International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

ANALYSIS OF VEGETABLE OILS AND SYNTHETIC OIL BLEND WITH ADDITIVES

K S Tarun
B.Tech in Mechanical Engineering
Bangalore, Karnataka, India

Abstract -- **Plant based oils are replacing inorganic lubricants because of its atmosphere-friendly properties and they have become an important source for the development of bio-lubricants. For the necessity of ensuring the ability if vegetable oils as a pure or partial bio-lubricant. Pure vegetable oils have only a few drawbacks that was overcome by blending different non-edible vegetable oils (Neem and Pongamia) with a synthetic oil (SAE 50) that is commercially available, then Viscosity Index Improvers and Pour Point Depressants were added by percentage of weight which in turn helped in using the vegetable oils as a potential bio-lubricant. Experiments were carried out on blends to determine the compatibility as a potential lubricant. Flash point, fire point, kinematic viscosity, wear rate and chemical composition of the blends were determined using Cleveland apparatus, Saybolt viscometer, pin-on-disc apparatus and Fourier Transform Infrared (FTIR) Spectroscopy. All of the results were compared to the pure SAE 50 oil and finally optimal emulsions having properties of a good lubricant was obtained. In the experiments carried out, the blends S30J70 and S80N20 show good lubricating properties.**

Keywords— **Bio-Lubricants, Additives, Pin-on-disc, FTIR Spectroscopy, Vegetable Oils**

I. INTRODUCTION

Lubricants are substances that are used in-between mating surfaces to reduce friction, heat generation, and also wear and tear of the mating surfaces. Lubricants are commonly used in mechanical systems having moving parts that rub against each other during the operation of the machines. The process of using lubricants can be termed as Lubrication. Lubrication reduces wear and tear of mating surfaces and helps the machines to operate smoothly and efficiently for longer durations.

Adhvaryu et al.(2005) stated there are different types of lubricants available in the market, most of them are based on mineral oil which is derived from crude oil. These oils tend to harm the eco-system because of its toxic nature and non-biodegradability [1]. Shahabuddin et al.(2012) : Fossil fuels are depleting over the past decade due to sudden spike in the consumption of petroleum products. Since lubrication plays a major role to any machine having moving parts, the world is searching for an alternative solution to mineral based lubricants. Lubricants that are Eco-Friendly, Non-Toxic and Biodegradable. Bio-Lubricants which are lubricants derived from plant sources is the solution. Biodegradable oils are considered an important alternative to traditional lubricants as a result of the increase in awareness of environmental pollution and harm caused to the eco-system due to petroleum products. Vegetable oil-based lubricants is a very good alternative to the ones available in the current market throughout the world [2]. Sundus et al.(2017) claimed that the usage of vegetable oil as fuels has further encouraged scientists to exploit their potential as bio lubricants [3]. Thames. S.F et al.(1999) said in their work that countless vegetable oils including sperm whale oil, castor oil, peanut oil and rape seed oil appeared in the middle ages as complex machines made from iron and copper were extensively used during those periods [4]. Tarun et al.(2019) stated that it was discovered parenthetically that mixing sperm oil used for lubrication of spinning and weaving machines, along with crude oil would extend the lifecycle of the machines to more than a decade. Since then, crude oil-based lubricants were quickly replaced by plant-based lubricants or blends containing both vegetable oils and crude oils [5]. Dinda,S et al.(2008): Vegetable oils have low volatility due to high molecular weight of the triacylglycerol molecule and have a narrow range of viscosity changes with temperature. In addition, these oils have high solubilizing power for polar contaminants and additive molecules [6].

