Determination of oil life for crane Liebherr Model D9408 diesel engine by Oil Condition Monitoring

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Abstract: The aim of this study is to choose and investigate the best oil replacement time by oil condition monitoring for crane Liebherr model D9408 diesel engine. This is achieved by investigating different oil sample analyses of crane Liebherr model D9408 diesel engine. According to the majority indices results of the oil analysis, But not for all of them, they had an acceptable function after 160 running hours. The variation percent of plumb in wear debris analysis was above 50 percent. According to the Total Base Number (TBN) analysis, the oil had an acceptable function until 150 running hours. Additive depletion results showed that the oil had an acceptable function after 150 running hours, and absolute variation percent of each additive material after 160 running hours were not more 50 percent. Pollutant materials results of this table showed that the variation percent of each pollutant material after 160 running hours was not more than 50 percent. Also the Particle Quantifier (PQ) results showed that the variation percent of PQ after 160 running hours was not more than 50 percent. Results of oils analysis for viscosity didn't give us a reliable consequence. Right now, the oil of the diesel engine is replacing every 125 hours, but overall the best time for replacing the oil for this engine has been calculated as 150 running hours. [Journal of American Science 2010;6(5):136-141]. (ISSN: 1545-1003).

Keywords: Oil analysis; Oil Condition Monitoring; Oil time replacement; Machine Condition Monitoring; Wear debris materials

1. Introduction

Machine condition monitoring has long been accepted as one of the most effective and cost efficient approaches to avoid catastrophic failures of machines (Toms, 1998; Barron, 1997). There are several methods to monitor the condition of a machine, such as acoustic condition monitoring, thermal condition monitoring, vibration condition monitoring, and others. However, practical experience has shown that oil condition monitoring technique is a suitable method for reciprocating machinery (Barron, 1997).

Oil condition instruments are suitable for use in all major industrial applications, including iron and steel, agriculture, military, mines and quarries, power generation transport, and used oil analysis. Recent evidence showed that oil analysis technique provided greater and more reliable information, resulting in a more effective maintenance program with large cost benefits to industry (Troyer, 1999; Byington,1999).

Preventative maintenance program is essential for optimizing operational efficiency and performance of machinery and lubricant oil. The main limitation is that it is comparatively expensive to operate and can also be a time-consuming activity. The employment of this technique can be used as both predictive and proactive tools in order to identify machine wear and diagnose faults occurring inside machinery against different kinds of oil s. However, recent evidence shows that oil analysis technique provides greater and more reliable in formation, thereby resulting in a more effective maintenance program with large cost benefits to industry (Byington, 1999; Mathew, 1987; Maxwell, 1997; Troyer, 1999).

Lubricating oil in internal combustion engines is exposed to various strains depending on the operating conditions, the fuel quality, the ambient conditions and operating parameters. The rate of deterioration strongly depends on these influences. In order to avoid an engine failure, the oil must be changed before it looses its protective properties. At the same time, an unnecessary oil change should be avoided for environmental and economical reasons. In order to determine the optimum oil change interval reliably, it is necessary to monitor the actual physical and chemical condition of the oil. The oil's ageing process is very much influenced among other things, by the fuel quality, due to the blow-by gases of the combustion process. Therefore, especially for gas engines fueled with biogas of a priori unknown and fluctuating fuel quality, the direct monitoring of the oil condition is essential (Agoston, 2005).

The monitoring of oil and oil-based liquids (including emulsions) is an important task in a number of application areas ranging from the food industry to automotive applications. In the latter field, there has recently been increased interest in monitoring the condition of lubricants facilitating proper engine operation. Monitoring the engine oil condition at first instance allows the implementation of increased oil drain intervals. Moreover, it provides increased insight into the actual state of the engine, which enables the detection of possibly approaching engine failures but also the monitoring of the performance of engine oils of varying quality. Similar considerations hold for other applications where oils are used as lubricants (Jakoby, 2003).

As a general rule, machines do not break down or fail without some form of warning, which is indicated by increased wear debris materials. By measuring and analyzing the oil of a machine, it is possible to determine both the nature and severity of the defect, and hence predict the machine's failure (Davies, 1997; Williams, 1994) and also choose the best oil for the machine and investigate optimum operating time for that oil. Oil analysis may have two purposes: safeguarding the oil quality (contamination by parts, moist) and safeguarding the components involved (characterization of parts). Oil analysis is mostly executed off-line by taking samples. However, for safeguarding the oil quality, application of on-line sensors is increasing. Sensors are nowadays available, at an acceptable price level, for count the part and measure the moisture of oil. Besides this, Safe-guarding the state of the oil filter (pressure loss over the filter) is mostly applied nowadays for hydraulic as well as for lubrication oil.

