and corrosion protection of the gear parts. Gear oil provide reliable, efficient (low friction), low maintenance operation of gears at different speeds, temperature, oil contaminations. The aim of this work is to investigate the effectiveness of the wear debris analysis of gear oil. Energy efficient oil is becoming popular
Lubrication monitoring is often underrated among the techniques that constitute condition monitoring. Chemical analysis which is usually based on spectrometric analysis to examine the elemental content of the lubricating oil has often provided good revelations about the health of the machine. In third world economies like Nigeria, where availability of expensive vibration monitoring and performance monitoring equipment constitute great hindrance to good maintenance planning and execution, exploitation of the available spectrometric analysis facilities in the higher institutions of learning, research institutions and industrial laboratories promises a lot of rewards as shown in the various cases reviewed.

Keywords
Lubrication Monitoring, Condition Monitoring, Health, Maintenance, Spectrometric Analysis

I. Introduction
Oil monitoring is a key component of successful condition monitoring programmes. It can be used as a predictive and proactive tool to identify the wear modes of rubbing parts and diagnose the faults in machinery. By analyzing the oil sample, the residual life of used gear oil is determined and a fault in the machine has to be prematurely shut down
James (1992) has defined condition monitoring as a maintenance philosophy that involves periodic measurement of the mechanical and process parameters that concerns a machine in order to gain a relative indication of the mechanical state of the machine. The biggest use of condition monitoring is in confirming that the equipment is in good health. A machine in good health refers to a machine with a good level of availability and reliability; this translates to good and continuous financial returns.
Condition monitoring in machineries usually centers on the following fundamental areas:
- Performance monitoring
- Vibration monitoring
- Lubrication monitoring
- Visual monitoring, and
- Non – destructive techniques

A. Lubrication Monitoring
The lubricating oil circulating round within an operating engine or machine is similar to the blood circulating within the living human body. Just as samples of the blood can be extracted and examined in a quest to identify the health state of the blood owner, samples of lubricating oil circulating round within a machine can also be indicative of the health of the machine. According to Hunt (1997), the advantage of monitoring a fluid (lubricant) is that the fluid is highly likely to carry the evidence of faults from a variety of positions within the machine to some point where a monitor can be fitted. Lubrication monitoring is a veritable tool for the establishment of the wear rate and level in the machine. The laboratory or chemical analysis of the lubricating oil that has been used in the machine is also useful in establishing the particular member undergoing wear; this is achieved through the monitoring of the concentration of elements in the used oil.

B. Lubricating Oil Contamination
Lubricating oil usually gets contaminated by carbonaceous particles from incomplete combustion of the fuel, unburned fuel, solid and dust particles, wear debris, free water molecules and other chemical substances that causes or inhibits oxidation.Oxidation of the lubricating oil may be indicated by an increase in its viscosity, although increase in viscosity is also caused by the presence of suspended oil-insolubles. Decrease in viscosity of the oil may indicate a situation of fuel dilution.Water within the oil can be responsible for the initiation of failure, and is usually difficult to detect quickly or remove. Once the water content in the oil has exceeded the saturation point of the oil, free water molecules starts to exist, this free water is responsible for most oxidation of components and the formation of emulsion that increase friction while altering the lubrication properties of the oil. In the course of lubrication monitoring, wear monitoring is also done indirectly. By monitoring the quantity, sizes and shapes of the wear particles or contaminants, it is possible to tell what component is deteriorating as well as, its rate or level of deterioration without dismantling the machine. The concentration levels of the metallic contaminants may vary widely depending on their origin, that is, whether they are major or minor alloying constituents of the wearing component, the type and operating characteristics of the component and machine, and the nature of present incipient defectsThe limit for the concentration level of a particular contaminant is not a thing that could be easily set based on just simple rational specifications. The decision to take a machine out of service as a consequence of a particular high concentration level must be based on the diagnosis of the source, the concentration trend and the relevance of the deterioration source to the overall reliability of the system. The following three methods are commonly used for contaminant analysis in the lubricating oil:
- Magnetic plug inspection
- Ferrographic oil analysis system (FOAS
- or Ferrograghy), and
- Spectrometric oil analysis procedure

While magnetic plug inspection and ferrographic oil analysis system are both effective, they are inferior to the spectrometric oil analysis procedure in that they are limited to detecting ferro-based wear elements alone.

II. Data Collection & Experimentations
For this study all the gear oil sample are collected from Perm Motors, Gwalior as shown in Table 1.The grade of gear oil which is used in the gear box is 75w90.