Totten, G.E et al.(2006) : Yearly, 40 million tons of lubricants are expended globally and they have an extensive array of applications from vehicle engines to office chairs. It has been stated that over 12 million tons of lubricant waste is released into the

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

environment each year [7]. Fox.N et al.(2007) and Jayadas,N et al.(2006) : Nevertheless, it is a thought-provoking task to dispose the waste of inorganic lubricant due to its non-biodegradable nature. Vegetable oils are mainly triglycerides which contain three hydroxyl groups and long chain unsaturated free fatty acids attached at the hydroxyl group by ester linkages [8 and 9]. Mofijur. M et al.(2012) : The main limitations of vegetable oils are its deprived low temperature behaviour, lesser oxidation, low thermal stability and gumming effect [10].

Quinchia.L et al.(2010)To improve the substantiality of bio-lubricants, some mechanical properties including the existing range of viscosities are to be enhanced. To do so, environmentally friendly viscosity reformers can be used. Viscosity is one of the most important property of lubricants, as it determines the quantity of friction between the sliding surfaces and whether the film developed can be sufficiently thick enough to avoid wear from metal-to-metal contact [11]. Gomez MG, Masjuki H, and Agarwal AK et.al.(2000,1999,2002) : The lubricants derived from plants or animals are known as bio lubricant. In addition to demonstration of good lubricity properties like flash point, fire point, kinematic viscosity, coefficient of friction, etc., these oils have good bio-degradability since these oils degrade rapidly, causing less harm to the eco system. Further, the results found from tribological studies of blends exhibits minimum coefficient of friction, having greater potential to improve the friction and wear characteristics of the tribology pairs. Apart from the tribological benefits, various researches have shown the use of vegetable oils and biofuels reduces the amount of pollutants like CO2 and other hydrocarbons [12-14].

Regardless of having lots of advantages of bio-lubricant over petroleum-based lubricant, the effort to formulate bio-lubricants and its applications are very few. The research work carried out on Jatropha and Neem oils in terms of blending it with a synthetic oil are very few and the usage of SAE 20W40 over 20W50 synthetic oil was common. Hence, in this study, blends of various vegetable oils: Jatropha (J), Pongamia (P) and Neem (N), along with Synthetic oil: SAE 20W50 (S) were prepared at different ratios. The bench-mark for all the tests of the blends was the synthetic oil SAE 20W50. The Flash and Fire Points of the blends was determined using Cleveland Apparatus. Kinematic Viscosity of the blends was determined using Saybolt Viscometer. The anti-wear characteristics of the blends were evaluated using pin-on-disc tribometer. All the blends were further tested on FTIR Spectroscopy to obtain the chemical compositions of each of the blends in order to identify the optimal bend that has chemical properties closest to that of the synthetic oil SAE 20W50.

II. EXPERIMENTAL DETAILS

A. Preparation of Blends –

The blends of non-edible vegetable oils and synthetic oil was prepared in numerous ratios using a mechanical stirrer as shown in Fig.1. The blends were mixed in the mechanical stirrer for a duration of 40min each and at a speed of 600rpm. This was done to obtain an optimal emulsion. The obtained blends were samples of 100ml each.

Fig.1: Mechanical Stirrer

The obtained blends were labelled as follows:

- Synthetic Oil: ***SAE20W50***
- 80% Synthetic oil + 20% Neem: ***S80N20***
- 30% Synthetic oil + 70% Neem: ***S30N70***
- 50% Synthetic oil + 50% Neem: ***S50N50***
- 80% Synthetic oil + 20% Pongamia: ***S80P20***

B. Blending the obtained samples with Additives –

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

Fig.2: SAE20W50, S30J70, S50J50 and S80N20 Blends

In this experiment, two additives were used. A pour point depressant: Polymethacrylate, and a viscosity index improver: Butadiene Olefin. For every 100ml blend obtained in the previous step was further blended with two additives, namely- Polymethacrylate and Butadiene Olefin. These additives were added by percentage of weight to the base blend i.e. every base blend was mixed with 12% of Polymethacrylate and 15% of Butadiene Olefin by weight (12ml of Polymethacrylate and 15ml of Butadiene Olefin for every 100ml of base blend). Hence the final samples obtained were each 127ml.The samples are as shown in Fig.2.

