Performance of Apricot oil based Bio-Lubricant under extreme pressure conditions using Four-Ball Tester

Anshul Kumar*, Rajiv Chaudhary and Ramesh Chand Singh

Mechanical Engineering Department, Delhi Technological University, Delhi, India

**Corresponding Author: ansh.k92@gmail.com*

Abstract:

The search for a bio-degradable alternative to petroleum based lubricant has become an essential thing. Various environmental elements are degrading due to the disposal of non-biodegradable petroleum based products into the environment. In the presented research work, apricot oil based bio-lubricant was prepared and blended with 15W40 oil at different proportions, these blends were then tested for wear, friction and extreme pressure performance according to ASTM D4172 and ASTM DIN 51350-02 respectively. The test results shows that the blend of 30% bio-lubricant and 15W40 oil has better wear and friction performance compared to the other blends. In regards of extreme pressure performance, the blends of bio-lubricant and 15W40 oil showed inferior performance as compared to pure 15W40 oil alone.

Keywords: Apricot oil, Extreme pressure, Four-Ball tester.

Number: 10.14704/nq.2022.20.7.NQ33246 **Neuro Quantology 2022; 20(7):1961-1965**

Introduction:

The natural reserve of fossil fuel is continuously depleting as its usage rate increases with the technological changes in the world. This has caused the hunger among researchers to find alternatives to fossil fuels. Also, the issues related to the disposal of products of fossil fuel have caused an additional excitement among researcher to find bio-degradable alternatives to fossil fuels.

Environmental pollution caused by petroleum-based lubricants has been a source of worry. The lubricant spilled over water bodies has had a negative impact on the marine ecology. Because petroleum-based lubricants are not biodegradable, their disposal has long been difficult [1]. The hunt for renewable energy sources was fuelled by the increasing needs of decreasing fossil fuel energy reserves, rising production costs, overall environmental damage. Solar energy, Hydro energy and vegetable oils have all made major contributions to addressing global renewable energy demands [2]. As a result of these factors, it becomes necessary to discover an alternative to petroleum-based lubricants.

Bio-lubricants are one of the options available for reducing the use of mineral oil. Many researchers are interested in developing bio-lubricants because of its bio-degradable nature and environmentally benign behaviour [3]. Bio-lubricant is a type of lubricant made from naturally occurring resources such as vegetable or animal oil. Bio-lubricants are non-toxic and environmentally benign because they degrade fully in nature. Plants seeds are the primary source of vegetable oils needed to make bio-lubricants.

Various edible and non-edible investigations have used bio-lubricants in their studies. The researchers have used both blended and refined bio-lubricants [4], [5]. Soyabean oil and palm oil were employed as transformer oils because they strong dielectric characteristics [6]. The sunflower oil blends improved tribological behaviour, oxidation stability, and kinematic viscosity, indicating that they might be used to replace mineral oil in textile and tannery industries [7], [8]. The use of palm oil in a light-duty diesel engine increased the system's tribological qualities [9], [10]. The use of coconut oil as a lubricant in the 2T oil for auto rickshaws improved tribo-pair wear [11]. The coefficient of friction and wear in a waste cooking oil blend were reduced by 10% [12]. At 150°C, the Jatropha bio-lubricant blend was stable, with stable physicochemical features and a lower coefficient of friction [13].

The chemical process of creating bio-lubricant and bio-diesel from vegetable oils and animal fats is known as transesterification [1]. It is a reversible chemical process that involves the extraction of fatty acids from animal fat or vegetable oil, as well as the addition of alcohol and a catalyst. The esters of heavy alcohols derived from vegetable oil and animal fat are known as bio-lubricants. Bio-lubricants have similar lubricant characteristics to petroleum oil-based lubricants.

Apricot oil methyl ester (AOME) was made from raw apricot kernel oil via transesterification [2]. In this procedure, apricot oil triglycerides were combined with an alcohol in the presence of a catalyst. The alcohol employed to convert raw apricot oil into AOME in this study was potassium Hydroxide. The reaction was carried out for 120 minutes at a temperature of 75°C.

The goal of this research is to analyse the tribological behaviour of pure apricot oil based biolubricant and various blends of 15W40 oil and biolubricant. Friction and wear test were analysed through Four-ball testing method using ASTM D4172 method and also the extreme pressure behaviour was analysed using ASTM DIN 51350-02.

