# VIBRATION ANALYSIS FOR DIAGNOSTIC OF LOCAL FAULTS IN ROLLING ELEMENT BEARING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

'Saya/Kami* akui bahawa telah membaca
karya ini dan pada pandangan saya/kami* karya ini
adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal-Bendalir)

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OKTOBER 2008

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*Ayahanda,Bonda Serta Keluarga Tersayang*
*Doamu Menjadi Penawarku*
*Darjat Seseorang Terletak Pada Usaha Bukan Pangkat atau Pencapaian*

OTHMAN BIN SALLEH
MARIAH YUSOF
NUR FARHANAH MOHAMED FOZI
HARTINI OTHMAN
NAZRI OTHMAN
ZURAIMI OTHMAN
AHMAD KHAIRO OTHMAN
AMIRA OTHMAN

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## ABSTRACT

The experimental studies were undertaken to investigate the local faults in rolling element bearings. It is important to identify the problems because nowadays, condition monitoring and prediction can be done for machinery faults diagnosis and improvement by using vibration analysis as the important role. On the other hand, bearing is like a heart to a machine, to make the machine works smooth especially in rotating parts. One of the most common and reliable techniques for detecting rolling element bearing problems is the Demodulation or Enveloping technique. This technique is derived from demodulating the high resonant frequency created by the impacts which are generated by the interactions between the rolling element and the defects. The envelope that is obtained from the demodulation process will thus be analyzed in the frequency domain. The demodulated spectrum will highlight the bearing defect frequencies which will not be buried under running speed harmonics and low frequency components. In this thesis, envelope detection have been chosen to diagnose the local faults in rolling element bearing because of the accurately of the measurement rather than other type of vibration analysis besides of the highlighted bearing defect frequencies.

# ABSTRAK

Kajian eksperimen dijalankan untuk mengkaji kerosakan biasa ke atas galas guling. Ini adalah penting untuk mengenalpasti masalah kerana sekarang pemerhatian keadaan dan ramalan (condition monitoring and Prediction) boleh dilakukan untuk mengenalpasti masalah yg timbul pada mesin dan cara-cara untuk menambahbaikan menggunakan analisa getaran sebagai medium utama. Selain itu juga, galas adalah komponen penting sesebuah mesin khususnya mesin yang melibatkan putaran. Untuk menganalisa dan mengesan masalah ke atas galas guling ialah dengan menggunakan “Demodulation” ataupun teknik “Envelope”. Teknik ini menyingkirkan frekuensi resonan yang tinggi yang dihasilkan oleh lagaan pengguling dengan tempat yang rosak. “Envelope” yang didapati dari proses penyingkiran akan dianalisa didalam domain frekuensi. Spektrum itu akan menunjukkan frekuensi-frekuensi pemasalahan dimana ianya tidak akan ditenggelamkan oleh harmonik operasi kelajuan dan komponen frekuensi rendah. Di dalam tesis ini, teknik “Envelope” telah dipilih untuk mengdiagnosis pemasalahan yang didapati oleh galas guling kerana kecekapan yang dihasilkan oleh pengukurannya berbanding dengan kaedah getaran yang lain.

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| SYMBOLS | | DEFINITIONS |
|---|---|---|
| BPFO | = | Ball Passing Frequency Outer Race, local faults on outer race |
| BPFI | = | Ball Passing Frequency Inner Race, local faults on inner race |
| BSF | = | Ball Faults Frequency, local faults on rolling element |
| FTF | = | Fundamental Train Frequency, faults on the cage or mechanical looseness |
| RPM | = | Rotate per minutes |
| Nb | = | Number of ball or rollers |
| Bd | = | Rolling element diameter |
| Pd | = | Pitch diameter |
| $\theta$ | = | Contact angle |

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# CHAPTER I

# INTRODUCTION

## 1.1 Overview

Rolling element bearings are among the most significant components in the vast majority of machines and exacting demands are made upon their carrying capacity and reliability. The continued research and development of rolling element bearing technology has enabled engineers to calculate the life of a bearing with some substantial accuracy, thus enabling bearing life and machine service life to be accurately coordinated.

Unfortunately it sometimes happens that a bearing does not attain its calculated rating life. Fatigue and surface distress usually describe the limits for reliable operation of a rolling element bearing. Under different operating conditions, the bearings have different life spans and in general bearing failure is caused by surface distress and is indicated by temperature rise. This leads to bearing damage in due course, resulting in micro-pitting, smearing, indentation and plastic deformation, besides surface corrosions.

