# Wear Particle Analysis of Engine Oil Used in Heavy Dumper Truck in Open Cast Mines

Mayukh Sarkar[a],

[a]School of Mechanical Engineering, Lovely Professional University, Punjab, India

**Abstract**

Heavy mining equipment like dumpers dozers shovels are considered to the back bone of the industries. Majority of the production is completely relying upon this heavy equipment. So for obvious reason the periodic maintenance is considered to be one of the most important concerns for the industries. In this work the Atomic Emission Spectroscopic (AES) analysis has been done for 15W40 Engine oil used in a Komatsu 785 100 Ton capacity dumper. From the analysis the wear particle suspended in the lubricant has been analyzed and counted in terms of ppm. From these wear particle analysis the part which is under abnormal wear condition has been figured out. For the test purpose used lubrication oil has been collect ted at seven different hours of operation and the results of all these seven different hours has been compared.

## Introduction

Wear particle analysis is a very useful method to analyze machines reliability [1]. Atomic Emission Spectroscopy has proved its capability as one of the most important predictive maintenance tool for wear particle analysis since past few decades as this process is do not need any complex sample preparation method [2]. This method has already been opted by many heavy equipment industries including mining and marine industries [3]. Oil condition monitoring are generally performed to understand three basic details of lubricant, they are the fluid property, fluid contamination and amount of suspended wear particle [4]. Atomic emission spectroscopy is used to analyze and count the suspended wear particles. Wear debris analysis for these heavy machines are very crucial as this can prevent the failure of the machines [5] otherwise failure of such machine is unavoidable [6].

Since many decades ago it was very well established facts that wear particles produced due to different wear mechanism [7]. Almost a century ago it was stated that the wear particles can specify the condition of friction of two mating surfaces [8]. Because of these properties of wear particle the analysis has gained interest among the researchers since mid of the previous century [9]. For all these reasons Atomic Emission Spectroscopy has been used in many industries for wear prediction as well as machine health forecasting [10-13]. It has also proved its superiority than any kind of predictive maintenance to identify wear mechanism and wear modes present in a machine [14-18].

## Source of Metal Particles

In AES analysis the amount and count of the metallic particle in ppm can be obtained. In order to produce proper forecasting of the engine and oil health condition it is very important to understand the source of particle.

Iron particles are found in the used oil when there is deterioration in cylinder liners, crankshaft, gears, anti-friction bearing etc. Chromium particles are responsible for ring, antifriction bearing, cylinder liners, coating degradation whereas molybdenum particle produced due to piston ring oil additive greases synchro rings etc. Nickel particles are generated due to the degradation of antifriction bearing, turbine components etc.

Manganese particles also produce due to abnormal loading in antifriction bearing, shaft, and valves. Vanadium particle are produce due to valve and fuel contaminant and Titanium particle form due to the degradation spring, and valve component. Aluminium wear particle are considered as the fatal one as they are formed due to piston, plain bearing, torque converter thrust washer failure. Higher amount of copper and tin is responsible for wear in plain bearing. Magnesium, calcium, zinc, phosphorus, sulphur, barium and boron found due to oil additive. If the amount of these metals is present in higher amount in oil then it considered that the lubricating oil has been degraded completely. Sodium and silicon are majorly responsible for see water and dart entry respectively [19].

## Experimental Analysis

In this work the engine oil of a Komatsu 785 100 Ton capacity dumper has been collected at seven different operating hours i.e. at 10501$^{th}$ hour, 10997$^{th}$ hours, 11492$^{th}$ hours, 11987$^{th}$ hours, 12494$^{th}$ hours, 13003$^{th}$ hours, and 13503$^{th}$ hours. 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 1

