COMPARATIVE TRIBOLOGICAL INVESTIGATION OF BIO-LUBRICANT FORMULATED FROM WASTE COOKING OIL

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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)"

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This report is submitted in partial fulfilment of the requirement for Bachelor of Mecahnical Engineering (Automotive) with honours

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DECLARATION

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

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DEDICATION

I dedicated this report to my beloved parents, Mahmud bin Yahya and Hamidah binti Adanan, siblings and also my friend.

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ABSTRACT

The use of lubricant is still applied extensively in automotive industry. Nowadays, most of the lubricants which are available in the market are based on mineral oil, derived from petroleum oil that are not adaptable to the environment because of their toxicity and non-biodegradability. Besides, it is very difficult to dispose the wastes of the mineral lubricant due to its nonbiodegradable nature. As the alternative solution, a comparative investigation of bio-lubricant formulated from waste cooking oil will be conduct. This thesisr outlines the tribological characteristics of waste cooking oil (WCO) contaminated bio-lubricant by using Four-ball tribo testing machines. To formulate the bio-lubricants, 10 to 40% by volume of waste cooking oil were blended with the base lubricant SAE 40. Experimental results showed that the lubrication regime that occurred during the test was boundary lubrication while the main wear mechanisms were abrasive and the adhesive wear. During four ball tribo testing, the lowest wear was found with the addition of 20% WCO, and above 20% contamination, the wear rate was increased considerably. The addition of waste cooking oil in the base lubricant acted as a very good lubricant additive which reduced the friction and wear scar diameter during the tribo test. The application of 20% bio-lubricant in the automotive engine will enhance the mechanical efficiency and take part to reduce the dependency on petroleum oil as well.Thus as an alternative lubricant source, waste cooking oil (WCO) can be played a vital role to substitute the petroleum.

ABSTRAK

Di dalam bidang automotif, bahan pelincir digunakan secara meluas. Malangnya pada masa kini, kebanyakan pelincir yang didapati di pasaran adalah berasaskan minyak mineral, atau diperolehi daripada minyak petroleum yang tidak bersesuaian dengan alam sekitar kerana bersifat dan ianya bukan biodegredasi. Selain dari itu, sisa minyak pelincir mineral ini amat sukar untuk dilupuskan kerana sifat ke tidak biodegradasinya. Bagi menyelesaikan masalah ini, satu usaha telah digarap iaitu dengan melakukan penyelidikan terhadap bio-pelincir yang mengunakan minyak masak terpakai. Maka satu kajian akan dijalankan berkaitan ciri-ciri bio-pelincir yang akan diuji mengunakan mesin *four ball tribo tester*. Untuk menghasilkan bio-lubricant yang seimbang, 10% hingga 40% isipadu bahan minyak masak terpakai akan dicampur dengan minyak pelincir asas iaitu SAE40. Hasil daripada eksperimen mendapati bahawa pertambahan 20% minyak masak terpakai akan menghasilkan daya geseran dan calar yang paling rendah. Selain itu, isipadu 20% daripada hasil pertambahan minyak masak terpakai menunjukkan nilai geseran dan calar semakin meningkat. Keseluruhannya, dengan penambahan bahan minyak masak terpakai dengan miyak pelincir asas dapat mengurangkan tahap geseran ketika ujian tribo dijalankan. Penggunaan 20% bio-pelincir akan dapat meningkatkan daya kecekapan dalam bidang enjin aotomotif dan sekali gus mengurangkan tahap pergantungan terhadap petrol juga. Kesimpulannya, bahan minyak masak terpakai memainkan peranan sebagai alternative untuk sumber pelincir di masa akan datang.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The term of biolubricants applies to all lubricants which are both rapidly for humans and aquatic environments. A modified standard oxidation procedure, more suitable for the chemical composition of the biolubricant, has been carried out. Biolubricants must be used in priority for all applications where there is an environmental risk. While, lubrication oil can be defined as a substance that to reduce friction between surfaces in mutual contact, which ultimately reduces the generated when the surfaces move. It may also have the function of transmitting forces, transporting foreign particles, heating or cooling the surfaces. The property of reducing friction is known as lubricity. One of the single largest applications for lubricants, in the form of motor oil, is protecting the internal combustion engines in motor vehicles and powered equipment. Unfortunately, various type of lubricants are not adaptable to the environment. Hence, in this experiment the edible source waste cooking oil will be replace as new bio-lubricant. Waste cooking oil is a more generic term for oil that has been contaminated with substances that may or may not be hazardous but it can be recycled. Waste cooking oil can be reproduced into soap and animal feed. However, the most valuable product would be biolubricant. In the recycling industry, used cooking oil recovered from restaurants and food-processing industries is called recycled vegetable oil (RVO), used vegetable oil (UVO), waste vegetable oil (WVO), or yellow grease.

