Journal of Engg. Research ICARI Special Issue pp. 205-214 DOI : 10.36909/jer.ICARI.15269

# Tribological Analysis of novel Apricot oil based Biolubricant against 15W40 oil tested on High Temperature Tribometer

Anshul Kumar*, Rajiv Chaudhary and Ramesh Chand Singh

*Mechanical Engineering Department, Delhi Technological University, Delhi, India*
** Corresponding Author : anshulbro16@gmail.com*

## ABSTRACT

Nowadays, petroleum products have become an integral part of day-to-day life. Lubricants made from petroleum products were widely used as automobile lubricants. But the use of petroleum-based lubricants has significantly damaged the environment. The concern of environmental damage caused by petroleum-based lubricants has increased the search for environmentally friendly lubricants. The vegetable oil-based lubricants proved to be environmentally friendly. In the present work, a bio lubricant is produced from the apricot oil, scientifically known as Prunus Armeniaca, using the trans-esterification method. The tribological behavior is analyzed for pure bio-lubricant, 15W40 oil, and also for the blend of apricot oil and 15w40 at different volume percentages. A high-temperature Pin on disc tribometer is used to perform friction and wear tests at 40$^{o}$C and 100$^{o}$C. It was found that the blend of apricot oil-based bio-lubricants and 15W40 lubricant showed better tribological behavior as compared to the pure bio-lubricant and 15W40 oil alone.

**Keyword:** Biolubricant; Apricot oil; High temperature tribometer; 15W40 Oil.

## INTRODUCTION

Lubrication is a process of providing fluid in between the two surfaces having relative motion between them. Lubricant is a material which reduces both the friction and wear between the two contacting surfaces. A lubricant act between the two surfaces and forms a layer in-between them. This reduces the chance of surface-to-surface contact, hence further reduces friction and wear. Lubricants smoothen out the motion between the surfaces and also ease the transfer of heat, generated within the contacting surfaces.

From a long time, a lubricant produced from mineral oil was used to provide lubrication between various machine elements. But, a concern has been raised over environmental pollution caused by the petroleum based lubricants. The spillage of the lubricant over water bodies have caused dangerously affected the marine ecosystem. Petroleum based lubricants are not biodegradable in nature; hence its disposal has always been a challenge. The increasing demands of depleting fossil fuel energy reserves, cost of production and the overall damage to the environment fuelled the search for renewable sources of energy (I.N.Dibal et al., 2018). Solar, hydro and vegetables have contributed significantly in meeting the global demands for renewable energy. Due to these reasons, a necessity arises for finding an alternative of petroleum based lubricant (Y.Singh et al., 2019).

Biolubricant is one of possibilities which is capable to reduce the usage of the mineral oil. Its biodegradable nature and environmental-friendly behavior made the development of biolubricant a field of interest for many researchers.

Bio-lubricant is considered as lubricant developed from naturally available materials either from vegetable oil or animal oil. Bio-lubricants are non-toxic in nature and environmental friendly as they completely degradable in nature. Plant seeds are the main source of vegetable oils required for the production of bio-lubricants. Some of the vegetable oils which can be utilized for production of bio-lubricant are castor oil (A.K.Singh.,2011), groundnut oil (Asere et al., 2008), jatropha oil (Shahbuddin et al., 2013), soyabean (Kulendran., 2010), sunflower oil (G.S.Kumar et al., 2012), coconut oil (M.Varghese et al., 2012), rapeseed oil (R.Kreivaitis et al., 2012), karanja oil, palm oil, olive oil. The vegetable oils obtained from various plants and fruit seeds, were chemically modified to form a biolubricant.

Transesterification is the chemical process of producing biolubricants and biodiesel from the vegetable oils and animal fats. It is a reversible chemical process which mainly includes fatty acid, retrieved from the animal fat or vegetable oil, alcohol & catalyst. Biolubricants are the esters of heavy alcohols originated from vegetable oil and animal fat. Biolubricants have lubricating properties quite similar to those of petroleum oil-based lubricants (J.Salimon et al., 2010).

