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Controlling silicon and soot content in the crank case oil to improve performance of diesel engine

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ABSTRACT

The lubricant contamination of diesel engines component wear, leading to loss of engine performance and life. Lubricant analyses are used to predict possible worst condition of equipment, which may lead to premature failures. The content of microelement in the crank case oil can be used to find the damaged condition of the equipment. Periodical lubricant analysis can reveal the microelements in the crank case oil. Copper, Iron, Chromium, Lead, Aluminum and Silicon are the micro-metallic particles normally come to the oil from wear and tear of the engine. Among these microelements Silicon and Soot play a vital role in wear and tear of the engine. Four engines are used for this study. Two brand new 12 Cylinder, V-Type CATERPILLAR Engines of 5AG 2301–3412 DITA model–coupled with 500 KVA power generator sets, parallel operated engines based on power demand. SAE 15W40 (Unique oil) CAT Fluid CI 4 has been used. Another two sets of old 3406 C DITA and 3306 B DITA Cat Engine with CAT DEO 15W40 oil has also been used for this analysis. In this study, the behavior of both silicon and soot materials for the increased wear and tear are analyzed. Experimental results revealed that, controlling both Silicon and Soot will improve the life of other components of the engine in an appreciable level.

KEY WORDS: Diesel Generator, Crank case oil, Wear and tear analysis, Silicon and soot materials, Lubricant analysis

1. INTRODUCTION

Emission requirements of a diesel engines is based on the soot content levels in engine crank case oil will increase significantly due to retarded timing to lower Nox (Esangbedo, 2012). This study made in Cummins M11 engine. Results proved that soot level 9% in the crank case oils to extend filter life, maintain oil pumpability (Gautam, 1998). Patel and Aswath (2014), also studied about effect of soot on piston deposits and crank case oils. The root cause of entry of soot in crank case oils analyzed in this study. Also how the soot initiates the wear and tear on moving parts are also analyzed. Sharma (2016) analyzed the reasons for increased soot levels in crank case oil. The main reasons found in his study were: lower oil consumption reduces the soluble organic fraction (SOF) in the exhaust. It also lowers the fresh oil added to the crank case and therefore increases the soot in oil; high top- ring pistons lower the transient emissions by reducing the crevice volumes between the top ring, piston top and line wall (Poort, 2015).

Engine life and performance is mainly depending on the lubrication types and quality of lubrication used. The life span of lubricant usage that is change of lubricant period is fixed as per the manufacturers design and recommendations (Xie, 2016). Even though on due course of work, the formation of micro elements is unavoidable and will contaminate the engine crank case oil, leading to premature failures (Edelbauer, 2010; Agarwal and Dhar, 2012).

In the prevailing situation, the life span and quality of lubricants will be determined by the presence of micro elements of oil (Schneider, 2006). In turn, this micro constituent in the contaminated oil determines the condition of equipments and the same time, some of the micro elements badly affects the life and quality of lubricants and accelerates the wear and tear of engine (Murali Manohar, 2012; Sundar Raj, 2010). So far no studies were made on Silicon content in the crankcase oil.

In this present work, a detailed investigation was made on the silicon contents of the crank case oil. Hence, the relation between the silicon and soot content and the other micro constituents in the sample oil affecting the condition of the equipment is analyzed. Finally a technique is suggested to control the silicon and soot content to improve the life of the engine.

2. MATERIALS AND METHODS

The micro elements can be identified from the sample oil analysis, periodically drawn from the sump (engine oil crank case).The presence of such micro constituents in oil determines the condition of corresponding components of equipment. The Table 1 shows the microelement constituents identified in the oil and the components from where the microelement is received. The other constituents of oil like water, soot, oxidants, Nitrates, Sulphur products and Total Base Number also can be determined from the sample oil analysis, which affects the quality and life of lubricants (Torbacke, 2014).