| Hours | Fe | Cr | Pb | Cu | Sn | Al | Ni |
|---|---|---|---|---|---|---|---|
| 10501 | 17.1 | 0.6 | 5.1 | 3.1 | 0 | 3.1 | 1.9 |
| 10997 | 24.9 | 1.1 | 8.9 | 156 | 0 | 1.7 | 0.1 |
| 11492 | 14.1 | 1.8 | 14.1 | 39 | 0 | 0 | 0 |
| 11987 | 11.9 | 1.4 | 6.1 | 5.5 | 0 | 1.5 | 0 |
| 12494 | 51.9 | 11.9 | 4.9 | 33.1 | 0 | 2.1 | 8.3 |
| 13003 | 11.8 | 1.2 | 7.1 | 72.7 | 0 | 0.9 | 0.1 |
| 13503 | 32.4 | 2.1 | 11.1 | 24.4 | 0 | 1.5 | 0.7 |
| | | | | | | | |
| Hours | Ag | Si | B | Na | Mg | Ca | Ba |
| 10501 | 0.1 | 5.9 | 2.4 | 3.9 | 6.7 | 2832 | 0 |
| 10997 | 0.1 | 3.7 | 10.6 | 4.9 | 10.1 | 3534 | 0 |
| 11492 | 0 | 4.4 | 0.7 | 80.1 | 36.3 | 3789 | 0 |
| 11987 | 0 | 3.1 | 0.9 | 6.9 | 5.8 | 2671 | 0 |
| 12494 | 0.1 | 5.9 | 19.9 | 4.9 | 9.1 | 2732 | 0 |
| 13003 | 0 | 2.9 | 1.1 | 71.9 | 0.6 | 1778 | 0 |
| 13503 | 0 | 8.1 | 0.1 | 74.9 | 1.8 | 1709 | 0 |
| | | | | | | | |
| Hours | P | Zn | Mo | Ti | V | Mn | Cd |
| 10501 | 1087 | 1389 | 0.8 | 0.5 | 0 | 1.2 | 0 |
| 10997 | 1218 | 1576 | 4.1 | 0 | 0.2 | 0 | 0 |
| 11492 | 1228 | 1667 | 5.9 | 0.1 | 0.8 | 0 | 0.6 |
| 11987 | 1078 | 1319 | 1.1 | 0 | 0.7 | 0 | 0 |
| 12494 | 1110 | 1354 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 |
| 13003 | 1031 | 967 | 0.1 | 0 | 0.1 | 0 | 0 |
| 13503 | 919 | 919 | 0 | 0 | 0.3 | 0.1 | 0 |

.

## Discussion

It has been seen from the Table 1 that the wear particle concentration at different hours are having many different and diversified value. It ranges between 0.7 ppm to 3789 ppm. So it is not possible to plot all the data in a same graph, otherwise many data will not be visible. for the proper understanding of the wear particle count, the data of Fe, Cu, Na, Mg has been plotted in Figure 1. Figure 2 has been for Cr, Pb, Si, and Figure 3 has been plotted against the wear particle count of Al, Ni, Mo and Mn. Figure 4 Consists of the data of Ca, P and Zn

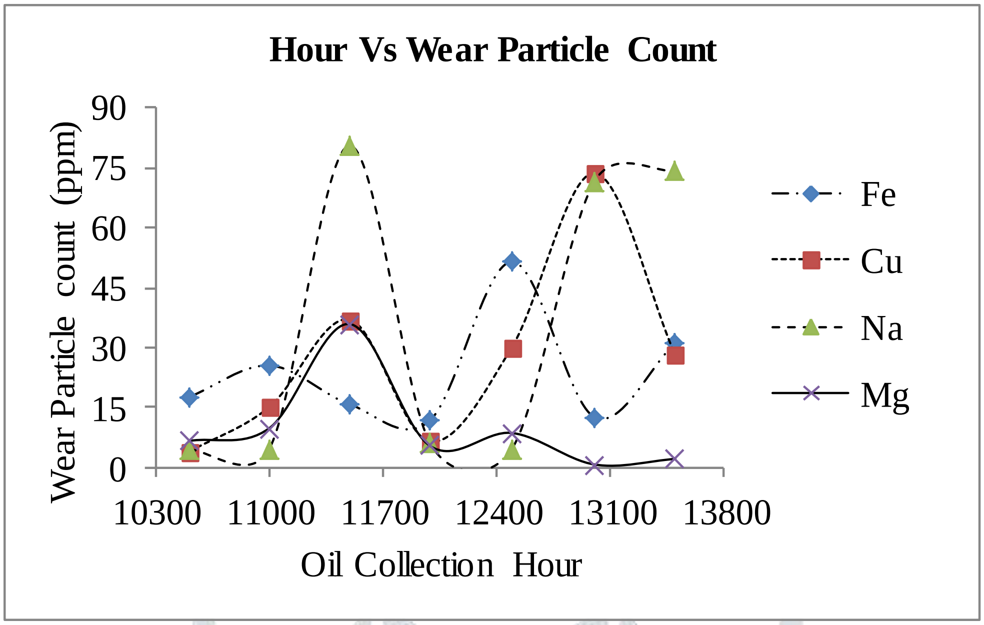


Figure 1: Wear Particle concentration of Fe, Cu, Na, Mg

From Figure 1 it has been observed that the wear particle count of copper and sodium has been increased abnormally at sixth sampling time. As the copper and sodium amount both has been increased together, we can assume that this may not a component failure but lubricant failure because both of them is conventionally use as oil additive. Simultaneously it can also be observed form Figure 4 that the quantity of Ca, P and Zn was also considerably high at the same sampling time then it can easily be predicted that the oil was degraded completely at the time of sixth sampling.

