Diagnosis of Antifriction Bearing Defects by Vibration Monitoring and Frequency Analysis –Some Case Studies

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Abstract—**Defective antifriction bearing is one of the important causes of machinery vibration. Catastrophic failure of the antifriction bearing of any critical machine in process industry leads to unplanned shut down of entire process which turns in to production loss and increased cost of maintenance. Monitoring of Bearing vibrations and its analysis helps to detect or diagnose bearing problems. Authors have come across many vibration related problems of rotating machines where vibration monitoring, analysis and fault diagnosis technique has implemented to detect mechanical faults. Present paper deals with review of implementation of this technique and some case studies.**

Index Terms—**Preventive maintenance, condition monitoring, vibration analysis, Fault diagnosis.**

I. Introduction

A Number of rotating machines namely crushers, pulverizers, blowers, centrifuges, agitators, conveyors etc. are linked together in process industry to perform production cycle of a particular product. Catastrophic failure of any one of these machines disrupts entire process with staggering losses in terms of production, manpower, money. For example failure of a bearing of fiberizer or a coupling of steam turbine in sugar industry causes plant stoppage of minimum of eight hours and costs more than $3500 for its repair and replacement .In order to minimize the production loss and to reduce production cost it is essential to implement preventive maintenance technique for rotating machines in process industry like cement, sugar and refinery etc. The condition based preventive maintenance through vibration monitoring, analysis and fault diagnosis is the technique that has proven its best suitability for all kind of rotating machines. The concept of using vibration monitoring, analysis for fault diagnosis for preventive maintenance of rotating machines is based on three facts-

i)Firstly, it is normal for machine to vibrate. Even machine in excellent condition have some measurable vibrations because of small and minor defect. Therefore each machine will have a level of vibration that can be regarded as normal and acceptable.

ii)Secondly, when machinery vibration increases or become excessive, mechanical trouble is usually the reason. Thus monitoring of machines vibration will provide warning about trouble.

iii)Finally, each mechanical defect such as unbalance, misalignment, worn gears, looseness, faulty bearing etc. generate vibrations in its own way. Therefore analysis of vibration makes it possible to identify the machine fault.

General procedure of preventive maintenance of rotating machine consist of measurement of overall vibration levels of the machine periodically and recording it on vibration monitoring data sheet. Measurement of vibration is carried out on all the bearings of machine in three directions viz. horizontal, vertical and axial. Vibration monitoring record thus obtained is used to decide condition of the machine as on monitoring date and to see the trend of vibration over the past duration. Vibration severity criterion such as ISO:2372 , ISO:10816 , IRD Mechanalysis criterion for vibrations in rotary machine is used to decide the condition of machine. If the vibration level of machine exceeds the permissible value specified in the criterion, further analysis is carried out by taking frequency spectrum and vibration phase plot of the machine. Frequency spectrum gives the value of predominant frequency of vibration.

By correlating overall vibration levels, predominant frequency and nature of phase with the machine parameters viz. speed, bearing number, no. of blades in case of fans etc., exact fault responsible for abnormal vibration is pinpointed. Table No.1 helps to diagnose fault with the help of frequency analysis. Once the fault is detected, it is rectified during planned shutdown or on weekly holiday by carrying out repair, replacement of component or modification in machine. Authors have used this technique in different sugar industries during this decade by which many catastrophic failures and plant shut downs were avoided. This presentation gives case studies related to the bearing failures and their diagnosis.

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TABLE I. TYPICAL VIBRATION CHARACTRITICS OF MACHINE FAULTS

Type of Fault	Nature of vibration Amplitude	Frequency of vibration	Phase
Unbalance	Proportional to unbalance largest in radial direction	1 x RPM	Steady, single reference mark
Parallel misalignment in coupling	Large in radial and vertical directions	2 x RPM	Two reference mark
Angular Misalignment in coupling	Largest in axial direction	1 x RPM	Single reference mark
Bad antifriction bearings	Unsteady vibrations, High value of vibration acceleration	Several times RPM	Erratic reference mark
Bad gears	High value of vibration velocity and acceleration	Gear teeth times RPM	Erratic reference mark

