Vegetable oils as lubricant base oil : A Review

RANI.S, TARUN M S,M.L.JOY , K.PRABHAKARAN NAIR
Department of Mechanical Engineering
National Institute of Technology Calicut, Calicut

***Abstract*— The demand for industrial lubricants is increasing day by day. Due to the industrial revolution most of the Asian countries becomes the manufacturing centers for the world. Lot of used lubricants is thrown to the environment which may damage the environment. In this scenario industry started searching for environmental friendly, renewable and less toxic lubricants . The biolubricant formulation is one of the upcoming research areas in tribology. In this paper the lubricant properties of vegetable oils have been discussed with the available literature.**

***Keywords*— environmental friendly; renewable; Biolubricant formulation**

I. INTRODUCTION

Mineral oil and synthetic oil from petrochemical are mainly used as base oil in present lubricant industry. The petroleum resources are diminishing rapidly and the rate of production from older domestic oil fields and decrease in the rate of finding new reserves are one of the main problems of the 21st century. Petroleum products are poorly degradable [1] and cause severe environmental hazards when released [2] .The spilling of mineral oil causes negative changes in the sand which affects the agricultural growth a lot [3]. On the other hand the demand of lubricants are increasing tremendously which forces the industry to find more effective, biodegradable , less toxic lubricants .

As per global lubrication market survey of 2004, 37.4 million tons of lubricant is consumed per annum. The major application areas of lubricant are automotive application (53%), Industrial application (32%), Process Oils (10%), Marine application (5%) as shown in Fig 1 [4]. KLINE , a Brazilian oil company market survey shows that the highest lubricant demand is in Asia around 42% in 2011 and it may become 48% in 2020 [5]. Developments will be strongest in the developing Asian countries due to the rapid industrialization and increasing rate of usage of automobiles. By considering the extreme demand of lubricants and the environmental hazard due to the usage of mineral oils pushes the industry to find out more variety of biodegradable lubricants. One of the easily available and commercially good biodegradable lubricants is vegetable oils.

The total lubricant consumption in Western Europe was 5,020,000 tons/year in 2002, of which 50000 tons per year were based on vegetable oils. In the US around 8,250,000 tons/year were consumed in 2002 among which 25,000 tons/year were based on vegetables [6].

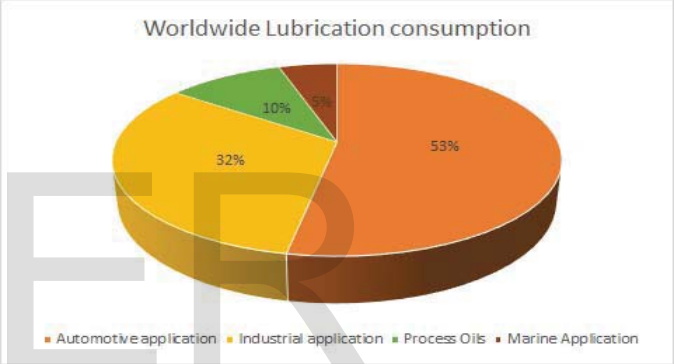

Fig. 1. Worldwide lubrication consumption in 2004 [4]

The renewable and biodegradable vegetable oils have been used various industrial applications like Chain saw bar lubricants [7], engine lubricants [8,9], drilling lubricants [10], metal cutting fluid [11,12], hydraulic fluids [13,14] and Greases [15,16].

The functions of lubricants are to reduce friction and wear, to prevent rust, dirt and oxidation. The lubricants provide reduced friction and wear by creating a protective layer between the mating surfaces. Good lubricants should have desired viscosity, high viscosity Index, high thermal stability, and low pour point, high resistance to oxidation and low coefficient of friction and wear.

Usually the industrial lubricants consist of 80% base oil and the remaining 20% additives. The type and quantity of the additives depend upon the nature of the base oil and the desired properties for each application.

In this paper we are discussing various lubricant properties of vegetable oil like , viscosity , viscosity index, oxidative stability , lubricity , biodegradability, toxicity , friction and wear . The present review was based on the bio lubricant formulation using various vegetable oils.

II. STRUCTURE OF VEGETABLE OILS

Vegetable oils are triglycerides. Three fatty acids are connected to a glycerol molecule as shown in Fig. 2. Fatty acids are normally long unbranched hydrocarbon attached to hydrogen and other groups and the chain terminating with

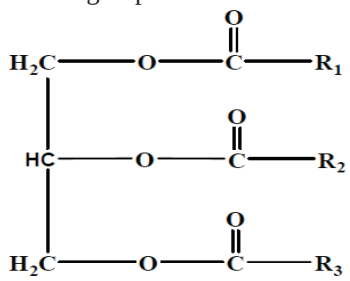

Fig. 2. Structure of Triglycerides (R1, R2 and R3 are the fatty acids)

Carboxylic acid. Fatty acids are even numbered chains with 14 to 22 carbon atoms. If the bond between the carbons is single bond then the fatty acid is saturated fatty acid. If the carbon-carbon double bond is present then it is an unsaturated fatty acid. If only one double bond is present then it is mono unsaturated fatty acids and if more than one double bond is present, it is called poly unsaturated fatty acids. The combinations of these fatty acids in the vegetable oil depend on the type of oil, the climatic conditions and the type of sand [17].