The analysis procedure can be divided into two parts, the data acquisition and data interpretation undertaken after each sample analysis. Engine crank case oil samples drawn periodically just prior to the engine oils service period and the sample oil is analyzed to find out the quantity of such active micro elements (Agarwal, 2003).

Table.1. Micro constituents

Micro constituents	Received from components
Copper	Determines the condition of bearings and bushes.
Iron	Determines the condition of rubbing materials of iron components.
Chromium	Determines the journal bearings and push rod materials, caps, etc.
Lead	Determines the bearings materials and various joints condition.
Aluminum	Determines the condition of casting and alloy materials used in the components.
Silicon	Determines the condition of seals, joints, iron components, rubber bushes, etc.
Soot	Is the burnt materials of fuels and crank case oils

Table.2. Specifications of the engines under study

Engine Number	Engine specifications and Model	Remarks
1	Brand new 12 Cylinder V-Type CATERPILLAR Engines of 5AG 2301 – 3412 DITA model – coupled with 500 KVA	Dust proof parallel operation with engine number 2. Turbocharged after cooled.
2	Brand new 12 Cylinder V-Type CATERPILLAR Engines of 5AG 2301 – 3412 DITA model – coupled with 500 KVA	Dust proof parallel operation with engine number 1. Turbocharged after cooled.
3	3406 C DITA Cat Engine with CAT DEO 15W40 oil	Turbo charged after cooled
4	3306 B DITA Cat Engine with CAT DEO 15W40 oil	Turbo charged after cooled

3. RESULTS

Two new 12 cylinder V type Cater pillar Engines used for test sample analysis for this purposes. The above said engines are used in parallel operation according to the load demand and the sample oil drawn at the same time from both the engines. This study on machines started from 0 hour meter readings, i.e., brand new machines. The first sample collected at 226 hours from engine 1 and 220 hours from engine 2 just prior to the first crank case oil service. Refer to the silicon values in the Tables 3 and 4. The second sample collected at 465 and 467 operating hours-just prior to the second crank case oil service. The same way, third samples collected from the engines at the hour meter readings of 717 in engine 1 and 716 in engine 2 respectively. Air filter cleaning carried out in every 50 hours of operation. On comparing the values of Silicon contents with Soot contents in (refer Tables 3 and 4) with other micro elements like Fe (iron) in each sample periods, it drastically is varied in between 250hrs and 500 hours of operation. Also from the tables 3 and 4 it is shown that silicon & soot are the combined elements inducing wear and tear of iron (Fe) and other metallic particles. In engine 1 initially at 220 hour sample more soot materials found, it is due to excess oil entry through initial commissioning stage and in the latter stages it is stabilized between 20 to 25 ppm.

Table.3. Microelement Constituents of Engine 1

HMR	Cu	Fe	Cr	Pb	Al	Si	W	F	St	Oxi	Nit	Sul	TBN
226	2	4	1	2	1	2	N	N	38	0	0	13	Pass
465	3	11	1	2	1	11	N	N	20	0	0	12	Pass
717	3	8	1	2	1	7	N	N	20	0	0	12	Pass

Table.4. Microelement Constituents of Engine 2

HMR	Cu	Fe	Cr	Pb	Al	Si	W	F	St	Oxi	Nit	Sul	TBN
226	4	15	1	2	2	5	N	N	74	0	0	12	Pass
465	3	12	1	2	1	12	N	N	20	0	0	12	Pass
717	3	7	1	2	1	7	N	N	18	0	0	12	Pass

Table.5. Microelement Constituents of Engine 3

HMR	Cu	Fe	Cr	Pb	Al	Si	W	F	St	Oxi	Nit	Sul	TBN
1873	2	4	1	2	1	5	N	N	38	0	0	13	Pass
1957	2	10	1	3	1	12	N	N	56	0	0	13	Pass
2203	1	44	1	2	1	3	N	N	36	0	0	13	Pass
2266	1		1	1	2	10	N	N	34	0	0	13	

HMR - Hour meter reading, Cu – Copper, Fe – Iron, Cr – Chromium, Pb – Lead, Al – Aluminum, Si – Silicon, W – Water, F – Fuel, St – Soot, Oxi – Oxidants, Nit - Nitrates, Sul – Sulphur products, TBN – Total Base Number.