Vibration analysis has been used in rotating machines faults diagnosis for decades and is claimed that vibration monitoring is the most reliable method of assessing the overall health of a rotor system (P. A. Lagan, 1999). When measuring vibration, there are several methods that can be used which are overall vibrations, FFT spectrum, Acceleration Enveloping, phase, SEE Technology (Acoustic Emissions) and high frequency detection (HFD). Machines have complex mechanical structure that oscillate and this result in a machines related frequency spectrum that characterizes healthy machines behaviors. The frequency component in the spectrum will change when a mechanical part such as rolling element bearing either wear or break up. In fact, each fault in a rolling element bearing produces vibration with distinctive characteristics that can be measured and compared with reference ones in order to perform the faults detection and diagnosis.

Extensive literature is available on diagnosing rolling element bearing defects using vibration analysis. However, answers to numerous questions remain indefinable, such as the effects of rotor weight (load), speed and damage severity on the vibration signature.

In this project, a research is conducted to diagnose the local faults in rolling element bearing by analyzing the vibration data that been measured. A test rig will be built in order to study the local faults on rolling element of bearing. Vibration measurement data will be collected by CMVA65 Microlog Data Collector/Analyzer and various Microlog plots will be manipulated for analysis and to generate FFT (Fast Fourier Transformation) spectrum reports from the Microlog data collector.

## 1.2 Project Objectives and Scopes

The objectives of this project are as follow;

1) To diagnose bearing faults using vibration analysis methods (Envelope Detection)
2) To investigate parameters that may affect machine life, which is related as well as bearing vibration measurement.

To achieve the above objectives, the scopes need to be considered as follow;

1) To build up the experiment test rig for diagnostic.
2) Conduct vibration measurement using FFT Vibration Analyzer and analysis the vibration spectrum
3) Calculating the bearing frequencies
4) Identifying side bands and centre frequencies
5) Perform vibration analysis for the bearings.

## 1.3 Problem Statement

In studying the vibration study for diagnostic local fault in rolling element bearing, there are several things that need to understand in order to solve the problem. Rolling-element bearings often work well in non-ideal conditions, but sometimes minor problems cause bearings to fail quickly and mysteriously. However, for lower horsepower and lighter loaded machines, the rolling element bearing is a popular choice. Most industry nowadays used rolling element bearings in their machine. The rolling element bearing is used to support force by placing it through the round elements between the two pieces.

The predictive maintenance philosophy of using vibration analysis to lower operating costs and increase machinery availability is gaining acceptance throughout industry. Since most of the machinery in a predictive maintenance program contains rolling element bearings, it is imperative to understand how to monitor and diagnose problems associated with them. In this project, using the vibration analysis we can try to diagnose the local faults in rolling element bearing because it is the best analysis that can capture the problems.

# CHAPTER II

# LITERATURE REVIEW

Vibration analysis is probably the most important tool to diagnose a problem in a machine and has become accepted and proven worldwide in industries. There are many ways to monitor a subject but the most effective is vibration monitoring. By using the vibration analysis, we can trace a problem to its root and also can be a reference to a problem. Usually problems will occur when the machine in high vibrate.

The rolling element bearings are the most important part in the rotating part or a machine. Roller bearings are generally used for applications requiring high load carrying capability, but radial ball bearings are the most common type of rolling element bearing. Most of the past research, they do used the radial ball bearing but however it can also give some other fault such as misalignment or shaft deflection. To overcome the problems, the most suitable solution that comes out is to use the self aligning ball bearing.

The steel balls, cage, and inner ring can rotate freely at a certain angle, as it is stated that the bearings have self-aligning features. Accordingly, misalignment of the bearing shaft due to the machining and installation of the shaft and housing will be automatically adjusted. Furthermore, if an adapter is used on the tapered bore of the inner diameter, installation and disassembly are much simpler and for this reason adapters are used in this project.

According to Howard, I. M. (1994), art of machine condition monitoring knows what to look for and successful diagnosis is having the ability to measure it and to correlate the results with known failure mechanisms. Vibration analysis has been used as a condition monitoring tool for bearing fault detection and diagnosis, probably ever since the first use of bearing when the systems were “something sound weird”. Much has been written about vibration analysis for bearing fault detection over the last twenty five years.

