A STATISTICAL MODEL FOR DETERMINING FRICTION AND WEAR OF SK11 IN ENGINE OIL

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "A Statistical Model for Detremining Friction and Wear of SK11 Ball Bearing in Engine Oil" is the result of my own work except as cited in the references.

Signature	**:...................................**
Name	**:...................................**
Date	**:...................................**

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved parents and my friends

ABSTRACT

In this project, several tools have been used during running the experiment. Firstly, it has been stand by the material that using such as lubricant with engine types of SAE 15W-40 an SK11 ball bearing. From these material, it has several parameters that will be followed before starting the experiment. Secondly, the experiment has been running by a Four-Ball Tester machine. The machine has been setup with several parameters before running the experiment such as value of load, speed and temperature. The result of the experiment will be cover the friction and wear rate of the SK11 ball bearing. Next, the result of friction and wear will be analyze into the S/N ratio and ANOVA in Taguchi method to get a proper statistical model result. Based on the analysis, the optimal parameter and model has been developed. Value for wear rate and coefficient of friction analyzed from Taguchi method observes that the result were significant.

ABSTRAK

*Dalam projek ini, terdapat beberapa kaedah dan alatan yang digunakan semasa menjalankan eksperimen. Pertama, ia terdiri daripada balan pelincir seperti minyak engine jenidd SAE 15W-40 dan bola SK11. Daripada bahan-bahan ini, terdapat beberapa parameter yang perlu diikuti sebelum menjalankan eksperimen. Yang kedua, eksperimen ini dijalankan mengunakan mesin Four-Ball. Beberapa parameter perlu di set pasa mesin sebelum menjalan eksperimen seperti nilai beban, kelajuan dan suhu. Nilai geseran dan kadar calar bola yang dihasilkan akan digunakan sebagai data hasil dari eksperimen ini. Seterusnya, hasil tersebut akan dianalisi ke dalam nisbah S/N dan ANOVA dengan mengunakan kaedah Taguchi untuk mendapatkan model statistic yang sepatutnya***.** *Merujuk pada analisis, optimum parameter untuk kadar calar pada bola dan kadar geseran telah ditentukan. Melihat dari kedua-dua nilai tersebut, data yang didapati untuk kedua-dua analysis dapat disahkan signifikan melalui kaedah Taguchi.*

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LIST OF ABBREVIATIONS

DOE	Design of Parameters
ANOVA	Analysis of Variance
OA	Orthogonal Array
WSD	Wear Scar Diameter
SK11	Carbon Chrome Steel
S/N	Signal to Noise
COF	Coefficient of Friction

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The focus for the project is about wear and friction. Lubricant are usually liquid, solid and gases or any combination of solids, liquids and gases. Lubrication used in an engine is important to separate surfaces in relative movement, flushing away particles, cooling the engine and reducing wear and friction. In order to reduce wear and friction, lubrication oil will be the main issued. Lubricant usually consists of two main components which are 90% base oil and 10% additives. Besides, consumption of lubricant oil increase with 1.5 % to 2% annually, thus by eliminating or reducing them is now impossible (Golshokouh, et al, 2014).In other hand, lubricants are an integral part of industrial application and in automobile engine.

Wear is a surface damage that occur due to the removal of material during sliding contact of two surfaces. Wear can occur as a result of several mechanism which includes abrasion and adhesion (Les Girard, et al, 2015). (Girard. L. et al) run a wear test that show the scar size of bearing lubricated with engine oil was a lot smaller compared with the scar size of bearing lubricated with mineral oil.

Other test run showed that the worn surface of a ball bearing lubricated with SAE 15W40 diesel engine oil had severe adhesive wear due to not enough support at the high-pressure contract area and result in plastic deformation. (Abdullah, et al , 2013)

1.2 PROBLEM STATEMENT

Friction and wear are the important aspect in the engine oil performance. Existing engine oil is only at high temperature, speed and load. So, in this project low value of load, speed and temperature with engine oil will be test to improve the performance of engine right after engine start up. Hence, Taguchi method is the method that will be used while doing the research because of the variance reduction for the experiment with optimum setting of control parameters.