C. Flash and Fire Point –

The physical properties of the blends such as flash point and fire point were obtained using Cleveland Apparatus as shown in Fig.3. The Cleveland or open-cup method is one of the methods in chemistry to determine flash and fire points of any petroleum product. Firstly, the test cup made of brass is filled with one of the blends obtained, up to the mark given on the cup. The filled cup is then placed onto an electric heater along with a thermometer to measure the temperature of the blend. As the temperature of the blend is gradually increased, a glowing splinter is introduced at the surface of the blend at every 5°C increments. The lowest temperature at which the splinter causes the vapour to ignite is known as the flash point. The consecutive temperature at which the vapours remain ignited for at least 5 seconds is known as the fire point. The temperature range of the Cleveland apparatus used in this experiment is 100°C to 250°C. The obtained flash and fire points of all the blends is shown in Table.1.

Fig.3: Cleveland Apparatus

Blends	Flash Point (°C)	Fire Point (°C)
SAE20W50	225	230
S30J70	230	240
S80N20	235	240
S50J50	230	235

Table.1: Flash and Fire Points of Various Blends

D. Kinematic Viscosity –

Viscosity is a very important property of a good lubricant, as it defines the internal resistance offered by the layers of oils against flow. It affects the thickness of the lubricant directly along with wearing of the mating surfaces. The kinematic viscosity of the blends was obtained using a Saybolt Viscometer as shown in Fig.4. The apparatus consisted of a stainless-steel water bath with an oil cup placed centrally. The lid of the water bath contains a socket for the thermometer and a rotatable arrangement for stirring the oil in the cup for even distribution of heat. The blend was poured onto the cup up to the marking and placed on the slot given. And a thermometer is placed touching the surface of the oil to measure the temperature of the oil. The temperature of the water bath is controlled by a regulator. When the blend reaches a temperature of 40°C, the cork under the cup is released and 60cc of the blend is allowed to flow into a beaker placed under. A timer is simultaneously started when the cork is opened and it is stopped when the 60cc of oil

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

is completely filled in the beaker. Saybolt universal seconds (t) can be converted into kinematic viscosity (v) by using the equations below:

When t < 100sec; v = 0.226t – 195/t Centistokes

When t > 100sec; v = 0.220t – 135/t Centistokes

The calculated kinematic viscosity in mm of all the blends is listed in Table.2. And the graphical comparisons of the kinematic viscosities (in mm^2/s) of the blends is shown in Fig.5.

Fig.4: Saybolt Viscometer

Blends	Kinematic Viscosity@40°C (mm^2/s)
SAE20W50	23.03
S30J70	21.28
S80N20	19.54
S50J50	16.08

Table.2: Kinematic Viscosity of Various Blends

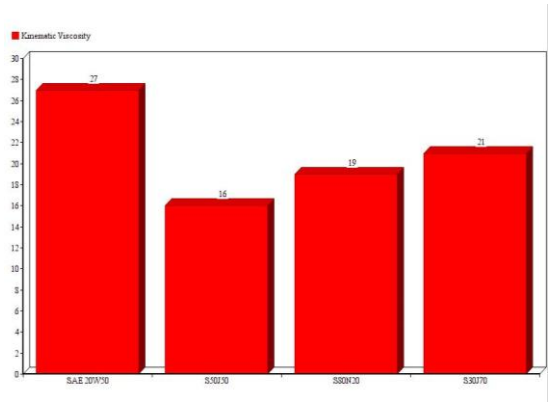

Fig.5: Graph Comparing Kinematic Viscosities of the Blends

E. Pin-on-disc Apparatus –

This experiment was conducted on a DUCOM Rotary Tribometer for testing friction and wear. The specimen used for the pin was Aluminium 6082. The dimensions of the pin were 10mm diameter and 60mm length. The device as well as a schematic diagram of the pin-on-disc apparatus is as shown in Fig.6. The aluminium pin was mounted on top of the counter disc, the pin lever is attached to a lever mechanism that is connected to a load by means of a pulley system. The constant load applied was 90N at a disc speed of 600rpm. The lubricant blend was allowed to continuously flow between the pin and disc. The wear rate v/s sliding distance was plotted alphanumerically and is as shown in Fig.7.