II. TYPES OF BEARING FAILURES

Antifriction bearing fails in different way. If it is mounted on the shaft with the help of sleeve, interference fit between shaft and sleeve may change during operation and sleeve become loose on the shaft .This condition is a mechanical loosens which causes higher vibration on that particular bearing as compared to the vibrations on the other bearings of the machine. Such vibration gives a peak at 2 x RPM of the shaft. However if unbalance exists in the rotor, frequency analysis revels peak at 1 x RPM as well as 2 x RPM. Similar looseness condition may occur if sleeve taper and bore taper of the bearing do not match properly. During mounting of such bearings it may appear that sufficient grip between sleeve and inner race has achieved however due to partial surface contact between sleeve and bore, the grip diminishes over the period of time due to dynamic loading and assembly becomes loose. It has been observed that looseness in the bearing occur due to oversize machining of the bore of pedestal. Such looseness gives vibration frequency at 2 x RPM of the shaft.

Another typical characteristic of this type of failure is increased bearing temperature .Looseness permits relative motion between bearing pedestal and outer race of the bearing which are supposed to operate in the condition of interference fit. The relative motion causes heavy friction under working condition and subsequent temperature rise at mating surfaces. Authors have experienced such bearing failures where bearing sleeve seized with shaft and inner race so immensely that for removal of seized sleeve and inner race the gas cutting was used.

Second type of failure of the bearing is related to the fatigue. Pits are developed on inner race track, outer race track or on rolling elements of the bearing due to fatigue. Development of pits takes place gradually and severity of vibration on such bearing depends on number pits developed and their depth. Usually such bearing failure revels gradual increment in the vibrations at frequency many times rotating speed of the machine. Authors have come across such failures in the bearings and it has been found that failure of the bearing by pitting always give high acceleration value at frequency many times speed of the shaft.

Third type failure is fracture of the inner race of the bearing. This failure takes place due to heavy interference between inner race and shaft or sleeve in case of sleeve mounted bearing. This happens because in general coefficient of expansion of the shaft or sleeve is larger than the inner race. Under the condition of poor quality and quality of lubricant or due to failure of cooling system the shaft and sleeve expand more than inner race causing further increase in interference which ultimately causes crack in inner race. Usually such failures are catastrophic in nature and only be diagnosed in time by continuous monitoring system in which vibration sensors are mounted permanently on each of the bearings and continuous on line signal processing is carried out.

III. CASE STUDIES

A. Case Study No.1

This case study is of Fiberizer machine used in one of the sugar industries. The function of the machine is to cut the sugar cane before it fed to extraction process. The machine speed is usually kept between 650 to 750 rpm and power of the machine prime mover is about 1250kW. The vibration level on non-drive end bearing of the machine was severe. In order to diagnose the fault in the machine, spectrum analysis was carried out. Frequency spectra were taken on the non-driving end bearing of the machine.Figure 1a to 1c shows these spectra.

Frequency spectra revealed predominant peak at frequency of 2 x RPM of the machine. The misalignment of the coupling and looseness in the bearing were the possible causes. Coupling assembly was checked and it was found to be within permissible limit. Hence the possible cause was looseness in bearing assembly. Therefore bearing assembly was opened to see its condition. It was observed that sleeve was loosely fitted on the shaft. The gap between shaft and sleeve was found to be 0.3mm. The sleeve was tightened fully to keep clearance between rolling element and outer race of 200 microns. After tightening the sleeve vibration levels were found well within limit. Figure 2 a to 2c shows spectra after rectification.

B. Case Study No.2

This Case study is of similar machine at another sugar factory. During crushing season of 2012 all of sudden vibration levels of the machine increased to the abnormal condition. High level of vibration acceleration was recorded. Frequency spectra taken on the bearing revealed predominant peak at frequency of 3 x RPM of the machine.

High value of acceleration with frequency at 3 x RPM is indicative of damaged bearing. Hence it was recommended to replace the bearing. On recommendation, the bearing is replaced by new one. After replacement of the bearing,

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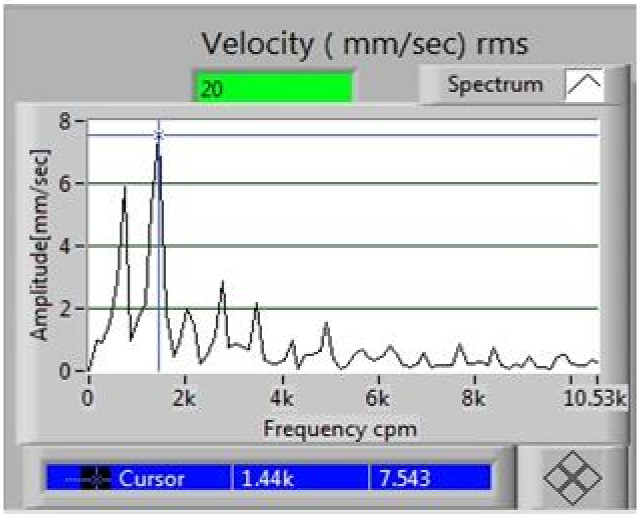

