FAULT DETECTION FOR ROTATING MACHINE USING TIME FREQUENCY LOCALIZATION METHOD

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I certify that the project entitled *"Fault Detection for Rotating Machine Using Time Frequency Localization Method"* is written by *Mohd Nor Hisyam bin Che Ab Aziz*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

(MIMINORAZEANSUHAILA BINTI LOMAN)

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature : ....

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ABSTRACT

Bearing is one of the important things in machining. Bearing are considered as critical mechanical components and a defect in a bearing causes malfunction to machine. Failed machines can lead to economic loss and safety problems due to unexpected and sudden production stoppages. These machines need to be monitored during the production process. Because of that, on-line condition monitoring become alternatives to solve this problem compared with off-line monitoring. Objective of this project is to analyze data acquired from testing of fault detection to differentiate between the defective bearings and good bearings using an accelerometer. A set of good bearing and defective bearing with different failure was using in this experiment. Four units of bearing which is one is good bearing, one corroded bearing, one sandy bearing, and one bearing with damage at the ball was used in this experiment. The data were obtained from experiment on test rig using Bruel & Kjaer accelerometer and data acquisition system. All the bearings were run with different speed which is 4000rpm, 7000rpm, and 10000rpm. The data were analyzed using PULSE LabShop software. The data from three rotations for each bearing was analyzed using time domain, frequency domain, and time-frequency domain analysis. The time-frequency domain method used in this experiment is Short-time Fourier Transform (STFT), and S-transform. STFT and S-transform are applied to detect the location of the signal that has high vibration. The highly damaged bearing is detected based on the high magnitude distribution value in the obtained time-frequency domain. Based on the result, it has a different in vibration between all the bearings. The data for a good bearing were used as benchmark to compare with the defective bearing. For a good bearing, higher vibrations occur at low frequency which is below than 5 kHz using a STFT and below 5μHz when using S-transform. For the defective bearings, the higher vibrations occur at high frequency which is above than 5 kHz when using a STFT analysis and above 5μHz when using S-transform. From the graph, the different between good bearing and defective bearings can be made. The findings indicate that time frequency localization transform method can be used to develop an effective condition monitoring tool. The use of signal processing analysis in this study can be used in industrial applications. This signal processing analysis is recommended to use in on-line monitoring of parameters while the machine is producing.

ABSTRAK

Galas bebola merupakan salah satu komponen penting dalam sesuatu mesin. Galas bebola dianggap sebagai komponen mesin yang kritikal dan kerosakan pada galas bebola boleh menyebabkan mesin tidak berfungsi. Mesin yang rosak akan membawa kepada kerugian dan masalah keselamatan berdasarkan mesin yang berhenti beroperasi secara tiba-tiba dan tidak dijangka. Mesin-mesin perlu sentiasa dipantau semasa beroperasi. Oleh sebab itu, pemantauan keadaan mesin semasa mesin sedang beroperasi menjadi satu kaedah untuk menyelesaikan masalah ini berbanding dengan pemantauan ketika mesin tidak beroperasi. Objektif kajian ini ialah untuk menganalisis data yang dihasilkan daripada ujikaji pengesanan kerosakan untuk membezakan diantara galas bebola yang elok dan galas bebola yang rosak menggunakan *accelerometer*. Satu set galas bebola yang elok dan bebola galas yang berbeza jenis kerosakan telah digunakan di dalam kajian ini. Empat biji galas bebola dengan satu darinya elok, satu galas bebola berkarat, satu bebola galas berpasir dan satu galas bebola yang rosak bebolanya telah digunakan di dalam kajian ini. Data diperolehi dari kajian ke atas alat ujikaji dengan menggunakan *accelerometer* Bruel & Kjaer dan alat pengumpul data. Semua galas bebola beroperasi dengan kelajuan berbeza iaitu 4000, 7000, dan 10000 pusingan per minit. Data kemudiannya dianalisis menggunakan perisian PULSE LabShop. Data daripada tiga putaran untuk setiap galas bebola dianalisis menggunakan analisis domain masa, domain frekuensi dan domain masa-frekuensi. Analisis domain masa frekuensi yang digunakan di dalam ujikaji ini ialah Penjelmaan Fourier masa-singkat (STFT) dan Penjelmaan-S. STFT dan Penjelmaan-S diaplikasikan untuk mengesan lokasi isyarat getaran yang tinggi. Galas bebola yang rosak teruk dikesan berdasarkan nilai taburan getaran yang diperolehi dari domain masa-frekuensi. Berdasarkan keputusan, terdapat perbezaan getaran diantara semua galas bebola. Data untuk galas bebola yang elok digunakan sebagai penanda aras untuk dibandingkan dengan galas bebola yang rosak. Untuk galas bebola yang elok, getaran yang tinggi terhasil pada frekuensi rendah iaitu di bawah 5 kHz dengan menggunakan analisis STFT dan di bawah 5µHz dengan menggunakan analisis Penjelamaan-S. Untuk galas bebola yang rosak, getaran yang tinggi terhasil pada frekuensi yang tinggi iaitu di atas 5 kHz dengan menggunakan analisis STFT dan di atas 5µHz dengan menggunakan analisis Penjelamaan-S. Berdasarkan graf, perbezaan antara galas bebola yang elok dan galas bebola yang rosak dapat dikenalpasti. Kajian ini menunjukkan kaedah penjelmaan masa-frekuensi setempat dapat digunakan bagi membangunkan alat pemantauan yang berkesan. Penggunaan analisis pemprosesan isyarat dalam kajian ini boleh digunakan dalam aplikasi industri. Analisis pemprosesan isyarat dalam kajian ini dicadangkan untuk digunakan sebagai kaedah pemantauan mesin ketika mesin sedang beroperasi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$w(t)$	the window function
$x(t)$	signal to be transformed
$X(\tau,\omega)$	Fourier Transform
τ	Time axis
ω	Frequency axis
t	Time variable
Pxx	Value for PSD
F_s	Sampling frequency
S	Matrix of S_T
k	Scaling factor

