Condition Based Maintenance (CBM) Through Vibration Spectrum Analysis for Improving the Reliability of B-1 Conveyor (DIVE542) Diagnosis of Fault through Vibration Spectrum Analysis Technique

K.RaviRaju, B.MadhavaVarma, N.Ravi Kumar

Abstract*— The success of a company often depends on the continued, safe and productive operation of rotating machinery. An effective maintenance program is vital to this kind of success. The quality of company's maintenance program determines how long the machines will run, how safe they are for the people working around them, and how productive the machine will be. Berar these things in mind while you consider the following benefits of a CBM program in greater detail. The operation and maintenance of high valuable machines is very important in increasingly stiff global market and requires that it provides maximum return on investment with minimum maintenance costs. Improving plant efficiency by implementation of latest techniques in maintenance can lead to significant savings with improvement in overall operating efficiency of plants. This project brings outs the importance of vibration analyzing in maintaining the machines. The vibration analysis can be simplified and make time saving by analyzing the FFT (Fast Fourier transform) or amplitude vs. frequency spectrum. By analyzing the spectrum we can estimate the cause of vibrations in the machine.

Keywords*— Fault diagnosis, CBM, FFT, vibration amplitude, Spectrum analysis, phase, and coast down,

I. INTRODUCTION

"CBM is a preventive maintenance initiated as a result of an item from routine or continuous checking "In the past decades, many successful efforts have been made to use vibration analysis as means for condition monitoring of rotating machinery. A number of methods such as statistical analysis and time domain analysis have shown a high Potential for the early detection of malfunctions and diagnosis of machines (Long and Boutin, 1996; Girdhar et al., 2004) [1]. CBM should mature to integrate technique to reduce data from all sources and channels into a centralized system that produces information accessible to all levels of the preventive maintenance. A number of methods such as statistical analysis, spectral analysis, etc. have been shown to offer high potential for the early detection of malfunctions and diagnosis of machines [2].

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Mechanical faults in rotating equipment's often show their presence through abnormal vibration signals compared the normal ones.Technique for machines condition monitoring based on the analysis of vibration signal is being used widely [1-4]. However most of the studies have been carried out on simple mechanical faults, such as gears, rolling bearings [5-7] and other rotating machines. [17-18]. Since the machines vibration amplitude-versus-frequency Characteristics will be presented in the form of graphics plots or FFTs, it is most important to use the same amplitude range for each FFT to simply the comparison of the data obtained at each bearing and measurement direction. If the data is presented with different amplitude scales, the interpretation and the evaluation of the data becomes an extremely tedious, time consuming and confusing task.

This paper deals with vibration analysis method based on time domain analysis for CBM. The importance of using the same full-scale amplitude range for each plot can best be illustrated by examining comparative horizontal, vertical and axial FFTs. This data was taken on the outboard (MNDE,MDE) bearings of the motor, and the full-scale amplitude range for each the FFTs are in 1.0in/sec. in this case, it is immediately apparent that the vibration amplitude in the horizontal direction at a frequency of 1800 CPM is nearly the same, yet would not appear so. For routine periodic checks, most FFTs data collector are used in an auto ranging mode which means that the instrument automatically selects the most appropriate full scale range for each overall measurements and FFT taken. While this is a great time saver when collecting routine data on many machines, when the data collector is being used to collect FFTs as a part of a detailed vibration analysis over riding the auto-ranging features to a "fixes" fill –scale range, simply taken and record overall amplitudes at each measurement point and a transducer direction to determine the highest amplitudes reading. Then simply select the lowest full-scale amplitude range that will accommodate the highest reading recording and leave the instruction set to this range for all FFTs. By doing this, all FFTs observed on the instrument display screen will be directly comparable in the field.

Identifying the problem component based on frequency: Most problems generate vibration with frequencies that are exactly related to the rotating speed of the part in trouble.

