METHOD OF IMPROVING THE EFFICIENCY OF AUTOMOTIVE TRANSMISSIONS

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ABSTRACT

A method for improving the fuel economy of an automobile is disclosed. The method involves lubricating an automotive transmission system with a lubricant composition containing (a) an oil of lubricating viscosity; (b) a viscosity modifying polymer comprising linear polymers characterized by the formula:

\[ D'-PA-D' \]

and star polymers characterized by the formula:

\[ (D'-PA-D')_n-X \]

wherein D', PA, D' are polymer blocks as defined herein; and (c) a performance additive package.
Fig. 1

Bivariate Fit of NEDC Results

Fig. 2

NEDC Fuel Consumption versus Kinematic Viscosity at 20°C
METHOD OF IMPROVING THE EFFICIENCY OF AUTOMOTIVE TRANSMISSIONS

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is continuation-in-part of U.S. patent application Ser. No. 13/332750, filed on Dec. 21, 2011 and titled “Viscosity Index Improvers for Lubricating Oil Compositions”, which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

[0002] As automotive transmission manufacturers strive to improve the efficiency of the different types of transmissions they manufacture, e.g. manual transmissions, stepped automatic transmissions, continuously variable transmissions, dual clutch transmissions, hybrid transmissions, etc., technologists have learned that energy loss within the system can be reduced by changing the viscometric characteristics of the transmission fluid used in the transmission. Specifically, it is now well known in the industry that fuel economy benefits can be realized by lowering the viscosity of the transmission fluid. Fuel economy benefits can be increased by lowering the kinematic viscosity at 20°C (“KV20”) of a transmission fluid. As a result, technologists have been attempting to formulate transmission fluids having lower viscosities like KV20 to realize greater fuel economy benefits.

[0003] Surprisingly, the inventors of the present invention have discovered that a transmission fluid formulated with a novel viscosity modifying polymer exhibits improved fuel economy over transmission fluids formulated with conventional viscosity modifying polymers like polymetacrylates when the kinematic viscosities of the transmission fluid of the invention and the transmission fluids formulated with conventional viscosity modifying polymers, respectively, are the same.

[0004] The present invention relates to a method for improving the fuel economy of an automobile comprising the steps of: lubricating an automotive transmission with a lubricant composition comprising: (a) an oil of lubricating viscosity; (b) a viscosity modifying polymer comprising a linear triblock polymer and/or star-polymer having multiple triblock arms coupled to a central core, such as a divinylbenzene (DVB) core, wherein the triblock polymers or triblock arms contain a block derived from monoalkenyl arene monomer positioned between two partially or fully hydrogenated blocks derived from diene, wherein at least one of the diene blocks is a copolymer derived from mixed diene monomer, in which from about 65 wt. % to about 95 wt. % of the incorporated monomer units are from isoprene and from about 5 wt. % up to about 35 wt. % of the incorporated monomer units are from butadiene, and wherein at least about 80 wt. % of butadiene is incorporated into the random copolymer block in a 1,4-configuration; and (c) a performance additive package.

[0005] The method of the present invention surprisingly delivers improved energy efficiency and better fuel economy to automobiles.

SUMMARY OF THE INVENTION

[0006] In a non-limiting embodiment, the present invention is a method for improving the fuel economy of an automobile comprising the steps of: lubricating an automotive transmission with a lubricant composition comprising: (a) an oil of lubricating viscosity; (b) a viscosity modifying polymer comprising a linear triblock polymer and/or star-polymer having multiple triblock arms coupled to a central core, such as a divinylbenzene (DVB) core, wherein the triblock polymers or triblock arms contain a block derived from monoalkenyl arene monomer positioned between two partially or fully hydrogenated blocks derived from diene, wherein at least one of the diene blocks is a copolymer derived from mixed diene monomer, in which from about 65 wt. % to about 95 wt. % of the incorporated monomer units are from isoprene and from about 5 wt. % up to about 35 wt. % of the incorporated monomer units are from butadiene, and wherein at least about 80 wt. % of butadiene is incorporated into the random copolymer block in a 1,4-configuration; and (c) a performance additive package. Such method can include other steps such as running or operating the automobile.
The present invention utilizes standard methods for lubricating a transmission as are well known in the art. And the lubricant composition used in the method of the present invention is produced by blending the components described below according to procedures which are well known in the industry using standard equipment.

(a) The Oil of Lubricating Viscosity

The oil of lubricating viscosity (also referred to herein as “lubricating oil(s)”) contemplated for use in this invention comprises natural lubricating oils, synthetic lubricating oils or mixtures of natural lubricating oils and synthetic lubricating oils. Suitable lubricating oils include base stocks obtained by isomerization of synthetic wax and slack wax, as well as basestocks produced by hydrocracking (rather than by solvent treatment) the aromatic and paraffinic components of the crude. The lubricating oil has a kinematic viscosity ranging from about 2 to about 10 mm²/s (cSt) at 100°C, for example, from 2 to 6 mm²/s (cSt), or from 3 to 5 mm²/s (cSt), at 100°C.

