UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE CONCEPTUAL DESIGN AND ANALYSIS OF USED COOKING OIL FILTRATION PROCESS FOR BIO-LUBRICATION APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Maintenance Technology) (Hons.)

by

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ABSTRAK

Bio pelincir adalah pelincir yang dihasilakan daripada minyak sayuran asli dan sebahagiannya daripada minyak masak terpakai. Pengeluaran minyak masak yang terpakai semakin meningkat setiap tahun menyebabkan kaedah pelupusan yang digunakan untuk melupuskan minyak masak terpakai menjadi semakin terhad yang boleh mencemarkan alam sekitar dan hidupan liar. Tujuan kajian ini adalah untuk mereka bentuk dan menghasilkan prototaip untuk proses penapisan minyak masak terpakai bagi penggunaan bio pelinciran. Lakaran 3D direka dengan menggunakan perisian SolidWorks. Penapis ini dibina daripada polyropylene dan activated carbon sebagai media penapis , PVC paip , plastik dan bekas keluli tahan karat , pemanas, pam elektrik dan tapak yang diperbuat daripada kayu . Ujian produk dan analisis minyak dijalankan untuk menguji keupayaan penapis yang telah dihasilkan. Penentuan keberkesanan sistem penapisan adalah dengan menggunakan tiga kaedah ujian berdasarkan kaedah ASTM dan ISO iaitu ASTM D6595. Viscometer pemanas dan ISO 4406 untuk mengesan unsur-unsur, bahan cemar, zarah dan kelikatan minyak. Daripada hasil ujian jumlah zarah dan kelikatan minyak menunjukkan penurunan. Kelikatan minyak masak yang telah digunakan menurun dari 49 cSt kepasa 44.9 cSt selepas ditapis. Hasil ujian menunjukkan keberkesanan prototaip dan media penapis yang dihasilkan dan digunakan . Dengan pengeluaran produk ini, minyak masak yang telah ditapis boleh digunakan sebagai bahan mentah untuk bio pelinciran dan pada masa yang sama dapat mengurangkan pencemaran yang disebabkan oleh kaedah pelupusan minyak masak terpakai.

ABSTRACT

Bio-lubricant is a lubricant that is made from pure vegetable oil and some of them from used cooking oil. The production of used cooking oil is increasing every year causes the disposal method that used to dispose used cooking oil become limited and harm the environment. The purpose of this study is to design and develop a device for filtration process of used cooking oil for bio lubrication application. The 3D drawing of the filter is designed by using the SOLIDWORKS software. The filter is built from polypropylene and activated filter media, PVC vessel, plastic and stainless steel tank, heater, electrical pump and base made from wood. Product testing and oil analysis is conducted to test the ability of the filter that was developed. Determination of filtering system effectiveness is by using three test based on ASTM and ISO method which are ASTM D6595, Heated Viscometer and ISO 4406 to detect the elements, contaminants, particles and viscosity of the oil. According to the test result, the amount of particles and viscosity of the oil is decrease. The viscosity of the oil is decreased from 49 cSt to 44.9 cSt after filtration process. The results show the effectiveness of the prototypes and filter media that was produce and used. With the production of this product, the oil that filtered oil can be used as a raw material for bio lubrication and at the same time can reduce the pollution.

DEDICATION

I would like to dedicate my project to my beloved parents, my supervisor Mr Azrin Bin Ahmad and to all my friends for supporting me from the beginning till the completion of this project

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ASTM	-	American Standard Testing Method
BC	-	Before Century
HOQ	-	House of Quality
KV	-	Kinematic viscosity
ISO	-	International Organization for Standardization
NAS	-	National Aerospace Standard
PVC	-	Polyvynil Chloride
PP	-	Polypropylene
QFD	-	Quality Function Deployment
RDE	-	Rotating Disc Electrode
UCO	-	Used cooking oil
cSt	-	Centistokes
cm	-	Centimeter
g	-	gram
J	-	Joule
Kg	-	Kilogram
m	-	meter
mL	-	Milimeter
Mpa	-	Mega Pascal
^{o}C	-	Degree Celcius
^{o}F	-	Degree Fahrenheit
µm	-	micrometer

CHAPTER 1
INTRODUCTION

1.1 Background of study

Most lubricants are made from mineral oil (non vegetable source or petroleum) and some are synthetic chemicals. Plant-based lubricants are available and are widely used in some applications. Around 90% of lubricants currently used could be replaced by plant-derived materials. There is renewed interest in vegetable oil-based lubricants, due to their distinct performance properties and environmental profiles.

