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(54) **POWER TRANSMISSION FLUID WITH ENHANCED FRICTION CHARACTERISTICS**

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(57) **ABSTRACT**

A power transmission fluid composition, a power transmission containing the fluid, a method of operating a power transmission with the fluid and method of improving friction durability for a power transmission fluid. The power transmission fluid includes (a) a base oil and (b) an additive composition having therein (i) at least one ashless dispersant; (ii) a metal detergent providing greater than about 100 ppm metal in the power transmission fluid composition; (iii) a friction modifying amount of an imidazoline; (iv) a succinimide friction modifier; and (v) a non-hydroxy tertiary amine friction modifier other than (iii).

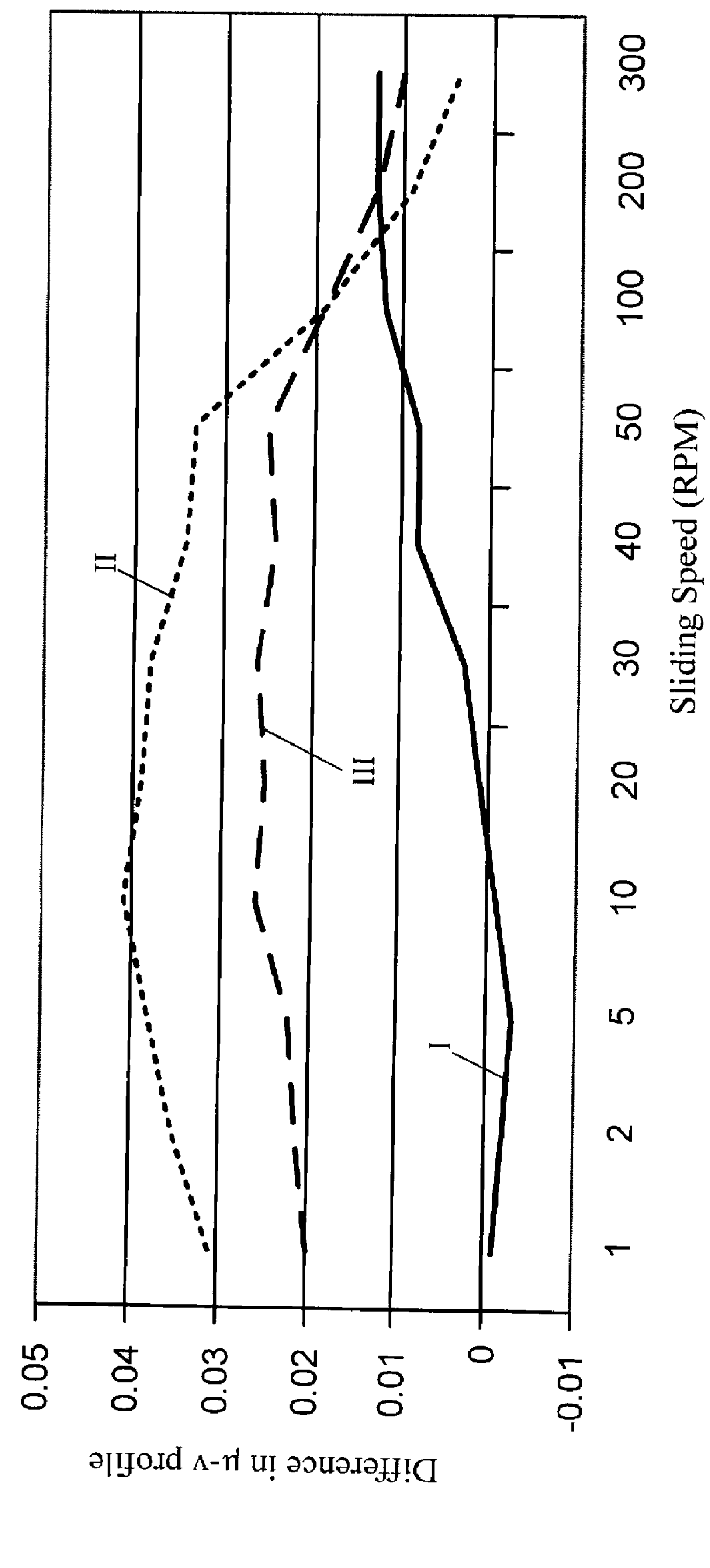

Difference in μ-v profile
0.05
0.04
0.03
0.02
0.01
0
-0.01
1
2
5
10
20
30
40
50
100
200
300
Sliding Speed (RPM)
I
II
III

FIG. 1

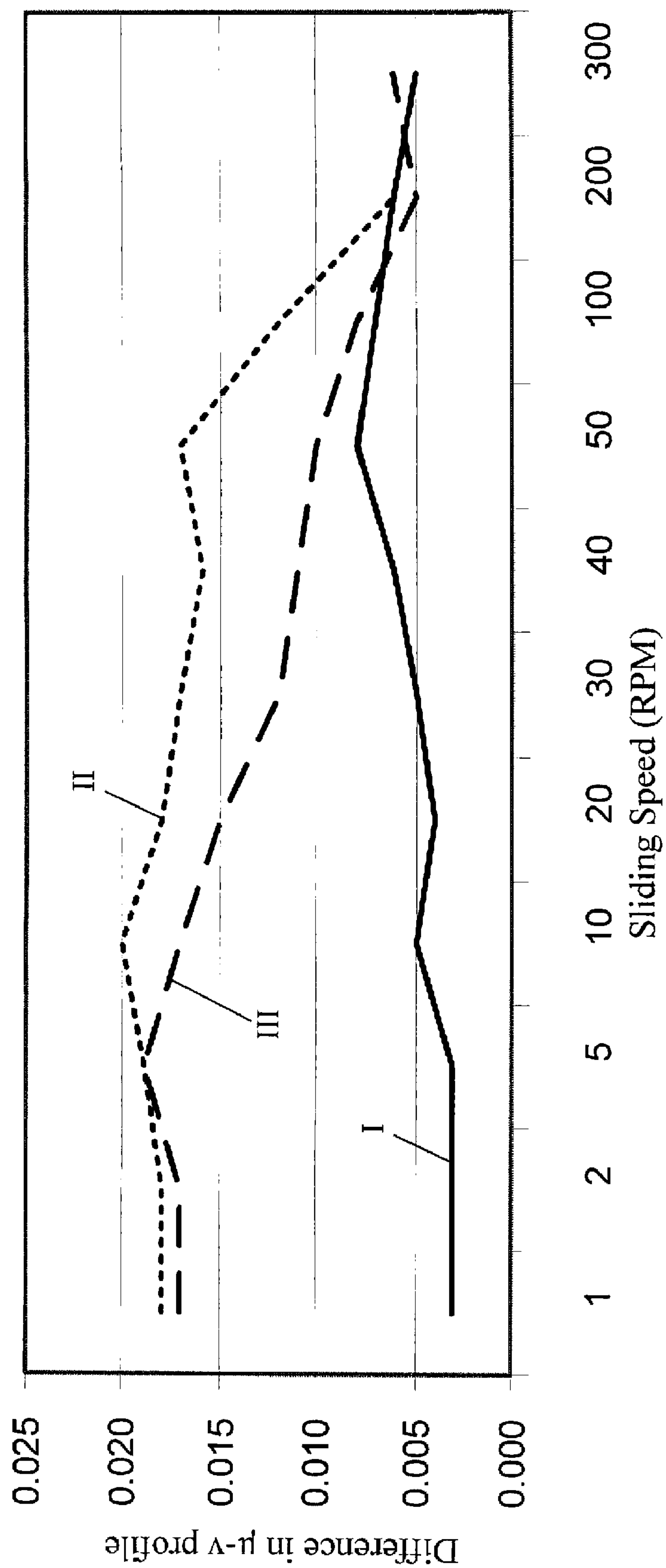

Difference in μ-v profile
0.025
0.020
0.015
0.010
0.005
0.000
Sliding Speed (RPM)
1
2
5
10
20
30
40
50
100
200
300
I
II
III

