

Methods of Solubilizing Alkyl Polyols

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/587,784, filed October 4, 2023, which is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to methods of improving solubility of alkyl polyols in lubricating oil compositions.

BACKGROUND

[0003] Lubricating oil compositions containing alkyl polyols may have favorable properties such as reducing friction, improving anti-fatigue and anti-wear. However, due to their relatively high polarity, alkyl polyols face solubility challenges in an oil of lubricating viscosity.

SUMMARY OF THE INVENTION

[0004] In one aspect, there is provided a method of improving the solubility of an alkyl polyol in a lubricating oil composition, the method comprising lubricating the engine with a lubricating oil composition comprising: (a) a major amount of an oil of lubricating viscosity; (b) alkyl polyol having 2 to 20 carbon atoms; and (c) a solubility-enhancing additive comprising a detergent, dispersant, or anti-wear additive; wherein the amount of alkyl polyol is from about 0.001 wt. % to about 0.5 wt. % based on the total weight of the lubricating oil composition.

[0005] In another aspect, there is provided a method of improving the solubility of glycerol in a lubricating composition, the method comprising lubricating the engine with a lubricating oil composition comprising: (a) a major amount of an oil of lubricating viscosity; (b) glycerol; and (c) at least one detergent, succinimide dispersant, or amine phosphate anti-wear additive; wherein the amount of glycerol is from about 0.001 wt. % to about 0.5 wt. % based on the total weight of the lubricating oil composition.

DETAILED DESCRIPTION

[0006] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[0007] The term “a major amount” of a base oil refers to where the amount of the base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, “a major amount” of a base oil refers to an amount of the base oil more than 50 wt. %, more than 60 wt. %, more than 70 wt. %, more than 80 wt. %, or more than 90 wt. % of the lubricating oil composition.

[0008] “HOB” refers to high overbased with a TBN above 250 on an actives basis and “LOB” refers to low overbased with a TBN below 100 on an actives basis.

[0009] The term "Total Base Number" or "TBN" refers to the level of alkalinity in an oil sample, which indicates the ability of the composition to continue to neutralize corrosive acids, in accordance with ASTM Standard No. D2896 or equivalent procedure. The test measures the change in electrical conductivity, and the results are expressed as mgKOH/g (the equivalent number of milligrams of KOH needed to neutralize 1 gram of a product). Therefore, a high TBN reflects strongly overbased products and, as a result, a higher base reserve for neutralizing acids.

[0010] The present disclosure relates to lubricating oil compositions that have a high or improved capacity to solubilize alkyl polyols. The lubricating oil composition comprises an oil of lubricating viscosity, alkyl polyol and a solubility-enhancing additive. The solubility-enhancing additive may be a detergent, dispersant, or anti-wear additive. Increasing solubility of alkyl polyols in lubricating oil compositions (e.g., electric driveline fluid, tractor hydraulic fluid, TO-4, AW hydraulic oil, automotive engine oil, marine engine oil) can provide numerous performance benefits such as enhanced wear or anti-fatigue performance.

The Oil of Lubricating Viscosity

[0011] The lubricating oil compositions disclosed herein generally comprise at least one oil of lubricating viscosity. Any base oil known to a skilled artisan can be used as the oil of lubricating viscosity disclosed herein. Some base oils suitable for preparing the lubricating oil compositions have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapters 1 and 2 (1996); and A. Sequeria, Jr., "Lubricant Base Oil and Wax Processing," New York, Marcel Decker, Chapter 6, (1994); and D. V. Brock, Lubrication Engineering, Vol. 43, pages 184-5, (1987), all of which are incorporated herein by reference. Generally, the amount of the base oil in the lubricating oil composition may be from about 70 to about 99.5 wt. %, based on the total weight of the lubricating oil composition. In some embodiments, the amount of the base oil in the lubricating oil composition is from about 75 to about 99 wt. %, from about 80 to about 98.5 wt. %, or from about 80 to about 98 wt. %, based on the total weight of the lubricating oil composition.

[0012] In certain embodiments, the base oil is or comprises any natural or synthetic lubricating base oil fraction. Some non-limiting examples of synthetic oils include oils, such as polyalphaolefins or PAOs, prepared from the polymerization of at least one alpha-olefin, such as

ethylene, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases, such as the Fisher-Tropsch process. In certain embodiments, the base oil comprises less than about 10 wt. % of one or more heavy fractions, based on the total weight of the base oil. A heavy fraction refers to a lube oil fraction having a viscosity of at least about 20 cSt at 100° C. In certain embodiments, the heavy fraction has a viscosity of at least about 25 cSt or at least about 30 cSt at 100° C. In further embodiments, the amount of the one or more heavy fractions in the base oil is less than about 10 wt. %, less than about 5 wt. %, less than about 2.5 wt. %, less than about 1 wt. %, or less than about 0.1 wt. %, based on the total weight of the base oil. In still further embodiments, the base oil comprises no heavy fraction.