1.3 OBJECTIVE OF PROJECT

The objectives of this project are as follows:

i. To define the optimal parameters for friction and wear reduction of SK 11 ball bearing in engine oil type of SAE 15W-40.
ii. To determine statistical model for friction and wear of SK 11 ball bearing in engine oil using L_9 Taguchi orthogonal arrays method.

1.4 SCOPE OF PROJECT

This research is carried out to study the prediction for friction and wear of SK11 in engine oil. The Four-Ball Tester experiment will be conducting for this research. The design of experiment under Taguchi method will be uses to set up the parameter for this research by using Minitab software. The parameter that are going to be used in this experiment are load, speed and temperature. The analysis of variance (ANOVA) and S/N ratio is used to analyse the friction and wear of SK11 ball bearing in engine oil.

CHAPTER 2

LITERATURE REVIEW

2.1 LUBRICANT REGIMES

Based on the friction experiment of bearing, Stribeck curve will expressed which part that the lubricant occurs. In the diagram, friction coefficient, f plotted as a function of the

Stribeck number, ηU/P where η is the dynamic viscosity of the oil, U is the relative speed between lubricated surfaces and P is pressure or load between the surfaces. Lubricating friction are divided into three regimes such as boundary, mixed or elastohydrodynamic and hydrodynamic lubrication.

$$lubricant\ regimes \equiv \frac{squeezed\ film\ thickness, h}{average\ surface\ roughness, R_a} \quad (1)$$

From the equation (1) (Les Girard, et al, 2015), if $h < R_a$, the direct contact occurs between high asperities of bearing surfaces. This lubricant called boundary lubrication and the regime will result in high friction and high wear. At this regimes, the friction coefficient is a constant and relatively large value of approximately 0.1 (Coy, 1998). Mixed lubrication where $h \approx R_a$ is characterized of intermittent contact between sliding surfaces at moderates speed and loads. During the mixed lubrication, the friction coefficient drops drastically to a minimum on the order of 0.001 to 0.002. The majority of the normal load between surfaces are supported by the pressurized lubricant and only a few sharp surfaces are brought into contact (Les Girard, et al, 2015). Last lubricant regimes is hydrodynamic lubrication where $h \gg R_a$. This lubrication condition occurs with high relative speeds or load. As the pressure in the oil produced by speed and viscosity overcomes load, the two surfaces in this regimes are completely separated by a film of lubricant. Friction and wear do not occur in this regime.

These three lubrication regimes can be visualized in the Stribeck curve as shown in figure 2.1.

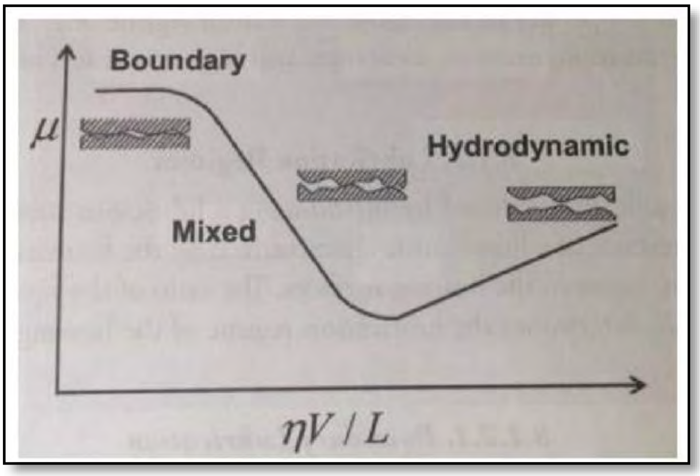

Figure 2.1: Stribeck curve showing three lubrication regimes. (Les Girard, et al, 2015)

2.2 LUBRICANT COEFFICIENT FRICTION

Determination of lubricants friction coefficient is a kind of oiliness test in the friction and wear test. Based on the changing of experimental parameters, contact resistance curves can be obtained. From the specific test method, the relationship between the friction coefficient and the contact resistance show that the friction coefficient increase rapidly with time to a saturated value. Generally, the value of contact resistance decreases with increasing normal load, but the friction coefficient increase as the normal load increase. Then, for standard test method it shown that the start of the test contact resistance quickly increase to a maximum value. It is because the initial lubricant condition between sliding and stationary ball is one of direct contact, so the contact resistance will present at lower value at the beginning of the test (Kuo, Chiou, & Lee, 1996). The different of both test are shown in Figure 2.2 and Figure 2.3.

