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Shaft Misalignment Detection using Stator Current Monitoring

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Abstract

This paper inspects the misaligned of shaft by using diagnostic medium such as current and vibration. Misalignments in machines can cause decrease in efficiency and in the long-run it may cause failure because of unnecessary vibration, stress on motor, bearings and short-circuiting in stator and rotor windings. In this study, authors investigate the onset of instability on a shaft mounted on journal bearings. Shaft displacement and stator current samples during machine run up under misaligned condition are measured, analyzed and presented here. Verification of shaft alignment is done by precision laser alignment kit. Result shows that misalignment is the parameter that is more responsible for the cause of instability.

Keywords

Misalignment, Motor current signature analysis, Fault Diagnosis, Induction Motor.

1. Introduction

Misalignments are common mechanical fault conditions in induction machine applications. Particularly in industrial process electric motors experience a wide range of mechanical problems. Misalignment causes a decrease in motor efficiency, and misaligned machinery is more prone to failure due to increased loads on bearings and couplings. It causes over the 70% of rotating machinery vibration problems [1]. Misalignment may be present because of thermal distortion, improper machine assembly and asymmetry in the applied load. Since a perfect alignment and balance between rotor shafts cannot be achieved practically, a misalignment is virtually always present in the machine. However it will be within an acceptable level. Hence, an in-depth knowledge on the vibration characteristics is helpful for understanding and diagnosing the rotor shaft misalignment to avoid any failure or damage. Apart from this a poorly aligned, balance machine and motor vibration can cost a steel industry 20% to 30% in process down time and poor quality.

Misalignment of machinery shaft cause reaction forces in the coupling, which has effect on the machine and this is a major cause of machinery vibration [2]. Gibbons [3] derived the misalignment reaction forces generated in different couplings. Sekhar and Prabhu [4] numerically evaluate the vibration response of the rotor for the coupling misalignment. They suggest 2X vibration response as characteristics signature of misaligned shaft. It shows that mystery still surrounds the exact response of vibration for the misalignment.

Misalignment in a motor drive system is a condition where the centerlines of coupled shafts do not coincide. This is one of the severe conditions that occur very frequently in motor drive systems and are most of the time responsible for drive failure [5]. Shaft misalignment effects negatively influence the rolling, sealing and coupling parts and can also produce eccentricity in the air-gap. The misalignment conditions are broadly classified as angular (offset) and parallel and combination of these two. Offset misalignment, is sometimes referred as parallel misalignment. This is typically measured at the coupling center. Angular misalignment is sometimes referred as gap or face, is the difference in the slope of one shaft, and usually occurs in the moveable machine, as compared to the slope of the shaft of the other machine, usually in the stationary machine. Almost all misalignment conditions of motor drive systems seen in practice are a combination of these two basic types [6-7].

The diagnosis of shaft misalignment condition is mainly done using motor current signature analysis (MCSA) and vibration analysis [8-13]. The MCSA extracts the features of current using fast Fourier transform (FFT). The FFT analysis of stator current shows a significant increase in the amplitude of the spectrum.

In this paper, various tests were carried out on a machine fault simulator (MFS) with 0.5 inch diameter shaft to observe the misalignment. In this work, authors use data for shaft displacement from bearing and current samples.

2. Experimental Setup

Experiment is conducted on the machine fault simulator (MFS) is shown in fig 1. The experimental setup is placed in Dynamics and Machinery lab at Indian Institute of Technology Patna.

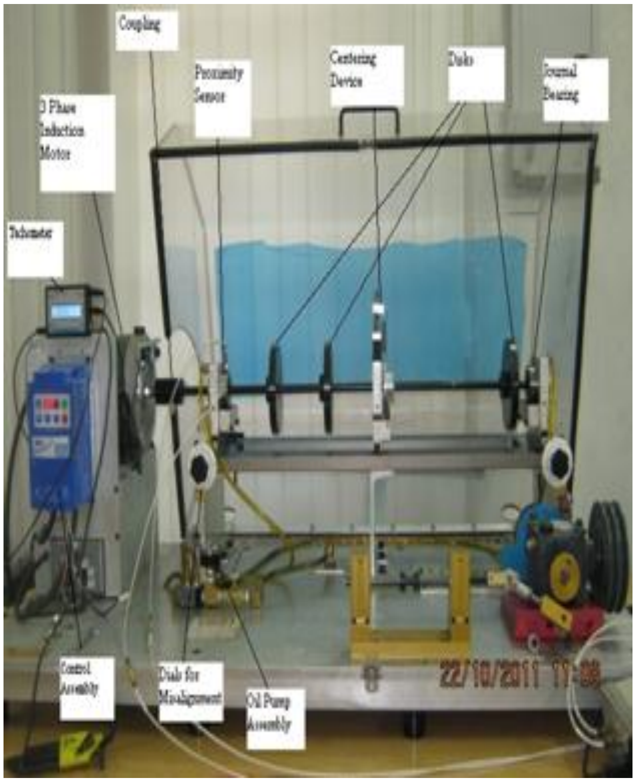

Fig 1: Front view of MFS

Block diagram for machine fault simulator with journal bearing, 0.5 inches shaft and centering device are also shown in fig. 2.

