Synthesis of Soy based Biodegradable Grease

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Abstract—The use of biodegradable lubricants in industrial as well as automotive applications has gained significance in recent years. Owing to their superior properties and performance characteristics bio-lubricants offer an ideal alternative to conventional mineral oil based lubricants. In addition the use of bio grease negates the need for additional expenditure to ensure proper disposal of non-biodegradable grease. There has been a growing interest in the production of bio-based and biodegradable greases. Calcium sulfonate greases are some of the most versatile greases and are often used as multi-purpose greases. Some calcium sulfonate greases are classified as food grade greases. They also show potential to be used in various sectors like agriculture, forestry, railways including other areas of application. This paper presents the formulation process and standardized test results of calcium sulfonate based bio-grease along with an overview of the various manufacturing processes that can be employed in the synthesis of grease.

Keywords*- Biodegradable, Lubricants, Seed oil, Additives, Thickener, Nontoxic, Grease*

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I. INTRODUCTION

Grease is a form of semi-solid lubricant used in difficult to reach places in a mechanically rubbing or dynamic systems. Grease acts as reservoir for lubricant-based fluids and additive molecules. The basic components of grease (base fluid, thickener system and various additives) are held together in a structured matrix. Grease is not just a highly viscous mixture but a complex, physical, multi-phase system. It can demonstrate the properties of a solid or a liquid, depending on the conditions to which it is subjected. Bio lubricants make use of seed based oil as base fluid as opposed to mineral oil which is used as base fluid in conventional lubricants. Seed oils are non-toxic in nature and biodegradable. This reduces the adverse effects on the environment which is commonly associated with mineral oil based greases.

II. DESCRIPTION OF THE COMPONENTS

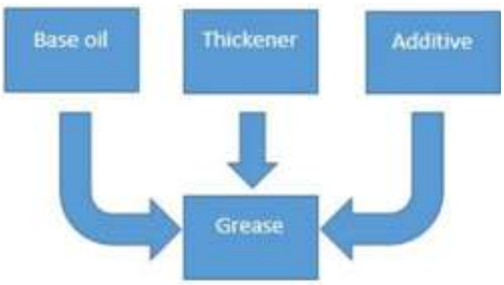

Fig 1:- Composition of grease

(A) BASE OIL

Base oil forms the major component of the grease structure. The amount of base oil determines the consistency and therefore the viscosity of the end product. A multitude of base oils can be used for the formulation of greases. These oils can be either mineral, synthetic or vegetable based. Different base oils impart a different set of properties to the grease.

Mineral oils are classified into three types namely aromatic, naphthenic, and paraffinic. Aromatic and naphthenic oils are largely available and have good solubility characteristics. But due to the carcinogenic nature of these oils they have been replaced by paraffinic oils. To achieve better properties like wider range of operating temperature or chemical resistance synthetic oils can be used.

Due to growing environmental concerns factors such as biodegradability and toxicity have gained significance in recent years. These issues can be remedied by using suitable vegetable based oils in place of mineral oil for grease formulation. A variety of vegetable oils, such as rapeseed, canola, sunflower, soybean, palm, and coconut oil can be used. For the purpose of this paper soybean oil [alpha-linolenic acid (C-18:3), 7-10%, linoleic acid (C-18:2), 51%; monounsaturate oleic acid (C-18:1), 23%, Stearic acid (C-18:0), 4%, and palmitic acid (C-16:0), 10%][13] has been used as the base oil for the preparation of grease.

(B) THICKENERS

Apart from base oil, thickener forms the second major component of grease structure. The thickener forms the fiber structure that traps the base oil molecules and provides viscosity to the grease. The length and density of these fibers determines the hardness of the grease. When a fiber breaks into smaller fragments, the consistency decreases, whereas when they split into thinner fragments, the consistency increases.

Thickeners are of two types namely soap based and non-soap based (forming complex greases). Soap based greases include thickeners such as calcium soap, sodium soap, aluminium soap and lithium soap. Out of the non-soap based thickeners, calcium sulfonate exhibits desirable properties such as superior mechanical and shear stability compared to other non-soap based greases, resulting in less leakage and run-out during operation. High-temperature life of calcium-sulfonate greases are also better, allowing these greases to be used at higher temperatures. They also have better dropping point.[11] Due to the above mentioned advantages calcium sulfonate was chosen as the thickener for preparation of the grease.