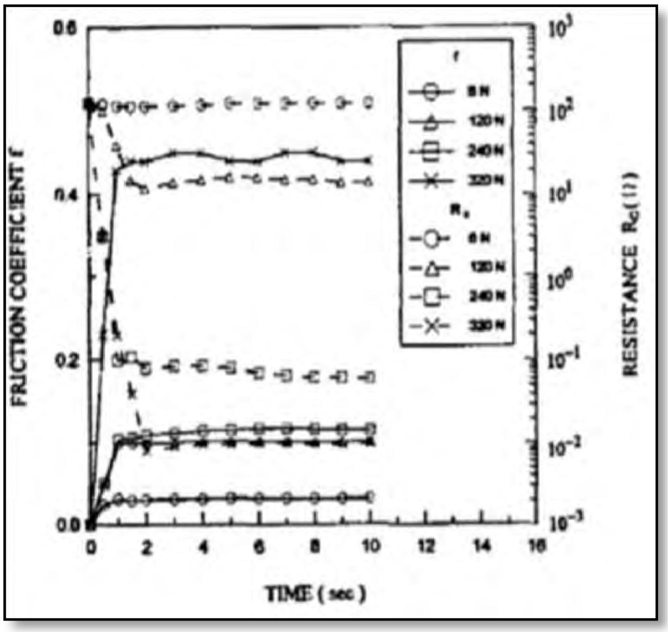

Figure 2.2: The Friction Coefficient and Contact Resistance Curve for the Specific Test Method. (Kuo et al., 1996)

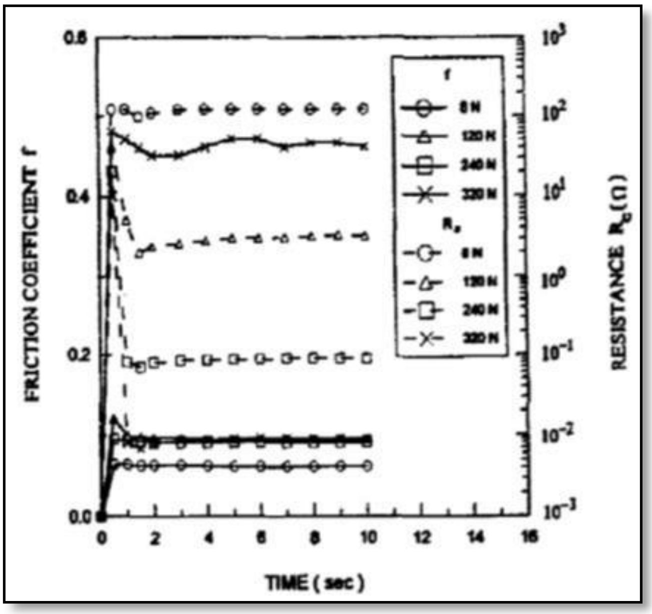

Figure 2.3: The Friction of Coefficient and Contact Resistance curves for the Standard Test Method. (Kuo et al., 1996)

In the past, there are only determining lubricant friction coefficient at certain load and cycles by using oiliness testing machine and Falex Ring-Block Test Machine. As the result, the differential ability of those test is very limited. It only provide the result for certain load condition.

