WEAR DEBRIS DETECTION AND ANALYSIS OF AUTOMOTIVE ENGINE LUBRICATING OIL

HAFIZUDDIN BIN SHARINGAT

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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HAFIZUDDIN BIN SHARINGAT
B041110021
BMCA
Email: hafizd63@gmail.com

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Projek Sarjana Muda II

Supervisor: PUAN SUSHELLA EDAYU BINTI MAT KAMAL

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

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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 of Mechanical Engineering (Automotive) with Hons"

Signature: ....
Supervisor: PN SUSHELLA EDAYU BINTI MAT KAMAL
Date: ....

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HAFIZUDDIN BIN SHARINGAT

This report is submitted in
fulfillment of the requirements for the award of
Bachelor of Mechanical Engineering (Automotive) with Honours

Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

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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: ....

Author: HAFIZUDDIN BIN SHARINGAT

Date: ....

DEDICATION

Special to my

beloved Mom and Dad

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ABSTRACT

This study is about wear debris detection and analysis of automotive engine lubricating oil. The purpose of this study was to investigate wear debris produced by the sliding condition in automotive engine parts. Wear debris will be produced by the friction between two sliding automotive parts. This debris will cause the defect on automotive engine if not controlled properly. Thus, this study will helps the maintenance engineer to schedule the overhauled of the engine and prepare the spares and replacement of engine parts according to the amount and shape of wear debris. By using pin-on-disc machine, wear test experiment was conducted. From wear test, the data of coefficient of friction and friction force was collected from data logging system to be analyzed. A material was being selected based on the material that used frequently for automotive parts. The debris produced from the friction of the material selected and rotating disc from this machine were collected for analysis. Scanning Electron Microscopy (SEM) was used in analyzing the wear debris collected. The size of wear debris was measured from the image scanned by SEM. EDX analysis software was used to determine the composition of wear debris produced from wear test.

ABSTRAK

Laporan ini mengenai kajian dan pengesanan serpihan besi pada minyak pelincir enjin. Tujuan kajian ini dijalankan adalah untuk mengkaji serpihan besi yang dihasilkan oleh geseran yang berlaku pada bahagian-bahagian dalaman enjin. Serpihan besi terhasil daripada geseran di antara dua bahagian dalam enjin. Serpihan ini akan menyebabkan kerosakan pada enjin jika tidak dikawal dengan baik. Jadi, kajian ini akan membantu jurutera penyelenggara untuk menjadualkan penukargantian dan menyediakan alat ganti bahagian enjin berdasarkan jumlah atau rupa bentuk serpihan besi. Satu ujian geseran telah dijalankan dengan menggunakan mesin *pin-on-disc*. Daripada ujian geseran tersebut, data yang didapati daripada sistem pengumpulan data diambil untuk dianalisis. Bahan yang digunakan sebagai bahan ujikaji dipilih berdasarkan bahan yang kerap digunakan pada bahagian enjin. Serpihan yang dihasilkan dari geseran antara bahan yang dipilih dengan cakera dari mesin ini telah diambil untuk dianalisis. *Scanning Electron Microscopy (SEM)* telah digunakan untuk menganalisis serpihan besi yang dikumpulkan. Saiz serpihan besi diukur daripada imej yang dihasilkan oleh mesin *SEM*. *EDX analysis software* digunakan untuk mengenalpasti bahan serpihan besi yang terhasil daripada ujian geseran.

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CHAPTER 1

INTRODUCTION

1.0 BACKGROUND STUDY

Wear appears as the gradual removal of material from contacting and rubbing surfaces of solids during their relative sliding. The mechanism of wear involves formation of debris particles. The particles have small sizes and different shapes. The wear debris can be rolled over into cylindrical, spherical and needle-like particles. The presence of wear debris between sliding surfaces affects frictional and wear behavior significantly. In an automotive engine, wear debris frequently occurs especially on sliding of piston and engine block. This debris can be removed by engine lubricating oil. The excessive wear debris in automotive engine can cause the defect on the operation of the engine. Thus, this research was carried out to investigate the wear debris reproduce by the sliding condition in automotive engines. Most of the automotive engine parts use aluminum as the material. Thus, aluminum rods are decided to be used in this research. This rod were used for pin-on-disc test on tribological testing. The experiment was conducted to collect wear debris by the sliding condition between the aluminum rod and rotating disc. The wear debris produced then need to be analyzed.