(C) ADDITIVES

Additives are the chemicals added to the grease mixture in order to modify the properties of the lubricating grease. Primary functions of these additives include enhancing the existing desirable properties, suppressing the existing undesirable properties, and imparting new properties. The most common additives are oxidation and rust inhibitors. Others include extreme pressure, anti-wear, and friction-reducing agents. Calcium carbonate ($CaCO_3$) as an additive exhibits good performance in anti-wear and friction-reduction, load-carrying capacity, and extreme pressure properties.[8] The particles of boric acid (H_3BO_3), under high pressure and frictional traction, interact with load-bearing surfaces to provide excellent resilience and load carrying capacity. The layer structure of crystalline boric acid particles can slide over each other with relative ease and can reduce friction and wear.[10] This makes both of the above mentioned chemicals suitable additives for the purpose of imparting excellent extreme pressure properties to the grease. Acetic acid (CH_3COOH) and calcium hydroxide ($Ca(OH)_2$) were used as catalysts for the process.

III. ADVANTAGES OF BIO-GREASE

Bio-grease in general exhibits excellent lubricity, has higher viscosity index as compared to cheaper variants of conventional grease, possesses lower volatility, higher flash and fire point. Also unlike conventional grease, bio-based greases have better skin compatibility and pose less dermatological problems. Their biodegradability is better than conventional greases and the base oil used for the formulation of these greases is easily available.

IV. APPLICATIONS OF BIO-GREASE

Bio-greases offer applications in a wide variety of fields and are especially suitable for the lubrication of forestry machinery, construction vehicles, rail curve, rail flange and marine applications. In all the above mentioned fields there is a clear loss-lubrication situation where the lubricating grease eventually ends up either in soil or water. The biodegradability of these bio-based greases allows the wasted grease to degrade naturally and not harm the environment in the process. Case studies have displayed the benefits of bio-based greases including gearbox greases, wire rope lubricants and greases for bearings. The prime advantage of the superior lubricity of bio-based lubricants is the reduction in the energy consumption by about 7 to 15 per cent. The reduction in wear and friction results in increased life of the equipment.

V. SELECTION OF CHEMICALS

There are various processes that have been developed for synthesis of greases. Procedures differ on the basis of type of thickeners namely soap based and non-soap based. Different base oils demand different procedures in order to synthesize the grease properly. Most of the research has been with lithium based greases (soap based) as they provide a wide range of properties at low manufacturing cost. Soybean oil has been seen as a suitable alternative for mineral oils, as alkali refined soybean oil has been tested and proven to be of high oxidative stability as compared to mineral oils, whilst exhibiting other properties similar or better than that of conventional base oil for greases.

Calcium sulfonate greases are generally overbased so as to promote formation of calcite particles which impart the grease its properties. Some calcium sulfonate greases are classified as food grade greases meaning that these greases can be used in food industries without the risk of ruining the food products due to small amount of spills.

VI. SYNTHESIS OF GREASE

For the purpose of heating the grease mixture, a hot air oven was used. The hot air oven was put to preheat at 100 °C. In formulation of this grease, soybean oil was mixed with calcium sulfonate (TBN 300) along with the additive calcium carbonate and oleic acid inside a beaker. Oleic acid is a fatty acid added in order to expedite the reaction between base oil and thickener. This mixture was constantly stirred until a cream coloured solution was obtained. This solution was then put into the oven which had been preheating for 120 minutes. The said mixture was taken out after 15 minutes of heating. Additional thickener was added to the mixture along with acetic acid which acts as a catalyst for the mixture. This solution was stirred until its appearance turned smooth and it was again subjected to heating at 180 °C for 20 minutes and taken out. After being taken out, anhydrous calcium hydroxide was added along with boric acid in order to suppress formation of excess foam and give smoothness to the final product. This mixture after being stirred was subjected to heating at 200 °C for 60 minutes. It was observed that in this time, there was formation of foam in the mixture. The time taken for the formation of foam was observed to be dependent on the size of the sample, linking the foam formation time to area exposed to heating. After the amount of foam formed was observed to be sufficient, the mixture was taken out for stirring in order to release the carbon dioxide formed during the reaction. The mixture was again put into heating oven until the carbon dioxide was completely released from the mixture. The mixture was then allowed to cool for 3 hours. The product achieved after completion of the process was a greasy mixture with caramel colour and possessing a slightly pungent odour.

