Exploring The Efficacy And Potential Of Blended Vegetable Oil Lubricants In Automotive Applications: A Comprehensive Review

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Abstract: This review article aims to provide an overview of the use of blended vegetable oil lubricants in automobiles, focusing on their performance in terms of friction variations, wear scardiameter, and viscosity properties. The author discusses various aspects, including blending techniques and methods, environmental benefits, performance characteristics, challenges, limitations, and prospects. The discussions are based on previous studies and results in blended vegetable oil lubricants.
Furthermore, the author desires to conduct analytical research on this topic, mainlyif there is reasonable funding assistance from the government. The author believes that such research would benefit the nation's ecosystem, economy, agriculture, and automobile industry, potentially impacting employment opportunities. This article also highlights the importance and relevance of research in blended vegetable oil lubricants for automobiles, particularly for aspiring research scholars.

Keywords: Lubricants, Automobiles, Friction, Wear Scar Diameter, Viscosity, and Flash and Fire Point

1. Introduction

Blended vegetable oil lubricants for automobiles have gained popularity recently as a more environmentally friendly and sustainable alternative to traditional petroleum-based lubricants. These lubricants are typically a mixture of vegetable oils, such as soybean or canola oil, and additives to improve their performance characteristics. This review will explore the critical aspectsof blended vegetable oil lubricants, their advantages, disadvantages, and potential impact on the automotive industry. Blended vegetable oil lubricants have few advantages in sustainability, biodegradability, low toxicity, high lubricity, and reduced emissions.

Vegetable oils are renewable resources, and their production typically has a lower environmental impact than petroleum-based oils. Using vegetable oil-based lubricants can help reduce greenhouse gas emissions and reliance on finite fossil fuels. Vegetable oil lubricants are biodegradable, which means they break down more quickly in the environment than synthetic lubricants. This can reduce the environmental impact in case of spills or leaks. Vegetable oil lubricants are generally non-toxic, making them safer for the environment and human health. Vegetable oils have inherent lubricating properties, which can help reduce friction and wear in automobile engines. Blended vegetable oil lubricants can maintain good lubricity while providingthe necessary protection for engine components. Using vegetable oil-based lubricants can reduce harmful emissions, as they burn cleaner than petroleum-based oils. This can contribute to improvedair quality and reduced environmental pollution.

The challenges and disadvantages of blended vegetable oil lubricants are viscosity, oxidation and stability, cost, and compatibility. Vegetable oil lubricants can have higher viscositiescompared to traditional fats. This can affect their performance in extreme temperatures, potentiallyleading to issues in cold starts or high-temperature applications. Vegetable oils are prone to oxidation, leading to varnish and sludge formation. Manufacturers need to incorporate additives to enhance the stability and longevity of blended vegetable oil lubricants. Blended vegetable oil lubricants can be more expensive than conventional petroleum-based lubricants due to the cost ofproducing and refining vegetable oils. These lubricants may not be compatible with all engine types, and some modifications to engines or gaskets may be necessary to use them effectively.

Therefore, researchers and manufacturers are continually working on improving the performance of blended vegetable oil lubricants. This involves developing new additives to enhance stability, addressing issues related to high viscosity, and ensuring compatibility with a wide range of engines. Thus, blended vegetable oil lubricants for automobiles offer a promising and eco-friendlyalternative to traditional petroleum-based fats. They have clear environmental benefits, such as sustainability, biodegradability, and reduced emissions. However, viscosity, stability, and cost challenges need to be addressed to make them a more widespread choice in the automotive industry. As technology and research in this field advance, blended vegetable oil lubricants have the potential to play a significant role in reducing the automotive industry's environmental impact.