Hundreds thousands tonnes of lubricants that made from mineral oil are released into the environment every year and will pollute the environment and wildlife. But biodegradable lubricants can be released into the environment without causing harm to wildlife and are not a source of persistent pollution. Some applications such as chainsaws, agricultural greases and marine engines involve the 'total loss' of lubricant into the environment. In these applications, the use of bio lubricants is extremely desirable to reduce harm to the environment.

Vegetable oil based greases research has become an active research area for several decades (Erhan, 2005). For example olive oil was used as lubricant since 1650BC (Gawrilow, 2003). Using a vegetable oil as lubrication gaining popularity because of the significantly advantages to environment as the vegetable oil is renewability and biodegradability. These products are highly desirable in total loss

lubricants such as railroads because vegetable oil is known as biodegradable lubricant which their emission will not cause any harm to the environment when it comes in contact with soil or water. Table 1.1 shows the advantages of producing a lubricant from used cooking oil.

Table 1.1 Advantages of producing a lubricant from used cooking oil

Types of lubrication	Advantages
Bio-lubrication **(from waste cooking oil)**	Very good lubricity compare to the mineral oil lubricant
	Environmental friendly
	Cheaper than mineral oil and virgin vegetable oil.
	Higher viscosity index and good boundary lubrication properties
	Bio degradable and non toxic

Instead of using mineral oil and virgin vegetable oil as base oil to produce lubricant, used cooking oil is believed to be a potential source to meet the purpose. Producing a lubricant from used cooking oil can reduce the cost of production compared to other oil. Used cooking oil is actually a synthetic fat that usually used in baking, frying and other types of cooking. Used cooking oil is in the form of liquid or semi liquid that are very difficult to dispose. Several types of cooking oil includes of vegetables oil, coconut oil, palm oil and others. Each types of cooking oil have their own characteristics and fat composition. There are two characteristic of cooking oil which is saturated and unsaturated cooking oil. Saturated cooking oils are usually from plants that have higher in saturated fat like coconut oil and palm oil. Usually, saturated oil tends to be a solid or at least semi-solid at room temperature. While unsaturated cooking oil tends to remain at liquid at room temperature or in low

temperature like refrigerator. Three types of fat that are contains in unsaturated oil which is monounsaturated fats, polyunsaturated fats and trans fatty acids.

The use of cooking oil cause the amount of the waste cooking oil increase every year, but the option of disposal method is limited and can harm the environment. Currently, waste cooking oil in the United States is recycled for animal feed, pet food, glues and cosmetics. Since 2002, an increasing number of European Union countries have banned the inclusion of waste vegetable oil from catering in animal feed. However, waste cooking oils from food manufacturing continues to be used in animal feed until today. Other method use to dispose used cooking oil is by pouring used cooking oil down the drain and by open burning (Uchida et al., 2001).

Instead of throwing or discarding it into the drain and open burning, the waste vegetable oil can be recycled into other precious material such as biodiesel and lubricant like grease. One method of recycling used cooking oil is by filtration process. These can be done by designing a filter of used cooking oil and the product from the filtration process can be use for bio lubrication and bio diesel.

Filtration process is one of the important process in producing a lubricant from used cooking oil. Improvement in filtration technology now made recycling a viable option. Typically various filtration systems remove particulates, additives, food particles, water, oxidation products and recover the base oil. The oil may get purified during the process.

1.2 Problem Statement

Used cooking oil is produced daily either by household user or by commercial and industry use worldwide. Used cooking oil can damage the environment such as water pollution, and air pollution if not properly controlled. Even the cooking oil is not acutely toxic like most petroleum product but with the uncontrolled release can result in significant environmental damage. Option for disposing of used cooking oil is usually limited and difficult due to the density of the oil is lighter compared to the density of the water and also due to the form of oil which is in liquid or semi-liquid.

A disposal method like pouring down in the drain can cause clogs pipes and damage wastewater or septic system. Studies show that 60% of this fluid is not accounted for and ends up in ground water, rivers, and on the ground itself, causing harm to the environment, fish and wildlife (Erhan, 2006). Other method use to dispose used cooking oil by open burning and using it as fuel in most standard heating system. These types of disposal can cause a black smoke and soot which is prohibited and may damage the system. In addition, the particular recurring use of used cooking oil is dangerous to consumers because the used cooking oil will form a toxic compound such as peroxides, aldehyde and polymer through several reactions during frying process (Kulkarni and Dalai, 2006). One of the ways to treat used cooking oil by converting to lubricant.

