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Suitability of Alternative Lubricants for Automotive Gear Applications

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ABSTRACT
Rising environmental concerns due to the problems associated with conventional mineral lubricants has renewed interest in usage of alternative resources. Various attempts have been made to explore the possibilities of utilizing vegetable oils for range of applications. Properties like excellent viscosity features, higher biodegradability, lower toxicity, better renewability & natural lubricity etc shows its potential as lubricants inspite of certain technical problems. Critical issues like lower oxidation stability , poor cold temperature properties affects the performance of vegetable oils and restricts its application to limited range . Gear oils are the hidden workhorses of automotive applications. This article highlights the suitability of various vegetable oils for lubricant formulation as an alternative in automotive gearing applications.
Key words: Lubricant, Mineral Oils, Alternative Resource, Vegetable Oils, Automotive Gear

I. INTRODUCTION

Lubrication is the phenomena of imparting a safe layer of fluid between the interactive relatively moving surfaces. The basic functions of a lubricant are friction and wear reduction, heat removal and contaminant suspension. Development of lubricants has become an integral part of the development of machinery and its corresponding technologies [1]. This in turn has revolutionised the society and its surroundings. World demand of lubricant is on rise and is driven primarily by economic growth which is more for developing nations.

Industrial and automotive lubricant shares significant percentage of lubricant market ie. around 2.4 billion gallons per year. Mostly conventional mineral oil based lubricant contains toxic petroleum stocks and special chemical additives which proves harmful to environment and difficult to dispose after use. This affects the human health and the environment adversely [2-4]. Improper lubricant usage and unsafe disposal practices renders it's significant amount lost to environment which is estimated to 50%. Adverse toxicological effects of conventional mineral oils and lubricants on environment, elevated crude oil cost due to global shortage has renewed interest in usage of alternative resources. Biodegradability has become an important design parameter in lubricant formulation. Literature reports the usage of alternative forms (Vegetable / animal fats) prior to birth of human civilization. Their usage got replaced by petroleum based fluids equipped with premium properties to cater the need of rising population, better machineries and technologies [5-7]. Mineral oils have dominated the market for lubricant formulations since its discovery. Two oil crisis of 1979 and 1983 proved the worth of mineral oil as a limited resource. Undue exploitation of limited crude reserve and rising concerns for environment has forced the mankind to deploy other versions to formulate lubricants. Development and application of environmental friendly lubricants are increasing daily as a result of stringent regulations imposed on mineral oil based formulations. Lubricant formulations on the basis of alternative sources began some two decades ago. Vegetable oils are one of the fewer potential candidates which can be used as substitute to toxic mineral lubricants. They are triglycerides of long chain fatty acids with varying physiochemical structure from monosaturated to polyunsaturated. They are known to outperform conventional grades of oils in terms of better to excellent oiliness, lubricity, viscosity , ignition temperature properties. Higher Comparative Costs and the lower functional properties like poor cold flow character and suppressed oxidation stabilities restrict the circulation of such environment friendly lubricants inspite of the major global concern. This is still in the development phase . Of the innumberable varieties worldwide fewer vegetable oils have been explored for lubricant formulation that too are prominently edible in nature. India being the prime importer of oils for domestic purpose, the usage of edible oils for such purpose shall widen the gap for basic consumption in household purposes [8-10]. Therefore, the only available option is to utilize the non edible vegetable or plant oils. Also there is variation in the availability of plant varieties across the country depending upon the climate and conditions. Hence it is very important to identify the plant species available locally for catering the local market needs for particular range of application after performing series of tribological tests on the new formulations. Indian climate harbors variety of non edible oil varieties althroughout the country. Literature reviews reports that systematic efforts have been made by several researchers worldwide to use vegetable oils of Sunflower, Peanut, Soyabean, Rapeseed, Olive, Cottonseed, Jatropha, Pongamia, Rubber seed, Jojoba etc as an alternate fuel. Fewer work has been reported for lubricant formulations using coconut, palm, canola, castor, olive oils and there lies much more to be explored on this front. **Table.1** shows statistical data about the prominent Indian non edible oil varieties requiring full scale evaluation for lubricant purpose keeping in view the Indian climatic conditions.

