Rheological Analysis on Thumba Oil for Sustainable Bio-Lubricant in Electric Vehicle Application

Sagar Galgat, Febin T Biju, YV Surya, Hema Venkat Sai Kumar, Deepraj Limboo, Niranjan Singh, Krishna Chowdary, Ankit Kotia

School of Mechanical Engineering, Lovely Professional University Punjab

Corresponding email: ankitkotia@gmail.com

Abstract. The demand for automotive lubricant increasing and consequences in dumping of lubrication oil leads towards the bio lubricants. The present study analyzes rheological properties of Thumba oil to have sustainable lubricant to electric vehicle. The oil samples are tested in plain and with MWCNT and Cerium oxide (CeO_{2}) nanoparticles. It was observed MWCNT and CeO_{2} made 11% and 9% improvement in viscosity at lower shear rate respectively, however no significant change was observed at higher shear rate. Shear thinning nature of thumba oil biolubricant reduce with the dispersion of nanoparticles and hence contributed in enhancement of lubrication behaviour.

1. Introduction

In this present scenario with the increase in industrialization and modernization has led to a rise in energy consumption alongside the increase in global population together leads towards the biofuel. Excessive use of fossil fuels by the societies over last century, has led to a severe decrease in fuel reserves by this way its found non-renewable energy source is not going to last more than 2 generations, as a result researches and development authorities searching for alternative chemicals and other type of energy sources to decrease the dependency on traditional fossil fuels. Many other types of renewable energy sources like biomass, wind, geothermal or solar energy, hydropower is readily available and proposed as potential energy sources [1-3].

Lubricants are substances which are used to reduce friction which are in mutual contact and to dissipate heat created due to friction. Lubricants are also used to transport foreign particles and transmitting forces. The annual production of lubricants is 30-40 million tones and these are mainly used in industrial applications. Typically, a lubricant consists of a base oil and additives.

Additives are used less than 10% in lubricants to improve viscosity index, more anti-wear and anti-friction characteristics and to resist corrosion and oxidation. Powdered form of dry graphite, PTFE, molybdenum disulfide are used and are termed as Non-liquid lubricants. These lubricants offer lubrication at greater temperature (up to 350 °C) than the liquid and oil based lube are able to operate. Variety of additives are used to improve the characteristics performance of the lubricants. In modern automotives lubricants contain 10 or more additives. Some of the main families of additives are: detergent which prevent deposits formation on surfaces and and ensure cleaning of the the engine components; Corrosion inhibitors are used to absorb acid which corrode the metal parts, these are usually alkali materials and salts; Anti scuffing additives are used at extreme pressure to form protective films on friction parts, mainly sulphur components such as dithiophosphates are used;
Anti-wear additives are used to suppress the wear and tear on metal parts by forming a protective “Tribofilms” films, some examples are phosphates esters and zinc dithiophosphates; Friction modifier are used in boundary lubrication regime where direct contact of surface take place by reducing friction and wear; Anti-foaming agents such as silicon components are mainly used to increase surface tension and to minimize form formation; To maintain viscosity at higher temperatures viscosity index improvers(VIIs) such as poly acrylates and butadiene are used; Antioxidants are used to reduce and lower the rate of oxidation of hydrocarbon molecules, their additives are also called in metal deactivators.

The lubricants obtained from bio-based sources are termed as bio-lubricants. These lubricants show excellent characteristics and properties required for a perfect lubricant. These are considered to be renewable sources and readily biodegradable which makes them perfectly applicable in industrial applications such as paints, plastics, solvents, emulsifiers, lubricants, resins, etc. Selecting the starting oil to synthesize bio-lubricant is important and should be carefully done because vegetable oils are mostly used in the food chain. Use of such oils in industrial application can increase in speculations, which eventually increase price and cause social imbalance. After considering and using these data a more sustainable alternative oil should be made in use which will not interfere with food chain [4].

Bio-lubricants are organic compounds and are renewable sources which are obtained from the vegetable oils, animal fats, plants and other renewable resources. They are triglycerides esters(fats obtained from the animal and plants). Common lubricant base oils are derived from Canola oil, castor oil, palm oil, rapeseed oil and tall oil from tree sources. These vegetable oils are hydrolyzed to yield acids to form synthetic esters. The naturally derived lubricants also include Lanolin which is wool grease which acts as a natural water repellent. Whale oils are also used back ago as friction modifier additives for automotive transmission fluid. Many international companies and organizations are studying characteristics and more improved lubricants from organic matter to reduce the emission and contamination of the environment. The employment of non-edible oil has various advantages over the petrochemical based lubricants. Such as inedible plants can be cultivated in harsh environments and balance the ecological conditions, obtained easily at low price and moreover biodegradable in nature [2]. The past few years environment friendly lubricants are majorly in focus and increasing rapidly. However, these lubricants are poor in oxidation and lesser thermal stability, this is because of the higher degree of unsaturation in fatty acid chain of olefins and the beta-hydrogen of glycerol backbone which are highly susceptible for oxidation. Some chemical methods and modifications for unsaturation can be done such as epoxidation, hydroxylation etc.

