DEVELOPMENT AND TRIBOLOGICAL TESTING OF ENVIRONMENT FRIENDLY BIO-LUBRICANTS FROM VEGETABLE OILS

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Abstract: The wide use of petroleum-based lubricants increases concerns with regard to pollution, and the rising of awareness of greenhouse gases has produced a demand for the use of environmentally friendly and biodegradable lubricants for industrial applications. Vegetable oils are one of the bio-oils that is a good choice for the replacement for petroleum products, due to their environmentally friendly characteristics. Many researchers have accomplished bio lubricants from sunflower oil, corn oil, palm oil and soy oil but few have studied Jatropha, neem and pongamia oil, as a lubricant. In this study, Variation of the coefficient of friction with sliding distance for bio lubricants with Jatropha, neem and pongamia as base oils were studied. Experiments were conducted using a pin on disc tribotester. The results were compared with those of 20W50 mineral oil.

1. INTRODUCTION

Lubrication is the process of using a material to reduce friction and wear between any two mating surfaces, and the material which is used for this process known as ‘Lubricant’. Lubricants are frequently used in mechanical systems to help them operate efficiently and run for longer periods of time.

Various types of lubricants are available all over the world including mineral oil, refined oil and synthetic oil. Most of the lubricants which are available in the market are based on mineral oil, which is derived from petroleum products. These ate harmful to environment because of their toxicity and non-biodegradability [1]. Petroleum reserves are depleting over the past few years due to increased consumption. Petroleum based lubricants causes environmental pollution, thus an alternative lubricant should be used to meet future demand [2]. Biodegradable oils are considered an important alternative to conventional lubricants as a result of the increased awareness of environmental pollution. Vegetable oil-based lubricants can be a good alternative for mineral oil-based lubricants in the current market.

The use of vegetable oils as a lubricant in the industrial sector is not a new idea. It was recorded that olive oil was used to move stone or lumber in ancient Egypt during the construction of colossal buildings. Various vegetable oils including sperm whale oil, castor oil, peanut oil, and rape oil appeared in the middle ages as complex machines made from iron and copper were widely used. It was discovered incidentally that mixing sperm oil used for lubrication of spinning and weaving machines, with crude oil would extend the life of the machine to more than ten years. Since then, vegetable oil lubricants were quickly substituted by crude oil-based lubricant products. In the twentieth century, machinery became more complicated and sophisticated and the lubricating materials were needed to work in severe environmental conditions incomparable to that of the past. Through World War I and II, automobiles, aircrafts, diesel locomotives and large vessels were developed, driving the advancement in oil refining and lubricating products. A solvent refining method was invented in the 1920s and the use of additives to improve the performance of lubricants increased rapidly across the industries in the 1930s. In the 1950s, as jet airliners were introduced, the development of lubricants that could work well even at the temperature lower than 50 degrees below zero was needed, resulting in the emergence of multi-purpose oil. More advanced methods were discovered in the 1990s, allowing the improvement and manufacture of a wide range of high-quality lubricants using mineral oil which can compete with fully synthetic oil.

For the last three decades, the lubrication industry has been trying to formulate environmentally friendly lubricants with technical characteristics equal to those of mineral oil. These bio-lubricants should be biodegradable and non-toxic, unlike conventional mineral-based oils [3]. 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 [4].

Annually, 40 million tons of lubricants are consumed worldwide and they have a wide range of applications from car engines to office chairs. It has been reported that over 12 million tons of lubricant waste is released into the environment every year [5]. However, it is a challenging task to dispose the wastes of the mineral 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 [6]. The main limitations of vegetable oils are its poor low temperature behavior, inferior oxidation, low thermal stability and gumming effect [7]. To improve the substantiality of bio-lubricants some technical properties including the available range of viscosities are needed to be improved. To do so, environmentally friendly viscosity improvers can be used. Viscosity is one of the most significant properties of lubricants since, it determines the amount of friction between the sliding surfaces and whether the film developed can be thick enough to avoid wear from solid-to-solid contact [8].

Despite of having lots of advantages of bio-lubricant over petroleum-based lubricant, the attempt to formulate the bio-lubricant and its applications are very few. Thus, in this study we wanted to extend our investigation to test the tribological characteristics and compatibility of non-edible oil based bio-lubricants for different applications in various sectors.