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Thus frequencies that are exactly related to the rotating speed of the part in trouble. Thus frequencies that are exactly 1x RPM or multiples (harmonics) of 1 RPM such as 2x,3x,4x,etc. in addition, same problem may cause vibration frequencies that are exact sub harmonics of 1 x RPM such as 1/2x, 1/3x,1/4 x RPM. In any event, the FFT analysis data cum relationship between the measured vibration frequency and the rotating speed of the various machine elements. In addition to identifying the problem machine component based on frequency, the second purpose of FFT analysis data is to limit or reduce the list of possible problems based on the measured vibration frequencies. As started earlier, each mechanical and operational problem generates its own unique vibration frequency, a list of the problems that causes or generate that particular frequency can be made, which greatly reduces the long list of possibilities. Excessive vibration at 4800 CPM which is 1 x RPM of the motor. This may be due to unbalance of the motor or structural vibrations or gear box vibration, CBM plays an effective role using the FFT analyzer for spectrum analysis to detect the fault the motor.

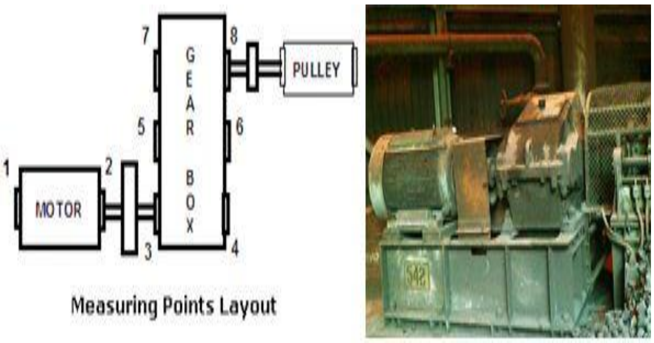

FIG.1 Motor Layout

Equipment Details

Equipment Type -Belt conveyor drive
Handling medium - burden (iron ore, sinter, coke)
Location - burden handling station in BF-1 (blast furnace-1)
Motor type - three phase induction motor.
Motor Speed - 990 rpm
Motor Power rating -200 kW
Gear box bearing type - spherical rollers
Type of bearing cooling - oil lubricated
Type of coupling - pin bush coupling
Belt type - Rubber
Idlers -Truffing, Impact,
Belt cleaning - Scrappers cleaning
Belt width -1.2 metes

MONITORING POINTS: Vibration readings are taken and respective spectrums, time waves and overall values are collected in vertical, horizontal and axial directions at the following bearing points. Total bearing points are 8 nos.

1. Motor non drive end bearing (MNDE).
2. Motor drive end bearing (MDE)
3. Gear box input shaft bearing point (GINP1)
4. Gear box intermediate shaft bearings (GINTR1)
5. Gear box output shaft bearings (GOUTP1)
6. Gear box input shaft bearing point (GINP2)
7. Gear box intermediate shaft bearing point (GINTR2)
8. Gear box output shaft bearing point (GOUTP2)

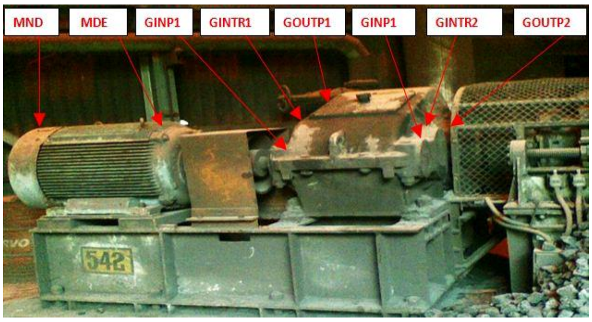

FIG2: monitoring points of motor and gear box.

Instruments used for data collection

1) **Single channel vibration analysis.**
   Make model: CSI 2117
   Frequency range: 10 Hz to 10 kHz
   Software : CSI Master Trend
2) **Dual channel vibration analyzer**
   Make model : Vibxpert 2011
   Frequency range: Frequency range: 0.5 Hz to 40 kHz
   Dynamic range : 96 Db.
   Software : Omini trend.