FIG. 2

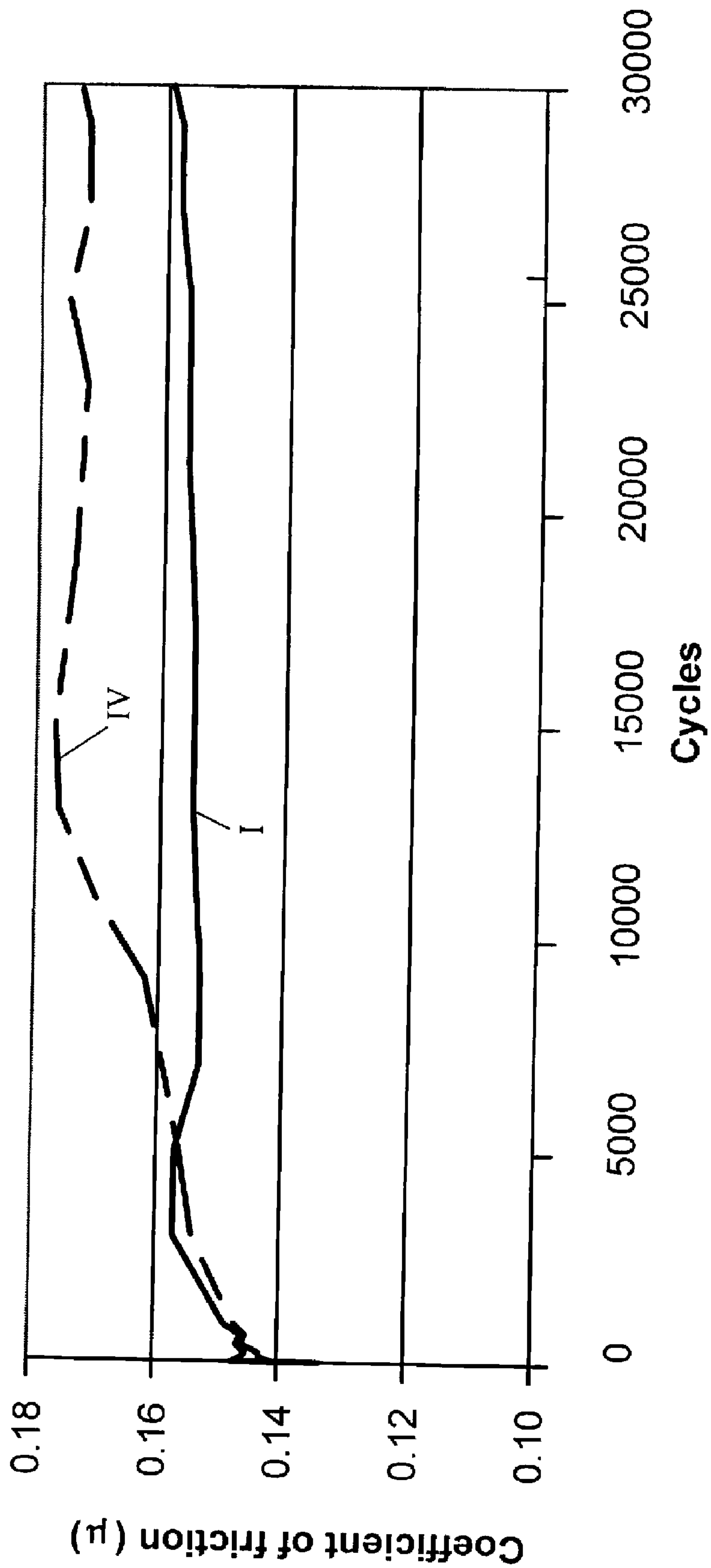

Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
Cycles
0
5000
10000
15000
20000
25000
30000
I
IV

FIG. 3

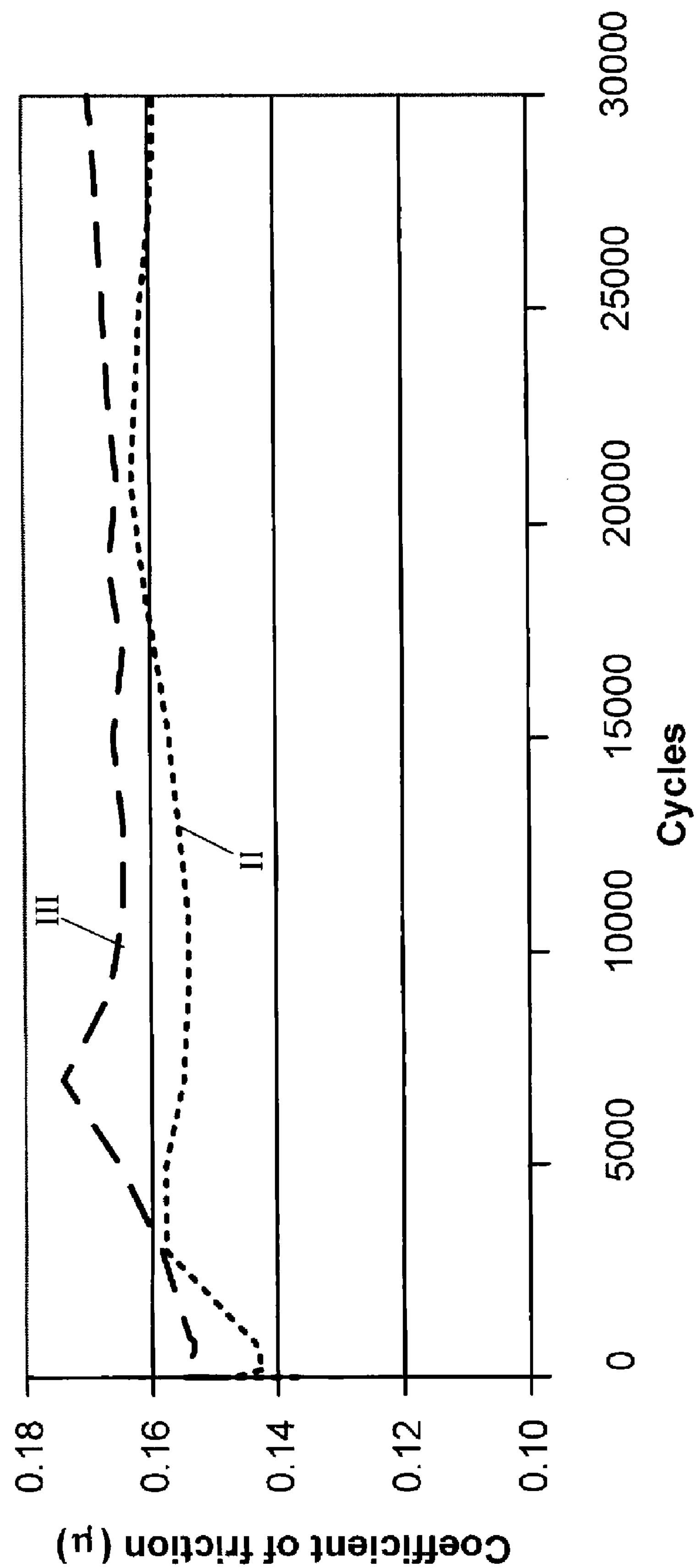

Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
Cycles
0
5000
10000
15000
20000
25000
30000
III
II

FIG. 4

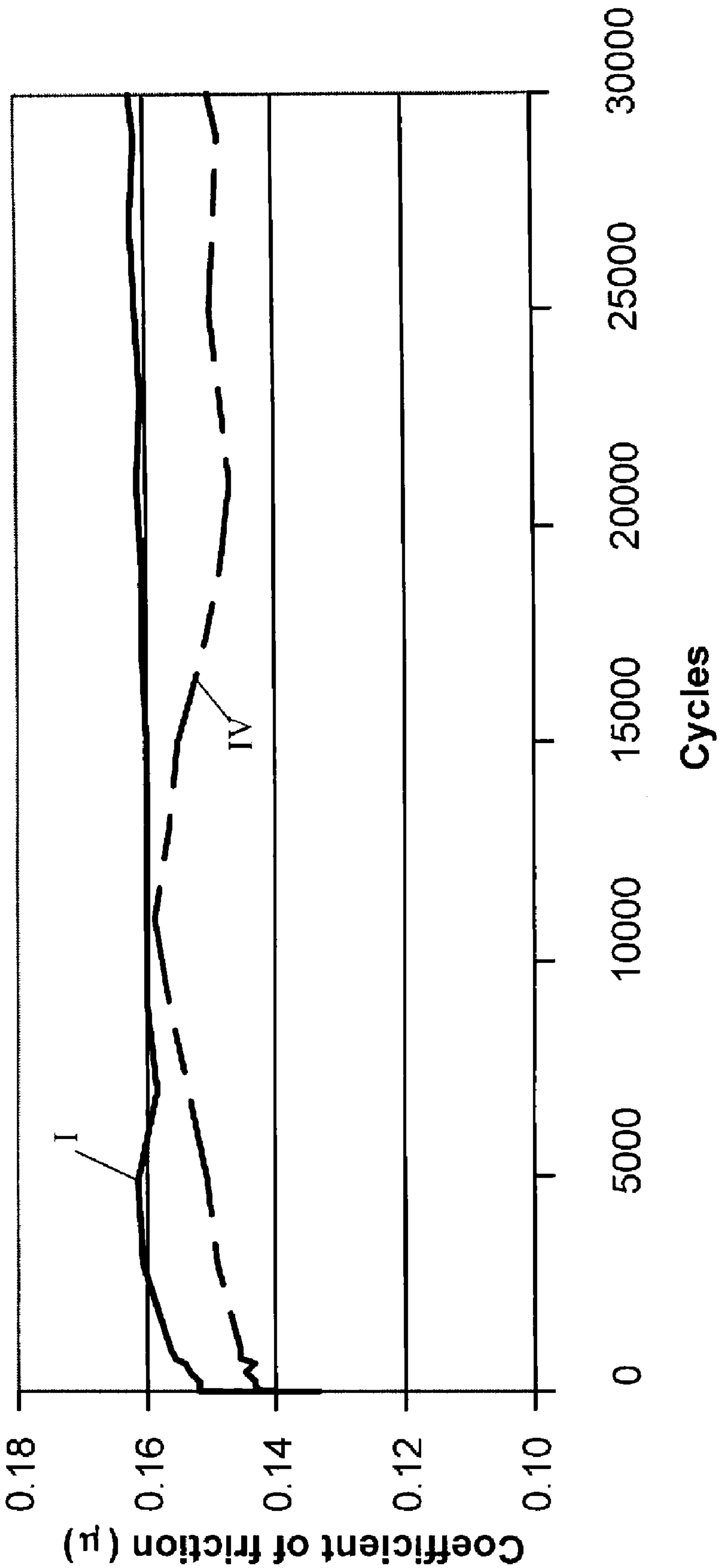

Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
Cycles
0
5000
10000
15000
20000
25000
30000
I
IV

