

METHOD FOR IMPROVING THERMAL-OXIDATIVE STABILITY AND ELASTOMER COMPATIBILITY

FIELD

[0002] This disclosure relates to di-alkylated aromatic base stocks, lubricating oils containing the di-alkylated aromatic base stocks, and, in an industrial, automotive or other apparatus lubricated with the lubricating oil, improving thermo-oxidative stability and elastomer compatibility.

BACKGROUND

[0003] Lubricants in commercial use today are prepared from a variety of natural and synthetic base stocks admixed with various additive packages and solvents depending upon their intended application. The base stocks typically include mineral oils, poly alpha olefins (PAO), gas-to-liquid base oils (GTL), silicone oils, phosphate esters, diesters, polyol esters, and the like.

[0004] Many synthetic base stocks offer good thermo-oxidative stability in lubricant formulations when properly additized. However, elastomer compatibility requirements for synthetic lubricant formulations can limit synthetic base stock selection due to compatibility performance. Synthetic base stocks, with hetero-atoms, e.g., esters, are polar and have high compatibility with elastomers causing swelling and softening changes that can compromise elastomer performance. This is especially true for acrylonitrile-butadiene elastomers (NBR). Synthetic base stocks that are non-polar, such as PAOs, have an inherently opposite effect in NBR, with tendencies to extract elastomer plasticizer causing shrinkage and hardening. As a result, formulations using synthetic base stocks require proper selection to ensure elastomer integrity. Those which don't could experience elastomer incompatibility issues such as severe

swelling and disintegration to shrinkage. Each of these scenarios can lead to seal failures. If severe enough, seal failures can cause loss of lubrication and potential harm to the equipment.

[0005] While commercially available synthetic base stocks such as alkylated naphthalene (AN) have polarities in between that of esters and PAOs, they too have shown limitations in thermo-oxidative stability and elastomer compatibility balance as synthetic base stocks. This is inherent to their chemical structures, commercial AN's consist of various isomers and substitution distributions.

[0006] Formulations comprised of the lowest viscosity grades of commercial ANs perform well in terms of their thermo-oxidation behavior, however, they have undesirable NBR elastomer swell. Formulations with higher viscosity commercial ANs have been found to be more neutral in elastomer compatibility performance, but show more debits in thermo-oxidation behavior.

[0007] Equipment manufactures continue to place higher demands on synthetic lubricants through the introduction of new elastomer compatibility requirements and/or redefining existing elastomer requirements. This is to ensure optimum performance of the equipment by providing no damage or harm to elastomeric materials used in the equipment, e.g., seals, hoses, and the like.

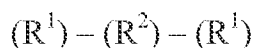
[0008] Therefore, there is a need for a base stock that exhibits a desired balance of thermo-oxidative stability and elastomer compatibility.

[0009] The present disclosure also provides many additional advantages, which shall become apparent as described below.

SUMMARY

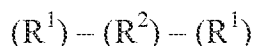
[0010] This disclosure is directed in part to a di-alkylated aromatic base stock. The base stock exhibits significantly superior thermal-oxidative stability and elastomer compatibility/manageability in neat form or in lubricant formulations in comparison with conventional alkyl naphthalene (AN) base stocks. These base stocks provide for longer life lubricants with more neutral NBR elastomer compatibility.

[0011] This disclosure relates in part to a method for improving thermo-oxidative stability and elastomer compatibility in an apparatus lubricated with a lubricating oil by using as the lubricating oil a formulated oil comprising a lubricating oil base stock; wherein the lubricating oil base stock comprises a di-alkylated aromatic base stock of the formula:



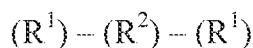
wherein each R^1 is the same or different and represents a C_{10} - C_{30} alkyl group; R^2 represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein BI is TMN minus 2 (two terminal methyl carbons); wherein the di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

[0012] This disclosure also relates in part to a lubricating oil comprising a lubricating oil base stock; wherein the lubricating oil base stock comprises a di-alkylated aromatic base stock of the formula:



wherein each R^1 is the same or different and represents a C_{10} - C_{30} alkyl group; R^2 represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein BI is TMN minus 2 (two terminal methyl carbons); wherein the di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

[0013] This disclosure also relates in part to a di-alkylated aromatic base stock of the formula:



wherein each R^1 is the same or different and represents a C_{10} - C_{30} alkyl group; R^2 represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, wherein the

di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein BI is TMN minus 2 (two terminal methyl carbons); and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

[0014] It has been surprisingly found that the di-alkylated naphthalene containing base stocks of this disclosure improve both thermo-oxidation stability and elastomer compatibility/manageability, when compared to conventional alkylated naphthalene base stocks. The base stocks of this disclosure minimize varnish, sludge, wear and corrosion through the reduction of oxidation byproducts in lubricant formulations and thus extended oil drain interval, increase lubricant service life, reduce environmental footprint and provide sustainability benefits.

[0015] Further objects, features and advantages of the present disclosure will be understood by reference to the following drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 graphically depicts the average alkyl carbon number versus the ration of oxidation and NBR elastomer volume swell as shown in the Examples.

[0017] Fig. 2 shows results for oxidation testing and elastomer volume swell testing for di-alkylated naphthalene base stocks of this disclosure as shown in the Examples.

[0018] Fig. 3 shows total methyl number (TMN) and branching index (BI) results for di-alkylated naphthalene base stocks of this disclosure as shown in the Examples.

DETAILED DESCRIPTION

[0019] All numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0020] Synthetic base stocks are chosen for top-tier synthetic lubricant formulations because of the high performance levels they offer, due to their unique chemical composition(s). Synthetic base stock selection for synthetic lubricant formulations are determined by the application and its performance requirements. Two key performance criteria required for top-tier synthetic lubricant formulations include good thermo-oxidative stability and acceptable elastomer compatibility. This disclosure is directed to top-tier synthetic lubricant formulations offering desired balance in thermo-oxidative stability and elastomer compatibility. The formulations of this disclosure are comprised of alkylated naphthalene synthetic base stocks, specifically di-alkylated naphthalenes.

[0021] This disclosure provides lubricating oils useful as industrial oils (e.g., circulating oils, compressor oils, gear oils, and the like), automotive oils (engine oils, diesel engine oils, and the like), marine oils (engine oils, diesel engine oils, and the like), mechanical system oils, and in other applications characterized by an excellent balance of thermo-oxidative stability and elastomer compatibility/manageability. The lubricating oils are based on high quality base stocks including a di-alkylated aromatic base stock. In the present specification and claims, the terms base oil(s) and base stock(s) are used interchangeably. The lubricating oils of this disclosure can be used preferably in the formulation of industrial lubricants, and also in the formulation of automotive engine lubricants, greases, hydraulic lubricants, marine lubricants, gas turbine engine oils, gear oils, and the like. As used herein, the term “apparatus” refers to any industrial (e.g., compressor, gear box, etc.), automotive (e.g., engine, diesel engine, etc.), marine

(e.g., engine, diesel engine, etc.), mechanical system, or other device or equipment lubricated with a lubricating oil.

[0022] As used herein, thermo-oxidative stability is determined in accordance with the testing procedure described in the Examples, and elastomer compatibility is determined by ISO-1817. Viscosity is determined by ASTM D-445.

Lubricating Oil Base Stocks

[0023] A wide range of lubricating oils is known in the art. Lubricating oils that are useful in the present disclosure are both natural oils and synthetic oils. Natural and synthetic oils (or mixtures thereof) can be used unrefined, refined, or rerefined (the latter is also known as reclaimed or reprocessed oil). Unrefined oils are those obtained directly from a natural or synthetic source and used without added purification. These include shale oil obtained directly from retorting operations, petroleum oil obtained directly from primary distillation, and ester oil obtained directly from an esterification process. Refined oils are similar to the oils discussed for unrefined oils except refined oils are subjected to one or more purification steps to improve the at least one lubricating oil property. One skilled in the art is familiar with many purification processes. These processes include solvent extraction, secondary distillation, acid extraction, base extraction, filtration, and percolation. Rerefined oils are obtained by processes analogous to refined oils but using an oil that has been previously used as a feed stock.

[0024] Groups I, II, III, IV and V are broad categories of base oil stocks developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org) to create guidelines for lubricant base oils. Group I base stocks generally have a viscosity index of between 80 to 120 and contain greater than 0.03% sulfur and less than 90% saturates. Group II base stocks generally have a viscosity index of between 80 to 120, and contain less than or equal to 0.03% sulfur and greater than or equal to 90% saturates. Group III stock

generally has a viscosity index greater than 120 and contains less than or equal to 0.03% sulfur and greater than 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stocks include base stocks not included in Groups I-IV. The table below summarizes properties of each of these five groups.

	Base Oil Properties		
	Saturates	Sulfur	Viscosity Index
Group I	<90 and/or	>0.03% and	≥80 and <120
Group II	≥90 and	≤0.03% and	≥80 and <120
Group III	≥90 and	≤0.03% and	≥120
Group IV	Includes polyalphaolefins (PAO)		
Group V	All other base oil stocks not included in Groups I, II, III or IV		

[0025] Natural oils include animal oils, vegetable oils (castor oil and lard oil, for example), and mineral oils. Animal and vegetable oils possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils derived from coal or shale are also useful in the present disclosure. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrorefined, or solvent extracted.

