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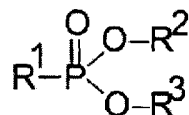
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1062 XK Amsterdam (NL)**(54) **Power transmission fluids**

(57) A power transmission fluid composition for extreme pressure applications. The power transmission fluid includes a base oil, and an additive composition containing an extreme pressure performance improving amount of an ester of phosphonic acid of the formula:



where R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen, a succinimide dispersant, and, optionally, a metal-based detergent. The optional detergent is substantially devoid of calcium cations.

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Description**FIELD**

[0001] The present disclosure relates to power transmission fluids having improved characteristics particularly for extreme pressure applications. The power transmission fluids disclosed herein may include fluids suitable for use in an automatic transmission (ATF) and/or a manual transmission.

BACKGROUND

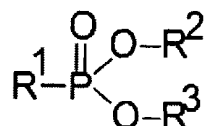
[0002] New and advanced transmission systems are being developed by the automotive industry. These new systems often involve high energy requirements. Therefore, component protection technology must be developed to meet the increasing energy requirements of these advanced systems.

[0003] Extremely high metal-on-metal pressures are present in newer automatic and manual transmissions such as step automatic transmissions, continuously variable transmissions, manual or automated manual transmissions. High pressures are also present in various gear drive components such as automotive differentials and power transmission gear drive components. The high pressures present in such transmission and gear drive components mean that lubricants used in these systems must be suitable for such extreme pressure applications to prevent wear and avoid seizure of the rotating and contacting components. Thus, there continues to be a need for additives which reduce wear and prevent seizure under extremely high pressure operating conditions.

SUMMARY OF THE EMBODIMENTS

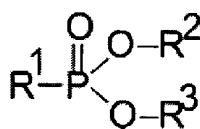
[0004] Power transmission fluids formulated according to the present disclosure provide improved high pressure characteristics. In particular additives and fluids containing the additives are described which are suitably formulated to protect transmission and drive components in metal-on-metal contact situations.

[0005] In an embodiment, a power transmission fluid composition for extreme pressure applications is provided. The power transmission fluid includes a base oil, and an additive composition containing an extreme pressure performance improving amount of an ester of phosphonic acid of the formula:



where R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen. The additive also includes a succinimide dispersant, and, optionally, a metal-based detergent. When used, the detergent component is substantially devoid of calcium cations.

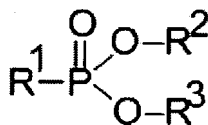
[0006] Another embodiment provides a method of improving extreme pressure characteristics for a transmission fluid. The method includes providing a base oil and adding to the base oil an additive composition including (1) from about 0.01 to about 1.0 weight percent based on the total weight of the base oil and additive composition of an ester of phosphonic acid of the formula:



[0007] In the formula, R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen. The additive composition also includes from about 2 to about 5 weight percent based on the total weight of the transmission fluid of a succinimide dispersant and, optionally, from about 0.0 to about 0.2 weight percent based on the total weight of the transmission fluid of a metal-based detergent.

The detergent is substantially devoid of calcium cations.

[0008] Yet another embodiment provides an additive concentrate for a transmission fluid or gear lubricant. The additive concentrate includes a base oil carrier fluid. Another component of the additive concentrate is an extreme pressure performance improving amount of an ester of phosphonic acid of the formula:



where R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen. A succinimide dispersant and an optional metal-based detergent may also be included in the additive concentrate. The detergent is substantially devoid of calcium cations.

[0009] Power transmission fluids of the foregoing embodiments are formulated to provide enhanced extreme pressure properties for applications where metal-to-metal contact is made under high pressures, e.g., pressures in excess of 2 GPa. Such fluids are suitable for automatic and manual transmissions such as step automatic transmissions, continuously variable transmissions, manual or automated manual transmissions. High metal-to-metal contact pressures such as those found in automotive transmissions, for example, may cause damage to transmission parts if a lubricant is used that does not possess sufficient extreme pressure protection characteristics. However, power transmission fluid compositions as described herein have greatly improved extreme pressure performance characteristics.

[0010] Both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the present invention, as claimed.

DETAILED DESCRIPTION OF EMBODIMENTS

[0011] As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of a molecule and having a predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

(1) hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is completed through another portion of the molecule (e.g., two substituents together form an alicyclic radical);

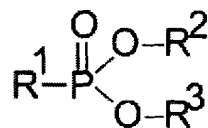
(2) substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of the description herein, do not alter the predominantly hydrocarbon substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, allylmercapto, nitro, nitroso, and sulfoxy);

(3) hetero-substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this description, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Hetero-atoms include sulfur, oxygen, nitrogen, and encompass substituents such as pyridyl, furyl, thienyl and imidazolyl. In general, no more than two, or as a further example, no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be no non-hydrocarbon substituent in the hydrocarbyl group.

Extreme Pressure-Improving Additive

[0012] As power transmission fluids operate under increasingly severe conditions, the oils used to lubricate those transmissions may be formulated to endure higher temperatures and pressures. To reduce equipment problems and increase the interval between transmission oil changes, the oil additive packages may be formulated so that important oil properties change as little as possible in the face of these stresses. An important characteristic of a power transmission fluid is its extreme pressure properties. High metal-on-metal contact pressures found in newer automotive transmissions and in gear drives can cause damage to transmission parts and gear drives if the lubricant used in the system is not formulated to provide sufficient extreme pressure protective properties.

[0013] In an embodiment, a power transmission fluid may include a base oil and an additive composition. The additive composition includes an extreme pressure performance improving amount of an ester of phosphonic acid of the formula:



where R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen. The additive also includes a succinimide dispersant, and, optionally, a metal-based detergent. When used, the detergent is substantially devoid of calcium cations. The succinimide dispersant used in such fluids may be a post-treated succinimide dispersant.

[0014] The phosphonic acid ester may be a di-organo or tri-organo phosphonate. Examples include, but are not limited to, methyloctadecylhydrogen phosphonate, bis(2-ethylhexyl) 2-ethylhexyl phosphonate, ethyloctadecylhydrogen phosphonate, dimethyloctadecylphosphonate, dimethylocta-decenylphosphonate, diethyl-2-ethyldecylphosphonate, ethylpropyl-1-butylhexadecyl-phosphonate, methylethyloctadecylphosphonate, methylbutyl eicosyl-phosphonate, dimethylhexatriacontylphosphonate. Methods for making phosphonic acid esters are described in U.S. Patent No. 2,2724,718 to Siles et al., and U.S. Patent No. 3,812,222 to Kleiner et al., for example.

[0015] An extreme pressure performance improving amount of the ester of phosphonic acid as described above in combination with a base oil to provide a power transmission fluid may range from about 0.01 to about 1.0 percent by weight of the total weight of the transmission fluid, as a further example, from about 0.03 to about 0.5 weight percent, and as an even further example, from about 0.03 to about 0.25 weight percent.

Base Oil

[0016] Base oils suitable for use in formulating transmission fluid compositions according to the invention may be selected from any of the synthetic or natural oils or mixtures thereof. Natural oils include animal oils and vegetable oils (e.g., castor oil, lard oil) as well as mineral lubricating oils such as liquid petroleum oils and solvent treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinicnaphthenic types. Oils derived from coal or shale are also suitable. The base oil typically has a viscosity of, for example, from about 2 to about 15 cSt and, as a further example, from about 2 to about 10 cSt at 100° C. Further, oils derived from a gas-to-liquid process are also suitable.

