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Development and Tribological Analysis of Bio-Based Lubricant Using Two Non-Edible Oils: Castor Oil and Neem Oil

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A B S T R A C T

Lubricants play a very important role in multiple industries in minimizing wear and friction between two moving parts. Most lubricants are produced from petroleum oil which is poorly biodegradable and toxic in nature. Hence these lubricants are highly undesirable due to environmental hazards and the health and safety of the operator. Bio-Lubricants like Castor Oil have found a potential scope in research and are being used in various applications as a substitute for these chemical lubricants. This paper examines the Tribological Properties of developed Bio-Lubricants, prepared using Castor Oil and Neem Oil in a mixing ratio of 20%. Wear and Friction analysis has been carried out using Pin on Disc apparatus at varying loads, which has shown that the blend of Castor Oil as a base with 20% Neem Oil has promising properties, with around 70% reduction in wear rate at specific loads, hence showcasing a tremendous capacity for being used in maintenance applications. An overall reduction in wear and coefficient of friction was observed in the developed mixture, making it a potential environment-friendly replacement for chemical lubricants and an upgrade over Pure Refined Castor Oil.

1. INTRODUCTION

1.1 Lubricants

A lubricant is a substance used to reduce friction and wear between two surfaces that are in contact with each other. It can be a liquid, such as oil or water, or a solid, such as grease or graphite [1]. In the mechanical engineering industry, lubricants are used to prevent the failure of moving parts in machines and equipment due to excessive wear, overheating, or seizure.

The choice of lubricants and their properties, such as viscosity, chemical composition, and

additives, plays an important role in engineering applications [2]. The lubricant should have the right viscosity to form a protective film between the moving surfaces without being too thick to impede movement or too thin to evaporate or leak. Chemical compatibility of lubricant with the surface material it is used upon is important. It must hold out against corrosion, oxidation and contamination.

Moreover, modification of lubricants can be done to suit certain applications by incorporating additives, such as anti-wear agents, friction modifiers, rust inhibitors, and extreme pressure agents. These substances improve the lubricants' efficiency under high temperatures and pressure, or other extreme circumstances.

Industries like automotive, manufacturing, aerospace, and energy depend heavily on lubricants for smooth and efficient operation. Hence, lubricants play a significant role in ensuring optimal system performance.

1.2 Bio Lubricants

Escalating environmental issues have impacted many industries. Conventionally used petroleum-based lubricants harm the environment after it is released into the waterways and soil. Thus, there's a huge demand for biodegradable lubricants in the mechanical engineering industry.

Biodegradable lubricants are generally made from renewable materials like animal fats or vegetable oils. These can be easily decayed by microorganisms in the soil or water. Because of their fast and safe breakdown in the environment, they do not pose to be harmful to wildlife and surrounding, keeping it pollution-free [3].

Castor oil is a vegetable oil extracted from the seeds of the Ricinus communis, the scientific name of the castor plant. It belongs to the Euphorbiaceae family. Castor plants are non-edible, widespread, and well-known for their therapeutic applications as laxatives. In India, castor plants are widely available, and the seeds of these plants contain 40 to 60 percent oil by volume [4]. Castor oil benefits from the presence of the hydroxyl group, which makes it more oxidatively stable than its competitors and suitable for use as a base lubricant [5].

Castor Oil has been highly researched as an individual substitute to petro-based lubricants and has shown promising results in decreasing wear in mechanical applications as a substitute for present industry-grade lubricants.

Neem oil is a type of vegetable oil that is derived from the seeds and fruits of the neem tree, which is an evergreen tree that is commonly found in India. The botanical name of neem is Azadirachta indica and it belongs to Meliaceae, the mahogany family, This oil typically has a reddish-brown or greenish-brown colour [6].

The properties of Castor Oil and Neem Oil have been mentioned in Table 1.

Table 1. Properties of Oils used.

S. No.	Characteristics	Castor Oil	Neem Oil
1	Colour	Pale Yellow	Brown Yellow
2	Density (g/ml)	0.95	0.89
3	Viscosity at 30°C (mm^2/s)	273.1	36.7
4	Iodine Value	83	72
5	Flash Point (°C)	230	187

2. TESTING SETUP

2.1 Pin on Disc Apparatus

A Pin on Disc apparatus (depicted in Fig 1) has been used to perform this experimental study. The Pin on Disc machine can be used to determine the tribological properties of a wide range of materials under varying normal loads. A revolving disc is contacted by a stationary pin positioned on a pin holder moving at a predetermined speed. When lubricating oil is present, the pin slides and exerts a frictional force against the disc.