III. THE RHEOLOGICAL AND CHEMICAL PROPERTIES

Viscosity is the resistance to flow and is the most important criteria of the lubricant .The viscosity requirement vary with the application. If the viscosity is more, the frictional loss will be less where as if the viscosity is less, wear will be more .Hence the viscosity should be optimum for all the applications [18]. The viscosity decreases with increase in temperature. The variation of viscosity with temperature is less for vegetable oils. The viscosity index is high for vegetable oils.

The important chemical properties of vegetable oil which controls the lubricant characteristics are acid number, iodine number and saponification number. The acid number is a measure of free fatty acids present in the oil .This can be expressed as the milligram of potassium hydroxide required to neutralise one gram of oil. Iodine number indicates the unsaturation present in the oil. This is the milligram of Iodine absorbed by one gram of sample. Saponification value is the milligram of potassium hydroxide required to saponify one gram of oil.

IV. THERMAL PROPERTIES

The thermal characteristics of vegetable oil are very good compared to mineral oils [19]. The important thermal properties are flash point, fire point and pour point. Flash point is the temperature at which the lubricant gets evaporated and produce flashes with the help of external flame. The fire point is the temperature at which the lubricant gets fired with the help of external flame .This is the safe working temperature of the lubricant. Another important thermal property is pour point. This is the lowest temperature at which the lubricant can flow without crystallisation. This property is important in cold countries and in winter seasons. The saturated fatty acid has high pour point where as the unsaturated fatty acid has less pour point [20].

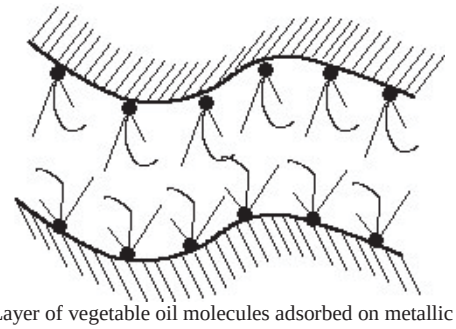

Fig. 3. Layer of vegetable oil molecules adsorbed on metallic surfaces

V. OXIDATIVE STABILITY

The vegetable oils react with oxygen to form undesirable products like aldehydes and ketones which reduces the lubricant properties. The unsaturated fatty acids cause more oxidation than saturated fatty acids. The relative rates of oxidation of oleic acid (one unsaturated carbon bond), linolic acid (two unsaturated carbon bond) and linolenic acids (three unsaturated carbon bond) are 1, 10, and 100, respectively [17].

The less oxidative stability of vegetable oils is due to auto oxidation. This is the generation and propagation of free radicals in the oil. In order to improve the oxidative stability we have to reduce the free radical generation (primary anti-oxidant) and propagation of free radicals (secondary anti-oxidants.). The oxidative stability can be improved by chemical modification like epoxidation, hydrogenation [21, 22] and adding antioxidants [23].

VI. TRIBOLOGICAL PROPERTIES

The lubricity of vegetable oils is very good compared to mineral based oils .This due to the ability of the vegetable oils to adsorbed on the surface and form a layer, with polar head adhering to the surface [24] as shown in fig 3.
Studies show that vegetable oils has excellent friction and wear characteristics [25,26] Goyan et al. evaluated the wear scar and coefficient of friction of rape seed oil , sunflower oil and castor oil and concluded that the chemical structural differences affects the friction and wear [27].

VII. CONCLUSION

The vegetable oils are well suited as industrial lubricant base stocks. The viscosity index and thermal stability of the vegetable oils are very good. The oxidative stability of the vegetable oils is very less. Chemical modification and suitable anti-oxidants are required to improve the oxidative stability. The tribological properties of vegetable oil are always superior to mineral oils at room temperatures. The vegetable oils are

highly biodegradable, less toxic and renewable lubricant base oil which needs to be developed by adding suitable additives.

References

[1] *Biodegradation and Toxicological Evaluation of Lubricant Oils.* **Ivo ShodjiTamada, Paulo Renato Matos Lopes, Renato NallinMontagnolli and Ederio DinoBidoia.** Brasil : Brazilian Archives of Biology and Technology , 2012, Vol. 55. 951-956.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

[2] *Biodegradation of mineral oils – A review.* **Ori-jesu, Emmanuel O. Aluyor and Mudiakeoghene.** Nigeria. : African Journal of Biotechnology, 2009, Vols. Vol. 8 (6),. 915-920.

[3] *Evaluation of the Effects of Pollution with Spent Lubricating Oil on the Physical and Chemical Properties of Soil.* **Kayode . J, Ph.D., A.A. Oyedeji, B.Sc., and O. Olowoyo, B.Sc.** Nigeria. : The Pacific Journal of Science and Technology, 2009, Vol. 10. 387 -391.

[4] **Mang T, Dressel W.** *Lubricants and Lubriction.* s.l. : John Wiley publishers, 2006.