Fig.3 CSI and VIBXPERT, vibration analyzers

II. DATA COLLECTION

Vibration readings in mm/sec taken on 27/09/2012

NOTE: *Conveyor is running with (100%) full load.*

DIRECTION	MNDE	MDE	GINP1	GINP2
VERTICAL	0.8	0.7	2.4	2.2
HORIZONT-AL	1.2	1.4	1.8	1.4
AXIAL	1.7	1.6	1.3	1.2

DIRECTION	GINTR1	GINTR 2	OUTP1	OUTP2
VERTICAL	1.9	1.2	1.5	1.7
HORIZONTAL	2.1	1.7	1.9	1.8
AXIAL	1.7	2.0	1.7	1.4

All tabular form readings are taken in mm/sec with respect to motor full speed 900 rpm. As per ISO 2372 this equipment belongs to class-3 and the maximum vibration limit for this equipment is 4.5 mm/sec. The above Readings are within the limits

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Fig .4 Taking readings at output motor drive end readings.

Fig .5 Taking readings of output gear shaf

Vibration readings in mm/sec taken on10/10/2012
NOTE: *Conveyor is running with (100%) full load*

DIREECTON	MNDE	MDE	GINP1	GINP2
VERTICAL	0.9	0.8	2.4	2.5
HORIZONTAL	1.5	1.3	1.8	1.2
AXIAL	1.6	1.7	1.3	1.4

DIREECTON	GINTR1	GINTR 2	OUTP1	OUTP2
VERTICAL	2.0	1.5	1.1	1.9
HORIZONTAL	2.3	1.5	2.3	1.3
AXIAL	2.0	2.3	1.6	1.2

As per ISO 2372 this equipment belongs to class-3 and the maximum vibration limit for this equipment is 4.5 mm/sec. as compared to previous reading this reading slightly increased but within the limits

Vibration readings in mm/sec taken on 16/12/2012
NOTE: *Conveyor is running with (100%) full load.*

DIREECTON	MNDE	MDE	GINP1	GINP2
VERTICAL	2.1	3.7	2.5	2.6
HORIZONTAL	6.3	6.8	1.5	2.0
AXIAL	1.3	1.7	1.2	1.5

DIREECTON	GINTR1	GINTR2	OUTP1	OUTP2
VERTICAL	1.3	1.5	1.2	1.2
HORIZONTAL	2.2	1.8	1.2	1.7
AXIAL	1.7	2.1	1.5	1.4

Fig6. Takeing vibration readings at MDE and MNDE

Fig.7 Taking the readings at motor points and gear points

Vibration readings in mm/sec taken on 19/12/2012
NOTE: *Conveyor is running with (100%) full load*.

DIRECTION	MNDE	MDE	GINP1	GINP2
VERTICAL	**2.2**	**3.8**	**2.7**	**2.8**
HORIZONTAL	**7.9**	**7.1**	**1.4**	**1.9**
AXIAL	**2.7**	**1.8**	**1.7**	**1.8**

DIRECTION	GINTR1	GINTR2	OUTP1	OUTP2
VERTICAL	**1.4**	**1.7**	**1.4**	**1.3**
HORIZONTAL	**2.0**	**1.9**	**1.3**	**1.8**
AXIAL	**1.9**	**2.2**	**1.6**	**1.8**

Phase readings taken on 19/12/2012
NOTE: *Conveyor is running with (100%) full load*

DIRECTION	MNDE	MDE	GINP1	GINP2
VERTICAL	**122**	**125**	**120**	**115**
HORIZONTAL	**216**	**217**	**210**	**211**
AXIAL	**95**	**92**	**90**	**89**

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DIRECTION	GINTR1	GINTR2	OUTP1	OUTP2
VERTICAL	114	117	116	119
HORIZONTAL	210	218	216	114
AXIAL	94	92	93	92

Phase and corresponding vibration amplitude readings are taken in the coast down test in horizontal direction on 21/12/2012 NOTE: *Conveyor is running with (100%) full load*