Table 1: Gear Oil Samples

S.No.	Sample Code	Reg. No.	Source	Total running
1.	A	Fresh for Maruti Alto	Gear Box (Maruti alto)	Fresh Oil
2.	B	MP03/ CA/0582	Gear Box (Maruti alto)	20720 Km.
3.	C	MP07/ OC/0780	Gear Box (Maruti alto)	20993 Km.
4.	D	MP02/ CO/0304	Gear Box (Maruti alto)	24575 Km.
5.	E	MP06/ CA/0582	Gear Box (Maruti alto)	41635 Km.
6.	F	MP07/ EA/2227	Gear Box (Maruti alto)	81506 Km.

A. Spectrometric Oil Analysis Procedure

Spectrometric analysis methods are based on the principles of atomic physics whereby an atom emits or absorbs light of a certain wavelength within the ultraviolet and visible region of the energy spectrum when there is an upset in the energy balance within its atomic structure.

Spectrometric oil analysis procedure based maintenance is implemented through the following steps:

- oil sampling
- Spectrometric analysis
- Diagnosis – data analysis, and
- Validation of the diagnosis

Spectrometric analysis method for oil samples is used to determine the quantity and level of the dissolved and atomized wear contaminants (especially metals) in the lubricating oil by these two broad methods:

- Emission spectrometry
- Atomic absorption spectrometry

It is a procedures for extracting fluid samples from operating systems and analyzing them spectroscopically to determines the concentration of key elements represented in the entrained fluid contaminant. Molecular spectroscopy uses principles of chemical physics to determine molecule concentrations. This has some distinct benefits for tracking additives. First, because molecular concentrations are being measured directly, additive decomposition, like the hydrolysis of ZDDP cited above, become immediately apparent. Secondly, many molecular spectroscopic may cover a multitude of analytical techniques, such as Fourier transform infrared (FTIR) and gas chromatography etc.Spectroscopy is the most widely applied technique for debris monitoring. It provides a quantitative, multi-elemental analysis of wear debris in lubricating oil. The elemental concentration of as many as 20 elements are reported in parts per million (ppm). Wear metals such as iron, aluminum, chromium, copper, tin, lead, silver, titanium and nickel are detectable, as well as lubricant additives such as calcium, barium, zinc, phosphorus, magnesium, boron and molybdenum. Certain contaminants such as silicon, sodium and potassium are also routinely detected.

Fig. 1 is a schematic diagram to illustrate emission spectrometry procedure. The system consist of a narrow slit, a grating or a prism (to separate the component wavelength as it passes through the slit), photoelectric system to detect and measure the spectra radiation, data processing electronic components and a print-out system. The prepared sample will have been "digested" before being subjected to a direct high voltage excitation of about 15kV to cause the metallic impurities in the oil samples to emit their characteristic radiation that can be spectrally analyzed.

The operation of the atomic absorption spectrometry which is shown schematically in fig. 2 is somewhat similar to that of the emission spectrometry. Their basic difference lies in the fact that instead of subjecting the sample to direct high-voltage as in emission spectrometry, oxy-acetylene flame is used to atomize the metallic elements in the atomic absorption spectrometry method. The wave-length of the light absorbed by the elements in the sample is detected and measured by the spectrometer.

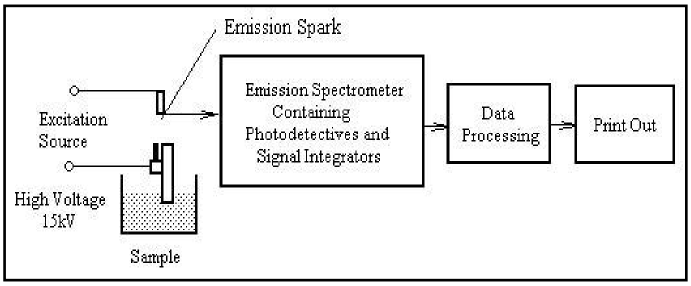

Fig. 1: Schematic Illustration of the Emission Spectrometric Analysis

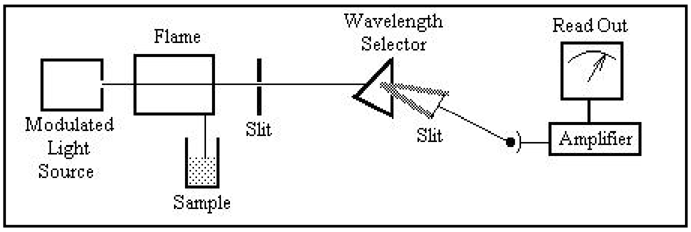

Fig. 2: Schematic Illustration of the Atomic Absorption Spectrometric Analysis

Spectrometric analyzers are surprisingly more available in Nigeria than we think, many chemistry and geology departmental laboratories in the Universities and Polytechnics has these machines as well as, various metallurgical, chemical and mineral exploration based research institutes located all around the country. Some private firms like Tractor and Equipment Nigerian limited has established Fluid Analysis Laboratory (Fluids Analysis Technology and Marketing, Port-Harcourt) where they carry out all their lubricating oil analysis for their various commercial maintenance operations and services.