Engine lubrication oil degrades at varying rates depending on the lubricant, engine type and application. Traditional maintenance programs are designed to change oil on predetermined intervals (such as run time/mileage), with more advanced algorithms taking into account load and operating temperature of the engine, or lab analysis. Conservative interval based maintenance programs spend too many resources changing oil and longer intervals may result in engine damage. Lab based oil condition approaches also have significant time lag and other logistical difficulties (Bennett, 2005).

One of the most important aspects of oil analysis that requires improvement is the fact that the wear debris quantification does not always correlate with the real wear that one means to measure. Measurements are affected by different factors that should be compensated or accounted for if a proper wear analysis is to be achieved. Also, for practical operating equipment, there are many factors which affect the wear of parts such as engine age, type of service, environmental conditions of work, engine metallurgy, etc. These are difficult to evaluate (Macian, 2003).

2. Materials and methods

The experimental and testing was conducted on crane Liebherr model D9408 diesel engine. Details of engine components are given in table 1. Six running hours were conducted, they were 110, 120, 130, 140, 150, and 160 hours. Right now, the oil of the diesel engine is replacing every 125 hours. The objective of this research is to choose and investigate the best oil replacement time by oil condition monitoring for crane Liebherr model D9408 diesel engine. This is achieved by investigating different oil sample analyses of crane Liebherr model D9408 diesel engine.

Table 1: Details of crane Liebherr model D9408 diesel engine

Engine component	Description
Model of engine	LIEBHERR D9408, diesel engine
Number of cylinder	8 cylinders
Maximum power (kW)	400 KW at 1900 rpm
Cooling system	Water

Wear means the loss of solid material due to the effects of friction of contacting surfaces. According the results of researchers if the concentration wear debris materials were between 50 to 100 ppm, fifty percent change in wear debris materials could show the fault in engine (Poley, 2000). An important factor in any monitoring program is the ability to obtain reliable trend information or details of gradual changes with time or running hours. A careful observation of these trends can be very revealing. Any significant variation from the trends such as rapid increase or decrease in a measured value, gives early warning of an impending problem, well before the limit value is reached. Oil condition monitoring involves sampling lubricants from critical rotating plant and equipment and then analyzing the lubricant for clues as to the operational condition of the machinery under inspection (Ahmadi et al., 2009b).

3. Results and discussion

3.1. Wear debris analysis

According to ASTM D-6595 standard and by using the Atomic Emission Spectroscopy (AES) tests, the amount of the wear debris materials of oil samples has been investigated. The wear debris materials of oil samples between 110 and 160 hours and the results were shown in figure 1. It has been shown that there weren't any significant difference between values.

It has been shown in table 2 that the variation percent of the majority of wear debris materials were below than 50 percent. Only the variation percent of plumb was above 50 percent. Also the results showed that variation percent of each wear debris material until 160 running hours was below than 50 percent.

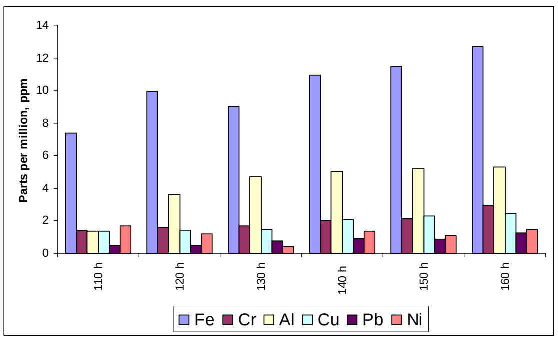

Fig 1: Wear debris analysis results during different running hours

Ahmadi et al. explained that according to the results of researchers if the concentration of wear debris materials were between 50 to 100 ppm, fifty percent change in wear debris materials could show the fault in engine. An important factor in any monitoring program is the ability to obtain reliable trend information or details of gradual changes with time or running hours. A careful observation of these trends can be very revealing. Any significant variation from the trends such as rapid increase or decrease in a measured value, gives early warning of an impending problem, well before the limit value is reached (Ahmadi et al., 2009b).