[0013] In certain embodiments, the lubricating oil compositions comprise a major amount of a base oil of lubricating viscosity. In some embodiments, the base oil has a kinematic viscosity at 100° C. from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 centistokes (cSt) to about 20 cSt, or from about 5 cSt to about 16 cSt. The kinematic viscosity of the base oils or the lubricating oil compositions disclosed herein can be measured according to ASTM D 445, which is incorporated herein by reference.

[0014] In other embodiments, the base oil is or comprises a base stock or blend of base stocks. In further embodiments, the base stocks are manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and re-refining. In some embodiments, the base stocks comprise a re-refined stock. In further embodiments, the re-refined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use.

[0015] In some embodiments, the base oil comprises one or more of the base stocks in one or more of Groups I-V as specified in the American Petroleum Institute (API) Publication 1509, Fourteenth

Edition, December 1996 (i.e., API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils), which is incorporated herein by reference. The API guideline defines a base stock as a lubricant component that may be manufactured using a variety of different processes. Groups I, II and III base stocks are mineral oils, each with specific ranges of the amount of saturates, sulfur content and viscosity index. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0016] In some embodiments, the base oil comprises one or more of the base stocks in Group I, II, III, IV, V or a combination thereof. In other embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof. In further embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof wherein the base oil has a kinematic viscosity from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 cSt to about 20 cSt, or from about 5 cSt to about 16 cSt at 100° C.

[0017] The base oil may be selected from the group consisting of natural oils of lubricating viscosity, synthetic oils of lubricating viscosity and mixtures thereof. In some embodiments, the base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocrackate base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. In other embodiments, the base oil of lubricating viscosity includes natural oils, such as animal oils, vegetable oils, mineral oils (e.g., liquid petroleum oils and solvent treated or acid-treated mineral oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types), oils derived from coal or shale, and combinations thereof. Some non-limiting examples of animal oils include bone oil, lanolin, fish oil, lard oil, dolphin oil, seal oil, shark oil, tallow oil, and whale oil. Some non-limiting examples of vegetable oils include castor oil, olive oil, peanut oil, rapeseed oil, corn oil, sesame oil, cottonseed oil, soybean oil, sunflower oil,

safflower oil, hemp oil, linseed oil, tung oil, oiticica oil, jojoba oil, and meadow foam oil. Such oils may be partially or fully hydrogenated.

[0018] In some embodiments, the synthetic oils of lubricating viscosity include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. In other embodiments, the synthetic oils include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups can be modified by esterification, etherification, and the like. In further embodiments, the synthetic oils include the esters of dicarboxylic acids with a variety of alcohols. In certain embodiments, the synthetic oils include esters made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers. In further embodiments, the synthetic oils include tri-alkyl phosphate ester oils, such as tri-n-butyl phosphate and tri-iso-butyl phosphate.

[0019] In some embodiments, the synthetic oils of lubricating viscosity include silicon-based oils (such as the polyalkyl-, polyaryl-, polyalkoxy-, polyaryloxy-siloxane oils and silicate oils). In other embodiments, the synthetic oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0020] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil. Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0021] In further embodiments, the base oil comprises a poly-alpha-olefin (PAO). In general, the poly-alpha-olefins may be derived from an alpha-olefin having from about 2 to about 30, from about 4 to about 20, or from about 6 to about 16 carbon atoms. Non-limiting examples of suitable

poly- α -olefins include those derived from octene, decene, mixtures thereof, and the like. These poly- α -olefins may have a viscosity from about 2 to about 15, from about 3 to about 12, or from about 4 to about 8 centistokes at 100° C. In some instances, the poly- α -olefins may be used together with other base oils such as mineral oils.

[0022] In further embodiments, the base oil comprises a polyalkylene glycol or a polyalkylene glycol derivative, where the terminal hydroxyl groups of the polyalkylene glycol may be modified by esterification, etherification, acetylation and the like. Non-limiting examples of suitable polyalkylene glycols include polyethylene glycol, polypropylene glycol, polyisopropylene glycol, and combinations thereof. Non-limiting examples of suitable polyalkylene glycol derivatives include ethers of polyalkylene glycols (e.g., methyl ether of polyisopropylene glycol, diphenyl ether of polyethylene glycol, diethyl ether of polypropylene glycol, etc.), mono- and polycarboxylic esters of polyalkylene glycols, and combinations thereof. In some instances, the polyalkylene glycol or polyalkylene glycol derivative may be used together with other base oils such as poly- α -olefins and mineral oils.

[0023] In further embodiments, the base oil comprises any of the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, and the like) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, and the like). Non-limiting examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the like.

