

LOW MOLECULAR WEIGHT DISPERSANTS

CROSS-REFERENCE TO RELATED APPLICATION

[001] This application claims the benefit of U.S. Provisional Patent Application No. 63/339,569, filed May 9, 2022, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[002] This disclosure relates to lubricant additive compositions and lubricating oil compositions containing the same. More specifically, this disclosure describes low molecular weight dispersants that improve engine cleanliness.

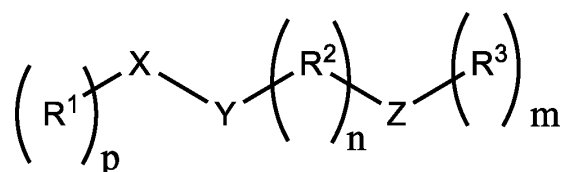
BACKGROUND

[003] While automotive engines are constantly being improved, developing new engine oils and additive packages offers a quicker and/or more cost-effective path to improving performance factors such as fuel efficiency, oxidative stability, volatility, and more.

[004] Oxidative stability is an important performance factor as poor oxidative stability often leads to deposit formation which in turn can cause stalling and poor acceleration. Additionally, the deposits can increase fuel consumption as well as increase production of harmful exhaust pollutants.

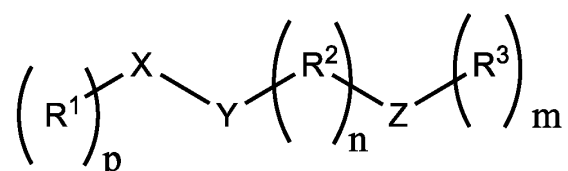
SUMMARY

[005] In one aspect, there is provided a lubricating oil composition comprising: a major amount of base oil; and a lubricant additive having the following structure:



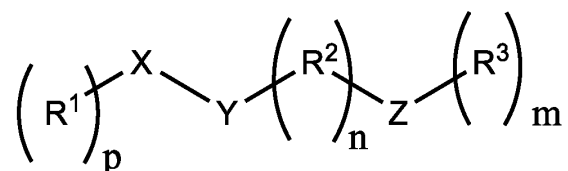
wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

[006] In another aspect, there is provided a method of lubricating an engine, the method comprising lubricating the engine with a lubricating oil composition comprising: a major amount of base oil; and a lubricant additive having the following structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

[007] In yet another aspect, there is provided a method for improving piston cleanliness or oxidation inhibition in an engine, the method comprising lubricating the engine with a lubricating oil composition comprising: a major amount of base oil; and a lubricant additive having the following structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen,

or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

DETAILED DESCRIPTION

[008] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

[009] The present disclosure relates to a lubricant additive that prevents or reduces deposit formation (e.g., reduce soot deposits on pistons) thus improving cleanliness in engines. The lubricant additive may be formulated in base oil along with other lubricant additives to impart performance benefits to the resulting lubricating oil composition.

[010] In some embodiments, the present disclosure relates to engine flush products containing the additive, mixed products containing the additive and used lubricating oil composition, and methods of using the same.

[011] In some embodiments, the engine flush product is an aftermarket additive package wherein the additive is dissolved in solvent. The aftermarket additive package is suitable for rapidly cleaning or removing accumulated deposits, sludge, and other gunk from an internal combustion engine.

[012] An engine flush process can remove sludge, heavy deposits, and/or other gunk that may have been built up from engine oil. A typical engine flush process involves adding the additive as an aftermarket additive (e.g., engine flush product) to an internal combustion engine through the oil-filler port. After the engine is allowed to idle, the additive is added to mix with the existing lubricating oil composition which

has "used base oil". This mixed product can dissolve or clean sludge, heavy deposits, and/or gunk residing in the engine. The mixed product is then drained along with the dissolved sludge, deposit, and/or gunk.

[013] In some embodiments, the lubricating oil composition disclosed herein can be used as a rapid cleaning fluid. The rapid cleaning fluid can be used during rapid cleaning service to remove accumulated deposits, sludge, and other gunk from an internal combustion engine. A rapid cleaning service can remove sludge, heavy deposits, and/or other insoluble material that may have been built up over time.

[014] The cleaning process may be comprised of using the lubricant in the engine sump or crankcase and circulating the lubricating oil without starting the engine. An additional step would include circulating the lubricating oil and allowing it to soak under a static condition for 15 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 7, hours, 8 hours, 9 hours, 10 hours, 11 hours, 12 hours, 16 hours, 20 hours, 24 hours, 2 days, 3 days, 4 days, 5 days, 6 days, or a week. Another cleaning step could include starting and operating the engine at any running condition appropriate for the engine design and fuel for 15 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 7, hours, 8 hours, 9 hours, 10 hours, 11 hours, 12 hours, 16 hours, 20 hours, 24 hours, 2 days, 3 days, 4 days, 5 days, 6 days, or a week. In some embodiments, the lubricating oil composition disclosed herein may be used for removing existing deposits from the crankcase, rocker cover, camshaft region, timing gear cover, cylinder head, combustion chamber, piston rings and/or ring grooves in an internal combustion engine.

[015] When used during a rapid cleaning service, the lubricating oil composition can require the lubricant additive at a higher concentration than is typically used during regular maintenance. This lubricating oil with higher amounts of the deposit cleaning lubricant additive is used to lubricate and clean the engine. The resulting mixed product (concentrated lubricating oil and deposits) can then be flushed. The flushing step typically occurs after completion of the cleaning step.

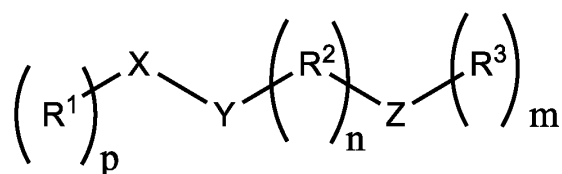
[016] In some embodiments, the cleaning step of the rapid cleaning service involves lubricating the engine with the lubricating oil composition for 15 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 7, hours, 8 hours, 9 hours, 10 hours, 11 hours, 12 hours, 16 hours, 20 hours, 24 hours, 2 days, 3 days, 4 days, 5 days, 6 days, or a week. The exact amount of time can vary depending on a number of factors such as, but not limited, the size of engine, the amount of deposits in the engine, desired level of cleanliness, and so forth.

[017] In some embodiments, the flushing takes place after 5 minutes, after 15 minutes, after 30 minutes, after 45 minutes, after 1 hour, after 2 hours, after three 3, after 4 hours, after 5 hours, after 6 hours, after 8 hours, after 12 hours, after 16 hours, after 24 hours, after 2 days, after 3 days, after 4 days, after 1 week, after 2 weeks, after 3 weeks, after 4 weeks, after 6 weeks, after 8 weeks from the cleaning step. In some embodiments, the flushing step can occur up to a period equivalent to about 25% of the OEM recommended oil change interval period.

[018] In some embodiments, the lubricating oil composition, rapid cleaning fluid, or engine flush product disclosed herein has a total base number (TBN) of 2 to 200 mgKOH/g such as 2 to 175, 2 to 150, 2 to 100, 5 to 200, 5 to 175, 5 to 150, 5 to 100, 10 to 200, 10 to 175, 10 to 150, 10 to 100, 50 to 200, 50 to 175, 50 to 150, and 50 to 100.

Lubricant Additive

[019] The lubricant additive composition of the present disclosure is a dispersant that can be represented by the following generalized chemical structure I:



Structure I

wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3. In some embodiments, X is a cyclic or acyclic alkyl group. In some embodiments, Y may include one or more hydrogens. In some preferred embodiments, Z is nitrogen.

[020] Each R^1 is independently a moiety that includes 10 to 400 carbon atoms, such as 10 to 390, 10 to 380, 10 to 370, 10 to 360, 10 to 350, 10 to 340, 10 to 330, 10 to 320, 10 to 310, 10 to 300, 10 to 290, 10 to 280, 10 to 270, 10 to 260, 10 to 250, 10 to 240, 10 to 230, 10 to 220, 10 to 210, 10 to 200, 10 to 190, 10 to 180, 10 to 170, 10 to 160, 10 to 150, 10 to 140, 10 to 130, 10 to 120, 10 to 110, 10 to 100, 10 to 90, 10 to 80, 10 to 70, 10 to 60, 10 to 50, 10 to 40, 10 to 30, 10 to 20, 20 to 400, 20 to 390, 20 to 380, 20 to 370, 20 to 360, 20 to 350, 20 to 340, 20 to 330, 20 to 320, 20 to 310, 20 to 300, 20 to 290, 20 to 280, 20 to 270, 20 to 260, 20 to 250, 20 to 240, 20 to 230, 20 to 220, 20 to 210, 20 to 200, 20 to 190, 20 to 180, 20 to 170, 20 to 160, 20 to 150, 20 to 140, 20 to 130, 20 to 120, 20 to 110, 20 to 100, 20 to 90, 20 to 80, 20 to 70, 20 to 60, 20 to 50, 20 to 40, 20 to 30, 30 to 400, 30 to 390, 30 to 380, 30 to 370, 30 to 360, 30 to 350, 30 to 340, 30 to 330, 30 to 320, 30 to 310, 30 to 300, 30 to 290, 30 to 280, 30 to 270, 30 to 260, 30 to 250, 30 to 240, 30 to 230, 30 to 220, 30 to 210, 30 to 200, 30 to 190, 30 to 180, 30 to 170, 30 to 160, 30 to 150, 30 to 140, 30 to 130, 30 to 120, 30 to 110, 30 to 100, 30 to 90, 30 to 80, 30 to 70, 30 to 60, 30 to 50, 30 to 40, 40 to 400, 40 to 390, 40 to 380, 40 to 370, 40 to 360, 40 to 350, 40 to 340, 40 to 330, 40 to 320, 40 to 310, 40 to 300, 40 to 290, 40 to 280, 40 to 270, 40 to 260, 40 to 250, 40 to 240, 40 to 230, 40 to 220, 40 to 210, 40 to 200, 40 to 190, 40 to 180, 40 to 170, 40 to 160, 40 to 150, 40 to 140, 40 to 130, 40 to 120, 40 to 110, 40 to 100, 40 to 90, 40 to 80, 40 to 70, 40 to 60, 40 to 50, 50 to 400, 50 to 390, 50 to 380, 50 to 370, 50 to 360, 50 to 350, 50 to 340, 50 to 330, 50 to 320, 50 to 310, 50 to 300, 50 to 290, 50 to 280, 50 to 270,

