Condition Monitoring of Internal Combustion Engine Using Oil Analysis Program

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Abstract
Engine oil analysis is a process that involves a sample of engine oil, whether unused or used, and analyzing it for various properties and wear metal particle in order to monitor wear metals, TAN, TBN, Viscosity, Water Content and contamination. Engine oil sample have been analysed by Spectrometric oil analysis program and oil test center (kittiwake), determine the wear rate, and overall service condition of an engine, along with spotting potential problems and catastrophic failure before it happens. After experiment work have been done, results show information of petrol engine car has max wear of component as compare to diesel engine car. Both petrol and diesel engine car oil samples have been contaminated by water and acid at same level. Due to increased water and acid content present in oil, corrosion increased.

Keywords
Condition Monitoring, Wear Metal Particle, Oil Analysis, Engine Component Failure and SOAP

I. Introduction

Engine is the heart of automobile vehicles. Engine performances are directly dependent upon the health of its components like piston, cylinder, cylinder head, crankshaft, cam shaft, connecting rod etc. Metals in lubricating oil can come from various sources, such as wear, contamination and additives [1]. Wear metals result from friction or corrosion of the engine components; for example pistons, bushing, piston ring and bearings, during operation. Contamination can come from dirt, leaks or residual metal pieces. Additives used as detergents, anti-oxidants and anti-wear agents, are added in order to reduce engine wear. Wear of a specific component is heralded by an increase in the concentration of a particular metal, or the sudden appearance of a metal [2]. Since different engine components are composed of different alloys, the increase of a particular metal can be used to identify impending failure of a specific component. An analysis of trace metals in engine oil has permitted the identification of wearing components before severe failure, without dismantling of the engine. Spectrometric Oil Analysis Program (SOAP). The determination of Al, Cd, Cr, Cu, Fe, Mg, Ni, Pb, Sn and Zn using atomic absorption spectroscopy. The used engine oil samples were digested with HCL [3-4]. By knowing the amount of each elemental metal in the sample, able to narrow down and monitor wear patterns of specific components in an engine, such as bearings or valve stems. Not only can an analysis detect these elemental metals, also detect various types of contamination too. Insoluble matter (carbon, dirt, etc), fuel, or coolant can all be detected, and give the ability to spot any abnormalities before they become a costly or dangerous problem. This allows increasing an engine's service life, reducing repair bills, unscheduled down time, and potential catastrophic failures [5].

As lubricant degrades, contaminates such as water, fuel and coolant are accumulated into the lubricant. The source of water in the engine lubricant can be from a diffusion of vapor water from the atmosphere, water condensation promoted by cyclic variation of temperature, and aging of the lubricant [6]. Fuel contamination decreases the viscosity of lubricant, and this is typically leads to increased engine wear. Presence of fuel in the lubricant can be caused by leaking/defective injectors, excessive idling, incomplete combustion, worn liner/rings and poor fuel quality. Some detergents do not effectively neutralize all acidic species present in the lubricant, and thereby thus reserving their own base, which shows up as TBN, while in fact the oil may no longer not provide sufficient any protection against bearing corrosion. This hypothesis is supported with bench and engine test data. Total Acid Number (TAN) measurements be included in this analysis. Where time and cost allows, wear metals content, oxidation, soot content, and viscosity should also be evaluated [7].

II. Experimental work

In this research, two used engine oil samples collected by two different automobile vehicles, one is petrol engine car and other is diesel car. Same grade of fresh oil samples have collected of both used sample also and complete description of about fresh and used oil samples is given in Table 1.

Table 1: Description of Collected Samples

S. No.	Oil Sample Name	Sample Representation	Oil Condition	Used Life (in KM)
1.	Petrol car engine fresh oil	P-00	Fresh	00
2.	Petrol car engine used oil	P-2400	Used	2400
3.	Diesel car engine fresh oil	D-00	Fresh	00
4.	Diesel car engine used oil	D-8860	Used	8860

A spectrophotometer is a device to measure light intensity at different wavelengths. It produces light with a light source, and after the light passes through a subject, the light is diffracted into a spectrum which is detected by a sensor and interpreted into results we can use. The output of a spectrophotometer is usually a graph of light intensity versus wavelength. It is a maintenance tool which is used to check the condition of the oil lubricated mechanical systems (Examples: Motors, Engines, Gear boxes, Hydraulic systems). The systems can be kept under surveillance without dismantling them. Abnormally worn compounds can be localized and replaced before a catastrophic failure occurs. The quantity and type of wear metals in sample of lubricating oil is determined. The quantity can indicate something about the magnitude of the wear and the type of wear metals can reveal which component is wearing out.