Apart from being biodegradable and non toxic towards environment, biolubricants heighten the performance benefits of a lubricant including improved lubricity, high flash point temperature, low volatility, higher viscosity indices, low compressibility, higher detergency, and higher resistance to humidity (S.Rani et al., 2014) (S.C.Cermak et al., 2013). Beside all these benefits, biolubricants have two main issues i.e. poor low temperature performance and low thermal oxidative stability. These shortcomings of a biolubricant can be improved by chemical modification to make biolubricant a feasible alternative to petroleum based lubricant for various applications (S.Soni et al., 2014).

In India, the production of apricot mainly occurs in the northern part of India. According to the report of Food and Agriculture Organisation corporate statistical database, in the year 2017 estimated total world production was 4,257,241 metric tonnes, which is approximately 9.7% higher than total production of 2016. India stands at 35$^{th}$ position in production of apricot. In India, the production of Apricot has increased from 15541 tonnes in 2017 to 16145 tonnes in 2019.

In this research work, a novel vegetable oil extracted from the seed of apricot fruit is used to create a novel biolubricant. The apricot oil is extracted from its kernel in a traditional method. The tribological behavior of a novel biolubricant is analysed using a High Temperature Pin-on-disc tribometer. A comparison is also made between the behavior of Novel biolubricant, commercial 15W40 lubricant and also at different proportions of these two.

## MATERIALS AND METHODS

Apricot (Prunus armeniaca) kernel oil (khubani oil) is extracted by using traditional method. In a traditional method of oil extraction, an apricot kernel paste is formed in a mortar as shown in Figure 1. After that the paste is kneaded manually until the paste exudes the oil. Pandey at el. observed that kernels gave around 53.4% of oil (J.P.Pandey et al., 2014).


(a) (b)

**Figure 1.** (a) Traditional Mortar ; (b) Extracted Apricot oil

Extracted oil is chemically transformed into a methyl ester with the process of trans-esterification process. The product formed from trans-esterification is known as Apricot oil Methyl Ester (AOME) as shown in Figure 2. In this research work, the developed bioluricant is blended with commercially available mineral lubricant (15W40) at different volume ratios. A homogenous mixture of biolubricant and 15W40 lubricant is prepared at 40$^{o}$C using a magnetic stirrer. A total of 11 test samples were prepared at different volume ratio. Table 1 shows the experimental samples by blending commercial oil and prepared AOME.

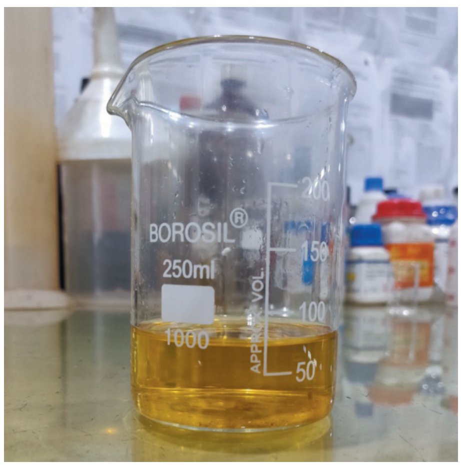



**Figure 2.** Chemically Prepared Apricot Oil Methyl Ester (AOME)

**Table 1.** Test samples at different volume ratio.

| Sample | % Volume of 15W40 | % Volume of AOME |
|---|---|---|
| S1 | 100 | 0 |
| S2 | 90 | 10 |
| S3 | 80 | 20 |
| S4 | 70 | 30 |
| S5 | 60 | 40 |
| S6 | 50 | 50 |
| S7 | 40 | 60 |
| S8 | 30 | 70 |
| S9 | 20 | 80 |
| S10 | 10 | 90 |
| S11 | 0 | 100 |