FIG. 5

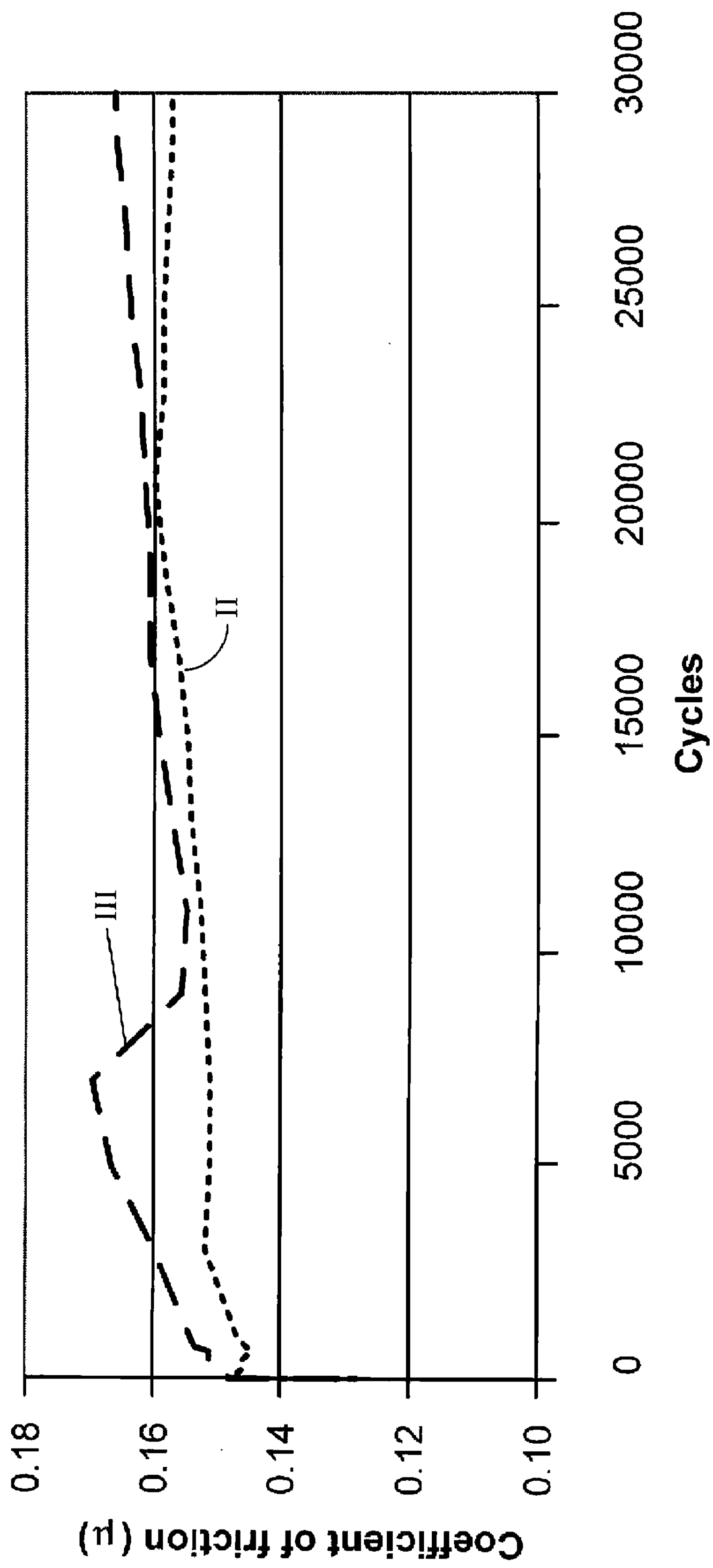

Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
Cycles
0
5000
10000
15000
20000
25000
30000
II
III

FIG. 6

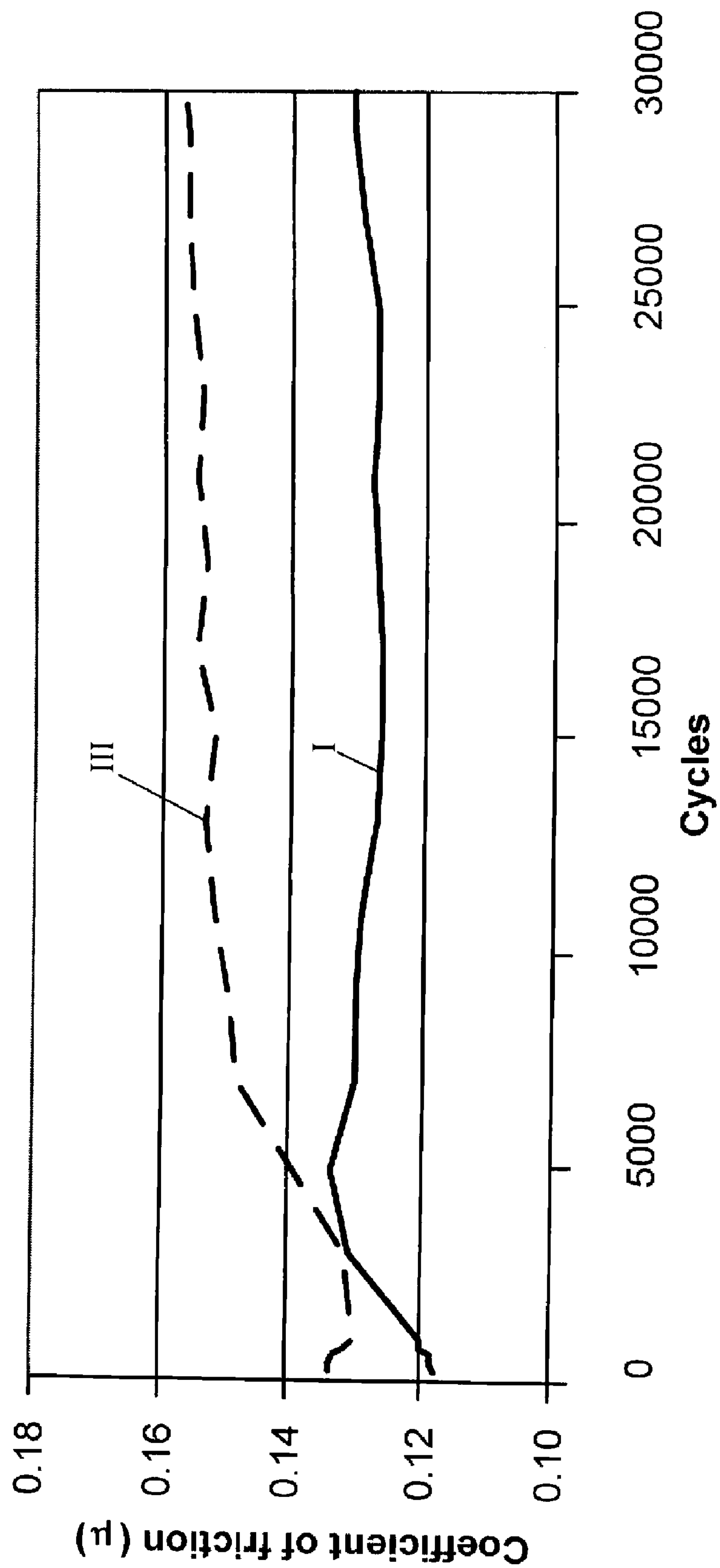
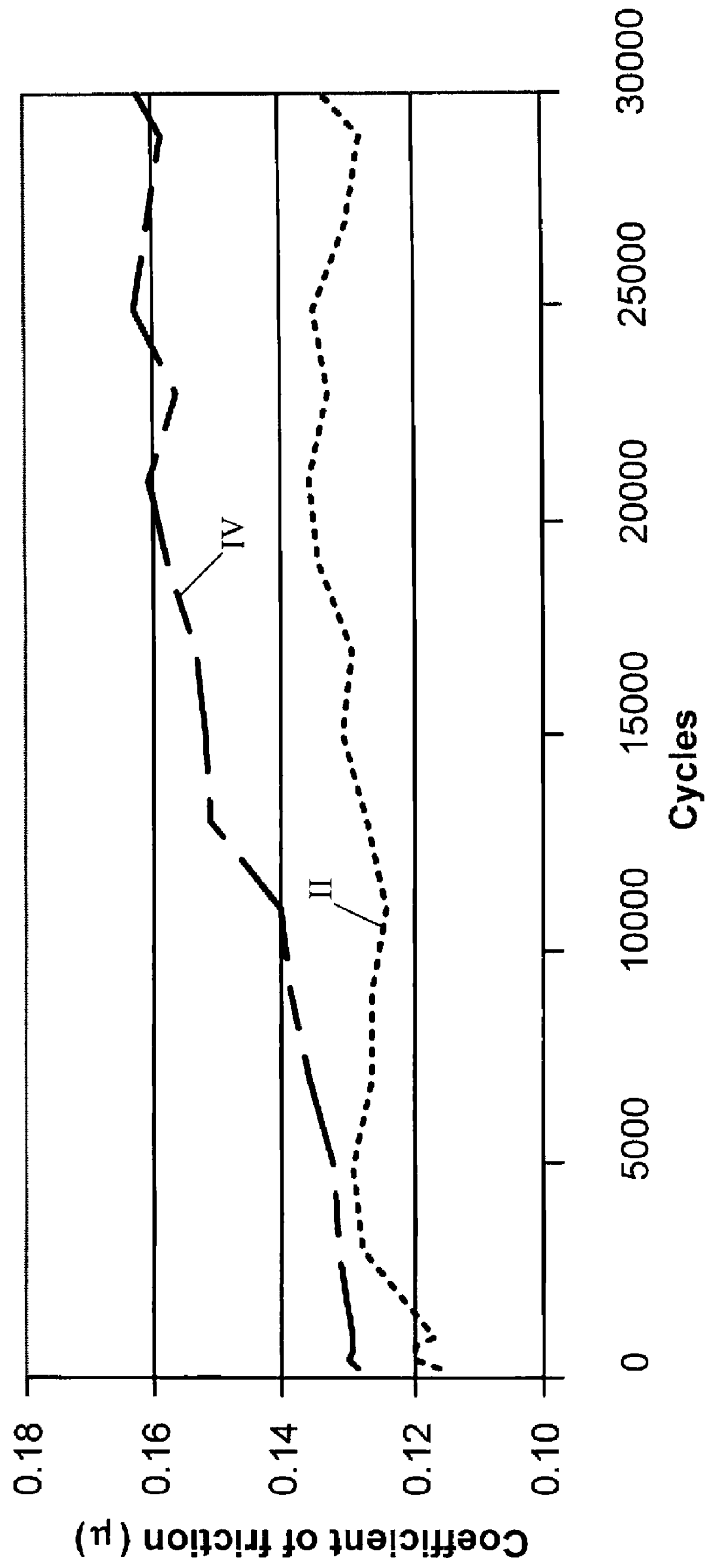

Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
Cycles
0
5000
10000
15000
20000
25000
30000
I
III

FIG. 7



Coefficient of friction (μ)
0.18
0.16
0.14
0.12
0.10
0
5000
10000
15000
20000
25000
30000
Cycles
IV
II

FIG. 8

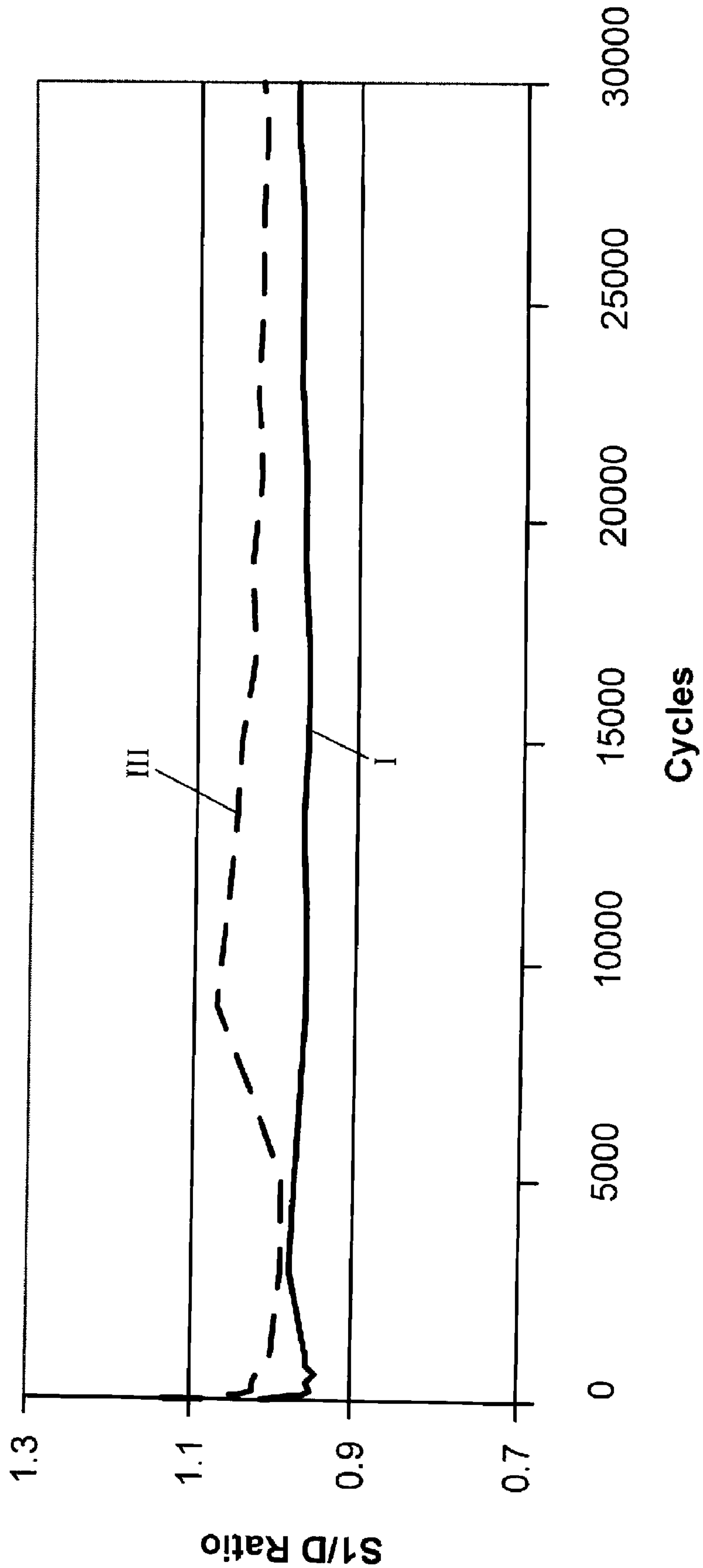

S1/D Ratio
1.3
1.1
0.9
0.7
0
5000
10000
15000
20000
25000
30000
Cycles
III
I

FIG. 9

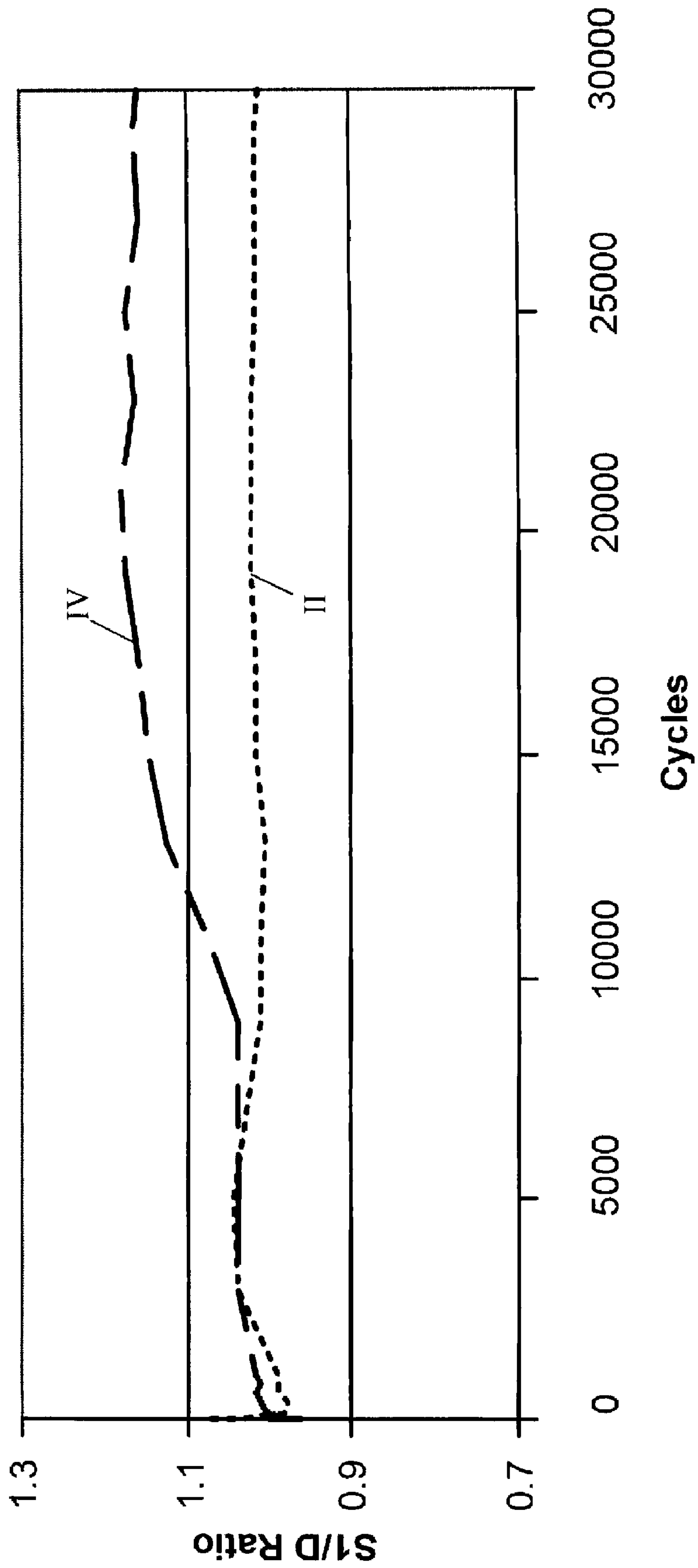

S1/D Ratio
1.3
1.1
0.9
0.7
0
5000
10000
15000
20000
25000
30000
Cycles
IV
II

FIG. 10

POWER TRANSMISSION FLUID WITH ENHANCED FRICTION CHARACTERISTICS

FIELD

[0001] The present disclosure relates to a power transmission fluid having improved and/or extended durability and enhanced friction characteristics. The present disclosure may comprise a fluid suitable for power transmitting fluids, such as an automatic transmission fluid (ATF) and/or a manual transmission fluid. Power transmitting fluids of the present disclosure may comprise friction modifiers, a borated dispersant, and a metal detergent.

BACKGROUND AND SUMMARY

[0002] Automotive power transmission fluids are called upon to provide specific frictional properties under very demanding conditions of temperature and pressure. Changes in a fluid's frictional properties as a function of relative sliding speed, temperature, or pressure as a result of these conditions may cause performance degradation immediately noticeable to the vehicle operator. Such effects may include unacceptably long or short gear shifts, vehicle shudder or vibration, noise, and/or harsh shifts ("gear change shock"). Thus, there is a need for transmission fluids that undergo minimal frictional changes under conditions of high temperatures and pressures. Such fluids would minimize equipment and performance problems while maximizing the interval between fluid changes. By enabling smooth engagement of torque converter and shifting clutches, these fluids would minimize shudder, vibration, and/or noise, and in some cases improve fuel economy, over a longer fluid lifetime. As newer transmissions are developed for improved fuel economy, there continues to be a need for fluids that are specifically formulated for such newer transmissions.

[0003] In view of the ongoing needs for improved transmission fluids, exemplary embodiments of the disclosure provide a power transmission fluid composition, a method of operating a power transmission with the fluid and method of improving friction durability of a power transmission fluid. Power transmission fluids formulated according to the present disclosure provide improved friction durability and improved performance for smooth engagement of torque converter and shifting clutches and minimized shudder, vibration and/or noise, and/or improved fuel economy.

[0004] In one exemplary embodiment, a power transmission fluid includes (a) a base oil and (b) an additive composition having therein (i) at least one ashless dispersant; (ii) a metal detergent providing greater than about 100 ppm metal in the power transmission fluid composition; (iii) a friction modifying amount of an imidazoline; (iv) a succinimide friction modifier; and (v) a non-hydroxy tertiary amine friction modifier other than (iii).

[0005] Another exemplary embodiment provides a method of improving friction durability by adding to a base oil an additive composition. The additive composition may include (a) at least one ashless dispersant; (b) a metal detergent providing greater than about 100 ppm metal in a composition containing the base oil and additive composition; (c) a friction modifying amount of a hydroxyalkyl imidazoline; (d) a succinimide friction modifier; and (e) a non-hydroxy tertiary amine friction modifier other than (c).

[0006] Power transmission fluids of the embodiments described herein are formulated to deliver improved friction durability, i.e., friction characteristics that change very little when the fluid is subjected to thermal and oxidative stresses. As used herein, "friction durability" means the ability of a fluid to resist physical and chemical changes that adversely affect the friction properties of the fluid during use. The disclosed power transmission fluids are suitable for use in transmissions where high stressing of the lubricant is routine, such as transmissions with a slipping torque converter, a lock-up torque converter, a starting clutch, and/or one or more shifting clutches. Such transmissions may include four-, five-, six-, seven, or eight-speed transmissions, or may include continuously variable transmissions (chain, belt, and disk type). The fluids may also be used in manual transmissions, including automated manual and dual-clutch transmissions.

[0007] Both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the disclosed embodiments, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGS. **1-2** illustrate the difference in μ-v friction profiles before and after laboratory aging for different friction materials for a fluid containing an additive composition according to the disclosure and for conventional fluids.

[0009] FIGS. **3-4** illustrate the low speed dynamic coefficients of friction in a Ford clutch friction durability test for a fluid containing the additive composition according to the disclosure and for conventional fluids.