Fig.6: DUCOM Pin-On-Disc Apparatus

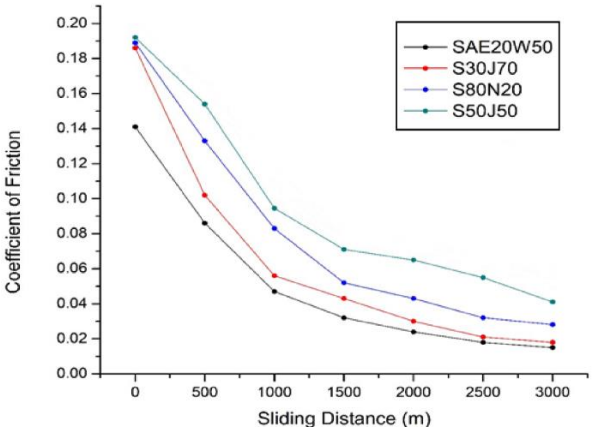

Fig.7: Variation of Coefficient of Friction v/s Sliding Distance

F. FTIR Spectroscopy –

The Fourier Transform Infrared Spectroscopy is a method that is used to categorize organic, inorganic and polymeric substances. The FTIR apparatus is shown in Fig.8. This method is a non-destructive

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

investigation which uses infrared light to scan test specimens and derive its chemical properties from the graphs. The device passes infrared rays through the sample, where some of the radiation is reflected and the remaining is absorbed by the sample oil as shown in the schematic diagram Fig.9. Ideally, half of the rays are refracted towards the moving mirror and the remaining is transmitted towards the moving mirror. The rays are reflected from both the mirrors to the beam splitter and a tiny fraction of the original light passes through the sample. This light is focused onto the detector. The difference in path length is called Optical Path Difference. The absorbed radiation is transformed into rotational and vibrational energy by the sample particles. The resultant signal at the detector presents as a spectrum, typically from 3000 cm^{-1}-500cm^{-1}, representing a molecular fingerprint of the blend. The working of the device is as shown in Fig.10. Every molecule or chemical compound will produce a unique spectral fingerprint, which helps identify if the necessary properties of a good lubricant is seen in the formulated blends and helps to conclude the optimal blends.

All the obtained graphs in FTIR Analysis is as follows:

- ***SAE20W50:*** *Fig.11*
- ***S30J70:*** *Fig.12*
- ***S80N20:*** *Fig.13*
- ***S50J50:*** *Fig.14*