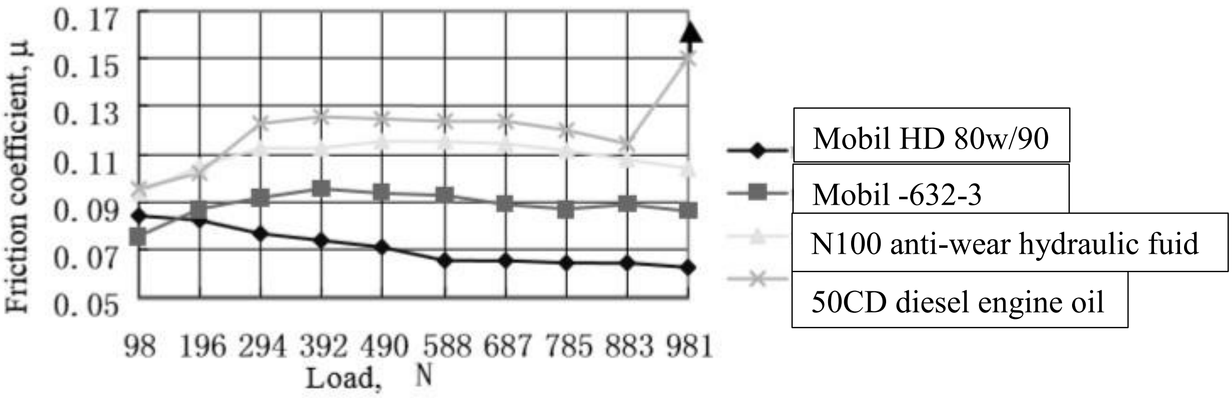

Figure 2.4: The load vs friction curve of 4 oil. (Jiyuan et al., 2001)

From the graph above, it shown that friction coefficient tends to decrease as the load is increase. It show the better improvement of friction reduction and the test state in boundary lubrication. If the friction coefficient is between 0.05-0.1, it is occur in boundary lubricating state. As a result, it can reduce friction coefficient, decrease wear rate, increase load-carrying capacity and improve boundary lubricating effect (Jiyuan, Quan, & Lixia, 2001). According to Figure 2.5, there are no significant changes show in coefficient of friction of Jatropha oil and hydraulic with increasing of temperature (Golshokouh et al., 2014).

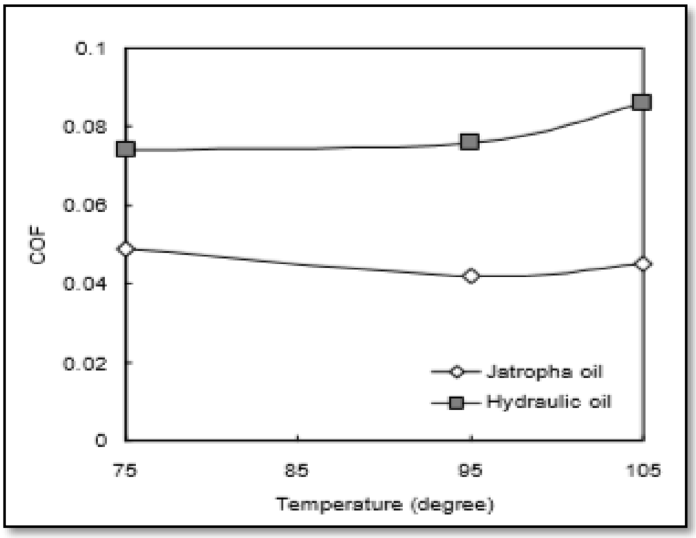

Figure 2.5: Effect of temperature on coefficient of friction for Jatropha and hydraulic oil. (Golshokouh et al., 2014).

2.3 WEAR TESTING

Wear is defined as surface damaged due to the removal of material during contact between two surfaces. The process of wears can be analysed in term of four mechanism which is adhesion, abrasion, tribo-fatigue and tribo-chemical reaction. In case of relationship between wear scar diameter and contact resistance, the specific speed method has larger contact resistance than the standard test method because it possess a better initial lubricant conditions. Based on the test between specific speed method and standard test method, it shown that there are no wear scars occurs at the contact surface under light load. But, small wear scar occurs in standard test method under same operation. It is believed that standard test method are mainly caused the wear scar occurs by initial direct contact (Kuo et al., 1996). The result as shown in the Figure 2.6 and Figure 2.7. In general, the higher the value of wear scar diameter, the more severe the wear (Kapsiz, Durat, & Ficici, 2011).