[0026] Group II and/or Group III hydroprocessed or hydrocracked base stocks, as well as synthetic oils such as polyalphaolefins, alkyl aromatics and synthetic esters, i.e. Group IV and Group V oils are also well known base stock oils. The Group III base stock is highly paraffinic with saturates level higher than 90%, preferably 95%, a viscosity index greater than 125, preferably greater than 135, or more preferably greater than 140, very low aromatics of 3%, preferably less than 1%, and aniline point of 118 or higher.

[0027] Synthetic oils include hydrocarbon oil such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, for example). Polyalphaolefin (PAO) oil base stocks, the Group IV API base stocks, are a commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C₆, C₈, C₁₀, C₁₂, C₁₄, C₁₆ olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073, which are incorporated herein by reference in their entirety. Group IV oils, that is, the PAO base stocks have viscosity indices preferably greater than 130, more preferably greater than 135, still more preferably greater than 140.

[0028] Esters may be useful in the lubricating oils of this disclosure. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

[0029] Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, preferably the hindered polyols such as the neopentyl polyols; e.g., neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol with alkanoic acids containing at least 4 carbon atoms, preferably C₅ to C₃₀ acids such as saturated straight chain fatty acids including caprylic acid, capric acids, lauric acid, myristic acid, palmitic acid, stearic acid,

arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures of any of these materials.

[0030] Esters should be used in a amount such that the improved thermo-oxidative stability and elastomer compatibility provided by the lubricating oils of this disclosure are not adversely affected. The esters preferably have a D5293 viscosity of less than 10,000 cP at -35°C.

[0031] Non-conventional or unconventional base stocks and/or base oils include one or a mixture of base stock(s) and/or base oil(s) derived from: (1) one or more Gas-to-Liquids (GTL) materials, as well as (2) hydrodewaxed, or hydroisomerized/cat (and/or solvent) dewaxed base stock(s) and/or base oils derived from synthetic wax, natural wax or waxy feeds, mineral and/or non-mineral oil waxy feed stocks such as gas oils, slack waxes (derived from the solvent dewaxing of natural oils, mineral oils or synthetic oils; e.g., Fischer-Tropsch feed stocks), natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, foots oil or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials recovered from coal liquefaction or shale oil, linear or branched hydrocarbyl compounds with carbon number of 20 or greater, preferably 30 or greater and mixtures of such base stocks and/or base oils.

[0032] GTL materials are materials that are derived via one or more synthesis, combination, transformation, rearrangement, and/or degradation/deconstructive processes from gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks such as hydrogen, carbon dioxide, carbon monoxide, water, methane, ethane, ethylene, acetylene, propane, propylene, propyne, butane, butylenes, and butynes. GTL base stocks and/or base oils are GTL materials of lubricating viscosity that are generally derived from hydrocarbons; for example, waxy synthesized hydrocarbons, that are themselves

derived from simpler gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks. GTL base stock(s) and/or base oil(s) include oils boiling in the lube oil boiling range (1) separated/fractionated from synthesized GTL materials such as, for example, by distillation and subsequently subjected to a final wax processing step which involves either or both of a catalytic dewaxing process, or a solvent dewaxing process, to produce lube oils of reduced/low pour point; (2) synthesized wax isomerates, comprising, for example, hydrodewaxed or hydroisomerized cat and/or solvent dewaxed synthesized wax or waxy hydrocarbons; (3) hydrodewaxed or hydroisomerized cat and/or solvent dewaxed Fischer-Tropsch (F-T) material (i.e., hydrocarbons, waxy hydrocarbons, waxes and possible analogous oxygenates); preferably hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxing dewaxed F-T waxy hydrocarbons, or hydrodewaxed or hydroisomerized/followed by cat (or solvent) dewaxing dewaxed, F-T waxes, or mixtures thereof.

[0033] GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxed wax or waxy feed, preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100°C of from 2 mm²/s to 50 mm²/s (ASTM D445). They are further characterized typically as having pour points of -5°C to -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of 80 to 140 or greater (ASTM D2270).

[0034] In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base

stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than 10 ppm, and more typically less than 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this materially especially suitable for the formulation of low SAP products.

[0035] The term GTL base stock and/or base oil and/or wax isomerate base stock and/or base oil is to be understood as embracing individual fractions of such materials of wide viscosity range as recovered in the production process, mixtures of two or more of such fractions, as well as mixtures of one or two or more low viscosity fractions with one, two or more higher viscosity fractions to produce a blend wherein the blend exhibits a target kinematic viscosity.

[0036] The GTL material, from which the GTL base stock(s) and/or base oil(s) is/are derived is preferably an F-T material (i.e., hydrocarbons, waxy hydrocarbons, wax).

[0037] Base oils for use in the formulated lubricating oils useful in the present disclosure are any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils and mixtures thereof, preferably API Group II, Group III, Group IV, and Group V oils and mixtures thereof, more preferably the Group III to Group V base oils due to their exceptional volatility, stability, viscometric and cleanliness features. Minor quantities of Group I stock, such as the amount used to dilute additives for blending into formulated lube oil products, can be tolerated but should be kept to a minimum, i.e. amounts only associated with their use as diluent/carrier oil for additives used on an "as-received" basis. Even in regard to the Group II stocks, it is preferred that the Group II stock be in the higher quality range associated with that stock, i.e. a Group II stock having a viscosity index in the range $100 < VI < 120$.

[0038] In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) and hydrodewaxed, or hydroisomerized/cat (and/or solvent) dewaxed base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than 10 ppm, and more typically less than 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this material especially suitable for the formulation of low sulfur, sulfated ash, and phosphorus (low SAP) products.

[0039] The basestock component of the present lubricating oils will typically be from 80 to 99 weight percent of the total composition (all proportions and percentages set out in this specification are by weight unless the contrary is stated) and more usually in the range of 90 to 99 weight percent.

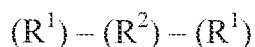
Di-Alkylated Aromatic Base Stocks

[0040] Di-alkylated aromatic base stocks useful in this disclosure include, for example, di-alkylated naphthalenes and di-alkylated benzenes. The di-alkylated aromatic base stock can be any hydrocarbyl molecule that contains at least 15% of its weight derived from an aromatic moiety such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These di-alkylated aromatic base stocks include di-alkyl benzenes, di-alkyl naphthalenes, di-alkyl diphenyl oxides, di-alkyl naphthols, di-alkyl diphenyl sulfides, di-alkylated bis-phenol A, di-alkylated thiodiphenol, and the like. The hydrocarbyl groups can range from C₆ up to C₆₀ with a range of C₈ to C₄₀ often being preferred. A mixture of hydrocarbyl groups is often preferred. The hydrocarbyl group can optionally

contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100°C of approximately 3 cSt to 50 cSt are preferred, with viscosities of approximately 3.4 cSt to 30 cSt often being more preferred for the di-alkylated aromatic base stock. Naphthalene or methyl naphthalene, for example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like.

[0041] The di-alkylated aromatic base stock can contain a major portion of di-alkylated aromatic base stock (e.g., di-alkylated naphthalenes) and a minor portion of other alkylated materials (e.g., mono-alkylated, polyalkylated naphthalenes). The aromatic can be mono-, di- or poly-functionalized. For multiple aromatic ring structures such as naphthalenes, the di-alkylation can be on one ring or on separate rings.

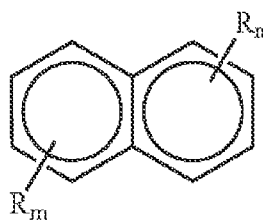
[0042] The di-alkylated aromatic base stock useful in this disclosure can be represented by the formula:



wherein each R^1 is the same or different and represents an alkyl group, and R^2 represents an aromatic moiety (e.g., naphthalene). As described herein, the branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein BI is TMN minus 2 (two terminal methyl carbons).

[0043] The R^1 alkyl groups can be linear or branched. R^1 can be a C_1 - C_{30} , preferably C_1 - C_{20} or C_{10} - C_{30} linear alkyl group; a C_3 - C_{300} , preferably C_3 - C_{100} , more preferably C_3 - C_{30} or C_{10} - C_{30} branched alkyl group; or mixtures of such groups. The R^2 aromatic group can be naphthalene, benzene, and the like.

[0044] Illustrative di-alkylated naphthalenes useful in the present disclosure are described, for example, in U.S. Patent Publication No. 2008/0300157. A preferred di-alkylated naphthalene of this disclosure has the formula:



wherein $n+m=2$, and R is C_1 - C_{30} , preferably C_1 - C_{20} linear alkyl group, C_3 - C_{300} , preferably C_3 - C_{100} , more preferably C_3 - C_{30} branched alkyl group or mixtures of such groups with the total number of carbons in R_m and R_n , preferably being at least 2.