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Bearing is a common component in machinery. The basic purpose of a machine bearing is to provide a near frictionless environment to support and guide a rotating shaft. There are many types of bearing available nowadays. General bearing styles are utilized at this time which is the rolling element bearing. For lower horsepower and lighter loaded machines, the rolling element bearing is a popular choice.

There are many types of rolling elements bearing, such as ball bearings, roller bearings, needle bearings, tapered roller bearing, spherical roller bearings and thrust bearings. In industrial application, rolling element bearings are considered as critical mechanical components and a defect in such a bearing may cause malfunction and may even lead to catastrophic failure of the machinery. Therefore, they have received great attention in the field of condition monitoring.

Different methods are used for detection and diagnosis such as vibration, acoustic and temperature measurements. Among these, vibration and acoustic measurements are the most widely used (Tandon and Choudry 1999). Several techniques have been applied to measure the vibration and acoustic responses from defective bearings, for example, vibration measurements in time and frequency domains, the shock pulse method, sound pressure and sound intensity techniques and the acoustic emission method. A lot of research have been done and published, on the detection and diagnosis of bearing defects by vibration and acoustic methods.

(Tandon and Choudry 1999) presented a detailed review of the different vibration and acoustic methods, such as vibration measurements in time and frequency domains, sound measurements, and the acoustic emission method. (White 1984) describes a method for simulating the machinery faults signals which are impulsive in nature and analyzed them. The basic understandings of the rolling element bearing's vibration monitoring fault detection are proposed by (Reimchi, Sudmersen et al. 2003). (McFadden and Smith 1984) describe the basic understandings of the rolling element bearing vibration for a defected case and a well-established model that considers the load distribution around the circumference of the rolling element bearing and the impulsive response of the bearing structure.

(Kiral and Karagulle 2002) provide a detailed review about simulation and analysis of vibration signals generated by rolling element bearing with defects. The vibration measurement methods can be classified as in time and in frequency domains. A brief review on the monitoring techniques in time and in frequency domain can be found in research by (Mathew and Alfredson 1984). Recently time-frequency domain analysis has become more popular. The Short Time Fourier Transform method is used by researchers(Yang, Mathew et al. 2002; Ihn and Chang 2004; Cristalli, Paone et al. 2006; Kim, Lee et al. 2007) in condition monitoring of rolling element bearings due to its superiority in time and frequency resolution while processing the vibration signals.

1.2 PROBLEM STATEMENT

Today's industry uses increasingly complex machines, some with extremely demanding performance criteria. Bearings are a one of the common component in machinery. In industrial applications, bearings are considered as critical mechanical components and a defect in such a bearing causes malfunction to machine. Failed machines can lead to economic loss and safety problems due to unexpected and sudden production stoppages. These machines need to be monitored during the production process. However, conditioning monitoring requires effective fault diagnosis. Before this, people detect the defective bearing using a conventional method such as, listening to the sound with their ears. They can detect failure when they hear an abnormal sound from rotating machine. But this method is not practical, and after that, people used an off-line monitoring to detect the failure. Off-line monitoring is defined as monitoring when the machine is not producing or monitoring via a workpiece which is off the machine. The former is not an effective use of the machine and the research activity in this area at this time is the measurement of the workpiece. Thus, there is a time lag of one workpiece before faults are noted. This method can affect the productivity of the machine, and can decrease the total production. People nowadays start using an on-line monitoring to detect failure at the machine. On-line monitoring is a monitoring of parameters while the machine is producing. On-line monitoring has the advantage of more direct diagnosis of machine faults and a much quicker response to fault development, and especially the catastrophic failure. On-line monitoring lends itself to automation.