[0024] In further embodiments, the base oil comprises a hydrocarbon prepared by the Fischer-Tropsch process. The Fischer-Tropsch process prepares hydrocarbons from gases containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons may require further processing in order to be useful as base oils. For example, the hydrocarbons may be dewaxed, hydroisomerized, and/or hydrocracked using processes known to a person of ordinary skill in the art.

[0025] In further embodiments, the base oil comprises an unrefined oil, a refined oil, a re-refined oil, or a mixture thereof. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. Non-limiting examples of unrefined oils include shale oils obtained directly from retorting operations, petroleum oils obtained directly from primary distillation, and ester oils obtained directly from an esterification process and used without further treatment. Refined oils are similar to the unrefined oils except the former have been further treated by one or more purification processes to improve one or more properties. Many such purification processes are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, and the like. Re-refined oils are obtained by applying to refined oils processes similar to those used to obtain refined oils. Such re-refined oils are also known as reclaimed or reprocessed oils and often are additionally treated by processes directed to removal of spent additives and oil breakdown products.

Alkyl Polyol

[0026] The lubricating oil composition contains an alkyl polyol. The alkyl polyol has 2 to 20 carbon atoms such as from 2 to 19 carbon atoms, 2 to 18 carbon atoms, 2 to 17 carbon atoms, 2 to 16 carbon atoms, 2 to 15 carbon atoms, 2 to 14 carbon atoms, 2 to 13 carbon atoms, 2 to 12 carbon atoms, 2 to 11 carbon atoms, 2 to 10 carbon atoms, 2 to 9 carbon atoms, 2 to 8 carbon atoms, 2 to

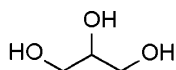
7 carbon atoms, 2 to 6 carbon atoms, 2 to 5 carbon atoms, 2 to 4 carbon atoms, 2 to 3 carbon atoms, 3 to 20 carbon atoms, 3 to 19 carbon atoms, 3 to 18 carbon atoms, 3 to 17 carbon atoms, 3 to 16 carbon atoms, 3 to 15 carbon atoms, 3 to 14 carbon atoms, 3 to 13 carbon atoms, 3 to 12 carbon atoms, 3 to 11 carbon atoms, 3 to 10 carbon atoms, 3 to 9 carbon atoms, 3 to 8 carbon atoms, 3 to 7 carbon atoms, 3 to 6 carbon atoms, 3 to 5 carbon atoms, 3 to 4 carbon atoms, 4 to 20 carbon atoms, 4 to 19 carbon atoms, 4 to 18 carbon atoms, 4 to 17 carbon atoms, 4 to 16 carbon atoms, 4 to 15 carbon atoms, 4 to 14 carbon atoms, 4 to 13 carbon atoms, 4 to 12 carbon atoms, 4 to 11 carbon atoms, 4 to 10 carbon atoms, 4 to 9 carbon atoms, 4 to 8 carbon atoms, 4 to 7 carbon atoms, 4 to 6 carbon atoms, 4 to 5 carbon atoms, 5 to 20 carbon atoms, 5 to 19 carbon atoms, 5 to 18 carbon atoms, 5 to 17 carbon atoms, 5 to 16 carbon atoms, 5 to 15 carbon atoms, 5 to 14 carbon atoms, 5 to 13 carbon atoms, 5 to 12 carbon atoms, 5 to 11 carbon atoms, 5 to 10 carbon atoms, 5 to 9 carbon atoms, 5 to 8 carbon atoms, 5 to 7 carbon atoms, 5 to 6 carbon atoms, 6 to 20 carbon atoms, 6 to 19 carbon atoms, 6 to 18 carbon atoms, 6 to 17 carbon atoms, 6 to 16 carbon atoms, 6 to 15 carbon atoms, 6 to 14 carbon atoms, 6 to 13 carbon atoms, 6 to 12 carbon atoms, 6 to 11 carbon atoms, 6 to 10 carbon atoms, 6 to 9 carbon atoms, 6 to 8 carbon atoms, 6 to 7 carbon atoms, 7 to 20 carbon atoms, 7 to 19 carbon atoms, 7 to 18 carbon atoms, 7 to 17 carbon atoms, 7 to 16 carbon atoms, 7 to 15 carbon atoms, 7 to 14 carbon atoms, 7 to 13 carbon atoms, 7 to 12 carbon atoms, 7 to 11 carbon atoms, 7 to 10 carbon atoms, 7 to 9 carbon atoms, 7 to 8 carbon atoms, 8 to 20 carbon atoms, 8 to 19 carbon atoms, 8 to 18 carbon atoms, 8 to 17 carbon atoms, 8 to 16 carbon atoms, 8 to 15 carbon atoms, 8 to 14 carbon atoms, 8 to 13 carbon atoms, 8 to 12 carbon atoms, 8 to 11 carbon atoms, 8 to 10 carbon atoms, 8 to 9 carbon atoms, 9 to 20 carbon atoms, 9 to 19 carbon atoms, 9 to 18 carbon atoms, 9 to 17 carbon atoms, 9 to 16 carbon atoms, 9 to 15 carbon atoms, 9 to 14 carbon atoms, 9 to 13 carbon atoms, 9 to 12 carbon atoms, 9 to 11 carbon atoms, 9