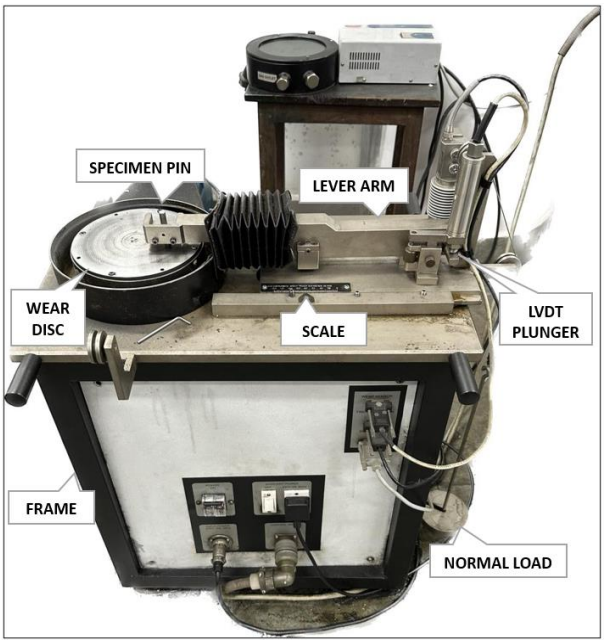

Fig. 1. Pin on Disc Apparatus.

2.2 Test Specimen

A typical cylindrical-shaped specimen has been taken for analysis, having a length of 30 mm and a pin diameter of 8 mm to perform the experiment on the Pin On Disc apparatus. Since rough surfaces make it harder to quantify wear, the pin's surface has been polished for accuracy.

Brass is the material used to make the testing pin used in this experiment.

2.3 Test Parameters

The following test parameters have been considered in this experiment:

1. Normal Load: For this experiment, a load variation of 10N to 40N has been considered, with a gap of 10N in each consecutive test.
2. Speed: The relative sliding speed between the pin and disc has been taken as 1000 RPM in each case, while the load varies.
3. Time: The running time of the experiment was 20 minutes at a selected speed of rotation, with a load increment of 10N every 5 minutes.
4. Running Diameter: The diameter of the track at which the pin rotates on the disc is taken as 80mm for this experimental study.
5. Flow rate: A constant flow of oil has been maintained throughout the experiment, with oil being pushed onto the disc at an interval of every 10 seconds.

2.4 Lubricants Used

Two lubricant blends have been used in this experiment to validate and compare their tribological performance.

Pure Neem Oil has been used to establish a baseline for Wear and Friction characteristics at different loads and operating conditions.

To further enhance the properties of the baseline, a blend of Pure Castor Oil has been created with Pure Neem Oil (Blend 1). The mixing has been done in the ratio of 80:20 since previous studies have indicated the most optimal performance to be achieved at a mixing ratio of 20%.

The various mixing ratios used in this experiment have been indicated in Table 2.

Table 2. Oil Blends Used for Analysis.

S.No.	Refined Castor Oil (mL)	Refined Castor Oil (mL)	Mixing Ratio (%)
1	1000	0	0
2	800	200	20

2.4.1 Creation of Blend

For this experiment, a base oil volume of 800mL was taken. Blend 1 was created in a ratio of 80:20 by mixing 200mL of Neem Oil with 800mL of Castor (base) oil in a magnetic stirrer. A total blend of 1000mL was achieved as a result of mixing.

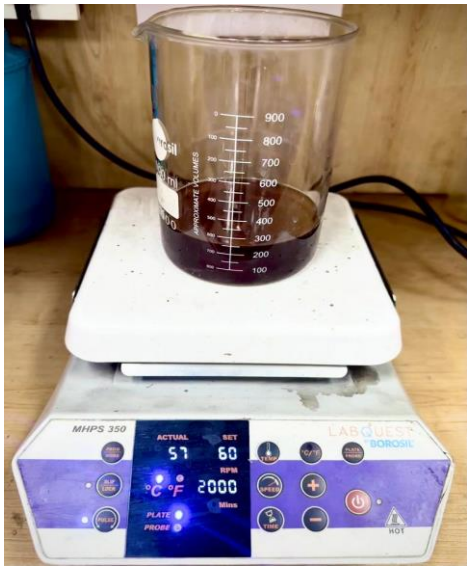

Fig. 2. Mixing blends using a magnetic stirrer.

