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Condition Monitoring Of Cooling Tower Fan Gearboxes by Wear Debris and Vibration Analysis – A Case Study

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Abstract- In these days condition monitoring plays a main role in many of the industries. Lubricantsare essential and expensive components of machine systems needing sampling, analysis and monitoring. Monitoring can be either performance testing or oil condition monitoring or vibration analysis. Hear wear debris analysis and vibration analysis plays a curtail role in the maintenance of the cooling tower. Components of the gear box fail without proper maintenance. For the reduce of the heavy expenses analysis is done. Key component of the cooling tower fan is the gearbox. Maintenance of gearboxes is difficult and expensive, given the location and therefore condition monitoring techniques have been applied to detect common failure mechanisms. Future condition monitoring may be possible using low cost on-line techniques. With these oil analysis and vibration techniques, monitoring has been done and gear box failures has been detected.

Index Terms- *condition monitoring, failure mechanisms, gearbox, lubricant.*

I. Introduction

It has long been accepted that condition- based maintenance is the most effective and cost-efficient approach to maximizing the life of industrial machinery. Vibration and wear debris analyses are two key components of any successful condition-monitoring program and can be used as both predictive and proactive tools to identify active machine wear and diagnose faults occurring inside machinery. When these techniques are conducted independently, only a portion of machine faults are typically diagnosed. However, practical experience has shown that integrating these two techniques in a machine condition-monitoring program provides greater and more reliable information, bringing significant cost benefits to industry.

Vibration analysis in particular is becoming increasingly popular as a predictive maintenance procedure and as a support for machinery maintenance decisions. As a general rule, machines do not break down or fail without some form of warning, which is indicated by an increased vibration level. By measuring and analyzing the vibration of a machine, it is possible to determine both the nature and severity of the defect, and hence predict the machine’s failure.

The overall vibration signal from a machine is contributed from many components and structures to which it may be coupled. However, mechanical defects produce characteristic vibrations at different frequencies, which can be related to specific machine fault conditions. By analyzing the time and frequency spectrums and using signal processing techniques, both the defect and natural frequencies of the various structural components can be identified.

Practitioners of oil analysis are familiar with the practice and advantages of oil wear debris analysis. Compared to vibration analysis, oil and particle analysis have certain advantages, as they can provide direct and early information on wear modes and the machine’s condition. In fact, in many instances it has been proven to be a leading indicator of active machine wear, compared to vibration analysis. In addition, oil analysis has certain advantages in monitoring low-speed machinery (less than 5 rpm), where it is usually difficult to apply vibration analysis techniques. However, wear debris analysis cannot effectively uncover all manners of failure mechanisms on its own. For this reason, both oil analysis and vibration analysis are necessary and vital parts to an effective program.

Both wear debris analysis and vibration analysis are complicated in terms of their analysis requirements, and the demand of human expertise and experience. Experts in the two fields are often isolated from each other. Hence, effective integration of the two condition-monitoring techniques can be challenging in a working environment, especially for remote industries such as offshore drilling, mine sites and other isolated operations. In recent years, research toward this goal has been conducted, but with limited achievement. However, advances in technological innovation, including artificial intelligence and advanced computer analysis techniques, have created renewed optimism at the prospects of overcoming these obstacles to develop a new integrated approach to machine condition monitoring.

II. PROBLEM IDENTIFICATION

Access to continuous information allows you to detect problems before they lead to failure. Vibration alerts warn of pending problems, enabling further investigation to detect and diagnose the fault so maintenance can be scheduled.

Overall vibration with embedded temperature measurement will identify developing mechanical faults. The technology provides advanced diagnostics for early indication of bearing and gearbox faults. Vibration energy bands enhance trending and

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alarming, making it easier to interpret the data. More detailed information can be accessed through high resolution spectra and waveform data.

Trend values can be compared against appropriate alert levels, informing you when the condition of the gearbox or motor is deteriorating — as well as providing the underlying cause of the problem. Vibration monitoring data is communicated over a self-organizing Smart Wireless network, removing the additional costs associated with running cables.