[0010] FIGS. **5-6** illustrate the midpoint dynamic coefficients of friction in a Ford clutch friction durability test for a fluid containing the additive composition according to the disclosure and for conventional fluids.

[0011] FIGS. **7-8** illustrate the static breakaway coefficients of friction in a Ford clutch friction durability test for a fluid containing the additive composition according to the disclosure and for conventional fluids.

[0012] FIGS. **9-10** illustrate ratios of low speed dynamic friction to midpoint dynamic friction (S1/D) in a Ford clutch friction durability test for a fluid containing the additive composition according to the disclosure and for conventional fluids.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0013] 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:

- **[0014]** (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);
- **[0015]** (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, alkylmercapto, nitro, nitroso, and sulfoxy);

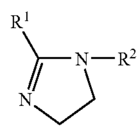
[0016] (3) hetero-substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this description, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Hetero-atoms include sulfur, oxygen, nitrogen, and encompass substituents such as pyridyl, furyl, thienyl and imidazolyl. In general, no more than two, preferably 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.

[0017] Since power transmission fluids operate under increasingly severe conditions, the oils used to lubricate those transmissions should be formulated to endure higher temperatures and pressures. In order to minimize equipment problems and maximize the interval between transmission oil changes, the oil additive packages should be formulated so that important oil properties change as little as possible in the face of these stresses. In particular, the frictional properties of the oil, which depend in great measure on the additive package, must stay substantially constant. Substantially constant frictional properties ensure smooth engagement of torque converter and shifting clutches and minimized shudder, vibration and noise, and improved fuel economy. It has been found that the components herein disclosed, when blended into a base oil of suitable viscosity, impart to that oil greatly improved friction durability and other characteristics that are needed for newer more fuel efficient transmissions.

[0018] In an exemplary embodiment, a power transmission fluid includes a base oil and an additive composition. The additive composition may contain at least one succinimide dispersant, a metal detergent providing greater about 100 ppm metal in the transmission fluid, a friction modifying amount of an imidazoline, a succinimide friction modifier, and a non-hydroxy tertiary amine friction modifier other than the imidazoline.

Imidazoline

[0019] An important component of the additive composition is the imidazoline, having the following general structure:



wherein R^1 is a straight or branched hydrocarbon chain containing from 10 to 25 carbon atoms and R^2 is a C_2 to C_4 hydroxyalkyl group.

[0020] Examples of suitable fatty acid hydrocarbyl imidazolines include but are not limited to heptadecenyl hydroxyalkyl imidazoline, octadecanoyl hydroxyalkyl imidazoline, linoleyl hydroxyalkyl imidazoline, linolenyl hydroxyalkyl imidazoline, docosanoyl hydroxyalkyl imidazoline, oleyl hydroxyalkyl imidazoline, eicosanoyl hydroxyalkyl imidazoline, tetracosanoyl hydroxyalkyl imidazoline, heptacosanoyl hydroxyalkyl imidazoline, and hexacosanoyl hydroxyalkyl imidazoline, wherein in each of the above, the alkyl group of the hydroxyalkyl is a C_1 to C_4 alkyl group. A particularly useful fatty acid hydrocarbyl imidazoline is 2-oleyl-1-hydroxyethyl imidazoline, due to its commercial availability and efficacy. The fatty acid hydrocarbyl imidazoline is included in a finished power transmission fluid in an amount ranging from about 0.005 to about 0.05 wt. %

Ashless Dispersant

[0021] Fluid and additive compositions described herein may contain at least one oil-soluble ashless dispersant. For example, such compositions may contain at least one oil-soluble phosphorus- and boron-containing ashless dispersant present in amount such that the amount of phosphorus in the ashless dispersant relative to the amount of nitrogen in the dispersant ranges from about 0.1 to about 1.0 phosphorous to 1.0 nitrogen and the amount of boron in the ashless dispersant relative to the amount of nitrogen in the dispersant ranges from about 0.05 to about 0.5 boron to 1.0 nitrogen.

[0022] The foregoing phosphorus- and/or boron-containing ashless dispersants may be formed by phosphorylating and/or boronating an ashless dispersant having basic nitrogen and/or at least one hydroxyl group in the molecule, such as a succinimide dispersant, succinic ester dispersant, succinic ester-amide dispersant, Mannich base dispersant, hydrocarbyl polyamine dispersant, or polymeric polyamine dispersant. Occasionally oil or solvents may be added to dispersants to improve their handling properties. All quantities of dispersants here are described on an oil- or solvent-free basis.