Fig.8: FTIR Spectroscope

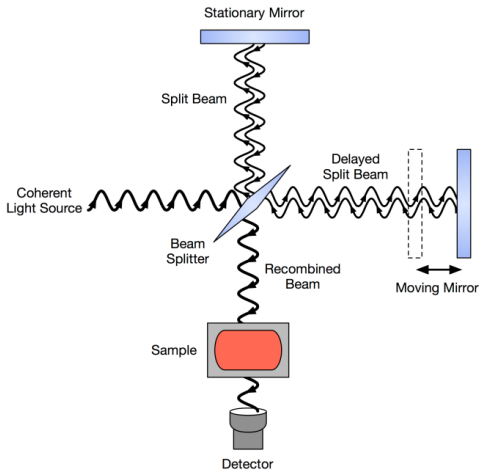

Fig.9: Working of FTIR Spectroscopy

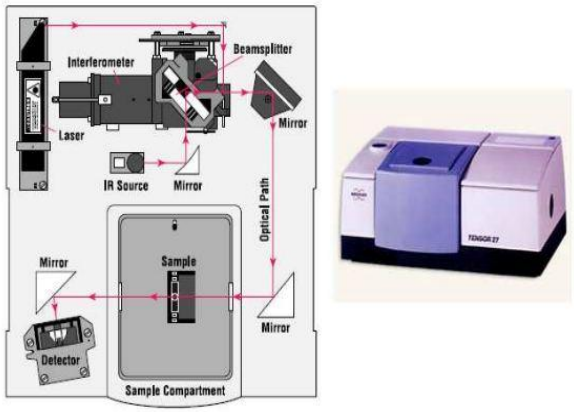

Fig.10: Schematic diagram and instrument of FTIR Spectroscopy

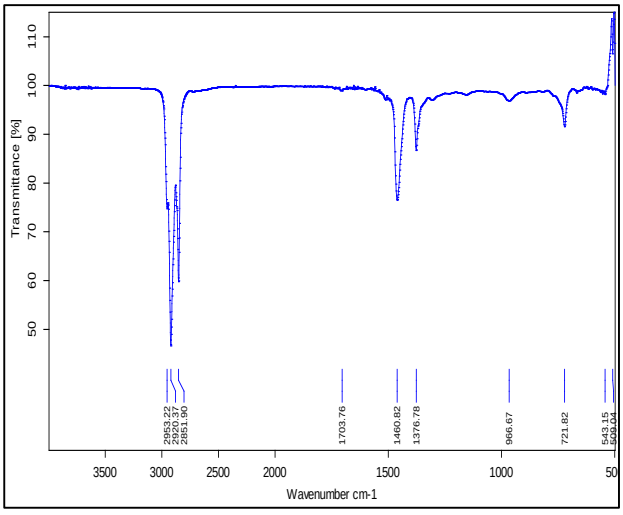

Fig.11: FTIR Graph of SAE 20W50

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 10, ISSN No. 2455-2143, Pages 94-100
Published Online February 2020 in IJEAST (http://www.ijeast.com)

