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Atomic Emission Spectroscopic Analysis of Wear Particles Suspended in Used Lubricating Oil

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Abstract

Heave earth moving machineries are used in open cat mines to excavate coal, ore, overburden materials etc. And for obvious reason these heavy machines are considered to be the back bone of the mining industries. In this case the unintended failure of these machines ultimately results in serious production loss. In order to prevent such types of failures, the industries generally opt for different predictive maintenance tools. Although there are many different methods are there but Atomic Emission Spectroscopic (AES) analysis is considered to be one of the important method among them. In this work the AES analysis of engine oil collected from a Caterpillar 777 100-ton haul truck will be done. The oil for the same has been collected at five different hours of operation of the engines and the particle count in ppm has been obtained as result.

Introduction

Since past few decades Atomic Emission Spectroscopic Analysis is considered to be one of the most useful condition monitoring tools. This method is considered to be one of the most cost efficient methods for predicting sudden failure of machines [1]. Among all other condition monitoring method, used lubricating oil analysis is the important one [2-4]. In this method the amount of different wear particle that are carried by the lubricating oil is counted. This wear particle also known as wear debris providesuseful information about the equipment. Wear debris analysis using AES technology enable us to predict the chances of failure as well the health condition of the oil. This method has already proved its importance in many industries due to its reliable as well as cost effective results [5-8]. In present scenario oil condition monitoring using AES technology has proved its superiority as compared to other predictive maintenance tool to to identify wear mechanism and wear modes present in a machine [9-13].

Condition monitoring of used lubricating oil provides us the parts per million (ppm) values of the metallic particle present in the lubricating oil. From this ppm value of different metallic particles the prediction of wear rate can be performed. For example, the abrupt change in the value of Nickel (Ni), Chromium (Cr) along with Iron (Fe) indicated the abnormal wear on bearing material. Change in Al indicates the wear on piston, only Fe indicated the corrosion is various parts and so on [14, 15].

Methodology

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Atomic emission spectroscopy (AES) is a chemical analysis method which makes use of the strength of light emitted from a flame, plasma, arc, or spark at a specific wavelength to determine the amount of a metallic particle in terms of ppm in a sample [16]. In this method the sample of used lubricating oil is subjected to a high amount of energy and thermal environment which will finally excite the atoms present in the suspended metallic particles. The source used for providing this energy can be an electrical arc, a flame, or more recently plasma.The emission spectrum of an element exposed to such a power source consists of a collection of the allowable emission wavelengths, normally called emission lines. Because of the discrete nature of the emitted wavelengths, this emission spectrum can be used as a unique function for qualitative identity of the element. Atomic emission using electrical arcs has been extensively used in qualitative analysis. Emission techniques can also be used to determine how many different types of metallic particle and in what quantity is present in a sample. For a "quantitative" analysis, the intensity of light emitted on the wavelength of the element to be determined is measured. The intensity of emission at this wavelength will be greater as the number of atoms of the analyzed element increases.

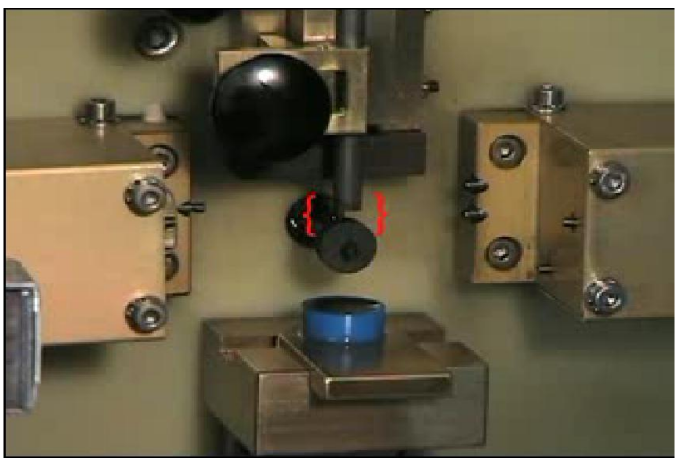

Figure 1: Atomic Emission Spectroscopy Setup

Figure 1 is showing the Atomic Emission Spectroscopy set up used in lubricating oil analysis. The gap in between the rod and the carbon electrode disc is subjected to high temperature electric arc. Due to this high temperature a small portion of the oil sample vaporize and form plasma. At this high temperature the metallic particle present in this plasma emits some specific wavelengths light which then received by the optical sensors. The responses from the optical sensor are further amplified to produce the result.