1.1 PROBLEM STATEMENT

The condition of engine operation are related to the process of wear debris generation and their morphology. Wear debris generated are harmful to the engine parts if not controlled properly. So, classification of debris in different morphological classes provided valuable information on the current state of tribosystems. Thus, this research of wear debris detection and analysis of automotive engine lubricating oil will helps the maintenance engineer to scheduled the overhauled of the spares and replacement of engine parts.

1.2 OBJECTIVES

The purpose of this research was to conduct wear test experiment to reproduce the sliding condition as in automotive engine. Then, the objective is to analyze the pattern, size and type of wear debris produced by the wear test conducted. The correlation between wear rate, coefficient of friction and wear debris need to be investigated.

1.3 SCOPE

The scope of this research was to conduct tribological testing. Pin-on-disc machine was used in this experiment. Aluminum rods with 12 mm diameter were used as the material for this experiment. The main consideration in this experiment was to collect wear debris produced from the experiment to investigate its correlation between wear rate and coefficient of friction.

1.4 CONTENT OVERVIEW

This chapter shows the introduction of this research. It consists of problem statement, objectives and scope of this research. Next chapter will describes about the literature review of this this research. The previous study related to wear debris detection and analysis of automotive engine lubricating oil will be described. Then, chapter 3 will descibes the review methodology that had been planned in carry out this research. Chapter 4 will described the results and discussion of the experiment. Lastly, chapter 5 will describes the conclusion and recommendation for this study.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter will describes the previous study related to wear debris detection and analysis of automotive engine lubricating oil. This literature review will begin with the fundamental of wear debris, the analysis step by previous study and necessary machine and components used. Study on other previous projects are intended to ease the progress of this research.

2.1 FUNDAMENTAL OF WEAR DEBRIS

According to Alfred (2005), wear appears as gradual removal of a material from contacting and rubbing surfaces of solids during their relative sliding. The mechanism of wear involves formation of debris particles. The particles have small sizes and different shapes. The wear debris can be rolled over into cylindrical, spherical and needle-like particles. Particles are detached from rubbing surfaces and they form a more or less continuous interfacial layer. They transmit forces, momentum and displacement at the contact interface. The presence of wear debris between sliding surfaces affects frictional and wear behaviour significantly.

The friction process elements operating in contact conditions always involves heat generation and wear of their surfaces. Wear and frictional heat apart from fatigue, fracture and corrosion are main factors which restrict a life time of machines and mechanical devices. Numerous machine component parts must be taken out of service not due to failure caused by exceedence of the limit stress but due to wear manifested in removal of a material.

2.2 WEAR DEBRIS ANALYSIS

Sondhiya and Gupta (2012) said that wear debris analysis is well-known in condition monitoring of tribosystem. The condition of machine operation are related to the process of wear debris generation and finally to their morphology. Thus, classification of wear debris in different morphological classes provided valuable information on the current state of tribosystem. Metallic wear debris are differentiated by their morphology into several classes. It has been found that each type of wear debris has its own generation mechanism involving a specific wear process.

According to Lovicz and Dalley (2005), six basic wear particles types are identified that generated through wear process. These types of particles including ferrous and non-ferrous metal. There are Normal Rubbing Wear, Cutting Wear Particles, Spherical Particles, Severe Sliding Particles, Bearing Wear Particles and Gear Wear Particles. The particles are differentiated to each classes to determine their type of wear and its source.

Normal Rubbing Wear happened when two parts/materials under load slide into each other and causes wear of parts of the shear mixed layer. Rubbing wear particles consists of flat platelets, generally 5 microns or smaller, although they may range up to 15 microns depending on equipment application. There should be little or no visible texturing of the surface and the thickness should be one micron or less. In automotive engine parts, this type of wear particles usually occurs in rotating shafts and valve seats. Figure 2.1 shows the sample ofRubbing Wear particles.