Some of the problem identifications are:

Bearing Defects:

Bearings often operate under heavy, variable load and extreme environmental conditions. Because of the force applied to bearings in a cooling tower, defects often progress quickly and lead to friction, bearing damage, and gearbox failure.

Shaft Misalignment:

Due to the length of the shaft in a cooling tower and the thermal changes that the shaft experiences, misalignment are a common issue. Stress inside the shaft can damage couplings, cause bearing fatigue, and even lead to shaft breakage.

Broken/Chipped/Worn Teeth:

Shaft misalignment causes increased load on the input gear, which causes bad meshing of the gears and generates debris. Damaged and misaligned gears can result in failure of the gearbox.

Coupling Issue:

Excessive shaft misalignment can damage the coupling, which can lead to shaft separation. Severe coupling damage can lead to gearbox failure, damaged shafts, and rotor cracks.

Insufficient Lubrication:

The extreme conditions of the cooling tower often lead to issues with lubrication. Bearing wear and gear teeth damage caused by insufficient lubrication contributes to premature equipment failure. However, the inaccessibility of a cooling tower makes it virtually impossible to perform accurate grease and oil analysis.

Steps Involved overcoming the Problem:

The two types of analysis to overcome the problem:

1. Oil Analysis.
2. Vibration Analysis.

III. EXPERIMENTAL PROCEDURE

OIL ANALYSIS

In order to reduce the failure and to reduce vibrations, an oil analysis is performed.

Tan Preparation:

Materials required for Tan preparation:

The materials required for Tan preparation are,Tan table chart, Reagent ‘C’ chemical for tan, 2ml sample oil, Reagent d (200ml distil water + 2gm KOH pallets).

Procedure:

Take 25ml cylinder + add 10ml of reagent c followed by 2ml of sample oil.Then titrate with reagent d up to the end point.Conclusion is that the solution should turn to pink in colour.

Preparation of Moisture:

The materials required for the preparation of moisture are, Reagent ‘A’ – 15 ml,5ML sample oil, Reagent B 15 drops, Hydro Gauge.

Procedure:

Take 15ml of reagent ‘A’ in cylinder tube.Add 5ml of sample oil pour the mixture into the hydro gauge.Take a cap and pore 15 drops of reagent ‘B’ in the cap and dip it into hydroguage close the cap.Shake for 2minutes so that the mixture can absorb.

Preparation of Viscosity:

Materials required for the preparation of viscosity are,KinematicViscoBatha, Capillary Tube, Stop Watch, Rubber Ball, Sample Oil, Syringe, Calculator, Capillary Tube Chart, Oil Grade Chart

Procedure:

First set the temp to 40deg C for lubrication oil (except engine oil).Select the tube as per oil grade given by the customer and we should find the range. After finding the range we can select the tube by capillary tube chart after that insert the tube to K.V bath then pour the oil 7ml in the tube and heat the sample for 15-20 min.It gets heated and with the help of rubber ball suck the sample oil

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from the capillary tube the capillary tube has 2marks namely upper mark and lower mark when the sample touches the upper mark.Start stop watch and calculate how much time it takes for sample oil for travelling from upper path to lower path after that note the time in seconds multiply the time with capillary constant value no.

Slide preparation:

Materials required for slide preparation are ferrogram maker, glass slide, cleaner liquid, oil sample

Procedure:

First keep the slide on the ferrogram maker and add some oil sample to the tube installed in ferrogram maker now on the ferrogram maker so that the oil flows on the slide and the impurities in the oil attach to the slide.

VIBRATION ANALYSIS

It can forecast potential machinery problems and pinpoint their cause. Further the same provides periodic condition monitoring using instrumentation. A database is developed to record performance, establish machine histories, assist maintenance diagnostics and extend machinery reliability. Problems detected include imbalance, misalignment, motor and electrical defects, gear train defects, and bearing defects.

Generally, a set of instruments consisting of accelerometers, FFT analyser, recorder and set of cables are used to obtain spectral plots. If the hardware is interfaced with fault diagnostic system to the computerized maintenance management system, then suitable signals can provide information to the operator or maintenance staff.