2. Review Of Literature

Research and development in the field of Blended Vegetable Oil Lubricants (BVOL) continue to evolve. Scientists are working on improving these lubricants' oxidation stability and low-temperature performance. Additionally, efforts are being made to develop more sustainable and efficient processes for producing vegetable oil-based lubricants. Hence, the author hasrevealed many studies to find the facts that persist in the field of BVOL. Firstly, blending techniques and methods for blending vegetable oils with other lubricants, the role of additives in improving performance, and its considerations for formulation and compatibility. Secondly, the environmental benefits of BVOL are from reduced carbon footprint and greenhouse gas emissions, biodegradability and environmental impact, and the utilization of renewable resources.

Thirdly, the performance characteristics of BVOL are identified as viscosity andlubrication properties, thermal stability and oxidation resistance, and wear protection and engine durability. Fourthly, the challenges and limitations from the higher viscosities compared to traditional lubricants, oxidation and failure of stability and longevity, more expensive thanconventional petroleum-based lubricants and these lubricants may not be compatible with all engine types, and some modifications to engines or gaskets may be necessary to use them effectively. Finally, future prospects of conducting research on improving the performance of blended vegetable oil lubricants. This involves developing new additives to enhance stability, addressing issues related to high viscosity, and ensuring compatibility with a wide range of Engines. Therefore, blended vegetable oil lubricants for automobiles offer a promising and eco-friendly alternative to traditional petroleum-based fats. They have clear environmental benefits, such as sustainability, biodegradability, and reduced emissions. However, viscosity, stability, andcost challenges need to be addressed to make them a more widespread choice in the automotive industry. As technology and research in this field advance, blended vegetable oil lubricants have the potential to play a significant role in reducing the automotive industry's environmental impact.

The author has reviewed a few pieces of literature to understand the performance of blended vegetableoil lubricants in various aspects related to friction variations, wear scar diameter, and viscosity properties. Ebtisam K et al. (2017) have studied "Manufacturing of environment-friendly bio-lubricants from vegetable oils" and stated that "the T.M.P. esters synthesized from methyl esters based on palm oil and Jatropha oil showed good potential as a base stock in biodegradable lubricantformulation. Despite their high pour point, other lubrication properties such as viscosity, ViscosityIndex, and flash point are comparable to commercial industrial oil ISO VG46. Bio lubricants from natural oils, especially non-edible oils, are promising for special and environmentally sensitive applications.

The FTIR spectrum of palm and Jatropha oil-based T.M.P. esters indicates that the lubricant esterification reaction was close to completion. TGA for Palm Oil T.M.Pesters, in the presence of nitrogen uni stage weight loss ended at 461°C, and tristage weight lossended at 512°C under air. D.S.C. for the palm oil T.M.P. esters indicates one endothermic peakat approximately 420°C (in nitrogen), while in the presence of air, it shows two exothermic peaks, one at 360°C and another at 502°C. TGA analysis of jatropha oil T.M.P. esters obtained in the presence of nitrogen is bi-stage weight loss ended at 463°C, and Tetra stage weight loss ended at 512°C under air. D.S.C. thermogram for jatropha oil T.M.P. esters indicates one endothermic peak at459°C in the presence of nitrogen and two exothermic peaks, one at 389°C and another at 514°C inthe presence of air."[1]

Owuna F.J. (2020) has written a review article on "Stability of vegetable-based oils used in the formulation of eco-friendly lubricants" and expressed that the lubricants are composed of 70–100% base oil and 1–30% additives and surfactants incorporated to enhance their performances.

Moreover, it provides dispersion stability to the lube oil. The base oil could be mineral base oil, synthetic base oils, re-refined based oils, biomass/vegetable base oils, or a blend of them. Vegetable base oils contain natural anti-ageing agents, making them stable to oxidant and extreme temperature conditions. They are also renewable, biodegradable, and eco-friendly sources of energy. Therefore, they have the potential to be used for the formulation of lubricants where mineral or hydrocarbon base oils are applicable and can reduce over-dependence on the consumption of fossilenergy sources."[2]