Figure 1a. Velocity Spectrum

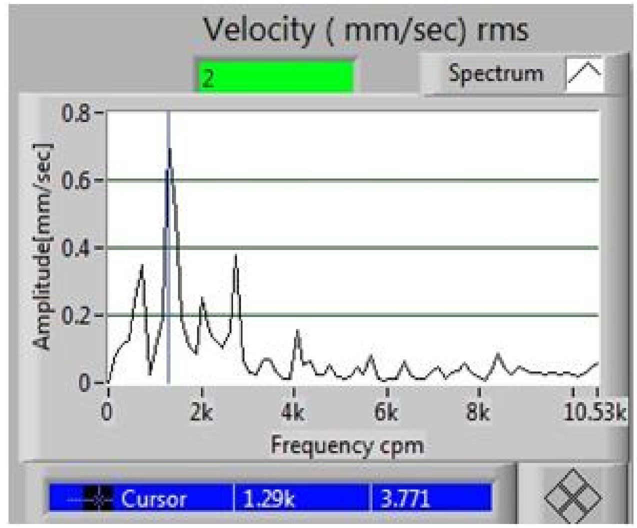

Figure 2a. Velocity Spectrum

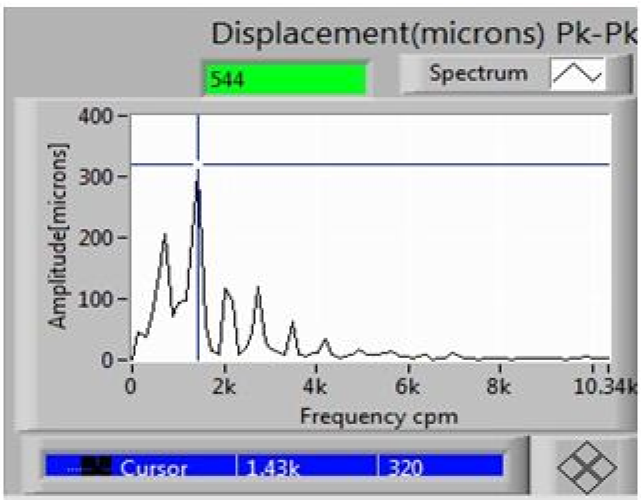

Figure 1b. Displacement Spectrum

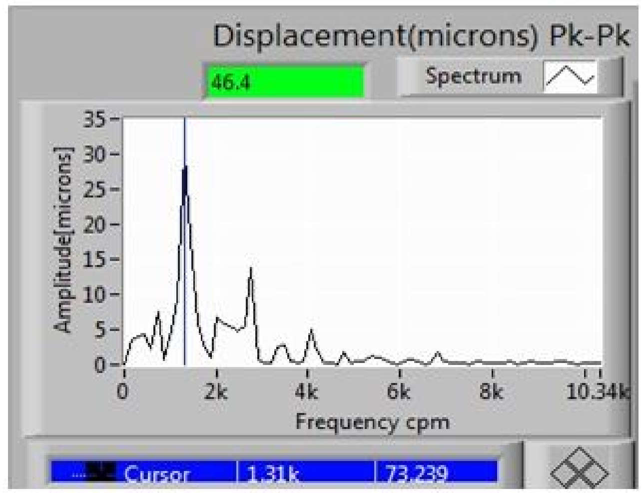

Figure 2b. Displacement Spectrum