The mixing in the magnetic stirrer was done at 2000 RPM, while the temperature was maintained at 60°C for 20 minutes.

The magnetic stirrer used for the experiment and mixing operation of the oil has been depicted in Fig 2.

3. ANALYSIS OF CHARACTERISTICS

At the point where a pin and a disc make contact, a beginning load of 10N was applied, and an oil sample flow was maintained continuously. The disc rotates at 1000 RPM (at a specific load) for a time period of 5 minutes. The coefficient of friction and wear was then measured for the specific loads and speed. Additional testing was done with increasing weights up to 40N, in a step difference of 10N each.

Testing for both the oil samples, i.e, pure castor oil and castor oil blended with neem oil, was done in the same physical conditions. Based on the experiments, the logarithmic curves showing the impact of load in N on wear rate in mm3/Nm and coefficient of friction were generated for the respective samples using the Pin on Disc apparatus. Finding an oil sample that benefits the following tribological qualities and improves lubrication is the goal of this research.

3.1 Wear Characteristics

The potential of formed oil samples was discovered for each varying load and a comparison was done for oil at high and low loading conditions to simulate mechanical applications in the industry. The graphs for both oil blends clearly show that for all oils, the wear rate increased as the applied load was increased.

The wear was tested at loads of 10N, 20N, 30N, and 40N for both oils at the constant speed of 1000 RPM. The recorded value distinctly indicated that castor oil blended with non-edible Neem Oil has better wear characteristics than refined castor oil.

A comparison graph comparing the wear was plotted for 10N and 40N loads, which has been shown in Fig 3.

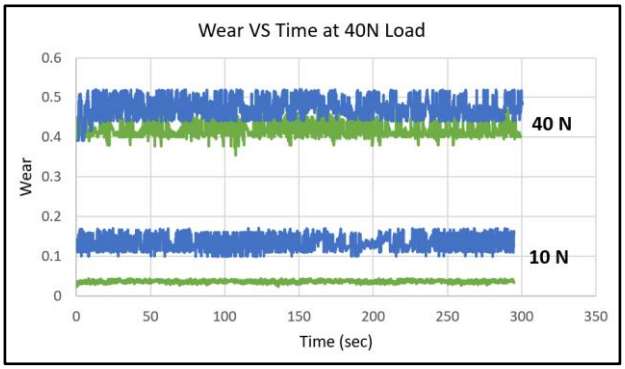

Fig. 3. Comparison graph of wear with time for oils at 10N and 40N load.

At an applied load of 10N a decrease of 70.17 % in wear was observed in the castor and neem oil blend. Whereas for the 40N load, the decrease in wear was noted to be 12.76 % in the castor and neem oil blend. From the observations, it can be stated that the neem oil when blended with castor oil in a 20% mixing ratio, proves to be a good lubricant resisting wear better than refined castor oil. Furthermore, the wear-resisting property of the Neem-Castor Blend is better at low load compared to high load but is still marginally better than castor oil alone.

3.2 Coefficient of Friction

For any equipment to perform properly and reduce energy losses, a lower coefficient of friction is preferred. As expected, a larger load led to a high coefficient of friction. More rubbing of the pin at higher loads resulted in a higher value of COF.

The figures of the coefficient of friction of pure castor oil and a blend of pure castor and neem oils (indicated in Fig 4), it is seen the latter has a lower coefficient of friction compared to pure castor oil. This is because the Neem oil in the mixture has the propensity to reduce friction.

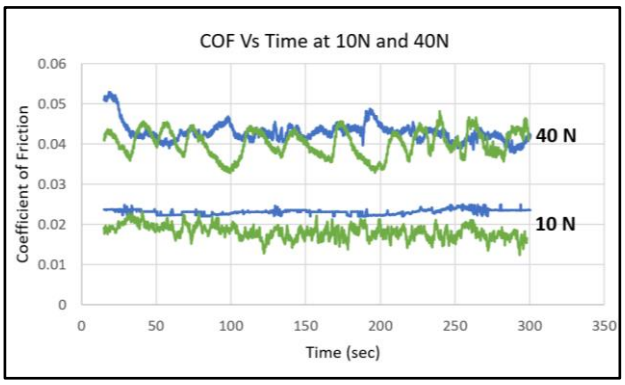

Fig. 4. Comparison graph of COF with time for oils at 10N and 40N load.

