IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 11, November 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

Effect of Age and Operating Conditions on the Wearing of Internal Engine Parts

M. U. Dabai [a], A. A. Zuru [a], F. W. Abdulrahman [b], I. Sada [c], and U. Z. Faruq [a].

a. Department of Pure and Applied Chemistry, Usmanu Danfodiyo University, Sokoto, Nigeria.

b. Chemistry Department, University of Abuja, Nigeria

c. Chemistry Department Umaru Musa Yar Adu'a University, Katsina, Nigeria.

ABSTRACT
Used (SAE 20W 50) oil samples of different age bracket, were collected by the Drain Stream method. Wear and additive metals were determined by Atomic Absorption Spectroscopy (AAS). The wear metals analyzed were Fe, Cr, Cu, Pb, Ni, Co, Cd, Ti and V while the additive metals included Ca, Mg and Zn. The results showed that concentration of wear metals increase with increase in the age of the vehicle and that of the additive metals decrease with increase in the age of the vehicle. This analysis indicates that used oil analysis can give an insight as to the part of the engine that is faulty, which needs to be replaced and can therefore serve as means of engine maintenance.
Keywords: Lubricating Oil, Contamination, Wear and Additive Metals.
Corresponding address: mudabai2002@yahoo.com (+2348062618989)

INTRODUCTION

Lubricating oil is a substance used in an internal combustion engine to create a separating film between surface of adjacent moving parts so as to reduce friction, wear and tear between parts of a machine (engine) thus protecting the engine in use [1]**.** In general, lubricants (engine oil inclusive) are substances introduced between moving parts of an engine in order to modify the friction characteristics, and to reduce damage and wear at the solid surfaces in relative motion. The process of introducing lubricants for the said purpose is known as lubrication [2].

Lubricating oils are useful derivatives of crude oil or petroleum through fractional distillation. Denser petroleum products are the major lubricant in the engine [3] and are mainly composed of hydrocarbon based oil and several additives; chemical compounds added to the refined base oils to impart some specific properties to the lubricating oil either by enhancing inherent properties or adding new desired ones to the finished product [4]. Each of these additives is meant to perform one or more functions, which may or may not relate to friction or wear [5]. Typical engine oil is, therefore, a mixture of base material and additives.

Although the primary function of lubricants is lubricating the various part of an engine so as to reduce friction; it also serves to keep engine parts clean; prevents deposition of carbon, soot and lacquer; prevent corrosion; serves as coolant and acts as seal preventing leakages between engine parts [6].

Different parts of the engine are composed of different alloys depending on the required properties For example, nickel is known to improved ductility and toughness of steel; while chromium and molybdenum increase hardness of materials [6].

Oil analysis tells a lot about how equipment was used and what condition it was in; oil that has been inside any moving mechanical apparatus for some time reflects the exact condition of that assembly [7].

Wear metals are typically present in oils as metallic particles rather than dissolved in the oil. The particle size and concentration of individual wear metal in oil differ from one metal to another and also depends on the engine type, age of the oil and the efficiency of the oil filter [8]. These wear metals are formed in the lube oils under harsh conditions of temperature and pressure that occur in heavy machinery. Under continuous heat and pressure, the surface of the metal piece becomes slightly oxidized; forms salt with the degradation product of the oil and become soluble in the oil, thus making the oil a working history of the machine.

In addition to the wear metals, high concentrations of various other compounds regarded as "contaminants" will be expected in the used oil. These contaminants include silica (dust), coolant, water, sludge, varnishes and carbon soot [9], and can come from dirt, leaks or residual metal pieces, while additives used as detergents, anti-oxidants, and anti-wear agents, are added in order to reduce engine wear [8].

Apart from wearing of the parts of an engine, faulty systems can also be indicated by the used lubricating oil analysis, for instance, the presence of coolant (typically ethylene glycol) in the oil indicates a leaking (faulty) coolant system [10]. Thus, the composition of the used lubricating oil would be expected to vary from that of the fresh/ unused oil.

This oil, if properly sampled, can be subjected to "analysis" to determine the quantity of wear metals contained therein, from which the extent of wear of the engine parts can be inferred [11] and can also be used to adequately identify and predict component failure, based on the composition of the metal and the speed at which they accumulate over time [12].

The aim of this paper to study how the age of the vehicle and the operating Conditions affect the wearing of the internal engine parts

MATERIALS AND METHODS

Materials

The materials used for this experiment were fresh and used QUARTZ 5000 (SAE 20W 50, a multigrade) lubricating oil from Honda automobiles of different age bracket.