Source of the metal particle

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In order to interpret an oil analysis report accurately it is vitally important to know where the various elements come from. The table below is containing information about various metal and its sources.

Table 1: General element and contamination sources [17]

Metal	Found in
Iron Particles	"Cylinder liners, crankshafts, etc."
Chromium Particles	"Cylinder liners, rings, shafts, etc."
Nickel Particles	"Anti-friction bearings, gears, etc."
MolybdenumParticles	"Piston rings, synchro rings, etc."
VanadiumParticles	"Turbine blades, valves, etc."
ManganeseParticles	"Shafts, valves, etc."
TitaniumParticles	"Turbine components, springs etc."
AluminiumParticles	"Pistons, plain bearings, etc."
CopperParticles	"Plain bearings, bushes, etc."
TinParticles	"Plain bearings, piston flashing etc."
MagnesiumParticles	"Oil additives"
CalciumParticles	"Oil additives"
ZincParticles	"Oil additives"
Phosphorus Particles	"Oil additives"
SulphurParticles	"Oil additives"
BariumParticles	"Oil additives"
BoronParticles	"Oil additives"
Lithium Particles	"Greases"
Sodium Particles	"Internal coolant leak, oil additives, etc."
Silicon Particles	"Dirt entry, oil additives, etc."

Experimental Results

In this work the lubricating of a Caterpillar 777 100-ton haul truck has been collected at five different operating hours i.e. at 2606th hour, 2801th hour, 3092th hour, 3606th hour and 4157th hour. The operating hours mentioned in this article are the total run time of the engine till the collection of the lubricating oil and certainly do not indicate the total run time of the lubricating oil. The results obtained from the AES analysis are tabulated in table 2.

Hours	Fe	Cr	Pb	Cu	Sn	Al	Ni
2606	9.1	0	1.2	3	0	0.5	0.2
2801	7.5	0.2	0	2.7	0	0	0
3092	9.1	0.3	1.1	2.4	0	1.1	0
3606	22.9	4.4	0.3	4	0	0	2
4157	6.4	0.3	1.9	2.9	0	0	0
Hours	Ag	Si	B	Na	Mg	Ca	Ba

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2606	0	7.6	59.9	4.1	15.5	2909	0
2801	0	8	58.4	83.4	15.6	2899	0
3092	0	6.4	9.1	14	43.5	2965	0
3606	0	3.8	12.2	6.5	411	1793	0
4157	0	4.7	2.1	4.5	10.4	1736	0
Hours	P	Zn	Mo	Ti	V	Mn	Cd
2606	954	1269	1.4	0.6	0	0.6	0.9
2801	1148	1298	1.2	0	0.8	0	0.6
3092	1087	1313	1.1	0	0.7	0	0.8
3606	1091	1211	3	0	0.1	0	0
4157	1120	1151	70.4	0	0.5	0	0.8

Discussion

It has been seen from the Table 2 that the wear particle concentration at different hours are having many different and diversified value. So it is not possible to plot all the data in a same graph, otherwise many data will not be visible. In order to minimize this problem in Figure 2 the wear particle concentration data for Iron (Fe), Chromium (Cr), Lead (Pb), Copper (Cu), Aluminum (Al), Nickel (Ni), and Silicon (Si), have been plotted. The main reason behind selecting all these element in a single graph is their value is ranging in between 0 ppm to 25 ppm. For the same reason Figure 3 has been plotted against Boron (B), Sodium (Na), and Molybdenum (Mo). It can be observed from Table 2 that value of these elements are ranging up to 84ppm.