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to 270, 210 to 260, 210 to 250, 210 to 240, 210 to 230, 210 to 220, 220 to 400, 220 to 390, 220 to 380, 220 to 370, 220 to 360, 220 to 350, 220 to 340, 220 to 330, 220 to 320, 220 to 310, 220 to 300, 220 to 290, 220 to 280, 220 to 270, 220 to 260, 220 to 250, 220 to 240, 220 to 230, 230 to 400, 230 to 390, 230 to 380, 230 to 370, 230 to 360, 230 to 350, 230 to 340, 230 to 330, 230 to 320, 230 to 310, 230 to 300, 230 to 290, 230 to 280, 230 to 270, 230 to 260, 230 to 250, 230 to 240, 240 to 400, 240 to 390, 240 to 380, 240 to 370, 240 to 360, 240 to 350, 240 to 340, 240 to 330, 240 to 320, 240 to 310, 240 to 300, 240 to 290, 240 to 280, 240 to 270, 240 to 260, 240 to 250, 250 to 400, 250 to 390, 250 to 380, 250 to 370, 250 to 360, 250 to 350, 250 to 340, 250 to 330, 250 to 320, 250 to 310, 250 to 300, 250 to 290, 250 to 280, 250 to 270, 250 to 260, 260 to 400, 260 to 390, 260 to 380, 260 to 370, 260 to 360, 260 to 350, 260 to 340, 260 to 330, 260 to 320, 260 to 310, 260 to 300, 260 to 290, 260 to 280, 260 to 270, 270 to 400, 270 to 390, 270 to 380, 270 to 370, 270 to 360, 270 to 350, 270 to 340, 270 to 330, 270 to 320, 270 to 310, 270 to 300, 270 to 290, 270 to 280, 280 to 400, 280 to 390, 280 to 380, 280 to 370, 280 to 360, 280 to 350, 280 to 340, 280 to 330, 280 to 320, 280 to 310, 280 to 300, 280 to 290, 290 to 400, 290 to 390, 290 to 380, 290 to 370, 290 to 360, 290 to 350, 290 to 340, 290 to 330, 290 to 320, 290 to 310, 290 to 300, 300 to 400, 300 to 390, 300 to 380, 300 to 370, 300 to 360, 300 to 350, 300 to 340, 300 to 330, 300 to 320, 300 to 310, 310 to 400, 310 to 390, 310 to 380, 310 to 370, 310 to 360, 310 to 350, 310 to 340, 310 to 330, 310 to 320, 320 to 400, 320 to 390, 320 to 380, 320 to 370, 320 to 360, 320 to 350, 320 to 340, 320 to 330, 330 to 400, 330 to 390, 330 to 380, 330 to 370, 330 to 360, 330 to 350, 330 to 340, 340 to 400, 340 to 390, 340 to 380, 340 to 370, 340 to 360, 340 to 350, 350 to 400, 350 to 390, 350 to 380, 350 to 370, 350 to 360, 360 to 400, 360 to 390, 360 to 380, 360 to 370, 370 to 400, 370 to 390, 370 to 380, 380 to 400, 380 to 390, or 390 to 400 carbon atoms.

[021] In some embodiments, R¹ may include, for example, saturated and unsaturated hydrocarbon groups, linear and branched alkyl groups, and polyalkyl groups (e.g., polyisobutenyl group or "PIB", polyethylene, polypropylene, etc.). The

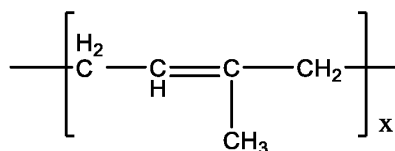
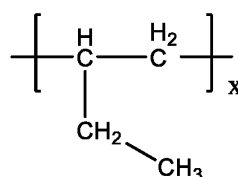
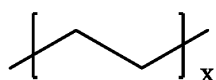
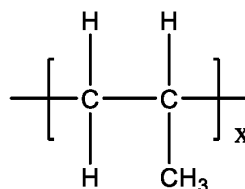
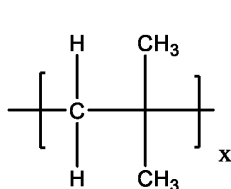
polyalkyl groups may be the obtained from a polymerization reaction using olefin monomers (e.g., isobutylene).

[022] In some preferred embodiments, R^1 is a polyisobutenyl group. In some preferred embodiments, the polyisobutenyl group has an average molecular weight of about 350 to about 5000. In some preferred embodiments, the polyisobutenyl group has an average molecular weight of about 150 to about 1250, such as about 200 to about 1200, about 300 to about 1100, about 400 to about 1000, about 500 to about 900, and about 600 to about 800. In some preferred embodiments, the polyisobutenyl group has an average molecular weight of about 250 to about 1000, such as about 300 to about 900, about 400 to about 800, and about 500 to about 700.

[023] In some preferred embodiments, the polyisobutenyl group has an average molecular weight of about 500 to about 4000, such as about 600 to about 5000, about 700 to about 5000, about 800 to about 5000, about 900 to about 5000, about 1000 to about 5000, about 500 to about 4000, such as about 600 to about 4000, about 700 to about 4000, about 800 to about 4000, about 900 to about 4000, about 1000 to about 4000, about 1100 to about 4000, about 1200 to about 4000, about 1300 to about 4000, about 1400 to about 4000, about 1500 to about 4000, about 1600 to about 4000, about 1700 to about 4000, about 1800 to about 4000, about 1900 to about 4000, about 2000 to about 4000, about 2100 to about 4000, about 2200 to about 4000, about 2300 to about 4000, about 2400 to about 4000, about 2500 to about 4000, about 2600 to about 4000, about 2700 to about 4000, about 2800 to about 4000, about 2900 to about 4000, about 3000 to about 4000, about 500 to about 3500, such as about 600 to about 3500, about 700 to about 3500, about 800 to about 3500, about 900 to about 3500, about 1000 to about 3500, about 1100 to about 3500, about 1200 to about 3500, about 1300 to about 3500, about 1400 to about 3500, about 1500 to about 3500, about 1600 to about 3500, about 1700 to about 3500, about 1800 to about 3500, about 1900 to about 3500, about 2000 to about 3500, about 2100 to about 3500, about 2200 to about 3500, about 2300 to about 3500, about 2400 to about 3500, about 2500 to about 3500, about 2600 to about 3500, about 2700 to about 3500, about 2800 to about 3500,

about 2900 to about 3500, about 3000 to about 3500, about 500 to about 3000, such as about 600 to about 3000, about 700 to about 3000, about 800 to about 3000, about 900 to about 3000, about 1000 to about 3000, about 1100 to about 3000, about 1200 to about 3000, about 1300 to about 3000, about 1400 to about 3000, about 1500 to about 3000, about 1600 to about 3000, about 1700 to about 3000, about 1800 to about 3000, about 1900 to about 3000, about 2000 to about 3000, about 2100 to about 3000, about 2200 to about 3000, about 2300 to about 3000, about 2400 to about 3000, and about 2500 to about 3000..

[024] Specific examples of R¹ include the following:

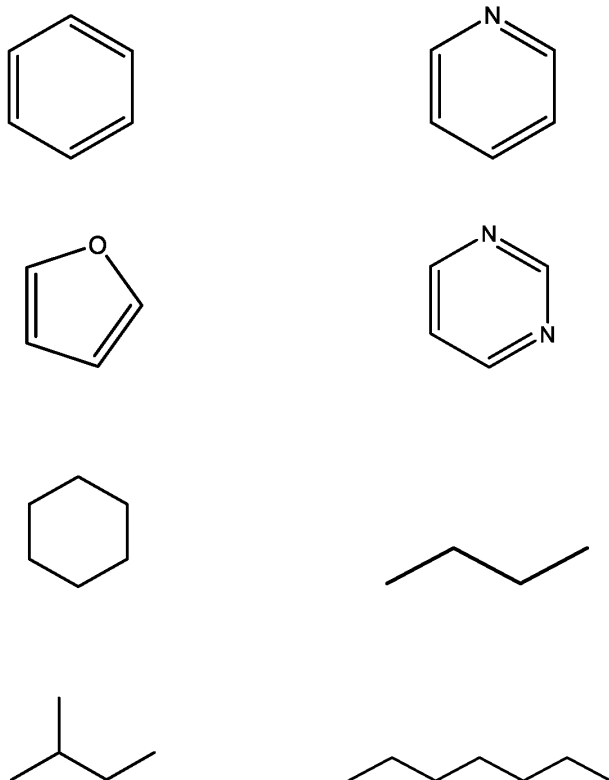


wherein x is an integer such that the total number of carbons is from 10 to 400 as described herein.

