Experimental Study to Identify the Vibration Signature of Bent Shaft

Ms. Pallavi Khaire
Department of mechanical engineering organization,
Fr. C. Rodrigues Institute of Technology,
Navi mumbai, India

Abstract— **Rotor systems have been widely used in mechanical engineering. The dynamics of rotor systems have been studied for over a century. With the high speed demand of today's machinery, it becomes more important than ever. Bent shaft is one of the common causes of machine vibration. Any defect in machine will affect vibration behavior and nature of this effect is different for different faults. Understanding and practicing the fundamentals of rotating shaft parameters is the first step in reducing unnecessary vibration, reducing maintenance costs and increasing machine uptime. In Industry 35% of the machine's down time is due to the poorly aligned machine and bending of shafts. Vibration signals give early indication of mechanical failures such as misalignment, unbalance and bent shaft etc. Hence condition monitoring based on vibration measurements can be used to identify bent shaft defects qualitatively. Many researchers have reported bent shaft related faults show dominant peak at 1×. The present study deals with experimental investigation of detecting unique vibration signature for bent shaft. Experimental studies are performed on a rotor dynamic test apparatus to predict the vibration spectrum for shaft bending when a shaft is bent at coupling end. A four pin type flexible flange coupling is used in the experiment. The rotor shaft vibrations are measured by using FFT analyzer. These acquired spectrums are compared with available literature for confirmation of experiment results. Experimental results shows that bent in shaft can be characterized primarily by 1X and 2X shaft running speed. The results are in good agreement as reported in literature review. The experimental study is carried out for baseline condition also to identify the change in vibration amplitude for baseline condition and bent shaft.**

Keywords— Flexible flange coupling, Bent shaft, FFT Analyzer

I. INTRODUCTION

Rotating machines are engines that transform the input energy, such as electrical energy, into useful energy. The findings show that bearing related faults are the most common machine faults, accounting for about 40% of total machine failures. Considering the importance of the bending in the shaft, detecting and diagnosing the bent is still elusive. The main causes of mechanical vibration are bent rotor shaft, unbalance, misalignment, looseness and distortion, defective bearings and so on. These are some of the most common faults that can be detected using vibration analysis.

Rotor shaft bending is the common problem in the operation of rotating machinery and is the heart of any industry. Due to current trends in the design of rotating machinery towards higher speeds manufacturers are tending to produce machines which operate closer to lateral critical speeds than has previously been necessary. The effect of coupling upon the critical speeds and its misalignment on vibration amplitudes of such machines is becoming an increasingly important consideration for rotor bearing systems. Perfect alignment of the driving and driven shafts cannot be achieved in practical applications thus a bent and misalignment condition is virtually always present in machine.

Identification of all above fault in machine is very important to avoid catastrophic failure. Vibration analysis is an important tool for identification of these defects. These aspects motivated in the present study to explore and confirm the effect of bent shaft on the vibration spectrum.

As per Mobius institute [1], the shaft may bend due to excessive heat, due its length, or it may be physically bent. A bent shaft predominantly causes high 1X axial vibration. The dominant vibration is normally at 1X and if the bend is near the center of the shaft, however 2X vibrations occurs if the bend is closer to the coupling. Vertical and horizontal axis measurements will also often reveal peaks at 1X and 2X, however the key is the axial measurement. Phase is also a good test used to diagnose a bent shaft. The phase at 1X measured in the axial directions at opposite ends of the component will be 180° out of phase [1].Suri Ganeriwala [2] studied bearing vibration and reaction force signatures caused by bent shafts were studied experimentally. The vibration and force spectrum signatures between baseline and bent shafts (center bent and coupling end bent) under two shaft speeds, 1000-rpm and 5000-rpm,were compared. The experiment results indicate that a center bent shaft will increase the bearing vibration and the vibration amplitude shows dominant peak at 1X of the shaft speed. However, a coupling end bent shaft gives peaks at 1X and 2X of the shaft speed. 2X amplitude is more than amplitude at 1X in case of coupling end bent [2].

