

**DIAGNOSING ROLLING ELEMENT BEARING FAILURE USING
VIBRATION ANALYSIS**

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ABSTRACT

This report presents vibration analysis for fault detection in rolling element bearing. Rolling element bearing is one of the important parts in rotary machine. The failure of rolling element bearing will affect the production and increase the maintenance cost. The maintenance cost increases because of failed rolling element bearing during operation of the machine will affect the other parts of the machine such as connecting rod, block sleeve, and many other important parts. Therefore, this project will come out with the data to predict the health of rolling element bearing and predict the onset of failure of rolling element bearing. This project will use the machinery faulty simulator as experiment apparatus. This apparatus will detect the vibration frequency at the bearing and the data will be converted to the spectrum by using VIBRA Quest software. The bearing that be used for the experiment is from RHP self-lube bearing insert 1120-3/4. This bearing will replace the old bearing at the experiment apparatus so that the best result will be taken. The bearing will be monitored until it damage and their data will be recorded to see the failure pattern. At the end of the project the prediction for onset of failure of rolling element bearing can be achieved.

ABSTRAK

Kertas kerja ini membentangkan analisis getaran yang dapat mengesan kerosakan pada komponen bearing. Bearing adalah komponen yang penting dalam setiap mesin. Kegagalan bahagian ini akan menjejaskan pengeluaran dalam sesuatu produksi. Ia akan membuatkan kos penyelenggaraan lebih tinggi jika mesin digunakan sehingga mesin gagal berfungsi kerana ia akan menjejaskan bahagian-bahagian penting yang lain dalam mesin seperti rod penyambung, blok, dan banyak bahagian-bahagian penting lain. Oleh itu projek ini akan datang dengan data untuk meramal jangka hayat bearing dan meramal permulaan kegagalan galas unsur bergolek. Projek ini akan menggunakan alat utk mengesan getaran sebagai radas eksperimen. Radas ini akan mengesan getaran pada bearing. Bearing akan dijalankan sehingga ia gagal dan data akan direkod utk melihat corak kegagalan

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CHAPTER 1

INTRODUCTION

1.1 Background

Bearing is a device that allows constrained relative motion between two or more parts. Usually, bearing is function in rotation movement or linear movement. It is function to transform directional motion into rotational motion. Bearing is classified by according to the motion they allow, the principle of their operation and the directions of load applied on it. The idea of using a rolling element or bearing to move heavy item is back to the ancient Egypt time, they are using logs to roll their large stones to the construction areas. With time past by and advance technology bearings have become more significant to production lines and new material have been used to produce bearing.[1]

There are six common types of bearing. That is plain bearing, rolling-element bearings, jewel bearings, fluid bearings, magnetic bearings and flexure bearings. Plain bearing also know as friction bearing is the simplest principle of bearing. This type of bearing comprising just a bearing surface and no rolling elements is used.[2] Rolling-element bearing can be classify into two types, that is ball bearings and roller bearings. Ball bearings are classified according to their bearing ring configurations. While roller bearings is classified according to the shape of the roller that been used.

Common type of rolling element bearing is ball bearing. This is because this type of bearing is easy to manufactured and therefore common usage in machinery. Ball bearing can support both radial and axial loads. Roller bearings is classify into five type, they are cylindrical roller, tapered roller, needle bearing, taper spherical roller and spherical roller.[3] Jewel bearing is a plain bearing that been used in precision instruments, it is commonly used in mechanical watched. Jewel bearing made of synthetic sapphire [4] Fluid bearing are bearings that support bearing load on a thin layer of a liquid , this liquid is pressurize by a pump. Magnetic bearing, this type of bearings support moving machinery without physical contact because it support a load by using magnetic levitation[5]. Flexure bearing, this is a simple and cheapest bearing compare to other type of bearing. A flexure bearing allow motion by bending their load element. [6]

Detecting rolling element bearing faults is the highest priority for most vibration analysts. Detecting the fault at the earliest opportunity should be the priority. Since bearings are subjected to deterioration relative to both usage and age, which leads to reduced products quality and increase in production costs, manufacturing industries worldwide carry out predictive maintenance on bearings and equipment to prevent or slow down such deterioration. This type of technique required an engineer to predict the best time on when the replacement need to be done on these rolling element bearing which it is onset of failure. By doing so, it is possible to create a proactive step in designing a system which has the lowest failure probability for the machines along part routes. This will ensure due date fulfilment and improve the overall performance of the manufacturing systems.

1.2 Objective

- i. To predict deterioration stage of rolling-element bearing by using vibration analysis of spectra
- ii. To predict onset of failure of rolling-element bearing and provide suggestion of rolling-element bearing replacement time.
- iii. To study the phenomena of vibration response to fault

1.3 Scope

- i. Condition based maintenance using vibration analysis on bearing on laboratory apparatus.
- ii. To determine bearing stage failure using vibration analysis.
- iii. Testing faulty bearing on laboratory apparatus to records their vibration signal.