The price of petroleum nowadays increases over time. Because of that situation, the production of lubricant from mineral oil becomes more expensive. There are many sources available that can be use as raw material to produce lubricant. One of them is used cooking oil. Production of lubricant from used cooking oil not only gives advantages to environment but also promising a production of lubricant with low cost.

1.3 Objective of Research

Based on the background and problem statement stated above, the objectives of this study are stated below:

i. To design and develop a device use for filtration of used cooking oil for bio lubrication application.
ii. To test the filtration ability of the device developed.
iii. To do oil analysis of the used oil as bio-lubrication or bio-diesel.

1.4 Scope of research

In order to achieve the objective of the research study, several scopes have been identified:

i. Designing a used cooking oil filter using SOLDWORKS software.
ii. Determine the characteristic of oil that suitable for bio lubrication application.
iii. Fabricate a used cooking oil filter to clean waste vegetable oil.
iv. To do oil analysis of the filtered oil from used cooking oil filtration process using Rotating Disc Electrode (RDE), Heated Viscometer and Laser Particle Counter.

CHAPTER 2
LITERATURE REVIEW

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2.1 Used cooking oil

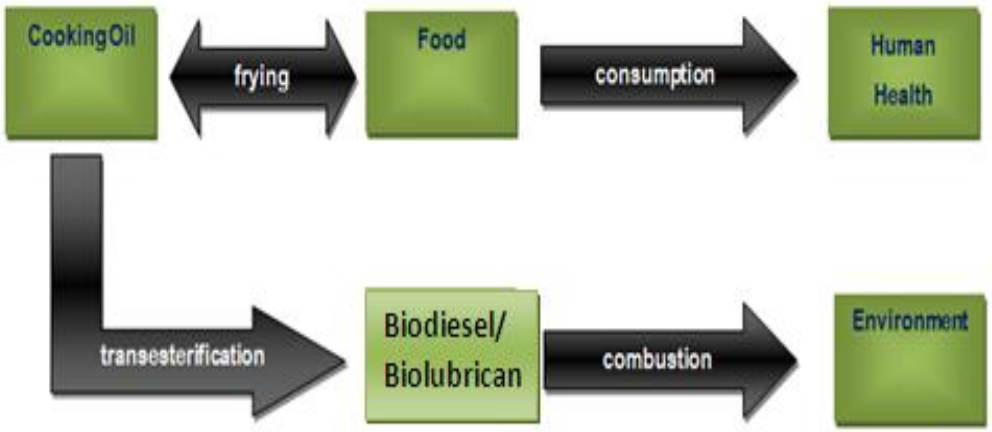

Figure 2.1 cooking oil flow

Figure 2.1 shows the flow of cooking oil. The usage of cooking oil is divided into two parts, which are for food production (frying process) and for the production of biolubricant and biodiesel. The productions of used cooking oil are from all over the world. In Europe Union (EU), the production of used cooking oil from snack food and french fries was estimated about 700,000-1,000,000 tonnes per year. In Asia such as China, Malaysia, Thailand, Indonesia, Hong Kong and India, about 40,000 tonnes waste cooking oil are produced per year and this production is increasing by year (Tajul et al., 2013). The source of this waste oil includes of

restaurant, dining room, fast food factory, catering industry and etc. During fryer process, the chemical and physical composition of the oil is changes and affects the quality of the oil. Usually used cooking oil are dark in colour and contain a hazardous and toxic substances like alfatoxin that very dangerous to the consumer (Chena et al., 2014). The characteristic of used cooking oil that shows in Table 2.1 make used cooking oil are suitable for bio-lubricant and biodiesel production.

Table 2.1 Chemical characteristic of the used cooking oil (Carlos et al., 2011)

Features	Used cooking oil characteristic
Acidity (%)	0.56
Moisture	0.25
Viscosity at 37ºC (centistokes)	44.78
Iodine index (Cgl2/g)	108.22
Peroxide index (meq. Oxygen active/Kg of sample)	16.61
Unsaponifiable material (%)	1.70
Ash (%)	0.030
Refractive index 25°C	1.4700
Density 15°C (g/mL)	0.9216
Flash point (Deg C)	220
Water Content (mass%)	0.075
Melting point (Deg C)	13.75

2.1.1 Used cooking oil as biolubricant

The production of lubricant from used cooking oil not only because of their prices that is lower than fossil fuel but it is also because of their environmental benefit and the fact that it is made from renewable resources. The production of lubricant from used cooking oil using a same method with fresh cooking oil, but used

cooking oil need to remove a contamination like water and food particles through filtration process.