to 10 carbon atoms, 10 to 20 carbon atoms, 10 to 19 carbon atoms, 10 to 18 carbon atoms, 10 to 17 carbon atoms, 10 to 16 carbon atoms, 10 to 15 carbon atoms, 10 to 14 carbon atoms, 10 to 13 carbon atoms, 10 to 12 carbon atoms, 10 to 11 carbon atoms, 11 to 20 carbon atoms, 11 to 19 carbon atoms, 11 to 18 carbon atoms, 11 to 17 carbon atoms, 11 to 16 carbon atoms, 11 to 15 carbon atoms, 11 to 14 carbon atoms, 11 to 13 carbon atoms, 11 to 12 carbon atoms, 12 to 20 carbon atoms, 12 to 19 carbon atoms, 12 to 18 carbon atoms, 12 to 17 carbon atoms, 12 to 16 carbon atoms, 12 to 15 carbon atoms, 12 to 14 carbon atoms, 12 to 13 carbon atoms, 13 to 20 carbon atoms, 13 to 19 carbon atoms, 13 to 18 carbon atoms, 13 to 17 carbon atoms, 13 to 16 carbon atoms, 13 to 15 carbon atoms, 13 to 14 carbon atoms, 14 to 20 carbon atoms, 14 to 19 carbon atoms, 14 to 18 carbon atoms, 14 to 17 carbon atoms, 14 to 16 carbon atoms, 14 to 15 carbon atoms, 15 to 20 carbon atoms, 15 to 19 carbon atoms, 15 to 18 carbon atoms, 15 to 17 carbon atoms, 15 to 16 carbon atoms, 16 to 20 carbon atoms, 16 to 19 carbon atoms, 16 to 18 carbon atoms, 16 to 17 carbon atoms, 17 to 20 carbon atoms, 17 to 19 carbon atoms, 17 to 18 carbon atoms, 18 to 20 carbon atoms, 18 to 19 carbon atoms, and 19 to 20 carbon atoms.

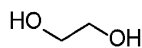
[0027] The alkyl polyol includes 2 or more alcohol groups such as 3 or more alcohol groups, 4 or more alcohol groups, and 5 or more alcohol groups. The term “alkyl”, as used herein, unless otherwise specified, includes a saturated straight, branched, cyclic, primary, secondary, or tertiary hydrocarbon. In some embodiments, the alkyl polyol may include one or more heteroatoms (e.g., N, S, O, etc.)

[0028] Non-limiting examples of alkyl polyols include glycerol (Structure 1), ethylene glycol (Structure 2), 3-amino-1,2-propanediol (Structure 3), 1,2,4-butanetriol (Structure 4), 1,1,1-tris(hydroxymethyl)propane (Structure 5), meso-erythritol (Structure 6), D-sorbitol (Structure 7), xylitol (Structure 8), 2,2-diethyl-1,3-propanediol (Structure 9), 3-methoxy-1,2-propanediol

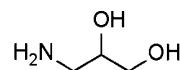
(Structure 10), 2,2-dimethyl-1,3-propanediol (Structure 11), pentaerythritol (Structure 12), and polyvinyl alcohol.



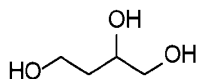
Structure 1



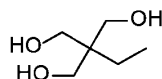
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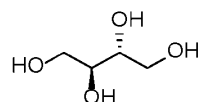
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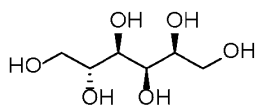
Structure 4



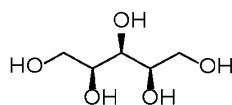
Structure 5



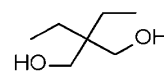
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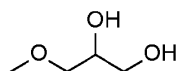
Structure 7



Structure 8



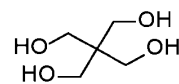
Structure 9



Structure 10



Structure 11



Structure 12

[0029] Suitable cyclic alkyl polyols include myo-inositol, D-(+)-xylose, and D-(+)-glucose. Other alkyl polyols include alcohol ethers such as diglycerol, triglycerol, diethylene glycol, triethylene glycol, dipentaerythritol, and tripentaerythritol.

[0030] Other alkyl polyols include sugars such as monosaccharides, disaccharides, polysaccharides, and variations (e.g., open or closed form) or derivatives thereof.

[0031] The exact amount of the alkyl polyol may vary depending upon the composition and amount of the oil or lubricating viscosity, the specific detergents and amounts, and the other desired properties of the lubricating oil composition.