1.2 PROBLEM STATEMENT

Most of the lubricants which are available in the market are based on mineral oil, derived from petroleum oil are not adaptable to the environment because of their toxicity and non-biodegradability (Adhvaryu et al., 2005; Salih et al., 2012). Unknown petroleum reserve, increasing consumption and environmental pollution have made concern regarding the use of petroleum based lubricant, thus to find the alternative lubricant to meet the future demand is an important issue (Shahabuddin et al., 2012a). As an alternative lubricant source, vegetable oil can be played a vital role to substitute the petroleum based lubricant partially as it possesses numerous advantages over base lubricant which are renewability, environmentally friendly, biodegradability, less toxicity and so on (Hwang and Erhan, 2002; Ing et al., 2011; Shahabuddin et al., 2012b; Siniawski et al., 2007; Salunkhe, 1992). It has been reported that, yearly 12 million tons of lubricant waste are released to the environment (Totten et al., 2003). However, it is very difficult to dispose the wastes of the mineral lubricant due to its nonbiodegradable nature. Furthermore, the unknown characteristics of bio lubricant in terms of wear, friction and wear scar diameter lead to this research. Due to all of these problem, this research will help in finding the suitability of waste cooking oil to replace or at least to reduce the uses of the conventional lubricant in the future based on its performance on wear scar diameter friction.

1.3 OBJECTIVE

1. To investigate wear and friction behavior in bio lubricant formulated from waste cooking oil.

2. To identify the amount of friction and wear scar diameter reduction when use waste cooking oil as bio lubricant source.

1.4 SCOPE

1. To prepare the sample waste cooking oil by using different kinds of purification and blending process.

2. Several instrumentations will be used to conduct the tribological testing namely Cygnus wear and Four-ball configuration machines.

3. The affecting factors of these type of lubrications performance in terms of friction and wear will be analyze

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Conventional lubricants are formulated based on mineral oils derived from petroleum. Mineral oil contains many classes of chemical components, including paraffin, naphthenic, aromatics, hetero-atom species, etc. Its compositions are pre-determined by the crude source. Modern oil refining processes remove and/or modify the molecular structures to improve the lubricant properties, but are limited in their ability to substantially alter the initial oil composition to fully optimize the hydrocarbon structures and composition (Kodali and Nivens, 2001). Mineral oils of such complex compositions are good for general-purpose lubrication, but are not optimized for any specific performance feature. The major advantages for mineral oils are their low cost, long history and user's familiarity. But this paradigm is now changing (Puşcaş et al., 2006).

2.2 LUBRICANT

The essential ingredients of an engine is among vehicle lubricants. Friction and debris can be reduce by lubricant with lubricates moving engine parts such as pistons, bearings, and others. Other than that, it also helps cool the engine, reduce corrosion and absorb harmful wastes resulting from the burning (Castrol 2001 & Rosli 1996).

Lubricants contain elements of various physical properties. Lubricating oils normally used is mineral oil. It is called mineral oil as the main ingredient of lubricants produced from the distillation of heavy distillates and residual oil that has been processed to obtain lubricants that meet the requirements of high viscosity, low pour point, and resistant to oxidation (Yusoff et al. 2002).

Lubricant is a substance (usually liquid) that is placed between two moving surfaces to reduce friction and wear between. Lubricant provides a protective thin layer which allows the two surfaces remain separate and "smooth", thereby reducing the friction between the two. Lubricants reacting chemically with the surface with the relationship just happens to be smooth and free of lubricant. Through this process, the corrosive particles dissolved in the lubricant, thereby making them good solvents and cleaners. Petroleum-based lubricants like Vaseline tend to dissolve petroleum products such as rubber and plastics, while water-based lubricants tend to dissolve polar substances (such as water and sewage); Therefore additional use. Lubricant should be replaced when the solute concentration reaches saturation level, because the inability to dissolve dirt particles allow additional friction with corrosive or attached to a moving surface, thereby creating space for the physical relationship between them (Norsalina Kosiep et al. 2006)

2.2.1 The Benefits of Lubrication

Benefits of lubricant is to maintain the moving parts. Other than that lubrication can separate the moving parts in the system. Hence friction and surface fatigue can be reduce with reduced heat generation, noise and vibration operation. Refinishing do it in some form. The most common way is by forming a physical barrier example a thin layer of lubricant separates the moving parts. This is named as a lubricant hydrodynamic. In the case of strong surface pressure or high temperature liquid layer is thinner and some power is transferred between the surfaces by smoothing. This is termed as a lubricant elastic - hydrodynamic. (Bart et al.2013)

Apart from that this medium can reduce friction, friction lubricant to the surface usually is less than the friction surface on the surface without any lubricant. The advantage of reducing friction to reduce heat and reduce the formation of wear particles including enhanced overall effectiveness. Lubricants may contain additional known as friction modifiers that bind to the surface of metals to reduce friction even when there is not enough lubricant is present in the lubricant hydrodynamic, e.g. to protect stripes on the engine valve train when first turned on. (Horvath et al. 2003)