Methodology:

The Bio-lubricating oil proved to be a viable alternative to conventional mineral oil based lubricants. Apricot (scientific name: Prunus armeniaca) oil is a bio-degradable and renewable edible oil that is made by crushing apricot seeds. For light duty operations, apricot based bio-lubricant may show to be a viable alternative to petroleum based lubricants. A homogenous mixture of apricot based lubricant in 15W40 lubricant was tested on Four-ball tester for extreme pressure and tribological analysis and compared to pure 15W40 and pure bio-lubricant.

With the trans-esterification process, extracted oil is chemically converted into methyl ester. As illustrated in Figure 1, the product of trans-esterification is known as Apricot oil Methyl Ester (AOME). The new bio-lubricant is mixed with commercially available petroleum based lubricant i.e. 15W40 at various volume ratios in this study. A magnetic stirrer is used to make a homogenous mixture of bio-lubricant and 15W40 lubricant at 40°C. A total of 7 test samples with various volume ratios were formed. Table 1 displays the experimental samples made by mixing 15W40 with bio-lubricants.

Table 1: Test Samples at different volume ratio.

Sample	% 15W40 lube	% Bio-lube
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50
G	0	100

I. Four-Ball tester

The Shell Four-ball Tester is used to characterise lubricant qualities like wear prevention, extreme pressure and frictional behaviour. The tester is made up of four balls arranged in an equilateral tetrahedron. The top ball rotates and makes contact with the below three balls, which remain stationary. Figure 1 shows the Four-Ball tester with its attachments.

Fig 1: Setup of Four ball tester

II. Wear and Friction Analysis (ASTM-D4172)

In this testing procedure, a Four-ball tester is utilised to determine the tribological characterisation of lubricant samples. The relative wear prevention qualities of lubricants are determined using this test procedure. Three steel balls with a diameter of 12.7mm are fastened and filled with the test lubricant sample in this operation. The rotating spindle was clamped with the fourth stell ball of the same diameter. With a load of either 196N or 392N, the fourth ball was squeezed into the cavity formed between the three stationary balls. A thermocouple integrated into a Four-ball tester was used to heat the test lubricant to a temperature of 75^{o}C. For 3600 seconds, the top ball was rotated at a speed of 1200 rotations per minute.

III. Extreme Pressure analysis (ASTM DIN 51350-02)

The ability of a lubricant to perform under extreme pressure circumstances is determined by testing its extreme pressure properties. The test begins with Low loads, which are loads at which the lubricant performs properly, a good lubricant film forms, and seizure is not detected. The load is gradually increased in accordance with the test standard until the lubrication fails, at which point the lubricant film no longer separates the surfaces and contact between the surfaces occurred. The load is gradually increased until failure occurs. Welding is the phrase for the last failure, which is characterised by higher noise levels and rapid fluctuations in the friction signal. Figure 2 shows the schematics of a Four-ball tester used to determine the extreme pressure and tribological performance.

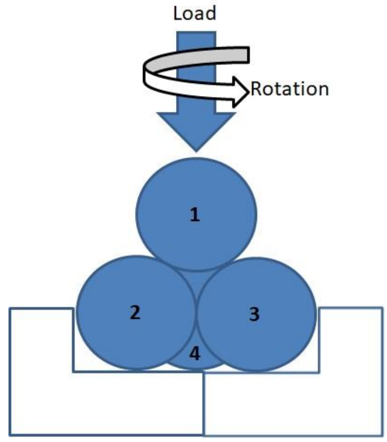
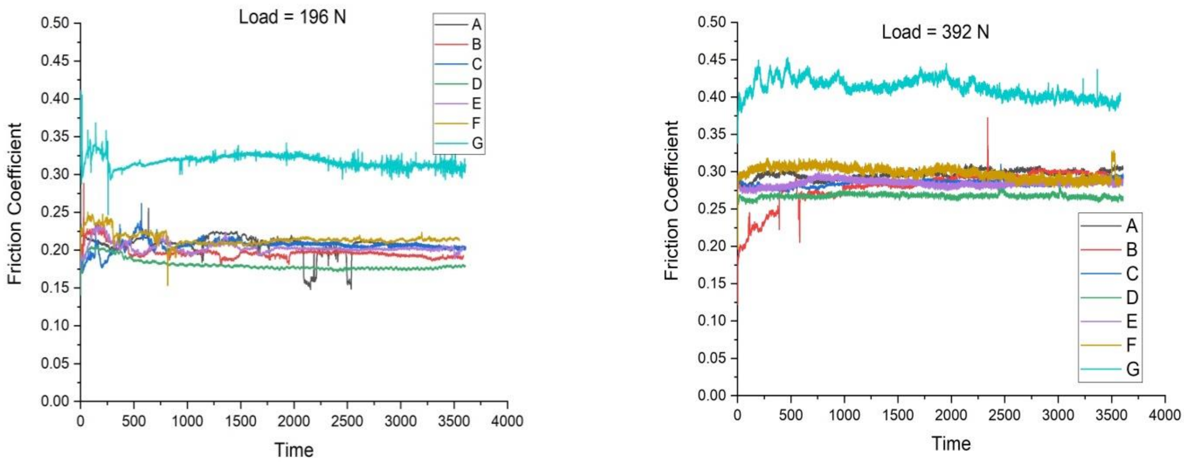