2. EXPERIMENTAL

The properties of the different non edible base oils i.e. (PONGAMIA OIL, NEEM OIL, and JATROPHA OIL) like Kinematic viscosity (at 40˚C), Density, Flash and Fire Point, Cloud Point, Pour Point, Acid Value along with SAE 20W50 synthetic oil are determined and compared in the table1.

Table1. Properties of synthetic oil and different Base oils

Name Of The Oil	Synthetic Oil (20w50)	Pongamia Oil	Neem Oil	Jatropha Oil
KinematicViscosity (at 40˚C)	22.7mm^2/sec	40.2 mm^2/sec	43 mm^2/sec	35.4mm^2/sec
Density	855kg/m^3	924 kg/m^3	920 kg/m^3	895 kg/m^3
Flash Point	230˚C	235˚C	240˚C	232˚C
Fire Point	236˚C	240˚C	247˚C	240˚C
Cloud Point	-15˚C	3.5˚C	9˚C	-10˚C
Pour Point	-21˚C	-3˚C	2˚C	-6˚C
Acid Value	5.9 mgKOH/g	10.2 mgKOH/g	7.3 mgKOH/g	9.1 mgKOH/g

2.1. LUBRICANT SAMPLE PREPARATION

To test the properties of the bio lubricant, various percentages of Neem (N), Jatropha (J) and Pongamia (P) oil were mixed with the commercial lubricant SAE 50 (S).The lubricant SAE 50 was used as a base lubricant and comparison purpose. The base oils were blended along with synthetic oil in the respective ratios of (20:80), (70:30), (50:50). The homogeneous mixing was done using a mechanical stirrer (fig.1) at controlled speed of 400rpm for duration of 30 minutes each.The total nine samples obtained are S30N70, S50N50, S80N20, S30J70, S50J50, S80J20, S30P70, S50P50, and S80P20.

Fig.1: Mechanical stirrer used for blending base oils with synthetic oil

2.2. FTIR MACHINE CONFIGURATION

2.2.1 FTIR ANALYSIS

Fourier Transform Infrared Spectroscopy, also known as FTIR Analysis or FTIR Spectroscopy, is an analytical technique used to categorize organic, polymeric, and, in some cases, inorganic materials. The FTIR analysis method uses infrared light to scan test samples and observe chemical properties. The FTIR instrument sends IR rays through a sample, some of the radiation is absorbed and some of it is passed through the sample as shown in fig.2. Approximately 50% of the light is refracted towards the fixed mirror and 50% is transmitted towards the moving mirror. Light is reflected from both the mirrors back to the beam splitter and a small fraction of the original light passes into the sample compartment. There, the light passes through the sample. On leaving the sample compartment the light is refocused on to the detector. The difference in the path length between the two arms to the interferometer is known as the *Optical Path Difference* (OPD).

The absorbed radiation is converted into rotational and/or vibrational energy by the sample molecules. The resulting signal at the detector presents as a spectrum, typically from 4000 cm^{-1} to 400cm^{-1}, representing a molecular fingerprint of the sample. Each molecule or chemical compound will produce a unique spectral fingerprint, making FTIR analysis a great tool for chemical identification.

