TRIBOLOGICAL PROPERTIES OF NANOPARTICLES AS LUBRICATING OIL ADDITIVES

ASHAFI'E BIN MUSTAFA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis 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:………………………………………………………

Supervisor:……………………………………………………….

Date:………………………………………………………………..

DECLARATION

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

Signature:…………………………………………………………

Author: ………………………………………………………….

Date: ……………………………………………………………

ACKNOWLEDGEMENT

ASSALAMUALAIKUM and wish the best for the viewers of my thesis or this report. First of all, Syukur Alhamdulliah to Allah S.W.T for giving this opportunity to me to able completes this Final Year Project Report. On preparing completing this report, many thanks to my supervisor, Dr Mohd Fadzli bin Abdollah by helping me and all the final year student until this report can be presented and finished along to fulfilling academic requirement for graduate. All the guide, teaching, passion by Dr to my will be remember for me to carry on to pursue a better knowledge.

Best regards to all my family member that continously support me and helping until this research and my studied to be completed. With their support and praying for are helping me alot to finish studies at UteM. Not forgotten to all the students in Faculty of Mechanical Engineering that always provide assistance at any circumtances for me and all the students who participate in Final Year Project. With all the their effort and guide, this report can able to finished within the time given

I am also gratefull to all the lecturers, technicans and Phd student and also anyone supporter which continously guide me until this research to be completed and succesfull writting this report for me to be able to graduate . Encouragement, guidance, critics, advices and motivation for supporting me and every students here to are well known to make us students be ready and steadly before entering working environment out there.

ABSTRAK

Geseran dan saiz kerosakan permukaan menjadi pengaruh utama untuk menentukan jangkahayat sesebuah mesin atau komponen enjin. Nilai geseran dan saiz geseran lebih rendah adalah digalakan bagi meningkat kecekapan sesebah mesin atau komponen enjin. Kajian ini mencadangkan untuk mengkaji akan penambahan Alumina (AL_2O_3) dan hexagonal Boron Nitride (H-Bn) sebagai bahan tambahan didalam minyak enjin diesel. focus kajian ini adalah untuk melihat kandungan rheologi terhadap minyakl enjin diesel tersebuat dengan mengunakan rekabentuk eksperimen (DOE). Eksperimen dilakukan dengan menentukan atau memperoleh nilai Pekali Geseran (COF), Diameter Kesan Parut (WSD) , Indek kelikatan (VI) minyak enjin diesel tersebut. Data-data yang diperoleh akan di optimum mengunakan ANOVA didalam Kaedah Taguchi. Keputusan yang terhasil disini adalah menunjukan akan kehadiran Alumina (AL_2O_3) dan hexagonal Boron Nitride (H-Bn) sebagai dapat mempengaruhi nilai-nilai COF, WSD dan VI minyak enjin diesel tersebut.

ABSTRACT

Friction and wear has become major influence in determine the lifespan of the machine or engine components. Lowest friction and wear are desirable to enhance the machine or engine performance. The purpose of this research is to investigate the influences of nanoparticle consist of Alumina (AL_2O_3) and hexagonal Boron Nitride (H-Bn) as an additive dispersed in diesel engine oil. This research is focus on rheological properties of the diesel engine oil lubricant by using DOE by Taguchi Method. The experimental work was conduct based on determine it COF, WSD and VI. The result was optimize by using ANOVA in Taguchi method was used. The outcome shows the effect containing Alumina (AL_2O_3) and hexagonal Boron Nitride (H-Bn) as an additive is improving COF, WSD and VI.

TABLE OF CONTENT

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.0 INTRODUCTION

Capability for increasing performance of any engine or machine is directly must be provided with a lubricant and additives objectively of overcoming friction by minimizing energy lost through friction. Recent studies have shown that advances in tribology could lead to savings of approximately 11% of total annual energy loss in three major areas that is power generation, transportation, and industrial processes [1].