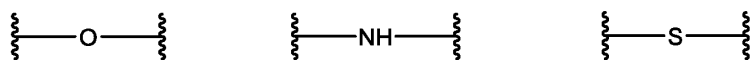
[025] X is a moiety that includes 1 to 10 carbon atoms, such as 1 to 9, 1 to 8, 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, 1 to 2, 2 to 10, 2 to 9, 2 to 8, 2 to 7, 2 to 6, 2 to 5, 2 to 4, 2 to 3, 3 to 10, 3 to 9, 3 to 8, 3 to 7, 3 to 6, 3 to 5, 3 to 4, 4 to 10, 4 to 9, 4 to 8, 4 to

7, 4 to 6, 4 to 5, 5 to 10, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 6 to 10, 6 to 9, 6 to 8, 6 to 7, 7 to 10, 7 to 9, 7 to 8, 8 to 10, 8 to 9, or 9 to 10 carbon atoms.

[026] Specific examples of X include the following:



[027] Examples of Y include, for example, the following:

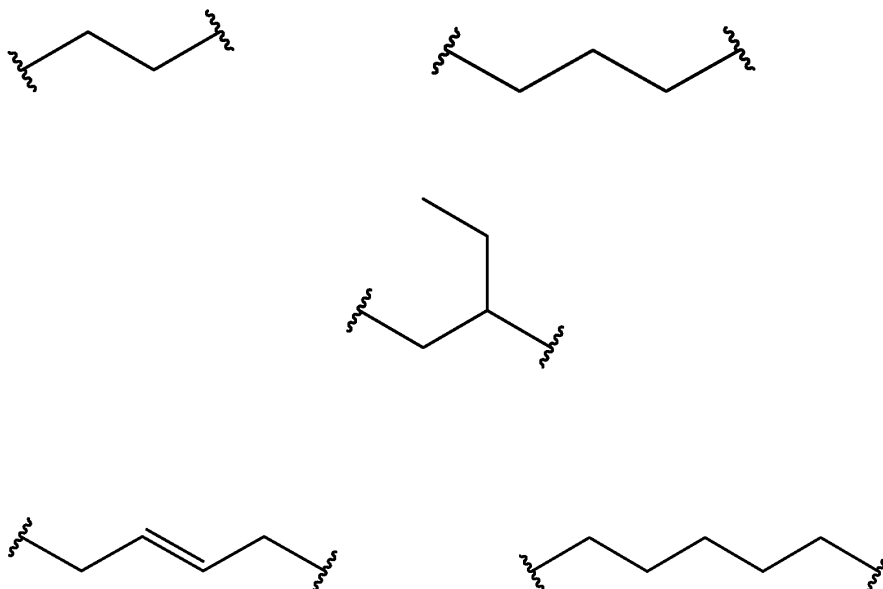


[028] Each R^2 is independently a moiety that includes 1 to 9 carbon atoms, such as from 1 to 8, 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, 1 to 2, 2 to 9, 2 to 8, 2 to 7, 2 to 6, 2 to 5, 2 to 4, 2 to 3, 3 to 9, 3 to 7, 3 to 6, 3 to 5, 3 to 4, 4 to 9, 4 to 8, 4 to 7, 4 to

6, 4 to 5, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 6 to 9, 6 to 8, 6 to 7, 7 to 9, 7 to 8, or 8 to 9 carbon atoms.

[029] Suitable examples of R^2 include, for example, saturated and unsaturated hydrocarbon groups, and linear and branched alkyl groups.

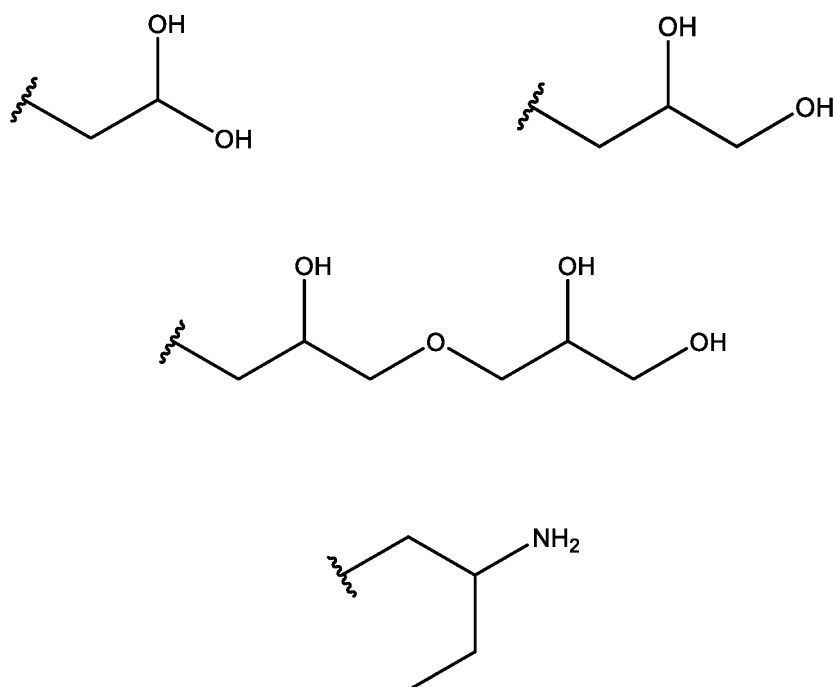
[030] Specific examples of R^2 include the following:



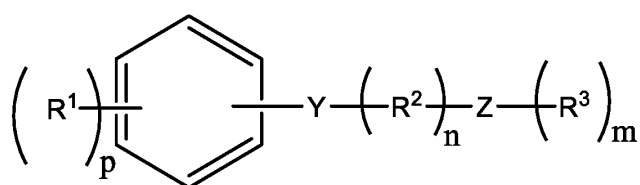
[031] Z is nitrogen, oxygen, or sulfur atom.

[032] Each R^3 is independently a hydrogen atom or a moiety that includes 1 to 9 carbon atoms, such as from 1 to 8, 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, 1 to 2, 2 to 9, 2 to 8, 2, to 7, 2 to 6, 2 to 5, 2 to 4, 2 to 3, 3 to 9, 3 to 7, 3 to 6, 3 to 5, 3 to 4, 4 to 9, 4 to 8, 4 to 7, 4 to 6, 4 to 5, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 6 to 9, 6 to 8, 6 to 7, 7 to 9, 7 to 8, or 8 to 9 carbon atoms. Each R^3 moiety includes one or more nitrogen, oxygen, or sulfur functionalization.

[033] Specific examples of R^3 include the following:



[034] In some preferred embodiments, the lubricant additive may have the following generalized Structure 2:

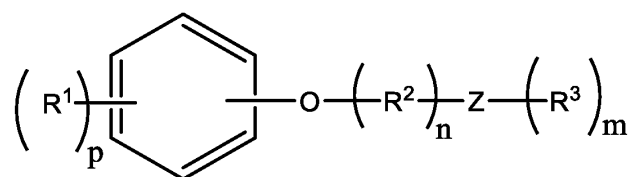


Structure 2

wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

[035] In some embodiments, Y may include one or more hydrogens.

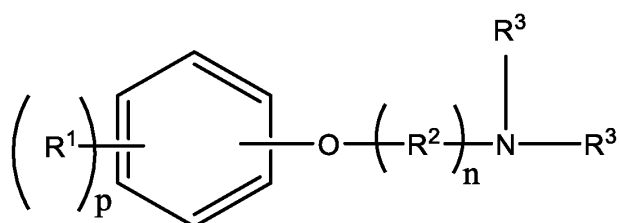
[036] In some preferred embodiments, the lubricant additive may have the following generalized Structure 3:



Structure 3

wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

[037] In some preferred embodiments, the lubricant additive may have the following generalized Structure 4:



Structure 4

wherein each R^1 is a hydrocarbyl group having 10 to 400 carbons; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, and n is 1 to 20.

