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VIBRATION ANALYSIS ON A BEARING USING SHOCK PULSE MEASURING TECHNIQUES

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VIBRATION ANALYSIS ON A BEARING USING SHOCK PULSE MEASURING TECHNIQUES

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Engineering with Honours (Mechanical and Manufacturing Engineering)

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Dedicated to my beloved family and supportive friends

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ABSTRACT

As rolling element bearing is the most important part in rotating machinery, it is inevitable for faults or defects to occur after running for a certain period of time. Technology nowadays allows the diagnostic of bearing abnormalities without destroying the structure. The study is carried out to inspect the bearing condition on rotating equipment of "whirling of shaft". Besides, the vibration behaviors of the bearing at variable speeds are also studied. Shock Pulse Analyzer is employed in order to achieve the objectives of the study. The experimental data are analyzed and discussed to identify the causes that influence the results. The data analysis obtained shows that the bearings under study are in a good condition. In addition, the bearings also experienced greater vibration severity when the operating speed is increased. Appropriate actions are suggested to minimize or rectify the flaws.

ABSTRAK

Bearing merupakan komponen yang paling penting dalam peralatan yang berpusing. Setelah beroperasi untuk satu jangka masa tertentu, bearing berpotensi untuk rosak. Teknologi terkini membolehkan kecacatan pada bearing dikesan tanpa memusnahkan struktur bearing tersebut. Kajian dijalankan untuk memeriksa keadaan bearing pada peralatan berpusing "whirling of shaft". Selain itu, sifat getaran yang ditunjukkan oleh bearing pada kelajuan yang berbeza turut dikaji. Shock Pulse Analyzer digunakan untuk mencapai objektif kajian ini. Berdasarkan analisis data yang diperoleh, bearing yang dikaji berada dalam keadaan yang baik. Bearing turut mengalami kekerasan getaran lebih ketara apabila kelajuan mesin meningkat. Tindakan yang berpatutan dikemukakan untuk mengurangkan atau memperbaiki kerosakan tersebut.

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NOMENCLATURES

A = amplitude

a_1 = life adjustment factor (reliability)

a_2 = life adjustment factor (material)

a_3 = life adjustment factor (operating conditions)

C = basic dynamic load rating (N)

d_f = frequency resolution

e = eccentricity

F = force

f_{max} = maximum resolvable frequency

$f_{Nyquist}$ = Nyquist frequency

f_s = sampling frequency

L_{10} = basic rating life (millions revolutions)

L_{10h} = basic rating life (hours)

L_{na} = adjusted rating life (millions revolutions)

m = mass of the component

N = number of samples

n = rotational speed (rev/min)

P = equivalent dynamic bearing load (N)

p = exponent of the life equation

r = shaft deflection

T = acquisition time

t = time (sec)

θ = whirling displacement

$\dot{\theta}$ = whirling speed

ϕ = phase angle (radians)

ϕ_w = phase angle lag of whirl with respect to shaft speed

ω = rotating speed

ω_n = natural frequency (rad/sec)

CHAPTER 1

INTRODUCTION

1.0 Introduction

Vibration is synonym with rotating machinery. Uncontrolled vibration may result of machine damage. It is then important to control such vibration to within reasonable limits for safe and reliable operation of the machine although it is impossible to totally eliminate the vibration. Most rotating machines used rolling element bearings to support rotating shafts by carrying the loads. The bearings application throughout the industry also plays an important role to minimize friction for the performance of the machines. They can be found in aerial coolers, pumps, turbines and other rotating machines. They can be classified into two main categories; namely, ball bearings and roller bearings. Ball bearings are the common type of rolling element bearing which support loads for both directions; radial (perpendicular to the shaft) and axial (parallel to the shaft). In contrast, roller bearings possess greater radial load-carrying capacity but lower axial load-carrying capacity compared to ball bearings.

Rolling element bearing failure is the condition where the bearing starts to damage and gradually fail to work properly. Bearing failure may contributed by several factors; lack of lubrication, metal fatigues, contamination and high temperatures. Monitoring the performance of the bearing is then important to prolong the usage. The purpose is to determine the right time to do the replacement besides maximize the bearing life. Bearing replacement can be done during early stage of bearing failure (premature) or to wait for the bearing to fail.

