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DETECTION PROCEDURES FOR SHAFT MISALIGNMENT DETECTION: AN OVERVIEW

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Abstract: In this paper an overview on the procedures for detection of shaft misalignment is given. Three types of misalignment are considered: the parallel, the angle and the complex (parallel/angle) misalignment. The methods of misalignment detection are analytical and experimental ones. Analytical procedures are based on the Timoshenko coupled beams theory. Variety of techniques are utilized: harmonic analysis, Fourier transformation, the least square technique, non parametric and parametric methods, harmonic balance method, wavelet analysis, artificial neural network, fuzzy logic, support vector machines method, improved discrete Fourier transformation etc. The experimental methods are based on: vibration measurements, shock pulse measurement, acoustic emission technique, temperature monitoring, thermography inspection, torque measuring etc. Recent measurement system comprises the laser light source for misalignment detection. Using the laser interferometer and the signal encoder the signal of misalignment is obtained. Finally, the monitoring of shaft misalignment is possible with a non-contact laser.
Keywords: shaft misalignment, fault detection, measuring procedures

1. INTRODUCTION

Recently, most of rotating machines operate with high speeds close to critical ones and for this reason vibration in the systems occurs. It is known that unbalance and shaft misalignment are the main causes of vibration problems in machines [1]. Misalignment can produce some other shortcomings such as: premature bearing failure, rapid wear of bearings due to induced mechanical heating effect, excessive seal lubricant leakage, coupling failure etc. Shaft misalignment increases reactions which bearings must absorb, induces mechanical looseness, damaging seals, allows fluids and impurities to enter the bearings. Due to this lacks, the lifetime of parts is significantly reduced while the energy consumption is increased, while the energy efficiency and economic effects are decreased. There are three different types of shaft misalignment:
(i) shaft angular misalignment in which shaft centrelines intersect,
(ii) shaft parallel misalignment in which shaft centrelines are parallel, and
(iii) a combined angular/parallel misalignment.
Various procedures of misalignment detection are developed: analytical and experimetal. In this paper an overview on the detection methods based on the both principles is given.

2. ANALYTICAL PROCEDURES

The problem of shaft misalignment can be treated by using the Timoshenko beam theory. Namely, the coupled rotor system is modelled using Timoshenko beam elements with coupled second order differential equations.

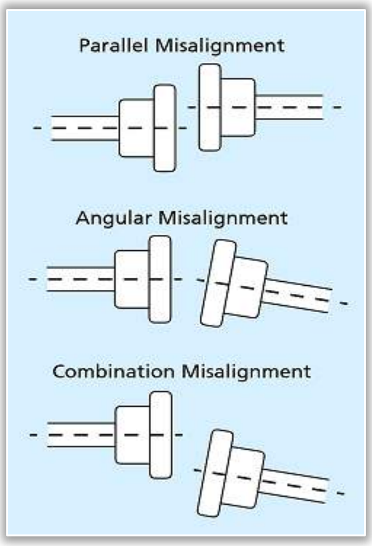

Figure 1. Types of misalignment

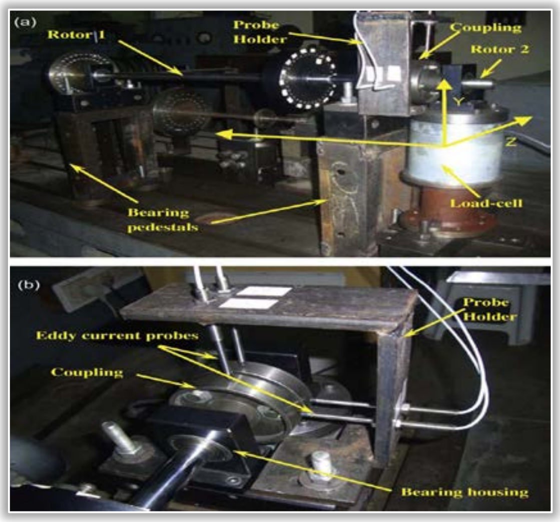

Figure 2. Set-up for measurement of misalignment excitation: (a) full view of the arrangement and (b) a close-up view showing probe locations on coupling surfaces [6]

Due to misalignment vibration appear. Their effect is recently, the nonlinear damping and stiffness properties are also included [2] and the presence of superharmonic components is presented. Along with lateral vibrations, axial and torsional vibrations are mathematically described and nature of the vibration response for the case of misalignment is examined. Variety of techniques are utilized harmonic analysis [3]: Fourier transformation, the least square technique [4], non parametric and parametric methods, harmonic balance method, wavelet analysis [5], artificial neural network, fuzzy logic, support vector machines, improved discrete Fourier transformation etc. Diagnostic features in the fast Fourier transform (FFT) of vibration response related to the type of misalignment have been revealed [6]. In [7] a programme for dynamic of systems of bodies MSC.ADAMS is developed where the Fourier transformation in frequency spectrums was applied for detction of symptoms of failure in misalignment of rotating machines.