The steps included in the Vibration Analysis are:

- Using FFT Analyser Collect the XYZ Axis Readings.

IV. RESULTS AND DISCUSSION

The experiment is done and the Oil Analysis and the Vibrational Analysis reports are as shown in the figure below.

Oil Analysis Report For Cooling Tower 1A:

The Oil analysis report for the cooling tower 1A is as shown in the Table 1

PREVENTIVE MAINTENANCE (OIL ANALYSIS REPORT)		
DATE	**MACHINE CONDITION INDEX**	**Remarks / Actions**
4-Jan-14	3.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
2-Feb-14	4	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
06-Mar-14	4.3	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
01-Apr-14	4.8	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
03-May-14	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
07-Jun-14	9.5	Oil sample tested found warning . Vibration Limits are Also Raising trend. (Oil Report attached)
02-Jul-14	14.2	Oil inspected, found metal particals gear box dismentled and inspetcedpinoin damaged, new spare pinoinrepalced.
04-Aug-14	4.2	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
09-Sep-14	4.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Oct-14	5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Nov-14	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Dec-14	5.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)

Table 1. MACHINE CONDITION INDEX ACCORDING TO ISO ISO 4406-1996

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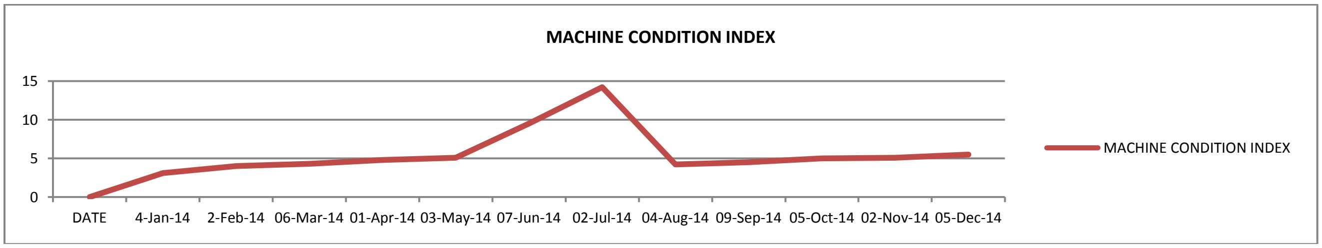
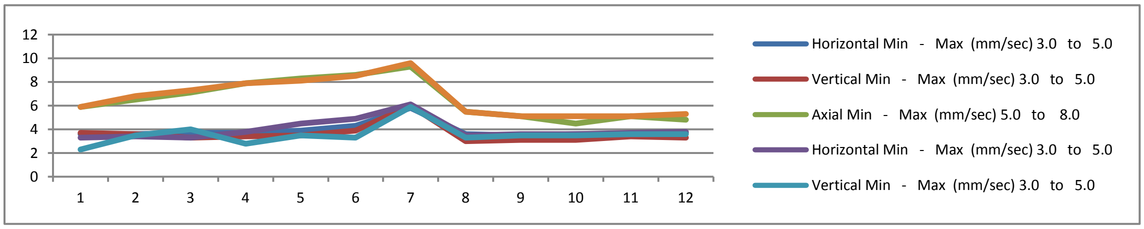
0 --NORMAL-- 5	6 --ABNORMAL-- 10	11--CRITICAL--15



Vibrational Analysis Report For Cooling Tower 1A:

The Vibrational analysis report for the cooling tower 1A is as shown in the figure.