[0045] For di-alkylated aromatic base stocks containing a major portion of di-alkylated aromatic base stock (e.g., di-alkylated naphthalenes) and a minor portion of other alkylated materials (e.g., mono-alkylated, polyalkylated naphthalenes), in the formula above, the other alkylated materials include those where $n+m=1$ and 3-8, preferably 1 and 3-6, more preferably 1 and 3-5.

[0046] Examples of typical di-alkyl naphthalenes are di- C_3 alkyl naphthalene, di- C_4 alkyl naphthalene, di- C_5 alkyl naphthalene, di- C_6 alkyl naphthalene, di- C_8 alkyl naphthalene, di- C_{10} alkyl naphthalene, di- C_{12} alkyl naphthalene, di- C_{14} alkyl naphthalene, di- C_{16} alkyl naphthalene, di- C_{18} alkyl naphthalene, etc., di- C_{10} - C_{14} mixed alkyl naphthalene, di- C_6 - C_{18} mixed alkyl naphthalene, or the di- C_3 , C_4 , C_5 ,

C₆, C₈, C₁₀, C₁₂, C₁₄, C₁₆, C₁₈ or mixture thereof alkyl monomethyl, dimethyl, ethyl, diethyl, or methylethyl naphthalene, or mixtures thereof. The alkyl group can also be branched alkyl group with C₁₀ to C₃₀₀, e.g., C₂₄-C₅₆ branched alkyl naphthalene, C₂₄-C₅₆ branched alkyl di-C₁-C₄ naphthalene. These branched di-alkyl group substituted naphthalenes or branched alkyl group substituted di-C₁-C₄ naphthalene can also be used as mixtures with the previously recited materials. These branched alkyl groups can be prepared from oligomerization of small olefins, such as C₅ to C₂₄ alpha- or internal-olefins. When the branched alkyl group is very large (that is 8 to 300 carbons), usually only one or two of such alkyl groups are attached to the naphthalene core. The alkyl groups on the naphthalene ring can also be mixtures of the above alkyl groups. Sometimes mixed alkyl groups are advantageous because they provide more improvement of pour points and low temperature fluid properties. The fully hydrogenated fluid di-alkyl naphthalenes can also be used for blending with GTL base stock/base oil, but the di-alkyl naphthalenes are preferred.

[0047] For alkylated aromatic base stocks containing a major portion of di-alkylated aromatic base stock (e.g., di-alkylated naphthalenes) and a minor portion of other alkylated materials (e.g., mono-alkylated, polyalkylated naphthalenes), examples of other alkyl naphthalenes are mono-, tri-, tetra-, or penta- versions of C₃ alkyl naphthalene, C₄ alkyl naphthalene, C₅ alkyl naphthalene, C₆ alkyl naphthalene, C₈ alkyl naphthalene, C₁₀ alkyl naphthalene, C₁₂ alkyl naphthalene, C₁₄ alkyl naphthalene, C₁₆ alkyl naphthalene, C₁₈ alkyl naphthalene, etc., C₁₀-C₁₄ mixed alkyl naphthalene, C₆-C₁₈ mixed alkyl naphthalene, or the mono-, tri-, tetra-, or penta- versions of C₃, C₄, C₅, C₆, C₈, C₁₀, C₁₂, C₁₄, C₁₆, C₁₈ or mixture thereof alkyl monomethyl, dimethyl, ethyl, diethyl, or methylethyl naphthalene, or mixtures thereof. The alkyl group can also be branched alkyl group with C₁₀ to C₃₀₀, e.g., C₂₄-C₅₆ branched alkyl naphthalene, C₂₄-C₅₆ branched alkyl mono-, tri-, tetra- or penta-C₁-C₄ naphthalene. These branched alkyl group substituted naphthalenes or branched

alkyl group substituted mono-, tri-, tetra- or penta C₁-C₄ naphthalene can also be used as mixtures with the previously recited materials. These branched alkyl group can be prepared from oligomerization of small olefins, such as C₅ to C₂₄ alpha- or internal-olefins. When the branched alkyl group is very large (that is 8 to 300 carbons), usually only one or two of such alkyl groups are attached to the naphthalene core. The alkyl groups on the naphthalene ring can also be mixtures of the above alkyl groups. Sometimes mixed alkyl groups are advantageous because they provide more improvement of pour points and low temperature fluid properties. The fully hydrogenated fluid alkylnaphthalenes can also be used for blending with GTL base stock/base oil, but the alkyl naphthalenes are preferred.

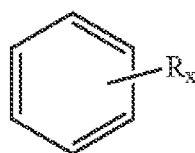
[0048] Typically the di-alkyl naphthalenes are prepared by alkylation of naphthalene or short chain alkyl naphthalene, such as methyl or di-methyl naphthalene, with olefins, alcohols or alkylchlorides of 6 to 24 carbons over acidic catalyst inducing typical Friedel Crafts catalysts. Typical Friedel-Crafts catalysts are AlCl₃, BF₃, HT, zeolites, amorphous aluminosilicates, acid clays, acidic metal oxides or metal salts, USY, etc.

[0049] The naphthalene or mono- or di-substituted short chain alkyl naphthalenes can be derived from any conventional naphthalene-producing process from petroleum, petrochemical process or coal process or source stream. Naphthalene-containing feeds can be made from aromaticization of suitable streams available from the F-T process. For example, aromatization of olefins or paraffins can produce naphthalene or naphthalene-containing component. Many medium or light cycle oils from petroleum refining processes contain significant amounts of naphthalene, substituted naphthalenes or naphthalene derivatives. Indeed, substituted naphthalenes recovered from whatever source, if possessing up to three alkyl carbons can be used as raw material to produce alkylnaphthalene for this disclosure. Furthermore, alkylated naphthalenes recovered from whatever

source or processing can be used in the present method, provided they possess kinematic viscosities, VI, pour point, etc.

[0050] Illustrative di-alkylated benzenes useful in this disclosure include, for example, those described in U.S. Patent Publication 2008/0300157. Di-alkylated benzenes having a viscosity at 100°C of 1.5 to 600 cSt, VI of 0 to 200 and pour point of 0°C or less, preferably -15°C or less, more preferably -25°C or less, still more preferably -35°C or less, most preferably -60°C or less are useful for this disclosure.

[0051] A preferred di-alkylated benzene of this disclosure has the formula:



wherein $x=2$. One or two of the alkyl groups can be small alkyl radical of C_1 to C_5 alkyl group, preferably C_1 - C_2 alkyl group. The other alkyl group can be any combination of linear C_{10} - C_{30} alkyl group, or branched C_{10} and higher up to C_{300} alkyl group, preferably C_{15} - C_{50} branched alkyl group. These branched large alkyl radicals can be prepared from the oligomerization or polymerization of C_3 to C_{20} , internal or alpha-olefins or mixture of these olefins. The total number of carbons in the alkyl substituents ranged from C_{10} to C_{300} .

[0052] For di-alkylated aromatic base stocks containing a major portion of di-alkylated aromatic base stock (e.g., di-alkylated benzenes) and a minor portion of other alkylated materials (e.g., mono-alkylated, polyalkylated benzenes), in the formula above, the other alkylated materials include those where $x=1$ and 3-6, preferably 1 and 3-5, more preferably 1, 3 and 4. For monoalkylated benzene, the R can be linear C_{10} to C_{30} alkyl group or a C_{10} - C_{300} branched alkyl group

preferably C₁₀-C₁₀₀ branched alkyl group, more preferably C₁₅-C₅₀ branched alkyl group. When n is 3 or greater than 3, one or two of the alkyl group can be small alkyl radical of C₁ to C₅ alkyl group, preferably C₁-C₂ alkyl group. The other alkyl group or groups can be any combination of linear C₁₀-C₃₀ alkyl group, or branched C₁₀ and higher up to C₃₀₀ alkyl group, preferably C₁₅-C₅₀ branched alkyl group. These branched large alkyl radicals can be prepared from the oligomerization or polymerization of C₃ to C₂₀, internal or alpha-olefins or mixture of these olefins. The total number of carbons in the alkyl substituents ranged from C₁₀ to C₃₀₀.

[0053] Illustrative di-alkylated benzenes include, for example, those in which one or two of the alkyl groups can be small alkyl radical of C₁ to C₅ alkyl group, preferably C₁-C₂ alkyl group. The other alkyl group or groups can be any combination of linear C₁₀-C₃₀ alkyl group, or branched C₁₀ and higher up to C₃₀₀ alkyl group, preferably C₁₅-C₅₀ branched alkyl group. These branched large alkyl radicals can be prepared from the oligomerization or polymerization of C₃ to C₂₀, internal or alpha-olefins or mixture of these olefins. The total number of carbons in the alkyl substituents range from C₁₀ to C₃₀₀. Preferred alkyl benzene fluids can be prepared according to U.S. Patent No. 6,491,809.