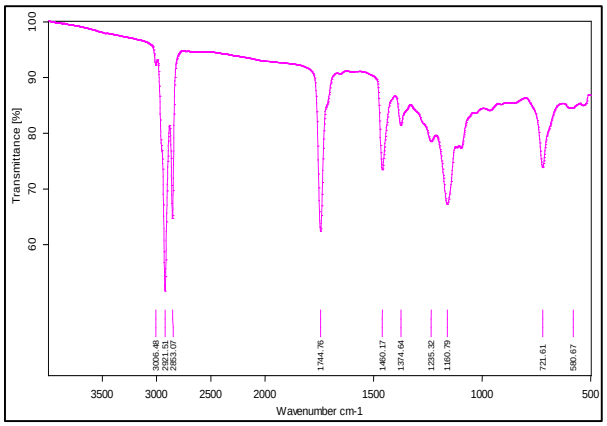

Fig.12: FTIR Graph of S30J70

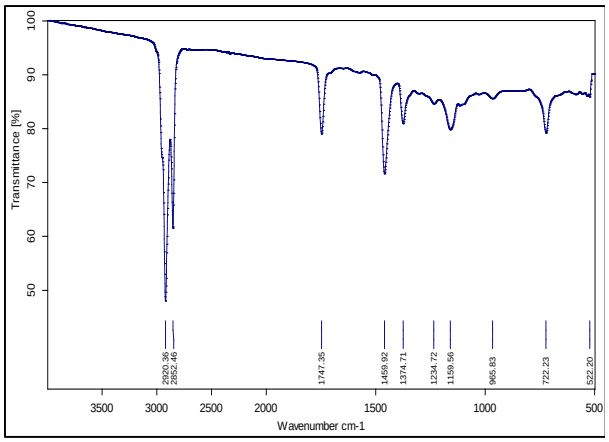

Fig.13: FTIR Graph of S80N20

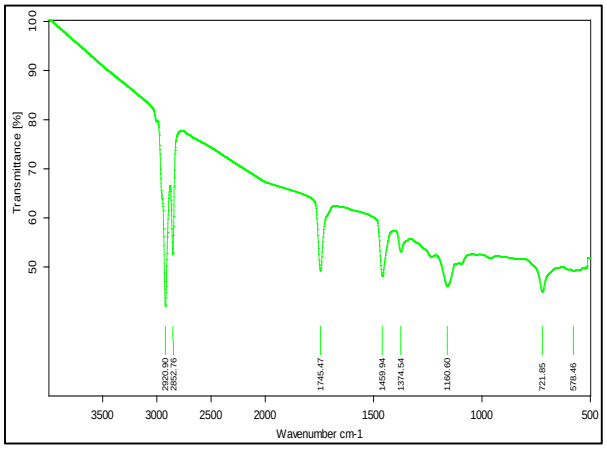

Fig.14: FTIR Graph of S50J50

III. RESULTS AND DISCUSSIONS

The optimized characteristics of all the six blends of bio-lubricants was studied and classified. Comparisons of various other parameters such as kinematic viscosity, flash point, fire point and wear rate of all the blends with the bench-mark commercially used synthetic oil (SAE 20W50) available in today's market. The composition of the blends was determined using FTIR Spectroscopy.

The pin-on-disc graph Fig.7. shows the coefficient of friction with different sliding velocities considered for different oil blends. According to the equation…… (1), the coefficient of friction was calculated.

$\mu = F/N$ ….. *(1)*

where; F = Frictional force in Newton and N = Load in Newton = 60N

With a rise in sliding velocity, the frictional coefficient decreases for several types of blends. In Fig.7, the blend S30J70 shows the minimum value of frictional coefficient close to the standard lubricant SAE 20W50 followed by S80N20 and S50J50 having the maximum value of coefficient of friction. This is because Jatropha oil contains large unsaturated fatty acids which develops higher strength in the lubricant film and acts as a boundary lubricant between the mating surfaces.

The FTIR spectrum of the blends and synthetic oil evidently shows the comparable absorption band in the region of 2864–2932 cm^{-1} and 1339–1461 cm^{-1} due to C–H stretching vibration, which specifies the identical functional group of alkanes in their molecular structures. Absorption bands in the region of 724–560 cm^{-1} indicate the presence of C–X chloride bonds of very strong intensity.

Also, the interferograms of all the blends shows absorption bands at 1749 cm^{-1} and 1740 cm^{-1}. These absorption bands are due to the C=O and C–O bond's stretching vibration in the ester which led to prove the existence of oxygen in these blends and this absorption band is absent in synthetic oil. It proves that these blends tend to oxidize before the synthetic oil. These esters can be removed using a chemical process known as Transesterification or by the addition of foreign substances into the blends known as additives. These additives can be added using binders which will help reduce the oxidational properties of the blends. It is seen that the transmittance is less in S50J50 (Fig.14), hence it cannot be used as bio lubricant. In comparison, the absorption bands of S30J70 blend (Fig.12) and S80N20 blend (Fig.13) are quite similar to synthetic oil SAE 20W50 (Fig.11) absorption bands. Therefore, these particular blends can be used as potential bio lubricants as an alternative to traditional lubricants derived from crude oils.

IV. CONCLUSIONS

The implications drawn from the above thesis are presented below:

- The interferograms of all the oil blends shows absorption bands at 1746 cm^{-1} and

1740 cm^{-1}. These absorption bands are due to the C=O and C–O bonds stretching vibration in esters which led to prove the presence of oxygen in these blends and these absorption bands is absent in case of pure synthetic oil. It proves that these blends tend to oxidize faster the synthetic oil.