Suitable natural lubricating oils include animal oils, vegetable oils (e.g., castor oil and lard oil), petroleum oils, mineral oils, and oils derived from coal or shale. The preferred natural lubricating oil is mineral oil.

The mineral oils useful in this invention include common mineral oil basestocks. This would include oils that are naphthenic or paraffinic in chemical structure as well as oils that are refined by conventional methodology using acid, alkali, and clay or other agents such as aluminum chloride, or they may be extracted oils produced, e.g., by solvent extraction or treatment with solvents such as phenol, sulfur dioxide, furfural, dichloroethylene, etc. They may be hydrotreated or hydronrefined, dewaxed by chilling or catalytic dewaxing processes, or hydrocracked. The mineral oil may be produced from natural crude sources or be composed of isomerized wax materials or residues of other refining processes.

A useful class of mineral oils comprises mineral oils that are severely hydrotreated or hydrocracked. These processes expose the mineral oils to very high hydrogen pressures at elevated temperatures in the presence of hydrosolgenation catalysts. Typical processing conditions include hydrogen pressures of approximately 3000 pounds per square inch (psi) at temperatures ranging from 300°C to 450°C over a hydrogenation-type catalyst. This processing removes sulfur and nitrogen from the lubricating oil and saturates any alkylene or aromatic structures in the feedstock. The result is a base oil with extremely good oxidation resistance and viscosity index. A secondary benefit of these processes is that low molecular weight constituents of the feed stock, such as waxes, can be isomerized from linear to branched structures thereby providing finished base oils with significantly improved low temperature properties. These hydrotreated base oils may then be further de-waxed either catalytically or by conventional means to give them exceptional low temperature fluidity. Commercial examples of lubricating base oils made by one or more of the aforementioned processes are Chevron RLOP, Petro-Canada P65, Petro-Canada P 100, Yukong, Ltd., Yuhase 4, Imperial Oil Canada MXT, Fortum Nexbase 3060, and Shell XHVI 5.2.

Suitable synthetic lubricating oils include hydrocarbon oils and halo-substituted hydrocarbon oils such as oligomerized, polymerized, and interpolymerized olefins (e.g., polybutylenes, propylene, propylene, isobutylene copolymers, chlorinated polyolefins, poly(1-hexenes), poly(1-decenes), etc., and mixtures thereof); alkylenbenzenes [e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)benzene, etc.; polyphenyls [e.g., biphenyls, terphenyls, alkylated polyphenyls, etc.]; and alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogs, and homologs thereof, and the like. The preferred oils from this class of synthetic oils are oligomers of α-olefins, particularly oligomers of 1-decene and other polyalkylolylefinas.

Suitable synthetic lubricating oils also include polyalkylolylefins (PAO) which are oligomers of terminally unsaturated alkenes. Polyalkylolylefins can be made from any terminally unsaturated olefin or mixtures of terminally unsaturated olefins. The preferred polyalkylolylefins are made from 1-olefine or 1-decene or mixtures thereof. The polyalkylolylefins can be derived from monomers having from about 4 to about 30, or from about 5 to about 20, or from about 6 to about 16 carbon atoms. The PAOs may have a kinematic viscosity at 100°C from about 2 to about 40 mm²/s (cSt) at 100°C.

The lubricating oil can comprise one or more synthetic and/or mineral oil basestocks classified as Group I, II, III, IV and/or V according to the API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils.

In a non-limiting embodiment of the invention, the oil of lubricating viscosity is a Group II or Group III oil.

In another non-limiting embodiment of the invention, at least 50% by weight of the oil of lubricating viscosity is a polyalkylolylefin (PAO).

The lubricating oil can be derived from refined oils, refined oils, and/or mixtures thereof. These types of lubricating oils are well known in the art.

The oil of lubricating viscosity is present in the composition in amounts ranging from about 1 to 95 wt. %, preferably 5 to 75 wt. %.

(b) The Viscosity Modifying Polymer

The viscosity modifying polymer comprises one or more linear polymers, which can be characterized by the formula:

\[ (D\text{-PA-D}')_n \]

and star polymers having multiple triblock arms coupled to a central core, which can be characterized by the formula:

\[ (D\text{-PA-D}')_n-X \]

wherein D' represents an “outer” block derived from diene; PA represents a block derived from monoaalkenyl arene; D' represents an inner random derived from diene; n represents the average number of arms per star polymer formed by the reaction of 2 or more moles of a polyaalkenyl coupling agent per mole of arms; and X represents a nucleus of a polyaalkenyl coupling agent.