Oil Sampling Procedure

The used oil samples, QUARTZ 5000 (SAE20W 50) from automobiles of different age brackets were collected from the "Total Filling Station" along Ahmadu Bello Way, within Sokoto Metropolis, north-western Nigeria using the Drain Stream Method, that is, by drawing the oil from underneath the engine compartment called the sump within 30 minutes after the engine had been shut down [13].

The procedure was conducted on vehicles that came for oil turnout and routine servicing but travelled 3000 – 4000 km. Sampling involved letting some of the oil drain and then catching a sample in an appropriate container at the operating temperatures of the oil.. The initial and the final streams were not used because they were not a representative sample [7]. Each sample container was then labelled and properly sealed to prevent any contamination during transit Fresh oil sample was also purchased from the same filling station:

Ashing

The sample (110g) was weighed into empty crucible and heated in a furnace at 650^{0}C for two (2) hours to burn off the hydrocarbon content and obtain an inorganic residue (ash) [15]. The ashes obtained were ground using a wooden pestle and mortar into fine powder, sieved through 250-mesh sieve and dissolved in an acid mixture [HCl:HNO_3 (3:1)] to obtain the sample solution[16].

Sample Analysis

Atomic Absorption Spectrometry was used to determine the concentrations of wear and additive metals in the used and fresh lubricating oil samples. The metal concentrations were determined using Shimadzu AA – 6300 Model by using specific cathodes for specific metals [16].

All assays were carried out in triplicates and the mean and standard deviation of all the values were determined.

Results

The results of the wear and additive metals in used Quartz 5000 (SAE 20W 50) lubricating Oil from Honda of different age bracket are outlined in Table 1 below:

Table 1: Results of Atomic Absorption Spectroscopic Analysis of Wear and Additive Metals in Used and Fresh Quartz 5000 Lubricating Oil (ppm):

Metals	Y'80-85	Y'86-90	Y'91-95	Y'96-00	Fresh Lube
Fe	344.05±21.36	252.21±28.20	221.42±45.56	202.22±22.12	0.53±0.20
Cr	42.19±2.54	41.04±2.68	31.02±3.61	36.04±2.22	0.01±0.00
Cu	30.37±2.70	26.85±2.31	21.04±1.99	23.54±2.00	0.08±0.00
Pb	73.33±9.14	50.36±8.52	48.34±7.36	63.57±8.44	1.58±-0.83

Ni	0.30±0.05	0.60±0.06	0.77±0.0.08	0.52±0.0.05	0.22±.0,04
Mn	4.28±.0.22	4.25±0.21	3.99±0.20	3.44±0.18	0.08±0.04
Cd	0.40±0.03	0.35±0.02	0.26±0.02	0.23±0.02	0.03±0.01
Co	0.40±0.24	0.38±0.21	0.35±0.20	0.35±0.22	0.01±0.00
Ca	130.37±24.34	126.85±13.85	121.14±23.05	123.54±23.91	1262.41±36.63
Zn	684.21±34.12	762.41±36.63	630.02±38.42	846.78±37.82	1457.12±32.72
Mg	251.68±18.55	223.16±15.02	210.24±16.14	123.82±15.33	1325.12±30.12
Cd	0.40±0.03	0.35±0.02	0.26±0.02	0.23±0.02	0.03±0.01

Key: Y = Year of Manufacture of the engine.
Data are mean ± The Standard Deviation of three replicate results:

Discussion

The quantitative analysis of the used Quartz 5000 (SAE 2OW 50) lubricating oil samples from automobiles of different age brackets were carried out using AAS. The results of the analyses are outlined in Table 1 above.

Wear Metals

Wear means the loss of solid material due to the effect of friction of contacting surfaces [17]. The deterioration of these surfaces in an engine is generally due to relative motion between two surfaces [18]. The wear metals analyzed include the following:

Iron

Iron is the main component of steel and depending on other metals or elements can vary over a very wide range from quite soft and malleable to very hard materials. When reading the iron result, it is very important to consider other metals such as: chromium, nickel, etc because they have a very significant effect on the type of steel that is wearing[19]. The results of the analysis of iron are all greater than the 76ppm reported by Hamad *et al*l [20] and also greater than the range of 100-200ppm reported by Fitch [10]. High levels of iron in used lubricating oils, are usually from the wearing of liners, camshafts, crankshaft, valve train, etc [21,22, 23]. The concentration of iron in the used lubricating oils is usually expected to be high since iron constitutes the principal element in most mechanical systems in a lubricant [24] and increase with increase with the age of the engine. The result of the fresh oil was, however, 0.50±0.20ppm.