- Evaluation of the friction and wear behaviour was carried out using a pin-on-disc tribometer. The specific wear rate of various percentages of Jatropha, Neem and Pongamia oil-based bio-lubricants were different. Among all the blends, S30J70 shows minimum specific wear rate.
- On comparing, the absorption bands of S30J70 blend (Fig.12) and S80N20 blend (Fig.13) are fairly similar to synthetic oil SAE 20W50 (Fig.11) absorption bands. Hence these respective blends can be used as potential bio lubricants.
- In comparing the final results of all the experiments carried out, the blends S30J70 and S80N20 shows very good lubricating properties. This is because both these blends show minimum wear rate close to SAE 20W50 and also the absorption bands of these blends obtained in FTIR Spectroscopy matches with the standard SAE 20W50. These blends also show good kinematic viscosity values closer to the synthetic oil.
- In conclusion, the blends - S30J70 and S80N20 can be used as an alternative for commercially available lubricants.

V. ACKNOLEDMENTS

I would like to acknowledge Poornaprajna Research Centre Bangalore and R&D Centre and
REVA University Bangalore for providing facilities and equipments necessary to carry out all of the experiments.

VI. REFERENCES

[1] Adhvaryu, A., Liu, Z., Erhan, S., (2005), Synthesis of novel alkoxylated triacylglycerols and their lubricant base oil properties Ind. Crop Prod. 21, (pp.113–119).

[2] Shahabuddin, M., Kalam, M.A., Masjuki, H.H., Mofijur, M., (2012), Tribological characteristics of amine phosphate and octylated/butylated diphenylamine additives infused bio-lubricant, Energy Educ. Sci. Technol. Part A: Energy Sci. Res. 30, (pp.123–136).

[3] Sundus F, Fazal M, Masjuki H., (2017), Tribology with biodiesel a study on enhancing biodiesel stability and its fuel properties, Renew Sustain Energy Rev. 70, (399–412).

[4] Thames, S.F. and H. Yu, (1999), Cationic UV-Cured Coatings of Epoxide-Containing Vegetables Oils, Surf.Coat.Technol. (pp.115 – 118 :2-3).

[5] K S Tarun, KVS Somnath, M Rajashekhar Reddy, Medhekar Nikhil Ajay, Niranjan Hiremath, (2019), Development and Tribological Testing of Environment Friendly Bio-Lubricants from Vegetable Oils, (DOI No: JETIR1905L19).

[6] Dinda,S., A.V.Patwardhan, V.V Goyd and N.C.Pradhan, (2008), "Epoxidation of cottonseed oil by aqueous hydrogen peroxide catalysed by liquid inorganic solids", Bioresource Technology, 99: (pp.3737-3744).

[7] Totten, G.E., Westbrook, S.R., Shah, R.J., (2003), Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing, ASTM International, West Conshohocken, PA, (pp. 885–909).

[8] Fox, N., Stachowiak, G., (2007), Vegetable oil-based lubricants—a review of oxidation. Tribol", Int. 40, (pp.1035–1046).

[9] Jayadas, N., Nair, K.P., (2006), Coconut oil as base oil for industrial lubricants – evaluation and modification of thermal, oxidative and low temperature properties, Tribol. int. 39, (pp.873–878).

[10] Mofijur, M., Masjuki, H.H., Kalam, M.A., Shahabuddin, M., Hazrat, M.A., Liaquat, A.M., (2012), Palm oil methyl ester and its emulsions effect on lubricant performance and engine components wear, Energy Procedia 14, (pp.1748–1753).

[11] Quinchia, L., Delgado, M., Valencia, C., Franco, J., Gallegos, C., (2010), Viscosity modification of different vegetable oils with EVA copolymer for lubricant applications, Ind. Crop Prod. 32, (pp.607–612).

[12] Gomez MG, Howard-Hildige R, Leahy J, et al., (2000), "Emission and performance characteristics of a 2 litre Toyota diesel van operating on esterified waste cooking oil and mineral diesel fuel", Urban air quality: measurement, modelling and management: Springer, (pp.13–20).

[13] Masjuki H, Maleque M, Kubo A, et al, (1999), Palm oil and mineral oil-based lubricants – their tribological and emission performance, Tribol Int.; 32, (pp.305–314).

[14] Agarwal AK., (2007), Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines, Prog Energy Combust Sci.; 33, (pp.233–271).