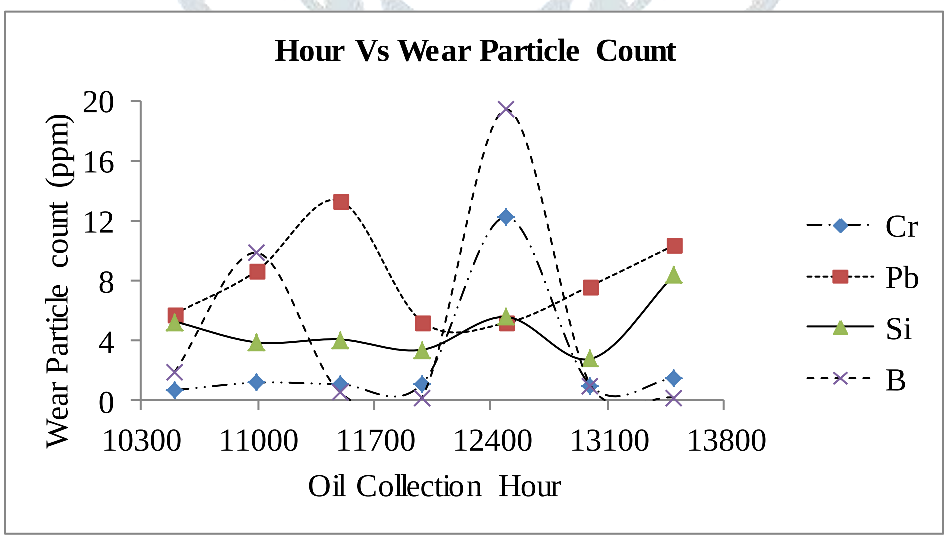


Figure 2: Wear Particle concentration of Cr, Pb, Si, B

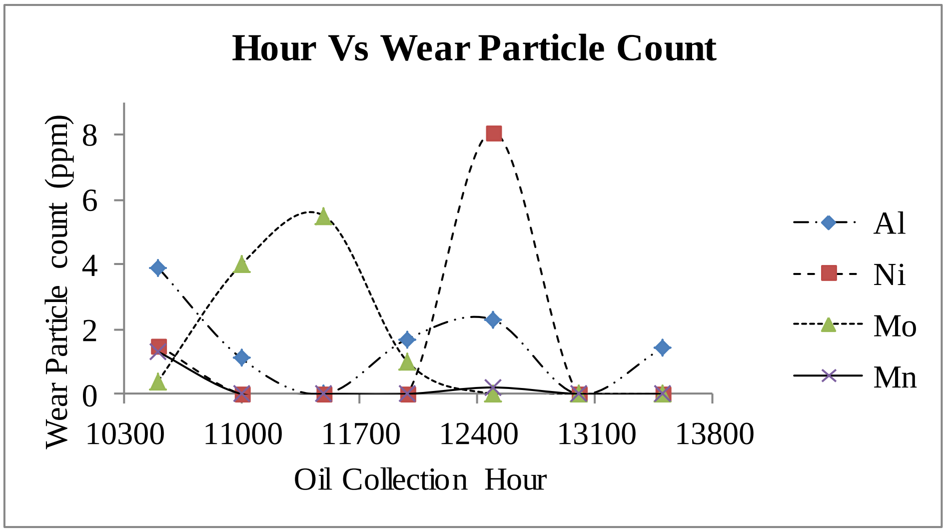


Figure 3: Wear Particle concentration of Al, Ni, Mo, Mn

From Figure 1 to Figure 3 it has been observed that at the fifth sampling time the amount of Ni, Cr and Fe particle has been increased abnormally. Aluminum particle count has also reached a considerable amount where the analysis for the same has also been required. At the same sampling time high concentration of boron particle has been found. From the above data it can be predicted that there was a failure in piston liner and bearing. High boron particle concentration on the other hand is an indication of internal coolant leak.