[0054] For di-alkylated aromatic base stocks containing a major portion of di-alkylated aromatic base stock (e.g., di-alkylated naphthalenes) and a minor portion of other alkylated materials (e.g., mono-alkylated, polyalkylated naphthalenes), illustrative monoalkylated benzenes include, for example, linear C₁₀ to C₃₀ alkyl benzene or a C₁₀-C₃₀₀ branched alkyl benzene, preferably C₁₀-C₁₀₀ branched alkyl benene, more preferably C₁₅-C₅₀ branched alkyl group. Illustrative multialkylated benzenes include, for example, those in which one or two of the alkyl groups can be small alkyl radical of C₁ to C₅ alkyl group, preferably C₁-C₂ alkyl group. The other alkyl group or groups can be any combination of linear C₁₀-C₃₀ alkyl group, or branched C₁₀ and higher up to C₃₀₀

alkyl group, preferably C₁₅-C₅₀ branched alkyl group. These branched large alkyl radicals can be prepared from the oligomerization or polymerization of C₃ to C₂₀, internal or alpha-olefins or mixture of these olefins. The total number of carbons in the alkyl substituents ranged from C₁₀ to C₃₀₀. Preferred alkyl benzene fluids can be prepared according to U.S. Patent Nos. 6,071,864 and 6,491,809.

[0055] Included in this class of base stock blend components are, for example, long chain alkylbenzenes and long chain alkyl naphthalenes which are preferred materials since they are hydrolytically stable and may therefore be used in combination with the PAO component of the base stock in wet applications. The di-alkyl naphthalenes are known materials and are described, for example, in U.S. Patent No. 4,714,794. The use of a mixture of monoalkylated and polyalkylated naphthalene as a base for synthetic functional fluids is also described in U.S. Patent No. 4,604,491. The preferred di-alkyl naphthalenes are those having a relatively long chain alkyl group typically from 10 to 40 carbon atoms although longer chains may be used if desired. Di-alkylnaphthalenes produced by alkylating naphthalene with an olefin of 14 to 20 carbon atoms has particularly good properties, especially when zeolites such as the large pore size zeolites are used as the alkylating catalyst, as described in U.S. Patent No. 5,602,086.

[0056] An alternative secondary blending stock is a di-alkyl benzene or mixture of alkylbenzenes. The alkyl substituents in these fluids are typically alkyl groups of 8 to 25 carbon atoms, usually from 10 to 18 carbon atoms and up to three such substituents may be present, as described in ACS Petroleum Chemistry Preprint 1053-1058, "Poly n-Alkylbenzene Compounds: A Class of Thermally Stable and Wide Liquid Range Fluids", Eapen et al, Phila. 1984. Tri-alkyl benzenes may also be produced by the cydodimerization of 1-alkynes of 8 to 12 carbon atoms as described in U.S. Patent No. 5,055,626. Other alkylbenzenes are described in U.S. Patent No. 4,658,072. Alkylbenzenes have been used as lubricant base stocks, especially for low temperature applications. They are

commercially available from producers of linear alkylbenzenes (LABs) such as Vista Chemical Co, Huntsman Chemical Co. as well as ChevronTexaco and Nippon Oil Co. The linear alkylbenzenes typically have good low pour points and low temperature viscosities and VI values greater than 100 together with good solvency for additives. Other alkylated aromatics which may be used when desirable are described, for example, in "Synthetic Lubricants and High Performance Functional Fluids", Dressler, H., chap 5, (R. L. Shubkin (Ed.)), Marcel Dekker, N.Y. 1993.

[0057] Also included in this class and with very desirable lubricating characteristics are the di-alkylated aromatic compounds including the di-alkylated diphenyl compounds such as the di-alkylated diphenyl oxides, di-alkylated diphenyl sulfides and di-alkylated diphenyl methanes and the a di-alkylated phenoxathins as well as the di-alkyl thiophenes, di-alkyl benzofurans and the ethers of sulfur-containing aromatics.

[0058] A preferred method for preparing the di-alkylated aromatic base stocks of this disclosure involves contacting at least one alkylatable aromatic compound with an alkylating agent and a catalyst under suitable reaction conditions. The resulting alkylaromatic compounds can be characterized by a dialkylate product content of at least 44 wt% and a tri- and higher poly-alkylate product content of no more than 20 wt%. The catalyst can be a low sodium zeolite USY catalyst. Such a process is disclosed in copending U.S. Patent Application Serial No. 13/313,380, filed December 7, 2011, the disclosure of which is incorporated herein by reference in its entirety.

[0059] Alternatively, the di-alkylated aromatic base stocks of this disclosure can be prepared by distillation of a crude alkylated aromatic stream. For example, a conventional product containing 10 wt% dialkylate and 90 wt% monoalkylate, trialkylate and higher alkylates can be distilled to give the dialkylate product in high selectivity.

[0060] In the above process, the reactor effluent stream can comprise at least 44 wt% dialkylate product and no more than 20 wt% trialkylate and higher polyalkylate product. The reactor effluent prior to any stripping step can comprise at least 44 wt%, preferably at least 50 wt%, preferably at least 55 wt%, preferably at least 60 wt%, preferably at least 65 wt%, preferably at least 70 wt%, preferably at least 75 wt%, preferably at least 80 wt%, preferably at least 85 wt%, preferably at least 90 wt%, and more preferably at least 95 wt% or greater of dialkylate product. The reactor effluent prior to any stripping step also can comprise no more than 30 wt%, no more than 25 wt%, no more than 20 wt%, no more than 15 wt%, no more than 10 wt%, no more than 5 wt%, no more than 2.5 wt%, and preferably 0 wt% of tri- and higher poly-alkylate products. The dialkylate products produced by the aboveprocess are preferred products for used in this disclosure.

[0061] The branching characteristics of the alkyl groups or substituents of the di-alkylated aromatic base stocks of this disclosure are determined as follows:

$$TMN = \frac{\text{Averaged chain length} \cdot \text{Sum of integrated areas for all methyl groups}}{\text{Carbon number} \cdot \text{Total integration area for all aliphatic carbons}}$$

$$BI = TMN \text{ minus } 2(\text{two terminal methyl carbons})$$

[0062] The branching characteristics of the alkyl groups or substituents of the di-alkylated aromatic base stocks of this disclosure are defined by the “total methyl numbers (abbreviated as TMN)” determined by C¹³ NMR spectroscopy. The determination of branching characteristics of dialkyl benzene are described, for example, in U.S. Patent No. 8,329,966, the disclosure of which is incorporated herein be reference in its entirety.

[0063] This disclosure provides a synthetic base oil composition comprising a di-alkyl aromatic compound having an alkyl side chain carbon number from C₁₀ to C₂₀ or greater, preferably from C₁₁ to C₂₀, more preferably from C₁₂ to C₁₆. In accordance with the present disclosure, the branching characteristics of the dialkyl side chains has a total methyl number ("TMN") determined by C¹³ NMR spectroscopy of from 1.0 to 2.1 or has a branching index ("BI") of from -1.0 to 0.1. In a preferred embodiment, the TMN of the di-alkyl aromatic compound is from 0.99 to 2.0 or wherein the BI is from -0.99 to 0.099. In a more preferred embodiment, the TMN of the di-alkyl aromatic compound is from 0.90 to 1.9 or wherein the BI is from -0.9 to 0.09.

[0064] The di-alkylated aromatic base stock component can be used in neat form. Lubricant compositions can contain greater than 10 wt. % of the di-alkylated aromatic base stocks of this disclosure, preferably from 15 wt. % to 95 wt. % or greater, more preferably from 20 wt. % to 95 wt. % or greater, and even more preferably from 25 wt. % to 95 wt. % or greater, depending on the application.

Other Additives

[0065] The formulated lubricating oil useful in the present disclosure may additionally contain one or more of the other commonly used lubricating oil performance additives including but not limited to dispersants, other detergents, corrosion inhibitors, rust inhibitors, metal deactivators, other anti-wear agents and/or extreme pressure additives, anti-seizure agents, wax modifiers, viscosity index improvers, viscosity modifiers, fluid-loss additives, seal compatibility agents, other friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, emulsifiers, densifiers, wetting agents, gelling agents, tackiness agents, colorants, and others. For a review of many commonly used additives, see Klamann in Lubricants and Related Products, Verlag Chemie, Deerfield Beach, FL; ISBN 0-89573-177-0. Reference is also

made to "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation of Parkridge, NJ (1973).

[0066] The types and quantities of performance additives used in combination with the instant disclosure in lubricant compositions are not limited by the examples shown herein as illustrations.

Viscosity Improvers

[0067] Viscosity improvers (also known as Viscosity Index modifiers, and VI improvers) increase the viscosity of the oil composition at elevated temperatures which increases film thickness, while having limited effect on viscosity at low temperatures.

[0068] Suitable viscosity improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are between 10,000 to 1,000,000, more typically 20,000 to 500,000, and even more typically between 50,000 and 200,000.

[0069] Examples of suitable viscosity improvers are polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity index improver. Another suitable viscosity index improver is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity index improvers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 molecular weight.

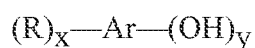
[0070] The amount of viscosity modifier may range from 0 to 8 wt%, preferably zero to 4 wt%, more preferably zero to 2 wt% based on active ingredient and depending on the specific viscosity modifier used.