Table.1: Statistics of Indian Non Edible Vegetable Oil Varieties

S.No.	Oil Variety	Annual Oil Production(TMT)	Oil Content %
1	Castor	1500	45 – 50
2	Mahua	200	35 – 40
3	Karanja	200	30 - 40
4	Jatropha	75	50 – 60
5	Linseed	600	25 - 35
6	Neem	1000	20 - 30

Castor is one of the prominent nonedible variety in terms of oil / oilseed production and quality of oil content followed by other varieties like mahua, jatropha, karanja, neem etc. These varieties flourishes in Indian environment from arid to tropical conditions requiring varying growing conditions and possess good to better features of natural lubricants . Also they contribute to the rural economy . Presently most of them caters as a raw material for variety of household and industrial applications ranging from medicinal to paints, soaps etc [11-14].

II. EFFECT OF STRUCTURE ON PROPERTIES

Vegetable oil comprises of mostly lipids (98%) which are naturally occurring organic molecules that dissolves in non polar organic solvents. Lipids are found in the form of triglycerides which are glycerol esters of fatty acids. Animal mostly contributes fats which are made of saturated compounds whereas vegetable mainly contributes oils containing certain unsaturated compounds. Fatty acids are primarily long chain unbranched aliphatic acids containing ten or more carbon atoms. The carbon atoms are attached to hydrogen and other groups with carboxylic acid at the terminal end. They are termed saturated for all the bonds in chain are single , unsaturated for one or more bonds and polyunsaturated for six and more bonds in chain. The physiochemical properties and performance for particular vegetable oil depends lot on the degree of linearity and bent profile of fatty acids. Increase in chain length renders fatty acids to become less water soluble and imparts better oily traits. Whereas percentage of linearity in saturated fatty acid chain raises its melting point abruptly so that it is almost solid at room temperature restricting it to be used as lubricant for wide range of operating conditions. Fatty acid composition of vegetable oils also shows variations due to different weather conditions, soil nature and sunlight quality apart from genetic traits within . Viscosity is by far the very basic and most important property of oil for lubrication purpose for specific application. Chemical structure and bond orientations have a profound effect on flow properties. Significant amount of unsaturated compounds like oleic, linoleic, linolenic fatty acids imparts varying amount of lubricity to the base product. Presence of polar groups and esters imparts better anticorrosion features and affinity to adsorb on metallic surfaces maintaining the film .Vegetable oils comprising of saturated fatty acids possess better oxidative stability to other unsaturated ones. Vegetable oil based lubricants cannot be used in every applications on account of insufficient amount of production and that too whole is not diverted for such applications. Therefore, they should be used at places where the properties and performances are best matched [15-18].

III. AUTOMOTIVE APPLICATION

Automotive applications for lubricants can be engine oils and gear oils .Engine oils run through the internal parts of the engine generating energy. Gear oils are the unseen workhorses of the automotive lubricants and commands the lubrication of automotive power trains. The power trains transfer the power from engine to the drive wheels. This equipment consists of one or more gear box assemblies that allows a smooth transfer of rotational energy through various speeds and torque ranges. In automotive vehicles these gearboxes consists of transmission and differential. An automotive lubricant provides protection to various moving parts like gears, bearings, seals etc. Lubricant in gear box provides two primary benefits, first is to lubricate the teeth and second is to remove heat generated from the gear operation. Selection of appropriate lubricant in a gear system provides for slip free power transmission at higher mechanical efficiency, good reliability, requiring low maintenance and long life. Practically lowest viscous oil should be used to minimize friction and churning losses and then suitable viscosity grade can be used depending upon the operating speed, load and temperature. Gear oils can be used in open or closed gear applications and accordingly the requirement for the same shall vary. A gear box of four stroke two wheeler is a common example of closed gear type application where oil operating temperature falls in the range of 40^{o}c-60^{o}c. Castor oil contains higher percentages of triglycerides of ricinoleic acid (85%) containing double bond and hydroxyl group in its structure imparting polarity. As a result it shows greater affinity to adsorb at metal / interacting surface resulting in reduced friction and wear. Additionally, it also have comparatively higher molecular weights inducing lower volatilities , higher viscosity index and better low temperature performance. This gives castor oil preference over other vegetable oils to be used as a base stock for lubricant formulation. Mahua oil contains higher percentages of saturated fatty acids (stearic and palmatic) showing better antioxidation characteristics and unsaturated types (Oleic) providing better antifriction features. Karanja oil also shows presence of major proportion of oleic and linoleic acids.The viscosity profile for such discussed nonedible oil varieties lies in the range of 13 cst to 260 cst in specific temperature range of 40 ^{o}c and 100 ^{o}c which are competitive to the available commercial oils.