Furthermore, friction and wear are two major reasons for engineering components in various systems happened to fail.The cost of equipment, installation, and repair related to frictional deficiencies, wear, and damage places can enormous burden to users.

In addition, there is some high technology in manufacturing, energy, and defense industries that are lubricant technologies have not kept up with it. In fact, tribological and mechanical limitations have been shown to be the critical factors hindering the transition from prototype to product in many high-tech applications. [2].

Lubrication can be considered as major part of a machine as any of the working parts. Each parts which make up any machine today must be carefully designed and precision made of the best materials to meet the demands of modern advance technology. But without proper lubrication, these machine or components would soon develop rapid wear and eventual failure. Then the machine would be useless as a production tool [3].

1.1 PROBLEM STATEMENT

Additives with a tribological action currently used in commercial lubricating oils are dithiocarbamate molybdenum (MoDTC) and zinc dithiophosphate (ZnDTP). These compounds are complex organic molecules containing sulfur and phosphorus. These two elements are known to be poisonous for catalytic converters because they hinder their properties functioning. Besides, these compounds are only active at high temperatures. This means a critical period in cold start of engines. Nanoparticles are well-recognized as promising additives to reduce friction and wear with respect to base oil. However, there is still lack of knowledge about the difference between hard and soft nanoparticles effects on the tribological performance of engine oil. Thus, this study is emphasis to investigate the tribological properties of both soft and hard nanoparticles dispersed in conventional engine oil.

1.1.1 Objective

1. To investigate tribological properties of soft and hard nanoparticles dispersed in engine oil.

1.1.2 Scope

1. The tested materials are based on hard (Alumina) and soft (Hexagonal Boron Nitride) nanoparticles as lubricating oil addictives.
2. The procedures for tribological testing according to ASTM D4172: Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)
3. Using Taguchi Method to design the experiments.

CHAPTER 2: LITERATURE REVIEW

2.0 INTRODUCTION

This chapter is an explanation through the fundamental that used to successfully finish this project. The main topics that included and elaborated in this chapter are focusing more on tribolgy properties, friction, wear and tear, lubricant and additives, engine oil, nanoparticles and another knowledge that corresponding to the experimental method.

2.1 AUTOMOTIVE ENGINE OIL

2.1.1 Issues Related to Energy Consumption in an Engine: Service Effects

Fuel is used to provide energy to the vehicle user. However, to save a fuel consumption against many factors. Heat loses it is one of the major factor to be considered because efficiency of the energy provided from the combustion engine loses before it can be used to wheel [1].

According to the figure 2.12 (derived from an automotive database) 11 % energy loses are caused by friction of the energy consumed by the light duty vehicle. Exhaust and cooling are the major on energy loses.

According to Stribeck diagram at figure 2.13, show that lubrication are divided three regimes that boundary, mixed and hydrodynamics, this regimes shown coefficient of friction against viscosity times speed per unit load (KN) where hydrodyanamics had a slightest number of cooefficient of friction but the regimes of the component is respect to the more speed and directly to higher pressure. While the others like valve train are where the torque at higher to move the vehicle and this is the regimes for wear and tear the engine component.

The range over which various engine components operate is indicated by the horizontal arrows. It should be noted that the vertical axis is drawn on a logarithmic scale, and the differences in friction would be greater if drawn on a linear scale. The low point on Figure 1.7 indicates the condition under which friction is a minimum