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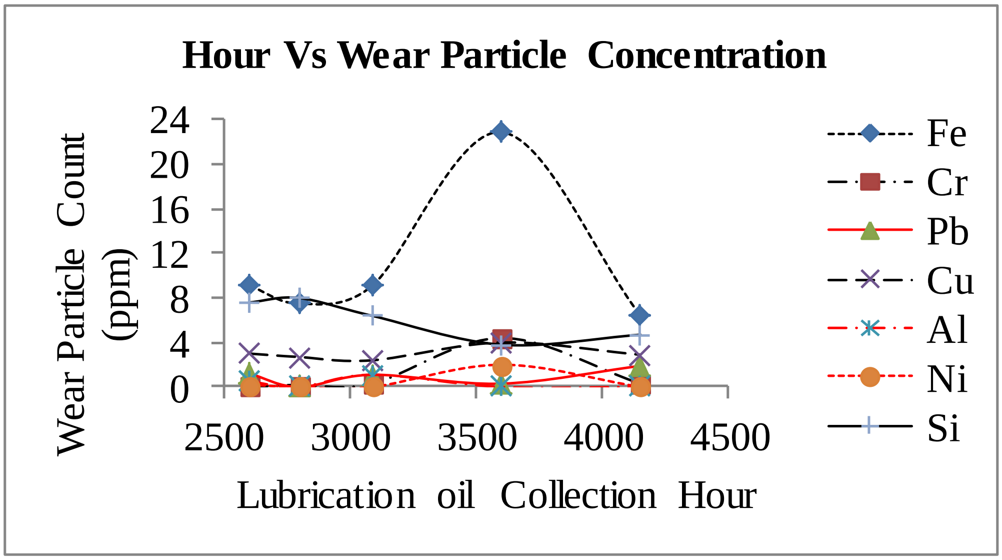

Figure 2: Wear Particle concentration of Fe, Cr, Pb, Cu, Al, Ni, Si.

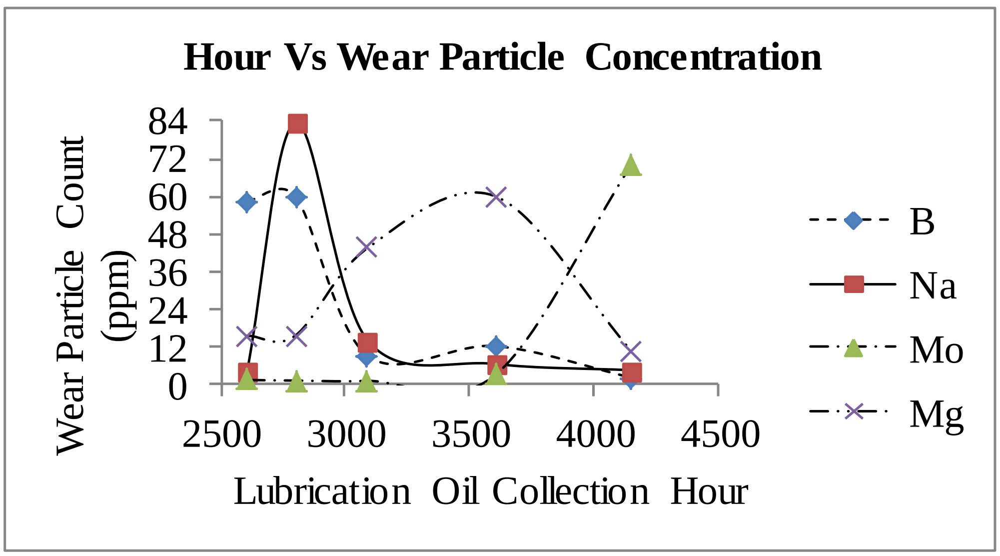

Figure 3: Wear Particle concentration of B, Na, Mo, Mg.

Figure 4 is consisting of the data of Titanium (Ti), Vanadium (V), Manganese (Mn), Cadmium (Cd) wear particle concentration. Although it has been seen from the graph that the value of the above material is very less which can be ignored, But Manganese is one the most important alloying element for steel as well as of many aluminum alloy. So it is important to monitor the ppm value of Manganese. Wear particle concentration data for Tin (Sn), Barium (Ba), and Silver (Ag) has not been plotted as there is no particle found in any of the hours. It has been seen that at the fourth sampling hours i.e. at 3606th hours the wear particle concentration of many element which include Fe, Cr, Cu, Ni, Mg is maximum and abnormal. From the table 1 it can be conclude that there must be some abnormal loading has been occurred in Engine block and the bearing

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associated with the engine. Some problem may also be arises from the additive of the lubricant also.