Table 2: Value, warning zone and variation percent of wear debris materials of oil in 160 running hours

Wear debris material	Value (ppm)	Average + 1* standard deviation (ppm)	Average + 2* standard deviation (ppm)	Variation percent
Fe	12.67	12.12	14.00	23.7
Cr	2.93	2.51	3.05	49.2
Al	5.33	5.73	7.25	27.0
Cu	2.47	2.34	2.82	32.6
Pb	1.24	1.09	1.37	55.0

3.2. Additive depletion

Once dispersion becomes "loaded" any added sludge, resin or soot will cause the oil to dump whatever it has collected and refuse to collect anymore. This results within a rapid period build-up engine deposits. The value of each additive material between 110 and 160 running hours has shown in figure 2. Results showed that the oil had an acceptable function after 150 running hours, and absolute variation percent of each additive material after 160 running hours were not more 50 percent.

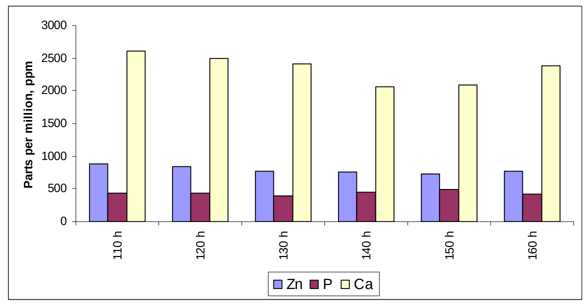

Fig 2: Result of additive materials analysis during different running hours

Ahmadi et al. illustrated that the building blocks of lube oil are known as base oil. Generally speaking, base oil is a mixture of various fractions from the crude oil refining process. Additives are then mixed within this base oil to impart additional desirable properties to the base oil. Base oil is refined by solvent extraction (usually with propane at a pressure high enough to keep it in liquid form) and hydrotreatment (reaction with hydrogen) (Ahmadi et al., 2009b).

3.3. Pollutant Materials

Silicon and sodium usually enter the oil from environment and they are known as pollutant materials. Figure 3 shows the amount of pollutant materials, silicon and sodium, in different oil analysis. The existence of silicon in oil analysis would be through entering dust into the engine.

Figure 3 and table 3 shows that the value of each pollutant material after 160 running hours was between the average of pollutant material plus two times of standard deviation of data those gotten during different running hours. Also the results of this table showed that the variation percent of each pollutant material after 160 running hours was not more than 50 percent. These results showed that the oil after 160 running hours could be used at more time and this shows that it is not commodious to change the oil at 125 running hour. There was no significant difference of pollutant materials among different running hours.

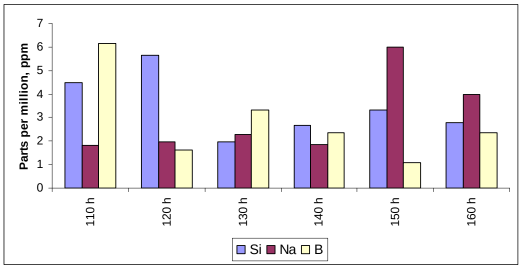

Fig 3: Pollutant materials analysis results during different running hours

pollutant material	Value (ppm)	Average + 1* standard deviation (ppm)	Average + 2* standard deviation (ppm)	Variation percent
Si	2.78	4.83	6.18	20.0
Na	3.98	4.66	6.34	33.8

Table 3: Value, warning zone and variation percent of pollutant materials of oil in 160 running hours

3.4. Wear Indices

Wear indices are belonged to important indices for showing the increasing of wear in engine parts. There are different wear indices, such as Particle Quantifier (PQ). This index shows the amount of particles that are bigger than 10 µm. Figure 4 shows the amount of PQ in the investigation between 110 and 160 running hours.

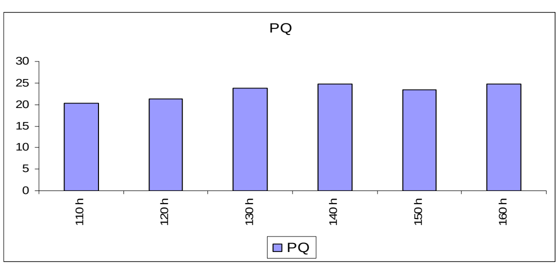

Fig 4: Particle Quantifier (PQ) analysis results during different running hours

Table 4 showed that the value of PQ after 160 running hours was between the average of PQ plus two times of standard deviation of data those gotten during different running hours. Also the results of this table showed that the variation percent of PQ after 160 running hours was not more than 50 percent.