The present study is focused mainly on thumba seed oil, it is consumed in only a few tribal areas but has not been fully exploited. The use of minor tree-borne Thumba (citrullus colocynthis L) oil as bio-lubricants preparation and utilization is the main context of the research paper here there are reports on preparation of biodiesel from thumba oil but, there are no relevant studies regarding the use of thumba oil as potential lubricants [5].

The hydrodynamically lubricated sliding contacts have excellent capacity to dampen noise. ICEs are loud and noisy at low speeds and sound from tyres and wind are more at high speeds. Increased traffic condition and noise pollution can damage hearing and cause cardiovascular diseases EV motors are more steadier and less noisy than the IC engines. But, need timely greasing and lubrication of components to reduce such problems especially at higher speeds (20,000 rpm). Moreover, grease allows lubricants to avoid leak and stay within the bearing because of the upper viscosity levels [6]. The lubrication of EV is similar to the corresponding IC engine vehicles driveline. However, in EV lubricants are not used for a single purpose rather there are several functions of lubricants in an EV. Conventional lubricants and synthetic oils cannot be used to lubricate the electric vehicle motors and transmission. Conventional mineral oils may not be able to fit the requirements of electric vehicles. Tribology is a study of the friction, wear and lubrication between contacting surfaces research study the tribological characteristics to improve operation
and exceeding the life cycle of components and machines [7-10].

Electric vehicles need lubricants specially designed for them to meet specific requirements in drivetrain. Studies are held to synthesize the best possible lubricants for greater efficiency and biodegradable in nature to protect the environment. The main aim to create lubricant from bio-renewable sources is to lower the degradation of the environment and be more efficient and durable in use. Lubricants used in lubricating IC engines are different from the same job for an EV motor. The former oils need to be examined to minimize engine friction and transmission fluid engine oils need to be replaced timely because of degradation due to combustion gases contaminating them. There is a significant fluctuation in power flows and high motor speed of 15000 revolutions per minute [11]. In electric vehicles several fluids are required: oils for gear reducer, oil specifically for electric motors for cooling purposes, thermal management fluids for battery stability and power electronics for fast charging and strong acceleration. All these fluids are under high voltages and have very specific properties also they are subjected to high temperature and they must be ensured to protect key components such as coils, circuits and prevent system damage. The vehicles lifespan will also be affected on the basis of lubricants used and more over safety concerns are more important when it comes to use lubricants for EV [12-14]. The chief objective of this recent study is to provide a summary on problems related to lubricants and methods and processes involved to synthesize plant-based oil from Citrullus Colocynthis L. And also various other parameters and modifications in the Thumba oil to make it affordable and usable. This study involves literature review on application and analysis of Thumba oil as potential bio-lubricant.

2. BIO LUBRICATION OIL AND ITS PREPARATION

The main aim of lubricants is to reduce the friction between the moving parts and to decrease wear and tear. The other main purpose to be most efficient lubricant and long-lasting than commercial or mineral lubricants. The last but not least it should be economical and initial investment for production also cost effective.

2.1. Classification

Lubricants used for automotive are categorized depending upon ASTM standards. The ASTM standards are mainly depend on the region and their climatic conditions. For example, in cold region 10 w 40 in this 10 indicates cold temperature and 40 indicates hot temperature. It also depends on the engine capacity. Different type of tests can be performed for preparation of bio lubrication oil they are

1. Gas Chromatographic analysis.
2. Spectral analysis.
3. Thermogravimetric analysis (TGA).
4. Physico-chemical analyse.

2.2. Thumba oil preparation

Epoxidation done for thumba seed oil, it is typical process for the preparation of 2-ethylhexyl esters of thumba fatty acids, NPG ester, and Hydrogen peroxide (H₂O₂).

2.3. Applications of bio-lubricants

It Includes:-

- Two stroke engines,
- Chainsaw bars,cables
- Marine lubricants.
2.4 Advantages
Price is twice as high as conventional petroleum based lubricant. Non availability of low-cost vegetable oil feedstock. Advance research and development should be invented. Adoption of microwave-assisted synthesis rather than conventional method. Mass plantation of Thumba plants is to be encouraged. Legislation to make change in the conventional production of methodology.

3. Results and discussion
Viscosity of thumba oil measured at shear rate to observed its lubrication behaviour. Figure 1 shows the viscosity of thumba oil (plain) reduces with increasing shear rate. This behaviour indicates shear thinning behaviour. It can also observed that viscosity gradually reduce at higher shear rate, which reflects need to incorporate nanoparticle additives.

