USING IMAGE PROCESSING AND QUANTITATIVE TECHNIQUE TO DETERMINE THE ONSET OF GEAR FAILURE

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor Mechanical Engineering (Plant and Maintenance)"

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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature: ....

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Date: 26 JUNE 2015

Dedicated to my beloved family

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ABSTRACT

The aim of this study is to predict the onset of gear failure based on operating hours. Wear Debris Analysis (WDA) has been proven useful in providing valuable information as it also provides supporting indication of the nature and severity of gear failure. It is important to analyse the basic features of wear debris for prediction of component machine condition. In this research, a back to back test rig was used to study the effect of deterioration stage of gear against abnormal loading time. This thesis proposes an offline sampling technique which uses image processing and particle counts to diagnose the condition of machinery. It emphasizes on using size, shape and surface texture of the particles generated over time to predict onset of gear failure. Therefore, maintenance action can be taken before gears reach catastrophic failure. By the end of the experiment, result shows an increasing of operating time, there will be an increasing of size and increasing the number of particle count of wear particles that generated from friction between two surfaces of gears.

ABSTRAK

Tujuan kajian ini adalah untuk meramal berlakunya kegagalan gear berdasarkan waktu operasi. Analisis Serpihan Haus (ASH) telah terbukti berguna dalam menyediakan maklumat yang berharga kerana ia juga menyediakan sokongan petunjuk kepada jenis dan tahap kegagalan gear. Ia adalah penting untuk menganalisis ciri-ciri asas serpihan haus untuk ramalan keadaan mesin komponen. Dalam kajian ini, „back to back oil test rig‟ telah digunapakai untuk mengkaji kesan peningkatan kemerosotan gear terhadap waktu bebanan tidak normal. Tesis ini mencadangkan teknik persampelan luar talian dengan menggunakan pemprosesan imej dan bilangan zarah untuk menganalisa keadaan jentera dan mesin. Ia memberi penekanan kepada saiz, bentuk dan tekstur permukaan zarah yang dijana dari masa ke semasa operasi untuk meramalkan masa berlakunya kegagalan gear. Oleh itu tindakan penyelenggaraan boleh diambil sebelum gear mencapai kegagalan yang amat teruk. Pada akhir eksperimen, keputusan menunjukkan peningkatan masa operasi gear, akan ada peningkatan saiz zarah dan peningkatan jumlah kiraan zarah serpihan haus yang dihasilkan oleh geseran daripada permukaan daripada dua gear.

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NOMENCLATURE

WDA	Wear Debris Analysis
LCA	Low Carbon Alloy
DLC	Diamond-like Coating Carbon
CHS	Carbon Hardened Steel
CBM	Condition Based Maintenance
CCD	Charge Couple Device
REB	Rolling Element Bearing
ATF	Automatic Transmission Fluid
DC	Direct Current
DV	Digital Viscometer
LED	Light Emitting Diode
RPM	Rotation Per Minutes

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Modern high speed and power machinery components will reach the end of their useful operating life due to a gradual or sudden failure like gears, bearings, pumps, hydraulics systems, turbines, compressors and motor [1]. A sudden failure is not desirable as it may involve in human life and interruption of machine operation [2]. To avoid and minimize sudden failure and possibility consequence, it's very important to determine the failure root cause from the component machine in near real time [3]. Wear is one of the failures that could occur in component and it is a normal characteristic of machine operation. Wear is something that's not required, but it happened nevertheless and also unwanted removal of surface particle [4]. Wear can reduce mechanical efficiency and a permanent loss of material. From the wear processes, debris was generated from rubbing surface and produce friction of load carrying machine component. Wear debris generate in lubricating oil carry important information related to the condition and health of the component machinery Condition based maintenance (CBM) also known as predictive maintenance aims to monitor life or health of a machine‟s condition really its reliability. CBM may go on a whole host of other connected benefit and valuable addition to comprehensive such as reduced maintenance cost, minimize damage of equipment, good financial return and limit production loss. Various technologies are employed as part of a comprehensive predictive maintenance program to monitor the signs of faults such as vibration analysis, thermography, wear debris analysis, oil analysis, ultrasonic testing and machine performance. Different condition monitoring techniques have their own advantages and disadvantages. Unfortunately, no single technique has been able to resolve all CBM requirements. Different of requirement in the plant is different based on selecting CBM techniques. The WDA technique has been developed in terms of wear debris size, shape, material composition, features of boundary and size distribution [5; 6]. The particles collected from lubricant oil are useful in machinery maintenance decisions for predicting and accessing machine condition. WDA is the most effective CBM strategy to detect and diagnosing the deterioration stage of machine component through the analysis of oil properties and wear particles. Furthermore, many good benefits can result from CBM practices when gear fault detection is preferred, although have not been applied widely in the industry due to lack of automation and time consuming. WDA can provide the detail of wear mode, wear severity, surface degradation rate and component source [7]. This motivates researcher to study the onset of gear failure related by using WDA.