High oleic content in cooking oil made this material more suitable to replace petroleum-based lubrication and synthetic ester. The substitutions of petroleum-based lubricant with bio based lubricant are not only can reduce the cost and limiting the usage of petroleum but it is also biodegradable, nontoxic, and renewable resource. Cooking oil characteristic such as high molecular weight of the triacylglycerol molecule and a narrow range of viscosity changes with temperature, make cooking oil very low volatility that suitable for bio lubricant (Adhvaryua et al., 2005).

The compositions of used cooking oil are triglycerides, free fatty acid and water. The content of free fatty acid in used cooking oil much higher than free fatty acid in fresh vegetable oil. The amount of free fatty acid in used cooking oil increase due to the presence of water and heat that generate the hydrolysis of triglycerides (Kawentar & Budiman, 2013). The productions of used cooking oil to lubricant compose of two step which is filtration process and transesterification process. Before transesterification process, contamination like food particles and water in used cooking oil need to remove through filtration process. While in transesterification process, the ester compound is exchanged to alkoxy group by using another alcohol. This reaction is using acid and base as a catalyzed. The lubricant from cooking oil can decrease the carbon monoxide and hydrocarbon when they operated in an engine. (Masjuki et al., 2011)

The most critical problem of vegetable oil based lubricant is has low oxidative stability and low temperature (Erhan and Asadauskas, 2000). According to the Adhvaryua et al., 2005, the best method to solve this problem is by addition of chemical additive. The combination of diluent (polyalphaolefin) and high-oleic vegetable oil as an additive is believe to improve the properties of bio base lubricant like oxidative stability and temperature.

2.1.2 Used cooking oil as biodiesel

Instead of using used cooking oil as lubricant, used cooking oil also used in production of biodiesel. The production of bio diesel from used cooking oil is to reduce the usage of petroleum diesel. This substitute of petroleum diesel with used cooking oil is the best alternative because it does not only reduce the environment pollution and energy storage but also renewable and domestic resource (Hossain and Boyce, 2009). The production of biodiesel from used cooking oil usually need higher cost compared to the production of petroleum based diesel fuel (Walke and Borikar, 2013).

The production of biodiesel was proven by Dr. Rudolf Diesel in 1900 at World Exhibition. He demonstrated the first diesel engine by using 100% peanut oil as fuel. Dr Diesel also suggests the use of vegetable oil as a fuel because it would greatly benefit in the development of agriculture (Celik et al., 2009). According to the Celik et al., 2009, in their study of usage and effect of biodiesel on an engine, it is proven that the usage of oil in engine no needs a modification on engines. At the end of research, they stated that there is no problem and no negative effect of the biodiesel to the engines.

According to the Hossein et al., 2013, the production of biodesel from used cooking oil through transesterification is the best method, but the oil must be clean from any contaminant ecspecially water content. There are two types of tranesterification process which is tranesterification process with catalyst and without catalyst. The alkali catalyst in this reaction will increase the rate and yield biodiesel.

2.2 Contaminant

Contaminants are represent to the solid or gas particles that present in all fluids. Contaminant in solid may be in the form of rigid or deformable solids and built in different size. Filter and sedimentation process are the types of separator that usually used to separate all types of contaminant in fluid. Some particle of contaminant in fluid can cause harm and very dangerous to the consumer like arsenic, mercury, copper in cooking equipment and etc. Each types of contaminant need specific types of medium to separate them from fluid. Medium that separated contaminant as known as media filter. (Sutherland, 2008 (a)). Types, contaminant sizes and separators is shown in Figure 2.2.