1.4 Problem Statement

Rolling element bearing (REB) is one of the main components of rotary machine. The failures of these components will cause a high maintenance and operational cost. Therefore, there is a need to predict the best time on when the replacement need to be done on these REB which is its onset of failure. Vibration analysis is one of the most common technique in predicting the onset of failures of REB. This project will propose the best way to use the analysis in predicting the onset of failures of REB

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Most of improvement in achieving high reliability in manufacturing system is contributed by research and development in manufacturing industries worldwide. In manufacturing industry back then, maintenance is somewhat uncalled for, but as time passes by and there is problem to be solved each day, maintenance has become a part of the production process and the core of the business itself.

Rolling-element bearing has ultimately long service lifespan when it is being applied and maintained properly. The ball, cylindrical roller, spherical roller, and tapered roller are the types of bearing that are commonly used. Normally, no signs of wear will be shown by bearings unless dirt, or abrasive foreign matter, got into them. The bearings may have longer service duration than the machine in which they were installed when they are selected rightfully, lubricated appropriately and protected from misuse. Eventually, bearing service duration comes to an end when the deterioration caused by rolling fatigue makes the operation turn out to be inadequate. [7]

2.2 Bearing failure

No rolling bearing can last forever as per say. Even though the perfect operating condition has been applied and the fatigue load limit has never been exceeded, the material of fatigue will appear naturally. The period until the first sign of fatigue appears is a function of the number of revolutions performed by the bearing and the magnitude of the load. Fatigue is produced when shear stresses cyclically appear instantly below the load carrying surface. Cracks occurred due to these stresses progressively extend up to the surface. The rolling elements passed over the cracks fragments of material break away is known as flaking or shedding [8]

The definition of rolling bearing life is the number of revolutions that the bearing can perform before the flaking starts to occur. However, the bearing is not out of use at once. This is due to the fact that flaking is a quite long, drawn-out process and makes its existence acknowledged by escalating noise and vibration levels in the bearing. Hence, there is always abundance of time to get ready to face the change of bearing. [9]

2.2.1 Flaking Failure

Figure 2.1 shows the bearing that undergoes the condition when surfaces disintegrate into irregular particles, which is known as flaking. As the pothole-like flaws develop due to contact loading, the bearing surface becomes rough and literally peels off. Rapid metal fatigue in cyclically stressed surfaces subject to disproportionate loads or exposed to excessive temperatures caused by insufficient clearances is the cause of the event. Flaking that develops on one side of a ball bearing raceway indicates that the contained overloading which caused it was forced mainly on one side of the race. The most apparent cause for this is excessive thrust loading in one direction axially.

In order to avoid a recurrence of flaking, preventive measure that can be taken into consideration may include using a bearing with a higher load rating, reducing an abnormal load, and possibly increasing lubricant viscosity.[10]



Figure 2.1 Bearing Flaking [10]

2.2.2 Seizing Failure

One of the most common failure modes when bearings are first put into service is seizing failure as shown in Figure 2.2. The lack of rolling element rotation results in a rapid and excessive rise in temperature. The surface hardness of the bearing races and rollers or balls is reduced, and the bearing is quickly rendered inappropriate for use. The first indicator of damage is the rollers, as their corners change colour due to loss of temper associated with excess temperatures. Metal to metal contact takes place between rolling elements and raceways, and then micro-welding and overheating occur. As this phenomenon progresses ever more rapidly, seizing takes place. There are three common causes of seizing and each one, or a combination of these, can result in overheating and bearing damage. The first causal factor is improper clearance among the bearing parts, the second is improper lubrication, and the third is excessive mechanical load.

Preventive measures to avoid a repetition of seizing comprise proper mounting fits, correct lubrication, and reducing excessive load.[11]



Figure 2.2 Seizing Failure [11]

2.2.3 Race Fracture

Improper mounting, insufficient internal clearance among bearing parts, or shock loads can result in fracture of bearing races. Figures 2.3 illustrate a split in the outer race of a bearing. The fracture often comes about as a consequence of sharp impacts during rotation caused by previous flaking. It should be suspected as the primary cause of bearing failure, if flaking is found in the split race. In some cases a crack may not be readily visible, but large enough to create fine metal chips that will deteriorate the bearing. Axial direction, like parallel to the shaft centreline, cracks on a bearing inner race can be caused by too tight of a fit between the race and shaft. The shaft mounting surface is most likely oversized, resulting in this condition, which often appears immediately after the improper installation. Precise measurement of the shaft, establishing the correct fit tolerances, and proper installation are essential to certify a full useful bearing life.

Preventive measures in order to avoid a recurrence of race fracture include proper mounting, correct fits, and eliminating shock loads.[12]



Figure 2.3 Race Fractures [12]

2.2.4 Retainer Failure

Retainers are spacing bands or cages that enclose and separate the rolling elements of a bearing. These assemblies may be damaged by unfamiliar matter such as dirt that entered the bearing. Metal particles produced by flaking or cracking can also lead to retainer and bearing failure. The cage is vulnerable to damage during mounting, when it is potentially exposed to being struck. In case of bearing over speeding, retainers may also fail.