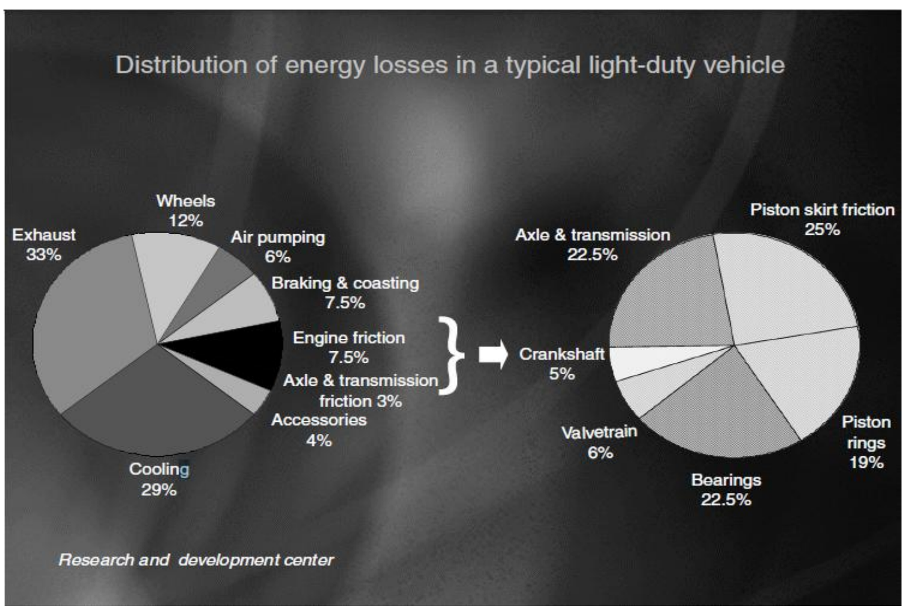

Figure 2.1 Typical values for energy loss in a light-duty vehicle [1]

(Source: Simon C. Tung and etc, 2006)

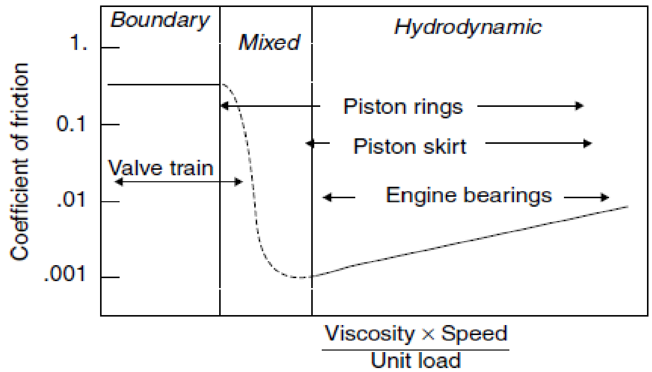

Figure 2.2**:** Stribeck diagram, including operating regions of several engine components [1].

(Source: Simon C. Tung and etc, 2006)

Before the engine oil start to standardize and exceedingly frequent oil changes were needed. Once the engine oil had been made up, it rapidly attract a lot of interest [1]. The main function of the engine oil lubricant is to prolong the life of moving components operating under many different conditions of such as speed, temperature, and pressure.
At lower temperatures the lubricant is expected to flow sufficiently in for smooth performance while at higher temperatures, the engine oil had to minimize wear happened on the moving parts. The lubricant does this by decreasing friction and removing heat from moving parts. Contaminants pose an additional problem, as they accumulate in the engine during operation. The contaminants may be wear debris, sludge, soot particles, acids, or peroxides. Another important function of the lubricant is to eliminate these contaminants from damaging the engine [1].

2.2 TRIBOLOGY

"Tribology" was defined as one of the four major disciplines of Mechanical Systems by a Committee of NSF of US in 1983 (The Panel Steering Committee for the Mechanical Engineering and Applied Mechanics Division of the NSF, 1984) and then the "Journal of Lubrication Technology" was renamed as "Journal of Tribology" of Transaction of American Society of Mechanical Engineers (ASME) [4].

Tribology has been defined in 1965 as "the science from behaviors of interaction surfaces in relative motion together with the active medium concerned (each of it is a tribo-element) in natural systems [4]. The relative motion of surfaces is defined by the relative motion of components and where the surfaces reside on. The interactions transmitted between surfaces are from the components in contact on the surfaces as well. Such joints are named kinematic pairs in mechanisms. The interacting surfaces in relative motion must function with other elements in a system or function with other elements for a system.