[0017] Synthetic oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, etc.); polyalphaolefins such as poly(1-hexenes), poly-(1-octenes), poly(1-decenes), etc. and mixtures thereof; alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, di-nonylbenzenes, di-(2-ethylhexyl)benzenes, etc.); polyphenyls (e.g., biphenyls, terphenyl, alkylated polyphenyls, etc.); alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof and the like.

[0018] Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute another class of known synthetic oils that may be used. Such oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methylpolyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl ether of polyethylene glycol having a molecular weight of about 500-1000, diethyl ether of polypropylene glycol having a molecular weight of about 1000-1500, etc.) or mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed C₃₋₈ fatty acid esters, or the C₁₃ Oxo acid diester of tetraethylene glycol.

[0019] Another class of synthetic oils that may be used includes the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, etc.) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc.) Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

[0020] Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, etc.

[0021] Hence, the base oil used which may be used to make the transmission fluid compositions as described herein may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. Such base oil groups are as follows:

¹ Groups I-III are mineral oil base stocks.				
Base Oil Group ¹	Sulfur (wt.%)		Saturates (wt.%)	Viscosity Index
Group I	> 0.03	and/or	< 90	80 to 120
Group II	≤ 0.03	And	≥ 90	80 to 120
Group II	≤ 0.03	And	≥ 90	≥ 120
Group IV	all polyalphaolefins (PAOs)			
Group V	all others not included in Groups I-IV			

[0022] As set forth above, the base oil may be a poly-alpha-olefin (PAO). Typically, the poly-alpha-olefins are derived from monomers having from about 4 to about 30, or from about 4 to about 20, or from about 6 to about 16 carbon atoms. Examples of useful PAOs include those derived from octene, decene, mixtures thereof, and the like. PAOs may have a viscosity of from about 2 to about 15, or from about 3 to about 12, or from about 4 to about 8 cSt at 100° C. Examples of PAOs include 4 cSt at 100° C poly-alpha-olefins, 6 cSt at 100° C poly-alpha-olefins, and mixtures thereof. Mixtures of mineral oil with the foregoing poly-alpha-olefins may be used.

[0023] The base oil may be an oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons may be hydroisomerized using processes disclosed in U.S. Pat. Nos. 6,103,099 or 6,180,575; hydrocracked and hydroisomerized using processes disclosed in U.S. Pat. Nos. 4,943,672 or 6,096,940; dewaxed using processes disclosed in U.S. Pat. No. 5,882,505; or hydroisomerized and dewaxed using processes disclosed in U.S. Pat. Nos. 6,013,171; 6,080,301; or 6,165,949.

[0024] Unrefined, refined and rerefined oils, either natural or synthetic (as well as mixtures of two or more of any of these) of the type disclosed hereinabove can be used in the base oils. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from primary distillation or ester oil obtained directly from an esterification process and used without further treatment would be an unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, etc. Rerefined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives, contaminants, and oil breakdown products.

Ashless Dispersants

[0025] The ashless dispersant used in the transmission fluids as described herein may be selected from any of the ashless dispersants known to those skilled in the art. Suitable ashless dispersants may include ashless dispersants such as succinimide dispersants, Mannich base dispersants, and polymeric polyamine dispersants. Hydrocarbyl-substituted succinic acylating agents are used to make hydrocarbyl-substituted succinimides. The hydrocarbyl-substituted succinic acylating agents include, but are not limited to, hydrocarbyl-substituted succinic acids, hydrocarbyl-substituted succinic anhydrides, the hydrocarbyl-substituted succinic acid halides (especially the acid fluorides and acid chlorides), and the esters of the hydrocarbyl-substituted succinic acids and lower alcohols (e.g., those containing up to 7 carbon atoms), that is, hydrocarbyl-substituted compounds which can function as carboxylic acylating agents.

[0026] Hydrocarbyl substituted acylating agents are made as by reacting a polyolefin or chlorinated polyolefin of appropriate molecular weight with maleic anhydride. Similar carboxylic reactants can be used to make the acylating agents. Such reactants may include, but are not limited to, maleic acid, fumaric acid, malic acid, tartaric acid, itaconic acid, itaconic anhydride, citraconic acid, citraconic anhydride, mesaconic acid, ethylmaleic anhydride, dimethylmaleic anhydride, ethylmaleic acid, dimethylmaleic acid, hexylmaleic acid, and the like, including the corresponding acid halides and lower aliphatic esters.

[0027] The molecular weight of the olefin can vary depending upon the intended use of the substituted succinic anhydrides. Typically, the substituted succinic anhydrides will have a hydrocarbyl group of from 8-500 carbon atoms. However, substituted succinic anhydrides used to make lubricating oil dispersants will typically have a hydrocarbyl group of about 40-500 carbon atoms. With high molecular weight substituted succinic anhydrides, it is more accurate to refer to number average molecular weight (Mn) since the olefins used to make these substituted succinic anhydrides

may include a mixture of different molecular weight components resulting from the polymerization of low molecular weight olefin monomers such as ethylene, propylene and isobutylene.

[0028] The mole ratio of maleic anhydride to olefin can vary widely. It may vary, for example, from about 5:1 to about 1:5, or for example, from about 1:1 to about 3:1. With olefins such as polyisobutylene having a number average molecular weight of about 500 to about 7000, or as a further example, about 800 to about 3000 or higher and the ethylene-alpha-olefin copolymers, the maleic anhydride may be used in stoichiometric excess, e.g. 1.1 to 3 moles maleic anhydride per mole of olefin. The unreacted maleic anhydride can be vaporized from the resultant reaction mixture.

[0029] Polyalkenyl succinic anhydrides may be converted to polyalkyl succinic anhydrides by using conventional reducing conditions such as catalytic hydrogenation. For catalytic hydrogenation, a suitable catalyst is palladium on carbon. Likewise, polyalkenyl succinimides may be converted to polyalkyl succinimides using similar reducing conditions.

[0030] The polyalkyl or polyalkenyl substituent on the succinic anhydrides employed herein is generally derived from polyolefins which are polymers or copolymers of mono-olefins, particularly 1-mono-olefins, such as ethylene, propylene and butylene. The mono-olefin employed may have about 2 to about 24 carbon atoms, or as a further example, about 3 to about 12 carbon atoms. Other suitable mono-olefins include propylene, butylene, particularly isobutylene, 1-octene and 1-decene. Polyolefins prepared from such mono-olefins include polypropylene, polybutene, polyisobutene, and the polyalphaolefins produced from 1-octene and 1-decene.

[0031] In some embodiments, the ashless dispersant may include one or more alkenyl succinimides of an amine having at least one primary amino group capable of forming an imide group. The alkenyl succinimides may be formed by conventional methods such as by heating an alkenyl succinic anhydride, acid, acid-ester, acid halide, or lower alkyl ester with an amine containing at least one primary amino group. The alkenyl succinic anhydride may be made readily by heating a mixture of polyolefin and maleic anhydride to about 180°-220°C. The polyolefin may be a polymer or copolymer of a lower monoolefin such as ethylene, propylene, isobutene and the like, having a number average molecular weight in the range of about 300 to about 3000 as determined by gel permeation chromatography (GPC).

[0032] Amines which may be employed in forming the ashless dispersant include any that have at least one primary amino group which can react to form an imide group and at least one additional primary or secondary amino group and/or at least one hydroxyl group. A few representative examples are: N-methyl-propanediamine, N-dodecylpropanediamine, N-aminopropyl-piperazine, ethanolamine, N-ethanoethylenediamine, and the like.