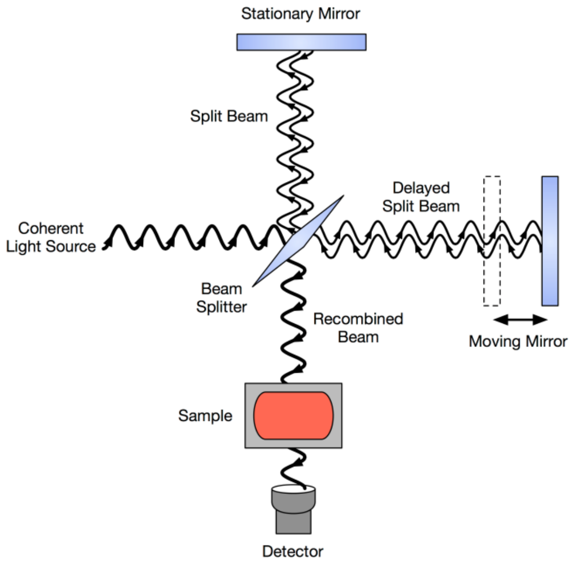

Fig.2: Schematic diagram of a Michelson interferometer, configured for FTIR

2.2.2 PREPARATION OF THE SPECIMEN

A drop of a liquid is positioned between a pair of polished sodium chloride plates, referred to as salt plates. When the plates are squeezed gently, a thin liquid film will be formed between them. Salt plates break easily and are water soluble. The salt plates are inserted into a holder which fits into the spectrometer. The FTIR Spectrometer used for this study was ALPHA FTIR Spectrometer from BRUKER (fig.3). The ALPHA is insensitive to vibration, so it can be placed almost anywhere and be immediately operational without any need for alignment. ALPHA delivers excellent sensitivity as well as X- Axis reproducibility and stability. Just few drops of any sample are enough for FTIR analysis and the time taken is 2-3 min.

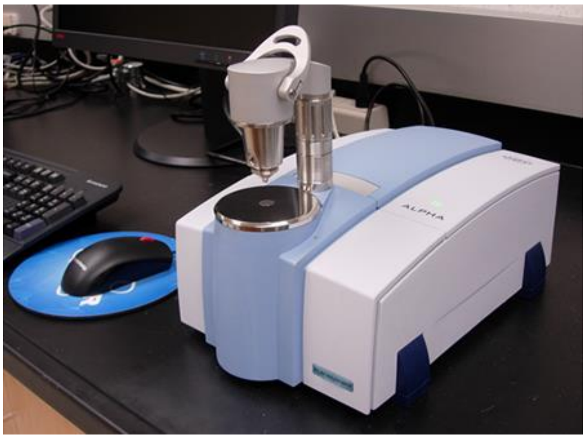

Fig.3: FTIR Spectrometer

2.3 DUCOM PIN ON DISC WEAR TESTING MACHINE CONFIGURATION

The Ducom Pin/Ball on Disk Tribometer is a test instrument designed for accurate and repeatable tribological characterization of bulk materials, coatings and lubricants. Easily changeable holders allow users to quickly change the nature of tribological contact to something that is relevant to their application. A wide range of factory installed and field upgradable options make this system very scalable, ensuring years of unrestricted research for various types of applications.

2.3.1. FRICTION AND WEAR EVALUATION

The instrument used in the friction and wear testing process was DUCOM pin on disc wear testing machine which is connected with a computer with data acquisition system. It is a pin-on-disc machine which is conducted by using a pin on a disc as testing specimens. Technical specifications of pin on disc apparatus are tabulated in Table2. During the test the load of 60 N and rotational speed of 400 rpm was applied to the pin.

Table2. Technical specifications of pin on disc apparatus

Model No	TR 20LE
Pin diameter	3-12mm
Ball diameter	10mm
Disc(diameter*thickness)	16*8mm
Wear track diameter	50-140mm
Sliding velocity	0.5-10m/s
Disc Speed	200-2000rpm
Normal Load	5-200N
Frictional force	0-200N
Wear	0-200µm

2.3.2 PREPARATION OF THE SPECIMEN FOR PIN-ON-DISC EXPERIMENT

The specimens (fig.4) were prepared from aluminum 6082 and cast iron material. Aluminum was used to build the pins and cast iron is used for the disc specimen. The dimensions of the pin were 10mm diameter and 50mm length. The surface of the pins was polished and made flat. Prior to conducting the test it was ensured that the surface of the specimens is cleaned properly i.e., free from dirt and fragments.

3. RESULTS AND DISCUSSION

3.1 FTIR RESULTS ANALYSIS

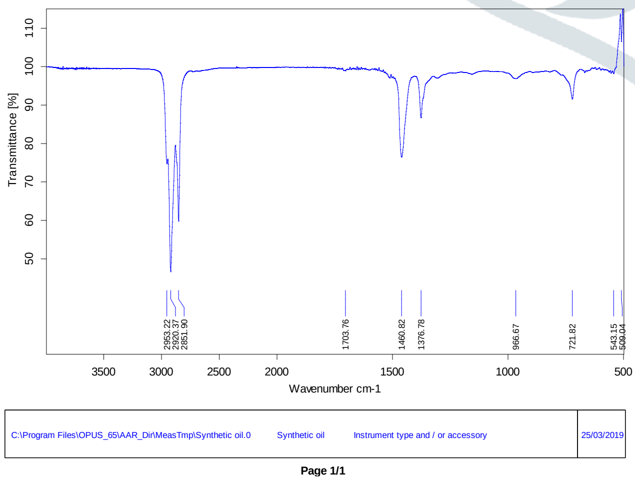

Fig.4: Synthetic oil (20 W 50)