1.3 OBJECTIVE

The objectives of this study are:

i. To acquire vibration and acoustic signal release from rotating machine.
ii. To analyze data acquire from testing fault detection in order to differentiate between the defective bearings and good bearings using time frequency localization method.

1.4 HYPOTHESIS

The bearing condition is related with the performance of the machine. When the bearing is faulty, the machine will be working in bad condition. Defective bearing will give different result with good bearing when come in terms of performance. The defective bearing can be recognized using time domain, frequency domain, and time frequency domain. Based on the graph, the defective bearing can be recognised without turning off the machine. S-Transform (S-T) will detect the failure in bearing better than using Short Time Fourier Transform (STFT) because it can apply multi resolution that can detect the changes of amplitude.

1.5 PROJECT SCOPES

i. Using rolling element bearings as a workpiece
ii. Measure the vibration using accelerometer with sampling frequency of 20kHz.
iii. Using a Short Time Fourier Transform and Stockwell Transform.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the literatures that related to fault detection on rotating machine. This chapter will review about types of bearing, types of bearing's failure, data acquisition and signal analysis about fault detection on rotating machine.

2.2 ROLLING ELEMENT BEARING

Machines could not operate at high speed in their familiar way without some means of reducing friction and the wear of moving parts. Several important engineering inventions made it possible to successfully operate heavily loaded shafts at high speed, including the rolling element bearing and hydrodynamic, hydrostatic, and magnetic bearings(Harnoy 2003). In this experiment, I am using a bearing from the types of rolling element bearing

Rolling element bearings, such as ball, cylindrical, or conical rolling bearings, are the most widely used in machinery. Rolling bearings are often referred to as antifriction bearings. The most important advantage of rolling element bearings is the low friction and wear of rolling relative to that sliding(Harnoy 2003). Rolling bearings are used in a wide range of applications. When selected and applied properly, they can operate successfully over a long period of time. Rolling friction is lower than sliding friction, therefore, rolling bearings have lower friction energy loses as well as reduced wear in comparison to sliding bearings.

There are many different kinds of rolling bearings, and before embarking on a discussion of the theory and analysis of their operation, it is necessary to become somewhat familiar with each type. A description for each of the most popular ball and roller bearings in current use is given below(Harris and Kotzalas 2007).

2.2.1 Ball Bearings: Radial Ball Bearings (Single row deep groove ball bearing)

A single row deep groove ball bearing is shown in Figure 2.1; it is the most popular rolling bearing. The inner and outer raceway grooves have curvature radii between 51.5 and 53% of the ball diameter for most commercial bearings.

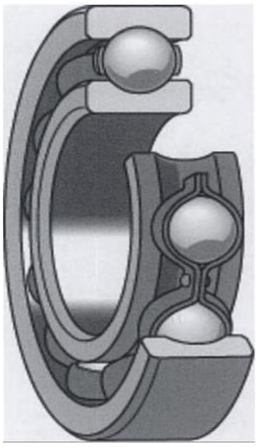

Figure 2.1: Single row deep groove ball bearing

Source: SKF

2.2.2 Ball Bearings: Radial Ball Bearings (Double Row Deep Groove Ball Bearings)

A double row deep groove ball bearing as shown in Figure 2.2 has greater radial-load carrying capacity than the single row types. Proper load sharing between the rows is a function of the geometrical accuracy of the grooves. Otherwise, these bearings behave similarly to single row ball bearings.

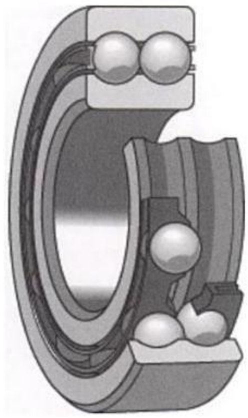

Figure 2.2: Double row deep groove ball bearings

Source: SKF

2.2.3 Ball Bearing: Angular Contact Ball Bearings (Single Row Angular Contact Ball Bearing)

Angular contact ball bearings as shown in Figure 2.3 are designed to support combined radial and thrust loads or heavy thrust loads, depending o the contact angle magnitude. Bearings having large contact angles can support heavier thrust loads. The bearings generally have groove curvature radii in the range of 52-53% of the ball diameter.