[0033] Suitable amines may include alkylene polyamines, such as propylene diamine, dipropylene triamine, di-(1,2-butylene)triamine, and tetra-(1,2-propylene)pentamine. A further example includes the ethylene polyamines which can be depicted by the formula $H_2N(CH_2CH_2NH)_nH$, wherein n may be an integer from about one to about ten. These include: ethylene diamine, diethylene triamine (DETA), triethylene tetramine (TETA), tetraethylene pentamine (TEPA), pentaethylene hexamine (PEHA), and the like, including mixtures thereof in which case n is the average value of the mixture. Such ethylene polyamines have a primary amine group at each end so they may form monoalkenyl-succinimides and bis-alkenylsuccinimides. Commercially available ethylene polyamine mixtures may contain minor amounts of branched species and cyclic species such as N-aminoethyl piperazine, N,N'-bis(aminoethyl)piperazine, N,N'-bis(piperazinyl)ethane, and like compounds. The commercial mixtures may have approximate overall compositions falling in the range corresponding to diethylene triamine to tetraethylene pentamine. The molar ratio of polyalkenyl succinic anhydride to polyalkylene polyamines may be from about 1:1 to about 3.0:1.

[0034] In some embodiments, the ashless dispersant may include the products of the reaction of a polyethylene polyamine, e.g. triethylene tetramine or tetraethylene pentamine, with a hydrocarbon substituted carboxylic acid or anhydride made by reaction of a polyolefin, such as polyisobutene, of suitable molecular weight, with an unsaturated polycarboxylic acid or anhydride, e.g., maleic anhydride, maleic acid, fumaric acid, or the like, including mixtures of two or more such substances.

[0035] Polyamines that are also suitable in preparing the dispersants described herein include N-arylphenylenediamines, such as N-phenylphenylenediamines, for example, N-phenyl-1,4-phenylenediamine, N-phenyl-1,3-phenylenediamine, and N-phenyl-1,2-phenylenediamine; aminothiazoles such as aminothiazole, aminobenzothiazole, aminobenzothiadiazole and aminoalkylthiazole; aminocarbazoles; aminoindoles; aminopyrroles; amino-indazolinones; aminomercaptotriazoles; aminoperimidines; aminoalkyl imidazoles, such as 1-(2-aminoethyl) imidazole, 1-(3-aminopropyl) imidazole; and aminoalkyl morpholines, such as 4-(3-aminopropyl) morpholine. These polyamines are described in more detail in U.S. Pat. Nos. 4,863,623 and 5,075,383. Such polyamines can provide additional benefits, such as anti-wear and antioxidancy, to the final products.

[0036] Additional polyamines useful in forming the hydrocarbyl-substituted succinimides include polyamines having at least one primary or secondary amino group and at least one tertiary amino group in the molecule as taught in U.S. Pat. Nos. 5,634,951 and 5,725,612. Examples of suitable polyamines include N,N,N',N"-tetraalkyldialkylenetriamines (two terminal tertiary amino groups and one central secondary amino group), N,N,N',N"-tetraalkyltrialkylene-tetramines (one terminal tertiary amino group, two internal tertiary amino groups and one terminal primary amino group), N,N,N',N',N"-pentaalkyltrialkylenetetramines (one terminal tertiary amino group, two internal tertiary amino groups

and one terminal secondary amino group), tris(dialkylaminoalkyl)aminoalkylmethanes (three terminal tertiary amino groups and one terminal primary amino group), and like compounds, wherein the alkyl groups are the same or different and typically contain no more than about 12 carbon atoms each, and which may contain from 1 to 4 carbon atoms each. As a further example, these alkyl groups may be methyl and/or ethyl groups. Polyamine reactants of this type

may include dimethylaminopropylamine (DMAPA) and N-methyl piperazine.

[0037] Hydroxyamines suitable for herein include compounds, oligomers or polymers containing at least one primary or secondary amine capable of reacting with the hydrocarbyl-substituted succinic acid or anhydride. Examples of hydroxyamines suitable for use herein include aminoethylethanolamine (AEEA), aminopropyldiethanolamine (APDEA), ethanolamine, diethanolamine (DEA), partially propoxylated hexamethylene diamine (for example HMDA-2PO or HMDA-3PO), 3-amino-1,2-propanediol, tris(hydroxymethyl)aminomethane, and 2-amino-1,3-propanediol.

[0038] The mole ratio of amine to hydrocarbyl-substituted succinic acid or anhydride may range from 1:1 to about 3.0:1. Another example of a mole ratio of amine to hydrocarbyl-substituted succinic acid or anhydride may range from about 1.5:1 to about 2.0:1.

[0039] The foregoing dispersant may also be a post-treated dispersant made, for example, by treating the dispersant with maleic anhydride and boric acid as described, for example, in U.S. Patent No. 5,789,353 to Scattergood, or by treating the dispersant with nonylphenol, formaldehyde and glycolic acid as described, for example, in U.S. Patent No. 5,137,980 to DeGonia, et al.

[0040] The Mannich base dispersants may be a reaction product of an alkyl phenol, typically having a long chain alkyl substituent on the ring, with one or more aliphatic aldehydes containing from 1 to about 7 carbon atoms (especially formaldehyde and derivatives thereof), and polyamines (especially polyalkylene polyamines). For example, a Mannich base ashless dispersants may be formed by condensing about one molar proportion of long chain hydrocarbon-substituted phenol with from about 1 to about 2.5 moles of formaldehyde and from about 0.5 to about 2 moles of polyalkylene polyamine.

[0041] Hydrocarbon sources for preparation of the Mannich polyamine dispersants may be those derived from substantially saturated petroleum fractions and olefin polymers, such as polymers of mono-olefins having from 2 to about 6 carbon atoms. The hydrocarbon source generally contains, for example, at least about 40 carbon atoms, and as a further example, at least about 50 carbon atoms to provide substantial oil solubility to the dispersant. The olefin polymers having a GPC number average molecular weight between about 600 and 5,000 are suitable for reasons of easy reactivity and low cost. However, polymers of higher molecular weight can also be used. Especially suitable hydrocarbon sources are isobutylene polymers and polymers made from a mixture of isobutene and a raffinate I stream.

[0042] Suitable Mannich base dispersants may be Mannich base ashless dispersants formed by condensing about one molar proportion of long chain hydrocarbon-substituted phenol with from about 1 to 2.5 moles of formaldehyde and from about 0.5 to 2 moles of polyalkylene polyamine.

[0043] Polymeric polyamine dispersants suitable as the ashless dispersants are polymers containing basic amine groups and oil solubilizing groups (for example, pendant alkyl groups having at least about 8 carbon atoms). Such materials are illustrated by interpolymers formed from various monomers such as decyl methacrylate, vinyl decyl ether or relatively high molecular weight olefins, with aminoalkyl acrylates and aminoalkyl acrylamides. Examples of polymeric polyamine dispersants are set forth in U.S. Pat. Nos. 3,329,658; 3,449,250; 3,493,520; 3,519,565; 3,666,730; 3,687,849; and 3,702,300. Polymeric polyamines may include hydrocarbyl polyamines wherein the hydrocarbyl group is composed of the polymerization product of isobutene and a raffinate I stream as described above. PIB-amine and PIB-polyamines may also be used.