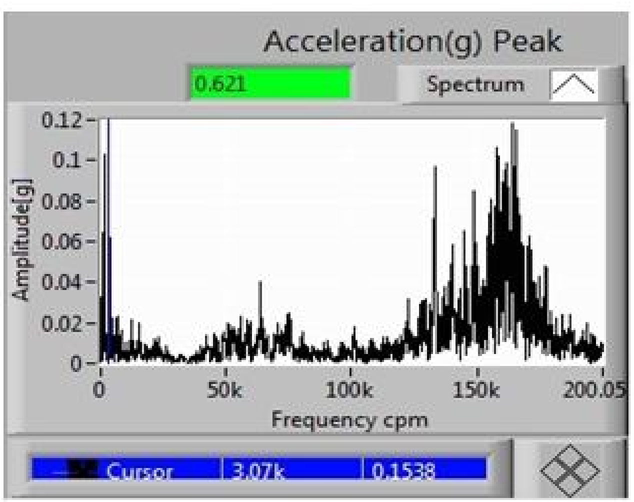

Figure 1c. Acceleration Spectrum

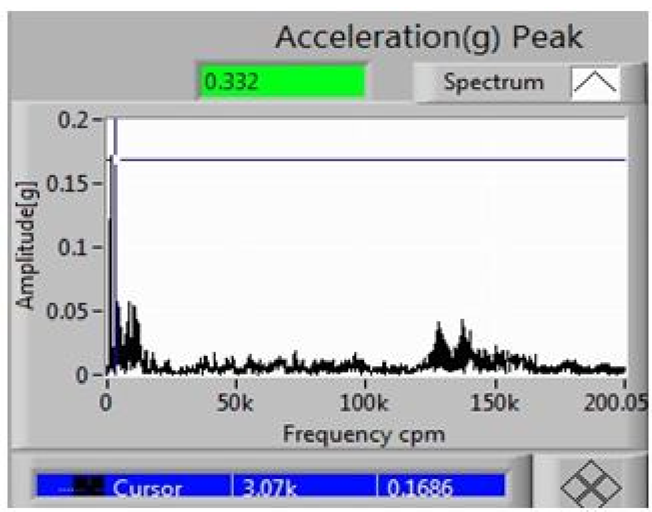

Figure 2c. Acceleration Spectrum

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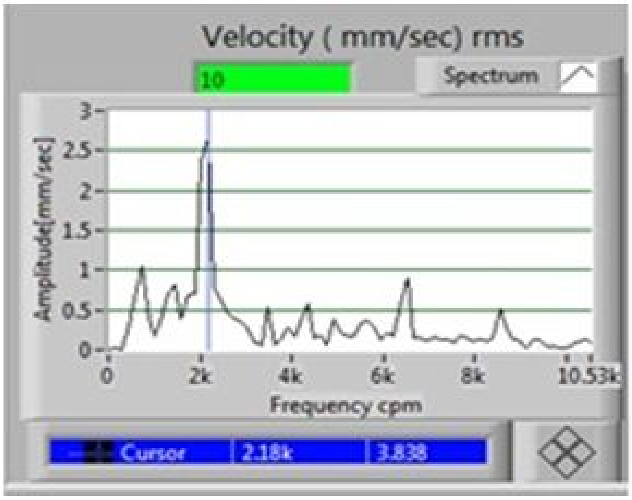