A review completed over twenty five years ago provided comprehensive discussion on bearing, their rotational frequencies, modes of failure, resonance frequencies and various vibration analysis techniques. The more common techniques which were used at that time included time and frequency domain techniques. These comprised techniques such as RMS, crest factor, probability density functions, correlation functions, band pass filtering prior to analysis, power and cross power spectral density functions, transfer and coherence functions as well as spectrum analysis, narrow band envelope analysis and shock pulse methods. It is interesting to note that these are the techniques which have continued to be used and have been further developed over the past two decades for bearing fault detection and diagnosis.

A large number of vibration signal processing techniques for bearing condition monitoring have been published in the literature across the full range of rotating machinery. Condition monitoring can be divided up into three main areas, detection, diagnosis and prediction. Detection can often be as simple as determine that a serious change has occurred in the mechanical condition of the machine. Diagnosis in effect determines the location and type of the fault, while prediction involves estimation of the remaining life of the damaged bearing. Over the past decade, the understanding of signal processing techniques and their application to bearing fault detection has increased extremely. The amount of information which can be getting from the vibration measured on rotating machinery is immense.

It would be anticipated that the general use of advanced signal processing techniques will become more widespread in the future. The review commences with an examination of the underlying science of bearing dynamics and resulting forces, the transmission of the stresses through the structure, the external noise and vibration environment, the measurement of the vibration and the effect of the class of machine on the diagnostic techniques which need to be used to detect impending failure. Rather than comparing the effectiveness of the various signal processing techniques for bearing fault detection, an emphasis has been placed upon discussion on the underlying factors associated with bearings, their modes of failure and the vibration environment and class of machine. The next logical step would be to undertaken a detailed comparison of techniques for the various modes of failure, class of machine, vibration environment, etc.

Meanwhile, according to Dr. Alexej. V. Barkov (1999), the method of rolling element bearing diagnostics using spectral analysis of the high frequency vibration envelope began in the middle 1970‟s. By the middle of 1980‟s new algorithms for diagnostics and condition prediction of the rolling surfaces were developed. These algorithms enabled defining the type and depth of multiple, simultaneous defects from a single vibration measurement. By 1990‟s the algorithms were automated and automatic diagnostic systems for rolling element bearings began to be used within many industries.

There are three advantages to use the single measurement method compared to others frequently used for rolling element bearing diagnostics. Firstly, high sensitivity of the method, second, the ability to gain an accurate assessment of condition and third is that the requirement for making the measurements are not very strict. However it does not usually provide reliable result to stand for.

From the journal of Basic Vibration Signal Processing for Bearing Fault detection by S. A. McInerny, Y. Dai (2003), they used many techniques to tackle the basic bearing fault detection such as Synthetic Signal that shares some of the characteristic features of the vibration signatures measured in bearing, Application of Traditional Spectral Analysis that are used to explain the limitations of simple spectral analysis when applied to bearing fault detection, Amplitude Modulation and the Hilbert Transform which Amplitude transform is defined as the multiplication of a high-frequency carrier signal by a low frequency modulating signal and the Hilbert Transform is quite difficult to analyze, and lastly is Envelope Analysis that refer to this project.

Refer back to Dr. Alexej. V. Barkov (1999), Envelope Detection or Amplitude Demodulation is the technique of extracting the modulating signal from an amplitude-modulated signal. Envelope Analysis can be used for diagnostics of machinery where the faults have an amplitude modulating effect on the characteristic frequencies of the machinery. Envelope Analysis is also the best analysis for diagnostics of local faults in rolling element bearing.

In last few decades, Swedish Ball Bearing Factory, (SKF) has done much research along with the in-plant testing conducted in an attempt to evaluate the condition of the rolling element bearings which included the bearing life. This life is very dependent upon the vibration to which bearing is subjected. By using the vibration and spike energy spectral analysis, the number of failure which have been identified to date tracking rolling element bearing failure stages. However this method need some connected studies which thoroughly conducted in laboratory.

Based on this literature review, it shows that vibration analysis and rolling element bearing are both important factors in condition monitoring. Furthermore, these two can give more and more benefits to the world. Vibration analysis is acceptable in the industries and rolling element bearing can gives a major problem if not to be considered. Most of the rolling element bearing"s problems can be tackling using vibration analysis.