[038] When formulated in engine oil (i.e., lubricating oil composition), used in an engine flush process as part of an aftermarket additive package, or used during a rapid cleaning service, the additive composition is usually present in concentrations ranging from about 0.1 to about 50.0 wt. % based on total weight of the lubricating oil composition (can be the mixed product), such as about 1 wt. % to about 50 wt. %, about 5 wt. % to about 50 wt. %, about 10 wt. % to about 50 wt. %, about 15 wt. % to about 50 wt. %, about 20 wt. % to about 50 wt. %, about 25 wt. % to about 50 wt. %, about 30 wt. % to about 50 wt. %, about 35 wt. % to about 50 wt. %, about 40 wt. % to about 50 wt. %, about 45 wt. % to about 50 wt. %, about 0.1 wt. % to about 45 wt. %, about 1 wt. % to about 45 wt. %, about 5 wt. % to about 45 wt. %, about 10 wt. % to about 45 wt. %, about 15 wt. % to about 45 wt. %, about 20 wt. % to about 45 wt. %, about 25 wt. % to about 45 wt. %, about 30 wt. % to about 45 wt. %, about 35 wt. % to about 45 wt. %, about 40 wt. % to about 45 wt. %, about 0.1 wt. % to about 40 wt. %, about 1 wt. % to about 40 wt. %, about 5 wt. % to about 40 wt. %, about 10 wt. % to about 40 wt. %, about 15 wt. % to about 40 wt. %, about 20 wt. % to about 40 wt. %, about 25 wt. % to about 40 wt. %, about 30 wt. % to about 40 wt. %, about 35 wt. % to about 40 wt. %, about 0.1 wt. % to about 35 wt. %, about 1 wt. % to about 35 wt. %, about 5 wt. % to about 35 wt. %, about 10 wt. % to about 35 wt. %, about 15 wt. % to about 35 wt. %, about 20 wt. % to about 35 wt. %, about 25 wt. % to about 35 wt. %, about 30 wt. % to about 35 wt. %, about 0.1 wt. % to about 30 wt. %, about 1 wt. % to about 30 wt. %, about 5 wt. % to about 30 wt. %, about 10 wt. % to about 30 wt. %, about 15 wt. % to about 30 wt. %, about 20 wt. % to about 30 wt. %, about 25 wt. % to about 30 wt. %, about 0.1 wt. % to about 25 wt. %, about 1 wt. % to about 25 wt. %, about 5 wt. % to about 25 wt. %, about 10 wt. % to about 25 wt. %, about 15 wt. % to about 25 wt. %, and about 20 wt. % to about 25 wt. %, about 0.1 wt. % to about 20.0 wt. %, about 0.1 wt. % to about 19.0 wt. %, about 0.1 wt. % to about 18.0 wt. %, about 0.1 wt. % to about 17.0 wt. %, about 0.1 wt. % to about 16.0 wt. %, about 0.1 wt. % to about 15.0 wt. %, about 0.1 wt. % to about 14.0 wt. %, about 0.1 wt. % to about 13.0 wt. %, about 0.1 wt. % to about 12.0 wt. %, about 0.1 wt. % to about 11.0 wt. %, about

[illegible]

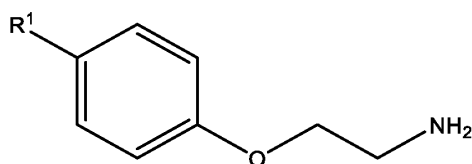
about 5.0 wt. % to about 16.0 wt. %, about 5.0 wt. % to about 15.0 wt. %, about 5.0 wt. % to about 14.0 wt. %, about 5.0 wt. % to about 13.0 wt. %, about 5.0 wt. % to about 12.0 wt. %, about 5.0 wt. % to about 11.0 wt. %, about 5.0 wt. % to about 10.0 wt. %, about 5.0 wt. % to about 9.0 wt. %, about 5.0 wt. % to about 8.0 wt. %, about 5.0 wt. % to about 7.0 wt. %, about 5.0 wt. % to about 6.0 wt. %, about 6.0 wt. % to about 20.0 wt. %, about 6.0 wt. % to about 19.0 wt. %, about 6.0 wt. % to about 18.0 wt. %, about 6.0 wt. % to about 17.0 wt. %, about 6.0 wt. % to about 16.0 wt. %, about 6.0 wt. % to about 15.0 wt. %, about 6.0 wt. % to about 14.0 wt. %, about 6.0 wt. % to about 13.0 wt. %, about 6.0 wt. % to about 12.0 wt. %, about 6.0 wt. % to about 11.0 wt. %, about 6.0 wt. % to about 10.0 wt. %, about 6.0 wt. % to about 9.0 wt. %, about 6.0 wt. % to about 8.0 wt. %, about 6.0 wt. % to about 7.0 wt. %, about 7.0 wt. % to about 20.0 wt. %, about 7.0 wt. % to about 19.0 wt. %, about 7.0 wt. % to about 18.0 wt. %, about 7.0 wt. % to about 17.0 wt. %, about 7.0 wt. % to about 16.0 wt. %, about 7.0 wt. %, to about 15.0 wt. %, about 7.0 wt. % to about 14.0 wt. %, about 7.0 wt. % to about 13.0 wt. %, about 7.0 wt. % to about 12.0 wt. %, about 7.0 wt. % to about 11.0 wt. %, about 7.0 wt. % to about 10.0 wt. %, about 7.0 wt. % to about 9.0 wt. %, about 7.0 wt. % to about 8.0 wt. %, about 8.0 wt. % to about 20.0 wt. %, about 8.0 wt. % to about 19.0 wt. %, about 8.0 wt. % to about 18.0 wt. %, about 8.0 wt. % to about 17.0 wt. %, about 8.0 wt. % to about 16.0 wt. %, about 8.0 wt. % to about 15.0 wt. %, about 8.0 wt. % to about 14.0 wt. %, about 8.0 wt. % to about 13.0 wt. %, about 8.0 wt. % to about 12.0 wt. %, about 8.0 wt. % to about 11.0 wt. %, about 8.0 wt. % to about 10.0 wt. %, about 8.0 wt. % to about 9.0 wt. %, about 9.0 wt. % to about 20.0 wt. %, about 9.0 wt. % to about 19.0 wt. %, about 9.0 wt. % to about 18.0 wt. %, about 9.0 wt. % to about 17.0 wt. %, about 9.0 wt. % to about 16.0 wt. %, about 9.0 wt. % to about 15.0 wt. %, about 9.0 wt. % to about 14.0 wt. %, about 9.0 wt. % to about 13.0 wt. %, about 9.0 wt. % to about 12.0 wt. %, about 9.0 wt. % to about 11.0 wt. %, about 9.0 wt. % to about 10.0 wt. %, about 10.0 wt. % to about 20.0 wt. %, about 10.0 wt. % to about 19.0 wt. %, about 10.0 wt. % to about 18.0 wt. %, about 10.0 wt. % to about 17.0 wt. %, about 10.0 wt. % to about 16.0 wt. %, about 10.0 wt. % to about 15.0 wt. %, about 10.0 wt. % to

about 14.0 wt. %, about 10.0 wt. % to about 13.0 wt. %, about 10.0 wt. % to about 12.0 wt. %, about 10.0 wt. % to about 11.0 wt. %, about 11.0 wt. % to about 20.0 wt. %, about 11.0 wt. % to about 19.0 wt. %, about 11.0 wt. % to about 18.0 wt. %, about 11.0 wt. % to about 17.0 wt. %, about 11.0 wt. % to about 16.0 wt. %, about 11.0 wt. % to about 15.0 wt. %, about 11.0 wt. % to about 14.0 wt. %, about 11.0 wt. % to about 13.0 wt. %, about 11.0 wt. % to about 12.0 wt. %, about 12.0 wt. % to about 20.0 wt. %, about 12.0 wt. % to about 19.0 wt. %, about 12.0 wt. % to about 18.0 wt. %, about 12.0 wt. % to about 17.0 wt. %, about 12.0 wt. % to about 16.0 wt. %, about 12.0 wt. % to about 15.0 wt. %, about 12.0 wt. % to about 14.0 wt. %, about 12.0 wt. % to about 13.0 wt. %, about 13.0 wt. % to about 20.0 wt. %, about 13.0 wt. % to about 19.0 wt. %, about 13.0 wt. % to about 18.0 wt. %, about 13.0 wt. % to about 17.0 wt. %, about 13.0 wt. % to about 16.0 wt. %, about 13.0 wt. % to about 15.0 wt. %, about 13.0 wt. % to about 14.0 wt. %, about 14.0 wt. % to about 20.0 wt. %, about 14.0 wt. % to about 19.0 wt. %, about 14.0 wt. % to about 18.0 wt. %, about 14.0 wt. % to about 17.0 wt. %, about 14.0 wt. % to about 16.0 wt. %, about 14.0 wt. % to about 15.0 wt. %, about 15.0 wt. % to about 20.0 wt. %, about 15.0 wt. % to about 19.0 wt. %, about 15.0 wt. % to about 18.0 wt. %, about 15.0 wt. % to about 17.0 wt. %, about 15.0 wt. % to about 16.0 wt. %, about 16.0 wt. % to about 20.0 wt. %, about 16.0 wt. % to about 19.0 wt. %, about 16.0 wt. % to about 18.0 wt. %, about 16.0 wt. % to about 17.0 wt. %, about 17.0 wt. % to about 20.0 wt. %, about 17.0 wt. % to about 19.0 wt. %, about 17.0 wt. % to about 18.0 wt. %, about 18.0 wt. % to about 20.0 wt. %, about 18.0 wt. % to about 19.0 wt. %, or about 19.0 wt. % to about 20.0 wt. %.

