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Determination of Oil Life for Crane Liebherr LHM 500g Model 301 by Oil Condition Monitoring

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Abstract: The objective of this research is to choose and investigate the best oil replacement time by oil condition monitoring for crane Liebherr LHM 500G model 301 that works near the sea in marine company. This was achieved by investigating different oil sample analyses of crane Liebherr LHM 500G model 301. The oil analysis was initially run under regular interval during machines life. Some series of tests were then conducted under the operating hours of machine. Oil samples were regularly collected. Numerical data produced by oil analysis were compared with another sample, in order to quantify the effectiveness of the results of oil condition monitoring technique. The results from this paper have given more understanding on the dependent and independent roles of oil analysis in predicting which oil is more suitable for working machine condition. According to the results, the oil used in this crane can be used more than 130 h and the best oil running time is 160 h.

Key words: Lubrication, machine condition monitoring, oil, oil analysis, oil time replacement, wear debris materials

INTRODUCTION

The most effective and cost-efficient groups of condition monitoring methods are oil analysis (Toms, 1998; Barron, 1996b). 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 oils. However, recent evidence shows that oil analysis technique provides greater and more reliable information, thereby resulting in a more effective maintenance program with large cost benefits to industry (Mathew and Stecki, 1987; Maxwell and Johnson, 1997; Troyer and Williamson, 1999; Byington *et al.*, 1999). 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). 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 *et al.*, 2005).

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

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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 *et al*., 2005).

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 part counting and moist. Besides, safeguarding the state of the oil filter (pressure loss over the filter) is mostly applied nowadays for hydraulic as well as lubrication oil (Barron, 1996a; Williams *et al*., 1994). The objective of this research is to choose and investigate the best oil replacement time for crane Liebherr LHM 500G model 301 that works near the sea in marine company by oil condition monitoring. This was achieved by investigating different oil sample analyses of crane Liebherr LHM 500G model 301. The oil analysis was initially run under regular interval during machines life. Some series of tests were then conducted under the operating hours of machine. Oil samples were regularly collected.

MATERIALS AND METHODS

The experimental and testing was conducted in Tidewater Company, Mahshahr seaport of Iran in 2008 on crane Liebherr LHM 500G model 301 using in marine company. The crane that was selected for the tests conducted in this work had a diesel motor. Details of engine components are given in Table 1. Six running hours were conducted, they were 110, 120, 130, 140, 150, and 160 h. Right now, company was replacing oil of diesel motor every 130 h. All of the oils were normal lubrication (20W40 cSt oil), which is the recommended oil to lubricate the engine under normal operating conditions. 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, 50% 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 and Mollazade, 2009b).

Table 1: Details of crane liebherr LHM 500G model 301engine

Engine component	Description
Model of engine	Daimler Benz Industrial, OM 444 LA
Number of cylinder	12 cylinders
Maximum output	491 KW at 1900 rpm
Cooling system	Water

RESULTS AND DISCUSSION

Wear debris analysis: Ahmadi and Mollazade (2009a, b) explained that according to the results of researchers if the concentration of wear debris materials were between 50 to 100 ppm, 50% 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 and Mollazade, 2009b).

The wear debris materials of oil samples between 110 and 160 h and the results were shown in Fig. 1. It has been shown that there weren't any significant difference between values.

The results showed that variation percent of each wear debris material was below than 50% and it showed that the engine oil until 160 running hours had acceptable condition.

It has be shown in Table 2 that the value of each wear debris material after 160 running hours was not between the average of wear debris material plus one and two times of standard deviation of data those gotten during different running hours. Also the results of Table 2 showed that variation percent of each wear debris material after 160 running hours were not more than 50%. These results showed that our oil after 160 running hours could be used at more time.

Abrasive materials: Oil samples were analyzed and the results of abrasive materials are shown in Fig. 2. Figure 2 and Table 3 showed that the value of each abrasive material after 160 running hours was not between the average of abrasive material plus two times of standard deviation of data those gotten during different running hours. Also the results of Table 3 showed that the variation percent of each abrasive material after 160 running hours was not more than 50%. These results showed that our oil after 160 running hours could be used at more time. There was not significant amount of abrasive materials were found between different running hours.