At least one of diene blocks D' and D", preferably each of diene blocks D' and D", are copolymer blocks derived from mixed diene monomer, in which from about 65 wt. % to about 95 wt. % of the incorporated monomer units are from isoprene and from about 5 wt. %, up to about 35 wt. % of the incorporated monomer units are from butadiene, and wherein at least about 80 wt. % of butadiene, preferably at least 90 wt. % of the butadiene is incorporated in a 1,4-configuration. Preferably, at least about 15 wt. % of the incorporated monomer units are butadiene monomer units. Preferably, no greater than about 28 wt. % of the incorporated monomer units are butadiene monomer units. Preferably, at least one of diene blocks D' and D", more preferably each of diene blocks D' and
D\textsuperscript{\circ}, are random copolymer blocks. Blocks D\textsuperscript{'} and D\textsuperscript{\circ} are preferably hydrogenated to remove at least about 80% or 90% or 95% of unsaturations, and more preferably, are fully hydrogenated. Outer block D\textsuperscript{'} has a number average molecular weight of from about 10,000 to about 120,000 daltons, more preferably from about 20,000 to about 60,000 daltons, before hydrogenation. Block PA has a number average molecular weight of from about 10,000 to about 50,000 daltons. Increasing the size of block PA can adversely affect the thickening efficiency of the star polymer. Therefore, the number average molecular weight of block PA is preferably from about 12,000 to about 35,000 daltons. Inner block D\textsuperscript{\circ} has a number average molecular weight of from about 5,000 to about 60,000 daltons, more preferably from about 10,000 to about 30,000 daltons, before hydrogenation. The term “number average molecular weight”, as used herein, refers to the number average molecular weight as measured by Gel Permeation Chromatography (“GPC”) with a polystyrene standard.

**[0028]** In addition to the size of blocks D\textsuperscript{'} , PA and D\textsuperscript{\circ}, the ratio between both the size of outer block D\textsuperscript{'} and inner block D\textsuperscript{\circ}, and block PA and inner block D\textsuperscript{\circ}, has been found to influence the shear stability properties of the star polymer. In star polymers of the present invention, the ratio of the number average molecular weight of outer block D\textsuperscript{'} to the number average molecular weight of inner block D\textsuperscript{\circ} is preferably at least about 1.4:1, such as at least about 1.9:1, more preferably at least about 2.0:1, and the ratio of the number average molecular weight of block PA to the number average molecular weight of inner block D\textsuperscript{\circ} is preferably at least about 0.75:1, such as at least about 0.9:1, more preferably at least about 1.0:1.

**[0029]** In addition to providing improved shear stability index (SSI) and thickening efficiency (TE), the star polymers of the present invention can provide improved viscometric properties in lubricating oil compositions and automatic transmission fluids, which result in fuel economy benefits. The star polymers of the present invention are more temperature responsive than prior star polymers, and begin to collapse at a temperatures of greater than 50°C, such as about 100°C or even 120°C, to reduce viscosity at the greatest range of temperatures at which significant thickening is unnecessary, while readily expanding at temperatures above 120°C, to provide sufficient viscosity to form thick oil films at engine operating temperatures, for good engine durability. Collapse with the star polymers of the present invention results in a reduced kinematic viscosity at 40°C, which improves viscosity index of a range of oil base stocks from Group I to Group IV. Increasing the initial coil collapse temperature (>50°C) reduces the hydrodynamic volume below 100°C and results in increased shear stability, without an adverse effect on thickening efficiency, thereby improving the TE/SSI balance. Increasing the initial coil collapse temperature to greater than 100°C provides a star polymer having a reduced hydrodynamic volume over a range of operating temperatures from 20°C to 90°C.

**[0030]** Preferably no greater than 30 wt. %, more preferably no greater than 25 wt. %, of the total amount of polydiene in the star polymers of the invention is derived from butadiene. Preferably, at least about 80 wt. %, more preferably, at least 90 wt. % of the total amount of butadiene, which can be incorporated into the polymer as 1, 2-, or 1,4-configuration units, is incorporated into the star polymer is incorporated in a 1,4-configuration. Increasing the percentage of butadiene incorporated into the polymer as 1,4-units can increase the thickening efficiency properties of the star polymer. An excessive amount polybutadiene, particularly polybutadiene having a 1,2-configuration, can have an adverse effect on low temperature pumpability properties.

**[0031]** Isoprene monomers used as the precursors of the copolymers of the present invention can be incorporated into the polymer in either a 1,4- or 3,4-configuration, or as a mixture thereof.

**[0032]** Linear polymers of the present invention may have a number average molecular weight of from about 25,000 daltons to about 1,000,000 daltons, such as from about 40,000 daltons to about 500,000 daltons, preferably from about 60,000 daltons to about 200,000 daltons.

**[0033]** Star polymers of the present invention can have from 4 to about 25 arms (n=about 4 to about 25), preferably from about 10 to about 20 arms. Star polymers of the present invention may have a total number average molecular weight of from about 100,000 daltons to about 1,000,000 daltons, preferably from about from about 400,000 to about 800,000 daltons, most preferably from about 500,000 to about 700,000 daltons.

**[0034]** The triblock linear polymers and triblock arms of the star polymers of the present invention can be formed as living polymers via anionic polymerization, in solution, in the presence of an anionic initiator, as described, for example, in U.S. Pat. No. Re 27,145 and U.S. Pat. No. 4,116,917.

**[0035]** The triblock linear polymers and triblock arms of the star polymers of the present invention can, and are preferably, prepared by step-wise polymerization of the monomers.