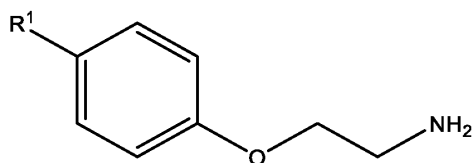
[039] In some embodiments, the additive is present in about 0.1 wt. % to about 4.5 wt. % based on the total weight of the lubricating oil composition, such as about 0.5 wt. % to about 4.0 wt. %, about 0.5 wt. % to about 3.5 wt. %, about 0.5 wt. % to about 3.0 wt. %, about 0.5 wt. % to about 2.5 wt. %, about 0.5 wt. % to about 2.0 wt. %, about 0.5 wt. % to about 1.5 wt. %, about 0.5 wt. % to about 1.0 wt. %, about 1.0 wt. % to about 5.0 wt. %, about 1.0 wt. % to about 4.5 wt. %, about 1.0 wt. % to about 4.0 wt. %, about 1.0 wt. % to about 3.5 wt. %, about 1.0 wt. % to about 3.0 wt. %, about

1.0 wt. % to about 2.5 wt. %, about 1.0 wt. % to about 2.0 wt. %, about 1.0 wt. % to about 1.5 wt. %, about 1.5 wt. %, to about 5.0 wt. %, about 1.5 wt. % to about 4.5 wt. %, about 1.5 wt. % to about 4.0 wt. %, about 1.5 wt. % to about 3.5 wt. %, about 1.5 wt. % to about 3.0 wt. %, about 1.5 wt. % to about 2.5 wt. %, about 1.5 wt. % to about 2.0 wt. %, about 2.0 wt. % to about 5.0 wt. %, about 2.0 wt. % to about 4.5 wt. %, about 2.0 wt. % to about 4.0 wt. %, about 2.0 wt. % to about 3.5 wt. %, about 2.0 wt. % to about 3.0 wt. %, about 2.0 wt. % to about 2.5 wt. %, about 2.5 wt. % to about 5.0 wt. %, about 2.5 wt. % to about 4.5 wt. %, about 2.5 wt. % to about 4.0 wt. %, about 2.5 wt. % to about 3.5 wt. %, about 2.5 wt. % to about 3.0 wt. %, about 3.0 wt. % to about 5.0 wt. %, about 3.0 wt. % to about 4.5 wt. %, about 3.0 wt. % to about 4.0 wt. %, about 3.0 wt. % to about 3.5 wt. %, about 3.5 wt. % to about 5.0 wt. %, about 3.5 wt. % to about 4.5 wt. %, about 3.5 wt. % to about 4.0 wt. %, about 4.0 wt. % to about 5.0 wt. %, about 4.0 wt. % to about 4.5 wt. %, or about 4.5 wt. % to about 5.0 wt. %.

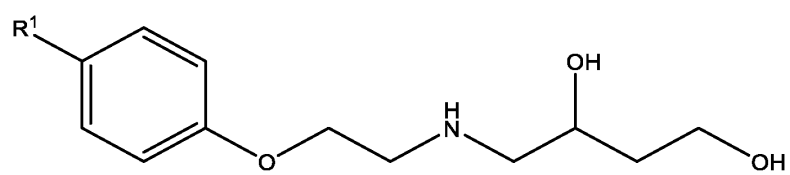
[040] Specific non-limiting examples of the lubricant additive composition include the following:



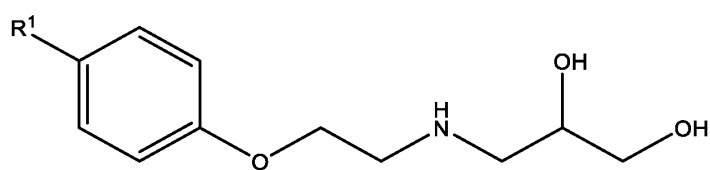
Compound 1 (solvent diluted)



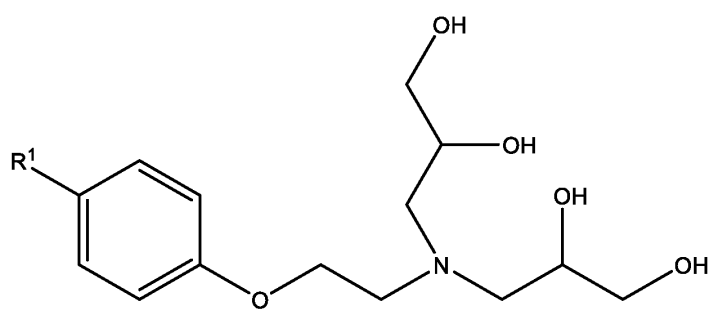
Compound 2 (same as Compound 1 but solvent distilled)



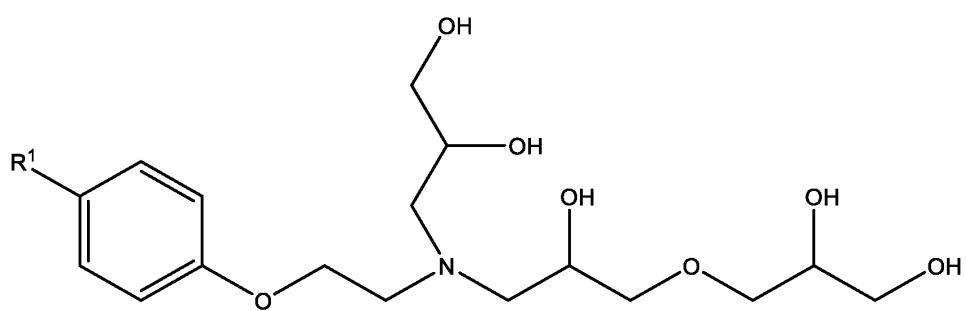
Compound 3



Compound 4



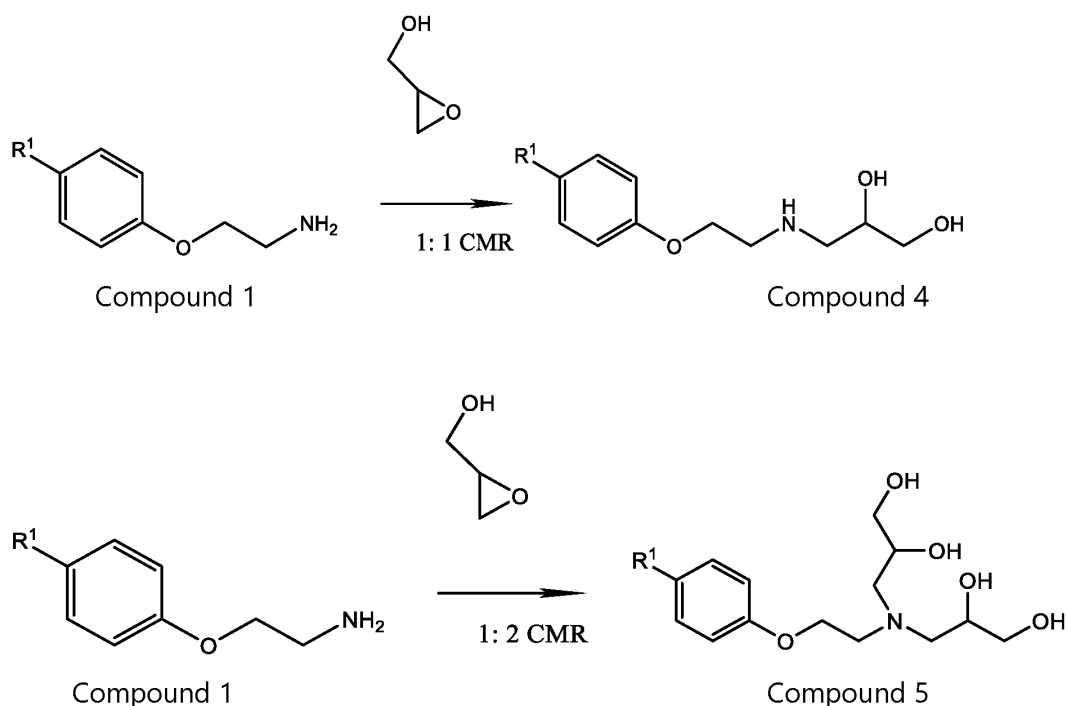
Compound 5

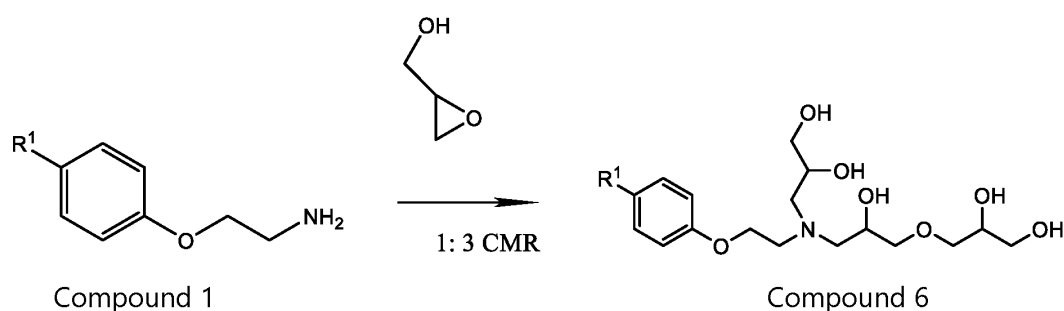


Compound 6

[041] The lubricant additive composition may be synthesized by any compatible method. For example, general synthesis of Compound 1 is described in detail U.S. Pat. No. 5,669,939, which is incorporated herein by reference. Such a reaction typically results in a product comprising Compound 1 dissolved in an organic solvent. In some embodiments, it may be desirable to evaporate the organic solvent before utilizing Compound 1.

[042] In some embodiments, Compound 1 can be used as a starting material to synthesize other lubricant additive compounds (e.g., Compounds 4, 5, 6). Shown below is a summary of how Compounds 4, 5, and 6 may be derivatized. The starting materials are the same in each reaction. Only the charge mole ratio (Compound 1 to glycidol) is varied. Other reagents besides glycidol may be contemplated. Moreover, it is not necessarily the case that the lubricant additive is a reaction product of or is derivatized by glycidol.