3. EXPERIMENTAL PROCEDURES

Based on theoretical consideration measuring procedures for misalignment detection are developed. Various methods for misalignment detection using measuring data are presented [8]. The main aim of the detection method is to get the result during the working process of the system without stop. The simplest and more traditional detection method is the vibration measuring [9]. Based on the fast Fourier transformation it is concluded that the misalignment gives the peak for 2X frequency of vibration. However, the method presents some drawbacks i.e. high influence of machine operational conditions and strong impact of the coupling type and stiffness on vibration spectra. To overcome this inconvenience another misalignment detection methods are applied. One of the procedures is the shock pulse measurement [10]. Unfortunately, it may cause erroneous diagnosis in the presence of strong background noise or other shock sources.

Over the past 20 years the acoustic emission technology has evolved as a significant opportunity to monitor and diagnose failures on rotating parts of machines [11, 12].

Chacon et al. [13] show that acoustic emission technique can be used as a reliable technique for misalignment detection, providing enhancements over vibration analysis. In [14] the method is applied for fault diagnosis of three-phases induction motor.

The shaft misalignments can be detected by temperature monitoring [15] measurement as well. The early detection of shaft misalignment is obtained by measuring of temperature of couplings using thermal imaging camera [16]. It is found that the transient temperature on the couplings detects the misalignment failure. In the paper [17] the thermography inspection is recommended for application for automatic detection of the problem with misalignment.

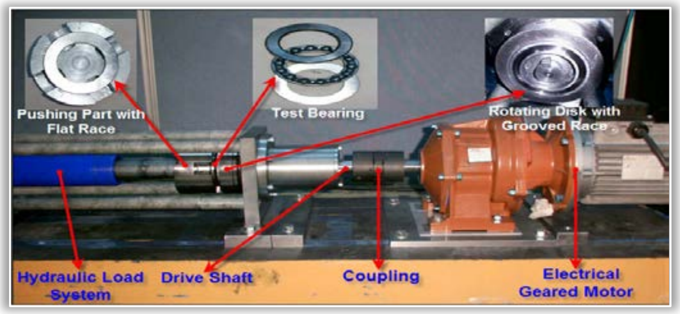

Figure 3. Test-rig layout for acoustic emission method [11]

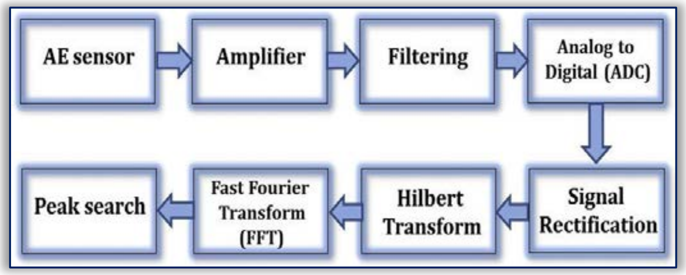

Figure 4. Schematic of the acoustic emission method [13]

Figure 5. Test-rig for temperature monitoring [15]

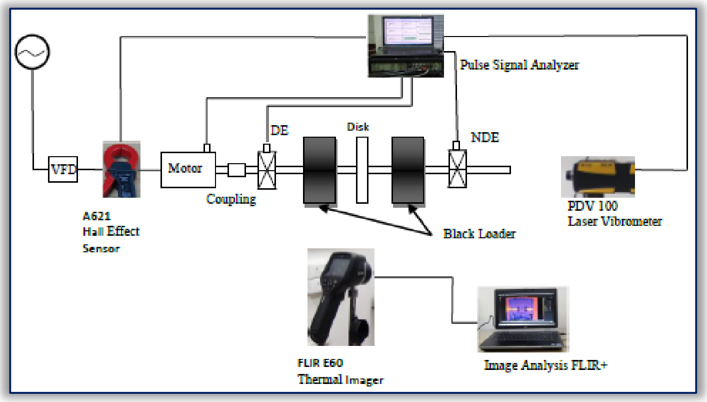

Figure 6. Line diagram of the experimental setup for thermal imaging [16]

The measurement system may comprise the laser light source for detection misalignment facilitates of two rotating shafts [18]. The positional changes of aligning drivelines in shaft couplings is possible to be obtained by the use of laser based metrology technique [19].