SLNO	SPEED IN RPM	PHASE IN DEGREES	VIBRATION AMPLITUDE IN mm/sec
1	995	216	7.9
2	963	216	7.7
3	918	215	6.8
4	874	217	5.8
5	832	216	5.5
6	791	215	4.8
7	751	214	4.5
8	691	216	4.0

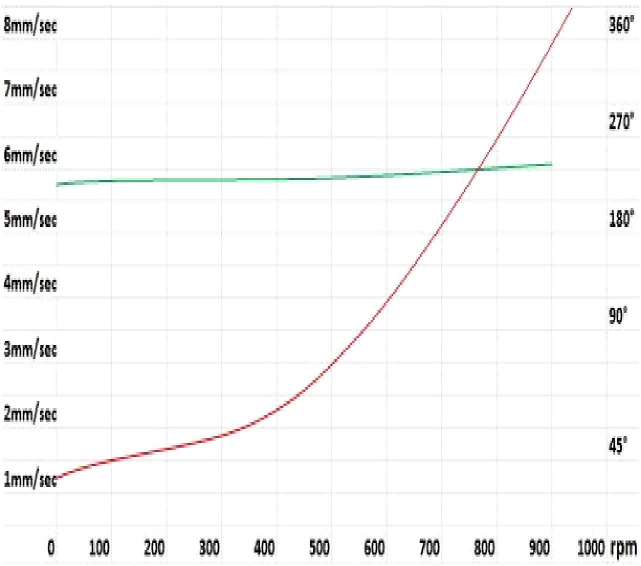


Fig.7 BODO PLOT: This graph gives the phase and amplitude difference at a time in coast down test

The phase difference and amplitude with respect to rpm of motor are normal and there is no electrical problem in the motor, coast down readings are taken without electrical supply to motor, sudden cut-off supply to motor from its maximum rpm.

Vibration readings mm/sec taken on 19/12/2012 NOTE: *Conveyor motor was decoupled and solo-run is taken the vibration readings are given below.*

DIRECTION	MNDE	MDE
VERTICAL	1.6	1.2
HORIZONTAL	2.8	3.4
AXIAL	1.2	1.6

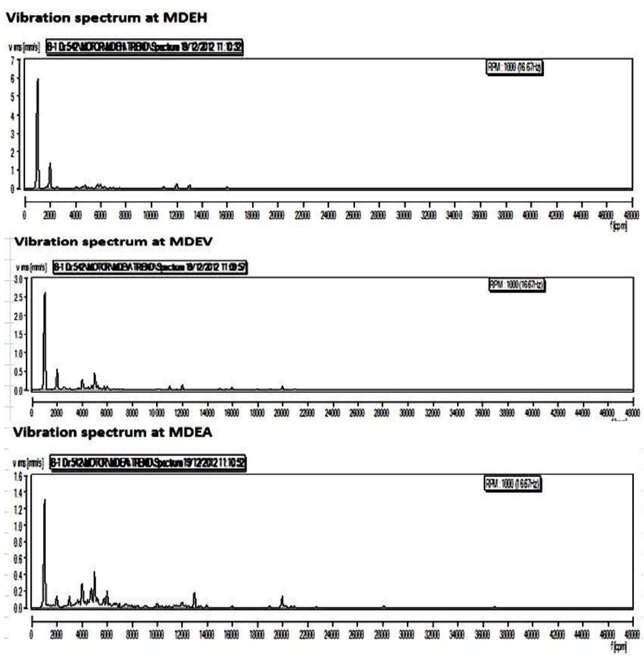
III. OBSERVATIONS AND DISCUSSION

From the above data it is noticed that Motor both MDE and MNDE bearing vibrations increased suddenly. Phase readings reveals that the phase shift between vertical to horizontal direction at motor both bearings is 90 degrees (approximately) and on the structure also same difference is noticed. In the coast down test it is noticed that the vibration amplitude is decreased with the corresponding decrease in the speed and the phase is almost stable. In the solo run test also same phenomena is observed with low level of vibration amplitude. Old motor was removed for scheduled maintenance (overhauling) and another motor was placed on the bed. Motor base vibration readings are also suddenly increased from 0.7 mm/sec to 2.5 mm/sec and proportionate ration is maintained from bottom to top.

