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RELATIONSHIPS BETWEEN OUT OF BALANCE AND MISALIGNMENT AND THEIR VIBRATION CHARACTERISTICS

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This thesis entitled "**Relationships Between Out of Balance and Misalignment and Their Vibration Characteristics**" was prepared and presented by Chua Chee Siang as a partial fulfillment of the requirement for the degree of Bachelor of Engineering with Honours (Mechanical Engineering and Manufacturing System) was hereby read and approved by:

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RELATIONSHIPS BETWEEN OUT OF BALANCE AND MISALIGNMENT AND THEIR VIBRATION CHARACTERISTICS

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This project is submitted in partial fulfillment of
the requirements for the degree of Bachelor of Engineering with Honours
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- Vibration

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Dedicated to my beloved family

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ABSTRACT

Majority of the machinery in industries nowadays consists of rotating or moving components. Any fault in this rotary component may lead to adverse vibration and thus the smooth running of the system. However, each type of machinery fault exhibits a characteristic vibration signature which is uniquely its own. The signal is the sum total of the design, manufacture, application, and wear of each of its components. Unbalance normally generates 1x rotating speed (RPM) dominant vibration in vibration spectrum, due to the cyclic excitation force that encounter each time the machine makes a full revolution. On the other hand, 2x RPM dominant vibration will normally presented in vibration spectrum for misalignment problem, where each of the two shaft causing a cyclic excitation forces. Phase relationship between inboard and outboard bearing across coupling, will be the easiest way to differentiate the above 2 mechanical defect, as misalignment normally will also generate high vibration at 1x RPM.

ABSTRAK

Kebanyakan mesin yang digunakan di dalam industri hari ini mengandungi komponen yang berpusing dan bergerak. Sebarang kerosakan di dalam komponen berpusing ini mungkin menyebabkan getaran, seterusnya mengakibatkan sistem tidak dapat berfungsi dengan lancar. Walaubagaimanapun, setiap jenis kerosakan pada komponen berpusing ini mempunyai sifat getaran yang unit. Signal ini merupakan hasil daripada kesalahan rekabentuk, proses pembuatan, cara penggunaan, dan hakisan yang dialami oleh komponen tersebut. Ketidakseimbangan biasanya menyebabkan 1xRPM dalam spectrum getaran, disebabakan daya yang dialami setiap kali mesin membuat satu putaran lengkap. Sebaliknya, 2xRPM getaran akan muncul di dalam spectrum getaran sekiranya ketidaktepatan garispusat aci merupakan masalah yang terbesar. Hubungan fasa di antara dua bearing sokongan, merupakan cara yand terbaik untuk membezakan di antara dua masalah tersebut, memandangkan ketidaktepatan garispusat aci kadangkala juga akan mengakibatkan getaran tinggi di 1xRPM.

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CHAPTER 1

INTRODUCTION

1.1 Background Of Vibration Monitoring

In today's fast changing marketplaces, many industrial plants are seeking methods and techniques to optimize the operating efficiency of their existing plants, by extending equipment life, and reducing operation and maintenance expenses, in order to remain competitiveness.

Suitable maintenance practice is necessary to ensure the continued, safe and profitable operation of industrial machinery and plant, that higher plant availability and reliability are achieved in the most cost effective manner [Shrieve and Hill, 1998].

Generally, maintenance activities may be categorized as either *reaction based, time based, or condition based.* Reaction-based maintenance normally takes the form of continuous operation until a failure occurs. Then, a correction action will be taken to repair the damage and return the machinery train to operation as soon as possible. This type of maintenance practice is also called Breakdown Maintenance. Time-based maintenance, is concerned with interrupting production on machinery at regular intervals for maintenance. This is done to reduce the number of unplanned stop that can arise from breakdown maintenance strategy. This type of maintenance practice is also called Preventive Maintenance. Condition based maintenance, on the other hand is based upon reasonable knowledge of the mechanical condition of machinery, which evaluates equipment condition to determine maintenance needs.

In order for the condition-based maintenance to be success, a condition-monitoring program is therefore needed. Condition monitoring of machinery can provide actual condition for a machine without the needs of dismantle, shutting down or even direct contact to the equipment. It also can identify machine train problems before they become serious. This indirectly provides the opportunity of organizing avoidance strategies to minimize lost time and unexpected costs, thus greatly improving manufacturing efficiency.