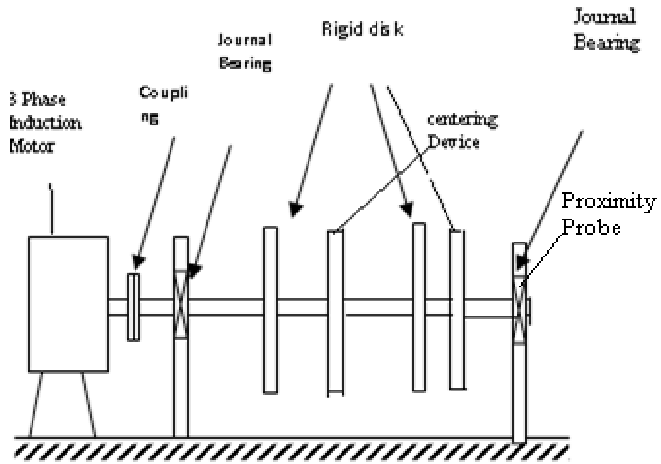

Fig 2: Block Diagram of MFS

Total experimental setup comprises of three major subsystems: Machine fault simulator, NV gate Oros data acquisition system and a computer, as shown in fig 3.

Fig 3: Side view of MFS with Complete Experimental Setup

Machine Fault Simulator with a 3-phase, 0.75 HP induction motor was used for experiment. The induction motor with a wiring enclosure are attached on the left side of the machine fault simulator and that wiring enclosure of the motor support permits access to the power supply and motor supply leads. These wirings can be pulled out from the enclosure sufficiently to install a current clamp sensor on the stator wiring that leads to support motor current signature analysis. Fig. 4 shows the wiring enclosure attached with current clamp sensor.

Fig 4: Current Clamp for Current Samples

The rotor shaft of machine fault simulator is supported by fluid film journal bearing. The length of the shaft between two journal bearings is 28.5 inches and the shaft diameter is of 0.5 inches. The lubrication oil used here is ISO 13 mineral oil and the pressure of oil is 12 psi. The displacement sensor used here are proximity probes which is mounted on the bearing housings to measure the displacement of shaft with respect to bearing housing. Displacement sensors are mounted on bearing housing in the horizontal and vertical directions as shown in fig 5.

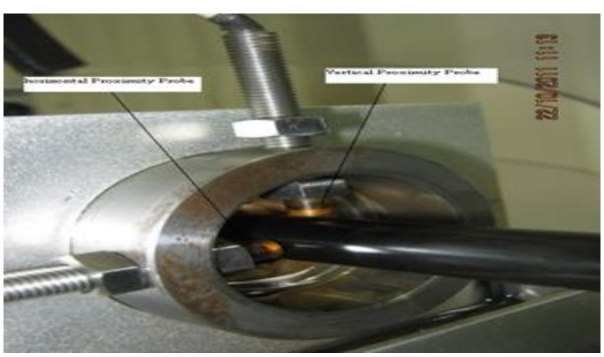

Fig 5: Mounting of Proximity Probes

In this paper, authors investigate the alignment of shaft using precision laser alignment kit. This instrument has three sections. One is transmitter, second is receiver and third is a controlling section as shown in fig. 6.

Fig 6: Precision Laser Alignment Kit

3. Experimental procedure

Experiment was conducted with three small disks installed on the shaft of the system that possesses smaller diameter with weight 767 grams. First disk was installed on 5.25 inches, second disk on 10 inches, third disk on 26 inches and centering device was installed on 14.25 inches from left side of journal bearing respectively. Alignment of shaft is checked by using precision laser alignment kit. Once, shaft of the machine is aligned then it is misaligning by 0.010 inches.

For this load condition, disk was installed at the shaft. Simulator ran up to 20 Hz speed, stayed at this speed for a while and freeze data at that. Some experimentation with the centering device and number and placement of rotor disks may be required. For test, rotor shaft displacements and current samples were measured and processed using NVgate data acquisition system. In this experiment sample rate taken is 12.8 kHz s/s.

After freezing data authors evaluate fast fourier transform (FFT) and as shown in below mentioned figures.

An FFT computes the discrete fourier transform (DFT) and produces the same result as evaluating the DFT definition directly, the only difference is that an FFT is much faster. A DFT decomposes a sequence of values into components of different frequencies but computing it directly from the definition is often too slow to be practical, Hence FFT is a way to compute the same result more quickly.

4. Experimental Result

The FFT of the displacement and current samples are generated using NVgate software packages and presented below. In the first experiment shaft is misaligned by 0.010 inches.

The shaft displacement and current samples of 20 Hz operating speed are illustrated here using FFT plot in Fig. 7. In fig 7, it can be noticed that the first peak appears when operating speed is reached, i.e. at 20 Hz. And all other harmonics occur due to misalignment. First above fig. shows the current and below fig. shows the shaft displacement samples.