## HIGH TEMPERATURE PIN ON DISC TRIBOMETER

For determining the coefficient of friction and wear of a tribo-pair, a High Temperature tribometer (ASTM G99) is used at different testing conditions. Figure 3 shows the position of different sensors incorporated in High Temperature Tribometer. A mild steel disc and a cast iron pin are utilized as a tribo-pair. The properties of a mild steel disc and cast iron disc are as in Table 2:

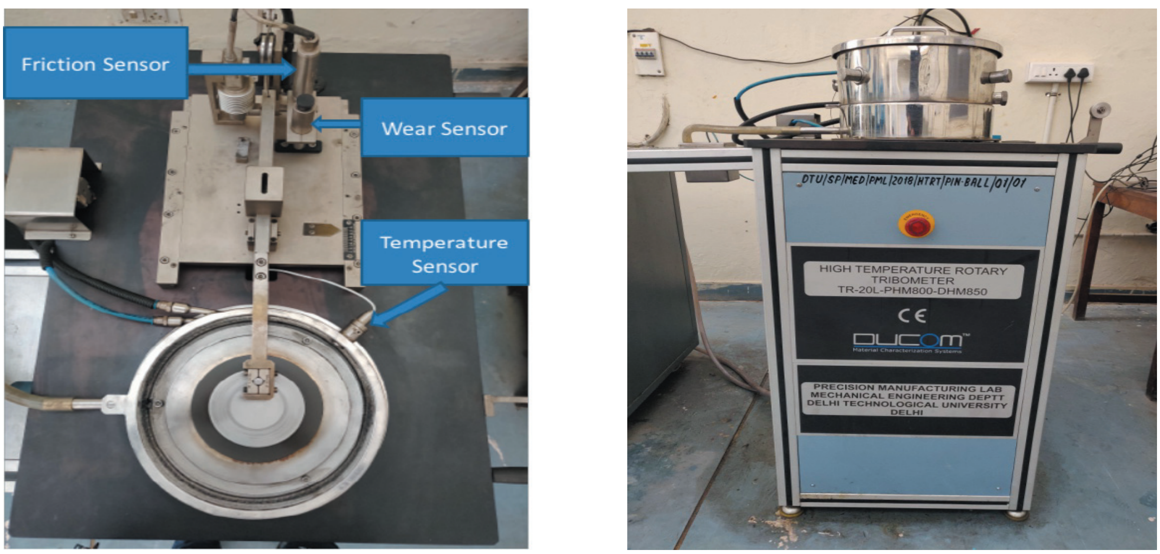



**Figure 3.** High Temperature Tribometer (ASMT G99)

**Table 2.** Material Properties of Tribo-pairs

| Properties | Mild steel Disc | Cast iron Pin |
|---|---|---|
| Density ($kg/m^3$) | 7885 | 7142.5 |
| Young's Modulus (Pa) | 2e11 | 1.5e11 |
| Specific Heat (J/Kg-K) | 463 | 459 |
| Thermal Conductivity (W/m-K) | 54.2 | 47.4 |
| Poisson's ratio | 0.3 | 0.27 |

Tests were performed at four different test speeds and at two different temperatures. A film of boundary lubrication is maintained in between the tribo-pair. A Drop-wise lubrication method is used to maintain boundary lubrication between the tribo-pairs. The parameters of the testing were given in the Table 3 below:

**Table 3** Parameters of Testing on High Temperature Pin-on-disc Tribometer.

| | |
|---|---|
| Speed (m/s) | 1.3, 1.57, 1.83, 2.09 |
| Sliding Distance (m) | 2000 |
| Normal Load (N) | 35 |
| Temperature (Deg Celcius) | 40 & 100 |
| Diameter of Disc (mm) | 100 |
| Diameter of Pin (mm) | 10 |