**[0036]** The solvents in which the living polymers are formed are inert liquid solvents, such as hydrocarbons e.g., aliphatic hydrocarbons such as pentane, hexane, heptane, octane, 2-ethylhexane, nonane, decane, cyclohexane, methlycyclohexane, or aromatic hydrocarbons e.g., benzene, toluene, ethylbenzene, the xylenes, diethylbenzenes, propylbenzenes. Cyclohexane is preferred. Mixtures of hydrocarbons e.g., lubricating oils, may also be used.

**[0037]** The temperature at which the polymerization is conducted may be varied within a wide range, such as from about −50°C to about 150°C, preferably from about 20°C to about 80°C. The reaction is suitably carried out in an inert atmosphere, such as nitrogen, and may optionally be carried out under pressure e.g., a pressure of from about 0.5 bars to about 10 bars.

**[0038]** The concentration of the initiator used to prepare the living polymer may also vary within a wide range and is determined by the desired molecular weight of the living polymer.

**[0039]** The resulting linear or star-shaped copolymers can then be hydrogenated using any suitable means.

**[0040]** Alternatively, the linear and star polymers of the present invention can be selectively hydrogenated.

**[0041]** The viscosity modifying polymer of the present invention is present in the lubricating composition in an amount from about 0.1 wt. % to about 2.5 wt. %, preferably from about 0.3 wt. % to about 1.5 wt. %, or from about 0.4 wt. % to about 1.3 wt. %, stated as mass percent active ingredient (AI).

**[0042]** (c) Additional Components and The Performance Additive Package

**[0043]** Performance additive packages useful in the present invention are well known to those skilled in the art. Suitable performance additive packages are concentrates comprising
mixtures of additive chemical components such as anti-wear agents, anti-oxidants, friction modifiers, inhibitors, detergents, etc., that when treated at appropriate dosages in lubricating base oils confer desirable properties to the resulting lubricant. In the case of the present invention these additive packages would be those capable of producing manual transmission fluids, automatic transmission fluids (ATFs), continuously variable transmission fluids (CVTFS), dual clutch transmission fluids (DCTFs) and other fluids that are commonly used in automotive transmissions.

[0044] Lubricant compositions according to the present invention can contain one or more of the following components: ashless dispersants; metal-containing or ash-forming detergents; antiwear agents; antioxidants; friction modifiers; pour point depressants; foam control agents; polymers capable of modifying the viscometric properties of fluids, etc.

[0045] Ashless dispersants maintained in suspension oil insolubles resulting from oxidation of the oil during wear or combustion. They are particularly advantageous for preventing the precipitation of sludge and the formation of varnish, particularly in gasoline engines. Suitable ashless dispersants include hydrocarbyl succinimides, hydrocarbyl succinamides, mixed ester/amides of hydrocarbyl-substituted succinic acid, hydroxyesters of hydrocarbyl-substituted succinic acid, and Mannich condensation products of hydrocarbyl-substituted phenols, formaldehyde and polyamines. Also useful are condensation products of polyamines and hydrocarbyl substituted phenyl acids. Mixtures of these dispersants can also be used.

[0046] 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 and extending engine life. Detergents generally comprise a polar head with a long hydrophobic tail, with the polar head comprising a metal salt of an inorganic or organic acid. The salts may contain a substantial 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 can be measured by ASTM D2896) from 0 to 80. A large amount of a metal base may be incorporated by reacting excess metal compound (e.g., an oxide or hydroxide) with an acidic gas (e.g., carbon dioxide). The resulting overbased detergent comprises neutralized detergent as the outer layer of a metal-base (e.g., carbonate) micelle. Such overbased detergents may have a TBN of 1.50 or greater, and typically will have a TBN of from 250 to 450 or more.

[0047] Antioxidants reduce the tendency of mineral oils to deteriorate in service leading to oxidative deterioration which can be evidenced by sludge in the lubricant, varnish-like deposits on the metal surfaces, and by viscosity growth. Suitable antioxidants include hindered phenols, alkaline earth metal salts of allylphenolthioesters having preferably C5 to C12 alkyl side chains, calcium nonylphenol sulfide, oil soluble phenates and sulfured phenates, phosphosulfurized or sulfurized hydrocarbons, phosphorous esters, metal thiocarboxamates, oil soluble cation compounds as described in U.S. Pat. No. 4,867,890 which is herein incorporated by reference, and molybdenum-containing compounds and aromatic amines.

[0048] Suitable friction modifiers include amides; the reaction product of a polyamine and a carboxylic acid or anhydride; succinimides and derivatives of succinimides; ethoxylated amines; etc. These friction modifiers are described in U.S. Pat. No. 6,613,722 which is incorporated herein by reference.

[0049] Lube oil flow improvers (“LOFIs”) also known as pour point depressants, lower the minimum temperature at which the fluid will flow or can be poured. Suitable pour point depressants comprise C8 to C18 dialkyl fumarate/vinyl acetate copolymers, and poly(ethylene-alt-maleic anhydride) copolymers.

[0050] Suitable foam control agents comprise polysiloxane compounds, for example, silicone oil or polydimethyl siloxane.