For any condition monitoring programs, vibration analysis is one of the dominant techniques used. The simple reason is that all machines vibrate, even machinery which is in good operating condition will vibrates at certain degree. Vibrations normally arise from the cyclic excitation forces, which are present within a machine. These forces are sometimes built into the design of the equipment, or can be due to real changes in the dynamic properties of the individual machine elements. These excitation forces may be transmitted to adjacent components or the adjoining machine structure, thus causing parts of the equipment remote from the source to vibrate accordingly to varying degrees [Mathew, 1985].

Since each type of mechanical defect has its own unique vibration characteristic, any change in vibration is a signal showing that the mechanical health of a particular machine is changing. Keeping this in mind and applying a systematic method of monitoring vibration on a piece of equipment at set intervals, any increase in vibration level recorded over time provides an early warning of impending trouble. Once this change in vibration level exceeds preset tolerances, corrective action should be initiated to prevent a costly breakdown failure [Larry Bowler].

For rotating machinery, the excitation forces that cause vibration are usually generated through the rotating motion of the machine parts. Because these forces change in direction or amplitude according to the rotational speed (RPM) of the machine components, it follows that most vibration problem will have frequency that are directly related to the rotational speed [Gardiner, 1998]. For this reason, unit of velocity (in/sec or mm/sec) was recognized as the most accurate means of monitoring the overall health of a piece of machinery. Because any change in the amplitude or the frequency of a generated vibration signal will produce a change in the measured velocity value.

Therefore, combination of trend and vibration spectrum can be used to analyze the failure mode associated with shafts, bearings, gears, couplings, motors and many other machine components.

1.2 Objective of Work

The aim of this project is to study the relationship between two common machinery faults, which is out of balance and misalignment. Experiment and studies will be carry out to determine the effects of out of balance and misalignment on the vibration characteristics of rotating machinery.

1.3 Definition of Terms

1.3.1 Definition of Vibration

Vibration is defined by Webster's New World Dictionary as "to swing back and forth; to oscillate". In the vibration industry, vibration means the pulsating motion of a machine or a machine part from its original place of rest. Vibration is the response of a system to some internal or external stimulus or force applied to the system. In vibration monitoring, 3 important parameters are normally being encounter, which are the Amplitude (Severity), Frequency (How many times per minute or seconds) and phase (How it is vibrating).

1.3.2 Definition of Unbalance

Unbalance is a common feature of all rotational elements. It is a side effect caused by the imperfection of material (e.g. heterogeneity) and the manufacturing process, as well as the effect of wear by use (e.g. erosion). Generally, each unbalance of mass in rotary motion is the source of rotational forces and moments of inertial forces which, being transferred through the bearings to the body of the machine, evoke vibrations in the whole system. There are several types of unbalance, which is static unbalance, moment unbalance, quasistatic unbalance and dynamic unbalance [Cempel, 1991].

1.3.3 Definition of Misalignment

The power unit of machinery and its working part (e.g. Steam turbine and pump) form in general separate components that is joined by a coupling at the shaft end. This joint is often not aligned and can distinguish a fault called misalignment. There are three types of shaft misalignment, which is radial, angular and oblique misalignment. This misalignment is normally the source of double rotary frequency (2 X RPM) vibration. The amplitude of these vibrations is directly proportional to the radial displacement and the angular displacement, and varies with the obliquity parameter [Cempel, 1991].

CHAPTER 2

LITERATURE REVIEW

2.1 Review of Fundamental Vibration Theory

From the "Handbook of Condition Monitoring" edited by Alan Davies, D.W Gardiner had made a review of the fundamental of vibration theory. Vibration means the motion of a machine, or machine part, back and forth from its position of rest. The motion of the weight from its position of rest, to the upper limit of travel, then to the lower limit of travel, and returns to its original position represent one cycle or period of motion.