## RESULTS

In Figure 5 and 7, the variation of pin wear with time is shown for different blend samples of 15W40 and biolubricant at 40$^o$C and 100$^o$C respectively. The operating condition of high temperature tribometer was fixed at 35 N normal loads and Rotational speed disc varies from 450 rpm to 554 rpm. It is observed that maximum pin wear occurs at the initial stage of testing. This initial stage is known as running-in period. During the running-in period, the sliding surface asperities were break off and caused abrasion wear between the contacting surfaces. After initial abrasion, a uniform contact zone is established between the surfaces. After running-in period, the wear rate becomes steady and an equilibrium state is attained. It is observed that, among all the blend samples, a blend of 70% 15W40 and 30% biolubricant i.e. S4 has minimum wear and S11 blend has maximum wear. The average wear of pin at 40$^o$C and 100$^o$C is shown in Table 4.

**Table 4.** Average Wear of S4 and S11 blends at different sliding speed and temperature.

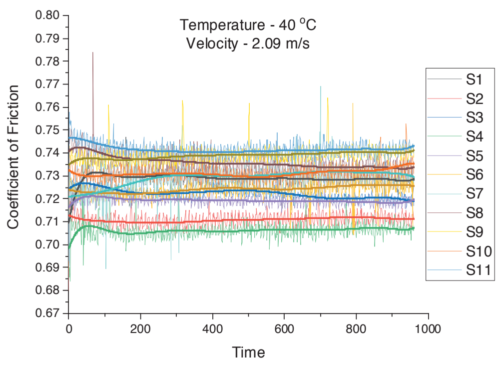
| | Speed (m/s) | Wear (micron) of S4 Blend | Speed (m/s) | Wear (micron) of S11 Blend |
|---|---|---|---|---|
| Temperature 40°C | 2.09 | 5.57 | 2.09 | 22.35 |
| | 1.83 | 9.24 | 1.83 | 25.70 |
| | 1.57 | 12.80 | 1.57 | 40.74 |
| | 1.30 | 17.38 | 1.30 | 44.33 |
| Temperature 100°C | 2.09 | 11.57 | 2.09 | 39.07 |
| | 1.83 | 16.14 | 1.83 | 42.79 |
| | 1.57 | 27.31 | 1.57 | 52.74 |
| | 1.30 | 32.80 | 1.30 | 58.33 |

These observations were attributed to the ability of S4 blend to have better consistency of lubricant film between the contacting surfaces and resistance to metal to metal contact.

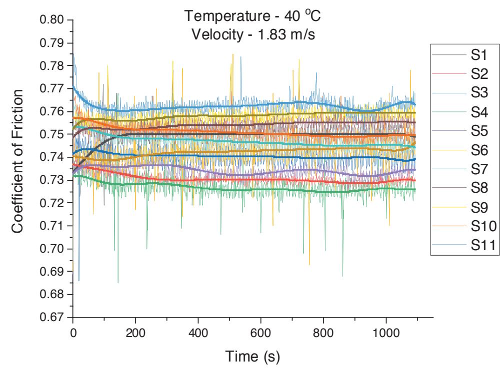
In Figure 4 and 6, the variation of coefficient of friction (CoF) with time is shown for different blend samples at 40°C and 100°C. From the results, it is observed that boundary lubrication regime is maintained between the contacting surfaces. For S11 blend, the value of CoF is highest among all the blend samples and for S4 blend, the value of CoF is lowest. The fatty acid components of the biolubricants formed multi and mono layer on the surface of the rubbing zone and made a stable film to prevent the contact between the surfaces. In Table 5 shows average coefficient of friction of S4 and S11 blends.