[0023] Succinimide ashless dispersants that may be phosphorylated or boronated include, but are not limited to, polyamine succinimides in which the succinic group contains a hydrocarbyl substituent containing at least 30 carbon atoms as described for example in U.S. Pat. Nos. 3,172,892; 3,202,678; 3,216,936; 3,219,666; 3,254,025; 3,272,746; and 4,234,435. 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 a polyamine containing at least one primary amino group. The alkenyl succinic anhydride may be made readily by heating a mixture of olefin and maleic anhydride to about 180° C.-220° C. The olefin is preferably a polymer or copolymer of a lower monoolefin such as ethylene, propylene, 1-butene, isobutene and the like. The more preferred source of alkenyl group is from polyisobutene having a GPC number average molecular weight of up to about 10,000, typically the range of about 500 to about 2,500.

[0024] As used herein, the term "succinimide" is meant to encompass the completed reaction product from the reaction of one or more polyamine reactants with a hydrocarbon-substituted succinic acid or anhydride (or like succinic acylating agent), and is intended to encompass compounds wherein the product may have amide, amidine, and/or salt linkages in addition to the imide linkage of the type that results from the reaction of a primary amino group and an anhydride moiety.

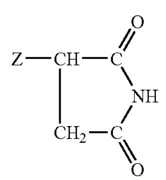
[0025] Alkenyl succinic acid esters and diesters of polyhydric alcohols containing 2-20 carbon atoms and 2-6 hydroxyl groups may be used in forming the phosphorus- and/or boron-containing ashless dispersants. Representative examples are described in U.S. Pat. Nos. 3,331,776; 3,381,022; and 3,522,179. The alkenyl succinic portion of these esters corresponds to the alkenyl succinic portion of the succinimides described above.

[0026] Suitable alkenyl succinic ester-amides for forming the phosphorylated and/or boronated ashless dispersant are described for example in U.S. Pat. Nos. 3,184,474; 3,576,743; 3,632,511; 3,804,763; 3,836,471; 3,862,981; 3,936,480; 3,948,800; 3,950,341; 3,957,854; 3,957,855; 3,991,098; 4,071,548; and 4,173,540.

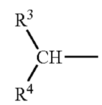
Succinimide Friction Modifier

[0027] In addition to the phosphorylated- and/or borated ashless dispersant described above, embodiments of the present disclosure may comprise a succinimide friction modifier prepared from an alkenyl succinic acid or anhydride and ammonia. The alkenyl group of the alkenyl succinic acid may be a short chain alkenyl group; for example, the alkenyl group may comprise about 12 to about 36 carbon atoms. Further, the succinimide may comprise a C_{12} to about C_{36} aliphatic hydrocarbyl succinimide. As a further example, the succinimide may comprise a C_{16} to about C_{28} aliphatic hydrocarbyl succinimide. As an even further example, the succinimide may comprise a C_{18} to about C_{24} aliphatic hydrocarbyl succinimide. The succinimide may be prepared from a succinic anhydride and ammonia as described in European Patent 0 020 037, herein incorporated by reference.

[0028] The succinimide may comprise one or more of a compound having the following structure:



wherein Z may have the structure:



wherein either R^3 or R^4 may be hydrogen, but not both, and wherein R^3 and/or R^4 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^3 and R^4 is from about 11 to about 35; 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.

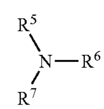
[0029] Exemplary succinimide friction-modifiers include, but are not limited to, 3-octenyl succinimide, 3-octenyl-4-methyl succinimide, 3-octenyl-4,4-dimethyl succinimide, 3-octenyl-4-ethyl succinimide, 3-octenyl-4-ethyl-4-methyl succinimide, 3-octenyl-4-butyl succinimide, 3-octenyl-4-vinyl succinimide, 3-octenyl-4-allyl succinimide, 3-octenyl-4-butenyl succinimide, 3-sec-octenyl succinimide, 3-sec-octenyl-4-isopropyl succinimide, 3-octyl succinimide, 3-octyl-4-methyl succinimide, 3-sec-octyl-succinimide, 3-sec octyl-4-methyl succinimide, 3-sec-octyl-4-ethyl succinimide, 3-sec-octyl-4-propyl succinimide, 3-sec-octyl-4,4-dimethyl succinimide, and 3-sec-octyl-4,4-diethyl succinimide.

[0030] The power transmission fluid may comprise a friction-modifying amount of the foregoing succinimide. For example, the power transmission fluid may comprise about 0.1 wt % to about 2.0 wt % of the succinimide. Further, the power transmission fluid may comprise about 0.2 wt % to about 0.8 wt % of the succinimide.

Additional Friction Modifiers

[0031] Another component of the power transmission fluid is a non-hydroxy amine friction modifier other than the imidazoline component described above. 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 shudder, noise, and harsh shifts.

[0032] A particularly suitable amine friction modifier is a non-hydroxy fatty tertiary amine friction modifier of the formula:



wherein each of R^5 and R^7 is a lower alkyl group having from 1 to 5 carbon atoms and R^6 is an aliphatic hydrocarbon group having from 6 to 20 carbon atoms. Typical non-hydroxy fatty tertiary amines include dialkyl alkylamines, which include, but are not limited to, dimethyl hexylamine, dimethyl octylamine, dimethyl decylamine, dimethyl dodecylamine, dimethyl tetradecylamine, dimethyl pentadecylamine, dimethyl hexadecylamine, dimethyl octadecylamine, diethyl hexylamine, diethyl octylamine, diethyl decylamine, diethyl dodecylamine, diethyl tetradecylamine, diethyl pentadecylamine, diethyl hexadecylamine, diethyl octadecylamine, dipropyl hexylamine, dipropyl octylamine, dipropyl decylamine, dipropyl dodecylamine, dipropyl tetradecylamine, dipropyl pentadecylamine, dipropyl hexadecylamine, and dipropyl octadecylamine.

[0033] The amount of amine friction modifier in the power transmission fluid may range from about 0.01 wt. % to about 1.0 wt. % based on the total weight of the power transmission fluid. A suitable range of amine friction modifier in the power transmission fluid may range from about 0.01 to about 0.05 wt. % based on the total weight of the power transmission fluid.

Detergent Component

[0034] Metal-containing or ash-forming detergents function both as detergents to reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion. Detergents generally comprise a polar head with a long hydrophobic tail where the polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal, in which case they are usually described as normal or neutral salts, and would typically have a total base number or TBN (as measured by ASTM D2896) of from 0 to about 150. Large amounts of a metal base may be included by reacting an excess of a metal compound such as an oxide or hydroxide with an acidic gas such as carbon dioxide. The resulting overbased detergent comprises micelles of neutralized detergent surrounding a core of inorganic metal base (e.g., hydrated carbonates). Such overbased detergents may have a TBN of 150 or greater, and typically ranging from about 250 to about 450.

[0035] Detergents that may be used include oil-soluble neutral and overbased sulfonates, phenates, sulfurized phenates, and salicylates of a metal, particularly the alkali or alkaline earth metals, e.g., sodium, potassium, lithium, calcium, and magnesium. The most commonly used metals are calcium and magnesium, which may both be present. Mixtures of calcium and/or magnesium with sodium are also useful. Particularly convenient metal detergents are neutral and overbased calcium or magnesium sulfonates having a TBN of from 20 to 450, neutral and overbased calcium or magnesium phenates and sulfurized phenates having a TBN of from 50 to 450, and neutral or overbased calcium or magnesium salicylates having a TBN of from 130 to 350. Mixtures of such salts may also be used. The presence of at least one overbased detergent is desirable.

[0036] The amount of detergent in the power transmission fluid according to the disclosed embodiments may range from about 0.01 to about 1.0 percent by weight based on the total weight of the finished lubricant composition. A suitable amount of detergent in the power transmission fluid may provide greater than about 100 ppm calcium or magnesium to the power transmission fluid.

Base Oil

[0037] The base oil may comprise any suitable base oil. For example, the base oil may comprise a natural lubricating oil, a mixture of natural lubricating oils, a synthetic oil, a mixture of synthetic oils, and/or a mixture of natural and synthetic oils. The natural lubricating oil or mixture of natural lubricating oils may comprise a mineral oil, a vegetable oil, gas to liquid oil stocks, and/or a mixture thereof. The synthetic oil or mixture of synthetic oils may comprise one of an oligomer of an alphaolefin, an ester, an oil derived from a gas-to-liquid process such as a Fischer-Tropsch process, and/or a mixture thereof. The base oil may comprise a kinematic viscosity of from about 2 cSt to about 10 cSt at 100° C.

Other Optional Components

[0038] The power transmission fluid may also include conventional additives used in automatic transmission fluid formulations, such as antioxidants, antiwear/extreme pressure additives, corrosion inhibitors, antifoamants, viscosity index improvers, pour point depressants, and diluent oils.

Antioxidants

[0039] Antioxidant compounds may be included in the power transmission fluid. 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-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-α-naphthyl amine, phenyl-α-naphthyl amine, and ring-alkylated diphenylamines. Sterically hindered tertiary butylated phenols, bisphenols and cinnamic acid derivatives and combinations thereof are particularly suitable antioxidants. A particularly suitable antioxidant is an alkylated diphenylamine. The amount of antioxidant in the transmission fluid described herein may range from about 0.01 to about 3.0 weight percent based on the total weight of the power transmission fluid.