Additive depletion: Ahmadi and Mollazade (2009a, b) illustrated that the building blocks of lube oil are known

Table 2: Value, warning zone and variation percent of wear debris materials of oil in 150 and 160 running hours

Running hours	Wear debris material,	Value (ppm)	Average + 1* standard deviation (ppm)	Average + 2* standard deviation (ppm)	Variation percent
	Fe	12.67	12.73	14.37	14.4
	Cr	1.43	1.87	2.49	13.9
	Al	5.43	6.73	9.25	28.9
160	Cu	2.47	4.35	5.98	9.0
	Pb	1.54	1.56	1.98	33.9
	Ni	1.45	1.62	2.04	21.0
	Mo	1.23	2.55	3.42	26.5
	Fe	12.48	12.38	14.01	16.0
150	Cr	0.83	1.91	2.59	32.0
	Al	5.18	6.71	9.44	30.5
	Cu	2.89	2.82	3.48	33.7
	Pb	0.98	1.48	1.89	8.6
	Ni	1.08	1.60	2.04	5.9
	Mo	2.20	2.71	3.66	24.9

Table 3: Value, warning zone and variation percent of abrasive materials of oil in 150 and 160 running hours

Running hour	Abrasive materials	Value (ppm)	Average + 1* standard deviation (ppm)	Average + 2* standard deviation (ppm)	Variation percent
	Si	2.78	4.83	6.18	20.0
160	Na	3.98	4.66	6.34	33.8
	B	2.36	4.61	6.41	16.1
	Si	3.34	5.08	6.54	7.6
150	Na	2.98	2.66	3.14	37.1
	B	1.07	4.90	6.90	63.1

Table 4: Value, average, average minus standard deviation and variation percent of additive materials of oil in 150 and 160 running hours

Running hour	Additive material, oil #1	Value (ppm)	Average – 1* standard deviation (ppm)	Average – 2* standard deviation (ppm)	Variation percent
	Zn	774	769.26	728.85	4.4
160	P	422	381.91	276.65	13.4
	Ca	2390	2411.62	2112.40	11.8
	Zn	827	776.07	735.33	1.2
150	P	592	388.06	275.93	18.4
	Ca	3091	2490.34	2205.67	11.4

Table 5: Value, warning zone and variation percent of particle quantifier index of Oil in 150 and 160 running

Running hour	Wear index	Value (ppm)	Average + 1* STDV(ppm)	Average + 2* STDV(ppm)	Variation percent
160	PQ	21.75	26.56	29.78	6.8
	TDPQ	1.00	1.64	2.08	16.3
150	PQ	23.34	27.15	30.64	1.4
	TDPQ	1.67	1.71	2.20	35.3

Table 6: Value, average, average minus standard deviation and variation percent of physical & chemical indices of oil in 150 and 160 running hours

Running hour	Physical & chemical indices	Value (ppm)	Average (ppm)	Average – 1* STDV(ppm)	Variation percent
160	VIS40	158	158.63	156.76	1.6
	TBN	7.57	7.50	7.11	3.9
150	VIS40	159	159.42	157.84	1.2
	TBN	7.63	7.55	7.15	3.9

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).

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 after 160 running hours has shown in Fig. 3 and Table 4. Results showed that absolute variation percent of each additive material after 160 running hours were not more 50%.

Particle counting: This is a special useful test for a hydraulic system with high sensitivity (e.g., servo-valves). In such a text, a certain quantity of hydraulic oil flows through a sensor, where all the insoluble material in the oil is detected and counted using the principle of light absorption. The value of particle quantifier after 160 running hours has shown in Fig. 4. It has shown in Fig. 4 and Table 5 that the average of particle quantifier is less than 50% and these indices were in acceptable range.