**Table 5.** Average coefficient of friction of S4 and S11 blends at different sliding speed and temperature.

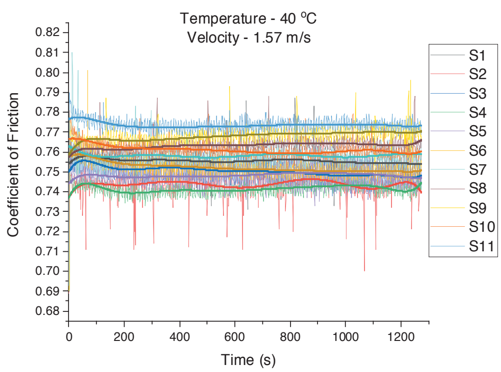
| | Speed (m/s) | CoF of S4 Blend | Speed (m/s) | CoF of S11 Blend |
|---|---|---|---|---|
| Temperature 40°C | 2.09 | 0.706 | 2.09 | 0.741 |
| | 1.83 | 0.726 | 1.83 | 0.762 |
| | 1.57 | 0.741 | 1.57 | 0.773 |
| | 1.30 | 0.752 | 1.30 | 0.800 |
| Temperature 100°C | 2.09 | 0.761 | 2.09 | 0.800 |
| | 1.83 | 0.782 | 1.83 | 0.839 |
| | 1.57 | 0.803 | 1.57 | 0.863 |
| | 1.30 | 0.832 | 1.30 | 0.914 |



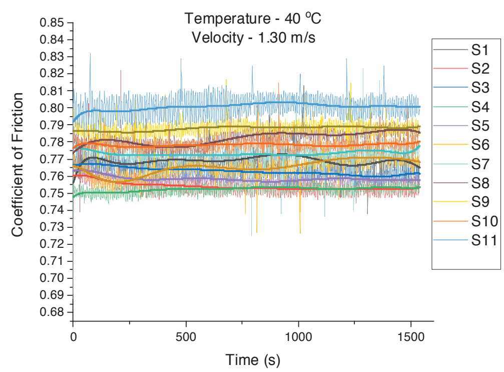

(a)




(b)

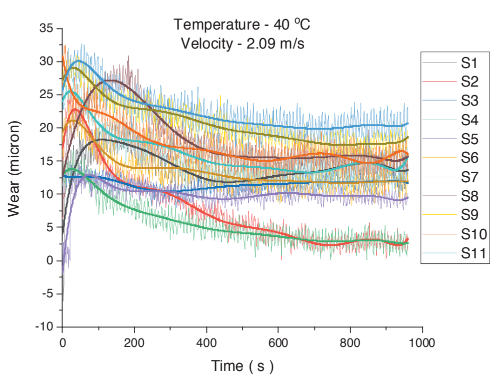



(c)

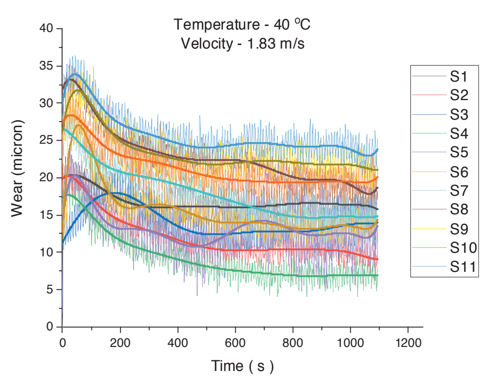



(d)

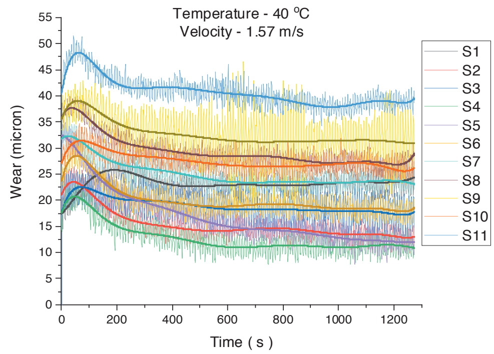
**Figure 4.** Behavior of Coefficient of Friction with Time at 40°C at sliding speed of (a) 2.09 m/s, (b) 1.83 m/s, (c) 1.57 m/s and 1.30 m/s