Table 4: Value, warning zone and variation percent of PQ of oil in 160 running hours

Wear index	Value (ppm)	Average + 1* standard deviation (ppm)	Average + 2* standard deviation (ppm)	Variation percent
PQ	24.75	24.88	26.75	7.5

3.5. Viscosity

In this study the viscosity has been investigated by ASTM D-445 standard. The viscosity of industrial oils, by contrast, is mostly measured at 40ºC. The viscosity can be decreased by adding more fluid oil, or as a result of high water content, of by shearing of the VI-improver. The viscosity can be in creased by adding a more viscous oil, and by oil oxidation (e.g. as a result of overheating). The viscosity characteristics of oils at 40 ºC have been shown in table 6. The viscosity of industrial oils, by contrast, is mostly measured at 40ºC. Results of oils analysis for viscosity don't give us a reliable consequence. Figure 5 shows the amount of viscosity in the investigation between 110 and 160 running hours.

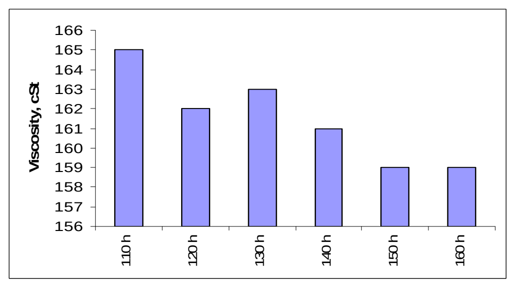

Fig 5: Viscosity analysis results during different running hours

3.6. Total Base Number (TBN)

In this study TBN has been investigated by ASTM D-2896 standard. Engines operating on heavier residual fuels are exposed to a more corrosive regime, as fuel sulphur levels are typically 2 to 4%. Here the TBN levels are typically between 20 and 40 dependent on fuel sulphur level. Maintaining a correct alkaline reserve is critical in preventing unnecessary corrosion of the upper piston, piston rings and top end bearing. Additionally, low TBN is indicative of reduced oil detergency (Ahmadi et al., 2009b).

The oil is continuously exposed to acidic combustion products and these must be neutralized before they could corrode engine parts (Ahmadi et al., 2009).

Too low a TBN volume can be due to: heavy oxidation of the oil, when the oil has been in service for too long, the oil level was insufficient, or due to a defective cooling system, producing overheating; use of a fuel containing a high sulphur content; use of an inappropriate lubricant; or contamination of the oil by fuel or water. The lowest recommended TBN for oil according to our fuel in Iran is 6. Figure 6 has shown the TBN change during the running hours of samples. Results showed that there wasn't significant difference between samples. The TBN level of each sample had more than recommended level of TBN. Figure 6 and table 5 shows the variation percent of viscosity and TBN at 40 ºC. According to the TBN analysis, the oil had an acceptable function until 150 running hours.

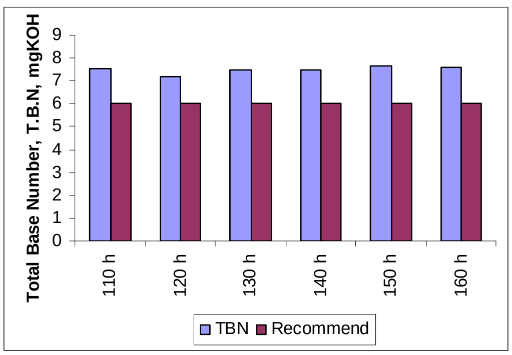

Fig 6: TBN changes during the different running hours

Table 5: Value, average minus standard deviation, average minus two times of standard deviation and variation percent of physical & chemical indices of oil in 150 and 160 running hours

Physical & chemical indices	Value (ppm)	Average - 1* standard deviation (ppm)	Average - 2* standard deviation (ppm)	Variation percent
VIS40	159	159.15	156.81	1.5
TBN	7.57	7.33	7.17	1.1

4. Conclusions

The objective of this research is to choose and investigate the best oil replacement time by oil condition monitoring for crane Liebherr model D9408 diesel engine. This is achieved by investigating different oil sample analyses of crane Liebherr model D9408 diesel engine. Right now, the oil of the diesel engine is replacing every 125 hours. According to the majority indices results of the oil analysis, But not for all of them, they had an acceptable function after 160 running hours. The variation percent of plumb in wear debris analysis was above 50 percent. Additive depletion results showed that the oil had an acceptable function after 150 running hours, and absolute variation percent of each additive material after 160 running hours were not more 50 percent. Pollutant materials results of this table showed that the variation percent of each pollutant material after 160 running hours was not more than 50 percent. Also the Particle Quantifier (PQ) results showed that the variation percent of PQ after 160 running hours was not more than 50 percent. Results of oils analysis for viscosity didn't give us a reliable consequence. According to the Total Base Number (TBN) analysis, the oil had an acceptable function until 150 running hours. Overall the best time for replacing the oil for this engine has been calculated as 150 running hours.

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