V. Hariharan, P.S.S.Srinivasan [3] studied effect of parallel misalignment on a rotor shaft with a rigid as well as flexible coupling. An experimental set up with rigid and flexible coupling is designed and manufactured. The setup is modeled in ANSYS and simulated. A parallel misalignment of 0.2mm is created in the set up with rigid coupling and the frequency spectrum is acquired. A rigid coupling is changed by a flexible coupling and same tests are carried out. These tests are simulated in ANSYS and results are compared which found to be in good agreement. They concluded that by using flexible coupling vibrations are reduced by 85-89% [3]. It is revealed from the literature study that it is important to detect the fault at earlier stage, so that the machine life can be enhanced with less cost. It is clearly proven that bent produces high vibration level in bearings. Therefore it is proposed to investigate experimentally the effect of bent shaft on frequency spectrum using flexible flange coupling and validate the typical spectrum reported in literature.

II. EXPERIMENTAL SETUP

The experimental setup is shown in fig. 1. The experimental setup consist of a 0.25 HP D.C. motor with extended shaft, a flexible flange coupling, single disk rotor and three identical self aligned ball bearing. The driven shaft is supported by two bearing and has a length of 430 mm with a bearing span of 300 mm. The diameter of shaft is 15.875mm.

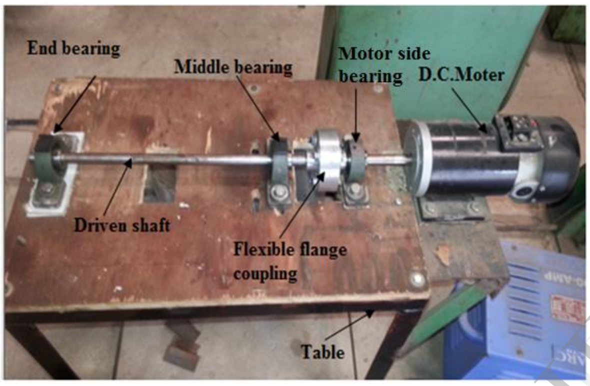

Fig .1. The experimental setup

Pedestal bearings are used in setup for supporting motor shaft. A four pin type flexible flange coupling is used to connect motor shaft and driven shaft. The bearing which is near to the coupling on driven side is called as middle bearing. Bearing fitted at the end of driven shaft is called as end bearing. Two shafts were tested in the experiment. Initially a straight shaft without bend is used for baseline condition. Later it is replaced by a shaft which has a bent at coupling end. A piezoelectric, Triaxial, shear type accelerometer (Type AC102-A, Sl. No 66760) is used along with the Photon+ (Bruel and Kajer make) ultra portable dynamic signal analyzer. This is a multichannel data recorder. The data acquired by Photon+ data recorder is processed with FFT software and then the measured vibration data are collected at a computer terminal through RT-PHOTON+ interface. Vibrations are measured in frequency domain. Therefore output display in terms of frequency vs amplitude graph is selected in RT-PHOTON software. Vibration amplitude is measured in terms of displacement. For measuring 1600 spectral lines, frequency band of 0-40 Hz. The vibration sensor is mounted on top of bearings for acquiring signal. A speed regulator is used to vary the motor speed.

III. EXPERIMENTAL PROCEDURE

Initially the rotor system is checked for alignment. To do this, the dial gauge method is used to make perfect alignment. Also, the surface level is checked by using spirit level. The setup is allowed run using shaft without bent for few minutes to allow all minor vibrations to settle. Then, the accelerometer is fitted on the bearing housing and connected with the FFT analyzer. Next, the vibration data measured by using FFT analyzer and saved in a computer. A typical vibration spectrum is acquired on the middle bearings for three different speeds viz. 300rpm, 600rpm and 900rpm to study the behavior of vibration frequency spectrum at different speeds and to check whether the unique signature of vibration on frequency spectrum is dependant of speed or not. Later the driven shaft is replaced by a bent shaft and same experimental procedure is followed and vibration spectrum is acquired on middle bearing for bent shaft.

IV. RESULTS AND DISCUSSION

Experimental study has been carried for investigating the effect of shaft bending on vibration spectrum. The results of the experimental study for baseline condition and bending are also compared.