[0032] In some embodiments the amount of alkyl polyol is from about 0.001 wt.% to about 0.5 wt.% based on the total weight of the lubricating oil composition such as at least about 0.001 wt.%, or at least about 0.05 wt.%, or at least about 0.1 wt.%, or at least about 0.3 wt.%, or at least about 0.4 wt.%, or at least about 0.4 wt.%, or at least about 0.5 wt.%, or at least about 0.75 wt.%, or at least about 1.0 wt. % up to about 1.5 wt.%, or up to about 1.25 wt.%, or up to about 1.0 wt.%, or up to about 0.9 wt.%, or up to about 0.8 wt. % based on the total weight of the lubricating oil composition.

Detergents

[0033] The lubricating oil composition comprises a metal detergent. Suitable metal detergents include metal carboxylate detergent, metal salicylate detergent, metal sulfonate detergent, or metal phenate detergent. The metal can be any metal suitable for making carboxylate, salicylate, sulfonate, or phenate detergents. Non-limiting examples of suitable metals include alkali metals, alkaline earth metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like.

[0034] Generally, the amount of the detergent is from about 0.001 wt. % to about 10 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition.

[0035] The metal detergents may have a wide range of TBN. In some embodiments, the metal detergent is a high-high overbased metal detergent, high overbased metal detergent, medium overbased metal detergent, or low overbased metal detergent. In some embodiments, the phenate may be a low overbased phenate.

[0036] Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylhydroxybenzoate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or Ca(OH)₂, to form the sulfonate.

[0037] Generally speaking, overbased detergents may be low overbased (LOB), e.g., an overbased salt having a TBN below 100 on an actives basis. In one aspect, the TBN of a low overbased salt may be from about 10 to about 100. In another aspect, the TBN of a low overbased salt may be from about 10 to about 80.

[0038] Overbased detergents may be medium overbased (MOB), e.g., an overbased salt having a TBN from about 100 to about 250 on an actives basis. In one aspect, the TBN of a medium overbased salt may be from about 100 to about 200. In another aspect, the TBN of a medium overbased salt may be from about 125 to about 175.

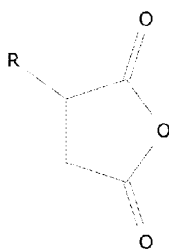
[0039] Overbased detergents may be high overbased (HOB), e.g., an overbased salt having a TBN above 250 on an actives basis. In one embodiment, the TBN of a high overbased salt may be from about 250 to about 600 on an actives basis.

[0040] Overbased detergents may be high-high overbased (HHOB), e.g., an overbased salt having a TBN above 600 on an actives basis. In one embodiment, the TBN of a high-high overbased salt may be from about 600 to about 800 on an actives basis.

Dispersant

[0041] The lubricating oil composition may include polyalkenyl succinimide dispersants such as those described herein. In general, the nitrogen content from the polyalkenyl succinimide based on the lubricating oil composition is from about 0.010 wt. % to about 0.30 wt. % such as from about 0.050 to about 0.25 wt. %, about 0.050 to about 0.20 wt. %, and about 0.050 to about 0.15 wt. %.

[0042] In one embodiment, a polyalkenyl bis-succinimide can be obtained by reacting a polyalkenyl-substituted succinic anhydride below:

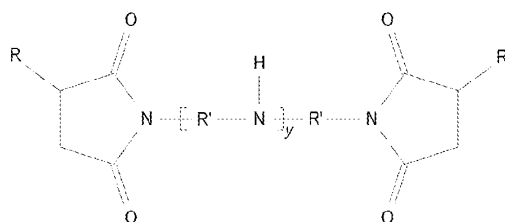


wherein R is a polyalkenyl substituent derived from a polyalkene group having a number average molecular weight of from about 500 to about 3000, with a polyamine. In one embodiment, R is a polyalkenyl substituent derived from a polyalkene group having a number average molecular weight of from about 1000 to about 2500. In one embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 500 to about 3000. In another embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 1000 to about 2500.

[0043] Suitable polyamines for use in preparing the bis-succinimide dispersants include polyalkylene polyamines. Such polyalkylene polyamines will typically contain about 2 to about 12 nitrogen atoms and about 2 to 24 carbon atoms. Particularly suitable polyalkylene polyamines are those having the formula: $\text{H}_2\text{N}-(\text{R}'\text{NH})_x-\text{H}$ wherein R' is a straight- or branched-chain alkylene group having 2 or 3 carbon atoms and x is 1 to 9. Representative examples of suitable polyalkylene polyamines include ethylenediamine, diethylenetriamine, triethylenetetraamine, tetraethylenepentamine, pentaethylene hexamine, and heavy polyamines (e.g., Ethyleneamine E-100, available from Huntsman Company).