The work details in this report will employ *Shock Pulse Method* (SPM) as a signal processing technique to measure shock pulses on rolling element bearings. The shocks generated by bearings will be displayed on the instrument by touching the bearing housing with the built-in probe. The bearing condition can be checked from the analysis of the intensity and amplitude of the shocks. It becomes a widely used technique for predictive maintenance throughout the world.

Further details of the report are described in the following chapters; Chapter 2 will describe on Literature Review in particular research work in this area. Chapter 3 will focus on the method employ and Chapter 4 will discuss the experimental result obtained. Conclusion and further recommendation work are discussed in Chapter 5.

1.1 Objectives

The experiment will be conducted on rotating equipment called whirling of shaft. This machine is considered as rotor system which consists of shaft supported by bearings and power-driven by electric motor. The experimental objective is to monitor bearing condition. Besides, the project's aim is to study the vibration characteristics of the bearings at variable speeds. The measuring results will be compared and analyzed.

In order to achieve the objectives, Shock Pulse Analyzer will be employed as the measuring instrument to get the measuring results of the bearings. The results will present the bearing condition and vibration behaviors at various speeds. These results are then studied.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Bearing is one of the most important components in rotating equipment in order to ensure the equipment runs smoothly and this may generate either acceptable or unpleasant vibration, depending on several factors. From these vibrations, bearing condition and vibration behavior can be identified and analyzed by the vibration analysis.

This chapter will review the shock pulse and vibrations, the measurement and the frequency domain. Furthermore, review of bearing including bearing components, dimensions, bearing life and lubrication are also described. In addition, the details of bearing faults such as unbalance, whirling, misalignment, mechanical looseness and damaged or worn rolling element bearing are reviewed. Comparison methods to diagnose faults on a bearing are also made which are nonlinear dynamical analysis and differential diagnosis of gear and bearing faults.

2.1 Vibration Theory

Vibration occurs in most environments. The occurrence of vibrations results in pressure disturbance in sound, and in many other environments. A system is forced to vibrate at the same frequency of the excitation when it is subjected to harmonic excitation (Thomson, 1993). Harmonic motion is the simplest form of periodic motion. The principle properties of this motion are displacement, velocity and acceleration (Inman, 2001).

Vibration displacement is the total distance travelled in one dimension by an object that vibrates in a system. Displacement can be measured either translational or rotational. In the unbalance case, the displacement corresponds to deflection of rotor from the origin which means center of mass of a rotating component does not coincide with the center of rotation. This phenomenon is called *mass eccentricity* (De Silva, 2005). The displacement, $x(t)$ is written as

$$x(t) = A \sin(\omega_n t + \phi) \qquad (2.1)$$

Vibration velocity is the speed of a mass which undergoes oscillation for harmonic motion. On the other hand, velocity is the rate of change of displacement with respect to time. By differentiating equation (2.1) will yield as follows

$$\dot{x}(t) = \omega_n A \cos(\omega_n t + \phi) \tag{2.2}$$

The relative amplitude of the velocity is larger than the displacement by a multiple of ω_n. Also, the velocity is 90° (or π/2 radians) out of phase with the displacement (Inman, 2001). The displacement is maximum when the velocity is zero and vice versa.

Vibration acceleration is defined as the second derivative of equation (2.1). The derivative yields

$$\ddot{x}(t) = -\omega_n^2 A \sin(\omega_n t + \phi) \tag{2.3}$$

Equation (2.3) shows the relative acceleration amplitude is larger than displacement by a multiple of ω_n^2. In addition, the acceleration is 180° (π radians) out of phase with the displacement and 90° (or π/2 radians) out of phase with the velocity (Inman, 2001). When no force is applied, the displacement and the acceleration will be zero. The maximum force applied results the maximum displacement and acceleration. However, the applied force is opposing the displacement direction.

The relationship between displacement, velocity and acceleration for harmonic motion is displayed in Figure 2.1.