Castor-Neem blend's coefficient of friction readings range from 0.01 to 0.02 at 10N load, which is a solid indication that it may be utilized as a lubricant in mechanical applications. An average reduction of 7 to 21 % was observed by using the developed blend.

4. RESULTS AND DISCUSSION

The experimental values demonstrate that the created lubricant Blend 1 consisting of Refined Castor and Neem Oil in a 20% ratio depicts better lubrication performance and wear characteristics than Pure Castor Oil. The percentage difference in properties of Wear and Coefficient of Friction compared between Pure Castor and Blend has been described in Table 3.

Table 3. Percentage Difference in Performance.

% reduction in Wear in Blend 1 (20% Neem Oil) as compared to Pure Castor Oil	
10N (Low Load)	**40N (High Load)**
70.17	12.76
% reduction in Coefficient of Friction in Blend 1 (20% Neem Oil) as compared to Pure Castor Oil	
10N (Low Load)	**40N (High Load)**
21.64	6.29

Certain findings from the above experimental work are as follows:

- For the Castor-Neem mixture, the Coefficient of Friction was found having a value less than 0.02, indicating a standard reduction of 21.64% over the Pure Castor blend at a low load of 10N, thus resulting in lower energy losses and enhanced fuel economy when used in the industry.
- Average 70.17% wear reduction has been observed in Castor-Neem Blend over pure Castor Oil at low loads, thus indicating an increase in efficiency, an indicator of the life of the mechanical design, and reduced mechanical wear of the machinery. Enhanced anti-wear properties increase the service life of the mechanism, and result in increased longevity and longer service intervals of the machinery.

5. COST ANALYSIS

A cost analysis has been performed for the developed Bio-Lubricant to ensure that it is viable for industrial usage as per given standards.

The cost has been compared to the Servo Gear Oil 90T, which is the nearest industry standard most widely used for similar applications, and easily accessible in the market.

Servo gear oil 90T considered in the analysis has a unit cost of Rs. 220 per litre in the market. The Castor and Neem oil used for the bio-lubricant preparation is easily available in the local market at a bulk cost of Rs. 100 per liter for Pure Castor and Rs. 500 per liter for Neem oil. As per experimental observations, the blend of 80% Castor oil + 20% Neem oil has been seen to have comparable characteristics to the Servo oil.

Considering commercial production has enhanced properties for mechanical applications, including an additional cost of Rs. 40 to 80, the end user cost would still be lower than the servo-grade oil. The developed bio-lubricant has an upper hand over the Servo oil, after considering the whole preparational cost, i.e., operational, environmental harm and maintenance charge.

Castor oil-based lubricants have an enormous capacity to restore environmental balance and reduce operational costs in the mechanical industry.

6. CONCLUSIONS

The purpose of this paper is to evaluate the tribological characteristics of Castor Oil and its combination with Neem Oil. Through experimentation and analysis, several significant findings were uncovered, which have been elaborated upon.

- The research conducted made significant progress by examining how refined neem oil can be used as an additive to refined castor oil to enhance its lubrication properties, by decreasing wear and coefficient of friction. The study hence discovered that blends of refined castor oil and refined neem oil possess great potential for utilization in mechanical applications.

- The coefficient of friction has been measured to be consistently below 0.02, for Castor-Neem Blend. At a low load of 10N, the blend demonstrated a 21% reduction. This decrease in friction leads to several benefits, including improved reliability, better fuel economy, and increased performance in mechanical applications. Additionally, the reduced friction results in cost savings by lowering maintenance expenses. As the friction decreases, the wear and tear on the machine are also minimized, which is expected to lead to reduced maintenance costs over time.
- A significant reduction in wear, of about 70.1% was seen for the developed Castor-Neem Blend at a load of 10N. A wear reduction consequently leads to an increase in mechanical operating efficiency and extends the design life of the application.
- A greater reduction in wear and coefficient of friction was noted at a low load of 10N compared to a high load of 40N, indicating that the developed Castor-Neem blend might work better at lower loads.
- In all the load testing cases, the performance of the developed Castor-Neem Blend was found to be better than Refined Castor Oil. The developed blend is also cheaper than servo-grade oil. Thus, it has the ability to replace conditionally used lubricants. The proposed blend is environment-friendly and has the potential to change future trends. For specialized applications, more research needs to be done in this field.

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