Zulkifli N.W.M. et al. (2013) have conducted research on "Experimental analysis of tribological properties of bio lubricant with nanoparticle additive" and probed that "the sudden abrupt C.O.F. changed from 80kg to 160 kg is because of the fluid film was not developed there. Therefore, at 160kg, there were sudden changes in C.O.F. at the beginning of the test because of therunning period. During this running period, the high contact pressure between two surfaces caused wear and the plastic deformations of the peaks and surfaces; the profile contact of the surface is gradually improved, and the surface pressure and C.O.F. decrease, so it enters a stable wear stage. At the same time, the adhesive wear started to take place at a load of more than 80kg. The adhesive wear occurred in the middle of the ball. Therefore, boundary lubrication occurred. The two surfaces were contacted because of the high-pressure load, which caused the plasticdeformation of the surfaces. Severe wear occurred at high load. The nanoparticle may be molten and welded on the shearing surface to protect the ball at high loads. Hence, T.M.P. esteradded with nanoparticle reduced C.O.F. up to 15% at high load for all loads. Nanoparticle also improved W.S.D. of the T.M.P. esters, especially at low load (40kg) by creating an additional protective layer."[3]

Imran et al. (2013) studied "Friction and Wear Characteristic of Jatropha Oil BlendedLube Oil" and said that "the rate of wear for various percentages of Jatropha oil-based bio-lubricantwas different. However, the rate of wear for 10% and 20% of Jatropha oil-based bio-lubricants arenear to the pure lubricant S.A.E. 40. In their experiment, the temperature of lubricating oil increases with sliding increasing time for each percentage of Jatropha oil-based bio-lubricant. However, JBL10 showed significant performance as it generates less heat than the other samples. It has beenfound that bio-lubricants have lower wear resistance and a higher coefficient of friction. Since jatropha oil-based bio-lubricants have a higher coefficient of friction compared to pure

Lubricant S.A.E. 40: It can be assumed that the fatty acid molecules available in Jatropha oil do not build a soap film on a surface test. Iron, aluminium, and chromium contentincreased for each experiment because of wear in the pin and disc. In term of viscosity, except JBL40 and JBL50, allbio-lubricants meet the ISO VG100 requirements."[4]

Samuel Gemsprim et al. (2021) conducted an experimental analysis of sliding wear testing on tribological evaluation of vegetable oil-based lubricant blends. They have stated that "the wear rate and coefficient of friction values obtained by the pin on disc wear tester show someimportant keynotes from this investigation. The Mahua - sunflower oil combination performs better than the castor – sunflower oil combination. This may be because of the higherviscosity index property of the former than the latter, which is highly desirable as a lubricant. Moreover, the frictional coefficient and thermal stability of the Mahua oil-based lubricant arebetter than those of the castor-based lubricant. The presence of free fatty acids is responsible for such behaviour. So, this experimental investigation reveals that vegetable oils can be used as potential bio-lubricants as an alternative to conventional industrial lubricants."[5]

Kreivaitis R. and M. Gumbytė (2018) have investigated the mixture of vegetable oil and synthetic esters as environmentally friendly base stock for low-temperature lubrication applications. They have stated that the friction process is smoother than synthetic oils and has three main steps. Initially, while the adsorbed layer separates the surfaces, there is a low and stable friction region. When the contact temperature reaches adsorption activation energy, the layer disappears or weakens, leading to friction rise. The further decrease in friction is due to a wear-induced decrease in contact pressure. The abrasion dominates the wear mechanism in all cases without A.W. (AntiwearAntiwear) additives. Many small grovesare formed on the wear scars lubricated with pure synthetic oils and their mixtures with VO(Vanadium (II) oxide). It is evidence of poor lubrication ability in boundary lubrication conditions.In contrast, the wear scar formed during the test lubricated with pure V.O. is very smooth. The wearscars formed in the case of lubrication with pure P.A.O. (Polyalphaolefin Oils) have less abrasion than that observed in the case of both mixtures. In the case of A.W. additive-loaded samples, wear scars are smothered and have some chemisorbed layer left on the surface. They have concluded that blending rapeseed oil with poly alpha olefins improves its low-temperature properties. More