Figure 3a. Velocity Spectrum

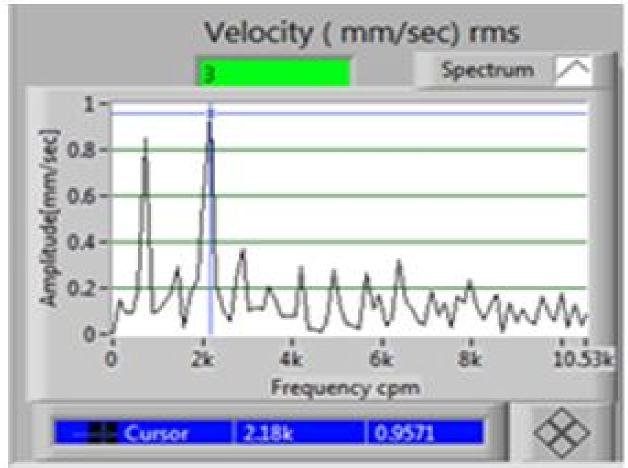

Figure 4a. Velocity Spectrum

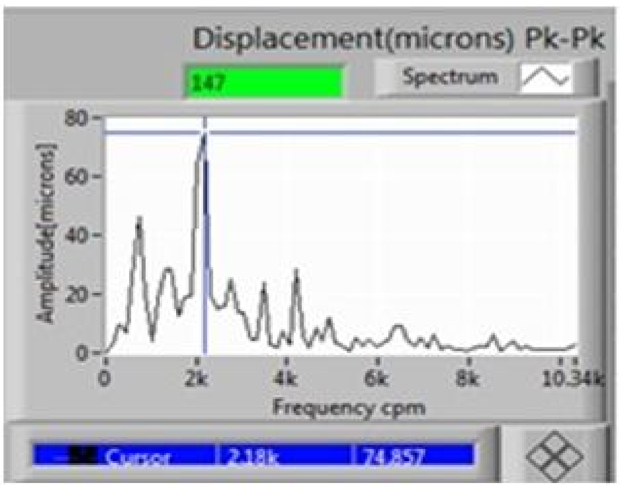

Figure 3b. Displacement Spectrum

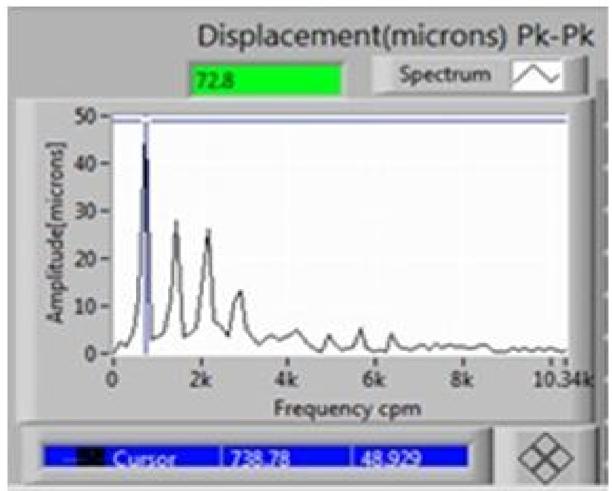

Figure 4b. Displacement Spectrum

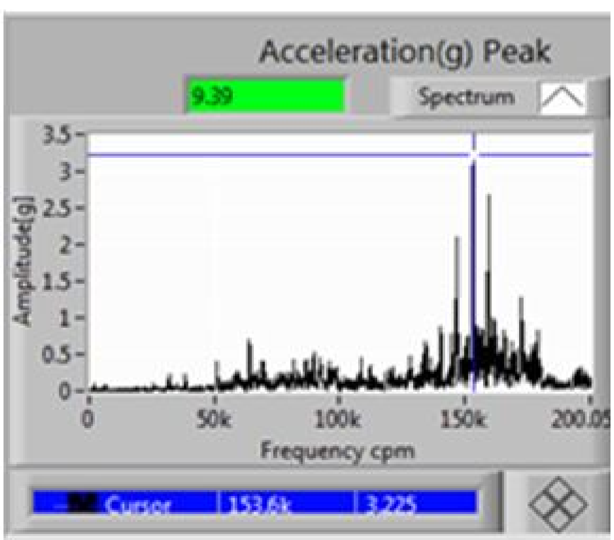

Figure 3c. Acceleration Spectrum

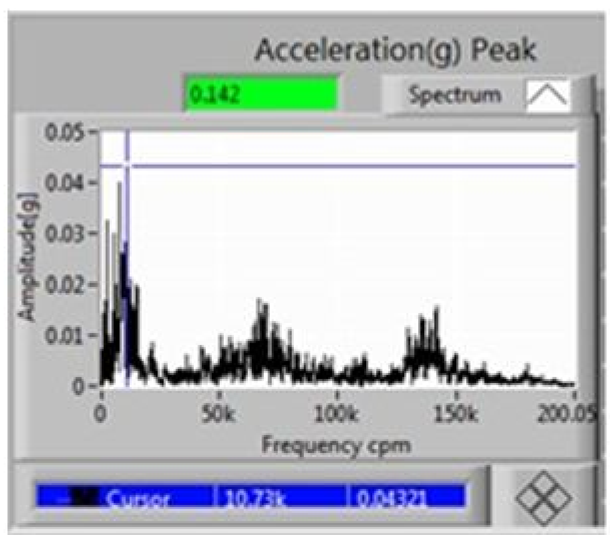

Figure 4c. Acceleration Spectrum

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vibration levels reduced to the normal. Figure3a to 3c shows vibration spectra for velocity, displacement and acceleration before rectification of the fault. Figure4a to4c shows corresponding spectra after rectification.

Conclusions

From the spectra from both the case studies ,it is clear that whenever bearing fault occur velocity as well as displacement of vibration increase to higher level, however acceleration of vibration do not increase considerably if looseness exist in the bearing assembly .The acceleration of vibration increases to high level if either rolling elements or race fails .

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