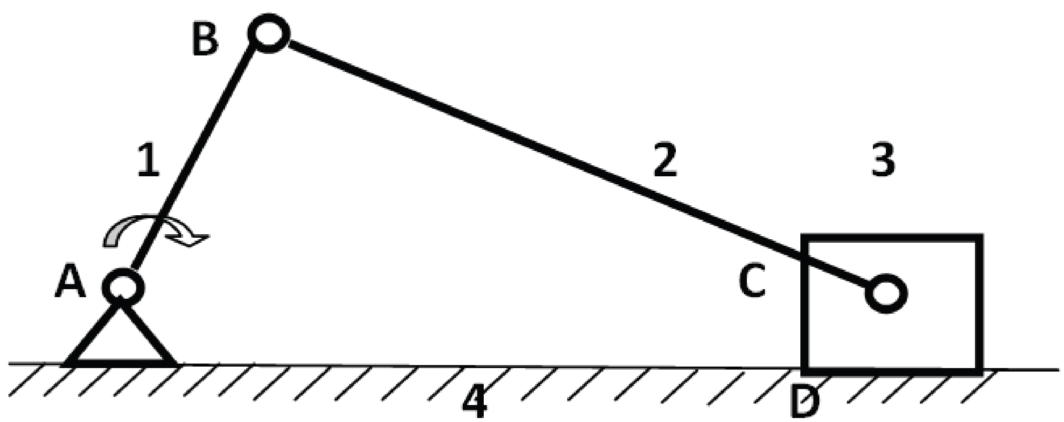

Figure 2.3: A crank-slider mechanism [4].

(Source : Chang-Hung Kuo, 2011)

For example, as shown in Figure 1 there is a plane kinematic chain of four components (1 - 4) with one fixed component (4, chassis), three revolute pairs (A – C) and one prismatic pair (D). If component at 3 starts moving, it will made a surface contact between both outer surfaces continuously with friction while moving at D surface. This kind of behaviors of interaction surfaces in relative motion together with the active medium concerned.

Furthermore, when a system is designed or developed whether is natural or machine system, it will be abstracted into a system consisting of tribo-elements and some supporting auxiliary sub-systems to study for behaviors on between the interacting surfaces in relative motion, it will be resulted of the behaviors and technology related to a tribo-system constructed . On current situation, it will be a liquid, a gas or a fat lubricant film to be kept between the interacting surfaces in relative motion to reduce friction and wear [4].