Then, 30 % improved low-temperature fluidity can be reached using 30 % of P.A.O. 4. Meanwhile, pure point temperature is reduced from -22 ˚C to -31 ˚C for pure rapeseed oil and its blend. Blending is also effective in low-temperature long-term storage. 10 % of P.A.O. 4 increased rapeseed oil's fluidity by 43 % after six hours of storage. To reach similar results, 30 % of P.A.O6 must be used. Rapeseed oil in the mixture with synthetic oils reduces their corrosiveness. Both synthetic oils diminish rapeseed oil's lubricity. However, their blends are compatible with an antiwear additive, which improves lubricity. The investigated blends can be used as base stocks to produce environmentally friendly lubricants for instants hydraulic or total loss.Choosing a particular application, all the other properties must also be improved."[6]

Timothy Yakubu Woma et al. (2019) wrote a review article on "Vegetable Oil Based Lubricants: Challenges and Prospects" and revealed that "in comparisons with mineral oils, the vegetable oils have good prospects as lubricants because vegetable oil in general possesses high flash point, high viscosity index, high lubricity and low evaporative loss. Vegetable oils are a renewable resource that is less dangerous to the soil, water, flora, and fauna during disposalor accidental spillage than mineral oil. The challenges of vegetable oil as lubricant base oil include high cost, competition between food and lubricant industries for vegetable oil, poor oxidative and hydrolytic stability, high-temperature sensitivity of tribological behaviour and poorcold flow properties. The current efforts to overcome these challenges include usingadditives,chemical modifications, thermal modifications, non-edible vegetable oils, and government commitment through legislation to encourage the use of vegetable base oil lubricants."[7]

Vrabie V et al. (2016) have written a review article on "Vegetable oils as an alternative fuel for a new generation of Diesel engines". They have revealed that "the vegetable oils are feasible substitutes for diesel fuel. The usage of vegetable oils as diesel fuel depends on world market prices for mineral products and is therefore of special interest only for countries with a large excess of vegetable oil production. Vegetable oils are available everywhere in the world andare renewable, as the seeds of the vegetables that produce oil can be planted year after year. Also, theyare "greener" to the environment, as they seldom contain sulphur elements. The main problem of using vegetable oils in diesel engines is the high viscosity of such fuels. Due to the need to adapt the combustion time, using vegetable oils in diesel engines generally leads to higher C.O., H.C. and PM. In contrast, vegetable oils reduce NOx emissions due to their slower combustion and lower temperatures in the combustion chamber. While vegetable oils represent an alternative fuel, they will continue to present risks related to their intrinsic characteristics, which neither car nor agricultural tractor and machinery manufacturers are willing to assume. The resultsfrom some experiments prove that vegetable oil and its blends are potentially good substitute fuelsfor diesel engines shortly when petroleum deposits become scarcer."[8]

Muthurathinam and Perumal (2022) have conducted experimental research entitled "Experimental study on the effect of nano Al2O3 in physiochemical and tribological properties of vegetable oil sourced bio lubricant blends" and expressed that "the different oil blends based on vegetable oil methyl esters with 1% and 2% Al2O3 nanoparticles were studied based on its physiochemical properties and tribological properties. They have observed that the addition of nano Al2O3 particles has showcased beneficial effects in physiochemical properties viz. density, viscosity and viscosity index in NOME and POME-based oil blends, which strongly recommends the use of appropriate quantity nano Al2O3 with these blends since the values are superior to the commercial lubricant SAE20W40. In the flash point, the addition of nano Al2O3 has positively changed the property, which is highly appreciable.