The shaft displacement and current samples for the misalignment of 0.030 inches are illustrated here using FFT plot in Fig. 8. In this fig. current is slightly changed but vibration samples show more distortion for the displacement samples.

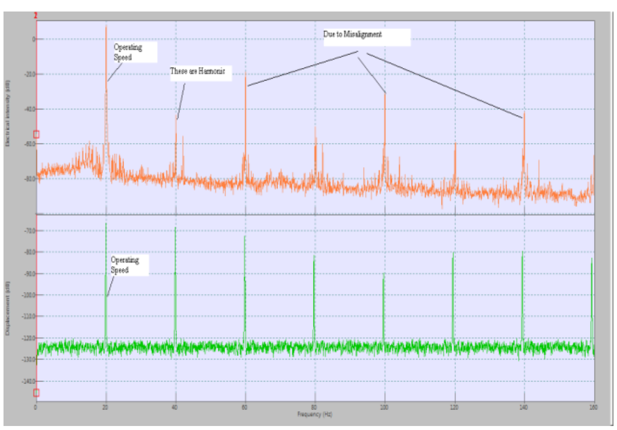

Fig 7: FFT plot for Current and Shaft Displacement samples at 20 Hz for misalignment of 0.010 inches

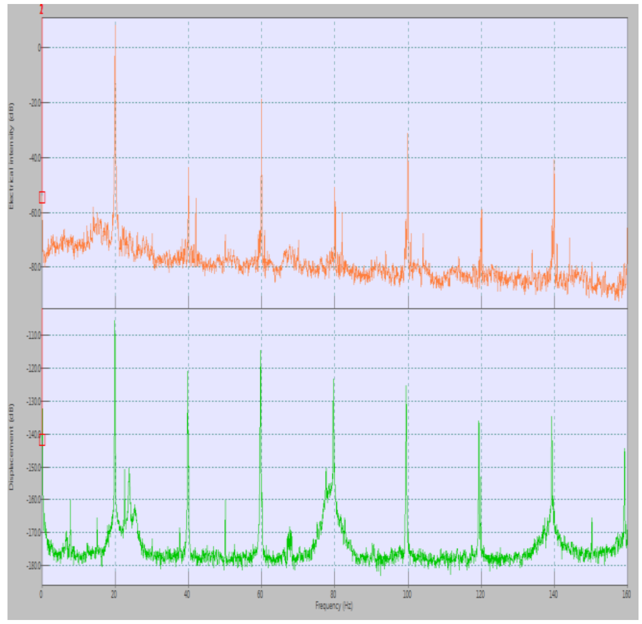

Fig 8: FFT plot for Current and Shaft Displacement samples at 20 Hz for misalignment of 0.030 inches

Simultaneously fig. 9 shows the effect of unbalance on the stator current samples.

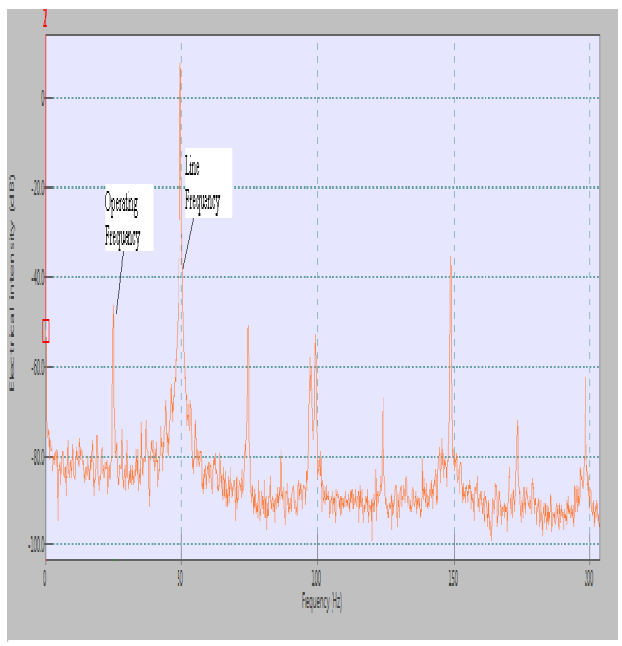

Fig 9: FFT plot for current samples

Above figures shows that unbalance identified easily at 25 Hz for current samples. Besides the operating frequency, there are some unidentified vibration components with constant frequency. FFT for current samples are taken in the db scale for the clear view.

5. Conclusion

In this paper, variation in the displacement of shaft and current samples for the study of misalignment and unbalance of shaft instability in journal bearings is presented using a spectraquest machine fault simulator. Variation in rotor displacement and stator current samples during machine run up under loading condition were measured, analyzed and presented. Misalignment of shaft and especially unbalance appears in both test conducted and harmonics of both the test are also observed. These can be identified easily in the dB scale plot. Some other vibrations components occur with this experiment were also observed and the reason for these vibration components is needs to be investigated in the future study.

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