Measurement specifications

Data is collected in terms of waveforms and spectrums
Amplitude is measured in mm/sec velocity (RMS)
Frequency measured in terms of cycles/min
Frequency range : 0 to 160000cpm
Sampling time for waveform – 4 sec
Resolution varies from 100 to 6400 lines in FFT spectra.
Data storage capacity – 1000kb
Number of averages – 1 to 9999
After data is recorded at the site from analyzer at is dumped into host computer for further analysis

Very high vibration at MDE of bearing in horizontal is 6.3mm/sec at 900 rpm of motor



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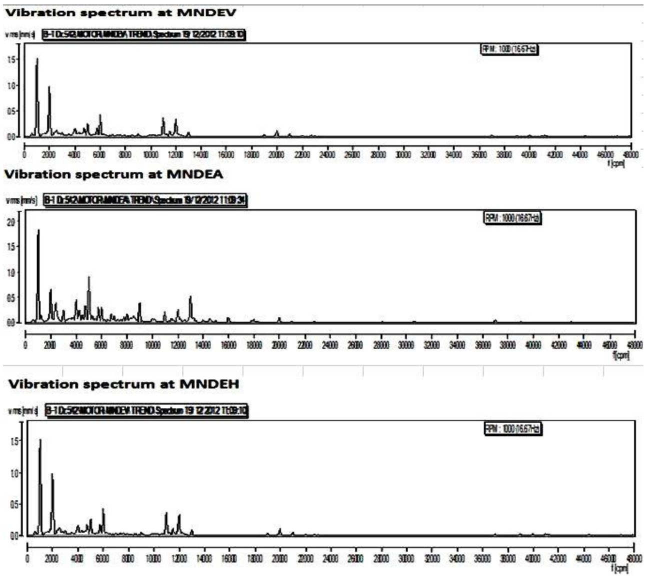

Fig 8. Spectrums of the motor in vertical, horizontal and axial directions are taken with vibxpert. The spectrum is in RMS (mm/sec) vs. frequency (cpm)

SPECTRUM ANALYSIS: In the spectrums predominant peak is observed at 1x rpm frequency (i.e. fundamental frequency at the MNDE at 6.3 mm/sec at 900 rpm ,The phase difference between vertical to horizontal direction at motor both bearings is 90 degrees . Decrease in vibration amplitude with the corresponding decrease in the speed and almost stable phase readings. The above three points and observations indicating that the motor rotor was unbalanced and there is no structural weakness. The motor was given for engineering work shop to unbalance because there is high vibration in horizontal direction at MNDE and MDE of the motor, as it results in 1 x rpm, no other harmonics present. After balancing the motor the healthy readings are in the below tabular form.

Vibration readings in mm/sec taken on23/12/2012

NOTE: Conveyor is running with (100%) full load.

DIRECTION	MNDE	MDE	GINP1	GINP2
VERTICAL	1.2	1.4	2.2	2.6
HORIZONTAL	2.2	2.4	1.7	1.4
AXIAL	1.5	1.8	1.4	1.6

DIRECTION	GINTR1	GINTR2	OUTP1	OUTP2
VERTICAL	2.2	1.8	1.3	2.0
HORIZONTAL	2.4	1.6	2.5	1.5
AXIAL	2.1	2.5	2.1	1.6

IV. CONCLUSION

The motor rotor was balanced, approximately 50 grams of weight is added to the rotor .After placing the over hauled motor on the bed alignment was done and trial run taken it is found that vibrations are decreased. The equipment is running smoothly and the present vibration readings are within the limit as per ISO 2372, and are 2.2 mm/sec at MNDE and 2.4 mm/sec at MDE.

V. NOMENCLATURE

CPM = cycle per minute.
RMS= root square mean value (mm/sec)
t = time
FFT = Fast Fourier transformations
CBM= condition based maintenance.

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