[0044] Methods for the production of ashless dispersants as described above are known to those skilled in the art and are reported in the patent literature. For example, the synthesis of various ashless dispersants of the foregoing types is described in such patents as U.S. Patent Nos. 2,459,112; 2,962,442; 2,984,550; 3,036,003; 3,163,603; 3,166,516; 3,172,892; 3,184,474; 3,202,678; 3,215,707; 3,216,936; 3,219,666; 3,236,770; 3,254,025; 3,271,310; 3,272,746; 3,275,554; 3,281,357; 3,306,908; 3,311,558; 3,316,177; 3,331,776; 3,340,281; 3,341,542; 3,346,493; 3,351,552; 3,355,270; 3,368,972; 3,381,022; 3,399,141; 3,413,347; 3,415,750; 3,433,744; 3,438,757; 3,442,808; 3,444,170; 3,448,047; 3,448,048; 3,448,049; 3,451,933; 3,454,497; 3,454,555; 3,454,607; 3,459,661; 3,461,172; 3,467,668; 3,493,520; 3,501,405; 3,522,179; 3,539,633; 3,541,012; 3,542,680; 3,543,678; 3,558,743; 3,565,804; 3,567,637; 3,574,101; 3,576,743; 3,586,629; 3,591,598; 3,600,372; 3,630,904; 3,632,510; 3,632,511; 3,634,515; 3,649,229; 3,697,428; 3,697,574; 3,703,536; 3,704,308; 3,725,277; 3,725,441; 3,725,480; 3,726,882; 3,736,357; 3,751,365; 3,756,953; 3,793,202; 3,798,165; 3,798,247; 3,803,039; 3,804,763; 3,836,471; 3,862,981; 3,872,019; 3,904,595; 3,936,480; 3,948,800; 3,950,341; 3,957,746; 3,957,854; 3,957,855; 3,980,569; 3,985,802; 3,991,098; 4,006,089; 4,011,380; 4,025,451; 4,058,468; 4,071,548; 4,083,699; 4,090,854; 4,173,540; 4,234,435; 4,354,950; 4,485,023; 5,137,980, and Re 26,433, herein incorporated by reference.

[0045] An example of a suitable ashless dispersant is a borated dispersant. Borated dispersants may be formed by boronating (borating) an ashless dispersant having basic nitrogen and/or at least one hydroxyl group in the molecule, such as a succinimide dispersant, succinamide dispersant, succinic ester dispersant, succinic ester-amide dispersant,

Mannich base dispersant, or hydrocarbyl amine or polyamine dispersant. Methods that can be used for boronating the various types of ashless dispersants described above are described in U.S. Pat. Nos. 3,087,936; 3,254,025; 3,281,428; 3,282,955; 2,284,409; 2,284,410; 3,338,832; 3,344,069; 3,533,945; 3,658,836; 3,703,536; 3,718,663; 4,455,243; and 4,652,387.

[0046] The borated dispersant may include a high molecular weight dispersant treated with boron such that the borated dispersant includes up to 2 wt% of boron. As another example the borated dispersant may include from about 0.8 wt% or less of boron. As a further example, the borated dispersant may include from about 0.1 to about 0.7 wt% of boron. As an even further example, the borated dispersant may include from about 0.25 to about 0.7 wt% of boron. As a further example, the borated dispersant may include from about 0.35 to about 0.7 wt% of boron. The dispersant may be dissolved in oil of suitable viscosity for ease of handling. It should be understood that the weight percentages given here are for neat dispersant, without any diluent oil added.

[0047] A dispersant may be further reacted with an organic acid, an anhydride, and/or an aldehyde/phenol mixture. Such a process may enhance compatibility with elastomer seals, for example. The borated dispersant may further include a mixture of borated dispersants. As a further example, the borated dispersant may include a nitrogen-containing dispersant and/or may be free of phosphorus.

[0048] A dispersant may be present in the power transmission fluid in an amount of about 0.1 wt% to about 10 wt%. Further, the power transmission fluid may include from about 2 wt% to about 7 wt% of the borated dispersant. Further, the power transmission fluid may include from about 3 wt% to about 5 wt% of the borated dispersant. Further, the power transmission fluid may include an amount of the borated dispersant sufficient to provide up to 1900 parts per million (ppm) by weight of boron in the finished fluid, such as for example, from about 50 to about 500 ppm by weight of boron in the finished fluid.

Metallic Detergents

[0049] Embodiments of the present disclosure may optionally include a metallic detergent, wherein the metallic detergent is substantially devoid of calcium cations. A suitable metallic detergent may include an oil-soluble neutral or overbased salt of alkali or alkaline earth metal with one or more of the following acidic substances (or mixtures thereof): (1) a sulfonic acid, (2) a carboxylic acid, (3) a salicylic acid, (4) an alkyl phenol, (5) a sulfurized alkyl phenol, and (6) an organic phosphorus acid characterized by at least one direct carbon-to-phosphorus linkage. Such an organic phosphorus acid may include those prepared by the treatment of an olefin polymer (e.g., polyisobutylene having a molecular weight of about 1,000) with a phosphorizing agent such as phosphorus trichloride, phosphorus heptasulfide, phosphorus pentasulfide, phosphorus trichloride and sulfur, white phosphorus and a sulfur halide, or phosphorothioic chloride.

[0050] Suitable salts may include neutral or overbased salts of magnesium or zinc. As a further example, suitable salts may include magnesium sulfonate, zinc sulfonate, magnesium phenate, and or zinc phenate. See, e.g., US 6,482,778.

[0051] Oil-soluble neutral metal-containing detergents are those detergents that contain stoichiometrically equivalent amounts of metal in relation to the amount of acidic moieties present in the detergent. Thus, in general the neutral detergents will have a low basicity when compared to their overbased counterparts. The acidic materials utilized in forming such detergents include carboxylic acids, salicylic acids, alkylphenols, sulfonic acids, sulfurized alkylphenols and the like.

[0052] The term "overbased" in connection with metallic detergents is used to designate metal salts wherein the metal is present in stoichiometrically larger amounts than the organic radical. The commonly employed methods for preparing the overbased salts involve heating a mineral oil solution of an acid with a stoichiometric excess of a metal neutralizing agent such as the metal oxide, hydroxide, carbonate, bicarbonate, or sulfide at a temperature of about 50 °C, and filtering the resultant product. The use of a "promoter" in the neutralization step to aid the incorporation of a large excess of metal likewise is known. Examples of compounds useful as the promoter include phenolic substances such as phenol, naphthol, alkyl phenol, thiophenol, sulfurized alkylphenol, and condensation products of formaldehyde with a phenolic substance; alcohols such as methanol, 2-propanol, octanol, Cellosolve.RTM. alcohol, Carbitol.RTM. alcohol, ethylene glycol, stearyl alcohol, and cyclohexyl alcohol; and amines such as aniline, phenylene diamine, phenothiazine, phenyl-beta-naphthylamine, and dodecylamine. A particularly effective method for preparing the basic salts includes mixing an acid with an excess of a basic alkaline earth metal neutralizing agent and at least one alcohol promoter, and carbonating the mixture at an elevated temperature such as 60 °C to 200 °C.

[0053] Examples of suitable metal-containing detergents include, but are not limited to, neutral and overbased salts of such substances as neutral sodium sulfonate, an overbased sodium sulfonate, a sodium carboxylate, a sodium salicylate, a sodium phenate, a sulfurized sodium phenate, a lithium sulfonate, a lithium carboxylate, a lithium salicylate, a lithium phenate, a sulfurized lithium phenate, a magnesium sulfonate, a magnesium carboxylate, a magnesium salicylate, a magnesium phenate, a sulfurized magnesium phenate, a potassium sulfonate, a potassium carboxylate, a potassium salicylate, a potassium phenate, a sulfurized potassium phenate, a zinc sulfonate, a zinc carboxylate, a zinc

salicylate, a zinc phenate, and a sulfurized zinc phenate. Further examples include a lithium, sodium, potassium, and magnesium salt of a hydrolyzed phosphosulfurized olefin having 10 to 2,000 carbon atoms or of a hydrolyzed phosphosulfurized alcohol and/or an aliphatic-substituted phenolic compound having 10 to 2,000 carbon atoms. Even further examples include a lithium, sodium, potassium, and magnesium salt of an aliphatic carboxylic acid and an aliphatic substituted cycloaliphatic carboxylic acid and many other similar alkali and alkaline earth metal salts of oil-soluble organic acids. A mixture of a neutral or an overbased salt of two or more different alkali and/or alkaline earth metals can be used. Likewise, a neutral and/or an overbased salt of mixtures of two or more different acids can also be used.

