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A review of biodegradable lubricants 3. Characterization, current status, and future improvement trends

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Abstract

The history of biodegradable lubricants has been presented in a series of articles, works and patents. Biodegradable lubricants are used to improve the properties of mineral oils or vegetable oils. To improve the properties of the oils, a wide range of biodegradable lubricants based on polymers were synthesized. A series of researches are related to the production of biodegradable lubricating oils that also possess a food-type non-toxic character.

Keywords: Lubricants, biodegradable, future, characterization

Introduction

The literature of recent years offers a wide range of articles, works and patents in the field of tribology, a field in which the performance criteria are becoming higher and higher, and the condition of biodegradability has become practically self-evident.

Thus, a series of studies have been carried out regarding the influence of lubricants on the environment and how their harmful effect can be eliminated or at least reduced ^[1].

The reaction is catalyzed homogeneously or heterogeneously, by acids and Lewis catalysts, such as: Nafion-silica composites, Amberlist 15, AlBr₃, FeCl₃, etc. ^[2].

The synthesis and biodegradability capacity of some adipic and sebacic esters was studied by a Polish research team ^[3]. Thus, ester oligomers with different ranges of molecular masses were synthesized from dimethyl adipate, dimethyl sebacate and neopentylglycol. The transesterification reactions were catalyzed by calcium methoxide ^[3].

The problem of the biodegradability of lubricants is not limited to the basic material the lubricating oil but the contribution of thickeners and the package of additives, important in the case of lubricating greases, must be taken into account ^[4].

Although it is somewhat divergent to the field of tribology, the issue of biodegradability is also important in the case of lubricants for the processing of plastic materials, mainly oils and fats. Thus, a composition containing 70% by weight of trimethylol propane trioleate, 7% by weight of calcium sulfonate, 15% by weight of sulfurized animal fat and 8% by weight of phosphate, showed excellent qualities in the processing of polymers ^[4].

It is proposed to use carboxylic acids, secondary products of the catalytic oxidation of cyclohexane, as substances for obtaining biodegradable lubricants ^[5]. The mixture of monocarboxylic acids (butyric, valeric and capric) separated from the mixture resulting from the catalytic oxidation of cyclohexane to cyclohexanone, was used to esterify polyhydric alcohols (pentaerythritol or trimethylol propane) resulting in ester oils within the ISO VG 10 and VG 22 viscosity classes which have properties comparable to those of commercial biodegradable ester oils. Modification of the commercial assortments of polyalkylene glycols (PAGs) by esterification of hydroxyl groups with a mixture of monocarboxylic acids from the C4-C6 series, changed some properties of PAGs, increasing their importance as a base oil for the production of lubricants ^[5].

Fatty acid neoalkyl glycol esters are considered non-toxic and biodegradable base oils for functional automotive fluids ^[6].

These fluids consist of esters of neopentyl glycol, trimethylol propane, pentaerythritol and dipentaerythritol with fatty acids having a chain length of C8-C36, an iodine index of less than 10 (preferably less than 1), a Noack volatility (DIN 51581) less than 7% (preferably less than 4%), and a pour point less than -20 °C (preferably below -40 °C).

Biodegradable or non-biodegradable additives can also be present in order to ensure the increase of the performance of the fluid. Such fluids can be used as engine oils, gear oils, automatic transmission fluids, traction fluids or hydraulic fluids (for example for shock absorbers), brake fluids and refrigeration units ^[7].

Synthetic lubricants and hydraulic fluids can be obtained by the electrophilic addition of carboxylic acids (their anhydrides, acyl halides, or neocarboxylic acids) to unsaturated fatty acids or their esters ^[8]: oleic, linoleic, linolenic, palmitoleic, eicosenoic, erucic acids or their methyl esters, glycerin-trioleate, pentaerythritol-tetraoleate, or mixtures of rapeseed, sunflower, palm, coconut or olive oils. The addition reaction is carried out in heterogeneous acid catalysis (zeolites, solid phosphoric acid, metal phosphates, acid oxides for example $B_2O_3GeO_2$, ion exchange resins) or homogeneous (H_2SO_4 , H_3BO_3 , HNO_3 , HCl , $AlCl_3$ and other halogenated acids and Lewis acids). The synthetic esters thus obtained are characterized by an increased resistance to oxidation and reduced toxicity ^[9].

Complex polyol esters show biodegradability characteristics, and lubricating compositions containing a polyfunctional alcohol ester and a saturated or unsaturated dicarboxylic acid residue having from about 9 to about 22 carbon atoms are also biodegradable ^[10].

Lubricants based on fully hydrogenated vegetable oils have a series of properties (lubrication capacity, rheology, optimal electrical insulation values and microbial biodegradability capacity) that give them a special position among the fluids that ensure the proper functioning of mechanical devices ^[11].

Biodegradable lubricants involve the use of lubricating compositions that are based on a biodegradable base oil, such as a polyol or polyalkylene glycol ester, a thickener based on calcium sulfonate and a phospholipid of natural origin as an antiwear additive (such as lecithin) and having a specific gravity greater than 1.0 at 15.6 °C (60 °F) for marine applications. The thickening agent may be a linear alkyl benzene sulfonic acid, acetic acid and 12-hydroxy stearic acid, and calcium carbonate as a solid film lubricant. The lubricant sinks when dispersed in water avoiding the formation of a glossy surface and biodegrades when submerged which means that it is established as an environmentally friendly lubricant ^[12]. As an observation we can say that this patent presents to some extent a composition claimed in another patent of the same authors, cited at position ^[13].

A biodegradable penetrating lubricant is composed of the following components

- At least one triglyceride
- An organic solvent chosen from:
 - (1) Ethyl lactate;
 - (2) Methyl ester;
 - (3) Combination of (1) and (2);
- An antioxidant;
- A corrosion inhibitor.

Optionally, the lubricant can be added further with other substances chosen from

- Viscosity modifier.
- Wear inhibitor.
- An emulsifier ^[14-24].

Conclusions

Obtaining a new generation of lubricants was the understanding of the need to eliminate or considerably reduce the content of toxic chemical compounds. The good lubricating properties as well as the high degree of biodegradability were the decisive criteria in the use of vegetable oils as a dispersion phase in lubricating greases.

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