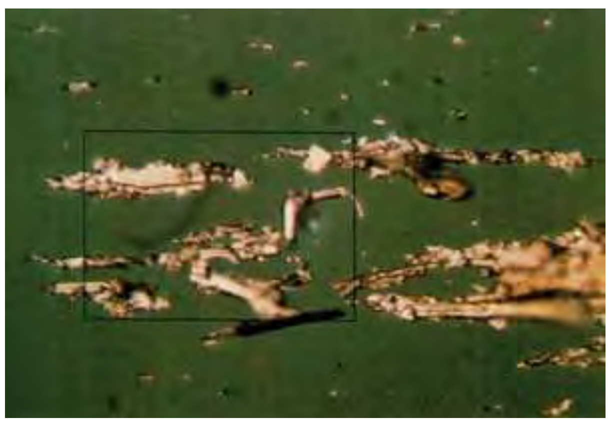

Figure 2.1: Rubbing wear particles (Lovics and Dalley, 2005)

Cutting wear particles are generated from one surface penetrating others. There are two ways to produce this type of wear. A component that relatively hard can become misaligned of broken causing hardly sharpened edge to penetrating a softer surface. Wear particles generated by this way is usually rough and larger about 2-5 microns wide and 25-100 microns long. Next, the contaminants such as sand or wear debris from other parts may become embedded in a soft wear surface likes tin alloy bearing. The abrasive particles stand out and penetrate the opposing wear surface. The particles that produces by this way are very fine wire-like particles. The thickness are about 25 microns and 5 microns long. Figure 2.2 shows the image of cutting wear particles.

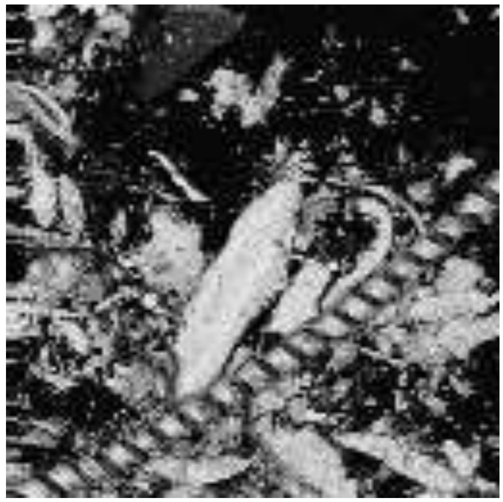

Figure 2.2: Cutting wear particles (Lentz and Toms, n.d)

Bearing cracks are generating spherical particles. The presence of spherical particles are good because it will gives signal of some problem in the engine might be happens because they can be detected before any actual spalling occurs. Roller bearing fatigue is not the only source of spherical metallic particles. They are known to be generated from cavitation erosion and more importantly by the process of welding or grinding. Spheres that produced by fatigue cracks can be compared to other mechanism based on their size. This type of wear basically over 5 microns diameter that generated by rolling fatigue. For spherical particles produced by welding, grinding and erosion are normally over 10 microns in diameter. Figure 2.3 shows the sample image of spherical wear particles.

Figure 2.3: Spherical wear particles produced by sliding wear process (Hurricks, 1974)

For severe sliding wear particles, this types of particles are identified by its parallel striations on their surfaces. The size are basically more than 15 micron, with length-to-width thickness ratio between 5 and 30 microns. Severe sliding wear particles sometimes show evidence of temper colour which may change the appearance after heat treatment process. Figure 2.4 shows the image of severe sliding particles. The parallel striations on the surface of the particles indicate the sliding motion happened.

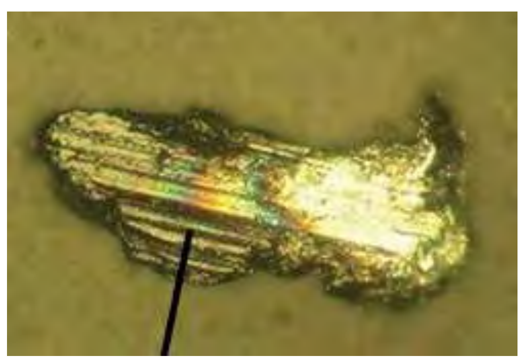

Figure 2.4: Severe sliding wear particles (Fitch, 2013)