1.2 PROBLEM STATEMENT

Gear is widely used in industrial application such as power generation in oil and gas industry. Gear is a component within a transmission device where it transmits rotational force to another gear or other component. Every gear has its own operating lifetime. Therefore, it only can be used in certain period based on its lifetime. Based on bathtub curve, gear will be operated based on its lifetime from infant mortality to normal life where it is at a low constant failure rate. After that, it will fail or end of life caused by worn –out due to fatigue of materials. A gear is failed when it no longer performs efficiently and safely for which it is designed. There are many causes of failure that may occur in certain system operation that involved in gear such as rubbing wear, cutting wear, rolling fatigue, severe sliding wear and combined rolling and sliding wear action between it solid surfaces.

When one of the gears is found to be defective while it is operating, it could affect the system and may cause serious damages. It can interrupt the production or can cause injury. Gear defect will further produce debris particles that are generated by wear processes. When the wear occurs, they can be classified as a type of failure occur by their shapes, sizes, edge details, colours, thickness ratios and surface textures. Wear debris is a characteristic of the condition under which it was formed and study of these wear particles can yield significant information about the state of the surface from which it is produced [5]. Wear is not only caused by two surfaces rubbing together, although it is a major cause. Wear condition is also due to vibration or multiple influence known as fatigue wear because of some other motion or external impact. Materials are lost from the surface of a component gear. Thus when wear occurs, it may not be able to be stopped, but it can be anticipated to a certain extent and action taken before wear-out [4].

Therefore, WDA is one of the ways to monitor the health of the gear. This case study will be focusing on three morphologies of wear debris analysis, which are shapes, size and surface textures. Three types material of helical gear will be used as tested gear, which is low carbon alloy (LCA), diamond-like carbon coating (DLC) and carbon hardened steel (CHS). Then, debris particles will be analysed using software AMS Suite Machinery Health Manager 5.5 to investigate the failure of machine component. By making wear debris analysis, it can help to recognize a type of failure based on information gain from qualitative and quantitative techniques.

1.3 OBJECTIVES

This research tries to accomplish the following objectives:

i. To use image processing to detect failure signs on wear debris particles generated from the gearbox.
ii. To use particle count for determining the onset failures of the gear.

1.4 SCOPE

i. Set up experimental work on back to back the gear test rig for collect wear debris particles.
ii. Use three types material of helical gear as tested gear, which is low carbon alloy (LCA), diamond-like carbon coating (DLC) and carbon hardened steel (CHS).
iii. Perform qualitative and quantitative techniques to determine the deterioration stage of gear failure.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The research served in this thesis is principally based on theoretical and experimental. This chapter will review and discuss about generation and process of wear debris, wear debris analysis, wear mechanism, wear morphology and types of failure of gear. Furthermore, recognize how knowledge of wear debris features will help to monitor the health, condition and deterioration stage of component machine such as size, shape, material composition, features of the boundary and size distribution.

2.2 WEAR DEBRIS ANALYSIS

Wear debris analysis is a great technique for non-instructive test of the oily part of machinery because provide valuable information and supporting indication of the nature and severity. WDA is widely applied technology in machine health and condition monitoring. Every debris particle contained in the lubricating oil has its own important in providing extremely valuable information on wear mechanism on the condition and the health of the machine component by analysis shape, size, quantity and composition of particles. The particle characteristics are appropriately specific so that the operating wear modes within the machine may be determined and allowing prediction of the imminent behaviour of the machine [8]. WDA technique is even capable to determine wear from many processes namely sliding, rolling, rubbing and cutting wear. Every mechanism is producing a different morphology. Wear debris comes in a wide variety of sizes and shapes. Size wear debris may vary anywhere from a few microns to thousand microns.