Spectrometric analysis of the oil for elemental content is a way of determining the particular component of the machine that is degrading and at what rate. This is possible when the alloying compositions of the components are known, for example, Czarnecki et al. (1991) listed the alloy components of a particular aero-engine component as follows: Mo-5, V-2, Cr-4, Mn-0.01, Fe-83, Ni-0.01, W-6 and others 0.01. Hunt (1997) and Hipkin and Heimann (1978) has suggested the following element and related component sources shown in Tables 1 and 2 for wear debris monitoring

III. Materials

The materials, reagents and equipment needed for the spectrometric analysis are as follows: muffle furnace, volumetric flasks, measuring cylinders, burettes, porcelain crucibles, glass rods, filtering papers, conical flasks, p-toluene solution, sulphuric acid solution, nitric acid solution and spectrophotometric analyzer.

Table 2: Wear Debris Elements and Their Likely Sources and Implications

Elements	Implications and Sources
Fe, C, Cr, Mo, Mn, Ni	Ferrous wear and Steel
Cu, Sn, Zn, Al, Pb	Non ferrous wear
C, H, O	Base oil
Zn, Mo, S, CU	Additives

Table 3: Wear Debris Elements and Their Likely Sources

Elements	Sources
Aluminum	Pistons, Bearings
Boron	In-leak of coolant
Chromium	Rings
Copper	Bearings
Iron	Rolling elements bearings, cylinder, gears
Lead	Bearings, fuel additives
Magnesium	Transmission
Silicon	Airborne dust
Tin	Journal bearings

IV. Experimentations & Reasults

The following are the graphs based on the results obtained for the spectrometric oil analysis carried out on the fresh and used gear oil. Percentage differences of concentration of the various elements checked for were plotted against the elements.

Table 4: Standard Table

S. No.	Sample ID	Type	Concentration	WL631	Wgt. Factor
1	10	STANDARD	10	.014	1
2	20	STANDARD	20	.029	1
3	30	STANDARD	30	.042	1

A. Standard Curve

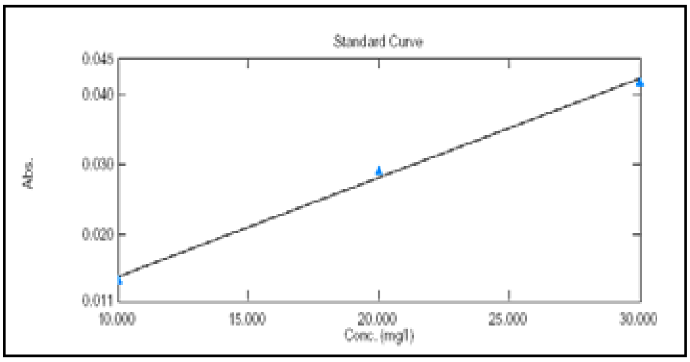

Fig. 3:

Table 5: SampleTable

S. No.	Sample code	Conc. p.p.m.	Wl631
1	A	0	0
2	B	80.568	.114
3	C	143.386	.203
4	D	161.443	.228
5	E	230.801	.326
6	F	574.772	.812

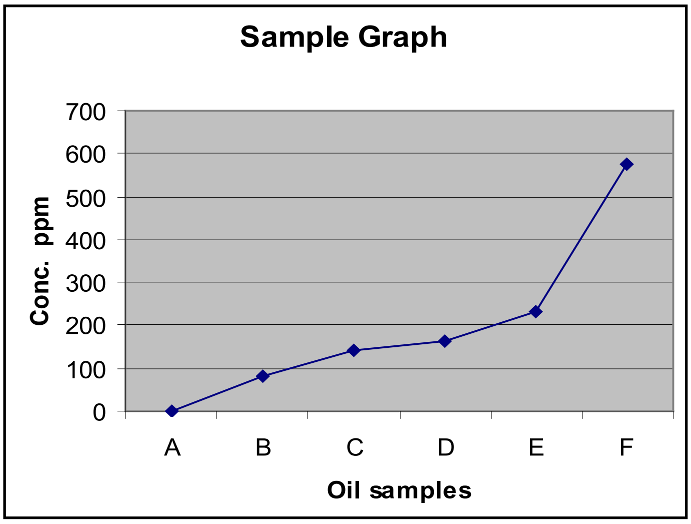

Fig. 4:

Results shows that % of carbon increases as the total running of Vehicles is increases

V. Acknowledgement

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