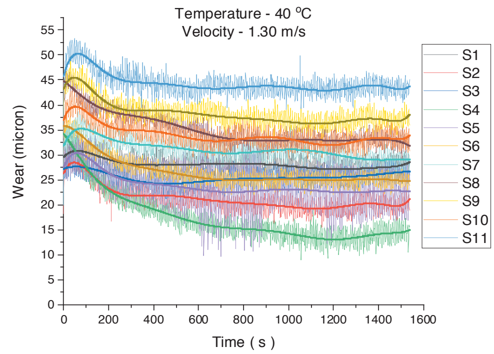

(a)




(b)

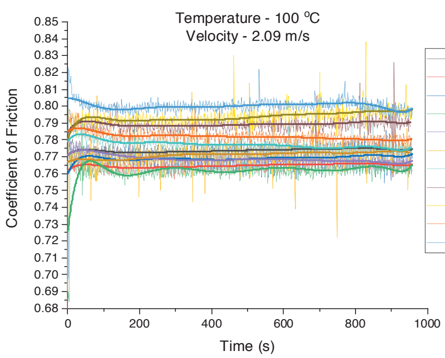



(c)

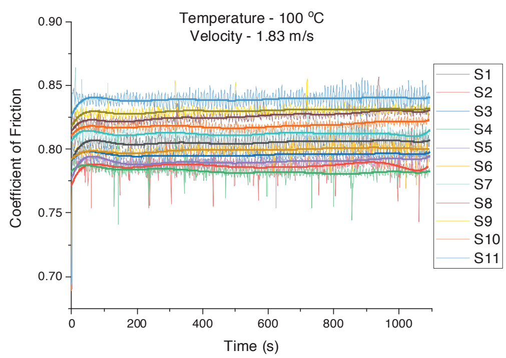



(d)

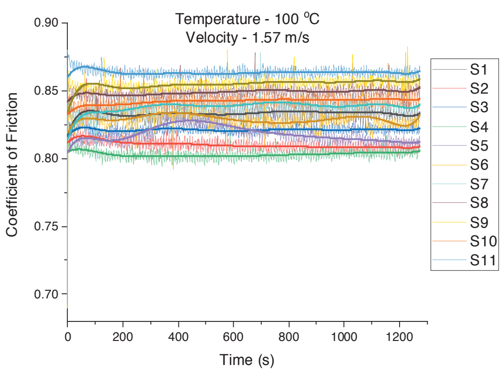
**Figure 5.** Behavior of Wear with Time at 40°C at sliding speed of (a) 2.09 m/s, (b) 1.83 m/s, (c) 1.57 m/s and 1.30 m/s



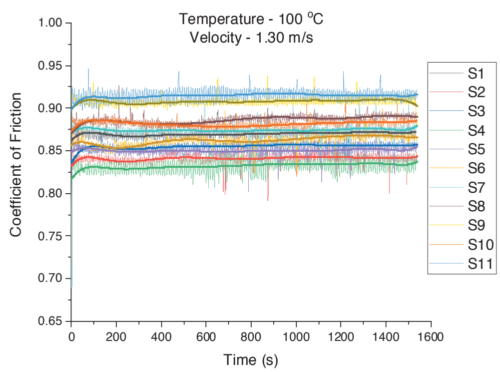

(a)




(b)




(c)




(d)

**Figure 6.** Behavior of Coefficient of Friction with Time at 100°C at sliding speed of (a) 2.09 m/s, (b) 1.83 m/s, (c) 1.57 m/s and 1.30 m/s