Fig 2: Schematic diagram of Four ball tester

Results:

The Triblogical Performance of sample test lubricants were determined by the graphical representation of Friction coefficient with respect to time, and amount of wear occurred on the stationary balls.

Figure 3 represents the variation of friction coefficient behaviour with respect to time. It is clearly observed that the sample 'D' has shown minimum friction coefficient as compared to pure 15W40 and pure apricot based Bio-lubricant. Similarly, from Figure 4, it is deduced that the wear produced on the steel balls is minimum when sample 'D' was used as a lubricant. Both these observations support the applicability of blended lubricant as compared to pure 15W40 and pure bio-lubricant.



(a) (b)

Fig 3: Variation of Friction Coefficient with Time at (a) 196 N, and (b) 392 N

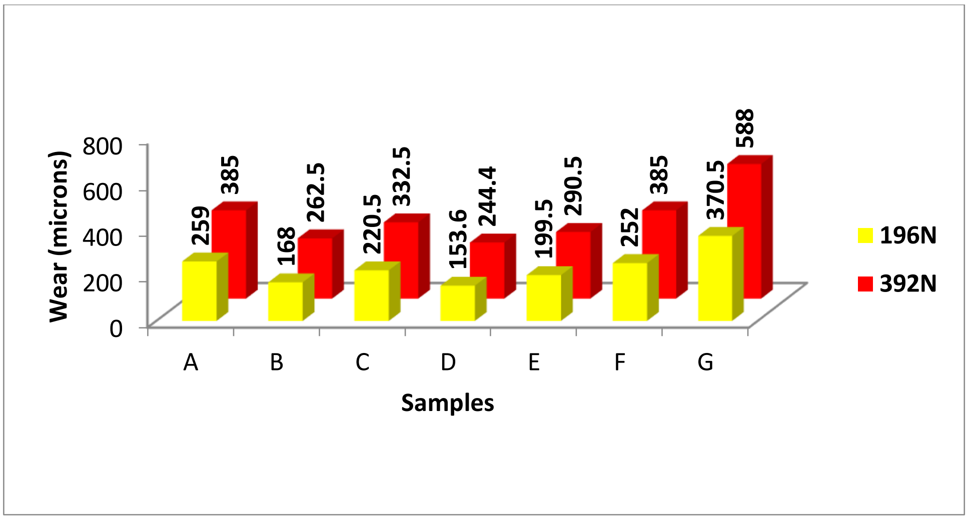


Fig 4: Wear in microns at different lubricant samples

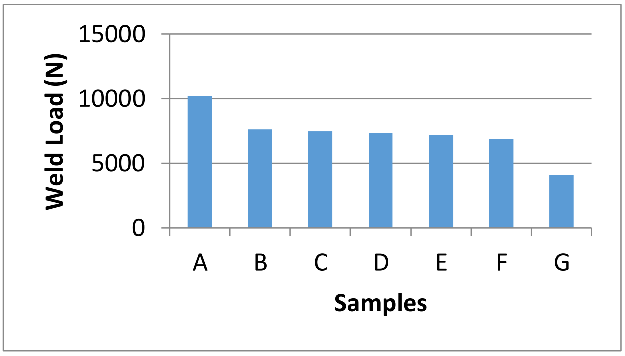


Fig 5: Variation of Weld Load for different lubricant samples

Four-ball tester was used to conduct the extreme pressure analysis in accordance with ASTM DIN 51350-02. The weld load was used to calculate the lubricant's extreme pressure performance. Figure 5 depicts the variation of weld load with respect different test samples. It was observed that various blends of 15W40 and bio-lubricants have performed worse under intense pressure conditions compared to the pure 15W40 oil. It is also observed that with the increase of bio-lubricant content in 15W40, the performance under extreme pressure degrades as the weld load value decreases.