[0051] Suitable polymers capable of modifying the viscometric properties of fluids include polysiloxane, copolymers of ethylene and propylene (OCP), poly(methacrylates), methacrylate copolymers, copolymers of an unsaturated dicarboxylic acid and a vinyl compound, interpolymers of styrene and acrylic esters, and hydrogenated copolymers of styrene/isoprene, styrene/butadiene, and other hydrogenated isoprene/butadiene copolymers, as well as the partially hydrogenated homopolymers of butadiene and isoprene.

[0052] Suitable anti-wear agents include oil-soluble phosphorus-containing compounds

[0053] Examples of suitable phosphorus compounds are: phosphites and thio phosphites (mono-alkyl, di-alkyl, tri-alkyl and partially hydrolyzed analogs thereof); phosphates and thio phosphates; amines treated with inorganic phosphorus such as phosphorous acid, phosphoric acid or their thio analogs; zinc dithiophosphates; amine phosphates.

[0054] Other examples of suitable phosphorus compounds include: mono-n-butyl-hydrogen-acid-phosphate; di-n-butyl-hydrogen phosphate; triphenyl phosphate; triphenyl thio phosphate; tri-n-butylphosphate; diethyl octodecyl phosphinate, 900MW polyisobutylene succinic anhydride (PIBSA) polynamine dispersant post treated with HPO3 and H2BO3 (see, e.g., U.S. Pat. No. 4,857,214); zinc(di-2-ethylhexylthiophosphate).

[0055] Suitable oil soluble phosphorus compounds also include esters of phosphoric and phosphorous acid such as di-alkyl, tri-alkyl, tri-aryl phosphites and phosphates and mixed thiophosphite phosphorus esters, for example as produced in U.S. Pat. No. 5,314,633, which is incorporated herein by reference.

[0056] An oil-soluble phosphorus-containing compound can be present in the composition in an amount ranging from about 5 to about 5000 ppm phosphorus.

[0057] Other suitable dispersants, antiwear agents, corrosion inhibitors, detergents, extreme pressure additives, and the like are disclosed in, for example, "Lubricant Additives" by C. V. Smallheer and R. Kennedy Smith, 1967, pp. 1-11 and U.S. Pat. No. 4,105,571, which are incorporated herein by reference.

[0058] As stated previously, suitable performance additive packages according to the present invention are concentrates comprising one or more of the components described above. Such performance additive packages are commercially available and well known to those skilled in the art. Examples of commercially available, performance additive packages are: (1) the following products manufactured by Infineum USA L.P. (Linden, N.J.): Infineum T4575, Infineum T4904 and Infineum T4300; (2) the following products manufactured by Alton, Inc. (Richmond, Va.): Hitec 2038, Hitec 2435 and Hitec 3491; and (3) the following products manufactured by Lubrizol Corporation (Wickliffe, Ohio): Lubrizol 9680, Lubrizol 6373 and Lubrizol DCT 03 VW.
When the performance additive packages are added to lubricating base oils at an appropriate treat rate, they confer desirable properties to the resulting lubricant composition. Depending on the specific performance additive package used, various lubricant compositions such as, manual transmission fluids, automatic transmission fluids (ATFs), continuously variable transmission fluids (CVTFs), dual clutch transmission fluids (DCTFs) and other fluids that are commonly used in automotive transmissions can be produced.

In various non-limiting embodiments, the performance additive package is present in the lubricant composition in an amount ranging from about 1.0 mass percent to about 20.0 mass percent. In a non-limiting embodiment, the present invention is a manual transmission fluid comprising an oil of lubricating viscosity as described above, a viscosity modifying polymer as described above, and specific performance additive package. An example of a commercially available, performance additive package for this embodiment is Infineum T4804 from Infineum USA (Linden, N.J.).

In another non-limiting embodiment, the lubricant composition of the invention is an automatic transmission fluid comprising an oil of lubricating viscosity as described above, a viscosity modifying polymer as described above, and specific performance additive package. Examples of commercially available, performance additive packages for this embodiment are: Lubrizol 6950, Lubrizol 7900, Lubrizol 9614, Hitec 403, Hitec 420, Hitec 427, Infineum T4520 and Infineum T4540.

In yet another non-limiting embodiment, the present invention is a CVT fluid comprising an oil of lubricating viscosity as described above, a viscosity modifying polymer as described above, and specific performance additive package. Examples of commercially available, performance additive packages for this embodiment are Infineum T4904, Hitec 2435 and Lubrizol 6373.

In another non-limiting embodiment, the present invention is a DCT fluid comprising an oil of lubricating viscosity as described above, a viscosity modifying polymer as described above, and specific performance additive package. Examples of commercially available, performance additive packages for this embodiment are Infineum T4300, Hitec 3491 and Lubrizol DCT 03 VV.