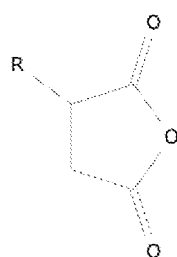


Succinimide Dispersant

[043] The lubricating oil composition may include succinimide dispersant. The succinimide dispersant may be present in about 0.1 wt% to about 10 wt% based on the total lubricating oil composition, such as about 0.1 wt% to about 9 wt%, about 0.1 wt% to about 8 wt%, about 0.1 wt% to about 7 wt%, about 0.1 wt% to about 6 wt%, about 0.1 wt% to about 5 wt%, about 0.1 wt% to about 4 wt%, about 0.1 wt% to about 3 wt%, about 0.1 wt% to about 2 wt%, about 0.1 wt% to about 1 wt%, about 0.5 wt% to about 10 wt%, about 0.5 wt% to about 9 wt%, about 0.5 wt% to about 8 wt%, about 0.5 wt% to about 7 wt%, about 0.5 wt% to about 6 wt%, about 0.5 wt% to about 5 wt%, about 0.5 wt% to about 4 wt%, about 0.5 wt% to about 3 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 10 wt%, about 1 wt% to about 9 wt%, about 1 wt% to about 8 wt%, about 1 wt% to about 7 wt%, about 1 wt% to about 6 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 4 wt%, about 1 wt% to about 3 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 10 wt%, about 2 wt% to about 9 wt%, about 2 wt% to about 8 wt%, about 2 wt% to about 7 wt%, about 2 wt% to about 6 wt%, about 2 wt% to about 5 wt%, about 2 wt% to about 4 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 10 wt%, about 3 wt% to about 9 wt%, about 3 wt% to about 8 wt%, about 3 wt% to about 7 wt%, about 3 wt% to about 6 wt%, about 3 wt% to about 5 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 10 wt%, about 4 wt% to about 9 wt%, about 4 wt% to about 8 wt%, about 4 wt% to about 7 wt%, about 4 wt% to about 6 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 10 wt%, about 5 wt% to about 9 wt%,

about 5 wt% to about 8 wt%, about 5 wt% to about 7 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 10 wt%, about 6 wt% to about 9 wt%, about 6 wt% to about 8 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 10 wt%, about 7 wt% to about 9 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 10 wt%, about 8 wt% to about 9 wt%, or about 9 wt% to about 10 wt%.

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



wherein R is a polyalkenyl substituent is 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.

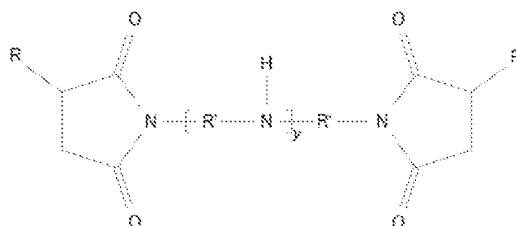
[045] In one embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 500 to about 3000. In another embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 1000 to about 2500.

[046] 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: $H_2N-(R'NH)_x-H$ 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).

[047] 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.

[048] 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.

Post-Treatment of Polyalkenyl Succinimide

[049] In some embodiments, the succinimide dispersant may be post-treated with an organic carbonate.

[050] Suitable organic carbonates include, for example, cyclic carbonates such as 1,3-dioxolan-2-one (ethylene carbonate or “EC”); 4-methyl-1,3-dioxolan-2-one (propylene carbonate); 4-ethyl-1,3-dioxolan-2-one (butylene carbonate); 4-hydroxymethyl-1,3-dioxolan-2-one; 4,5-dimethyl-1,3-dioxolan-2-one; 4-ethyl-1,3-dioxolan-2-one; 4,4-dimethyl-1,3-dioxolan-2-one; 4-methyl-5-ethyl-1,3-dioxolan-2-one; 4,5-diethyl-1,3-dioxolan-2-one; 4,4-diethyl-1,3-dioxolan-2-one; 1,3-dioxan-2-

one; 4,4-dimethyl-1,3-dioxan-2-one; 5,5-dimethyl-1,3-dioxan-2-one; 5,5-dihydroxymethyl-1,3-dioxan-2-one; 5-methyl-1,3-dioxan-2-one; 4-methyl-1,3-dioxan-2-one; 5-hydroxy-1,3-dioxan-2-one; 5-hydroxymethyl-5-methyl-1,3-dioxan-2-one; 5,5-diethyl-1,3-dioxan-2-one; 5-methyl-5-propyl-1,3-dioxan-2-one; 4,6-dimethyl-1,3-dioxan-2-one; 4,4,6-trimethyl-1,3-dioxan-2-one and spiro[1,3-oxa-2-cyclohexanone-5,5'-1',3'-oxa-2'-cyclohexanone]. Other suitable cyclic carbonates may be prepared from saccharides such as sorbitol, glucose, fructose, galactose and the like and from vicinal diols prepared from C₁ to C₃₀ olefins by methods known in the art.

Lubricating Oil

[051] The lubricating oil composition of the present invention includes one or more base oils (e.g., Group I, II, III, IV, or V). Moreover, the one or more base oils may include base oils from the same group (e.g., Group II Chevron Neutral Oil 600R®, Group II Chevron Neutral Oil 220R® and Group II Chevron Neutral Oil 100R®). The amount of base oil(s) is about 50 wt. % or greater ("major amount") based on the total weight of the lubricating oil composition.

[052] The oil of lubricating viscosity (sometimes referred to as "base stock" or "base oil") is the primary liquid constituent of a lubricant, into which additives and possibly other oils are blended, for example to produce a final lubricant (or lubricant composition). A base oil, which is useful for making concentrates as well as for making lubricating oil compositions therefrom, may be selected from natural (vegetable, animal or mineral) and synthetic lubricating oils and mixtures thereof.

[053] Oils used as the base oil will be selected or blended depending on the desired end use and the additives in the finished oil to give the desired grade of engine oil, e.g. a lubricating oil composition having an Society of Automotive Engineers (SAE). In one embodiment, the lubricating oil composition is a multi-grade oil for heavy duty or passenger car. The multi-grade oil may have a viscosity grade SAE of 0W- 12, 0W- 16, 0W-20, 0W-26, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W- 50, 5W-60, 10W, 10W-20, 10W-30, 10W-40, 10W-50, 15W, 15W-20, 15W-30, or 15W-40.

[054] Definitions for the base stocks and base oils in this disclosure are the same as those found in American Petroleum Institute (API) Publication 1509 Annex E ("API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils," December 2016). Group I base stocks contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group II base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group III base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120 using the test methods specified in Table E-1. 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.

[055] Natural oils include animal oils, vegetable oils (e.g., castor oil and lard oil), 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. 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.

[056] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers). Polyalphaolefin (PAO) oil base stocks are commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C₈ to C₁₄ olefins, e.g., C₈, C₁₀, C₁₂, C₁₄ olefins or mixtures thereof, may be utilized.

[057] Other useful fluids for use as base oils include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance characteristics.

[058] Non-conventional or unconventional base stocks/base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as isomerate/isodewaxate base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks. Other base oils include Coal to liquid (CTL) products and alkyl-naphthalene.

[059] Base oils for use in the lubricating oil compositions of 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.

[060] The lubricating oil composition may have a high temperature shear (HTHS) viscosity at 150° C of 2.9 cP or less, such as 2.8 cP or less, 2.7 cP or less, 2.6 cP or less, 2.5 cP or less, 2.4 cP or less, 2.3 cP or less, 2.2 cP or less, 2.1 cP or less, 2.0 cP or less, 1.9 cP or less, 1.8 cP or less, 1.7 cP or less, 1.6 cP or less, 1.5 cP or less, 1.4 cP or less, 1.3 cP or less, 1.2 cP or less, 1.1 cP or less, 1.0 cP or less, 1.0 to 2.9 cP, 1.3 to 2.9 cP) 1.0 to 2.6 cP, 1.3 to 2.6 cP, 1.0 cP to 2.3 cP, 1.3 cP to 2.3 cP, 1.0 cP to 2.0 cP, 1.3 cP to 2.3 cP, 1.0 cP to 1.7 cP, or 1.3 cP to 1.7 cP.

[061] The lubricating oil composition may have a viscosity index of at least 135 (e.g., 135 to 400, or 135 to 250), at least 150 (e.g., 150 to 400, 150 to 250), at least 165 (e.g., 165 to 400, or 165 to 250), at least 190 (e.g., 190 to 400, or 190 to 250), or at least 200 (e.g., 200 to 400, or 200 to 250). If the viscosity index of the lubricating oil composition is less than 135, it may be difficult to improve fuel efficiency while

maintaining the HTHS viscosity at 150° C. If the viscosity index of the lubricating oil composition exceeds 400, evaporation properties may be reduced, and deficits due to insufficient solubility of the additive and matching properties with a seal material may be caused.

[062] The base oil may have a kinematic viscosity at 100°C (ASTM D445) in a range of 3 to 12 mm²/s, such as 3 to 11 mm²/s, 3 to 10 mm²/s, 3 to 9 mm²/s, 3 to 8 mm²/s, 3 to 7 mm²/s, 3 to 6 mm²/s, 3 to 5 mm²/s, 3 to 4 mm²/s, 4 to 12 mm²/s, 4 to 11 mm²/s, 4 to 10 mm²/s, 4 to 9 mm²/s, 4 to 8 mm²/s, 4 to 7 mm²/s, 4 to 6 mm²/s, 4 to 5 mm²/s, 5 to 12 mm²/s, 5 to 11 mm²/s, 5 to 10 mm²/s, 5 to 9 mm²/s, 5 to 8 mm²/s, 5 to 7 mm²/s, 5 to 6 mm²/s, 6 to 12 mm²/s, 6 to 11 mm²/s, 6 to 10 mm²/s, 6 to 9 mm²/s, 6 to 8 mm²/s, 6 to 7 mm²/s, 7 to 12 mm²/s, 7 to 11 mm²/s, 7 to 10 mm²/s, 7 to 9 mm²/s, 7 to 8 mm²/s, 7 to 10 mm²/s, 7 to 9 mm²/s, 7 to 8 mm²/s, 8 to 12 mm²/s, 8 to 11 mm²/s, 8 to 10 mm²/s, 8 to 9 mm²/s, 9 to 12 mm²/s, 9 to 11 mm²/s, 9 to 10 mm²/s, 10 to 12 mm²/s, 10 to 11 mm²/s, or 11 to 12 mm²/s.