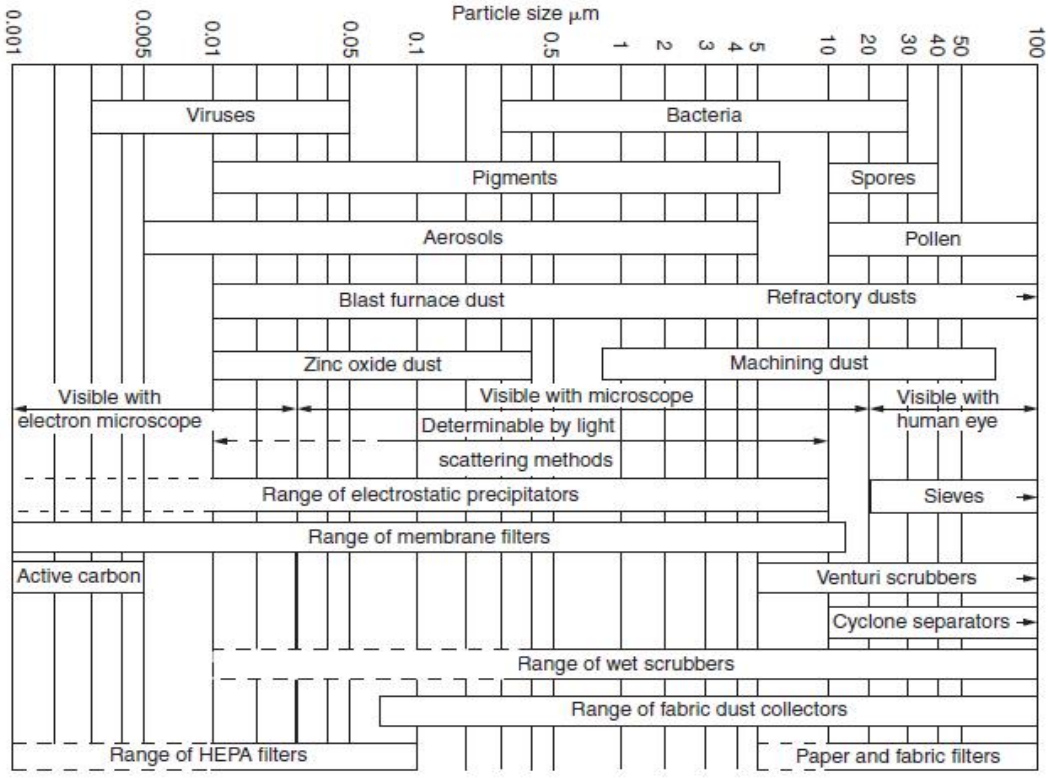

Figure 2.2 Types, contaminant sizes and separators (Sutherland, 2008 (a))

The most contaminant that usually found in used cooking oil is food particles and water that usually present during frying process. Food particles and water need to remove from used cooking oil before the filtered oil is used as lubricant or bio-diesel. Food particles can be remove by using filter medium in filtration process and water contents can be remove by heat the oil at 120^{o}F. The removal of water content from used cooking oil is very important because the water content in lubricant will damage the lubricated component. Water content in lubricant can cause corrosion to metal surfaces, lubricant degradation and poor lubricant (Harika et al., 2013). There are three forms of water content in lubricant oil which is dissolve, where there is limited amount of water content in oil which is very temperature dependent. Water content will dissolve in oil at 120^{o}F. Second form is emulsified where the water and oil are form tight bonds that are very difficult to break. The last form is free water. This form of water very harmful to lubricated parts, but very easy to separated (Qiang et al., 2012).

2.3 Filtration

Filtration process is a process of removing an impurities or contaminant from organic solution or to isolate an organic solid. In other word, filtration is the removing of solid particles in a fluid of liquid or gas by using a porous material. The solid particle in the fluid can be very small (in the micrometer range) or much larger, very rigid, spherical or irregular shape (Geankoplis, 1993). The filtration process has cover a very wide application in industries such as water filtration, oil filtration, gas filtration and etc.

Filtration process is divided into several types when considering into their mathematical analysis and several factor. There are two types of filtration which is depth filtration and surface filtration. This two filtration types have different way in removal of contaminant.

2.3.1 Fluid flow during filtration

Fluid flow is important in order to select the suitable material for media filter in filtration process. The basic law that usually used to measure the fluids flow through media is Darcy's law. It relies on the fact that the amount of flow between two points is directly related to the difference in pressure between the points, the distance between the points, and the interconnectivity of flow pathways. (Hensely & Barry, 2001).

The fluid flow on Darcy's Law can be described by

$$Q = \frac{CA\Delta(P - \rho gz)}{L}$$

Where :

P = pressure [Pa]

ρ = density [kg/m^3]

g = gravitational acceleration [m/s^2]

z = vertical coordinate (measured downwards) [m]

L = length of sample [m]

Q = volumetric flowrate [m^3/s]

C = constant of proportionality [m^2/Pa s]

A = cross-sectional area of sample [m^2]