As is well known in the art, the exact composition of the performance additive package will be determined by the desired end use application. Representative amounts of components found in a transmission fluid are summarized in the table below:

<table>
<thead>
<tr>
<th>Additive Component</th>
<th>Broad Wt.%</th>
<th>Preferred Wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI Improvers</td>
<td>1-12</td>
<td>1-4</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>0.01-3</td>
<td>0.02-1</td>
</tr>
<tr>
<td>Dispersants</td>
<td>0.10-10</td>
<td>2.5</td>
</tr>
<tr>
<td>AntiFoaming Agents</td>
<td>0.001-5</td>
<td>0.001-0.5</td>
</tr>
<tr>
<td>Detergents</td>
<td>0.01-6</td>
<td>0.01-3</td>
</tr>
<tr>
<td>Antiwear Agents</td>
<td>0.001-5</td>
<td>0.2-3</td>
</tr>
<tr>
<td>Pour Point Depressants</td>
<td>0.01-2</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Seal Swellants</td>
<td>0.1-8</td>
<td>0.5-5</td>
</tr>
<tr>
<td>Friction Modifiers</td>
<td>0.01-10</td>
<td>0.1-5</td>
</tr>
<tr>
<td>Antioxidants</td>
<td>0.01-10</td>
<td>0.1-5</td>
</tr>
</tbody>
</table>

The present invention also encompasses lubricating compositions as described above. According to the present invention, the lubricant composition of the invention has a viscosity measured at 100°C from 2.0 to 10.0 mm²/s (cSt), and a Brookfield viscosity of less than 15 Pa·s (15,000 cP), or less than 10 Pa·s (10,000 cP).

EXEMPLARY USE APPLICATIONS

The following non-limiting examples were prepared to illustrate the present invention.

The following transmission fluids were prepared: “Example 1” which is illustrative of a lubricant composition according to the present invention and “Examples 2-12” which illustrate comparative fluids comprising polyalkenyl acrylate polymers for viscosity modification.

Example 1 was made by blending the following components using standard equipment and procedures as are well known in the art: (1) 7 wt. % of the viscosity modifying polymer of the present invention which is labeled “STRIIB”; (2) 7.5 wt. % of a performance additive package commercially available from Infineum USA L.P. (Linden, N.J.) as Infineum T4200; (3) 0.2 wt. % of a LOFT, Viscosept 5011H supplied by Evonic RohMax USA, Inc.; and (4) the remainder is base oil PetroCanada Purity 65 (PC65) supplied by PetroCanada (Alberta, CA). All of the wt. % are based on the total weight of the lubricant composition.

The viscosity modifying polymer of the invention in the form of a star polymer having an average of about 12.5 arms per star molecule was made by mixing 10 wt. % of the star polymer with 90 wt. % Synthetic 5 alkylbenzene base oil supplied by ExxonMobil in a Silverson mixer for 2 hours at 120°C with a mixing speed of 2,500 to 3,000 rpm.

The resulting viscosity modifying polymer of the invention is an EP-S-EPT block polymer with 22 wt. % EB in D according to the present invention where D=D(Da)=33118; D(Da)=15358; PA(Da)=15626; D(Da)=2.4; PA(Da)=1.15; % BD In Arm=11.88; True Total Arm Mol. Wt.(Da)=62218; and PA Content (%)=25.01.

“EP” indicates ethylene/propylene units derived from polymerization of hydrogenated isoprene; “EB” indicates ethylene/butene units derived from polymerization of hydrogenated butadiene (“BD”); and “S” indicates units derived from styrene.

Comparative fluids, Examples 2-12, were made by blending the following components using standard equipment and procedures as are well known in the art: (1) one of four (4) base oils; (2) one of three (3) polymethacrylate polymers; (3) one of two (2) LOFTs; and (4) a performance additive package.

The three (3) different polymethacrylate viscosity modifiers (“VM”) used are all manufactured by Evonic RohMax USA, Inc. (Horsham, Pa.) and are as follows: Viscosept 12-075; Viscosept 12-115; and Viscosept 12-199.

The four (4) different base stocks used are as follows: PetroCanada Purity 65 (“PC65”) supplied by PetroCanada (Alberta, CA); Yubase 3 and Yubase 4 supplied by SK Lubricants Co. Ltd. (Seoul, Korea); and Synfluid PAO 2.5 ("PAO2.5") supplied by Chevron Phillips Chemical Company LLC (Woodlands, Tex.).

The two (2) LOFTs used are as follows: Viscosept 1-180 and Viscosept 5011H, both supplied by Evonic RohMax USA, Inc.

And the performance additive package was Infineum T4290 from Infineum USA. In the various exemplary fluids, either 15 wt. % or 7.5 wt. % of the performance additive package, based on the weight percent of the fluid, was blended to make the comparative fluid. The treat rate for each example appears under “Add Treat” in Table 1.

Table 1 shows the specific types and amounts of polymethacrylate polymer, LOFT and performance additive packages.
The comparative examples were blended to varying target kinematic viscosities at 100°C. ("KV100") by varying the amount of viscosity modifier for a given additive package treat rate and base oil mixture.

Example 13 was purchased. It is the factory fill fluid used by Hyundai Motor Company for its 6 speed transmissions.