Other Additives

[063] The present lubricating oil compositions may also contain conventional additives for imparting auxiliary functions to give a finished lubricating oil composition in which these additives are dispersed or dissolved. For example, the lubricating oil compositions can be blended with antioxidants, ashless dispersants, anti-wear agents, detergents such as metal detergents, rust inhibitors, dehazing agents, demulsifying agents, friction modifiers, metal deactivating agents, pour point depressants, viscosity modifiers, antifoaming agents, co-solvents, package compatibilizers, corrosion-inhibitors, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, can be employed for the preparation of the lubricating oil compositions of the invention by the usual blending procedures.

[064] Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is an ashless dispersant, a functionally effective amount of this ashless

dispersant would be an amount sufficient to impart the desired dispersancy characteristics to the lubricant. Generally, the concentration of each of these additives, when used, may range, unless otherwise specified, from about 0.001 to about 20 wt. %, such as about 0.01 to about 10 wt. %.

Formulation

[065] In general, the level of sulfur in the lubricating oil compositions of the present invention is less than or equal to about 0.7 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of sulfur of about 0.01 wt. % to about 0.70 wt. %, 0.01 to 0.6 wt. %, 0.01 to 0.5 wt. %, 0.01 to 0.4 wt. %, 0.01 to 0.3 wt. %, 0.01 to 0.2 wt. %, 0.01 wt. % to 0.10 wt. %. In one embodiment, the level of sulfur in the lubricating oil compositions of the present invention is less than or equal to about 0.60 wt. %, less than or equal to about 0.50 wt. %, less than or equal to about 0.40 wt. %, less than or equal to about 0.30 wt. %, less than or equal to about 0.20 wt. %, less than or equal to about 0.10 wt. % based on the total weight of the lubricating oil composition.

[066] In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.12 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.12 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.11 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.11 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.10 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.10 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.09 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.09 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the

present invention is less than or equal to about 0.08 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.08 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.07 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.07 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.05 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.05 wt. %.

[067] In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 1.60 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 1.60 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 1.00 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 1.00 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 0.80 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 0.80 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 0.60 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 0.60 wt. % as determined by ASTM D 874.

[068] Suitably, the present lubricating oil composition may have a total base number (TBN) of 4 to 15 mg KOH/g (e.g., 5 to 12 mg KOH/g, 6 to 12 mg KOH/g, or 8 to 12 mg KOH/g).

[069] The following non-limiting examples are illustrative of the present invention. Brief descriptions of how the examples were prepared are provided.

EXAMPLES

Baseline Formulation

[070] Baseline Formulation is SAE 5W-40 viscosity grade lubricating oil composition prepared by blending the following components:

- a) 0.017 wt% in terms of boron of a borated Ca sulfonate having a TBN of 160
- b) 0.02 wt% in terms of Ca of an overbased Ca phenate of TBN of 260
- c) 0.074 wt% in terms of P of ZnDTP
- d) 0.13 wt% in terms of Ca of an overbased Ca sulfonate having a TBN of 410
- e) antioxidants
- f) ethylene-propylene viscosity modifier

[071] The remainder of the lubricating oil composition includes a minor amount of foam inhibitor, pour point depressant, and a mixture of Group III base oil with a KV100 of 4 cSt and Group III base oil with KV 100 of 6 cSt.

Example 1

[072] The following components were added to Baseline Formulation to produce Example 1:

- 6.5 wt% of EC-treated succinimide
- 2 wt% of Compound 2

Example 2

[073] The following components were added to Baseline Formulation to produce Example 2:

- 6.5 wt% of EC-treated succinimide
- 2 wt% of Compound 1

Example 3

[074] The following components were added to Baseline Formulation to produce Example 3:

- 6.5 wt% of EC-treated succinimide

2 wt% Compound 3

Example 4

[075] The following components were added to Baseline Formulation to produce Example 4:

6.5 wt% of EC-treated succinimide

2 wt% of Compound 4

Example 5

[076] The following components were added to Baseline Formulation to produce Example 5:

4 wt% of EC-treated succinimide

2 wt% of Compound 4

Example 6

[077] The following components were added to Baseline Formulation to produce Example 6:

4 wt% of EC-treated succinimide

1 wt% of Compound 2

[078] The remainder of the lubricating oil composition includes a minor amount of foam inhibitor, pour point depressant, and base oil.

Example 7

[079] The following components were added to Baseline Formulation to produce Example 7:

8 wt% of EC-treated succinimide

Example 8

[080] The following components were added to Baseline Formulation to produce Example 8:

6 wt% of EC-treated succinimide

2 wt% of Compound 2

Example 9

[081] The following components were added to Baseline Formulation to produce Example 9:

6 wt% of EC-treated succinimide

2 wt% of Compound 3

Example 10

[082] The following components were added to Baseline Formulation to produce Example 10:

6 wt% of EC-treated succinimide

2 wt% of Compound 5

Example 11

[083] The following components were added to Baseline Formulation to produce Example 11:

6 wt% of EC-treated succinimide

2 wt% of Compound 4

Example 12

[084] The following components were added to Baseline Formulation to produce Example 12:

4 wt% of EC-treated succinimide

2 wt% of Compound 2

Example 13

[085] The following components were added to Baseline Formulation to produce Example 13:

4 wt% of EC-treated succinimide

1 wt% of Compound 2

Example 14

[086] The following components were added to Baseline Formulation to produce Example 14:

2 wt% of Compound 1

TDI 3 Engine Test

[087] Piston cleanliness and ring sticking were evaluated by TDI 3 engine test, which is very similar to the Volkswagen Turbocharged DI test, a European passenger car diesel engine test (CEC-L-78-T-99) and is part of the ACEA A/B and C specification promulgated by the European Automobile Manufacturers Association in 2004. This test was used to simulate repeated cycles of high-speed operation followed by idling. A Volkswagen 1.9 liter, inline, four-cylinder turbocharged direct injection automotive diesel engine (VW TDi) was mounted on an engine dynamometer stand. A 54-hour, 2-phased procedure that cycles between 30 minutes of 40° C. oil sump at idle and 150 minutes of 145° C. oil sump at full power (4150 rpm) was carried out without interim oil top-ups. After the procedure, the pistons were rated for carbon and lacquer deposits, as well for groove carbon filling. The piston rings were evaluated for ring sticking. Table 1 summarizes the TDI 3 results.

Table 1

	Baseline Formulation	Ex 1	Ex2	Ex3	Ex4	Ex5	Ex6
Average Piston Merit	50	59	57	59	59	57	54

Panel Coker Test

[088] The Panel Coker Test is a method for determining the relative stability of lubricants. It is often used to evaluate the deposit forming or lacquering tendency of the lubricants in contact with hot metal surfaces simulating deposit formation in engine cylinders and pistons. The test apparatus includes a rectangular stainless-steel reservoir, inclined 25° from horizontal. The test panel (95 mm by 45 mm) is held in place by a heating element, which is fitted with thermocouple probes to control the temperature of the aluminum or steel test panel. A horizontal shaft, fitted with a series of tines, is positioned above the oil, and is rotated at 1000 rpm. 300ml of the

lubricating oil under evaluation is placed in the Panel Coker apparatus and oil temperature is controlled at 100°C, while the test panel is heated to 300°C. During rotating of the shaft, the tines sweep through the test lubricant and lubricant droplets are thrown onto the heated test panel. The test panel is reweighed at the end of the test duration of 3 hours and the amount of deposit formed is determined. Weight gain of test panel and the amount of test lubricant consumed during the test are an indication of the lubricant's performance under high temperature conditions. Results are summarized in Table 2.

Table 2

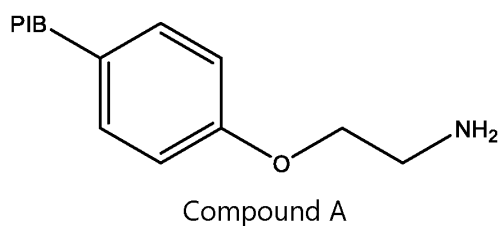
	Ex7	Ex8	Ex9	Ex10	Ex11	Ex12	Ex13	Baseline Formulation	Ex14
5min weight change (g)	0.0054	0.0016	0.0037	0.0039	0.0016	0.0039	0.0033	0.0094	0.0031
10min weight change (g)	0.0102	0.0038	0.0065	0.0061	0.0031	0.005	0.0059	0.0165	0.0061

Rapid Clean Deposit Removal

[089] Examples 15-17 and Comparative Example A were formulated to provide lubricating oil compositions meeting the following specification: SAE 30 viscosity grade (K_v @100 °C of about 15.0 mm²/s).

[090] Examples 15-17 were blended with the following components:

- Group II base oil
- 9.7 wt% of engine oil additive package (includes, e.g., dispersant, detergent, antioxidant, friction modifier)
- Compound A (diluted in 30 wt.% C9 aromatic solvent) at various treat rates (Table 4):



Comparative Example B (Table 3) was similar to Examples 15-17 but did not include Compound A.

Experimental Procedure I

[091] In the first set of experiments, various concentrations of Compound A were blended with a finished oil to observe its solvency and tendency to solubilize carbonaceous ring deposits. Blending of Compound A and the finished oil were blended took place at ambient temperature for 20 minutes.