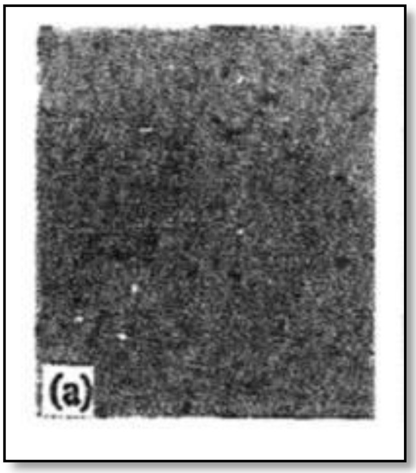

Figure 2.6: Specific Speed Method Sear Scar Result.(Kuo et al., 1996)

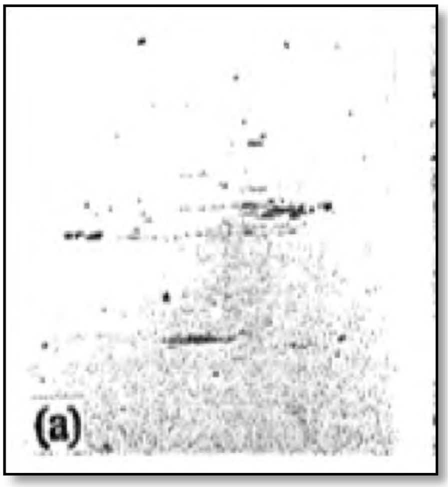

Figure 2.7: Standard Test Method Wear Scar Result.(Kuo et al., 1996)

Wear testing is important in engineering from two aspect. Firstly, from a material aspect which is it important to understand the wear properties of material in order to determine whether it suitable to use or not. Secondly, this testing also used to review surface treatment and conditions in order to find the most optimized setup. As a result, wear will occurs in several mechanism, including abrasion and adhesion. Abrasion is the removal of surface material, while adhesion is another mechanism of wear which is result in the transfer of material from surface to another. Based on the test with lubricant type and normal load, the diameter of surface scar in the high-wear test are larger than low-wear test as shown in Figure 2.7 and Figure 2.8. This improved that the higher load correspond to bigger wear (Les Girard, Naomi Kibrya, 2015).

Figure 2.8: Bottom (left) and top (right) ball bearing from low-wear test using engine oil. (Les Girard, Naomi Kibrya, 2015)

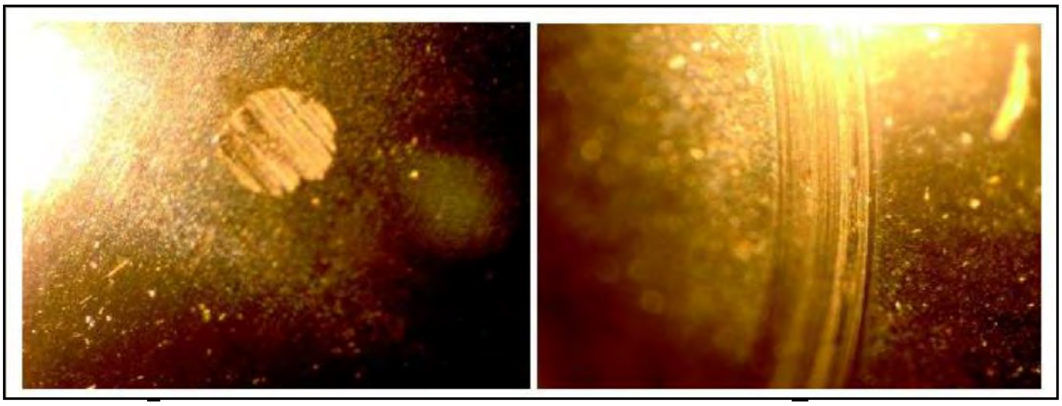

Figure 2.9: Bottom (left) and top (right) ball bearing from high wear test using engine oil. (Les Girard, Naomi Kibrya, 2015)

Based on effect of temperature and normal load, it shown that wear scar on the ball surface increase with increasing the temperature. Same way to the normal load, where the wear scar has direct relationship with the increase of loads (Syahrullail, et al, 2013). An experiment was carried to improve the result. Figure 2.10 shows the wear scar on ball specimen at different temperature while Figure 2.11 shows the wear scar on ball specimen with different load.