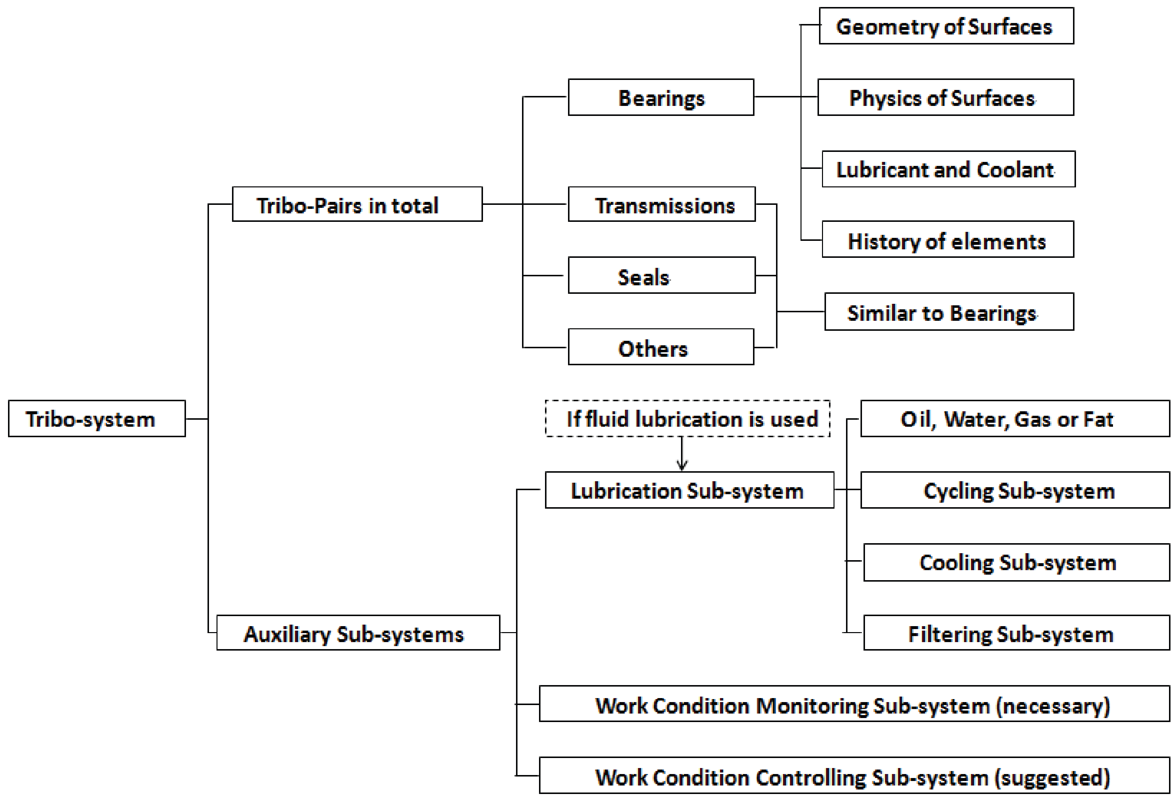

Figure 2.4: The block diagram of a typical tribo-system [4]

(Source: Chang-Hung Kuo, 2011)

2.3 FRICTION

Friction can be defined as resistance to movement between any two surfaces in contact with each other [6]. Friction also can be define as unwanted force that can be dangerous the system or machine that eventually without proper maintenance and right lubricant will causing failure to the machine or system.

Friction can be classified into two types; solid friction which may be either sliding or rolling, and fluid friction [6]. Sliding friction occurs when two surfaces slide over each other without lubrication as on the figure 2.3. Rolling friction occurs when a cylindrical or spherical body rolls over another surface without lubrication as in the modern ball and roller bearings as shown in figure 2.4. Less force is required to overcome rolling friction than sliding friction. It also known that solid friction coefficient is high when there is no lubrication.

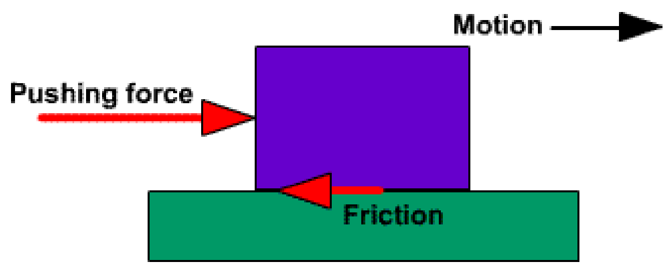

Figure 2.5: Sliding friction [7]

(Source: School for champions, 2012)

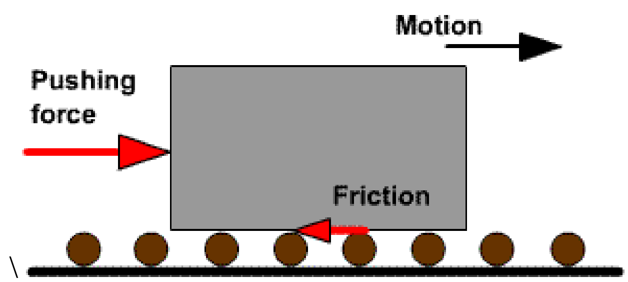

Figure 2.6: Rolling friction [7].

(Source: School for champions, 2012)

Now to compare fluid friction with solid friction, if a film of oil is introduced between the same two surfaces, tube is filling with the fluid. The fluid friction will happen as the resistance contact between the fluid and inner surface if the tube like in figure 2.5 below.