[092] Compound A was added in varying amounts to finished oils containing the engine oil additive package. Actual ring sections containing high concentration of carbonaceous deposits from an internal combustion engine were used for the experiments. The rings were prewashed with hexane, allowed to dry, and then then weighed to 4 decimal places. Next, the ring sections were carefully placed in beakers containing the finished oils (i.e., Examples 4-6 and Comparative Example B). The samples were allowed to sit with no agitation in the finished oils for 4, 6, and 24 hours. The approximate temperature of the finished oils was ~ 22 °C. Cloudiness formed around the sectioned ring pieces, indicating some removal of deposits. The ring segments were removed, rinsed with hexane, allowed to air dry, and then reweighed.

[093] As shown in Table 3, the concentration of Compound A in the finished oil correlates nicely with deposit removal as did soak/residence time with deposit removal. The accumulated ring weight loss which corresponds to deposit removal is reported in mg (higher mg value indicates better deposit removal performance).

Table 3

	Comp. Ex. A	Ex. 15	Ex. 16	Ex. 17
Compound A (wt %)	0.0	15.0	18.0	21.0
Additive Package (wt%)	9.7	9.7	9.7	9.7
Group II Base Oil (wt %)	90.3	75.3	72.3	69.3
Time				
4 hours (mg)	0.6	2.5	2.5	5.0
6 hours (mg)	1.1	5.5	6.5	9.0
24 hours (mg)	2.1	6.5	8.0	11.5

TBN Boost

[094] The effect of Compound A on the total base number (TBN) was observed by JIS K-2501:2003 8 (ASTM D2896) method (DH-2). As shown below in Table 4, Compound A provides a boost to the TBN despite being a soft base component (containing N only). A high TBN is generally desirable to neutralize the acidic by-products of combustion and oxidation.

Table 4

	Comp. Ex. B	Ex. 18	Ex. 19	Comp. Ex. C	Ex. 20	Ex. 21
Compound A (wt %)	0	1	2	0	1	2
EC-treated succinimide dispersant (wt %)	2	2	2	1.3	1.3	1.3
Borated bis-succinimide dispersant (wt %)	4.5	4.5	4.5	4.5	4.5	4.5
Viscosity	5W-30	5W-30	5W-30	5W-30	5W-30	5W-30
TBN (mgKOH/g)	5.51/6.05	6.4	6.86	5.75/5.76	6.44	6.87

Deposit Tests

[095] A 0W-20 formulated oil containing Compound A (inventive) and a comparative 0W-20 formulated oil were assessed using the Daimler OM471LA Performance test of heavy-duty engine oils. This engine test provides evaluations of piston cleanliness, bore polishing, oil consumption, general engine deposits, engine sludge, general engine wear, cylinder wear, piston ring sticking and ~~or~~ turbo charger deposits.

[096] The OM 471 LA Euro VI engine is a well proven production engine representative of Euro 6 heavy duty engine technology. This 6-cylinder inline engine is configured with steel pistons, 12.8 liters in displacement, turbo charger, and waste gate.

[097] The test is operated over a 600-hour duration (two consecutive blocks of 300-hour runs) and includes stop/start events to represent severe application of vehicles in the field. To ensure good test repeatability, a known fuel is used (Coryton RF 99-21). At the end of the test, the pistons are rated for piston deposits.

[098] The only difference between the inventive 0W-20 formulated oil and the comparative 0W-20 formulated oil is that the inventive oil contains 2.7 wt. % of Compound A in place of the 2.7 wt. % of ethylene carbonate-treated bis-succinimide dispersant present in the comparative oil. The following table shows deposit removal (as a percentage) observed in the undercrown and in the turbocharger housing.

	Comp. Ex. D	Example 22
Daimler Undercrown %	72.5	88
Daimler Turbocharger housing deposit %	78	84

[099] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined

with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0100] Likewise, the term "comprising" is considered synonymous with the term "including." Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising," it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of," "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa.

[0101] The terms "a" and "the" as used herein are understood to encompass the plural as well as the singular.

[0102] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[0103] The foregoing description of the disclosure illustrates and describes the present disclosure. Additionally, the disclosure shows and describes only the preferred embodiments but, as mentioned above, it is to be understood that the disclosure is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the

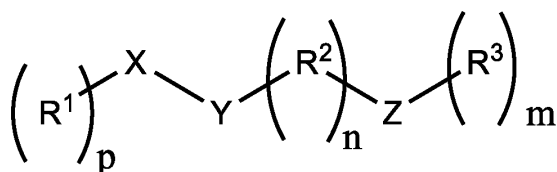
relevant art. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

[0104] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

[0105] The embodiments described hereinabove are further intended to explain best modes known of practicing it and to enable others skilled in the art to utilize the disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the description is not intended to limit it to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.

CLAIMS

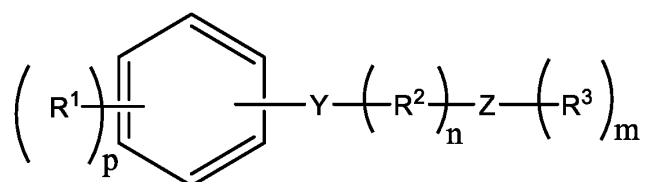
1. A lubricating oil composition comprising:
a major amount of base oil; and
a lubricant additive having the following structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

2. The lubricating oil composition of claim 1, wherein the lubricant additive is present in about 0.1 to about 50.0 wt. % based on total weight of the lubricating oil composition.
3. The lubricating oil composition of claim 1, wherein R^1 is a polyalkyl group.
4. The lubricating oil composition of claim 1, wherein R^1 is a polyisobutenyl group.
5. The lubricating oil composition of claim 1, further comprising a succinimide dispersant.
6. The lubricating composition of claim 5, wherein the succinimide dispersant has been post-treated with ethylene carbonate.

7. The lubricating oil composition of claim 1, wherein the lubricant additive has the following generalized structure:

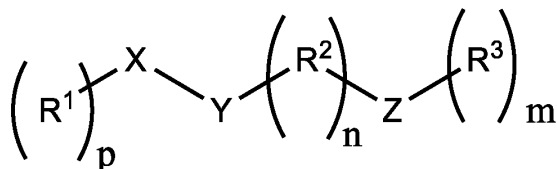


wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

8. A method of lubricating an engine, the method comprising lubricating the engine with a lubricating oil composition comprising:

a major amount of base oil; and

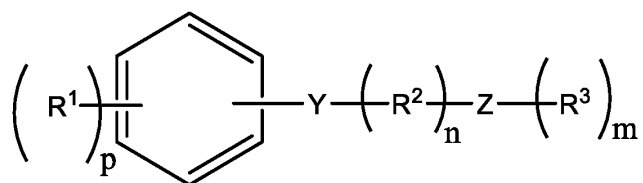
a lubricant additive having the following structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

9. The method of claim 8, wherein the lubricant additive is present in about 0.1 to about 50.0 wt. % based on total weight of the lubricating oil composition.

10. The method of claim 8, wherein R¹ is a polyalkyl group.
11. The method of claim 8, wherein R¹ is a polyisobutenyl group.
12. The method of claim 8, further comprising a succinimide dispersant.
13. The method of claim 12, wherein the succinimide is the succinimide dispersant has been post-treated with ethylene carbonate.
14. The method of claim 8, wherein the lubricant additive has the following generalized structure:

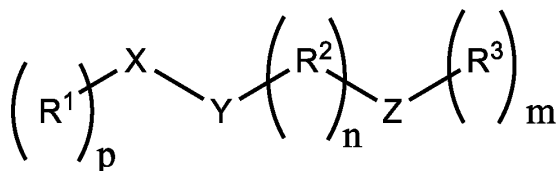


wherein each R¹ is independently a hydrocarbyl group having 10 to 400 carbons; Y is nitrogen, oxygen, or sulfur; each R² is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R³ is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

15. A method for improving piston cleanliness or oxidation inhibition in an engine, the method comprising lubricating the engine with a lubricating oil composition comprising:

a major amount of base oil; and

a lubricant additive having the following structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; X is an alkyl, aryl, or heteroaromatic group having 1 to 10 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.

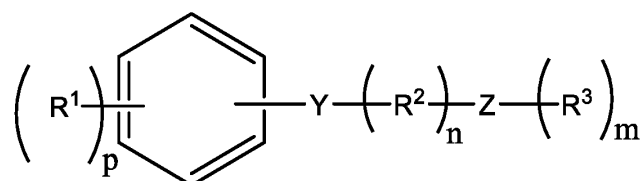
16. The method of claim 15, wherein the lubricant additive is present in about 0.1 to about 5 wt. % based on total weight of the lubricating oil composition.

17. The method of claim 15, wherein R^1 is a polyalkyl group.

18. The method of claim 15, wherein R^1 is a polyisobutenyl group.

19. The method of claim 15, further comprising a succinimide dispersant.

20. The method of claim 15, wherein the lubricant additive has the following generalized structure:



wherein each R^1 is independently a hydrocarbyl group having 10 to 400 carbons; Y is nitrogen, oxygen, or sulfur; each R^2 is independently a hydrocarbyl group having 1 to 9 carbons; Z is nitrogen, oxygen, or sulfur; and each R^3 is independently a hydrogen or hydrocarbyl group having 1 to 9 carbons with one or more nitrogen, oxygen, or sulfur functionalization, wherein p is 1 to 3, n is 1 to 20 and m is 0 to 3.