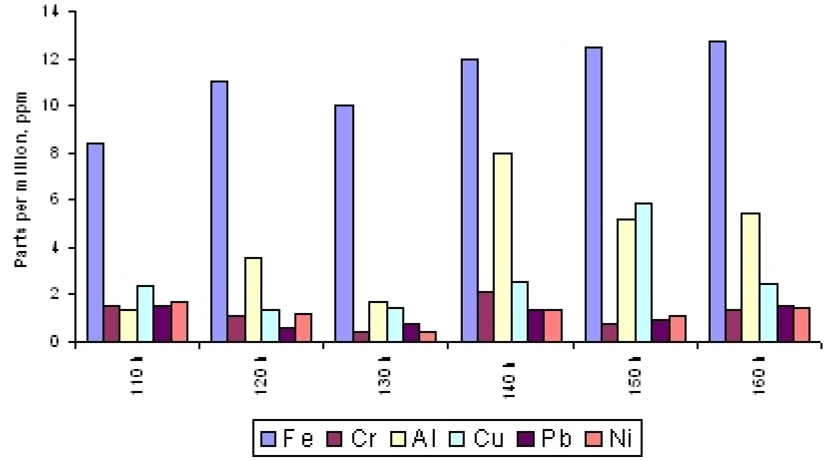

Fig. 1: Wear debris analysis results for the three oils d uring different running hours

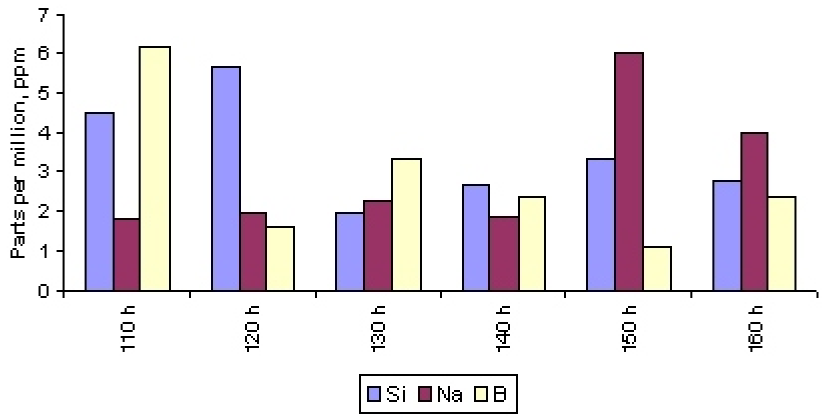

Fig. 2: Result of abrasive materials analyses for three oils during different running hours

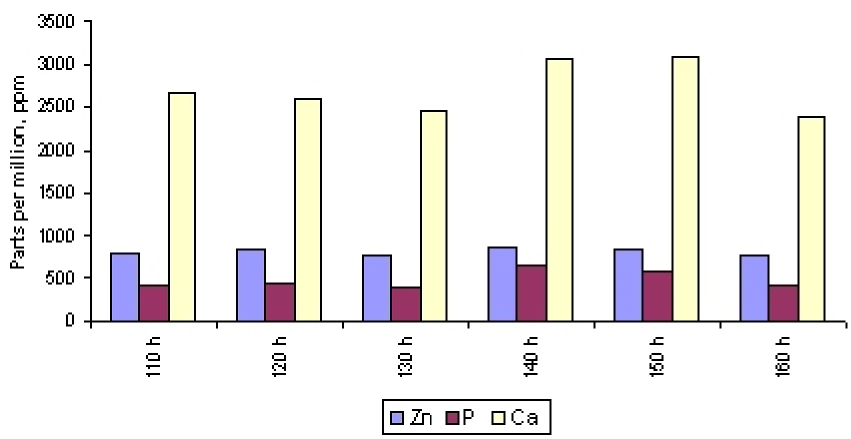

Fig. 3: Result of additive materials analysis for the three oils during different running hours

Viscosity: The viscosity characteristics of oils at 40ºC have been shown in Table 6. 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 increased by adding a more viscous oil, and by oil oxidation (e.g. as a result of overheating). Results of oils analysis showed that there