[0044] Generally, the polyalkenyl-substituted succinic anhydride is reacted with the polyamine at a temperature of about 130°C to about 220°C (e.g., 145°C to 175°C). The reaction can be carried out under an inert atmosphere, such as nitrogen or argon. Generally, a suitable molar charge of polyamine to polyalkenyl-substituted succinic anhydride is from about 0.35:1 to about 0.6:1 (e.g., 0.4:1 to 0.5:1). As used herein, the “molar charge of polyamine to polyalkenyl-substituted succinic anhydride” means the ratio of the number of moles of polyamine to the number of succinic groups in the succinic anhydride reactant.

[0045] One class of suitable polyalkenyl succinimides may be represented by the following:



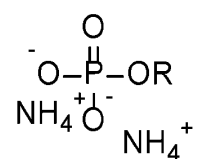
wherein R and R' are as described herein above and y is 1 to 11.

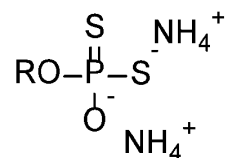
[0046] In some embodiments, the succinimide dispersant may be post-treated by a reactive boron compound or organic carbonate.

[0047] Suitable boron compounds that can be used as a source of boron include, for example, boric acid, a boric acid salt, a boric acid ester, and the like. Representative examples of a boric acid include orthoboric acid, metaboric acid, paraboric acid, and the like. Representative examples of a boric acid salt include ammonium borates, such as ammonium metaborate, ammonium tetraborate, ammonium pentaborate, ammonium octaborate, and the like. Representative examples of a boric acid ester include monomethyl borate, dimethyl borate, trimethyl borate, monoethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate, tripropyl borate, monobutyl borate, dibutyl borate, tributyl borate, and the like.

Anti-wear Additive

[0048] The anti-wear additive of the present disclosure includes a salt of nitrogen-containing and phosphorus-containing compounds. More specifically, the anti-wear additive is the alkyl ammonium salt of a phosphate or dithiophosphate. Suitable anti-wear additives such as alkyl ammonium phosphate and alkyl ammonium dithiophosphate are shown below: The alkyl group (R) is a C1-C20 hydrocarbyl group.





[0049] Generally, the amount of the anti-wear additive is from about 0.001 wt. % to about 10 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition.

Other Additives

[0050] Optionally, the lubricating oil composition may further comprise at least an additive or a modifier (hereinafter designated as "additive") that can impart or improve any desirable property of the lubricating oil composition. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition. London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker (2003), both of which are incorporated herein by reference. In some embodiments, the additive can be selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

[0051] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from about 0.001 wt. % to about 10 wt. %, from about 0.01 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 2.5 wt. %, based on the total weight of the lubricating

oil composition. Further, the total amount of the additives in the lubricating oil composition may range from about 0.001 wt. % to about 20 wt. %, from about 0.01 wt. % to about 10 wt. %, or from about 0.1 wt. % to about 5 wt. %, based on the total weight of the lubricating oil composition.

[0052] The following examples are presented to exemplify embodiments but are not intended to limit the application to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments outside the stated ranges may still fall within the scope of the application. Specific details described in each example should not be construed as necessary features.

EXAMPLES

[0053] The following examples are intended for illustrative purposes only and do not limit in any way the scope.

Glycerol Capacity

[0054] Components were tested for glycerol capacity, which is the ability to help solubilize glycerol in finished oil. To test a given component, finished oil samples were prepared, each sample containing glycerol and one of the following: a detergent, anti-wear additive, or dispersant.

[0055] For a given component, a glycerol-to-component ratio can be observed at which point no additional glycerol can be solubilized into the finished oil. This ratio marks the glycerol capacity of the given component and is marked by an increase in haziness (haze).

[0056] In the experiments described herein, haze was measured using a BYK Haze-Gard Plus (from BYK Instruments) in a 10mm rectangular, open-top glass calorimeter cell (from Starna Cells Inc.).

[0057] When the component is a dispersant or amine phosphate, the glycerol-to-component ratios can be calculated according to Equation A, wherein the units for the glycerol-to-component ratio is PPM Glycerol per WT% Solubilizing Component.

$$\text{Equation A: } (\text{WT\% Glycerol} \times 10,000) / (\text{WT\% Solubilizing Component})$$

[0058] When the component is a detergent, the glycerol-to-component ratio is expressed in PPM Glycerol per mmol Ca as given by Equation B.

$$\text{Equation B: } (\text{WT\% Glycerol} \times 10,000) / (\text{mmol Ca})$$

[0059] At low glycerol-to-component ratios, low and near-constant haze levels are observed. Upon exceeding the glycerol capacity of a given component, an inflection point is observed in which a near linear and increasing haze levels are observed with increasing glycerol-to-component ratios. This inflection point marks the capacity of a given component to solubilize glycerol. Calculation of this inflection point can be obtained by performing linear regression analysis on the two different regimes and solving for the glycerol-to-component ratio (x). A higher glycerol-to-component ratio at the inflection point is indicative of a greater glycerol capacity.