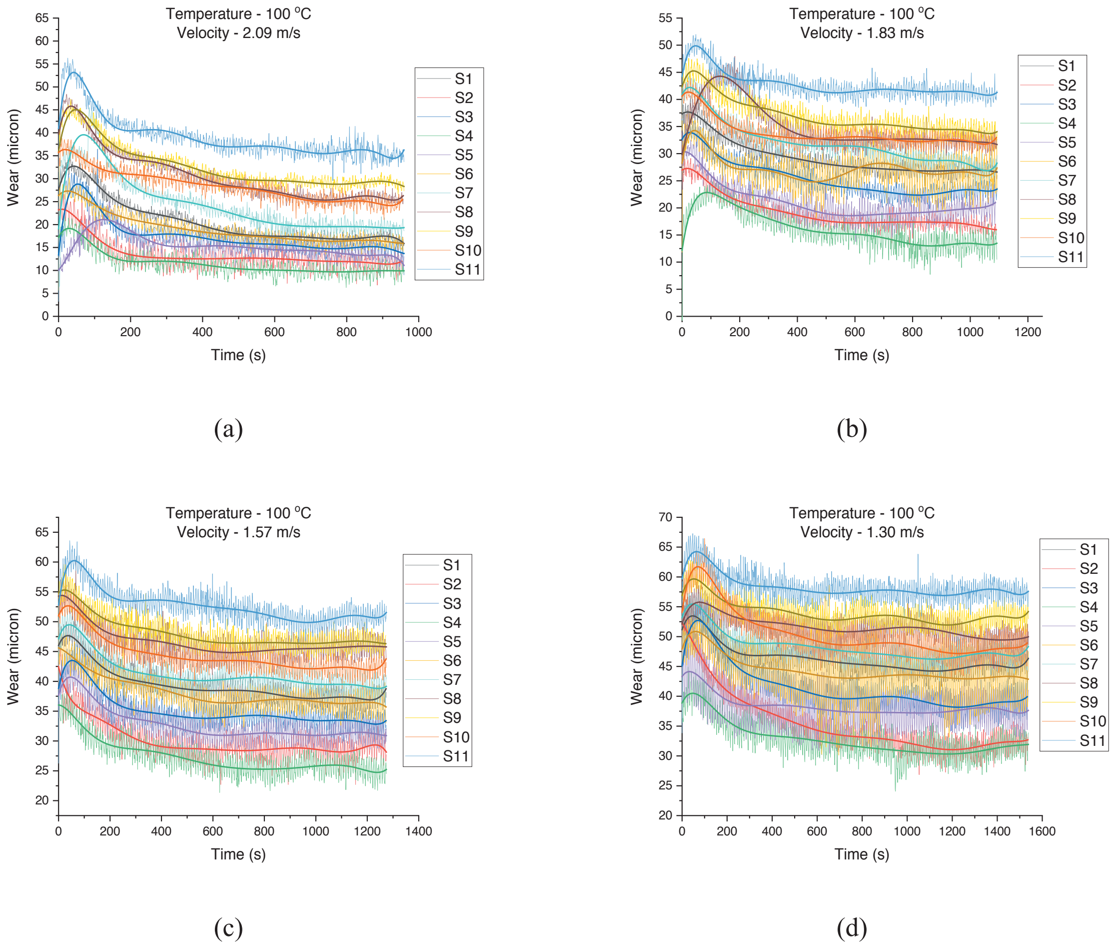



**Figure 7.** Behavior of Wear with Time at 100°C at sliding speed of (a) 2.09 m/s, (b) 1.83 m/s, (c) 1.57 m/s and 1.30 m/s

## CONCLUSION

From the results of experiments, the following observations were concluded:

1. For different blends of 15W40 and Biolubricant, the wear rate was found to be different. At different temperature and velocity conditions, a blend of 70% of 15W40 and 30% of Apricot oil methyl ester (AOME) proved to be the optimum blend having minimum wear whereas pure biolubricant shows highest wear.
2. The reason behind the highest wear for pure vegetable oil based Biolubricant is attributed to the removal of metallic soap film which is continuously formed on chemically reacting with metallic surface (F.P.Bowden et al., 1951).
3. It is also concluded that the coefficient of friction between the tribo-pair of mild steel and cast iron, varies differently for different blends of 15W40 oil and AOME under different temperature and velocity conditions. The S4 blend shows the minimum of value of coefficient of friction at both 40°C and 100°C whereas S11 blend shows maximum coefficient of friction.

