

LUBRICATING OIL COMPOSITIONS AND METHODS FOR IMPROVING FUEL ECONOMY IN AN INTERNAL COMBUSTION ENGINE USING SAME

BACKGROUND OF THE INVENTION

5 1. Technical Field

The present invention relates generally to lubricating oil compositions and to methods for improving fuel economy in an internal combustion engine using same. More particularly, the present invention is directed to the use of an ashless friction modifier in lubricating oil compositions and methods to improve the fuel economy in an internal
10 combustion engine such as a gasoline or diesel internal combustion engine employing the lubricating oil compositions.

2. Description of Related Art

The viscosity grade of an engine oil is a key feature when selecting a lubricating oil. The lubricating oil is typically chosen according to both the climatic temperatures to
15 which the engine is exposed, and the temperatures and shear conditions under which the engine operates. Thus, the oil must be of sufficiently low viscosity at ambient temperatures to provide adequate lubrication upon cold starting of the engine, and capable of maintaining sufficient viscosity to lubricate the engine when it is under a full operating load.

20 The Society of Automotive Engineers classification system, SAE J300, defines engine oil grade viscosity specifications. Single grades are designated as SAE 20, 30, 40, 50, and 60 grade, and are defined by a low shear rate kinematic viscosity range at 100°C (ASTM D445), as well as a minimum high shear rate viscosity at 150°C (such as ASTM D4683, CEC L-36-A-90, or ASTM D5481). Engine oils designated as SAE 0W through

25W have been classified according to their low temperature cranking viscosities (ASTM D5293), low temperature pumping viscosities (ASTM4684), and a minimum kinematic viscosity at 100°C. Multigrade oils meet both the high and low temperature viscosity requirements indicated in their nomenclature. For example, an engine oil designated as

5 SAE 5W-30 possesses the viscometric characteristics of SAE 30 motor oils as well as the low temperature viscometric qualities of SAE 5W.

A lubricating oil should be chosen with the appropriate high temperature kinematic and high shear rate viscosities for a given engine type and operating conditions in an effort to prevent the engine wear and oil consumption that can be associated with

10 inadequate boundary layer lubrication and oil thinning, respectively. Similarly, to afford low temperature engine protection, the maximum low temperature cranking and pumping viscosities of the lubricant should match the requirements imposed by the environment in which the engine will be operated. The maximum low temperature viscosity limits of a given oil grade are intended to define the oil's ability to facilitate engine starting in cold

15 weather, and to ensure the ready flow of cold oil to the oil pump, thereby minimizing the potential of engine damage due to insufficient lubrication.

In addition to selecting the appropriate multigrade oil, it is also necessary for the internal combustion engine to have its oil changed periodically in order to maintain the efficiency and mechanical integrity of the engine. However, it is common for oil change

20 intervals to lag behind other service intervals since consumers can view oil changes as one of the more inconvenient and, in some cases, costly regular maintenance aspects of vehicle ownership. Typically, recommended oil service intervals have been extended with the introduction of higher quality base stocks and better lubricant additive packages.

Yet regular oil changes still tend to lag behind other maintenance items such as, for example, air filter replacement, brake replacement, etc. The problem therefore is to further improve the lubricant technology in order to help counteract the impact of this vehicle maintenance problem.

5 There has also been an increasing concern in recent years to improve the fuel economy performance of an internal combustion engine, particularly that of passenger car engines and diesel fuel engines. The viscosity of the engine oil is one factor that influences fuel economy. The lower the oil's viscosity, the lower the viscous drag on the engine and hence the better the fuel economy performance. However, the lower viscosity
10 grade oils must still provide adequate lubrication to protect the engine.

A variety of compounds have been proposed as additives for lubricating oils to enhance the ability of the oils to, for example, disperse contaminants, resist oxidation, and reduce friction which, in turn, assist in increasing the fuel economy of the engine. For example, oil soluble molybdenum compounds such as, for example, molybdenum
15 dithiocarbamate, have been found to be useful as friction modifying additives in lubricants. This class of molybdenum compounds can provide enhanced fuel economy by reducing friction in internal combustion engines, but their long term friction reduction benefit during the service interval may be compromised given their efficacy as lubricant antioxidants.

20 One problem associated with the use of molybdenum compounds is that they serve as antioxidants when added to the engine. It is well known that lubricating oils are partially oxidized when contacted with oxygen at elevated temperatures for long periods. The oxidation in motor oils is particularly acute in the modern internal combustion

engine that is designed to operate under heavy workloads and at elevated temperatures. Accordingly, as the lubricating oil undergoes oxidation the molybdenum compounds will, in turn, be consumed as an antioxidant thus limiting their use as a friction modifier in the engine.

5 It is believed by applicants that 0.8 weight percent of a friction modifier based on the reaction product of coconut oil and diethanolamine has been sold commercially in a SAE 10W-30 engine oil composition having a typical kinematic viscosity of 11 centiStoke (cSt) at 100°C. However, the use of a high viscosity engine oil with a low amount of friction modifier limits the fuel economy benefit and low temperature
10 properties of the composition.