See Table 1 below for a summary of compositional information concerning the exemplary lubricant compositions. "Base Stock Viscosity"is the viscosity of the base stock prior to the addition of any additives. In the table, Viscoplex products appear as a “V” followed by the product number.

### TABLE 1

<table>
<thead>
<tr>
<th>Add Base Stock</th>
<th>Base Stock Visc</th>
<th>VM treat wt %</th>
<th>LOFI treat wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex</td>
<td>wt % Stock</td>
<td>[mPa·s]</td>
<td>[mPa·s]</td>
</tr>
<tr>
<td>1</td>
<td>7.5 PC65</td>
<td>2.5</td>
<td>7 V12-199</td>
</tr>
<tr>
<td>2</td>
<td>15 PC65</td>
<td>2.5</td>
<td>6 V12-199</td>
</tr>
<tr>
<td>3</td>
<td>7.5 PC55</td>
<td>2.5</td>
<td>8.5 V12-199</td>
</tr>
<tr>
<td>4</td>
<td>15 PC65</td>
<td>2.5</td>
<td>3.5 V12-199</td>
</tr>
<tr>
<td>5</td>
<td>7.5 PAO2.5</td>
<td>2.5</td>
<td>0 None</td>
</tr>
<tr>
<td>6</td>
<td>15 Yubase 3</td>
<td>3.0</td>
<td>4.7 V12-199</td>
</tr>
<tr>
<td>7</td>
<td>15 PC 65</td>
<td>2.5</td>
<td>7.5 V12-115</td>
</tr>
<tr>
<td>8</td>
<td>15 Yubase 3</td>
<td>3.0</td>
<td>1.5 V12-199</td>
</tr>
<tr>
<td>9</td>
<td>15 Yubase 3</td>
<td>3.0</td>
<td>5.5 V12-199</td>
</tr>
<tr>
<td>10</td>
<td>7.5 PC 65</td>
<td>2.5</td>
<td>5.5 V12-199</td>
</tr>
<tr>
<td>11</td>
<td>15 Mixture</td>
<td>3.7</td>
<td>11.5 V12-075</td>
</tr>
<tr>
<td>12</td>
<td>7.5 PAO2.5</td>
<td>2.5</td>
<td>4 V12-199</td>
</tr>
</tbody>
</table>

The kinematic viscosities at 20°C., 40°C. and 100°C.—KV20, KV40 and KV100—of the example fluids were measured using standard procedures. And the example fluids were evaluated for fuel economy according to the New European Driving Cycle ("NEDC") testing protocol in the following manner. Tests were conducted to measure the efficiency of a six speed automatic transmission lubricated with an example fluid was measured using the NEDC testing protocol (3) according to EU Directive 98/69/EC on a Hyundai Tucson vehicle. The NEDC procedure was a combination of the ECE-15 and the EUEDC (Extra Urban Driving Cycle) with a cold start procedure.

The result of the NEDC testing protocol is a fuel economy of the vehicle reported in liters of fuel consumed per 100 kilometers of driving. Lower numbers for fuel economy are the desired result.

Table 2 shows the following measured performance properties of the example fluids: KV20, KV40, KV100 and the results of the NEDC fuel economy testing protocol for each of the exemplary fluids.

### TABLE 2

<table>
<thead>
<tr>
<th>Ex</th>
<th>KV100 [cSt]</th>
<th>KV20 [cSt]</th>
<th>KV40 [cSt]</th>
<th>NEDC Result [l/100 km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.68</td>
<td>45.25</td>
<td>21.83</td>
<td>8.36</td>
</tr>
<tr>
<td>2</td>
<td>5.55</td>
<td>44.19</td>
<td>21.938</td>
<td>8.42</td>
</tr>
<tr>
<td>3</td>
<td>5.52</td>
<td>38.38</td>
<td>20.6085</td>
<td>8.45</td>
</tr>
</tbody>
</table>

A plot of the results in Table 2 is shown in FIG. 1. The plot show the statistical fit of a line generated by plotting Fuel Consumption in liters/100 km versus Kinematic Viscosity at 20°C. The “●’s” at KV20 of approximately 62 mm²/s are repeat runs of Example 13. Example 13 was measured six (6) times. The recorded values [l/100 km] were: 8.49, 8.50, 8.48, 8.52, 8.51 and 8.47. The average measurement of 8.50 l/100 km appears in Table 2. The “△’s” represent the NEDC values measured for Examples 2-12. The dotted lines represent a 95% confidence interval for the generated data. The “×” at KV20 of approximately 45.25 cSt represents Example 1 according to the present invention. For Example 1 at other KV20s, a dashed line was generated by extrapolating the statistical fit. A plot of only Examples 1, 2, 3 and 6-8 as well as repeat measurements for Example 13 are shown in FIG. 2.

In conclusion, lubricant compositions according to the present invention exhibit superior fuel economy performance over lubricant compositions containing conventional viscosity modifying polymers like polymethacrylates at the same kinematic viscosity. Example 1 and Example 2 are directly comparable. As shown in Table 2, Example 1 exhibits...
superior fuel economy performance to Example 2. The measured fuel economy for Example 1 was 8.36 liters/100 kilometers and the fuel economy of the comparative fluid having the same KV20, Example 2, was 8.42 liters/100 kilometers.