On the basis of experimental results of High Temperature Tribometer, it could be recommended that the blend of 70% of 15W40 oil and 30% of Apricot oil based Biolubricant is most favorable sliding machine operations as this blend has shown best wear and friction performance. The usage of S4 blend of commercial oil and vegetable oil based lubricant can reduce the demand of mineral oil based lubricant.

## REFERENCES

**I. N. Dibal & H. Ibrahim, 2018**. Production of Biolubricant From Castor Oil. Society of Petroleum Engineers.

**Y. Singh, A. Sharma, N. Kumar & W. Chen, 2019.** Development of bio-based lubricant from modified desert date oil ( balanites aegyptiaca ) with copper nanoparticles addition and their tribological analysis. Fuel. vol. 259: 116259.

**A. K. Singh, 2011.** Castor oil-based lubricant reduces smoke emission in two-stroke engines. Ind. Crop. Prod., vol. 33: 287–295.

**I. R. Ejilah & A. A. Asere, 2008.** A Comparative Performance and Emission Analysis of Blended Groundnut Oil and Mineral Oil Based Lubricants Using a spark ignition engine. Agricultural engineering International. vol. X: 1–13.

**M. Shahabuddin, H. H. Masjuki, M. A. Kalam, M. M. K. Bhuiya & H. Mehat, 2013.** Comparative tribological investigation of bio-lubricant formulated from a non-edible oil source (Jatropha oil). Ind. Crop. Prod., vol. 47: 323–330.

**B. Kulendran,2010.** Studies on soya bean oil based lubricant for diesel engines. Journal of scientific & Industrial research. Vol. 69: 794-797.

**G.S.Kumar, K. Balamurugan, S. Vinu, M. Radhakrishnan & G. Senthilprabhu, 2012.** Tribological and emission studies on two stroke petrol engine lubricated with sunflower methyl ester. Journal of scientific & Industrial research. Vol. 71: 562–565.

**Manu V. Thottackkad, Rajendrakumar Krishnan Perikinalil & Prabhakaran N. Kumarapillai, 2012.** Experimental evaluation on the tribological properties of coconut oil by the addition of CuO nanoparticles. International Journal of Precision Engineering and Manufacturing. Vol. 13:111-116.

**R. Kreivaitis, J. Padgurskas, M. Gumbytė, V. Makarevičienė & B. Spruogis, 2011.** The Influence Of Oxidation On Tribological Properties Of Rapeseed Oil. Transport. Vol. 26: 121-127.

**J. Salimon, N. Salih & E. Yousif, 2010.** Biolubricants : Raw materials , chemical modifications and environmental benefits. Eur. J. Lipid Sci. Technol. 112: 519–530.

**S. Rani, M. L. Joy & K. P. Nair, 2014.** Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants. Ind. Crop. Prod. Vol. 65: 328–333.

**S. C. Cermak, G. Biresaw, T. A. Isbell, R. L. Evangelista, S. F. Vaughn & R. Murray, 2013.** New crop oils — Properties as potential lubricants. Ind. Crop. Prod. Vol. 44: 232–239.

**S. Soni & M. Agarwal, 2014.** Green Chemistry Letters and Reviews Lubricants from renewable energy sources – a review. Green Chem. Lett. Rev. Vol. 7: 359–382.

**J. P. Pandey & A. Sarkar, 2014.** Traditional and Mechanical method of the oil extraction from wild apricot kernel. Research Journal of Chemical andEnvironmental Sciences. Vol. 2: 54–60.

**F. P. Bowden, D. Tabor & F. Palmer, 1951.** The Friction and Lubrication of Solids. Am. J. Phys. Vol. 19 : 428–429.