[0054] As is well known, overbased metal detergents are generally regarded as containing overbasing quantities of inorganic bases, generally in the form of micro dispersions or colloidal suspensions. Thus the term "oil-soluble" as applied to metallic detergents is intended to include metal detergents wherein inorganic bases are present that are not necessarily completely or truly oil-soluble in the strict sense of the term, inasmuch as such detergents when mixed into base oils behave much the same way as if they were fully and totally dissolved in the oil. Collectively, the various metallic detergents referred to herein above, are sometimes called neutral, basic, or overbased alkali metal or alkaline earth metal-containing organic acid salts.

[0055] Methods for the production of oil-soluble neutral and overbased metallic detergents and alkaline earth metal-containing detergents are well known to those skilled in the art, and extensively reported in the patent literature. See, for example, U.S. Pat. Nos. 2,001,108; 2,081,075; 2,095,538; 2,144,078; 2,163,622; 2,270,183; 2,292,205; 2,335,017; 2,399,877; 2,416,281; 2,451,345; 2,451,346; 2,485,861; 2,501,731; 2,501,732; 2,585,520; 2,671,758; 2,616,904; 2,616,905; 2,616,906; 2,616,911; 2,616,924; 2,616,925; 2,617,049; 2,695,910; 3,178,368; 3,367,867; 3,496,105; 3,629,109; 3,865,737; 3,907,691; 4,100,085; 4,129,589; 4,137,184; 4,184,740; 4,212,752; 4,617,135; 4,647,387; and 4,880,550.

[0056] The metallic detergents utilized in this invention can, if desired, be oil-soluble boronated neutral and/or overbased alkali or alkaline earth metal-containing detergents. Methods for preparing boronated metallic detergents are described in, for example, U.S. Pat. Nos. 3,480,548; 3,679,584; 3,829,381; 3,909,691; 4,965,003; and 4,965,004.

[0057] While any effective amount of the metallic detergents may be used to enhance the benefits of this invention, typically these effective amounts will range from about 0.01 to about 0.2 wt% in the finished fluid, or as a further example, from about 0.05 to about 0.1 wt% in the finished fluid.

Other Optional Components

[0058] The power transmission fluid may also include conventional additives of the type used in automatic transmission fluid formulations and gear lubricants in addition to the extreme pressure performance improving additives described above. Such additives include, but are not limited to, friction modifiers, antioxidants, viscosity index improvers, corrosion inhibitors, antirust additives, antiwear additives, metal deactivators, antifoamants, pour point depressants, air entrainment additives and/or seal swell agents.

Antiwear Agents

[0059] The antiwear agents may include phosphorus-containing antiwear agents which may include an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof. For example, the phosphorus-containing antiwear agent may include one or more of a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, a dihydrocarbyl phosphate, a trihydrocarbyl phosphate, any sulfur analogs thereof, and any amine salts thereof. As a further example, the phosphorus-containing antiwear agent may include at least one of dibutyl hydrogen phosphite (such as HiTEC® 528 antiwear agent available from Ethyl Corporation) and an amine salt of sulfurized dibutyl hydrogen phosphite (such as HiTEC® 833 antiwear agent available from Ethyl Corporation).

[0060] The phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 50 to about 500 parts per million by weight of phosphorus in the power transmission fluid. As a further example, the phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 150 to about 300 parts per million by weight of phosphorus in the power transmission fluid.

[0061] The power transmission fluid may include from about 0.01 wt% to about 1.0 wt% of the phosphorus-containing antiwear agent. As a further example, the power transmission fluid may include from about 0.2 wt% to about 0.3 wt% of the phosphorus-containing antiwear agent. As an example, the power transmission fluid may include from about 0.1 wt% to about 0.2 wt% of a dibutyl hydrogen phosphite or 0.3 wt% to about 0.4 wt% an amine salt of a sulfurized dibutyl hydrogen phosphate.

Friction Modifiers

[0062] Friction modifiers are used in automatic transmission fluids to decrease friction between surfaces (e.g., the

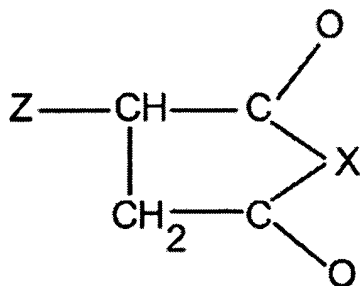
members of a torque converter clutch or a shifting clutch) at low sliding speeds. The result is a friction-vs.-velocity (μ -v) curve that has a positive slope, which in turn leads to smooth clutch engagements and minimizes "stick-slip" behavior (e.g., shudder, noise, and harsh shifts).

[0063] Friction modifiers include such compounds as aliphatic amines or ethoxylated aliphatic amines, ether amines, alkoxylated ether amines, aliphatic fatty acid amides, acylated amines, aliphatic carboxylic acids, aliphatic carboxylic esters, polyol esters, aliphatic carboxylic ester-amides, imidazolines, tertiary amines, aliphatic phosphonates, aliphatic phosphates, aliphatic thiophosphonates, aliphatic thiophosphates, etc., wherein the aliphatic group usually contains one or more carbon atoms so as to render the compound suitably oil soluble. As a further example, the aliphatic group may contain about 8 or more carbon atoms. Also suitable are aliphatic substituted succinimides formed by reacting one or more aliphatic succinic acids or anhydrides with ammonia or primary amines.

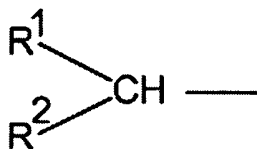
[0064] The succinimide may include the reaction product of a succinic anhydride and ammonia or primary amine. The alkenyl group of the alkenyl succinic acid may be a short chain alkenyl group, for example, the alkenyl group may include from about 12 to about 36 carbon atoms. Further, the succinimide may include a C_{12} to about C_{36} aliphatic hydrocarbyl succinimide. As a further example, the succinimide may include a C_{16} to about C_{28} aliphatic hydrocarbyl succinimide. As an even further example, the succinimide may include a C_{18} to about C_{24} aliphatic hydrocarbyl succinimide.

[0065] The succinimide may be prepared from a succinic anhydride and ammonia as described in European Patent Application No. 0 020 037, herein incorporated by reference. Further, the succinimide may include HiTEC® 3191 friction modifier, available from Ethyl Corporation. In some embodiments, no non-metallic friction modifier other than the succinimide disclosed herein is included.

[0066] The succinimide may include one or more of a compound having the following structure:



wherein Z may have the structure:



wherein either R^1 or R^2 may be hydrogen, but not both, and wherein R^1 and R^2 may be independently straight or branched chain hydrocarbon groups containing from about 1 to about 34 carbon atoms such that the total number of carbon atoms in R^1 and R^2 is from about 11 to about 35; X is an amino group derived from ammonia or a primary amine; and

wherein, in addition to or in the alternative, the parent succinic anhydride may be formed by reacting maleic acid, anhydride, or ester with an internal olefin containing about 12 to about 36 carbon atoms, said internal olefin being formed by isomerizing the olefinic double bond of a linear α -olefin or mixture thereof to obtain a mixture of internal olefins. The reaction may involve an equimolar amount of ammonia and may be carried out at elevated temperatures with the removal of water.