FGS. 1 and 2 further illustrate the superior fuel economy performance at a common KV20 of lubricant compositions according to the present invention as compared to lubricant compositions containing conventional viscosity modifying polymers like polymethacrylates. Clearly, the product of the current invention as represented by the “8” has a lower fuel economy than the comparative examples.

What is claimed is:

1. A method for improving the fuel economy of an automobile, comprising the following steps:
   (a) lubricating an automotive transmission system with a lubricant composition comprising (a) an oil of lubricating viscosity;
   (b) a viscosity modifying polymer comprising linear polymers characterized by the formula:
   \[ D' \text{-PA-}D'' \]
and star polymers characterized by the formula:
\[ p \frac{1}{(D' \text{-PA-}D'')} = X \]
wherein \( D' \) represents a block derived from diene; \( PA \) represents a block derived from mononalkenyl arene; \( D'' \) represents a block derived from diene; \( n \) represents the average number of arms per star polymer formed by the reaction of 2 or more moles of a polyalkenyl coupling agent per mole of arms; and \( X \) represents a nucleus of a polyalkenyl coupling agent;
wherein at least one of diene blocks \( D' \) and \( D'' \) is a copolymer block derived from mixed diene monomer, in which from 65 wt. % to 95 wt. % of the incorporated monomer units are from isoprene and from 5 wt. %, up to 35 wt. % of the incorporated monomer units are from butadiene, and wherein at least 80 wt. % of the butadiene is incorporated in a 1,4-configuration; and
wherein \( D' \) has a number average molecular weight of from 10,000 to 120,000 daltons; \( PA \) has a number average molecular weight of from 10,000 to 50,000 daltons; and \( D'' \) has a number average molecular weight of from 5,000 to 60,000 daltons; and
(c) a performance additive package.

2. The method of claim 1 wherein at least 50% by weight of the oil of lubricating viscosity is a polyalkeneol.

3. The method of claim 1 wherein the lubricant composition is an automatic transmission fluid and the additive package comprises one or more of the following components: an ashless dispersant; an anti-wear agent; an anti-oxidant; a corrosion inhibitor; a friction modifier; a seal swell agent; an anti-foamant; and/or a viscosity modifier.

4. The method of claim 1 wherein \( D' \) has a number average molecular weight of from 20,000 to 60,000 daltons.

5. The method of claim 1 wherein \( D'' \) has a number average molecular weight of from 10,000 to 30,000 daltons.

6. The method of claim 1 wherein \( PA \) has a number average molecular weight of from 12,000 to 35,000 daltons.

7. The method of claim 1 wherein \( D' \) has a number average molecular weight of from 20,000 to 60,000 daltons; \( D'' \) has a number average molecular weight of from 10,000 to 50,000 daltons; and \( PA \) has a number average molecular weight of from 12,000 to 35,000 daltons.

8. The method of claim 1 wherein the ratio between the number average molecular weight of \( D' \) and the number average molecular weight of \( D'' \) is at least 1.4:1.

9. The method of claim 1 wherein the ratio between the number average molecular weight of \( PA \) and the number average molecular weight of \( D'' \) is at least 0.75:1.

10. The method of claim 1 wherein the polymer is a star polymer and \( n \) is, on average, from 4 to 25.

11. The method of claim 1 wherein the polymer is a star polymer having a total number average molecular weight of from 100,000 daltons to 1,000,000 daltons.

12. The method of claim 1 wherein the polymer is a linear polymer having a total number average molecular weight of from 40,000 daltons to 1,000,000 daltons.

13. A lubricant composition capable of enabling an automobile to exhibit improved fuel efficiency comprising:
   (a) an oil of lubricating viscosity;
   (b) a viscosity modifying polymer comprising linear polymers characterized by the formula:
   \[ D' \text{-PA-}D'' \]
and star polymers characterized by the formula:
\[ (D' \text{-PA-}D'') = X \]
wherein \( D' \) represents a block derived from diene; \( PA \) represents a block derived from mononalkenyl arene; \( D'' \) represents a block derived from diene; \( n \) represents the average number of arms per star polymer formed by the reaction of 2 or more moles of a polyalkenyl coupling agent per mole of arms; and \( X \) represents a nucleus of a polyalkenyl coupling agent;
wherein at least one of diene blocks \( D' \) and \( D'' \) is a copolymer block derived from mixed diene monomer, in which from 65 wt. % to 95 wt. % of the incorporated monomer units are from isoprene and from 5 wt. %, up to 35 wt. % of the incorporated monomer units are from butadiene, and wherein at least 80 wt. % of the butadiene is incorporated in a 1,4-configuration; and
wherein \( D' \) has a number average molecular weight of from 10,000 to 120,000 daltons; \( PA \) has a number average molecular weight of from 10,000 to 50,000 daltons; and \( D'' \) has a number average molecular weight of from 5,000 to 60,000 daltons; and
(c) a performance additive package.