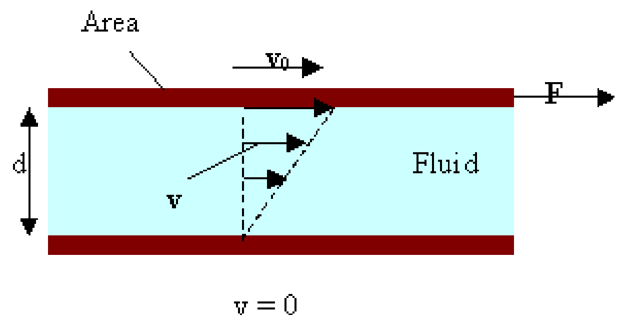

Figure 2.7: Fluid friction [8].

(Source: Labman physc, 2012)

When such surfaces flat, curved or spherical, are kept apart by a fluid film, we have what we call fluid friction and these surfaces are said to be lubricated. Therefore, in lubrication we actually reduce friction to a minimum by substituting fluid friction for solid friction [6].

2.4 WEAR

Wear can be defined as undesired removal of material due to mechanical action [6]. It also unwanted behavior that occurs because by friction and contact surface between or also can be called rub between two surfaces. Wear is divided into:

1. Adhesive
2. Abrasive
3. Corrosive
4. Fatigue

Adhesive wear means damage resulting when two metallic bodies rub together without the deliberate presence of an abrasive agent. Abrasive wear is characterized by damage to a surface by harder material introduced between two rubbing surfaces from outside. The severity of abrasive wear depends on size and angularity of abrasive particles and also the ratio between hardness of metal and the abrasive particles, more the tendency to wear [6].

Fatigue wear occurs due to cyclic stresses in rolling and sliding contacts as in gears and rolling bearings a shown in figure 2.6 below. The picture shows when rotation of the both gears will have a surface contact (rub) between both gear and resulted wear if lubricate is not applying on the gears. Corrosive wear occurs due to corrosion. Rusting is the example by the presence of moisture, oxygen availability and dusty conditions accelerate corrosive wear [6].