Suitable blending of these oils has immense potential in gear box applications for specific operating range. Researches have shown that oxidation defence mechanism or oxidation stability for oils reduces with increase in operating temperatures. Oxidation stability is a chemical reaction that occurs with a combination of the lubricating oil and oxygen primarily. Oxidation will lead to an increase in the oil's viscosity and deposits of varnish and sludge leading to improper oil film formation between the interacting parts. Generally, oxidation will reduce the service life of a lubricant by half, for every 10^{o}C (18^{o}F) increase in fluid temperature above 60^{o}C (140^{o}F) as per Arrhenius rate rule. Blends of above discussed vegetable oils under the critical temperature range can be effective in reducing the wear and tear [19-22].

IV. ECONOMIC FEASIBILTY

Cost is one of the factors to be considered when selecting lubricants. This stands true while making substitutions as using alternative forms of lubricants, fluids, and greases in place of mineral oils and synthetics. Treated and refined vegetable oils like castor, mahua, karanja etc. available in local market costs around Rs. 60–120per litre. This cost can be further reduced if they are produced in bulk. Mineral based commercial lubricants for automotive gear applications equipped with additives package designed for extreme operating condition on an average costs currently around Rs.240 per litre. Use of vegetable oils in straight and blended forms may have lower overall performance, which can be taken care of by proper and sophisticated treatment applied in the form of costly chemical or thermal modification. In general vegetable oil based lubricants costs around 2-2.5 times more expensive than the mineral oils in terms of performance and compatibility with the components [23]. Vegetable oils are much competitive using full accounting. The full accounting cost consists of capital cost, operating costs and environmental costs. Environmental costs includes disposal, reconditioning, reduction in emission reduction measures, reduction in cost of preventive and health safety measures, risk minimization and lower clean up costs for spillages. The greater lubricity of vegetable oils results in lower friction and wear, thus longer component life. Better adhesion to component causing lesser oil losses. Around 45-55% of oil is exposed to the environment directly, total life cycle costs makes the vegetable oil applications to be strongly economical and feasible [24]. Implementation of compulsive legal policies globally shall help in justifying the economic feasibility of expensive alternatives against the competitive mineral oil and their derivative lubricants.

V. CONLUSIONS

Following conclusions can be drawn from the above :

1. Alternative forms has to be explored at local and global level to cater the increasing demands of lubricants in industry and compliment the depleting mineral oils.
2. Use of nonedible oil varieties for lubricating tasks does not add up to the import bills of country.
3. Vegetable oil based lubricants cannot be used in every applications on account of insufficient amount of production and exploration. Moreover, they should be used at places where the properties and performances are best matched.
4. Chemical structure of oils and fatty acids have profound effect on the physical properties and tribological performances.
5. Prominent Indian nonedible oil varieties like castor, mahua, karanja etc. has immense potential in pure and blended form for lubricating automotive gears due to their good to better physiochemical properties.
6. Mineral based lubricants perform better in terms of overall performance and compatibility with

machinery components on account of strong base stocks and special additive package.

7. Lower overall performance of vegetable oil based lubricants can be increased to competitive levels by application of proper modification technique for desired application.
8. Full accounting costs plays an important role in deciding the feasibility of natural oils for specific applications.
9. Excessive usage of conventional oil grades to cater the ongrowing demands of technology has led to their faster depletion and as result the resource gap has to be filled by appropriate alternative.
10. Extensive exploration of alternatives and promoting their bulk production with implementation of legal policies may determine promising future for them.

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