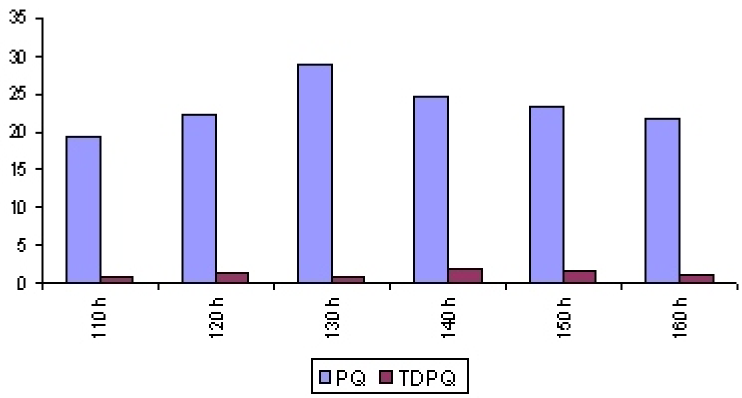

Fig. 4: Result of particle quantifier analysis for the three oils during different running hours

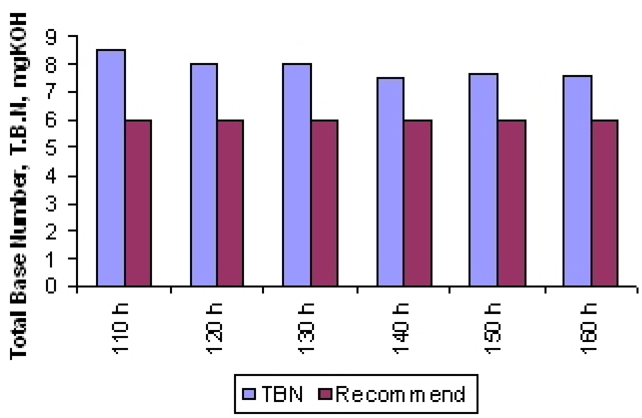

Fig. 5: TBN changes during the different running hours for three oils

wasn't any significant difference between viscosity characteristics of oils at 40ºC between samples.

Total Base Number (TBN): The oil is continuously exposed to acidic combustion products and these must be neutralized before they could corrode engine parts (Ahmadi and Mollazade, 2009a). 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 and Mollazade, 2009b).

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 5 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 5 and Table 6 showed the variation percent of viscosity at 40ºC and TBN. Results showed that variation percent of TBN and viscosity were less than 50%.

Ahmadi *et al.* described that oil condition monitoring technique has detected similar wear mechanisms associated with the engine. By comparing the results of the different months, a more reliable assessment of the condition of the test rig can be made. Meanwhile, the oil condition monitoring has its individual advantages. Wear debris analysis provides further insight on the wear rate and mechanism of the engine. Oil analysis has provided quick and reliable information on the condition of the bearings (Ahmadi and Mollazade, 2009b).

CONCLUSION

The results from this paper have given more understanding on the dependent and independent roles of oil analysis in predicting which oil is more suitable for working machine condition. Results of oils analysis show that there wasn't any significant difference between viscosity characteristics of oils at 40ºC among different running ours until 160 running hours. Results showed that the variation percent of wear debris materials of oil samples after 160 running hours were not more than average of that amount. The results showed that variation percent of each wear debris material was below than 50% and it showed that the engine oil until 160 running hours had acceptable condition. Results showed that the value of each abrasive material after 160 running hours was not between the average of abrasive material plus two times of standard deviation of data those gotten during different running hours. Also the results showed that the variation percent of each abrasive material after 160 running hours was not more than 50%. These results showed that our oil after 160 running hours could be used at more time. According to the results, absolute variation percent of each additive material after 160 running hours was not more than 50%. Results of oils analysis showed that there wasn't any significant difference between viscosity characteristics of oils at 40ºC between samples. Result showed that there wasn't significant difference between samples. The Total Base Number (TBN) level of each sample had more than recommended level of TBN. Results showed that variation percent of TBN and viscosity were less than 50%. The results showed that the oil used in this crane can be used more than 130 h and the best oil running time is 160 h.

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