Chromium

Chromium is one of the metals used to make steel harder. High levels of chromium, are normally associated with piston and rings wearing [18] or dirt coming through the air intake or broken rings [24]. The analysis of used oil samples showed that the concentrations of chromium increased with increase in the age of the vehicle, with values all within the acceptable range of 10-50ppm [10]. However, the values obtained for chromium in this research are substantially higher than the 21.00ppm reported in the work of Raymond *et al* [25] and 24.00ppm reported by Cotton *et al* [26]. The high levels of chromium obtained in this work could be as result the load on the engine, or the length of the time the oil has been in use [27].

Copper

Copper is the principal metallurgical component of brass and bronze, commonly found in bushings and turbo bearings while crankshaft and camshaft bearings may also have a layer of bronze residing just below a lead/tin bearing overlay [28]. The principal sources of copper in the used lubricating oil are from bearings or bushings and valve guides [24] and some copper containing antioxidant, such as copper naphthenates, oleates and polyisobutylene succinic anhydrides [29]. The levels of copper in this research were all relatively low compared to the expected values of between 30-50ppm per used oil samples [11] and 56.00ppm reported by Cotton *et al* [26], but higher than the 17.00ppm reported by Raymond *et al* [25], while the concentration of copper in the fresh oil sample was 0.08±0.00ppm. The values of copper in this research could be as a result of the wearing of the bearings or bushing and valve guide but the results are not considered as critical [11].

Lead

High concentrations of lead in used lubricating oils are usually from the anti-wear and extreme pressure (EP) additives, i.e., in addition to the wearing of the bearing and bushings [18, 24]. Concentrations of lead in used oils are greater than the range of 10-100ppm; they are considered critical [25]. The concentrations of lead in the samples analyzed were all within the acceptable 10 -100ppm range [11] and 10-160ppm proposed by the ASTM D5185 – 09 [30] for used oil, while a very low concentration (1.58±0.83ppm) was obtained for the fresh oil sample. The results in this work are therefore, not indicative of excessive wear of such engine components as bearing and bushings which are responsible for lead and are, therefore; considered acceptable [25]. However, there is increase in the concentration of lead with increase in the age of the vehicle. High concentration of lead in the1996-2000 vehicle could be due to additional load on the engine [27].

Nickel

Nickel is a metal usually found in stainless steels and in certain types of bearings, valve and valve guides [19]. The result of the analysis of nickel in the used oil samples showed marginally low concentrations of less than 1.00ppm, which are all in agreement with the results reported by the ASTM D185-09 [30] and are therefore acceptable. These results show decrease in the concentrations of nickel with increase in the age of the vehicle. High concentration of nickel in the newer vehicle could be due to additional load on the engine [27]. However, a very low value (0.22±0.04ppm) was obtained in the fresh oil sample.

Manganese

The sources of manganese in used lube oil could be from gasoline additive, i. e., methylcyclopentadienyl manganese tricarbonyl (MCMT), an organic manganese compound designed to boost octane levels in gasoline and can also be used as a sacrificial coating to aid the wear in new equipment [29].The results obtained for manganese in this research are higher than the 1.00ppm reported in the work of Hamad *et al* [21]. This amounts show increase in the concentrations of manganese with increase in age of the engine.

Cobalt

Cobalt in wear debris usually originates from wear of bearings [31]. Although cobalt was not mentioned in the wear metals its presence was detected in all the used oil samples analyzed. Generally, marginally low values were obtained for cobalt and the concentrations of cobalt in all the oil samples were less than 1ppm and increased with increase in the age of the vehicle while the fresh oil sample had a concentration of 0.01±0.00ppm Co.

Additive Metals

Additives are organic or inorganic compounds of metals dissolved or suspended as solids in oil, typically range between 0.1 to 30% of the oil volume, depending on the machine [32]. The additive metals analyzed in this work include the followings:

Calcium

Calcium is an additive metal normally from the lubricating oil additives, which include detergents, dispersants, and extreme - pressure additives usually in the form of calcium sulphonates, calcium phosphates and calcium phenates [33, 34]. The levels of calcium in today's gasoline engine oils can be in the range of 500 - 800 ppm [22]. The calcium content of the used oils samples in this research are lower than the 1357ppm reported by Hamad *et al* for used oils [20]. Low concentrations of calcium in the used oils could be as a result of the depletion of the lubricating oil additive package due to the emulsifying action of water moisture which might have found its way into the engine via leakages.