Antiwear/Extreme Pressure Agents

[0040] One or more antiwear/extreme pressure agents may be included in the power transmission fluids described herein. Such compounds include thiazoles, triazoles and thiadiazoles and sulfurized fatty acids and olefins. Examples include, but are not limited to, 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.

[0041] The sulfurized fatty acids and olefins may include, but are not limited to, dihydrocarbyl polysulfides; sulfurized olefins; sulfurized fatty acid esters of both natural and synthetic origins; trithiones; sulfurized thienyl derivatives; sulfurized terpenes; sulfurized oligomers of C_2-C_8 monoolefins; and sulfurized Diels-Alder adducts such as those disclosed in U.S. Pat. No. Re 27,331. Specific examples include sulfurized polyisobutene, sulfurized isobutylene, sulfurized diisobutylene, sulfurized triisobutylene, dicyclohexyl polysulfide, diphenyl polysulfide, dibenzyl polysulfide, dinonyl polysulfide, and mixtures of di-tert-butyl polysulfide such as mixtures of di-tert-butyl trisulfide, di-tert-butyl tetrasulfide and di-tert-butyl pentasulfide, among others. Combinations of such categories of sulfur-containing antiwear and/or extreme pressure agents may also be used, such as a combination of sulfurized isobutylene and di-tert-butyl trisulfide, a combination of sulfurized isobutylene and dinonyl trisulfide, a combination of sulfurized tall oil and dibenzyl polysulfide.

[0042] The total amount of antiwear/extreme pressure agent in the transmission fluids may range from about 0.01 to about 10 wt. % based on the total weight of the transmission fluid composition.

Viscosity Index Improvers

[0043] Optional viscosity index improvers for use in the above described power transmission fluids may be selected from commercially available materials including, but not limited to, styrene-maleic esters, polyalkylmethacrylates, and olefin copolymer viscosity index improvers. Mixtures of the foregoing products may also be used as well as dispersant and dispersant-antioxidant viscosity index improvers.

[0044] The polyalkyl(meth)acrylates which may be used may be prepared by the polymerization of C_1-C_{30} (meth) acrylates. Preparation of these polymers may further include the use of acrylic monomers having nitrogen-containing functional groups, hydroxy groups and/or alkoxy groups which provide additional properties to the polyalkyl(meth) acrylates such as improved dispersancy. The polyalkyl (meth)acrylates may have a number average molecular weight of from 10,000 to 250,000, for example, 20,000 to 200,000. The amount of viscosity index improver in the power transmission fluids described herein may range from about 0 to about 10 weight percent based on the total weight of the power transmission fluid.

Antifoam Agents

[0045] A foam inhibitor forms another component suitable for use in the compositions described herein. Foam inhibitors may be selected from silicones, siloxanes, polyacrylates, surfactants, and mixtures thereof. The total amount of antifoam agent in the power transmission fluids described herein may range from about 2 ppm Si to about 20 ppm Si weight percent based on the total weight of the power transmission fluid or from 50 ppm to 1000 ppm non-silicon containing foam inhibitor based on the total weight of the power transmission fluid.

Rust or Corrosion Inhibitors

[0046] Rust or corrosion inhibitors constitute another class of additives suitable for inclusion in the power transmission fluids. Various known anti-rust agents or additives are known for use in transmission fluids, and are suitable for use in the fluids according to the disclosed embodiments. Especially useful are alkyl polyoxyalkylene ethers, oxyalkyl amines such as 3-decyloxypropylamine, and polyoxypropylene-polyoxyethylene block copolymers.

[0047] Other suitable rust or corrosion inhibitors include acid phosphates; 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 total amount of rust or corrosion inhibitors in the fluid compositions may range from about 0 to about 1.0 wt. % based on the total weight of the power transmission fluid.

Pour Point Depressants

[0048] One or more pour point depressants may be included in the power transmission fluids to improve low temperature properties of the fluids. Examples of useful pour point depressants are polymethacrylates; polyacrylates; polyacrylamides; condensation products of haloparaffin waxes and aromatic compounds; vinyl carboxylate polymers; and terpolymers of dialkylfumarates, vinyl esters of fatty acids and alkyl vinyl ethers. Pour point depressants useful for the purposes of this disclosure and techniques for their preparation are described in U.S. Pat. Nos. 2,387,501; 2,015,748; 2,655,479; 1,815,022; 2,191,498; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 which are herein incorporated by reference for their relevant disclosures.

[0049] The amount of pour point depressant used in the fluid compositions described herein may range from about 0.0 to about 0.5 wt. % based on the total weight of the fluid composition.

[0050] In one embodiment, the pour point depressant is represented by the general structural formula: Ar(R)-(Ar1 (R1))-Ar2, wherein the Ar, Ar1 and Ar2 are aromatic groups of up to about 12 carbon atoms, (R) and (R1) are independently an alkylene group containing 1 to 100 carbon atoms with the proviso that at least one of (R) or (R1) is CH_2, and n is 0 to about 1000 with the proviso that if n is 0, then (R) is CH_2 and at least one aromatic moiety has at least one substituent, the substituents being selected from the group consisting of a substituent derived from an olefin containing about 8 to about 30 carbon atoms, and a substituent derived from a chlorinated hydrocarbon usually containing about 8 to about 50 carbon atoms and about 2.5 chlorine atoms for each 24 carbon atoms.

[0051] The power transmission fluids disclosed herein may comprise fluids suitable for any power transmitting application, such as a step automatic transmission or a manual transmission. Further, the power transmission fluids may be 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-, seven, and eight-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.

[0052] Key components of an exemplary power transmission fluid according to the disclosed embodiments (Fluid I) and a prior art power transmission fluid (Fluid IV) are provided in the following table:

TABLE 1

Components of Additive Concentrate	Weight Percent of Additive Fluid I	Weight Percent of Additive Fluid IV
C_{20}–C_{40} succinimide friction modifier	4.8	0.0
Imidazoline friction modifier	0.16	0.09
Tertiary amine friction modifier	0.16	0.0
metallic detergent(s)	0.8*	0.23**
Succinimide dispersant(s) (ca. 50 wt. % in process oil)	65.6	17.2
Conventional Additive Package Components	18.68	60.88
Mineral oil diluent	9.8	21.6
	100.0	100.0

*greater than 100 ppm metal cation
**less than 100 ppm metal cation

[0053] Power transmission fluids containing the additive concentrate of Fluid I provide suitable anti-shudder behavior, i.e., the ratios of low-speed dynamic friction to midpoint dynamic friction (S1/D) are one or less, suitable anti-shudder durability whereby the S1/D ratios are maintained over the lifetime of the fluid, suitable relatively high static coefficient of friction, suitable friction durability whereby the coefficients of friction are maintained over the lifetime of the fluid, suitable low levels of noise, vibration, and harshness (NVH), and maintenance of relatively low NVH levels over the lifetime of the fluid. Of the foregoing, the additives described herein may be particularly suitable for maintaining friction durability of power transmission fluids.

[0054] Several tests may be used to determine the friction durability of power transmission fluids. Results of tests conducted on fluids containing the additive concentrates as set forth in Table 1 and conventional ATFs II, III and IV are illustrated in FIGS. **1-10**.

[0055] One way to simulate extended use of a fluid in a transmission is to artificially "age" the fluid in the laboratory. The friction characteristics of the fluid (e.g., the change in friction as a function of relative velocity, or the μ-v profile) before and after such aging may be compared to determine the friction durability of the fluid. The smaller the difference in friction coefficient (μ) upon aging, the more stable the fluid. A durable fluid will therefore exhibit minimal change (i.e. a difference in μ close to zero) across a wide range of relative velocity. In the discussion below, "aging" means that the fluids were subjected to heating at 170° C. for 100 hrs.

[0056] FIGS. **1-2** show the differences upon aging in μ as a function of relative velocity for a fluid containing the additive composition of the invention (Fluid I) and for conventional fluids (Fluids II and III). The friction materials used were Borg-Warner SD-1777 (FIG. **1**) and Dynax D530-31 (FIG. **2**). The μ-v profiles shown in these figures were obtained with an SAE No. 2 machine as described in SAE 940821, herein incorporated by reference. The coefficients of friction were determined at speeds ranging from 1 to 300 RPM, an applied pressure of 890 kPa, a temperature of 120° C., and a slip time of 2.9 seconds. The friction characteristic behavior is relevant to the performance of a fluid in a torque converter clutch. Fluid I is clearly superior to the conventional fluids as it exhibits the smallest difference in the μ-v profile over the indicated speed range for these materials.

[0057] In another friction durability test, a clutch pack was installed in the test head of an SAE #2 machine that met the guidelines/specifications as outlined in procedure SAE J286. The clutch pack consisted of four steel plates and two friction plates disposed between the steel plates. Test fluid was added to the test head and the clutch pack was engaged and disengaged 30,000 times according to Ford's MERCON V specification, herein incorporated by reference. Various friction parameters were measured at specified intervals during the test. A suitable fluid has friction properties in the ranges specified by Ford in the MERCON V specification and maintains those properties over the course of the test as indicated by the slope of the curves in FIGS. **3-10**. Improved friction durability is reflected in the flatness of the friction traces in the figures.