2.3 WEAR DEBRIS GENERATION

Wear debris is a particle which have been shed or loss from the mechanical surface component [20]. Wear debris particle produced from the machine component like gears or bearing result of two surfaces rubbing, sliding or rolling together. Meanwhile the plastic flow or breakage occurs due excessive loading. It may also have some influences in developing a kind of wear. Wear debris generation is frequently illustrated based on a bathtub curve as shown in Figure 2.1. It is a statistical method used to demonstrate the general pattern of a machine system based on its operating time.

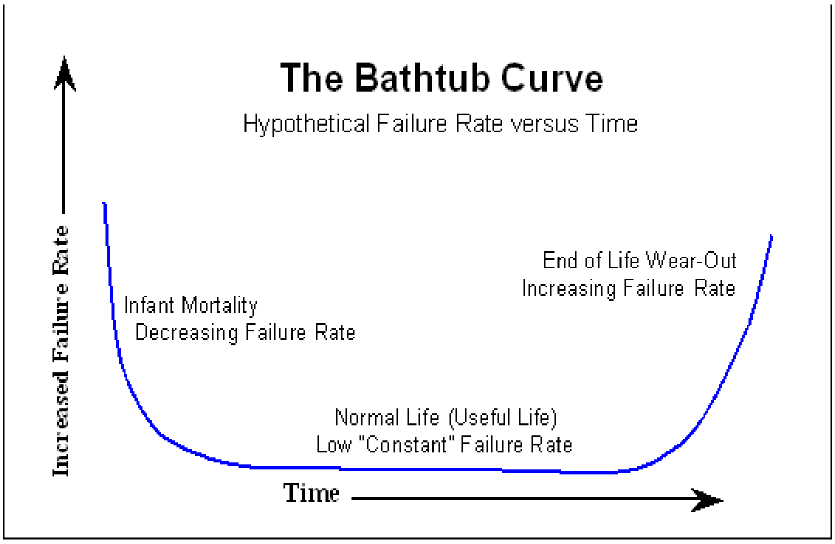

Figure 2-1: The bathtub curve [9]

„Bathtub curve" is basically has three regions of wear in life period, which is running-in, useful working life and end of life wear out. The curve describes the relative failure rate of an entire wear particle generation versus time. This bathtub curve is illustrated that a new machine has a relatively high probability of failure [10]. In the first period, also known as infant mortality it is decreasing rapidly of failure wear rate. This period is typically quite short interval. Wear is usually beneficial and provides an improvement for later running and particularly true for gears. Following the initial period the probability of failure is low and constant useful working life of the component for the normal life stage. At this period debris is produced quite small and minor in size and quantity. Lubrication is doing well in controlling the effect of wear of gears. The final stage is the disaster period because of the increasing failure rate. At this stage, fatigue starts to show with the result of large chunks of debris and increasing quantity of debris exponentially. The machine is so badly worn that there is serious misalignment and an overload of the component.

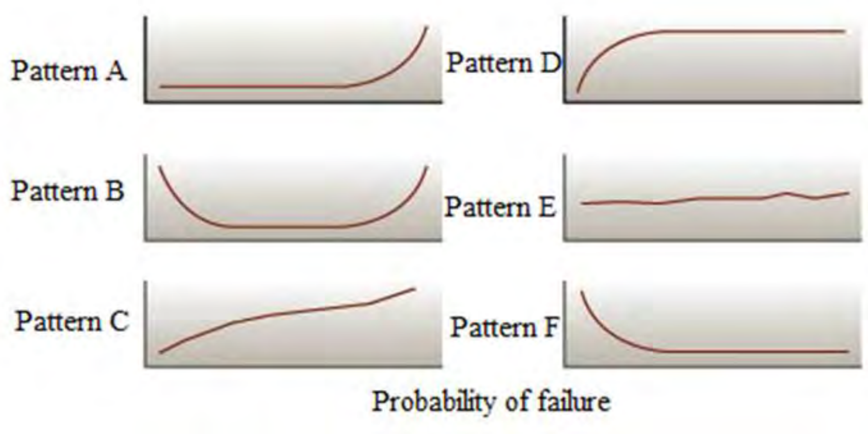

Figure 2-2: The six types of failure patterns

Figure 2-2, shows six patterns of failure [11]. Pattern A shows a constant increasing conditional probability of failure from beginning of the machine life and going with ending in the wear out region and about 2 % of failure rates. The longer operation time the high failure rate. This pattern is tough to differentiate between running-in and useful working life. Pattern B is the well-known bathtub curve as explained before based on Figure 2-1 and about 14 % of failure rates. Pattern C shows a consistently increasing conditional probability of failure rate from running-in to the