Antioxidants

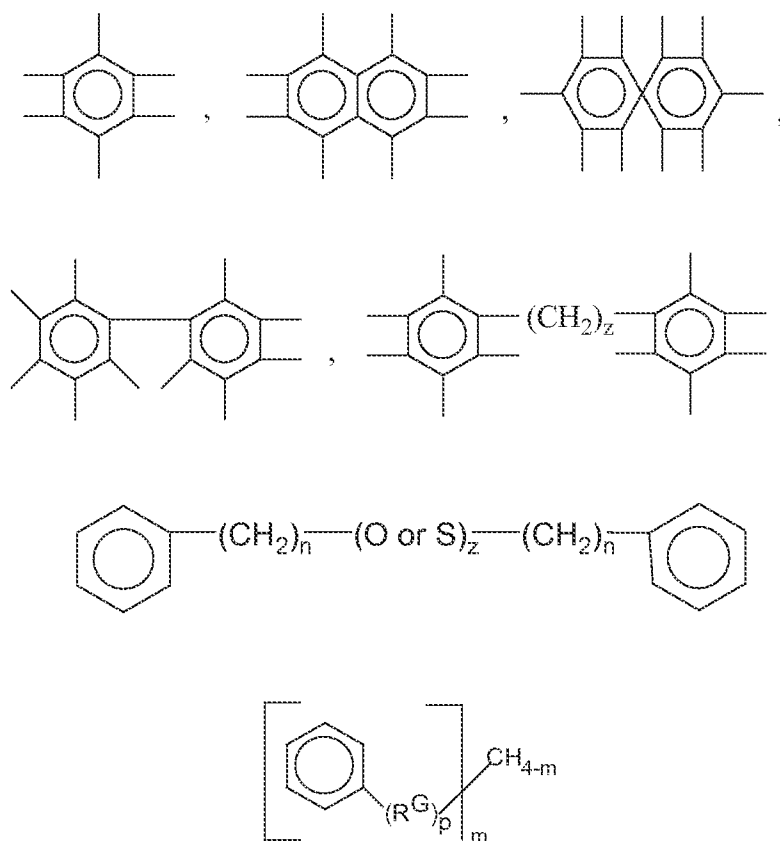
[0071] Typical anti-oxidant include phenolic anti-oxidants, aminic anti-oxidants and oil-soluble copper complexes.

[0072] The phenolic antioxidants include sulfurized and non-sulfurized phenolic antioxidants. The terms “phenolic type” or “phenolic antioxidant” used herein includes compounds having one or more than one hydroxyl group bound to an aromatic ring which may itself be mononuclear, e.g., benzyl, or poly-nuclear, e.g., naphthyl and spiro aromatic compounds. Thus “phenol type” includes phenol per se, catechol, resorcinol, hydroquinone, naphthol, etc., as well as alkyl or alkenyl and sulfurized alkyl or alkenyl derivatives thereof, and bisphenol type compounds including such bi-phenol compounds linked by alkylene bridges sulfuric bridges or oxygen bridges. Alkyl phenols include mono- and poly-alkyl or alkenyl phenols, the alkyl or alkenyl group containing from 3-100 carbons, preferably 4 to 50 carbons and sulfurized derivatives thereof, the number of alkyl or alkenyl groups present in the aromatic ring ranging from 1 to up to the available unsatisfied valences of the aromatic ring remaining after counting the number of hydroxyl groups bound to the aromatic ring.

[0073] Generally, therefore, the phenolic anti-oxidant may be represented by the general formula:



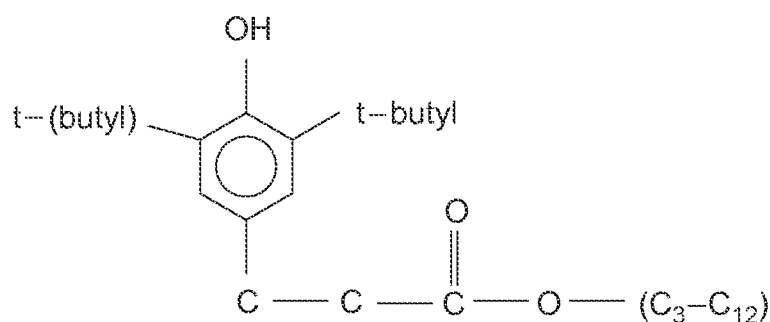
where Ar is selected from the group consisting of:



wherein R is a C₃-C₁₀₀ alkyl or alkenyl group, a sulfur substituted alkyl or alkenyl group, preferably a C₄-C₅₀ alkyl or alkenyl group or sulfur substituted alkyl or alkenyl group, more preferably C₃-C₁₀₀ alkyl or sulfur substituted alkyl group, most preferably a C₄-C₅₀ alkyl group, R^g is a C₁-C₁₀₀ alkylene or sulfur substituted alkylene group, preferably a C₂-C₅₀ alkylene or sulfur substituted alkylene group, more preferably a C₂-C₂ alkylene or sulfur substituted alkylene group, y is at least 1 to up to the available valences of Ar, x ranges from 0 to up to the available valences of Ar-y, z ranges from 1 to 10, n ranges from 0 to 20, and m is 0 to 4 and p is 0 or 1, preferably y ranges from 1 to 3, x ranges from 0 to 3, z ranges from 1 to 4 and n ranges from 0 to 5, and p is 0.

[0074] Preferred phenolic anti-oxidant compounds are the hindered phenolics and phenolic esters which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic anti-oxidants

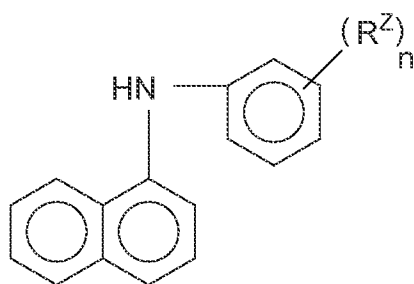
include the hindered phenols substituted with C_1+ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; 2-methyl-6-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4 methyl phenol; 2,6-di-t-butyl-4-ethyl phenol; and 2,6-di-t-butyl 4 alkoxy phenol; and



[0075] Phenolic type anti-oxidants are well known in the lubricating industry and commercial examples such as Ethanox® 4710, Irganox® 1076, Irganox® L1035, Irganox® 1010, Irganox® L109, Irganox® L118, Irganox® L135 and the like are familiar to those skilled in the art. The above is presented only by way of exemplification, not limitation on the type of phenolic anti-oxidants which can be used.

[0076] The phenolic anti-oxidant can be employed in an amount in the range of 0.1 to 3 wt%, preferably 0.25 to 2.5 wt%, more preferably 0.5 to 2 wt% on an active ingredient basis.

[0077] Aromatic amine anti-oxidants include phenyl- α -naphthyl amine which is described by the following molecular structure:



wherein R^Z is hydrogen or a C_1 to C_{14} linear or C_3 to C_{14} branched alkyl group, preferably C_1 to C_{10} linear or C_3 to C_{10} branched alkyl group, more preferably linear or branched C_6 to C_8 and n is an integer ranging from 1 to 5 preferably 1. A particular example is Irganox L06.

[0078] Other aromatic amine anti-oxidants include other alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula $R^8R^9R^{10}N$ where R^8 is an aliphatic, aromatic or substituted aromatic group, R^9 is an aromatic or a substituted aromatic group, and R^{10} is H, alkyl, aryl or $R^{11}S(O)_xR^{12}$ where R^{11} is an alkylene, alkenylene, or aralkylene group, R^{12} is a higher alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1 or 2. The aliphatic group R^8 may contain from 1 to 20 carbon atoms, and preferably contains from 6 to 12 carbon atoms. The aliphatic group is a saturated aliphatic group. Preferably, both R^8 and R^9 are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups R^8 and R^9 may be joined together with other groups such as S.

[0079] Typical aromatic amines anti-oxidants have alkyl substituent groups of at least 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than 14 carbon atoms. The general types of such other additional amine anti-oxidants which may be present include diphenylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more of such other

additional aromatic amines may also be present. Polymeric amine antioxidants can also be used.

[0080] Another class of anti-oxidant used in lubricating oil compositions and which may also be present are oil-soluble copper compounds. Any oil-soluble suitable copper compound may be blended into the lubricating oil. Examples of suitable copper antioxidants include copper dihydrocarbyl thio- or dithio-phosphates and copper salts of carboxylic acid (naturally occurring or synthetic). Other suitable copper salts include copper dithiacarbamates, sulphonates, phenates, and acetylacetonates. Basic, neutral, or acidic copper Cu(I) and or Cu(II) salts derived from alkenyl succinic acids or anhydrides are known to be particularly useful.

[0081] Such anti-oxidants may be used individually or as mixtures of one or more types of anti-oxidants, the total amount employed being an amount of 0.50 to 5 wt%, preferably 0.75 to 3 wt% (on an as-received basis).