Zinc

Burke (2001) and Quesnel (2001) are of the opinion that high values of zinc in lubricating oils are usually from the lubricating oil additive package, e. g., detergent, extreme pressure additives [11, 22], and dispersants, used as anti-wear additives, oxidation and corrosion inhibitors [24]. One common anti-wear additive is zinc dialkyldithiophosphate (ZDDP), which reduces the risk of metal-to-metal contact, which can lead to increased heat, result in oxidation and negatively affect the film strength [32].The concentration of zinc in the used oil samples analysed neither increase/decrease with decrease in age, since the highest concentration (846.78±37.82ppm) was found in the newer (1996-2000-) model. However, these results are in agreement with the work of Hamad *et al* [21], who reported a concentration of 701ppm for zinc in used oils but are lower than the 2500ppm reported in the works of Cotton *et al* [27]. This result is therefore acceptable and does not indicate the depletion of the lubricating oil additive package, such as detergent, extreme pressure additives, and dispersants [22].

Magnesium

Magnesium is another additive metal usually from detergent additives and some aluminium alloys [24], are in the form of magnesium oxide added to the lubricating oils to neutralize acids in the oil [35]. The concentrations of magnesium in the used oil samples, apart from the 1996-00-model (123.82±15.33ppm) were slightly higher than the 150ppm for used oil [20] and are therefore acceptable. The high concentration (1457.32±15.72ppm) of magnesium obtained in the fresh oil is indicative that as a lubricating oil additive package, its concentration depletes as the engine is being used.

Conclusion

Generally, the concentrations of the wear metals in the used lubricating oils samples seemed to be increasing with the age of the engine, with the highest concentrations of the wear metals mostly observed in the in the 1980-1985-age bracket; the older the engine, the more susceptible are the engine parts to wearing.

The results obtained in this work were mostly in conformity with the reported results with very few exceptions. The metal distributions for used crankcase oil sample, therefore, is a function of total engine operating time, age or the mechanical condition of the engine.

REFERENCES

[1]. K. Shonake, Engine lubrication. Punch Newspaper, 2012, www.punching,com/columnist/automedics/enginel-lubrication (Retrieved 27/06/12).

[2]. E. A. Avallone and T. Baumeiste, Standard handbook for mechanical engineers", 9th edition, vol.6, McGraw –Hill Book Company, New York, U.S.A. , 1987: 197-206.

[3]. N. J. George,V. I. Obianwu, A. E. Akpan and I. B. Obot, Lubricating and cooling capacities of different SAE 20W-50 engine oil samples using specific heat capacity and cooling rate, 2010, 1(2), 103-111. www.scholarsresearchlibrary.com (Retrieved 24/03/14).

[4]. K. Bienkowski, Coolants and lubricants, The truth, Manufacturing engineering, 1993. http//www.answers.com/topic/lubricatingoil

[5]. P. A. Willermet, Some engine oil additives and their effect on antiwear film formation, *Tribology letters*, 5(1), Springer, Netherlands. 1998: 41-7.

[6]. M. Barnes, Fourier transform infrared spectroscopy (FTIR), *Practicing Oil Analysis Magazine*". Noria Corporation, 2002, http://www. praticingoilanalysis.com/ article_ detail.asp (retrieved 31/07/010).

[7]. R. D. Grisso and S. Melvin, Benefits of oil analysis, Penton Media Inc., 2013. http://grounds-mag.com/mag/grounds_maintenance_benefits_oil_analysis_2/

[8]. T. T. Nham, and R. M. Bombelka, Determination of metals in lubricating oil by ICP-OES © Agilent Technologies, Inc., USA, 2010, http://www.chem.agilent.com/Library/applications/ICPES-2.pdf

[9]. A. Geach, Infrared analysis as a tool for assessing degradation in used engine lubricants, WearCheck Canada Inc,1997, wearcheck.ca/literature/techdoc/WZA002.htm

[10]. J. C. Fitch, (2003): What is oil analysis, 2003, NORIA Corpration, 1328 E. 43rd Court, Tulsa, OK 74105i, Oklahoma, www.theoildropserver101.com/whatisoilanalysis.htm (Retrieved 10/08/08).

[11]. B. Quesnel, Take sample, 2001, www.http://wearcheck.com/info/manag_take_sampl.asp (Retrieved 05/08/07).

[12]. M. Almeida, High-throughput/high-performance wear metal analysis using ICP, Leeman Labs, 6 Wentworth, USA. 2000, http://www.teledyneleemanlabs.com/resources/published/icp/Hthp%20wear%20metal%20analysis%20by%20ICP.pdf

[13]. D.A. Pacey, Oil analysis, Co-operative extension, Manhattan, K. S. service, 1986, http//practicing oil nalysis.com/article/detailesp (Retrieved, 30/09/07).