The T302 (1% less) showcased almost on-par value with SAE20W40. In frictioncharacteristics, the blends N102 (13.3% lesser friction) and P202 (12.8% lesser friction), which have the highest percentage of nano Al2O3 (2% wt.), have outperformed all the other blends by a fair margin. In addition, the other blends maintained better frictional resistance (about 3.1 to 13.3 per cent), demonstrating that bio-nano additions may be employed in high-friction applications.Similar behavior was also observed in wear scar analysis. As the percentage of nano Al2O3 increases, the wear scar diameter reduces correspondingly. Specifically, N102 and P202 showcased the smallest wear scar diameters at 374.5 (55.1% smaller) and 412.9 (50.5% smaller) compared to SAE20W40 oil. Other blends also reduced the W.S.D. by about 15 - 50%, which showsthat an optimum bio-nano additive combo with commercial lubricant will help reduce wear oncontacting surfaces. Throughout their study, the behavior of Tamanu oil Methyl ester-based blendshas adverse effects (except density and flash point) with the nanoparticle addition due to the non-compatible properties, which suggests avoiding the combination in any of the antiwear and antifriction applications. Overall, the results show that the friction and wear characteristics ofthe four-ball wear test strongly depend on the concentration of nano Al2O3 particles."[9]

Tarun (2020) has written an analytical article on "vegetable oils and synthetic oil blend with additives" and expressed that "the blends of Synthetic oil and Jatropha S30J70 (flash point 230ºCand fire point 240ºC) and S80N20 (flash point 235ºC and fire point 240ºC) shows excellent lubricating properties. This is because both these blends show a minimum wear rate close to S.A.E. 20W50 (flash point 225ºC and fire point 230ºC), and also, the absorption bands of these blends obtained in FTIR Spectroscopy match with the standard S.A.E. 20W50. These blends also show good kinematic viscosity values closer to the synthetic oil."[10]

3. Discussion

In exploring the fascinating realm of vegetable oil, the author of this literature has gained profound insights into its blending process and the remarkable properties it exhibits during tests for friction, W.S.D. (wear scar diameter), and viscosity. These revelatory findings present vegetableoils as promising contenders for the title of bio-lubricants, offering an alternative to conventional industrial lubricants as espoused by Samuel Gems Prim et al. in 2021.

However, the potential of vegetable oil and its blends extends even further! As the world faces the inevitable scarcity of petroleum deposits, these oils emerge as potential substitutes for diesel engines, as highlighted by Vrabie V et al. (2016). This hints at a greener future and emphasizes the profound impact of vegetable oils in mitigating our dependence on fossil energy sources.

Furthermore, the formulation of lubricants can benefit significantly from these investigatedblends. Reducing overreliance on mineral or hydrocarbon-based oils can significantlylessen our ecological footprint and embrace a more sustainable path. Such a groundbreaking notionis beautifully articulated by Owuna F.J. in 2020, stressing the importance of reducing ourconsumption of fossil energy sources by introducing vegetable oil-based lubricants. Ultimately, the examined blends of vegetable oils possess the potential to serve as exceptional basestocks to produce environmentally friendly lubricants. Whether employed in hydraulic

Systems or total loss lubrication scenarios, these innovative blends can lend their eco-friendly qualities to the manufacturing of lubricants, thereby contributing to a greener and more sustainablefuture.