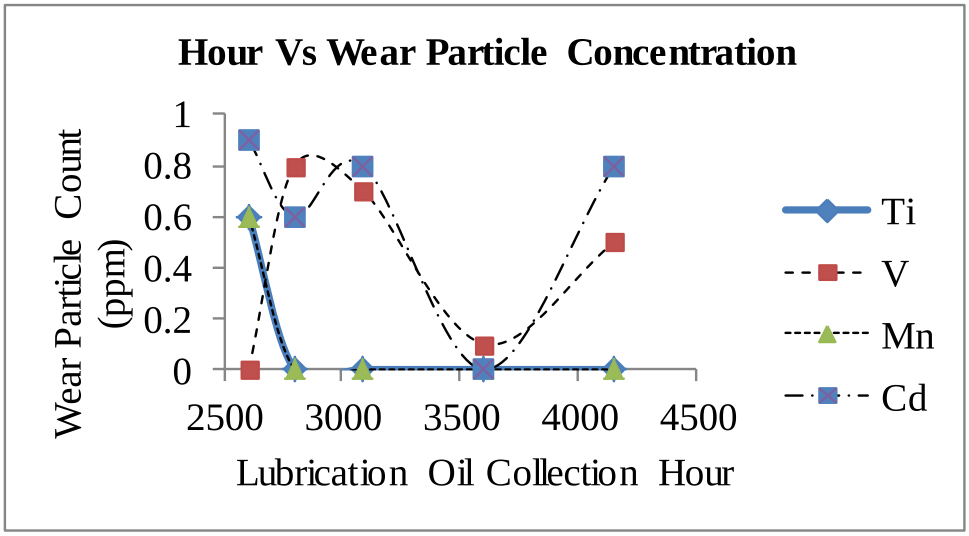

Figure 4: Wear Particle concentration of Ti, V, Mn, Cd

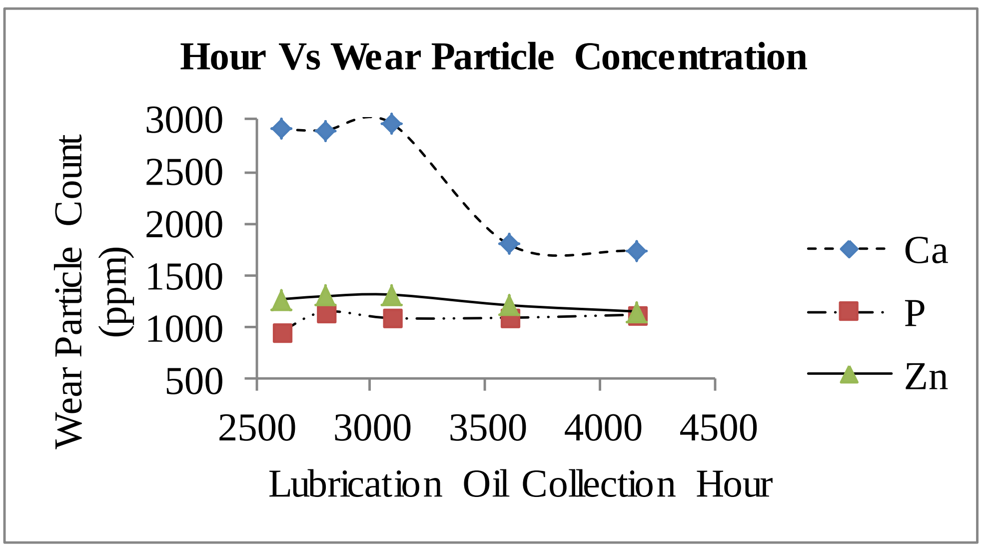

Figure 5: Wear Particle concentration of Ca, P, Zn

As per the Table 1 it can be conclude that the abnormal value of calcium (Ca), Phosphorus (P) and Zinc (Zn) are from the additives of lubricant. If the wear particle are forming out of the additives of lubricant that means the oil health has been completely degraded and the oil must be changed at no time. This values signifies that the whatever the used oil samples has been tested they have been collected at the end of their life.