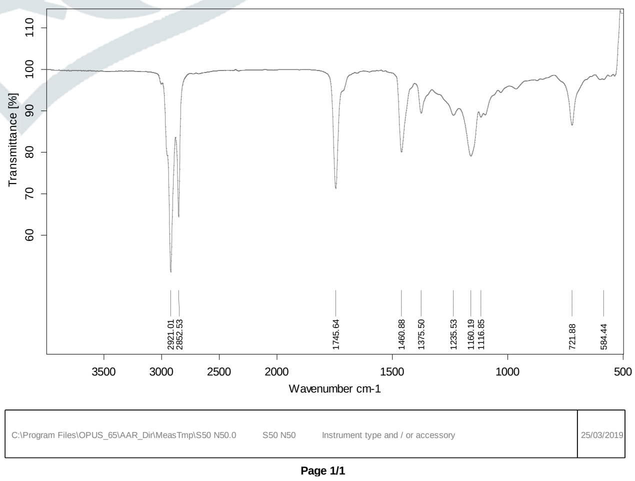

Fig.5: S50 N50 blend

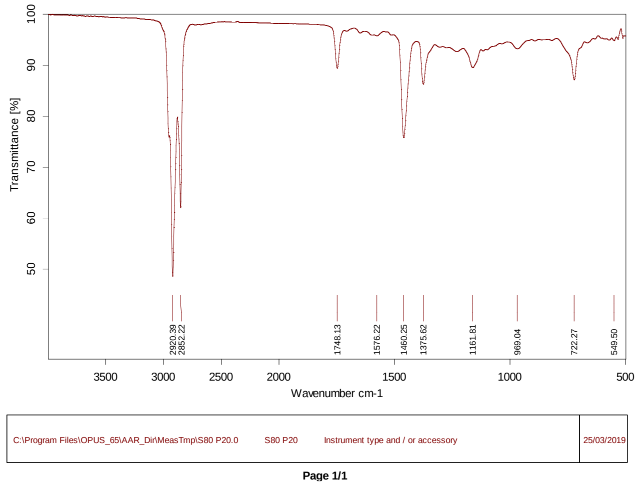

Fig.6: S80 P20 blend

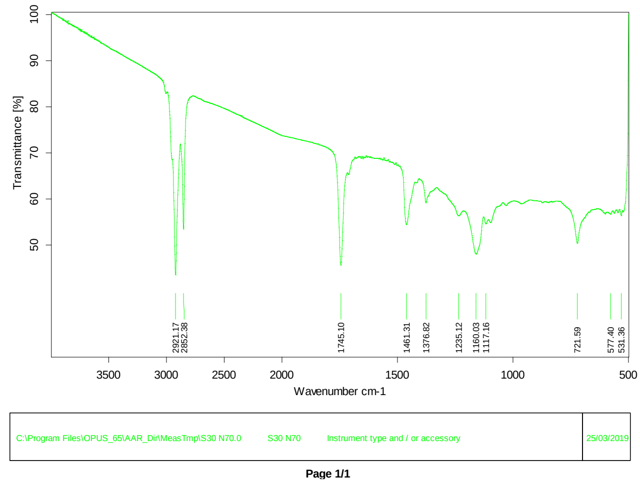

Fig.7: S30 N70 blend

The Fourier transform infrared spectroscopy (FTIR) spectrum of the blends and synthetic oil clearly shows the similar absorption band in the region of 2852–2921 cm^{-1} and 1344–1460 cm^{-1} due to C–H stretching vibration, which indicates the identical functional group of alkane in their molecular structural. Absorption bands in the region of 721–540 cm^{-1} indicate the presence of C–X chloride of strong intensity.

Also the interferograms of all vegetable oil blends shows absorption bands at 1748 cm^{-1} and 1744 cm^{-1}. These absorption bands are due to the C=O and C–O stretching vibration in ester which led to prove the presence 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 some chemical process.

It is seen that the transmittance is less in S30 N70 (fig.7), hence cannot be used as bio lubricant. On comparing, the absorption bands of S50 N50 blend (fig.5) and S80 P20 blend (fig.6) are quite similar to synthetic oil (fig.4) absorption bands. Hence the respective blends can be used as potential bio lubricants.