[0060] In testing the glycerol capacity of a given component, several finished oil samples were prepared. Each sample contained the same amount of the given component while varying the amount of glycerol present.

Baseline (No Solubilizing Component)

[0061] Comparative Examples A, B, C, D, E, and F contained increasing amounts of glycerol without the presence of a solubilizing component. Results are summarized in Table 1 below.

Table 1

Comparative Example	Glycerol %	% Haze
A	0	0.75
B	0.01	1.31
C	0.05	3.02
D	0.1	5.32
E	0.15	8.72
F	0.3	17.4

HHOB Sulfonate

[0062] The haze levels (%) for finished oils with a high-high overbased sulfonate detergent (90 mM) were measured (Examples 1-8). Results are summarized in Table 2 below.

Table 2

Example No.	Glycerol %	% Haze
1	0	2.5
2	0.05	2.5
3	0.1	3.1

4	0.15	11.3
5	0.2	18.4
6	0.25	25.6
7	0.3	32.2
8	0.35	38.1

HOB Sulfonate

[0063] Examples 9-16 contained a high overbased sulfonate detergent (90 mM) along with an increasing amount of glycerol. Haze was measured and the results are summarized in Table 3 below.

Table 3

Example No.	Glycerol %	% Haze
9	0	10.4
10	0.05	11.0
11	0.1	11.8
12	0.15	22.0
13	0.2	31.0
14	0.25	41.6
15	0.3	49.4

16	0.35	59.4
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LOB Sulfonate

[0064] Examples 17-29 contained a low overbased sulfonate detergent (90 mM) and increasing amounts of glycerol. Haze was measured and the results are summarized in Table 4 below.

Table 4

Example No.	Glycerol %	% Haze
17	0	1.66
18	0.0025	1.46
19	0.05	2.08
20	0.0075	2.32
21	0.1	1.42
22	0.125	2.28
23	0.15	2.12
24	0.175	3.11
25	0.2	3.21
26	0.225	3.31
27	0.25	3.16

[0065] Referencing Tables 2-4, the high-high overbased sulfonate (Examples 1-16) exhibited a lower capacity to solubilize glycerol compared to the low overbased sulfonate (Examples 17-27).

[0066] Examples 28-35 contained a high overbased phenate detergent (90 mM) and increasing amounts of glycerol. Haze was measured and the results are summarized below in Table 5.

Table 5

Example No.	Glycerol %	% Haze
28	0	0.6
29	0.0125	1.03
30	0.025	1.08
31	0.0375	1.36
32	0.05	1.64
33	0.0625	2.64
34	0.075	5.28
35	0.0875	8.81

[0067] The finished oils comprising high overbased phenate (Examples 28-35) generally exhibited a higher capacity to solubilize glycerol compared to the finished oils comprising high overbased sulfonate (Examples 9-16).

[0068] Examples 36-42 contained alkyl ammonium dithiophosphate anti-wear additive (1.0 wt.%) and increasing amounts of glycerol. Haze was measured and the results are summarized below in Table 6.

Table 6

Example No.	Glycerol %	% Haze
36	0	3.4
37	0.01	3.1
38	0.025	3.4
39	0.05	3.3
40	0.1	7.5
41	0.15	11.5
42	0.2	19.7

[0069] Examples 43-48 contained alkyl ammonium phosphate anti-wear additive (1.0 wt.%) and increasing amounts of glycerol. Haze was measured and the results are summarized below in Table 7.

Table 7

Example No.	Glycerol %	% Haze

43	0	2.4
44	0.025	2.1
45	0.05	2.6
46	0.1	5.7
47	0.15	10.5
48	0.2	16.9

[0070] As indicated in Tables 6 and 7, alkyl ammonium dithiophosphate (Examples 36-42) and alkyl ammonium phosphate (Examples 43-48) both provided good capacity to solubilize glycerol.

[0071] Examples 49-57 contained ethylene carbonate treated dispersant (5.0 wt.%) and increasing amounts of glycerol. Haze was measured and the results are summarized below in Table 8.

Table 8

Example No.	Glycerol %	% Haze
49	0	2.8
50	0.025	5.2
51	0.05	3.2
52	0.075	5.9
53	0.1	1.7
54	0.125	6.3

55	0.15	8.2
56	0.2	17.0
57	0.25	22.3

[0072] Examples 58-69 contained basic non-EC treated bis-succinamide dispersant (5.0 wt.%) and increasing amounts of glycerol. Haze was measured and the results are summarized below in Table 9.