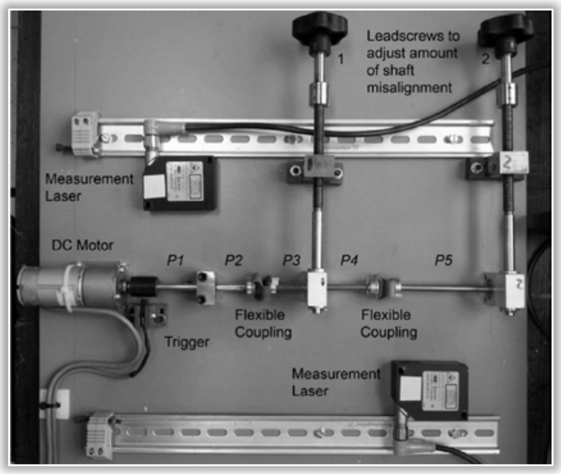

Figure 7. Experimental test rig for laser monitoring [21]

By using sets of lasers on a shaft alignment rig and then determining the average and periodic amplitude from an ensemble averaged signal, the degree of misalignment and the necessary correction action can be found. Using the laser interferometer and the signal encoder [20] the signal of misalignment is obtained. Finally, the monitoring of shaft misalignment is possible with a non-contact laser [21].

This monitoring is suitable to be applied for wind turbines. Measuring and estimating the torque with torque sensors the misalignment fault detection is possible [22]. The data are obtained by Fourier and wavelet transformation. It is concluded that the wavelet technique is more sensitive than the FFT. Additionally, the torque signatures of angular and parallel misalignment differ. The torque depends on the misalignment angle, angular position of the load and the load torque. This method is fast and efficient [23].

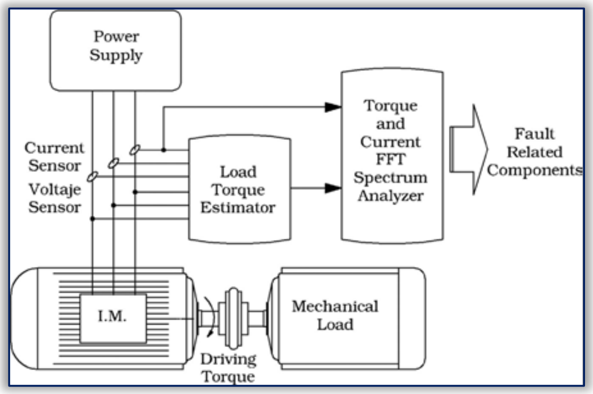

Figure 8. Functional block diagram for fault detection by torque measuring [22]

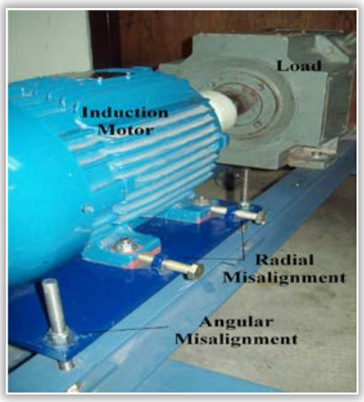

Figure 9. Laboratory assembley [22]

Finally, in [24] the energy efficiency of the aforementioned diagnostic methods for misalignment are compared. The discussion is based on parameters of wear in the system. Unfortunately, based on these dates the economic effects of misalignment cannot be obtained. The aim of the paper is to develop a procedure for estimation of system efficiency dependently on the value of the misalignment. A formula for power consume is formed. Based on the computed results improvements in maintenance strategies and economic benefits through improved production and less downtime, as well as indirect benefits through the need for fewer spare parts is available. Additionally, prediction of energy dissipation due to misalignment is possible.

4. CONCLUSIONS

Various analytical and measuring methods for misalignment diagnostics are mentioned in this paper. Using the data obtained by vibration and impulse analysis, acoustic emission, temperature and torque measuring. A new procedure for computing of the economic efficiency is suggested to be developed. The method would be based on power consumption in the system. The energy spent due to shaft misalignment would be computed analytically and measured experimentally. The experimentally obtained results would be applied for computing of the economic efficiency. Calculated solutions would be compared with the measured ones. In addition, the obtained result would be suitable for prediction of energy dissipation in systems where misalignment in shafts exist.

Note

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