3.2 PIN ON DISC RESULT ANALYSIS

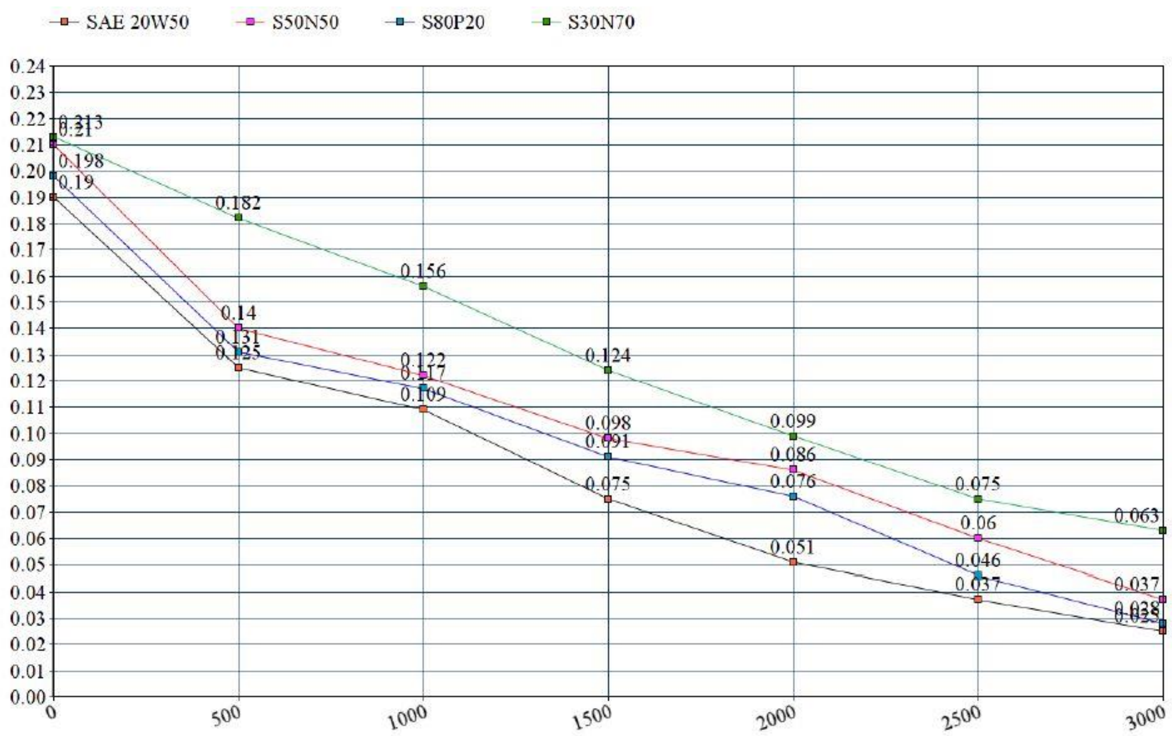

Fig.8: Variation of the coefficient of friction with a sliding distance

Fig.8 shows the coefficient of friction with different sliding velocities considered for different oil blends. According to the below mentioned Equation (1), the coefficient of friction was evaluated:

$$\mu = F/N; \quad (1)$$

Where F = frictional force in Newton.
N = load in Newton (60N);

With an increase of sliding velocity, the coefficient of friction decreases for different types of blends. S80P20 shows the minimum coefficient of friction nearer to the conventional lubricant, i.e. SAE 20W50. This is because pongamia oil contains large unsaturated fatty acids which develops higher strength in the lubricant film and acts as a boundary lubricant between the surfaces in contact.

4. CONCLUSION

- The interferograms of all vegetable oil blends shows absorption bands at 1748 cm^{-1} and 1744 cm^{-1}. These absorption bands are due to the C=O and C–O stretching vibration in ester which led to prove the presence of oxygen in these blends and this absorption band is absent in synthetic oil. It proves that these blends tend to oxidize faster the synthetic oil.
- On comparing, the absorption bands of S50 N50 blend (fig.6) and S80 P20 blend (fig.7) are quite similar to synthetic oil absorption bands. Hence the respective blends can be used as potential bio lubricants.
- Evaluation of the friction and wear behavior 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 was different. Among all the blends, **S80P20** show the minimum specific wear rate.

5. REFERENCES

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