Detergents

[0082] In addition to the alkali or alkaline earth metal salicylate detergent which is an optional component in the present disclosure, other detergents may also be present. While such other detergents can be present, it is preferred that the amount employed be such as to not interfere with the synergistic effect attributable to the presence of the salicylate. Therefore, most preferably such other detergents are not employed.

[0083] If such additional detergents are present, they can include alkali and alkaline earth metal phenates, sulfonates, carboxylates, phosphonates and mixtures thereof. These supplemental detergents can have total base number (TBN) ranging from neutral to highly overbased, i.e. TBN of 0 to over 500, preferably 2 to 400, more preferably 5 to 300, and they can be present either

individually or in combination with each other in an amount in the range of from 0 to 10 wt%, preferably 0.5 to 5 wt% (active ingredient) based on the total weight of the formulated lubricating oil. Furthermore, mixtures of neutral detergents and overbased detergents may be useful.

[0084] Such additional other detergents include by way of example and not limitation calcium phenates, calcium sulfonates, magnesium phenates, magnesium sulfonates and other related components (including borated detergents).

[0085] Another optional component of the present lubricant compositions is one or more neutral/low TBN or mixture of neutral/low TBN and overbased/high TBN alkali or alkaline earth metal alkylsalicylate, sulfonate and/or phenate detergent preferably neutral/low TBN alkali or alkaline earth metal salicylate and at least one overbased/high TBN alkali or alkalene earth metal salicylate or phenate, and optionally one or more additional neutral and/or overbased alkali or alkaline earth metal alkyl sulfonate, alkyl phenolate or alkylsalicylate detergent, the detergent or detergent mixture being employed in the lubricant composition in an amount sufficient to achieve a sulfated ash content for the finished lubricant of 0.1 mass % to 2.0 mass %, preferably 0.1 to 1.5 mass %, more preferably 0.1 to 1.0 mass %, most preferably 0.1 to 0.7 mass %.

[0086] The TBN of the neutral/low TBN alkali or alkaline earth metal alkyl salicylate, alkyl phenate or alkyl sulfonate is 150 or less mg KOH/g of detergent, preferably 120 or less mg KOH/g, most preferably 100 or less mg KOH/g while the TBN of the overbased/high TBN alkali or alkaline earth metal alkyl salicylate, alkyl phenate or alkyl sultanate is 160 or more mg KOH/g, preferably 190 or more mg KOH/g, most preferably 250 or more mg KOH/g, TBN being measured by ASTM D-2896.

[0087] The mixture of detergents may be added to the lubricant composition in an amount up to 10 vol % based on active ingredient in the detergent mixture,

preferably in an amount up to 8 vol % based on active ingredient, more preferably up to 6 vol % based on active ingredient in the detergent mixture, most preferably between 1.5 to 5.0 vol %, based on active ingredient in the detergent mixture.

[0088] By active ingredient is meant the amount of additive actually constituting the name detergent or detergent mixture chemicals in the formulation as received from the additive supplier, less any diluent oil included in the material. Additives are typically supplied by the manufacturer dissolved, suspended in or mixed with diluent oil, usually a light oil, in order to provide the additive in the more convenient liquid form. The active ingredient in the mixture is the amount of actual desired chemical in the material less the diluent oil.

Dispersants

[0089] During operation of a mechanical system, automotive engine, industrial compressor, or the like, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants may be ashless or ash-forming in nature. Preferably, the dispersant is ashless. So called ashless dispersants are organic materials that form substantially no ash upon combustion. For example, non-metal-containing or borated metal-free dispersants are considered ashless. In contrast, metal-containing detergents discussed above form ash upon combustion.

[0090] Suitable dispersants typically contain a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group typically contains at least one element of nitrogen, oxygen, or phosphorus. Typical hydrocarbon chains contain 50 to 400 carbon atoms.

[0091] A particularly useful class of dispersants are the alkenylsuccinic derivatives, typically produced by the reaction of a long chain substituted alkenyl succinic compound, usually a substituted succinic anhydride, with a polyhydroxy

or polyamino compound. The long chain group constituting the oleophilic portion of the molecule which confers solubility in the oil, is normally a polyisobutylene group. Many examples of this type of dispersant are well known commercially and in the literature. Exemplary U.S. patents describing such dispersants are 3,172,892; 3,215,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,511; 3,787,374 and 4,234,435. Other types of dispersant are described in U.S. Pat. Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants may be found, for example, in European Patent Application No. 471 071, to which reference is made for this purpose.

[0092] Hydrocarbyl-substituted succinic acid compounds are popular dispersants. In particular, succinimide, succinate esters, or succinate ester amides prepared by the reaction of a hydrocarbon-substituted succinic acid compound preferably having at least 50 carbon atoms in the hydrocarbon substituent, with at least one equivalent of an alkylene amine are particularly useful.

[0093] Succinimides are formed by the condensation reaction between alkenyl succinic anhydrides and amines. Molar ratios can vary depending on the amine or polyamine. For example, the molar ratio of alkenyl succinic anhydride to TEPA can vary from 1:1 to 5:1.

[0094] Succinate esters are formed by the condensation reaction between alkenyl succinic anhydrides and alcohols or polyols. Molar ratios can vary depending on the alcohol or polyol used. For example, the condensation product of an alkenyl succinic anhydride and pentaerythritol is a useful dispersant.

[0095] Succinate ester amides are formed by condensation reaction between alkenyl succinic anhydrides and alkanol amines. For example, suitable alkanol

amines include ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines and polyalkenylpolyamines such as polyethylene polyamines. One example is propoxylated hexamethylenediamine.

[0096] The molecular weight of the alkenyl succinic anhydrides will typically range between 800 and 2,500. The above products can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids such as oleic acid, and boron compounds such as borate esters or highly borated dispersants. The dispersants can be borated with from 0.1 to 5 moles of boron per mole of dispersant reaction product.

[0097] Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of the alkylphenols range from 800 to 2,500 or more.

[0098] Typical high molecular weight aliphatic acid modified Mannich condensation products can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or HN(R)_2 group-containing reactants.

[0099] Examples of high molecular weight alkyl-substituted hydroxyaromatic compounds are polypropylphenol, polybutylphenol, and other polyalkylphenols. These polyalkylphenols can be obtained by the alkylation, in the presence of an alkylating catalyst, such as BF_3 , of phenol with high molecular weight polypropylene, polybutylene, and other polyalkylene compounds to give alkyl substituents on the benzene ring of phenol having an average 600-100,000 molecular weight.

[00100] Examples of HN(R)_2 group-containing reactants are alkylene polyamines, principally polyethylene polyamines. Other representative organic compounds containing at least one HN(R)_2 group suitable for use in the

preparation of Mannich condensation products are well known and include the mono- and di-amino alkanes and their substituted analogs, e.g., ethylamine and diethanol amine; aromatic diamines, e.g., phenylene diamine, diamino naphthalenes; heterocyclic amines, e.g., morpholine, pyrrole, pyrrolidine, imidazole, imidazolidine, and piperidine; melamine and their substituted analogs.

[00101] Examples of alkylene polyamine reactants include ethylenediamine, diethylene triamine, triethylene tetraamine, tetraethylene pentaamine, pentaethylene hexamine, hexaethylene heptaamine, heptaethylene octaamine, octaethylene nonaamine, nonaethylene decamine, and decaethylene undecamine and mixture of such amines having nitrogen contents corresponding to the alkylene polyamines, in the formula $H_2N-(Z-NH)_nH$, mentioned before, Z is a divalent ethylene and n is 1 to 10 of the foregoing formula. Corresponding propylene polyamines such as propylene diamine and di-, tri-, tetra-, pentapropylene tri-, tetra-, penta- and hexaamines are also suitable reactants. The alkylene polyamines are usually obtained by the reaction of ammonia and dihalo alkanes, such as dichloro alkanes. Thus the alkylene polyamines obtained from the reaction of 2 to 11 moles of ammonia with 1 to 10 moles of dichloroalkanes having 2 to 6 carbon atoms and the chlorines on different carbons are suitable alkylene polyamine reactants.

[00102] Aldehyde reactants useful in the preparation of the high molecular products useful in this disclosure include the aliphatic aldehydes such as formaldehyde (also as paraformaldehyde and formalin), acetaldehyde and aldol (β -hydroxybutyraldehyde). Formaldehyde or a formaldehyde-yielding reactant is preferred.

[00103] Preferred dispersants include borated and non-borated succinimides, including those derivatives from mono-succinimides, bis-succinimides, and/or mixtures of mono- and bis-succinimides, wherein the hydrocarbyl succinimide is derived from a hydrocarbylene group such as polyisobutylene having a Mn of

from 500 to 5000 or more or a mixture of such hydrocarbylene groups. Other preferred dispersants include succinic acid-esters and amides, alkylphenol-polyamine-coupled Mannich adducts, their capped derivatives, and other related components. Such additives may be used in an amount of 0.1 to 20 wt%, preferably 0.1 to 8 wt%, more preferably 1 to 6 wt% (on an as-received basis) based on the weight of the total lubricant.