Conclusions:

In this study, various samples of blended bio-lubricant and 15W40 oil were taken and studies for their tribological and extreme pressure performance. A four-ball tester was utilised to complete the study by incorporating ASTM D4172 and ASTM DIN 51350-02 procedural methods. The following conclusions have been deduced from the study:

1. The optimum blend of bio-lubricant and 15W40 has shown the minimum friction coefficient and wear. The optimum blend was found when 30% of bio-lubricant blended with 70% of 15W40.
2. It can be concluded that a blend of bio-lubricant and 15W40 proved to have good anti-friction and anti-wear properties. Also, the bio-degradable nature of bio-lubricants reduces the dependability on petroleum based lubricants.
3. The apricot oil based bio-lubricant and its various blend with 15W40, under performs as compared to the pure 15W40 oil. Hence, the bio-degradable nature of apricot oil based bio-lubricant makes it good alternative for petroleum based lubricant for light duty applications.

References:

[1] Y. Singh, A. Sharma, N. K. Singh, and W. H. Chen, "Development of bio-based lubricant from modified desert date oil (balanites aegyptiaca) with copper nanoparticles addition and their tribological analysis," *Fuel*, vol. 259, no. May 2019, p. 116259, 2020, doi: 10.1016/j.fuel.2019.116259.

[2] A. Kumar, R. Chaudhary, and R. C. Singh, "Tribological analysis of novel apricot oil based biolubricant against 15w40 oil tested on high

temperature tribometer," *J. Eng. Res.*, vol. 2021, pp. 205–214, 2021, doi: 10.36909/jer.ICARI.15269.

[3] S. Chaudhary, V. K. Mahto, A. K. Jha, and S. Verma, "Tribological Investigation of Bio-Lubricant Based on Madhuca Longifolia and Sesamum Indicum," vol. 29, no. 10, pp. 5885–5892, 2020.

[4] S. M. Bashi1 and R. Y. and A. N. , U. U Abdullahi1, "Use of Natural Vegetable Oils As Alternative," *Inst. Eng. Malaysia*, vol. 67, no. 2, pp. 4–9, 2006.

[5] A. E. Atabani *et al.*, "Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production," *Renew. Sustain. Energy Rev.*, vol. 18, pp. 211–245, 2013, doi: 10.1016/j.rser.2012.10.013.

[6] S. Bhuyan, L. S. Holden, S. Sundararajan, D. Andjelkovic, and R. Larock, "Effect of crosslinking on the friction and wear behavior of soybean oil-based polymeric materials," *Wear*, vol. 263, no. 7-12 SPEC. ISS., pp. 965–973, 2007, doi: 10.1016/j.wear.2007.01.104.

[7] A. Rac and A. Vencl, "Performance investigation of chain saw lubricants based on new sunflower oil (NSO)," *Tribol. und Schmierungstechnik*, vol. 56, no. 3, pp. 51–54, 2009.

[8] L. A. Quinchia, M. A. Delgado, C. Valencia, J. M. Franco, and C. Gallegos, "Viscosity modification of high-oleic sunflower oil with polymeric additives for the design of new biolubricant formulations," *Environ. Sci. Technol.*, vol. 43, no. 6, pp. 2060–2065, 2009, doi: 10.1021/es803047m.

[9] K. K. Ming and D. Chandramohan, "Malaysian Palm Oil Industry at Crossroads and its Future Direction," *Oil Palm Ind. Econ. J.*, vol. 2, no. 2, pp. 2–7, 2002, [Online]. Available: http://palmoilis.mpob.gov.my/publications/opiejv2n2-10.pdf.

[10] E. A. Rahim and H. Sasahara, "A study of the effect of palm oil as MQL lubricant on high speed drilling of titanium alloys," *Tribol. Int.*, vol. 44, no. 3, pp. 309–317, 2011, doi: 10.1016/j.triboint.2010.10.032.

[11] N. H. Jayadas, K. Prabhakaran Nair, and A. G, "Tribological evaluation of coconut oil as an environment-friendly lubricant," *Tribol. Int.*, vol. 40, no. 2 SPEC. ISS., pp. 350–354, 2007, doi: 10.1016/j.triboint.2005.09.021.

[12] A. Adhvaryu, S. Z. Erhan, and J. M. Perez, "Tribological studies of thermally and chemically modified vegetable oils for use as environmentally friendly lubricants," *Wear*, vol. 257, no. 3–4, pp. 359–367, 2004, doi: 10.1016/j.wear.2004.01.005.

[13] M. F. M. G. Resul, T. I. M. Ghazi, and A. Idris, "Temperature dependence on the synthesis of jatropha biolubricant," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 17, no. 1, 2011, doi: 10.1088/1757-899X/17/1/012032.