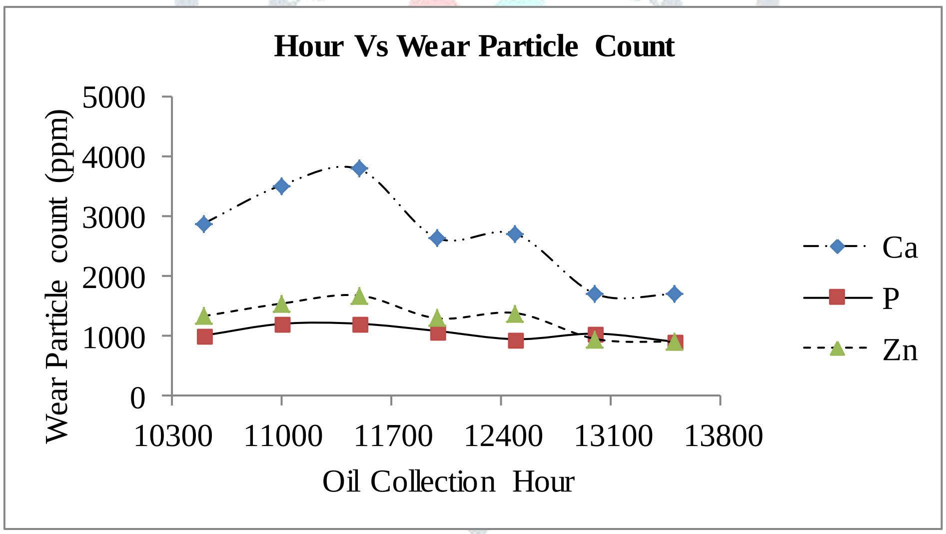


Figure 4: Wear Particle concentration of Ca, P, Zn

In every sampling hour it has been seen that the amount of Zn, Ca and P particle is always high. The higher amount of these particles is the indication of oil additives degradation. In this work all the oil samples has been collected at the end of their life. So, high concentration of these particles is expected.

## Conclusion

In this work used lubricating oil has been collected from a Komatsu 785 100 Ton capacity dumper engine. The oil has been collected at seven different hours. The samples have been collected after the end of their life. Atomic emission spectroscopic analysis has been done to analyze and count the metallic particle present in the oil. From the Atomic Emission Spectroscopic data, graph has been plotted and analyzed. It has been seen that the amount of Ca, Zn and P is always very high in these samples as they have been collected after the end of their life. It has also been found that at the fifth sampling hour there is an abnormal wear particle generation from piston ring, cylinder liners and bearing. The nature wear cannot be determined from this analysis and another supporting analysis like ferrographic analysis is required for the same.

**Reference**

[1]. Ashwani Kumar, Subrata Kumar Ghosh, Size distribution analysis of wear debris generated in HEMM engine oil for reliability assessment: A statistical approach, Measurement 131 (2019) 412–418.

[2]. T. A. MaryutinaN. S. Musina, Determination of metals in heavy oil residues by inductively coupled plasma atomic emission spectroscopy, Journal of Analytical Chemistry,October 2012, Volume 67, Issue 10, pp 862–867.

[3]. Macián, V., Payri, R., Tormos, B., Montoro, L., Applying analytical ferrography as a technique to detect failures in diesel engine fuel injection systems, 2006, Wear 260, p. 562–566.

[4]. Ebersbach, S., Peng, Z., Kessissoglou, N. J., The investigation of the condition and faults of a spur gearbox using vibration and wear debris analysis techniques, 2006, Wear 260, p. 16–24.

[5]. Myshkin, N.K., Kong, H., Grigoriev, A.Y., Yoon, E.S., 2001. The use of color in wear debris analysis, Wear 251, p. 1218–1226.

[6]. Wei HONG, Wenjian CAI, Shaoping WANG, Mileta M.TOMOVIC, Mechanical wear debris feature, detection, and diagnosis: A review, Chinese Journal of Aeronautics, Volume 31, Issue 5, May 2018, Pages 867-882

[7]. Dowson D. History of Tribology. 2nd ed. New Jersey: Wiley, 1998.

[8]. Fouvry S, Liskiewicz T, Kapsa P, Hannel S, Sauger E. An energy description of wear mechanisms and its ap-plications to oscillating sliding contacts. Wear 2003; 255(1–6):287-98.

[9]. Scott D. Debris examination —A prognostic approach to failure prevention. Wear 1975; 34(1):15-22.

[10]. 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.

[11]. 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.

[12]. 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.

[13]. 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.

[14]. T.M. Hunt, Condition Monitoring of Mechanical and Hydraulic Plant: a Concise Introduction and Guide, Chapman & Hall, 1996.

[15]. G.E. Newell, Oil analysis-cost effective machine condition monitoring technique, Ind. Lubr. Tribol. 51 (1999) 119–124.

[16]. 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.

[17]. T.B. Kirk, Numerical characterisation of wear debris for machine condition monitoring, in: International Tribology Conference—AUSTRIB '94, Perth, Australia, December 5–8, 1994.

[18]. D.P. Anderson, Wear Particle Atlas (revised ed.). Report NAEC-92-163, 1982.

[19]. John S. Evans, WHERE DOES ALL THAT METAL COME FROM, Technical Bulletin of Wear Check Africa, issue 47(2010), 1-6.