Pour Point Depressants

[00104] Conventional pour point depressants (also known as lube oil flow improvers) may also be present. Pour point depressant may be added to lower the minimum temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include alkylated naphthalenes polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. Such additives may be used in amount of 0.0 to 0.5 wt%, preferably 0 to 0.3 wt%, more preferably 0.001 to 0.1 wt% on an as-received basis.

Sulfur-Containing Compounds

[00105] Sulfur-containing compounds useful as additives in this disclosure include, for example, alkyl dithio carbamate, dialkyl dimercaptothiadiazole, other sulfur-containing metal passivators, and combinations of any of the foregoing. The sulfur-containing compounds can be used in conventional amounts.

Corrosion Inhibitors/Metal Deactivators

[00106] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include aryl thiazines, alkyl substituted dimercapto thiodiazoles

thiadiazoles and mixtures thereof. Such additives may be used in an amount of 0.01 to 5 wt%, preferably 0.01 to 1.5 wt%, more preferably 0.01 to 0.2 wt%, still more preferably 0.01 to 0.1 wt% (on an as-received basis) based on the total weight of the lubricating oil composition.

Seal Compatibility Additives

[00107] Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal compatibility agents for lubricating oils include organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride and sulfolane-type seal swell agents such as Lubrizol 730-type seal swell additives. Such additives may be used in an amount of 0.01 to 3 wt%, preferably 0.01 to 2 wt% on an as-received basis.

Anti-Foam Agents

[00108] Anti-foam agents may advantageously be added to lubricant compositions. These agents retard the formation of stable foams. Silicones and organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide antifoam properties. Anti-foam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers; usually the amount of these additives combined is less than 1 percent, preferably 0.001 to 0.5 wt%, more preferably 0.001 to 0.2 wt%, still more preferably 0.0001 to 0.15 wt% (on an as-received basis) based on the total weight of the lubricating oil composition.

Inhibitors and Antirust Additives

[00109] Anti-rust additives (or corrosion inhibitors) are additives that protect lubricated metal surfaces against chemical attack by water or other contaminants.

One type of anti-rust additive is a polar compound that wets the metal surface preferentially, protecting it with a film of oil. Another type of anti-rust additive absorbs water by incorporating it in a water-in-oil emulsion so that only the oil touches the surface. Yet another type of anti-rust additive chemically adheres to the metal to produce a non-reactive surface. Examples of suitable additives include zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines. Such additives may be used in an amount of 0.01 to 5 wt%, preferably 0.01 to 1.5 wt% on an as-received basis.

Antiwear Agents

[00110] Antiwear agents or additives may also be included in the present disclosure. Non-limiting exemplary antiwear agents include ZDDP, zinc dithiocarbamates, molybdenum dialkyldithiophosphates, molybdenum dithiocarbamates, other organo molybdenum-nitrogen complexes, sulfurized olefins, etc.

[00111] A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) may be present in the lubricating oils of the present disclosure. ZDDP can be primary, secondary or mixtures thereof. ZDDP compounds generally are of the formula $Zn[SP(S)(OR^1)(OR^1)(OR^2)]_2$ where R^1 and R^2 are C_1 - C_{18} alkyl groups, preferably C_2 - C_{12} alkyl groups. These alkyl groups may be straight chain or branched and can be derived from primary alcohols, secondary alcohols and mixtures thereof.

[00112] Preferable zinc dithiophosphates which are commercially available include secondary zinc dithiophosphates such as those available from for example, the Lubrizol Corporation under the trade designations "LZ 677A", "LZ 1095" and "LZ 1371", from for example Chevron Oronite under the trade

designation "OLOA 262" and from, for example, Afton Chemical under the trade designation "HITEC 7169".

[00113] The ZDDP is typically used in amounts of from 0.4 wt % to 1.2 wt %, preferably from 0.5 wt % to 1.0 wt %, and more preferably from 0.6 wt % to 0.8 wt %, based on the total weight of the lubricating oil, although more or less can often be used advantageously. Preferably, the ZDDP is a secondary ZDDP and present in an amount of from 0.6 to 1.0 wt % of the total weight of the lubricating oil.

[00114] The term "organo molybdenum-nitrogen complexes" embraces the organo molybdenum-nitrogen complexes described in U.S. Patent 4,889,647. The complexes are reaction products of a fatty oil, dithanolamine and a molybdenum source. Specific chemical structures have not been assigned to the complexes. U.S. Patent 4,889,647 reports an infrared spectrum for a typical reaction product of that disclosure; the spectrum identifies an ester carbonyl band at 1740 cm^{-1} and an amide carbonyl band at 1620 cm^{-1} . The fatty oils are glyceryl esters of higher fatty acids containing at least 12 carbon atoms up to 22 carbon atoms or more. The molybdenum source is an oxygen-containing compound such as ammonium molybdates, molybdenum oxides and mixtures.

[00115] Other organo molybdenum complexes which can be used in the present disclosure are tri-nuclear molybdenum-sulfur compounds described in EP 1 040 115 and WO 99/31113 and the molybdenum complexes described in U.S. Patent No. 4,978,464.

Friction Modifiers

[00116] A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers, also known as friction reducers, or lubricity

agents or oiliness agents, and other such agents that change the ability of base oils, formulated lubricant compositions, or functional fluids, to modify the coefficient of friction of a lubricated surface may be effectively used in combination with the base oils or lubricant compositions of the present disclosure if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this disclosure. Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers may include metal salts or metalligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates, Mo-alcohol-amides, etc. See U.S. Patent Nos. 5,824,627, 6,232,276, 6,153,564, 6,143,701, 6,110,878, 5,837,657, 6,010,987, 5,906,968, 6,734,150, 6,730,638, 6,689,725, 6,569,820; and also WO 99/66013; WO 99/47629; and WO 98/26030.

[00117] Ashless friction modifiers may also include lubricant materials that contain effective amounts of polar groups, for example, hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hydrocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination. Other friction modifiers that may be particularly effective include, for example,

salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers.

[00118] Useful concentrations of friction modifiers may range from 0.01 weight percent to 10-15 weight percent or more, often with a preferred range of 0.1 weight percent to 5 weight percent. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 10 ppm to 3000 ppm or more, and often with a preferred range of 20-2000 ppm, and in some instances a more preferred range of 30-1000 ppm. Friction modifiers of all types may be used alone or in mixtures with the materials of this disclosure. Often mixtures of two or more friction modifiers, or mixtures of friction modifier(s) with alternate surface active material(s), are also desirable.

Typical Amounts of Various Lubricant Oil Components

Compound	Approximate wt% (useful)	Approximate wt% (preferred)
Friction Modifiers	0.01-15	0.01-5
Antiwear Additives	0.01-6	0.01-4
Detergents	0.01-8	0.01-4
Dispersants	0.1-20	0.1-8
Antioxidants	0.01-5	0.01-1.5
Anti-foam Agents	0.001-1	0.001-0.1
Corrosion Inhibitors	0.01-5	0.01-1.5
Co-basestocks	0-50	0-40
Base Oils	Balance	Balance

[00119] The di-alkylated naphthalene containing base stocks of this disclosure improve both thermo-oxidation stability and elastomer

compatibility/manageability in lubricating applications. The use of di-alkylated naphthalene containing base stocks are desirable in lubricating oils in the presence of salicylate, sulfonate and phenate detergents, along with antioxidants and ashless antioxidants, along with succinimide based dispersants, along with zinc dialkyldithiophosphates, along with organic and metallic friction modifiers, along with corrosion inhibitors, along with defoamants and optionally in the presence of Group I, Group II, Group III, Group IV and Group V base oils. The di-alkylated naphthalene containing base stocks are useful in all lubricating oil applications, but are particularly useful in low viscosity fluids with a kinematic viscosity at 100°C between 3 and 20 cSt, more preferred at a kinematic viscosity range at 100°C between 5 and 15, and even more preferential at a kinematic viscosity range between 7 and 18 cSt at 100°C. Furthermore, the use of the di-alkylated naphthalene containing base stocks are desirable in engine oils with low sulfated ash levels (measured by ASTM D874) of 1 wt% or less, more preferred at levels 0.8 wt% or less.

[00120] In the above detailed description, the specific embodiments of this disclosure have been described in connection with its preferred embodiments. However, to the extent that the above description is specific to a particular embodiment or a particular use of this disclosure, this is intended to be illustrative only and merely provides a concise description of the exemplary embodiments. Accordingly, the disclosure is not limited to the specific embodiments described above, but rather, the disclosure includes all alternatives, modifications, and equivalents falling within the true scope of the appended claims. Various modifications and variations of this disclosure will be obvious to a worker skilled in the art and it is to be understood that such modifications and variations are to be included within the purview of this application and the spirit and scope of the claims.

EXAMPLES

[00121] Formulations were prepared for thermo-oxidative stability and NBR elastomer compatibility testing. Formulations included either 50 wt.% of a commercial AN or di-alkylated naphthalene (Di-AN) with the balance containing high metallocene PAO and typical industrial oil additives. As shown in Fig. 1, the results show that the formulations with Di-AN have a better balance in oxidation vs. NBR elastomer volume swell over the commercial formulations. Both performance attributes have the potential to impact oil performance in a positive way. Conventional alkylated naphthalenes (ANs) used in the Examples (e.g., AN 5, AN 9, AN 13 and AN 14) are commercially available materials under various trade names such as Synesstic™ and KR™ alkylated naphthalenes.