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III. Experimental Procedures

A. Experimental Procedure and Apparatus: FAAS GBC Avanta

Samples were decomposed using the microwave digestion with concentrated nitric acid, 5 mlHNO_3 for 5 ml oil sample in microwave digestion. For the decomposition of samples super pure nitric acid was used. Digested samples were diluted by 40ml distilled water. The atomic absorption spectrometer GBC Avanta equipped with flame atomization and hydride generation system HG 3000 with electric heating accessory EHT-10 (GBC, Australia) was used for all measurements. The instrument was equipped with a deuterium lamp background correction system. Standard instrument parameters for the analysis were applied. Copper, magnesium, and zinc were determined by the flame atomization technique with an acetylene air flame. Selenium was determined using the hydride generation technique. The quartz absorption tube for hydride generation was heated to 950◦C. [8]

B. Experimental Apparatus: Oil Test Centre (Kittiwake)

Oil test centre by kittiwake was used to study the oil properties. The instrument consist of a console, heated viscometer, water present in oil test, insoluble test, TBN test, TAN Test, number of reagents. The components should be clean by acetone before using in test. All test were performed according to detailed procedure which given by kittiwake manual [10].

1. Viscosity Test

Select mode 2 on viscometer, with the help of arrow key select the temperature 40°, Temperature display flashes as viscometer heats the oil, degree symbol flashes until the oil temperature stabilizes. Tilt the viscometer when prompted, when oil temperature is stable the display will show viscosity at 40° [10].

2. Water in Oil Test

Select mode 4 on console, place the cell on a level surface remove the endcap, add Reagent A up to the internal lip(20ml), add 5 ml of the test oil using the syringe provided. Cut the reagent B sachet and add it to the cell, place the cell on the console and allow reading to stabilize, press zero button to zero the reading and start the test. Remove the cell from the console and shake it for 2 minutes until the display reaches l20. Then replace the cell on the console. The display will read directly percentage of water contamination in oil sample [10].

3. Insoluble Test

Select mode 2 on console, place the cell onto the console, take the insolubles tube and fill with Reagent J to the till line. Gently insert the insolubles tube into the test cell, shake the sample thoroughly. Remove a small volume of oil using a disposable pipette provided, return one drop of oil to the test tube. Place the cell on the console allow any bubble to settle, return the tube to the test cell. The display will read directly in percentage of insolubles contamination of the oil sample [10].

4. TBN Test

Select mode 3, add Reagent C to the TBN cell until the level reaches the internal lip inside the cell bowl. Add test oil: New Oil TBN 0-20 add 10 ml test oil. Remove the cell from the console and shake until the display reaches 120, replace the cell onto the console, the display will show reference value for the new oil repeat the above procedure using used oil. Press enter, the display will ask for the reference value again press enter the display will ask the new oil TBN, press enter to display the used oil TBN [10].

5. TAN Test

Select mode 5, add Reagent D on the TAN tube fill it upto the mark. Shake the sample thoroughly, remove 1 ml oil using syringe. Add to the TAN tube. Now carefully fill the 1 ml syringe with reagent E, add 1 drop to the TAN tube, shake and place the tube back in the TAN cell. Press return and enter the syringe reading of Reagent E, again press return and the display will show the TAN [10].