[14]. W. R. Kneen, M.J.W. Rogers, and P. Simpsons, Chemistry: Facts, Patterns and Principles, Addison – Wesley Publisher, Philippines, 1972: 512-515.

[15]. I.M. Goncalves, M., Murillo, and A. M. Gonzalez, Determination of Metals in Used Lubricating oils by ASS using Emulsified Samples, 1998, vol 47(4), 1033-1044.

[16]. D.C. Gary, H, Henry, and E. James, Instrumental analysis, 1st edition, Allyn and Bacon Inc., London,1989, 73-75.

[17]. A. Verlinden, Used oil analysis at WearCheck, WearCheck Canada Inc 1997, http://www.wearcheck.com/literature/techdoc/WBE001.htm

[18]. J.A. Williams, Wear and wear particles - Some fundamentals, *Tribology International* 2005, 38(10), 863-870.

[19]. Metro Tech Systems Ltd, Sources of elements found in oil analysis, Bay 112, 5621 - 11th Street N.E. -Calgary, Alberta T2E 6Z7, Canada, 2009, http://www.metrotechsystems.ca/Tech05.htm (Retrieved 23/04/10).

[20]. A. Hamad, E. Al-Zubaidy, and M.E. Fayed, Assessment of used motor oil recycling opportunities in the United Arab Emirates**,** *J. King Saud Univ*., 2003, vol. 16, *Eng. Sci*. (2), 215-228.

[21]. J. A. Dolan, Motor Vehicle Technology, vol.1, Edward Arnold Limited, London, U.K., 1987, 314-321.

[22]. B. Burke, House boating and engine oil analysis, 2001, www.northwood-marine.com/engine%20oilanalysis.htm

[23]. D. Nicolai, Use of oil analysis as a tool to monitor engine health, 2003, www.noria.com/dictionary/default.asp

[24]. R. D. Grisso, Extension Engineering, Ag Machinery components of lubricating oils, 2nd edition, 1st Series, PYREX Publishing, London.1989, 491-499.

[25]. R.L.Raymond, J.O. Hudson and V.W. Hamison, Oil degradation in soil, *Applied and Environmental Microbiology,* 1975, *31*, 522-35.

[26]. E.O. Cotton, M.L. Whisman, S.W. Gowtzinger and J.W. Reynolds, Analysis of used motor oils. *Hydrocarbon Processing.*1977, 131-140.

[27]. J.S, Evans, Wear Limits Vs. Trends, Machinery Lubrication, Noria Corporation, 2009, http://www.machinerylubrication.com/Read/958/wear-limits-trends (Retrieved 05/06/10)

[28]. J.C Fitch, Copper and your diesel engine oils, oil analysis magazine, NORIA Corporation1328ECourt, Tulsa, Oklahoma, 2010, www.oildropserver10.com/whatisoilalanalysishtm (10/08/08).

[29]. J. Hansen, P. Skiba, and C.R. Hodgekins, Determination of iron in used lubricating oils by spectrochemical analysis, *Anal. Chem*., 1951, 23*(10), 195*: 1362–1365.

[30]. ASTM D5185 - 09 (1996): Standard test method for determination of additive elements, wear metals, and contaminants in used lubricating oils and determination of selected elements in base oils by inductively coupled plasma atomic emission spectrometry (ICP-AES), 100 Barr,Harbor Drive, West Conshohocken, PA, USA. http://www.astm.org

[31]. A.K. Aganwal, J. Bijwe and L.M. Das, Effect of biodiesel utilization of wear of vital parts in compression ignition engine, *J Eng. Gas TurbinesPower*, 2003, 125(2),, 604-610.

[32]. Oviedo, P. The Critical Role of Additives in Lubrication, 2012, Noria Corporation, http://www.machinerylubrication.com/Read/28980/additives-lubrication-role

[33]. R.A. Meyer, Enczclopedia of Physical Science and Technology, 2nd edition, vol. 17, Academic press California, 1992.

[34]. R.G. Larsen, Mc-Graw Hill Science and Technology, 8th edition, vol,10, , Mc-Graw Hill Book Company, New York, USA,1997 229-231.

[35**].** M. Martin, Everything You Ever Wanted to Know About Magnesium Oxide, Magnesia Specialties, LLC 8140 Corporate Drive, Suite 220, Baltimore, MD USA 21236, 2009,**.** http://www.magnesiaspecialties.com/students.htm (retrieved 06/07/09).