Preventive measures to avoid a recurrence of retainer failure include eliminating the means of entry for foreign matter getting into the bearing and care during mounting.[13]



Figure 2.4 Retainer Failures [13]

2.2.5 Rust Failure

There is one major cause of bearing rusting that is improper care during storage, maintenance, or when the associated machine is not operating. Bearings should be stored in a dry place, and even better, in the original manufacturer's container. If it is not stored as it should be, the rusting can take place. Improper care is when a fingerprint pattern can be observed. This was caused by managing of a bearing with moist or perspiring hands, probably during installation. This type of rusting is most crucial when it occurs on raceways or rolling elements. Microscopic pits develop at first and later the degradation expands into flaking. Water entering a bearing may cause localized rusting on a raceway at the pitch interval of the rolling.

The water may enter the bearing directly, as if the machine is submerged in a flood, or through condensation. The condensation could be produced by the surrounding air temperature dropping below the dew point with the bearing at rest. Rust may also occur as a result of exposure to liquid or gaseous corrosives, such as acids. The solution is to divert corrosive liquids or seal against corrosive gases.

Preventive measures to avoid a recurrence of rust include storing in a dry location, avoiding direct hand contact while mounting, and not allowing water to condense on or flood the bearing. The rust failure of bearing is illustrated in Figure 2.5.[14]



Figure 2.5 Rust Failure [14]

2.2.6 Wear

All bearings normally go through a wear period of several hours after preliminary operation, after which the rolling elements and raceways are “broken in,” and distinguishable wear ceases. Under unusual conditions wear may continue until clearances between bearing parts become excessive and the bearing is no longer acceptable for use. Inner races wear out into a noticeably eccentric shape. Common causes of wear are contamination of the lubricant, lapping effects due to dirt or metal chips or rust, and softening of hardened surfaces due to overheating. Above of all the factors, contamination is a leading cause of bearing failure, with contaminants being airborne dust, dirt or any abrasive that finds its way into the bearing. Bearings depend on the continuous presence of a lubricating film, typically only a few

millionths of an inch thick, between the races and rolling elements. Accumulated wear of retainers can result in seizing. Retainer wear and subsequent seizing is often linked to poor lubrication. However, pressed steel retainers, which are common to many ball bearings, are not prone to this type of failure. This is because lubricant can reach all parts of the bearing quite easily. On the other hand, retainers which enclose the rolling elements completely are likely to wear and seize when insufficiently lubricated.

Preventive measures to avoid a recurrence of wear include improved lubrication and improved sealing. [15]



Figure 2.6 Wear Failures [15]

2.2.7 Electrical Erosion

Bearings can be damaged and eventually destroyed by electrical currents. Stray currents may result in patterns such as those in Figures 2.7. Even a very low voltage, on the order of 2-3 volts, can cause enough of an arc to burn a small pit into races or rolling elements at points of contact. These pits will develop, through the process of wear, until the bearing is destroyed. Lower current (amperage) creates an alteration of the surface which appears as spaced grooves, whereas higher current will produce high temperature spots where the metal actually melts. The type of damage associated with an intermittent electric current is illustrated in Figure 27. Repeated temporary heating at the points of rolling contact will reduce the hardened temper of the bearing surfaces. The resulting uneven surface hardness produces

flaking, and visible fluting of the races may result apart of creating vibration. Any or all of these factors affect the bearing life. Destructive bearing currents are a rising alarm with electric motors powered by variable frequency drives. The drives produce electrical anomalies known as harmonics which result in stray currents passing through the motor bearings.

In order to avoid a recurrence of electrical erosion, the current source should be eliminated, the bearing should be insulated, and alternate grounding path should be provided. Particular attention must be paid to grounding paths during welding, to avoid passing welding currents through bearings.[16]



Figure 2.7 Electrical Erosion[16]

2.2.8 Roughening

Foreign material intrusion into a bearing lubricant leads to roughening of the load carrying surfaces. Every time a hard particle is trampled into the metal surface, a small cavity is left, and the surrounding material protrudes upward. As shown in Figure 2.8, small particles will leave a frosted appearance on the polished surface. The surface may appear to sparkle when viewed through a microscope in severe cases. The abundant small dents are moderately dark, and the raised areas surrounding them become highly polished by the continuing wear. Minor roughening may not seriously be affecting bearing life. However, severe roughening creates local stress concentrations result in flaking and premature bearing failure sooner or later.

Preventive measures to avoid a recurrence of roughening include improved lubrication, improved sealing, and cleaning of the shaft and housing prior to mounting.[17]



Figure 2.8 Roughening [17]

2.2.9 Brinelling Failure

When a bearing is dropped, or subjected to any other form of excessive impact, the rolling elements will drive against the raceways hard enough to produce indentations at the point of contact. The term for this situation is brinelling. Brinelling may also occur by applying a driving force to the balls or rollers, instead of the races, during mounting or dismounting. Noisy operation and vibration may stem from brinelling,

Preventive measures to avoid a recurrence of brinelling include proper handling and applying pressure only to the raceway being press fitted during mounting. Figure 2.9 illustrate the brinelling failure of a bearing.[18]