Three important characteristics that are important to define a vibration are : amplitude, frequency and phase. Amplitude describes how much a machine of system vibrates. Vibration amplitude can be measured in 3 main engineering units:

a) Displacement

Total distance travelled by the vibration part from one limit to another, normally referred as the "Peak to Peak" displacement.

b) Velocity

The speed required for a vibration part to move, for a certain distance. Vibration speed is constantly changing, since during a cycle of motion the highest velocity is selected for measurement.

c) Acceleration

The measurement of "rate of change of velocity", normally expressed in g's peak, where 1g is the acceleration produced by the force of gravity at the surface of the earth.

Vibration frequency describes the number of complete cycles that occur in a specified period of time. In other words, vibration frequency is the inverse of the period of the vibration, where

Frequency = 1/Period

The vibration frequency is normally measured in Hz (Hertz) or CPM (Cycle per Minute).

Phase is another important parameter required to describes vibration characteristic. Phase is defined as "The angle between the instantaneous position of a vibrating part and a fixed reference position". In short, phase measurement can provide information regarding the relative motion between two or more machinery parts [Gardiner, 1998].

2.2 Vibration Spectrum

From the Training Manual "Advanced Vibration Diagnostic and Reduction Techniques" published by Technical Associates of Charlotte Inc, James E. Berry had discussed about what is a vibration spectrum.

A vibration spectrum is a graph that plots the amplitude (mils, in/sec or g's) versus the vibration frequency (CPM or Hz). In other words, it is the presentation of vibration data in frequency waveform. Normally, vibration event are recorded by using an oscilloscope or a real time analyzer, where the signals are in the form of time domain.

Displaying and using the time domain is a very precise method which display the actual machine motion and to analyze the various vibration parameters. However, analyzing the time waveform itself can be very cumbersome and labor intensive when frequency needs to be determined. To simplify this process, vibration instruments are normally able to develop what is known as Fast Fourier Transform (FFT).

An FFT is the computer (microprocessor) transformation from time domain data (amplitude versus time) into frequency domain data (amplitude versus frequency). This FFT calculation technique was developed by Baron Jean Baptiste Fourier. The process of FFT is illustrated in figure 2.1.

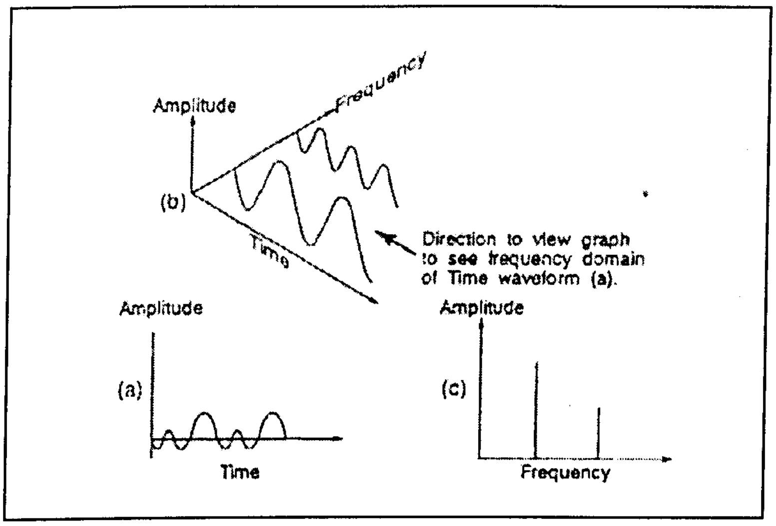

Figure 2.1 : Fast Fourier Transform

From the figure, a total time waveform is captured in the time domain first (a). This time domain waveform is then separated into its separate sine waveforms and displayed in three-dimensional coordinates of amplitude, time and frequency (b). From the combined waveform, the frequency of each sine wave is determined and the sine waves are placed in the respective position along the frequency axis. A view looking along each individual waveform is shown allowing the analyst to see the frequency domain of amplitude versus frequency (c). Details mathematic equations of FFT are shown in Appendix G and H.

2.2.1 Time Domain Analysis

Despite the usefulness of frequency domain vibration data, time domain data can sometime be applicable. An article from an Internet website has a discussion about the time domain analysis. The analysis of time waveform data is not a new technique. In the early days of vibration analysis, time waveform data was viewed on oscilloscopes and frequency components calculated by hand.