PREVENTIVE MAINTENANCE (VIBRATION ANALYSIS REPORT)							
1A - COOLING TOWER FAN GEARBOX							
DATE	Vibration (Velocity) mm/sec.						
	DRIVE END			NON DRIVE END			Remarks / Actions
	Horizontal	Vertical	Axial	Horizontal	Vertical	Axial	
	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	
	3.0 to 5.0	3.0 to 5.0	5.0 to 8.0	3.0 to 5.0	3.0 to 5.0	5.0 to 8.0	
4-Jan-14	3.6	3.7	5.9	3.3	2.3	5.9	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
2-Feb-14	3.6	3.6	6.5	3.4	3.5	6.8	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
06-Mar-14	3.7	3.3	7.1	3.3	4.0	7.3	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
01-Apr-14	3.7	3.4	7.9	3.8	2.8	7.9	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
03-May-14	3.9	3.5	8.3	4.5	3.5	8.1	Oil sample tested found Alert. Vibration Limits are Also Raising trend. (Oil Report attached)
07-Jun-14	4.3	3.9	8.6	4.9	3.3	8.5	Oil sample tested found warning . Vibration Limits are Also Raising trend. (Oil Report attached)
02-Jul-14	5.8	6.0	9.3	6.1	5.9	9.6	Oil inspected, found metal particals gear box dismentled and inspetcedpinoin damaged, new spare pinoinrepalced.
04-Aug-14	3.6	3.0	5.5	3.5	3.3	5.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
09-Sep-14	3.5	3.1	5.1	3.6	3.5	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Oct-14	3.6	3.1	4.5	3.6	3.5	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Nov-14	3.6	3.4	5.1	3.7	3.6	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Dec-14	3.7	3.3	4.8	3.8	3.6	5.3	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)



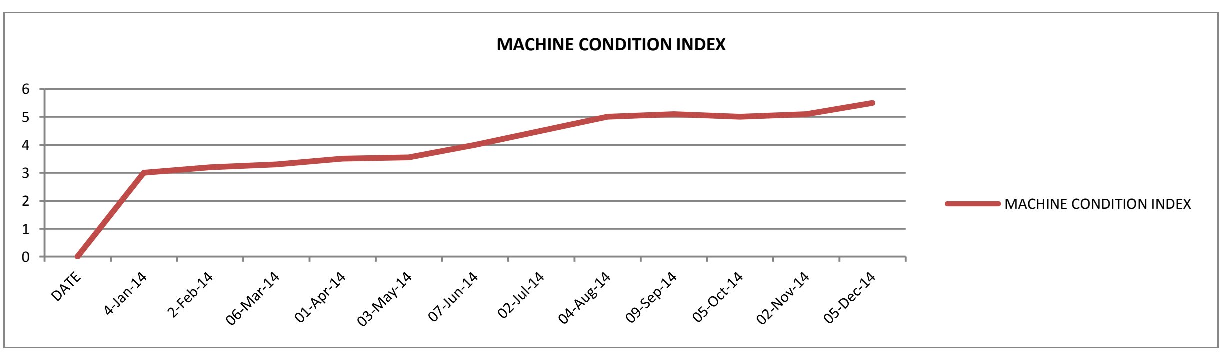
Oil Analysis Report For Cooling Tower 1B:

The Oil analysis report for the cooling tower 1B is as shown in the table 2.

PREVENTIVE MAINTENANCE (OIL ANALYSIS REPORT)		
DATE	**MACHINE CONDITION INDEX**	**Remarks / Actions**
4-Jan-14	3	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
2-Feb-14	3.2	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
06-Mar-14	3.3	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
01-Apr-14	3.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
03-May-14	3.55	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
07-Jun-14	4	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Jul-14	4.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
04-Aug-14	5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
09-Sep-14	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Oct-14	5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Nov-14	5.1	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Dec-14	5.5	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)