Additionally, the use of lubricants is it can transfer heat. Both gas and liquid lubricant capable of removing heat. However, the liquid lubricant is more efficient due to the high specific heat capacity. Usually a liquid lubricant always cycled to and from the coldest areas in the system, although the lubricant may also be used for heating than cooling when controlling the heat required. This cycle flows also determine the amount of heat taken out of the road kind of unit that is used at a particular time. High flow system is able to bring a lot of heat and have the added advantage of reducing thermal stress on the lubricant. With it cheaper lubricants can be used. The main disadvantages are high flow pumps usually require larger and larger cooling unit. Lubricants & Grease does not flow like pasta and not as effective as a conductor of heat, although it has contributed to the reduction of heat production in the beginning. (IA Inman. 2003)

2.3 BIOLUBRICANT

Synthetic biolubricants are used for two major reasons when an equipment demands specific performance features that cannot be met with conventional mineral oil-based lubricants, examples are extreme high or low operating temperature, stability under extreme conditions and long service life and when synthetic biolubricants can offer economic benefits for overall operation, such as reduced energy consumption, reduced maintenance and increased power output (Bart. 2013).

The trend with modern machines equipment is to operate under increasingly more severe conditions, to last longer, to require less maintenance and to improve energy efficiency. In order to maximize machine performance, there is a need for optimized and higher performance lubricants. Synthetic biolubricants are designed to maximize lubricant performance to match the high demands of modern machines equipment and to offer tangible performance and economic benefits (Schuchart et al., 1998).

Synthetic biolubricants differ from conventional lubricants in the type of components used in the formulation. The major component in a synthetic biolubricant is the synthetic base stock. Synthetic base stocks are produced from carefully-chosen and well-defined chemical compounds and by specific chemical reactions. The final base stocks are designed to have optimized properties and significantly improved performance features meeting specific equipment demands (Guzman, 2002).

2.3.1 The Properties of Biolubricant

The most commonly optimized properties of bio lubricant is viscosity index (VI). VI is a number used to gauge oil’s viscosity change as a function of temperature. Higher VI indicates less viscosity change as oil temperature changes a more desirable property.

Secondly is pour point and low temperature properties. Many synthetic base stocks have low PP, −30 to −70 °C, and superior low-temperature properties. Combination of low pour point and superior low-temperature properties ensures oil flow to critical engine parts during cold starting, thus, offering better lubrication and protection. Conventional mineral oils typically have pour points in the range of 0 to −20 °C. Below these temperatures, wax crystallization and oil gelation can occur, which prevent the flow of lubricant to critical machine parts.

Lastly is thermal/oxidative stability. When oil oxidation occurs during service, oil viscosity and acid content increase dramatically, possibly corroding metal parts, generating sludge and reducing efficiency. These changes can also exacerbate wear by preventing adequate oil flow to critical parts. Although oil oxidation can be controlled by adding antioxidants, in the long term service and after the depletion of antioxidant, the intrinsic oxidative stability of a base stock is an important factor in preventing oil degradation and ensuring proper lubrication (Fox and Stachowiak, 2007). Many synthetic base stocks are designed to have improved thermal oxidative stability, to respond well to antioxidants and to resist aging processes better than mineral oil.

2.3.2 The Benefits of Biodegradable Lubricant

The term biolubricants applies to all lubricants that are both rapidly biodegradable and non-toxic to humans and aquatic environments. A biolubricant may be plant oil-based or derived from synthetic esters manufactured from modified renewable oils or from mineral oil-based products.

The benefits of using biodegradable lubricants are less emission because it is due to the higher boiling temperatures of esters. Native triacylglycerol structures leads to partly gummy at high temperature and can accumulate acroleins, which are irritating. It's totally free of aromatics that over 90% biodegradable oils, non-polluting water. Other than that, the oil mist and oil vapor-reduction leads to less inhalation of oil mist into the lungs. Next better skin compatibility hence less dermatological effects. Equal and often higher tool life due to a higher wetting tendency of polar esters, which leads to a reduction in friction. Lastly, higher viscosity index and this can be an advantage when designing lubricants for use over a wide temperature range. This can also result in lower viscosity classes for the same applications combined with heat transfer easier.

2.3.3 The Regulation and Policies Of Biolubricant

In several European countries regulations and policies exist in favor of biolubricants;

i. In Germany, Austria, and Switzerland regulations are in place that forbid the use of mineral oil-based lubricants around inland waterways and in forest areas. In addition, the German federal government has introduced a program called "Market Introduction Program (MIP) Biolubricants and Biofuels" for the reimbursement of costs associated with substituting mineral oil-based lubricants for lubricants based on renewable resources with a mass content greater than 50%. This program, which is managed by the German Agency of Renewable Resources, is a success especially for hydraulic fluids.

ii. The Swedish City of Gothenburg has set up an advice and technology program for lubricant products, which has encouraged the manufacturing industry to switch to biolubricants. This so-called "Ren Smörja" (Clean Lubricants) project was a co-operation between municipal authorities, consultants, and industries and has resulted in environmental criteria for lubricating greases and hydraulic fluids. These criteria have been identified and are now a part of Swedish Standards. In addition, in the Scandinavian countries a tax exemption on biolubricants is in place.