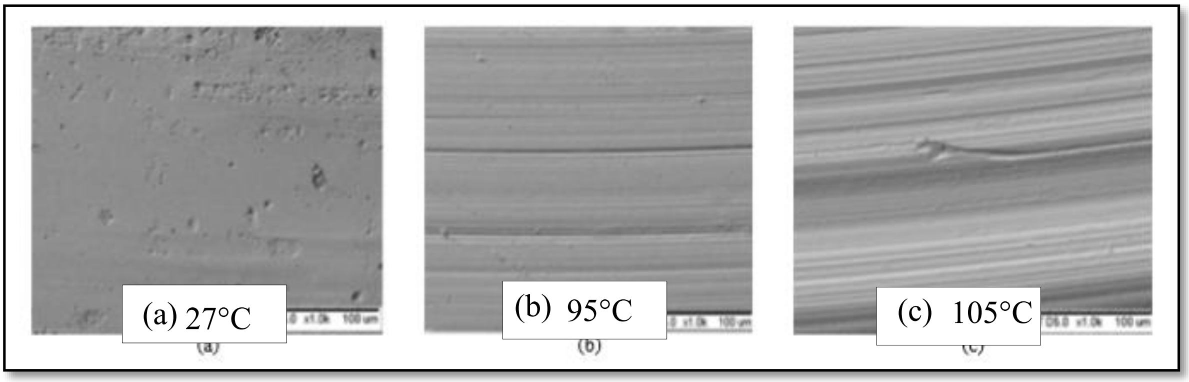

Figure 2.10: Wear scar on the balls specimen with different temperature (Syahrullail et al., 2013)

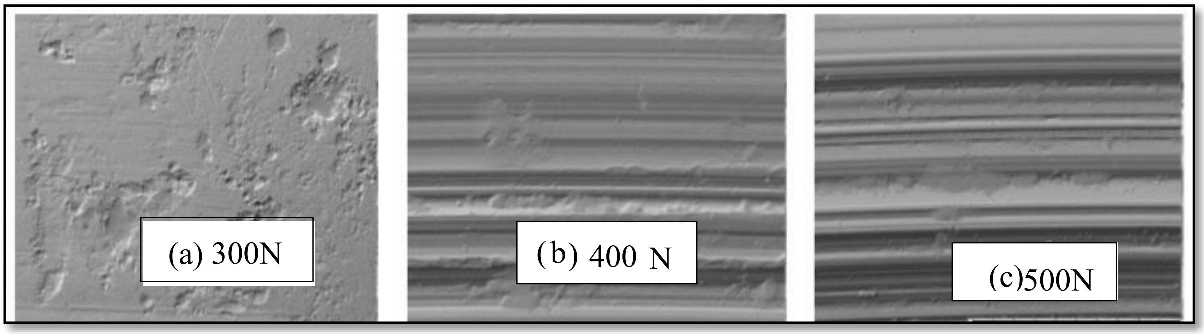

Figure 2.11: Wear scar on the balls specimens at different load.(Syahrullail et al., 2013)

These figure shown the ball surface at temperature 75°C is covered with small pits where it appear due to material transfer between contact parts. Also, from the figure for normal load 300N, several micro cutting observed on the balls. Micro cutting appeared when the adhesive wear occurs between surfaces and the lubricating film was broken down.

In term of rotational speed, it showed that the wear scar diameter increase as the rotating speed increases. It is shown in the Figure 2.12. It is observed that higher speed will cause the higher wear scar diameter. The increased wear with increase of speed may be related to the generation of higher heat between the contact surface as a consequence of higher speed (Fazal, Haseeb, & Masjuki, 2013)