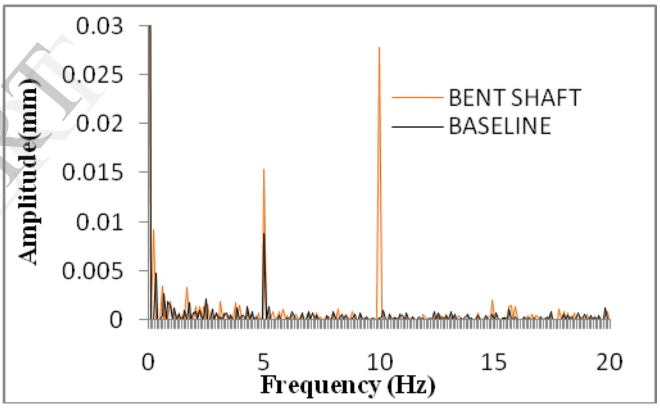

Fig .2. Comparison of baseline and bent shaft experimental study results on middle bearing at 5 Hz

The vibration spectrum acquired on middle bearing at a frequency of 5 Hz for aligned condition and for bent shaft is shown in figure 2. It shows the comparison of results obtained from aligned condition and bent shaft. At 300 rpm the maximum vibration amplitudes observed are 0.015mm and 0.027mm respectively from experimental results of bent shaft. For aligned condition the maximum amplitude is seen at 0.008mm which is very small as compared to the vibration spectrum for bent shaft. It means if in a shaft bent is present near coupling end 1X and 2X of the shaft speed shows dominant peak. Figure 3 and figure 4 shows Comparison of baseline and bent shaft experimental study results on middle bearing at 10 Hz, 15 Hz respectively. From figure 3 and figure 4 it is observed that the dominant peak for bent shaft occurs at 1X and 2X the shaft speed.

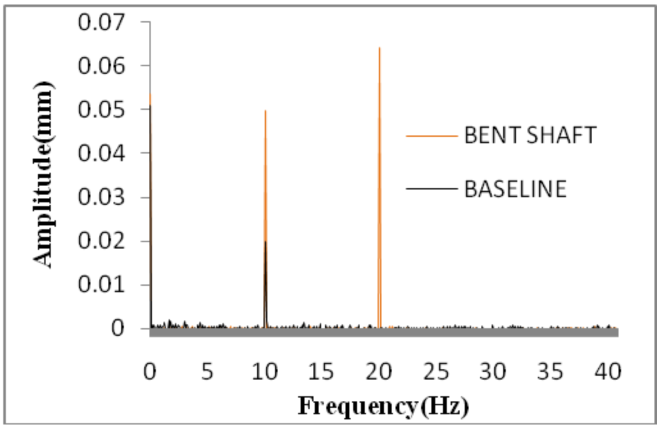

Fig .3. Comparison of baseline and bent shaft experimental study results on middle bearing at 10 Hz

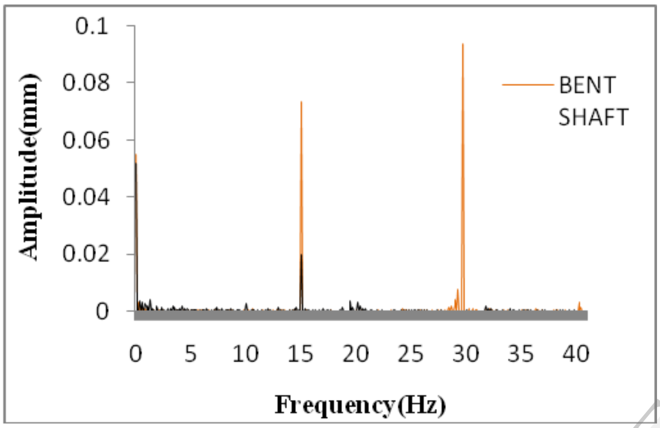

Fig . 4. Comparison of baseline and bent shaft experimental study results on middle bearing at 15 Hz

V. CONCLUSION

It is found from the experimental study that the bent shaft at coupling end shows dominant peak at 1X and 2x of rpm. This unique signature is independent of speed of the shaft since it shows same unique characteristics at 300rpm , 600rpm and 900 rpm. For a shaft having bent at coupling side shows maximum amplitude at 2X rpm as compared to 1X. It is also observed that as the speed increases vibration level experienced is more. These observations are in close agreement as reported in literature.

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