[0058] FIGS. **3** and **4** illustrate the low speed dynamic coefficients of friction for a fluid containing the additive composition according to the disclosure (Fluid I) and for conventional ATFs (Fluid II, Fluid III, and Fluid IV). According to FIG. **3**, Fluid I had the most constant low speed dynamic coefficient of friction of the fluids tested.

[0059] FIGS. **5** and **6** illustrate the midpoint dynamic coefficients of friction for a fluid containing the additive composition according to the disclosure (Fluid I) and for conventional fluids (Fluid II, Fluid III, and Fluid IV). According to FIG. **5**, Fluid I again had the most constant midpoint dynamic coefficient of friction of the fluids tested.

[0060] FIGS. **7** and **8** illustrate the static breakaway coefficients of friction for a fluid containing the additive composition according to the disclosure (Fluid I) and for conventional ATFs (Fluid II, Fluid III, and Fluid IV). As with the other characteristics, Fluid I (FIG. **7**) had the most constant static coefficient of friction of the fluids tested.

[0061] S1/D ratios for fluids I, II, III, and IV are provided in FIGS. **9** and **10**. Again, Fluid I showed a more constant S1/D ratio over the course of the test, indicating its superior durability compared to the conventional fluids.

[0062] Accordingly, the additives described herein not only provide good frictional characteristics to fresh power transmission fluids but also enable the power transmission fluids to maintain suitable performance durability over a period of time as demonstrated by the foregoing examples.

[0063] 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.

What is claimed is:

1. A power transmission fluid composition comprising: (a) a base oil and (b) an additive composition comprising (i) at least one ashless dispersant; (ii) a metal detergent providing greater than about 100 ppm metal to the transmission fluid composition; (iii) a friction modifying amount of an imidazoline; (iv) a succinimide friction modifier; and (v) a non-hydroxy tertiary amine friction modifier other than (iii).

2. The fluid of claim **1**, wherein the base oil comprises a natural lubricating oil, a mixture of natural lubricating oils, a synthetic oil, a mixture of synthetic oils, or a mixture of natural and synthetic oils.

3. The fluid of claim **2**, wherein the synthetic oil or mixture of synthetic oils comprises an oligomer of an alphaolefin, an ester, an oil derived from a gas-to-liquid process such as a Fischer-Tropsch process, or a mixture thereof.

4. The fluid of claim **1**, wherein the ashless dispersant comprises a boronated/phosphorylated dispersant.

5. The fluid of claim **1**, wherein the dispersant comprises about 0.1 wt % to about 0.7 wt % of boron.

6. The fluid of claim **1**, wherein the ashless dispersant comprises a hydrocarbyl substituted succinimide derived from polyisobutylene having a molecular weight ranging from about 700 amu to about 3000 amu.

7. The fluid of claim **1**, wherein the additive composition comprises from about 20 wt % to about 65.0 wt % of the dispersant.

8. The fluid of claim **1**, further comprising a hydrocarbyl-substituted succinimide wherein the hydrocarbyl group has a molecular weight ranging from about 500 amu to about 1200 amu.

9. The fluid of claim **1**, wherein the metal detergent comprises a detergent selected from the group consisting of an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and mixtures thereof.

10. The fluid of claim **9**, wherein the additive composition comprises from about 1.0 to about 10.0 weight percent of the succinimide friction modifier.

11. The fluid of claim **1**, wherein the amount of imidazoline in the additive composition ranges from about 0.05 to about 1.0 weight percent.

12. The fluid of claim **1**, further comprising a sulfurized fatty acid.

13. The fluid of claim **1**, further comprising one or more of an antioxidant, a corrosion inhibitor, a metal deactivator, an antifoam agent, a viscosity index improver, a rust inhibitor, and a pour point depressant.

14. The fluid of claim **1**, wherein the imidazoline comprises a C_{18}-C_{22} unsaturated fatty acid hydroxyalkyl imidazoline.

15. The fluid of claim **1**, wherein the fluid 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.

16. A method of improving friction durability in a transmission: adding to a base oil an additive composition comprising (a) at least one ashless dispersant; (b) a metal detergent providing greater than about 100 ppm metal to a fully formulated transmission fluid containing the base oil and additive composition; (c) a friction modifying amount of a hydroxyalkyl imidazoline; (d) a succinimide friction modifier; and (e) a non-hydroxy tertiary amine friction modifier other than (c).

17. The method of claim **16**, wherein the ashless dispersant comprises a boronated/phosphorylated dispersant.

18. The method of claim **16**, wherein the ashless dispersant comprises a hydrocarbyl substituted succinimide derived from polyisobutylene having a molecular weight ranging from about 1300 amu to about 3000 amu.

19. The method of claim **16**, wherein the additive composition comprises from about 20 wt % to about 65 wt % of the dispersant.

20. The method of claim **16**, wherein the metal detergent comprises a detergent selected from the group consisting of an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and mixtures thereof.

21. The method of claim **16**, wherein the additive composition comprises from about 1.0 to about 10.0 weight percent of succinimide friction modifier.

22. The method of claim **16**, wherein the amount of imidazoline in the additive composition ranges from about 0.05 to about 1.0 weight percent.

23. The method of claim **16**, wherein the imidazoline comprises a C_{18}-C_{22} unsaturated fatty acid hydroxyalkyl imidazoline

24. The method of claim **16**, further comprising a sulfurized fatty acid.

25. A method of lubricating a transmission comprising adding to the transmission a lubricating composition comprising an oil of lubricating viscosity including an additive composition comprising:

(a) at least one ashless dispersant;

(b) a metal detergent providing greater than about 100 ppm metal in the lubricating composition;

(c) a friction modifying amount of a C_{18}-C_{22} unsaturated fatty acid imidazoline;

(d) a succinimide friction modifier; and

(e) a non-hydroxy tertiary amine friction modifier other than (c).

26. The method of claim **25**, wherein the ashless dispersant comprises a boronated/phosphorylated dispersant.

27. The method of claim **25**, wherein the ashless dispersant comprises a hydrocarbyl substituted succinimide derived from polyisobutylene having a molecular weight ranging from about 1300 amu to about 3000 amu and a hydrocarbyl substituted succinimide derived from polyisobutylene having a molecular weight ranging from about 300 amu to about 1000 amu.

28. The method of claim **27**, wherein the additive composition comprises from about 20 wt % to about 65 wt % of the dispersant.

29. The method of claim **25**, wherein the metal detergent comprises a detergent selected from the group consisting of an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and mixtures thereof.

30. The method of claim **25**, wherein the additive composition comprises from about 1.0 to about 10.0 weight percent of succinimide friction modifier.

31. The method of claim **25**, wherein the amount of imidazoline in the additive composition ranges from about 0.05 to about 1.0 weight percent.

32. The method of claim **25**, wherein the imidazoline comprises a hydroxyalkyl imidazoline.

33. The method of claim **25**, further comprising one or more of an antioxidant, a corrosion inhibitor, a metal deactivator, an antifoam agent, a viscosity index improver, a rust inhibitor, an extreme pressure agent, and a pour point depressant.

34. An additive concentrate for a power transmission fluid, the additive concentrate comprising at least one ashless dispersant; a metal detergent providing greater than about 100 ppm metal to the transmission fluid composition; a friction modifying amount of an imidazoline; a succinimide friction modifier; and a non-hydroxy tertiary amine friction modifier other than the imidazoline.

35. The additive concentrate of claim **34**, wherein the ashless dispersant comprises a boronated/phosphorylated dispersant.

36. The additive concentrate of claim **34**, wherein the dispersant comprises about 0.1 wt % to about 2.0 wt % of boron.

37. The additive concentrate of claim **34**, wherein the ashless dispersant comprises a hydrocarbyl substituted succinimide derived from polyisobutylene having a molecular weight ranging from about 1300 amu to about 3000 amu.

38. The additive concentrate of claim **34**, wherein the additive composition comprises from about 20 wt % to about 65 wt % of the dispersant.

39. The additive concentrate of claim **34**, further comprising a hydrocarbyl-substituted succinimide wherein the hydrocarbyl group has a molecular weight ranging from about 500 amu to about 1200 amu.

40. The additive concentrate of claim **34**, wherein the metal detergent comprises a detergent selected from the group consisting of an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and mixtures thereof.

41. The additive concentrate of claim **34**, wherein the additive composition comprises from about 1.0 to about 10.0 weight percent of the succinimide friction modifier.

42. The additive concentrate of claim **34**, wherein the amount of imidazoline in the additive composition ranges from about 0.05 to about 1.0 weight percent.

43. The additive concentrate of claim **34**, further comprising a sulfurized fatty acid.

44. The additive concentrate of claim **34**, further comprising one or more of an antioxidant, a corrosion inhibitor, a metal deactivator, an antifoam agent, a viscosity index improver, a rust inhibitor, and a pour point depressant.

45. The additive concentrate of claim **34**, wherein the imidazoline comprises a C_{18}-C_{22} unsaturated fatty acid hydroxyalkyl imidazoline.

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