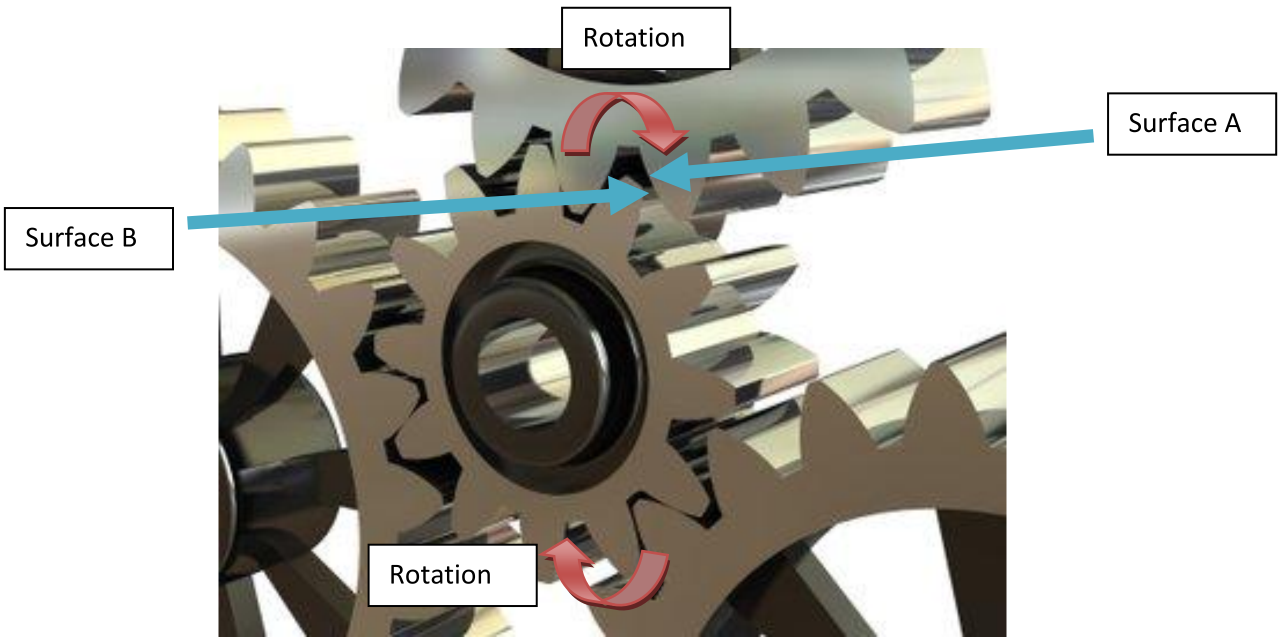

Figure 2.8: Rub surface method [9]

(Source: Interteck Petroleum Service, 2011)

2.5 LUBRICATION

By Ludema (1996) the principle of supporting a sliding load on a friction reducing film is known as lubrication. The substance of which the film is composed is a lubricant, and to apply it called lubricate as figure 2.7 below [10]. Advancing to high technology in modern industries, lubrication become more complex and advanced to use for high-tech applications respect to main function that is the prevention of metal-to-metal contact by means of an intervening layer of fluid or fluid-like material.

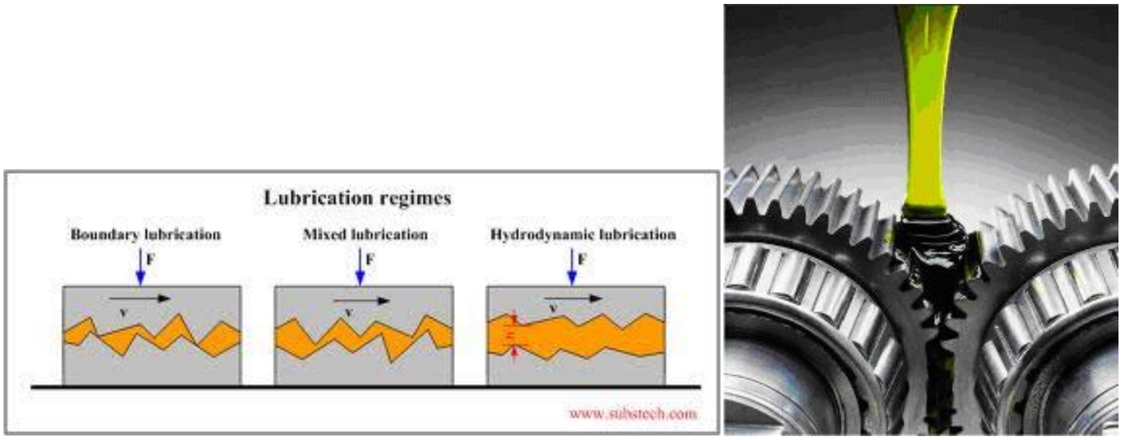

Figure 2.9: Show lubrication applied [11][12].

(Source: substech, 2011. imoa, 2012)

2.5.1 Functions of lubricants

Lubricants are agents introduced between two surfaces in relative motion to minimize friction. Selection and application of lubricants are determined by the functions they are expected to perform [6]. The principal functions of lubricants are to:

1. Control friction
2. Control wear
3. Control temperature
4. Control corrosion
5. Remove contaminants
6. Form a seal (grease)

By Rivzi and etc (2009) all fluid can be assumed as lubrication but it has different efficiency between all the fluids used. Indicator for showing better lubrication it by between successfully operation of a machine and failure. Modern equipment must be lubricated in order to improving its lifetime. A lubricant had several of functions. These include lubrication, cooling, cleaning and suspending, and protecting metal surfaces