When choosing a particular application, all the other properties must be improved (Kreivaitiset al., 2018). The Iron, Aluminum and Chromium content in each experiment increased because of wear occurring in the pin and disc. In terms of viscosity, except for JBL40 and JBL50, allbio-lubricants meet the ISO VG100 requirements (Imran et al., 2013). D.S.C. thermogram for jatropha oil T.M.P. esters indicate one endothermic peak at 459ºC in the presence of nitrogen and two exothermic peaks, one at 389ºC and another at 514ºC in the presence of air (Ebtisam K et al., 2017). Testing all loads, T.M.P. ester added with nanoparticle reduced C.O.F. up to 15% at high load.Nanoparticles also improved the W.S.D. of the T.M.P. esters, especially at low load (40kg), by creatingan additional protective layer (Zulkifli N.W.M. et al., 2013). The friction and wear characteristics strongly depend on the concentration of nano Al2O3 particles (Muthurathinam & Perumal,2022). The blends of Synthetic oil and Jatropha with flash points between 230ºC and fire point 240ºC, and flash point 235ºC and fire point 240ºC showed excellent lubricating properties (Tarun, 2020). The current efforts to overcome the challenges of lubricants include using additives, chemical modifications, thermal modifications, non-edible vegetable oils, and government commitment through legislation to encourage vegetable-based oil lubricants(Timothy et al., 2019).

Julia Carrell (2018) pointed out that "automotive lubricant standards, such asGF-6, are a vital set of guidelines to consider in developing a bio-lubricant for the automotive sector. The performance parameters, such as viscosity, durability and wear protection requirement,act as a helpful guide for developing a set of experiments for testing the suitability of a bio-lubricantfor this market. Additionally, due to variations in engine designs and materials, it is crucialto consider internal standards set by individual automotive manufacturers. Market research predicts that the bio-lubricants market will grow by 6.9% by 2024. The European and U.S.A. marketsare currently the largest, but emerging markets, such as India, Brazil and China, are predicted to grow faster due to the increase in passenger car use and the availability of crops to produce bio-lubricants.

There is an opportunity to take advantage of the legislative restrictions being imposed on biofuels and switch some biofuel production to bio-lubricant production to avoid some of the issues with using land that could produce food to produce non-food products. Before this can be done, an improvement in the tribological understanding of bio-lubricants is required and, thereforeacts as a bio-lubricant development driver. Therefore, A reasonable amount of research has been conducted investigating bio-lubricants ability to reduce wear and friction. The most researched bio-lubricants appear to be rapeseed, palm, soybean, castor, and sunflower oil, although many other sources of bio-lubricants, such as avocado,peanut, and olive oil, are under investigation. Materials most tested with bio-lubricants are various steel grades and finishes, some aluminum alloys and other metals such as copper. Some full-scale engine tests have been performed to assess the ability of bio-lubricants, such as jojoba and palm oil, to reduce wear and friction, and consequently performance and emissions, but research at this experimental level is limited."[11]

4. Conclusion

Blending ratios for vegetable oil lubricants depend on specific application requirements and the desired balance of properties. Determining the optimal blending ratios involves considering the characteristics of individual vegetable oils, their compatibility with other base oilsor additives, and the targeted performance goals. It is important to note that there is no universal approach to blending ratios, as the ideal formulation varies depending on the intended use of the lubricant. Ongoing research and development in bio-based lubricants continue to provide new insights and improved formulations.

Various types of vegetable oils, including soybean, canola, sunflower, olive, palm, coconut, corn, peanut, flaxseed, sesame, cottonseed, and grapeseed oils, offer diverse compositions, properties, and applications. These oils differ in their fatty acid composition, nutritional content, flavor profiles, and suitability for specific cooking or industrialpurposes. The choice of vegetable oil depends on factors such as taste preferences, cooking methods, and desired nutritional characteristics of the product. Base oils are fundamental in lubricant formulations as they provide essential lubricating properties.The characteristics of base oils significantly impact lubricant performance, including viscosity, viscosity index, pour point, flash point, oxidation stability, hydrolytic stability, additive solubility,film strength, de-emulsification, compatibility, biodegradability, and base oil type. Selecting a suitablebase oil depends on the intended application, operating conditions, and performance requirements. Lubricant formulations often involve combinations of base oils and additives to achieve the desiredbalance of properties.

If the government provides reasonable funding assistance for analytical research on"blended vegetable oil lubricants for automobiles," the author intends to direct the research. This research would contribute to the nation's ecosystem, economy, agriculture, and automobile industry, potentially leading to employment development.

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