[0067] One group of friction modifiers includes the N-aliphatic hydrocarbyl-substituted diethanol amines in which the N-aliphatic hydrocarbyl-substituent is at least one straight chain aliphatic hydrocarbyl group free of acetylenic unsaturation and having in the range of about 14 to about 20 carbon atoms.

[0068] An example of a suitable friction modifier system is composed of a combination of at least one N-aliphatic hydrocarbyl-substituted diethanol amine and at least one N-aliphatic hydrocarbyl-substituted trimethylene diamine in which the N-aliphatic hydrocarbyl-substituent is at least one straight chain aliphatic hydrocarbyl group free of acetylenic

unsaturation and having in the range of about 14 to about 20 carbon atoms. Further details concerning this friction modifier system are set forth in U.S. Pat. Nos. 5,372,735 and 5,441,656.

[0069] Another friction modifier system is based on the combination of (i) at least one di(hydroxyalkyl) aliphatic tertiary amine in which the hydroxyalkyl groups, being the same or different, each contain from 2 to about 4 carbon atoms, and in which the aliphatic group is an acyclic hydrocarbyl group containing from about 10 to about 25 carbon atoms, and (ii) at least one hydroxyalkyl aliphatic imidazoline in which the hydroxyalkyl group contains from 2 to about 4 carbon atoms, and in which the aliphatic group is an acyclic hydrocarbyl group containing from about 10 to about 25 carbon atoms. For further details concerning this friction modifier system, reference should be had to U.S. Pat. No. 5,344,579.

[0070] Another suitable group of friction modifiers include polyolesters, for example, glycerol monooleate (GMO), glycerol monolaurate (GML), and the like.

[0071] Generally speaking, the compositions may contain up to about 1.25 wt%, or, as a further example, from about 0.05 to about 1 wt% of one or more friction modifiers.

Antioxidants

[0072] In some embodiments, antioxidant compounds may be included in the compositions. Antioxidants include phenolic antioxidants, aromatic amine antioxidants, sulfurized phenolic antioxidants, and organic phosphites, among others. Examples of phenolic antioxidants include 2,6-di-tert-butylphenol, liquid mixtures of tertiary butylated phenols, 2,6-di-tert-butyl-4-methylphenol, 4,4'-methylenebis(2,6-di-tert-butylphenol), 2,2'-methylenebis(4-methyl-6-tert-butylphenol), mixed methylene-bridged polyalkyl phenols, and 4,4'-thiobis(2-methyl-6-tert-butylphenol). N,N'-di-sec-butyl-phenylenediamine, 4-isopropylaminodiphenylamine, phenyl-.alpha.-naphthyl amine, phenyl-.alpha.-naphthyl amine, and ring-alkylated diphenylamines. Examples include the sterically hindered tertiary butylated phenols, bisphenols and cinnamic acid derivatives and combinations thereof. The amount of antioxidant in the transmission fluid compositions described herein may range from about 0.01 to about 3.0 wt% based on the total weight of the fluid formulation. As a further example, antioxidant may be present in an amount from about 0.1 wt% to about 1.0 wt%.

Corrosion inhibitors

[0073] In some embodiments, copper corrosion inhibitors may constitute another class of additives suitable for inclusion in the compositions. Such compounds include thiazoles, triazoles and thiadiazoles. Examples of such compounds include benzotriazole, tolyltriazole, octyltriazole, decyltriazole, dodecyltriazole, 2-mercapto benzothiazole, 2,5-dimercapto-1,3,4-thiadiazole, 2-mercapto-5-hydrocarbylthio-1,3,4-thiadiazoles, 2-mercapto-5-hydrocarbyldithio-1,3,4-thiadiazoles, 2,5-bis(hydrocarbylthio)-1,3,4-thiadiazoles, and 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazoles. Suitable compounds include the 1,3,4-thiadiazoles, a number of which are available as articles of commerce, and also combinations of triazoles such as tolyltriazole with a 1,3,5-thiadiazole such as a 2,5-bis(alkyldithio)-1,3,4-thiadiazole. Materials of these types that are available on the open market include COBRATEC TT-100 and HiTEC® 4313 additive (Ethyl Corporation). The 1,3,4-thiadiazoles are generally synthesized from hydrazine and carbon disulfide by known procedures. See, for example, U.S. Pat. Nos. 2,765,289; 2,749,311; 2,760,933; 2,850,453; 2,910,439; 3,663,561; 3,862,798; and 3,840,549.

[0074] Rust or corrosion inhibitors are another type of inhibitor additive for use in embodiments of the present disclosure. Such materials include monocarboxylic acids and polycarboxylic acids. Examples of suitable monocarboxylic acids are octanoic acid, decanoic acid and dodecanoic acid. Suitable polycarboxylic acids include dimer and trimer acids such as are produced from such acids as tall oil fatty acids, oleic acid, linoleic acid, or the like. Products of this type are currently available from various commercial sources, such as, for example, the dimer and trimer acids sold under the HYSTRENE trademark by the Humko Chemical Division of Witco Chemical Corporation and under the EMPOL trademark by Henkel Corporation. Another useful type of rust inhibitor may comprise alkenyl succinic acid and alkenyl succinic anhydride corrosion inhibitors such as, for example, tetrapropenylsuccinic acid, tetrapropenylsuccinic anhydride, tetradecenylsuccinic acid, tetradecenylsuccinic anhydride, hexadecenylsuccinic acid, hexadecenylsuccinic anhydride, and the like. Also useful are the half esters of alkenyl succinic acids having 8 to 24 carbon atoms in the alkenyl group with alcohols such as the polyglycols. Other suitable rust or corrosion inhibitors include ether amines; acid phosphates; amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; aminosuccinic acids or derivatives thereof, and the like. Materials of these types are available as articles of commerce. Mixtures of such rust or corrosion inhibitors can be used. The amount of corrosion inhibitor in the transmission fluid formulations described herein may range from about 0.01 to about 2.0 wt% based on the total weight of the formulation.

Viscosity Index Improvers

[0075] Viscosity index improvers for use in the above described fluid transmission and gear lubricant compositions may be selected from polyisoalkylene compounds, polymethacrylate compounds, and any conventional viscosity index improvers. An example of a suitable polyisoalkylene compound for use as a viscosity index improver includes polyisobutylene having a weight average molecular weight ranging from about 700 to about 2,500. Embodiments may include a mixture of one or more viscosity index improvers of the same or different molecular weight.

[0076] Suitable commercially available viscosity index improvers may include styrenemaleic esters such as are available under the trade designation LUBRIZOL® 3702, LUBRIZOL® 3706 and LUBRIZOL® 3715 available from The Lubrizol Corporation; polyalkylmethacrylates such as those available from ROHM GmbH (Darmstadt, Germany) under the trade designations: VISCOPLEX® 5543, VISCOPLEX® 5548, VISCOPLEX® 5549, VISCOPLEX® 5550, VISCOPLEX® 5551 and VISCOPLEX® 5151, from Rohm & Haas Company (Philadelphia, Pa.) under the trade designations ACRYLOID® 1277, ACRYLOID® 1265 and ACRYLOID® 1269, and from Ethyl Corporation (Richmond, Va.) under the trade designation HiTEC® 5710, HiTEC® 5738, HiTEC® 5739, and HiTEC® 5742; and olefin copolymer viscosity index improvers such as HiTEC® 5747, HiTEC® 5751, HiTEC® 5770, and HiTEC® 5772, available from Ethyl Corporation and SHELLVIS® 200 available from Shell Chemical Company. Mixtures of the foregoing products can also be used as well as dispersant and dispersant-antioxidant viscosity index improvers.