The same procedure is followed for the 3rd and 4th Engines at different irregular intervals but after long run. The third engine's oil sample is considered for study even though when it was failed to run after 7174 hours of running. This study on machines 3 and 4 started from 1957 hour meter and 0 hour meter readings respectively, i.e., two old machines operated under variable load and dusty environments.

The first sample collected at 1957 hours from engine 3 and 274 hours from engine 4 just prior to the crank case oil service. The second sample is collected at 1873 and 2610 operating hours-just prior to the crank case oil service. The same way, third samples collected from the engines at the hour meter readings of 2203 in engine 3 and 5145 in engine 4. Air filter cleaning is carried out in every 50 hours of operation.

The iron (Fe) content is on the higher side whenever the silicon and soot contents are on the higher side (refer Tables 5 and 6). Therefore, it is evident that Silicon and Soot are the combined elements inducing more iron (Fe) content (Colacicco and Mazuyer, 1995). The Silicon and soot are the micro elements in engine oil contamination inducing the wear and tear of the machine. In engine 3 at 1957 hour, more soot and silicon materials found.

As a corrective measure, a new engine air filter is fitted after cleaning the breathing system of the engine (Singh, 2006). This drastically reduce the silicon and soot content at 2203 and 2266 hours respectively. Note that the silicon and soot contents are reduced to the normal operating level (Manikantan and James Gunasekaran, 2013).

Table.6. Microelement Constituents of Engine 4

HMR	Cu	Fe	Cr	Pb	Al	Si	W	F	St	Oxi	Nit	Sul	TBN
274	90	82	2	7	4	39	N	N	170	0	0	17	Pass
2610	11	120	3	3	7	36	N	N	132	0	0	14	Pass
5145	19	108	2	7	11	39	N	N	184	0	0	24	Pass
7174	56	472	22	81	49	245	N	N	192	0	0	18	Pass

In engine number 4, no measure is taken for air filter and breathing system hence the soot content is increased from 170 to 192 and silicon content is increased from 39 to 245. Note that the soot content is in the higher side even at 1873 hours and the silicon content is suddenly increased from 39 to 245 when operated from 5145 hours to 7174 hours at which the engine failed to run. In this engine it is proved that gradual increase in soot and Silicon contents encouraged the wear and tear of engine components till the engine fails to run (Green and Lewis, 2008).

The main entry of silicon into the engine crank case oil is from Air filters, engine breathing systems and seal joint materials. It is evident from the tables 3 and 4 that there is considerable reduction in silicon contents in the crank case oil due to new air filters and breather case filters changed at 465 and 467 hours respectively. The soot can be controlled by giving the additional filtering system in diesel tank or with good quality of diesel fuel or by improving the fuel firing system (Omidvarborna, Kumar and Kim, 2015). Note that due to dusty working environment, engines 4 and 5 showed increased the soot contents beyond normal. The engine lubrication oil cleaning include improved engine performance, longer engine life, reduced maintenance cost and longer lube oil service life.

4. CONCLUSION

From the oil analysis it is shown that the Silicon (Si) and Soot (St) are the main micro constituents which accelerate the wear and tear of engine parts. This wear and tear increase the content of Iron (Fe) in the engine crank case oil. Silicon and soot are the elements which contaminate oil easily, passing through crank case oil (lubricants) to turbo chargers, piston rings and liners, main bearings and push rod cups, various costlier components and accelerates the wear and tear, which, leading to premature failure of engine components. Hence it is shown that, controlling both Silicon and Soot will improve the life and quality of crank case oil, and increase in life of other components of the engine in an appropriate level. The lubricant oil analysis is an effective technique for assessment of engine friction and wear, which provides to support the development of new system analysis.

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