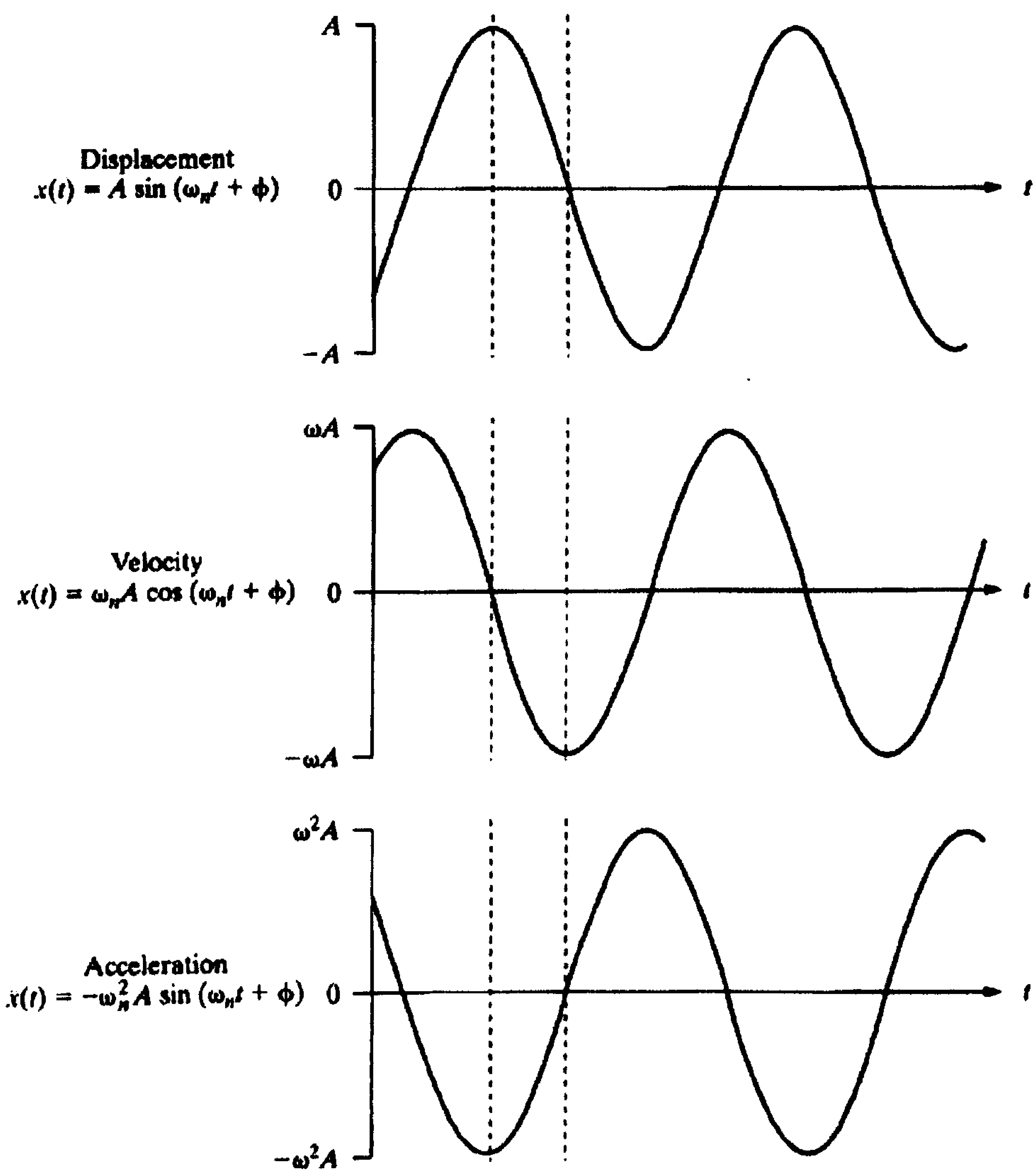

Figure 2.1: Relationship between Displacement, Velocity and Acceleration

(Inman, 2001)