Antifoam agents

[0077] In some embodiments, a foam inhibitor may form another component suitable for use in the compositions. Foam inhibitors may be selected from silicones, polyacrylates, surfactants, and the like. One suitable acrylic defoamer material is PC-1244 available from Monsanto Company. The amount of antifoam agent in the transmission fluid formulations described herein may range from about 0.01 wt% to about 0.5 wt% based on the total weight of the formulation. As a further example, antifoam agent may be present in an amount from about 0.01 wt% to about 0.1 wt%.

Seal swell agents

[0078] The seal swell agent used in the transmission fluid compositions described herein is selected from oil-soluble diesters, oil-soluble sulfones, and mixtures thereof. Generally speaking the most suitable diesters include the adipates, azelates, and sebacates of C₈-C₁₃ alkanols (or mixtures thereof), and the phthalates of C₄-C₁₃ alkanols (or mixtures thereof). Mixtures of two or more different types of diesters (e.g., dialkyl adipates and dialkyl azelates, etc.) can also be used. Examples of such materials include the n-octyl, 2-ethylhexyl, isodecyl, and tridecyl diesters of adipic acid, azelaic acid, and sebacic acid, and the n-butyl, isobutyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, and tridecyl diesters of phthalic acid.

[0079] Other esters which may give generally equivalent performance are polyol esters such as EMERY 2935, 2936, and 2939 esters from the Emery Group of Henkel Corporation and HATCOL 2352, 2962, 2925, 2938, 2939, 2970, 3178, and 4322 polyol esters from Hatco Corporation.

[0080] Suitable sulfone seal swell agents are described in U.S. Pat. Nos. 3,974,081 and 4,029,587. Lubrizol 730 additive (The Lubrizol Corporation) is understood to be a commercially-available sulfone type seal swell agent. Typically these products are employed at levels in the range of about 0.25 wt% to about 5 wt % in the finished transmission fluid. As a further example, they may be provided in an amount of about 0.25 wt% to about 1 wt%.

[0081] Suitable seal swell agents are the oil-soluble dialkyl esters of (i) adipic acid, (ii) sebacic acid, or (iii) phthalic acid. The adipates and sebacates should be used in amounts in the range of from about 1 to about 15 wt% in the finished fluid. In the case of the phthalates, the levels in the transmission fluid should fall in the range of from about 1.5 to about 10 wt%. Generally speaking, the higher the molecular weight of the adipate, sebacate or phthalate, the higher should be the treat rate within the foregoing ranges.

[0082] Additives used in formulating the compositions described herein can be blended into the base oil individually or in various sub-combinations. However, it is suitable to blend all of the components concurrently using an additive concentrate (i.e., additives plus a diluent, such as a hydrocarbon solvent). The use of an additive concentrate takes advantage of the mutual compatibility afforded by the combination of ingredients when in the form of an additive concentrate. Also, the use of a concentrate reduces blending time and lessens the possibility of blending errors.

[0083] The power transmission fluids disclosed herein may include fluids suitable for any power transmitting application, such as a step automatic transmission or a manual transmission. Further, the power transmission fluids of the present disclosure are suitable for use in transmissions with a slipping torque converter, a lock-up torque converter, a starting clutch, and/or one or more shifting clutches. Such transmissions include four-, five-, six-, and seven-speed transmissions, and continuously variable transmissions (chain, belt, or disk type). They may also be used in manual transmissions, including automated manual and dual-clutch transmissions.

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[0084] The following tables illustrate the steel-on-steel extreme pressure characteristics of transmission fluids as described herein evaluated using a Falex extreme pressure (EP) test according to ASTM D 3233. The Falex EP test measures the load carrying ability of an oil. According to the test, a 1/4 inch (6.35 mm) diameter test journal or pin is rotated at 290 rpm between two Vee Blocks immersed in the oil preheated to 51.7°C. Procedure A employs a constant increase in load applied by an automatic ratchet until failure as indicated by seizure of the test coupon or rapid loss of load caused by excessive wear. Procedure B employs load increments of 250 lbs with running for 1 minute at each increment until failure. The standard test pin is AISI 3135 Steel, HRB 87 and the standard Vee Blocks are AISI C-1137 Steel, HRC 20 to 24. The lubricant compositions were tested at 100°C and 150°C. Higher loads to seizure signify better extreme pressure (EP) performance. The baseline fluid contained the following components:

- (a) Friction modifiers - from about 0.01 to about 0.5 wt. %
- (b) Sulfur agents - from about 0.01 to about 1.0 wt. %
- (c) Anti-oxidants - from about 0.01 to about 2.0 wt. %
- (d) Anti-rust Agents - from about 0.01 to about 0.3 wt. %
- (e) Dispersants - from about 0.5 to about 10.0 wt. %
- (f) Anti-foam agents - from about 0.0001 to about 0.5 wt. %
- (g) base oil (mineral or synthetic) - balance of baseline fluid

[0085] The fluids listed in Table 1 contained the baseline fluid and the indicated amounts of the following components:

HiTEC® 611 detergent is an overbased calcium sulfonate available from Ethyl Corporation of Richmond, Virginia.
Zn phenate is zinc phenate.
HiTEC® 059 is a dimethyloctadecylphosphonate available from Ethyl Corporation.

Table 1

Fluid No.	HiTEC® 611 detergent (wt. %)	Zn Phenate (wt. %)	HiTEC® 059 (wt. %)	Falex EP Fail load (lbs) @ 100°C	Falex EP Fail load (lbs) @ 150°C
1	0.00	0.00	0.00	1250	1000
2	0.20	0.20	0.25	1250	1250
3	0.20	0.20	0.00	750	750
4	0.20	0.00	0.25	1000	750
5	0.00	0.00	0.25	2125	2000
6	0.00	0.20	0.00	750	500
7	0.00	0.20	0.25	2000	2000
8	0.20	0.00	0.00	1250	625

[0086] As shown by the foregoing table, a baseline fluid absent an extreme pressure performance improving amount of ester of phosphonic acid had a seizure load of 1250 pounds at 100°C and 1000 pounds at 150°C (Fluid No. 1). Much higher seizure loads were obtained with a baseline fluid containing an ester of phosphonic acid (Fluid Nos. 5 and 7) in the absence of a detergent containing calcium cations. The fluids containing a detergent having a calcium cation (Fluid Nos. 3 and 8) gave worse performance, i.e., lower seizure loads, than the baseline fluid. An analysis of the variance of the foregoing results indicated that the overbased calcium sulfonate had a strong negative effect on the Falex EP value, the phosphonate had a strong positive effect on the Falex EP value, and the zinc phenate had little or no effect on the Falex EP value. A strong negative interaction between the detergent component and the phosphonate component was also observed (Fluid Nos. 2 and 4). Separate experiments have shown that a low-base calcium phenate detergent also negatively impacts the Falex EP performance values.