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Conclusion

In this work Atomic Emission Spectroscopy has been performed for used lubricating oil analysis. The oil samples have been collected at five different hours from a Caterpillar 777 100-ton haul truckengine. The AES analysis has given the data in terms of parts per million (ppm). From the AES analysis has shown that there is a sudden abnormal change in Fe, Cr, Cu, Ni, Mg wear particle concentration at fourth sampling hours i.e. at 3606^{th} hours. The probable reason behind this has been figured out as the abnormal loading in engine block and the bearing associated with the engine. It has also been found that there is always an extremely high particle concentration of calcium (Ca), Phosphorus (P) and Zinc (Zn). This signifies that every time the lubricant has been collected after the end of the lubricant life.

Reference

1. Z. Peng, N.J. Kessissoglou, M. Cox, A study of the effect of contaminant particles in lubricants using wear debris and vibration condition monitoring techniques,Wear 258 (2005) 1651–1662.
2. B.J. Roylance, T.M. Hunt, Wear Debris Analysis, Coxmoor Publishing Company, Oxford, UK, 1999.
3. L.A. Toms, Machinery Oil Analysis: Methods, Automation and Benefits, second ed., Coastal, 1998.
4. T. Barron, Engineering Condition Monitoring, Addison Wesley Longman, 1996.
5. J. Mathew, J.S. Stecki, Comparison of vibration and direct reading ferrographic techniques in application to high-speed gears operating under steady and varying load conditions, J. Soc. Tribol. Lubr. Eng. 43 (1987) 646–653.
6. H. Maxwell, B. Johnson, Vibration and lube oil analysis in an integrated predictive maintenance program, in: Proceedings of the 21st Annual Meeting of the Vibration Institute, 1997, pp. 117–124.
7. D.D. Troyer, M. Williamson, Effective integration of vibration analysis and oil analysis, in: Proceedings of the International Conference on Condition Monitoring, University College of Swansea, Swansea, UK, March 21–25, 1999, pp. 411–420.
8. C.S. Byington, T.A. Merdes, J.D. Kozlowski, Fusion techniques for vibration and oil debris/quality in gearbox failure testing, in: Proceedings of the International Conference on Condition Monitoring, University College of Swansea, Swansea, UK, March 21–25, 1999, pp. 113–128.
9. T.M. Hunt, Condition Monitoring of Mechanical and Hydraulic Plant: a Concise Introduction and Guide, Chapman & Hall, 1996.
10. G.E. Newell, Oil analysis-cost effective machine condition monitoring technique, Ind. Lubr. Tribol. 51 (1999) 119–124.

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11. H.S. Ahn, E.S. Yoon, D.G. Sohn, O.K. Kwon, K.S. Shin, C.H. Nam, Practical contaminant analysis of lubricating oil in a steam turbinegenerator, Tribol. Int. 29 (1996) 161–168.
12. T.B. Kirk, Numerical characterisation of wear debris for machine condition monitoring, in: International Tribology Conference—AUSTRIB '94, Perth, Australia, December 5–8, 1994.
13. D.P. Anderson, Wear Particle Atlas (revised ed.). Report NAEC-92-163, 1982.
14. V. Sychra, I. Lang, G. Sebor, Analysis of petroleum and petroleum products by atomic absorption spectroscopy and related techniques, Prog. Anal. At. Spectrosc. 4 (1981) 341–426.
15. A.D. King, D.R. Hilligoss, G.F. Wallace, Comparison of results for determination of wear metals in used lubricating oils by flame atomic absorption spectrometry and inductively coupled plasma emission spectrometry, Atom. Spectrosc. 5 (1984) 189–191.
16. Fogel A G and Wright G J - Case Study: The Application of wear Debris Analysis for Monitoring Underground Continuous Coal Miners. Conf. Proc. of "Tribology 86"
17. John S. Evans, WHERE DOES ALL THAT METAL COME FROM, Technical Bulletin of Wear Check Africa, issue 47(2010), 1-6.