![Fig 1. Viscosity vs shear rate for plain thumba oil](image)

The rheological properties modified with the dispersion of MWCNT and CeO2 nanoparticles. Figure 2 shows variation on viscosity vs shear rate for MWCNT/thumba oil biolubricant. Sample was prepared by 30 minutes intensive ultrasonication. The viscosity test was performed with the help of LMDV 200 viscometer. Lubrication oil sample was placed under the viscometer and speed set to 1 RPM at room temperature due to high viscous its unable to calculate. So reading was considered from 5 RPM and the rest of result are conducted with equal interval of time and constant temperature. The test was performed up to 200 RPM to know the efficiency of lubrication oil. The presence of MWCNT improve the challenge of shear thinning of plain thumba oil.
Further, to test the improvement with cerium (CeO$_2$ (IV)) nanoparticle, the viscosity is measured at 0-200 s$^{-1}$ shear rate. It can be observed from Figure 3, that there is mild variation of viscosity with shear rate. This indicates improvement over the shear thinning behaviour.

4. Conclusion

Worldwide the lubricant market shows increased demand for products from renewable sources which has higher qualities and is environmentally friendly. There is great demand for lubricants in the coming scenario and thus to meet the desired requirements and properties there is need of developing flexible biolubricants from plants such as Thumba oil, rape seed and palm oil, etc so that
speculation can be avoided and there is an ecological balance. Biolubricants have superior quality and a long lifespan than the minerals. There was 11% and 9% improvement in viscosity at lower shear rate was observed with MWCNT and Cerium oxide (CeO$_2$) nanoparticles respectively. Biolubricant provides a potential ecofriendly substitution of mineral oil based lubricant. Production of such non-edible plants and other renewable sources for the production of the biolubricants to replace the petroleum based products. Biolubricants rheological analysis and other parameters should be checked and evaluated by making use of modern equipments, methods and technology.

REFERENCES

1. K. Kamalakar, G.N.V.T.SaiManoj, R.B.N. Prasad, M.S.L. Karuna, 2015, Thumba (Citrullus colocynthis L.) seed oil: A potential bio-lubricant base-stock, grasasaceites, vol. 66(1), pp.
2. H.M.Mobarak, E.Niza Mohamad, H.H.Masjuki, M.A.Kalam, K.A.H.Al Mahmud, M.Habibullah, A.M.Ashraful, 2014, The prospects of bio lubricants as alternatives in automotive applications, Renewable and Sustainable Energy Reviews, vol.33, pp. 34-43
3. http://elettrotechshop.it/ahoa/examples-of-lubricants.html
4. A.Campanella, M.A. Baltanás, M.C.Capel-Sánchez, J.M.Campos-Martín, J.L.G.Fierro, 2004, Soybean oil epoxidation with hydrogen peroxide using an amorphous TiSiO2 catalyst, Green Chemistry, vol.6, pp. 330-334
5. R.Shah, M.Woydt, N.Aragon, I.Kim, 2020, Tailoring Lubes for Electric Mobility, Lubes and Greases.
6. R.M.Gresham, 2006, HANDBOOK of LUBRICATION and TRIBOLOGY V O LU ME I: Application and Maintenance S E C O N D
7. F.Bottiglione, S.De Pinto, G.Mantriota, A.Sorniotti, 2014, Energy Consumption of a Battery Electric Vehicle with Infinitely Variable Transmission, Energies, vol. 7(12), pp.8317-8337
8. C.H.Chang, S.W.Tang, N.K.Mohd, W.H.Lim, S.K.Yeong, Z.Idris, 2018, Tribological behavior of bio lubricant base stocks and additives, Renew. Sustain. Energy Rev. 93, 145–157.
9. T.A.Mcekon, B.K.Sharma, J.T.Lin, S.Z.Erhan, 2007, Non food uses of oils and fats.
10. J.McNutt, Q.S.He, 2016, Development of bio lubricants from vegetable oils via chemical modification, J. Ind. Eng. Chem, vol. 36, pp. 1–12.
11. R.K.Hewstone, 1994, Environmental health aspects of lubricant additives, Sci. Total Environ, vol. 156, pp. 243–254.
12. A. Willing, 2001, Lubricants based on renewable resources-an environmentally compatible alternative to mineral oil products, Chemosphere, vol. 43, pp. 89–98.
13. Y.Singh, A.Sharma, A.Singla, 2019, Non-edible vegetable oil–based feedstocks capable of bio-lubricant production for automotive sector application- A review, Environmental Science and Pollution Journal, vol. 26, pp. 14867–14882.
14. Lubes'n'Greases Exclusive by Raj Shah, Mathias Woydt, Nathan Aragon and Issac Kim © LNG Main Copyright