IV. Results & Discussion

Table 2: Results of Petrol Engine Car Oil Sample

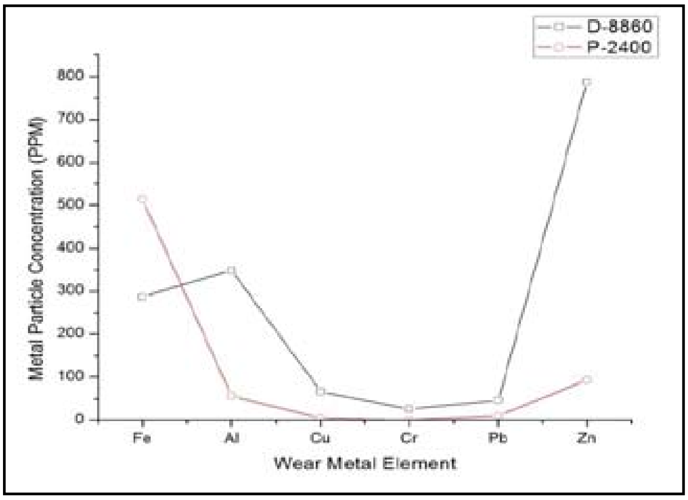
S. No.	Properties		P-00 (Fresh Oil) Specified Standard Value	P-2400 (Used – 2400 km)
1.	Appearance, Visual		Clear & Bright	Slightly Hazy
2.	Viscosity cSt @ 40˚C		148	108.6
3.	Viscosity cSt @ 100˚C		19.8	12.0
4.	TBN, mg KOH/g		11.0	1.1
5.	TAN			4.8
6.	Total Insoluble (present in oil)		0	0.3
7.	Water Content		0	0.25
8.	Wear metal analysis (ppm)		Nil	
	(1)	Iron (Fe)		513.3
	(2)	Aluminum (Al)		56.8
	(3)	Copper (Cu)		4.1
	(4)	Lead (Pb)		10
	(5)	Zinc (Zn)		93.2

Following table covers a sample of used crankcase oil taken from a high speed petrol fueled engine. Significant increases in viscosity and TAN indicate to be high oxidized and unsuitable for further service. Viscosity of lubrication oil of all the vehicles which was used for the investigation, are listed below in the following table in this test viscosity of the oil are determined at 100° C. It is clear with the help of above viscosity test that as vehicle life increases (in term of running kilometer) the viscosity of the engine-oil decreases, which recommend changing out oil. Results represent value of Total insoluble and Water content was low in sample, which gives information about less contamination and fuel dilution. It shows good condition of lubricating oil and it can use for further service. Wear metal element concentration identified by SOAP analysis, Concentration of Aluminum and Iron particles has increased with vehicle runs. So that the parts of engine which was made from aluminum and iron, wear rate increased with vehicle run.

Table 3: Results of Diesel Engine Car Oil Sample

S. No.	Properties	D-00 (Fresh Oil) Specified Standard Value	D-8860 (Used – 8860 km)
1.	Appearance, Visual	Clear & Bright	Hazy
2.	Viscosity cSt @ 40˚C	111	88.6
3.	Viscosity cSt @ 100˚C	15.2	10.4
4.	TBN, mg KOH/g	10.7	7.1
5.	TAN	00	4.9
6.	Total Insoluble (present in oil)	00	2.5
7.	Water Content	00	1.10
8.	Wear metal analysis (ppm)	Nil	
	(1) Iron (Fe)		287.0
	(2) Aluminum (Al)		348.4
	(3) Copper (Cu)		67.1
	(4) Chromium (Cr)		26.3
	(5) Lead (Pb)		46.0
	(6) Zinc (Zn)		787.2

Table 3 covers an example of used crankcase oil taken from a high speed diesel powered engine. High viscosity and TAN shows to be high oxidized and unacceptable for further service. Viscosity of lubricating oil of every last one of vehicles which was used for the examination, are recorded in the following table in this test viscosity of the oil are determined at 100° C. It is clear with the assistance of above viscosity test that as vehicle life increments (in term of running kilometer) the viscosity engine oil decreases, which recommend changing out oil. Wear metal component element concentration by SOAP analysis, Concentration of Aluminum, Zinc and Iron particles has increase with vehicle runs. So that the parts of engine which was made from aluminum and iron, wear rate increased with vehicle run.



Graph 1: Graph Between Wear Metal Element and Wear Particle Concentration in Both Oil Samples

V. Conclusion

Finally concluded that, test result of Petrol engine car oil sample (P-2400) shows lubricating oil has less contaminated and has low concentration of metal wear particle. It shows petrol car engine has good health condition and very less chances of prior failure of component while other hand Diesel engine car oil sample D-8860 has more contaminated and acid formed. Viscosity of oil also decreases significantly. Acid in oil, it has possibilities of corrosion of engine component and negative effect on part. Due to this, aluminum and iron component of engine has max wear out. Wear metal analysis shows that expected prior failure component in Diesel engine will neoprene seal, oil pump bushing, and piston rings. Oil sample has max concentration of zinc debris which shows max wear of neoprene seal or coolant leak. Finally concluded that petrol engine car health and condition is good, it has no chances of catastrophic failure as compare to diesel engine car. Diesel engine car will occur catastrophic failure before as compare to petrol engine car and diesel engine car health and condition is not good.

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