[0087] In the next set of experiments, the effect of use of a post-treated succinimide dispersant on the extreme pressure performance of a fluid was evaluated. Three succinimides were prepared from 2100 molecular weight polyisobutylene succinic acid and tetraethylenepentamine in a 2.4:1 molar ratio. The succinimides were post-treated with the capping agents indicated in Table 2. Succinimide No. 1 was treated with 0.1 wt % amount of boron. Succinimide No. 2 was treated with the same amount of boron and 1.3 wt % amount of nonylphenol and formaldehyde. Succinimide No. 3 was treated the same as succinimide No.2 and additionally with 1.0 wt % amount glycolic acid. Each of the post-treated succinimides was added to the same baseline fluid as described above in an amount of 2.5 wt. %. The Falex

EP values were determined as above and the results are as follows:

Table 2

Succinimide No.	Post-Treatment	Falex EP Fail load (lbs) @ 100°C	Falex EP Fail load (lbs) @ 150°C
1	Boron only	1000	1000
2	Boron and nonylphenol/formaldehyde	1250	1000
3	Boron and nonylphenol/formaldehyde and glycolic acid	1500	1250

[0088] As shown in the foregoing table, the succinimide post-treated with boron, nonylphenol/formaldehyde, and glycolic acid (Succinimide No. 3) gave significantly higher Falex EP values than the succinimide treated with boron alone (Succinimide No. 1) and the succinimide treated with boron and nonylphenol/formaldehyde (Succinimide No. 2). It is expected that a post-treated succinimide treated with boron, nonylphenol/formaldehyde, and glycolic acid, combined with a phosphonate according to the invention will achieve superior extreme pressure performance in a lubricant composition containing these components.

[0089] At numerous places throughout this specification, reference has been made to a number of U.S. Patents. All such cited documents are expressly incorporated in full into this disclosure as if fully set forth herein.

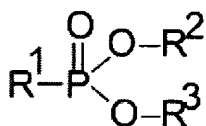
[0090] Other embodiments of the present invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. As used throughout the specification and claims, "a" and/or "an" may refer to one or more than one. Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, percent, ratio, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

Claims

1. A composition including:

(a) a base oil, and

(b) an additive composition including an extreme pressure performance improving amount of an ester of phosphonic acid of the formula:



where R¹ is a hydrocarbyl group containing from about 8 to about 24 carbon atoms, R² and R³ are independently selected from hydrogen and a hydrocarbyl group containing from about 1 to about 8 carbon atoms, provided that no more than one of R² and R³ is hydrogen, a succinimide dispersant, and, optionally, a metal-based detergent, wherein the detergent is substantially devoid of calcium cations.

2. The composition of claim 1, wherein the base oil includes one or more of a natural oil, a mixture of natural oils, a synthetic oil, a mixture of synthetic oils, and a mixture of natural and synthetic oils.
3. The composition of claim 2, wherein the natural oil includes one or more of a mineral oil, a vegetable oil, and a mixture of mineral oil and vegetable oil.
4. The composition of claim 2, wherein the synthetic oil includes one or more of an oligomer of an α -olefin, an ester, an oil derived from a Fischer-Tropsch process, an oil derived from a gas-to-liquid process, and a mixture thereof.
5. The composition of any one of claims 1-4, wherein the base oil has a kinematic viscosity of from 2 centistokes to 10 centistokes at 100° C.
6. The composition of any one of claims 1-5, wherein the succinimide dispersant includes a dispersant derived from a polyisobutenyl succinic anhydride (PIBSA) having a number average molecular weight ranging from 200 to 2100, as determined by gel permeation chromatography, and a polyalkylene polyamine.
7. The composition of claim 6, wherein the succinimide dispersant is derived from PIBSA and an amine in a molar ratio of PIBSA to amine ranging from 1:1 to 3:1.
8. The composition of claim 7, wherein the succinimide dispersant is post treated with one or more of a phosphorus-based acid, a boron-based acid, a carboxylic acid, an alkylphenol/aldehyde mixture, and a mixture of two or more of the foregoing.
9. The composition of any one of claims 1-8, wherein the composition includes from 0.03 to 0.25 percent by weight of the ester of phosphonic acid.
10. The composition of any one of claims 1-9, wherein the composition includes from 2 to 5 percent by weight of the succinimide dispersant.
11. The composition of any one of claims 1-10, wherein the optional metal-based detergent includes a detergent selected from one or more of a neutral sodium sulfonate, an overbased sodium sulfonate, a sodium carboxylate, a sodium salicylate, a sodium phenate, a sulfurized sodium phenate, a lithium sulfonate, a lithium carboxylate, a lithium salicylate, a lithium phenate, a sulfurized lithium phenate, a magnesium sulfonate, a magnesium carboxylate, a magnesium salicylate, a magnesium phenate, a sulfurized magnesium phenate, a potassium sulfonate, a potassium carboxylate, a potassium salicylate, a potassium phenate, a sulfurized potassium phenate, a zinc sulfonate, a zinc carboxylate, a zinc salicylate, a zinc phenate, and a sulfurized zinc phenate.
12. The composition of any one of claims 1-11, wherein the ester of phosphonic acid includes one or more of dimethyloctadecylphosphonate, methyloctadecylhydrogen phosphonate, bis(2-ethylhexyl) 2-ethylhexyl phosphonate, dimethyloctadecenyl phosphonate, diethyl-2-ethyldecylphosphonate, ethylpropyl-1-butylhexadecylphosphonate, methylethyldecylphosphonate, methylbutyl eicosylphosphonate, and dimethylhexatriacontylphosphonate.
13. The composition of any one of claims 1-12, wherein the additive composition further includes one or more of a friction modifier, an antioxidant, an antiwear agent, an antifoam agent, and a viscosity index improver.
14. The composition of claim 13, wherein the friction modifier includes one or more of an aliphatic fatty amine, an ether amine, an alkoxylated aliphatic fatty amine, an alkoxylated ether amine, an oil-soluble aliphatic carboxylic acid, a polyol ester, a fatty acid amide, an imidazoline, a tertiary amine, and a hydrocarbyl succinic anhydride or acid reacted with an ammonia or a primary amine.
15. The composition of any one of claims 13-14, wherein the antioxidant includes one or more of a bis-alkylated diphenyl amine, a phenyl alpha amine, a beta naphthyl amine, a sterically hindered phenol, a bisphenol, and a cinnamic acid derivative.
16. The composition of any one of claims 13-15, wherein the antiwear agent includes one or more of a phosphate ester and salts thereof, a phosphite ester and salts thereof, and a dialkyldithiophosphoric acid esters and salts thereof.

17. The composition of any one of claims 13-16, wherein the antifoam agent is one or more of a silicone and a polyacrylate.

18. The composition of any one of claims 13-17, wherein the viscosity index improver includes polyisobutylene having a weight average molecular weight ranging from 700 to 2,500.

19. The composition of any one of claims 1-18, wherein the composition is a power transmission fluid.

20. The composition of claim 19, wherein the composition is suitable for use in a transmission employing one or more of a slipping torque converter, a lock-up torque converter, a starting clutch, and one or more shifting clutches.

21. The composition of claim 19, wherein the composition is suitable for use in a belt, chain, or disk-type continuously variable transmission.

22. An automatic transmission containing the power transmission fluid of claim 19.

23. The automatic transmission of claim 22, wherein the automatic transmission is a continuously variable transmission.

24. The composition of any one of claims 1-18, wherein the composition is an additive concentrate wherein the base oil is a carrier fluid.

25. A method of improving extreme pressure characteristics of a transmission fluid including the step of:

mixing the ingredients of a composition as claimed in any one of claims 1-18, wherein the composition includes from 0.01 to 1.0 weight percent of the ester of phosphonic acid, based on a total weight of the base oil and additive composition; from 2 to 5 weight percent of the succinimide dispersant, based on the total weight of the base oil and additive composition; and from 0.0 to 0.2 weight percent of the metal-based detergent, based on the total weight of the base oil and additive composition.

26. An automatic transmission fluid including a base oil and from about 5 to 20 wt. % of the additive concentrate of claim 24, based on a total weight of the fluid.

27. A vehicle including an engine and a transmission, the transmission including the automatic transmission fluid of claim 26.

28. A vehicle including a differential, the differential including a lubricant containing an additive concentrate of claim 24.