Table 9

Example No.	Glycerol %	% Haze
58	0	2.0
59	0.025	4.5
60	0.05	5.9
61	0.075	4.7
62	0.1	6.5
63	0.15	5.1
64	0.2	5.8
65	0.3	6.4
66	0.4	6.3
67	0.45	4.0

68	0.5	13.9
69	0.55	20.2

[0073] Tables 8 and 9 suggest that non-EC treated bissuccinimide (Examples 58-69) have a higher capacity to solubilize glycerol compared to EC treated bissuccinimide (Examples 49-57).

[0074] The glycerol capacity of various detergents are summarized below in Table 10.

Table 10

Example No.	Type	Glycerol PPM: mM Ca
70	HHOB Sulfonate	14.2
71	HOB Sulfonate	15.8
72	LOB Sulfonate	>80
73	HOB Phenate	39.8

[0075] As shown in Table 10, Example 72, demonstrated a higher capacity to solubilize glycerol compared to Examples 70, 71, and 73. By comparison, glycerol without the presence of a solubilizing component (Comparative Examples A-F) demonstrated negligible solubility in lubricating oil.

[0076] The glycerol capacity of alkyl ammonium dithiophosphate and alkyl ammonium phosphate anti-wear additives are summarized below in Table 11.

Table 11

Example No.	Type	Glycerol PPM: wt.% Additive
74	Alkyl Ammonium Dithiophosphate	0.080
75	Alkyl Ammonium Phosphate	0.074

[0077] As shown in Table 11, the alkyl ammonium dithiophosphate of Example 74 exhibited a slightly higher capacity to solubilize glycerol than the alkyl ammonium phosphate of Example 75.

[0078] The glycerol capacity of dispersant additives (Examples 76-77) are summarized below in Table 12.

Table 12

Example No.	Type	Glycerol PPM: wt.% Additive
76	EC Treated bissuccinimide	233.1
77	Non-EC Treated bis-succinimide	916.4

[0079] As shown in Table 12, **Example 77**, exhibited a higher capacity to solubilize glycerol than **Example 76**.

[0080] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of embodiments of the invention. For example, the functions described above and implemented for operating are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this

application. Moreover, those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

CLAIMS

1. A method of improving the solubility of an alkyl polyol in a lubricating oil composition, the method comprising lubricating with a lubricating oil composition comprising:

(a) a major amount of an oil of lubricating viscosity;

(b) alkyl polyol having 2 to 20 carbon atoms; and

(c) a solubility-enhancing additive comprising a detergent, dispersant, or anti-wear additive;

wherein the amount of alkyl polyol is from about 0.001 wt. % to about 0.5 wt. % based on the total weight of the lubricating oil composition.

2. The method of claim 1, wherein the detergent is a high-high overbased metal detergent, high overbased metal detergent, medium overbased metal detergent, or low overbased metal detergent.

3. The method of claim 1, wherein the detergent is a magnesium detergent or a calcium detergent.

4. The method of claim 1, wherein the detergent is a carboxylate detergent, a salicylate detergent, a sulfonate detergent, or a phenate detergent.

5. The method of claim 1, wherein the dispersant is non-EC treated bissuccinimide or EC treated bissuccinimide.

6. The method of claim 1, wherein the anti-wear additive is an alkyl ammonium dithiophosphate or alkyl ammonium phosphate.
7. The method of claim 1, wherein the alkyl polyol is cyclic or branched.
8. The method of claim 1, wherein the alkyl polyol is glycerol, ethylene glycol, 3-amino-1,2-propanediol, 1,2,4-butanetriol, 1,1,1,-tris(hydroxymethyl)propane, meso-erythritol, D-sorbitol, xylitol, 2,2-diethyl-1,3-propanediol, 3-methoxy-1,2,-propanediol, 2,2-dimethyl-1,3-propanediol, pentaerythritol, or polyvinyl alcohol.
9. The method of claim 1, wherein the alkyl polyol includes heteroatoms.
10. A method of improving the solubility of glycerol in a lubricating composition, the method comprising lubricating with a lubricating oil composition comprising:
 - (a) a major amount of an oil of lubricating viscosity;
 - (b) glycerol; and
 - (c) at least one detergent, succinimide dispersant, or amine phosphate anti-wear additive;wherein the amount of glycerol is from about 0.001 wt. % to about 0.5 wt. % based on the total weight of the lubricating oil composition.

11. The method of claim 10, wherein the detergent is a high-high overbased metal detergent, high overbased metal detergent, medium overbased metal detergent, or low overbased metal detergent.
12. The method of claim 10, wherein the detergent is a magnesium detergent or a calcium detergent.
13. The method of claim 10, wherein the detergent is a carboxylate detergent, a salicylate detergent, a sulfonate detergent, or a phenate detergent.
14. The method of claim 10, wherein the dispersant is non-EC treated bissuccinimide or EC treated bissuccinimide.
15. The method of claim 10, wherein the anti-wear additive is an alkyl ammonium dithiophosphate or alkyl ammonium phosphate.