[5] V International Symposium of lubricants ,Additives & Fluids 2012 . s.l. : KLINE - Brazilian Oil company , 2012.

[6] *Market share of bio-lubricants in Europe and the USA.* **Whitby, David.** s.l. : Lipid Technology, 2004, Vol. 16. 125 - 129.

[7] *Environmentally considerate ester lubricants for the automotive and engineering industries.* **Randles, S.J. and Wright, M.** s.l. : Synthetic Lubrication, 9(2),, 1992. 145–161.

[8] *Time for a change? Assessing environmentally acceptable lubricants .* **Beitelman, A.D.,.** s.l. : Hydro Review, 1998.

[9] *Experimental investigation of coconut oil and palm oil as lubricants in four stroke engine.* **Kailas, Jagadish K Mannekote and Satish V.** s.l. : Trobology online , 2011. 76 - 82.

[10] *Ecological effects of low toxicity oil-based mud drilling in the beatrice oilfield.* **Addy, J.M., Harley, J.P., and Tibbetts, P.J.,.** s.l. : Marine Pollution Bulletin, 1984, Vol. 15. 429–43.

[11] *A Review of Application of vegetable oil based cutting fluids in machining nonferrous metals .* **Lawal, Sunday Albert.** s.l. : Indian journal of science and technology., 2013, Vol. 6. 28-35.

[12] *Developments in the formulation and application of vegetable oil based metal working fluids in turning process.* **Y.Nukman, S.A.Lawal &I.A. Choudhury &.** s.l. : International Journal of Advanced Manufacturing Technology., 2012.

[13] *Synthetic hydraulic fluids for high performance applications.* **Bartz, W.J.,.** Nashville, TN : STLE 55th Annual Meeting, 2000.

[14] *Environmentally adapted hydraulic oils.* **Kassfeldt, E. and Dave, G.** s.l. : WEAR 207, 1997. 41–45.

[15] *Total vegetable-oil based greases prepared from castor oil. .* **Dwivedi, M.C. and Sapre, Smita.** s.l. : Synthetic Lubrication 19(3), 2002. 229–241.

[16] Biologically degradable lubricating greases based on industrial crops. **Dresel, W.H.,.** s.l. : Ind. Crops Prod. 2, 1994, Vols. 281–288.

[17] **Rudnick, Leslie R.** *Synthetics, Mineral Oils,and Bio-Based Lubricants ,Chemistry and Technology .* s.l. : CRC , The Taylor & Francis, 2006.

[18] *Sensitivity of machines to lubricant viscosity.* **Bailey, Charles A.** U.S.Steel corporation : Proceeding of ASME symbosium ,American society of mechanical engineers, 1958. 33-36.

[19] *Lubricant base stock from vegetable oils.* **Asadauskas, Sevim Z. Erhan and Svaju.** s.l. : Industrial crops and products., 2000, Vol. 11. 277-282.

[20] *Correlating chemical structure and physical properties of vegetable oil esters. .* **Jorge de A . Rodrigues, Jr. Fabianne de P Cardoso ,Elizabeth R Lachter ,Luciana R.M.Estevao ,Edson Lima and Regina S.V. Nascimento.** s.l. : JAOCS, 2006, Vol. 83. 353-357.

[21] *Chemical modification of vegetable oils .* **Bajendra K Sharma, Atanu Adhvaryua,Zengshe Liu and Sevim Z Erhan.** s.l. : JAOCS, 2006, Vol. 83. 129-136.

[22] *Preparation and properties of lubricant base stoks from Epoxidised Soyabean oil and 2-Ethyl hexanol.* **Hong-Sik Hwang, Atanu Adhvaryu and Sevim Z Erhan.** s.l. : JAOCS, 2003, Vol. 80. 811-815.

[23] *Effect of anti oxidants on oxidative stability of biodiesel derived from vegetable oils and animal based feed stock.* **RizwanulFattah I M, H.H.Masjuki ,M.A.Kalam ,M.A.Hazrat ,B.M.Masum.** s.l. : Renewable and Sustainable Energy Reviews, 2014, Vol. 30. 356 - 370.

[24] *The Binding of Antiwear Additives to Iron Surfaces: Quantum Chemical Calculations and Tribological Tests.* **Weijiu, H., Yuanqiang, T., Boshui, C., Junxiu, D., and Xueye, W.,.** s.l. : Tribology International, 2003, Vol. 36. 163–168.

[25] *Lubrication properties of castor oil -Potential base stock for biodegradable lubricants.* **Asadauskas, S.Perez .J.M and Duda J.L.** s.l. : Lubrication Engineering, 1997, Vol. 53. 35-40

[26] *Oxidation Stability and Antiwear properties of High Oleic vegetable oils.* **Asadauskas, S.Perez .J.M and Duda J.L.** s.l. : Lubrication Engineering , 1996, Vol. 52. 877-882.

[27] *Biodegradable Lubricants .* **Goyan R.E, Joseph I.E and Layzell B.D.** s.l. : Lubrication Engineering, 1998, Vol. 54. 95-139.