Oxidation Test

[00122] Kinematic viscosity (KV) increase is a measure that is commonly used to determine oil failure due to oxidation. Tests conducted in high temperatures (170°C) environments with Cu catalyst, are a means to measure whether any particular oil has a longer oil life when compared to references.

[00123] To conduct the test, a sample is placed in an oxidation cell together with various organometallic catalysts that are dissolved in solution and then placed into the test cell. The cell and its contents are placed in a heating block maintained at a specified temperature, and a measured volume of dried air is bubbled through the test cell held at a pressure ranging from 0-100 psig for the duration of the test, with an air flow rate up to 250 cc/min. A constant temperature block, equipped with an electric heater and thermostatic control capable of maintaining the temperature within +/- °1F (0.5°C) in the range of 200°F (93°C) to 450°F (232°C) is used to maintain the specified temperature.

[00124] Periodically the test cell is sampled for viscosity, until the oil has oxidized. The oil condition is examined by measuring its KV at a specified temperature. Comparisons can then be made to the original KV of the oil. The time at which it takes the oil to reach a catastrophic increase in viscosity (200%) is used to determine the end of the test. Oxidation stability is key in achieving long oil life. Controlling oil viscosity increase through identifying robust performing base stock and additive combinations can minimize deposit (varnish/sludge) formation, and maintain good heat transfer and lubricating properties, including efficiency. The reduced oxidation, and thus increased performance of a lubricant, is especially desirable in high temperature applications and environments. DiAN formulations were compared to commercial AN products in the formulations set forth in Figs. 1 and 2. The results are set forth in Figs. 1 and 2.

Elastomer Compatibility Test

[00125] The effect of the basestocks on elastomers were tested in the formulations using a reference Nitrile rubber (NBR 28 SX) at 100°C for 168 hours. The volume of the nitrile rubber samples was measured at the end of the test and compared to that before the test. Higher numbers indicate more swelling and interaction between the base stocks and the elastomer materials. DiAN formulations were compared to commercial AN products in the formulations set forth in Figs. 1 and 2. The results are set forth in Figs. 1 and 2.

[00126] The high oxidation resistance obtained with DiAN formulations can extend oil drain intervals, reduce environmental footprint, and minimize varnish, sludge, and wear through the reduction of reduced oxidation by-products.

[00127] Low NBR elastomer swell obtained with DiAN formulations can provide for a compatible seal environment, thereby maintaining seal integrity and a good operating environment for the equipment.

[00128] The results in Figs. 1 and 2 show a step change in performance using average alkyl carbon number for the respective AN's. Formulation examples with Di-AN show higher performance in the thermo-oxidation ratio indicating good thermo-oxidation control (high hours to failure as the numerator) and smaller changes in NBR elastomer (lower swells as the denominator). The mono-alkylate sets the stage for the performance shift showing poorly in Fig. 1 with low ratio in spite of good (high) thermo-oxidation performance due to poor (high) NBR elastomer swell.

[00129] Total methyl number (TMN) and branching index (BI) were determined for Di-ANs of this disclosure. The results are set forth in Fig. 3.

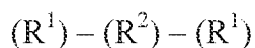
[00130] All patents and patent applications, test procedures (such as ASTM methods, UL methods, ISO methods, and the like), and other documents cited herein are fully incorporated by reference to the extent such disclosure is not inconsistent with this disclosure and for all jurisdictions in which such incorporation is permitted.

[00131] When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated. While the illustrative embodiments of the disclosure have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the disclosure. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as encompassing all the features of patentable novelty which reside in the present disclosure, including all features which would be treated as equivalents thereof by those skilled in the art to which the disclosure pertains.

[00132] The present disclosure has been described above with reference to numerous embodiments and specific examples. Many variations will suggest themselves to those skilled in this art in light of the above detailed description. All such obvious variations are within the full intended scope of the appended claims.

CLAIMS:

1. A method for improving thermo-oxidative stability and elastomer compatibility in an apparatus lubricated with a lubricating oil by using as the lubricating oil a formulated oil comprising a lubricating oil base stock; wherein the lubricating oil base stock comprises a di-alkylated aromatic base stock of the formula:



wherein each R^1 is the same or different and represents a C_{10} - C_{30} alkyl group; R^2 represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein BI is TMN minus 2 (two terminal methyl carbons); wherein the di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

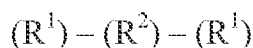
2. The method of claim 1 wherein, in the di-alkylated aromatic base stock, R^2 is naphthalene, and each R^1 is a C_{10} - C_{20} linear alkyl group, a C_{10} - C_{20} branched alkyl group; or mixtures of such groups.

3. The method of claims 1 and 2 wherein, in the di-alkylated aromatic base stock, branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 0.99 to 2.0 or have a branching index ("BI") of from -0.99 to 0.099.

4. The method of claims 1-3 wherein the di-alkylated aromatic base stock comprises di-C₁₀ alkyl naphthalene, di-C₁₂ alkyl naphthalene, di-C₁₄ alkyl naphthalene, di-C₁₆ alkyl naphthalene, di-C₁₈ alkyl naphthalene, or mixtures thereof.

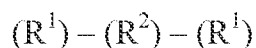
5. The method of claims 1-4 wherein the di-alkylated aromatic base stock comprises at least 90 wt.% dialkylate product and no more than 5 wt.% monoalkylate, trialkylate and higher polyalkylate product, and is present in an amount from 15 weight percent to 95 weight percent, based on the total weight of the lubricating oil.

6. A lubricating oil comprising a lubricating oil base stock; wherein the lubricating oil base stock comprises a di-alkylated aromatic base stock of the formula:



wherein each R¹ is the same or different and represents a C₁₀-C₃₀ alkyl group; R² represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C¹³ NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein BI is TMN minus 2 (two terminal methyl carbons); wherein the di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

7. The lubricating oil of claim 6 wherein, in the di-alkylated aromatic base stock, R^2 is naphthalene, and each R^1 is a C_{10} - C_{20} linear alkyl group, a C_{10} - C_{20} branched alkyl group; or mixtures of such groups.
8. The lubricating oil of claims 6 and 7 wherein, in the di-alkylated aromatic base stock, branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 0.99 to 2.0 or have a branching index ("BI") of from -0.99 to 0.099.
9. The lubricating oil of claims 6-8 wherein the di-alkylated aromatic base stock comprises di- C_{10} alkyl naphthalene, di- C_{12} alkyl naphthalene, di- C_{14} alkyl naphthalene, di- C_{16} alkyl naphthalene, di- C_{18} alkyl naphthalene, or mixtures thereof.
10. The lubricating oil of claims 6-9 wherein the di-alkylated aromatic base stock comprises at least 90 wt.% dialkylate product and no more than 5 wt.% monoalkylate, trialkylate and higher polyalkylate product, and is present in an amount from 15 weight percent to 95 weight percent, based on the total weight of the lubricating oil.
11. A di-alkylated aromatic base stock of the formula:



wherein each R^1 is the same or different and represents a C_{10} - C_{30} alkyl group; R^2 represents an aromatic moiety; wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 1.0 to 2.1 or have a branching index ("BI") of from -1.0 to 0.1, wherein TMN is calculated by dividing the sum of integrated areas for all methyl groups by the total integration area for all aliphatic carbons and multiplying the result by the averaged chain length carbon number, and wherein

BI is TMN minus 2 (two terminal methyl carbons); wherein the di-alkylated aromatic base stock comprises at least 44 wt% dialkylate product; and wherein thermo-oxidative stability and elastomer compatibility are improved as compared to thermo-oxidative stability and elastomer compatibility achieved using a lubricating oil base stock other than the di-alkylated aromatic base stock.

12. The di-alkylated aromatic base stock of claim 11 wherein R^2 is naphthalene, and each R^1 is a C_{10} - C_{20} linear alkyl group, a C_{10} - C_{20} branched alkyl group; or mixtures of such groups.

13. The di-alkylated aromatic base stock of claims 11 and 12 wherein branching characteristics of the alkyl groups have a total methyl number ("TMN") determined by C^{13} NMR spectroscopy of from 0.99 to 2.0 or have a branching index ("BI") of from -0.99 to 0.099.

14. The di-alkylated aromatic base stock of claims 11-13 comprising di- C_{10} alkyl naphthalene, di- C_{12} alkyl naphthalene, di- C_{14} alkyl naphthalene, di- C_{16} alkyl naphthalene, di- C_{18} alkyl naphthalene, or mixtures thereof.

15. The lubricating oil of claim 6 which further comprises one or more of a viscosity improver, antioxidant, detergent, dispersant, pour point depressant, corrosion inhibitor, metal deactivator, seal compatibility additive, anti-foam agent, inhibitor, and anti-rust additive.