Fig 2: End product of grease formulation.

VII. ALTERNATE MANUFACTURING PROCESS

Grease can also be manufactured using alternative heating technologies such as microwaves. When base oils are exposed to high temperatures exceeding 150 ^{0}C (302 ^{0}F) they undergo rapid oxidation, this reduces the lubricating efficiency as well as the overall life of the product. For this reason, they are mixed with chemicals (thickeners and additives) that provide the base oil with better oxidative stability and improve its lubricating efficiency.

Some of the conventional processes include heat imparted with the help of hot plates. When heating of oil is done using a hot plate, it is observed that the oil in contact with the surface of the hot plate gets heated up faster than the other regions,[12] this layer of oil undergoes oxidation that is irreversible in nature. The presence of these hot spots during the heating process results in the end product exhibiting inconsistent properties. Thus, in order to improve the properties of the product, different additives are added which in turn increases the cost of the product.

Microwave technology overcomes the shortcomings of hotplate method. The use of microwave technology eliminates these hot spots thus imparting the product more consistent properties. Microwaves provide uniform heating to the mixture. Use of microwave technology prerequisites usage of polar base oils. Although there are means available to increase the energy absorption of non-polar oils in order to make them more suitable candidates for base oils. Thus, vegetable oils like soybean oils can be used in this type of manufacturing method.

Conventional processes take 6-8 hours for synthesis of grease, by employing microwave technology this process time can be reduced to 3-4 hours. Additionally, it has been observed that heat gain using microwave takes less time, as a result higher temperatures can be attained faster in comparison to conventional processes.

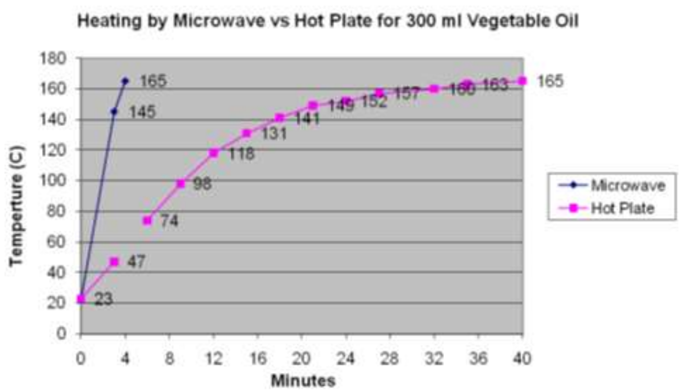

Fig 2: Time to Raise Temperature of Vegetable oil to 165 ^{0}C (329 °F) by Microwave VS by Hot Plate.[12]

VIII. HOT AIR OVEN

Hot air ovens are electrical devices used for heating test subjects. These ovens can reach temperatures ranging from 50 to 300°C. They are ideal for use in laboratory environment as they use dry heat for heating the subject and there is no pressure build up inside of the oven. They have double walled insulation which helps them to keep the heat in and conserve energy. There is an air circulating fan which circulates the hot air inside the oven. Higher temperatures can be reached safely using hot air ovens as compared to some other means. It is due to the above mentioned reasons that this source of heating was selected for the preparation of the sample.

IX. RESULTS

The product formed was a viscous mixture having greasy texture with a slight pungent odour. The product was found to be sticky and difficult to wash off from spatula dipped in the sample, indicating good water washout property. The dropping point was tested to be about 105°C suggesting the grease is suitable for applications in areas of normal working temperatures such as roll bearings, gears including other applications. Cone penetration test gave a penetration number of 284, suggesting that the product falls under NLGI consistency number (or NLGI grade) ‘2’. National Lubricating Grease Institute (NLGI) classifies grade 2 greases as normal greases that can be used in various greasing applications.

Also it was observed that if the amount of base oil is increased in the sample, its viscosity decreases significantly. The resulting product was a liquid solution having very low viscosity. This indicates that the consistency of the product decreases with increase in the amount of base oil.

X. CONCLUSION

The final product formed can be used for various lubricating applications. The product possesses excellent water resistant, anti-rust and anti-corrosive properties. It can be utilised for general application, plain and anti-friction bearing where temperatures are moderate (below 105 °C).

It can also be utilised for general chassis lubrication including suspension and steering system. It is also suitable for certain open and semi-enclosed gears as well as chain drives of farm equipment.

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