Table 2: MACHINE CONDITION INDEX ACCORDING TO ISO ISO 4406-1996

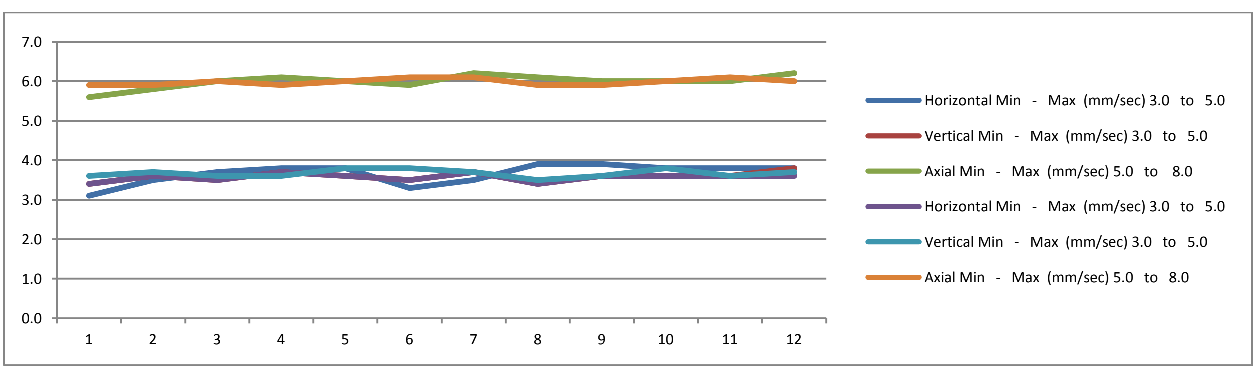
0	--NORMAL--	5	6	--ABNORMAL--	10	11	--CRITICAL--	15



Vibrational Analysis Report For Cooling Tower 1B:

The Vibrational analysis report for the cooling tower 1B is as shown in the figure.

PREVENTIVE MAINTENANCE (VIBRATION ANALYSIS REPORT)							
1A - COOLING TOWER FAN GEARBOX							
DATE	Vibration (Velocity) mm/sec.						Remarks / Actions
	DRIVE END			NON DRIVE END			
	Horizontal	Vertical	Axial	Horizontal	Vertical	Axial	
	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	Min - Max (mm/sec)	
	3.0 to 5.0	3.0 to 5.0	5.0 to 8.0	3.0 to 5.0	3.0 to 5.0	5.0 to 8.0	
4-Jan-14	**3.1**	**3.4**	**5.6**	**3.4**	**3.6**	**5.9**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
2-Feb-14	**3.5**	**3.6**	**5.8**	**3.6**	**3.7**	**5.9**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
06-Mar-14	**3.7**	**3.5**	**6.0**	**3.5**	**3.6**	**6.0**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
01-Apr-14	**3.8**	**3.7**	**6.1**	**3.7**	**3.6**	**5.9**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
03-May-14	**3.8**	**3.6**	**6.0**	**3.6**	**3.8**	**6.0**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
07-Jun-14	**3.3**	**3.5**	**5.9**	**3.5**	**3.8**	**6.1**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Jul-14	**3.5**	**3.7**	**6.2**	**3.7**	**3.7**	***6.1***	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
04-Aug-14	**3.9**	**3.4**	**6.1**	**3.4**	**3.5**	**5.9**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
09-Sep-14	**3.9**	**3.6**	**6.0**	**3.6**	**3.6**	**5.9**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Oct-14	**3.8**	**3.6**	**6.0**	**3.6**	**3.8**	**6.0**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
02-Nov-14	**3.8**	**3.6**	**6.0**	**3.6**	**3.6**	**6.1**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)
05-Dec-14	**3.8**	**3.8**	**6.2**	**3.6**	**3.7**	**6.0**	Oil sample tested found no abnormalities. Vibration Limits are with in range. (Oil Report attached)



V. CONCLUSION

Condition monitoring of the gear box fo the cooling tower through wear debris analysis and vibration analysis yielded the same results regarding the condition of both the gear boxes. Both the analysis reported abnormality in the 6th sample / visit and criticality in the 7th sample for the 1a cooling tower. Hear the equipment cost and time involved in the preparation of the reports is very much high in case of wear debris analysis when compare to vibration analysis however wear debris analysis gives an idea of the defective components of the gear box whereas the vibration analysis followed in this case needs spectrum analysis to get an idea on the defective elements of gear boxes but equipment capable of giving overall vibration and the spectra gives much quicker and precise results even in the case of vibration hence vibration analysis can be prepared over wear debris analysis considering the time and cost

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