It would therefore be desirable to provide a lubricating oil composition which provides significantly improved fuel economy and wear protection, which results in a reduction in emissions.

15 SUMMARY OF THE INVENTION

Disclosed are lubricating oil compositions and methods for improving the fuel economy of an internal combustion engine employing the lubricating oil compositions. Thus, in accordance with a first aspect there is provided, a

lubricating oil composition is provided which comprises (a) an oil of lubricating viscosity
20 having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and (b) a friction modifying effective amount of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

In a second aspect, there is provided a method for improving the fuel economy of an internal combustion engine which comprises operating the engine with a lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity in the range of about 2 to 10.5 cSt at 100°C and (b) a friction modifying effective amount of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

In a third aspect, there is provided a lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and comprising about 55 to about 85 weight percent of a first lubricating oil, and about 15 to about 45 weight percent of a second lubricating oil wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C; and (b) about 0.5 to about 5.0 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

In a fourth aspect, there is provided a lubricating oil composition comprising (a) an oil of lubricating viscosity comprising a first lubricating oil selected from the group consisting of a SAE 10W multigrade oil, a SAE 15W multigrade oil and mixtures thereof and a second lubricating oil selected from the group consisting of a SAE 0W multigrade oil, a SAE 5W multigrade oil and mixtures thereof and (b) 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

In a fifth aspect, there is provided a method of improving the fuel economy of an internal combustion engine which comprises operating the engine with the lubricating oil composition as defined above.

Disclosed is a lubricating oil composition comprising:

(a) an oil of lubricating viscosity having a kinematic viscosity of about 2 to 10.5 cSt at 100°C comprising:

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(i) a first lubricating oil comprising an oil of lubricating viscosity having a kinematic viscosity of 9.3 to about 16.3 cSt at a temperature of 100°C; and,

(ii) a second lubricating oil comprising an oil of lubricating viscosity having a kinematic viscosity in the range of about 2 to less than or equal to 9.3 cSt at a

temperature of 100°C, wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C; and,

(b) a friction modifying effective amount of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

5 A preferred alternative embodiment of the present invention is a lubricating oil composition comprising (a) an oil of lubricating viscosity and (b) 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

10 A particularly preferred alternative embodiment of the present invention is a lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and (b) 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an
15 alkanolamine.

Methods for improving the fuel economy of an internal combustion engine which comprises operating the engine with the foregoing alternative lubricating oil composition are also provided.

All kinematic viscosity measurements herein at a temperature of 100°C are made
20 with ASTM standard ASTM D445.

The term "glyceride" as used herein refers to glycerides that are derived from natural, i.e., animal or plant, sources, and to glycerides that are synthetically produced. Glycerides are esters of glycerol (a trihydric alcohol) and fatty acids in which one or

more of the hydroxyl groups of glycerol are esterified with the carboxyl groups of fatty acids containing from about 4 to about 75 carbon atoms and preferably from about 6 to about 24 carbon atoms. The fatty acids can be saturated or unsaturated, linear, branched or cyclic monocarboxylic acids. Where three hydroxyl groups are esterified, the resulting
5 glyceride is denoted a "triglyceride". When only one or two of the hydroxyl groups are esterified, the resulting products are denoted "monoglycerides" and "diglycerides", respectively. Natural glycerides are mixed glycerides comprising triglycerides and minor amounts, e.g., from about 0.1 to about 40 mole percent, of mono- and diglycerides. Natural glycerides include, e.g., coconut and soybean oils. Synthetically produced
10 glycerides are synthesized by the condensation reaction between glycerol and a fatty acid or mixture of fatty acids containing from about 6 to about 24 carbon atoms. The fatty acid can be a saturated or unsaturated, linear, branched or cyclic monocarboxylic acid or mixture thereof. The fatty acid itself can be derived from natural, i.e., plant or animal, sources. Examples include, but are not limited to, caproic, caprylic, capric, lauric,
15 myristic, palmitic, stearic, arachidic, oleic, linoleic and linolenic acids, and mixtures of any of the foregoing. The synthetically produced glycerides will contain from about 80 to about 100 mole percent triglycerides with the balance, if any, representing from about 0 to about 20 mole percent mono and di-glycerides, present in admixture with triglycerides.

20 Among other factors, the present invention is based on the unexpected and surprising discovery that the fuel economy of an internal combustion engine in addition to wear protection at low temperatures is improved while also reducing emissions when employing the foregoing lubricating oil compositions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graphical representation of the speed vs. time of an EPA-75 Test Cycle.

Figure 2 is a graphical representation of the speed vs. time of an EPA Highway Fuel Economy Driving Schedule.

Figure 3 is a diagram of the experimental setup for the High Frequency Reciprocating Rig (HFRR) Test.

Figure 4 is a graphical representation of the results of the HFRR test for the lubricating oil compositions of Examples 2 and 4 and Comparative Examples B and C.

Figure 5a is a graphical representation of low temperature operability for the cold starting cranking test (ASTM D5293) for the lubricating oil composition of Example 2 versus a SAE 10W-30 grade oil of Comparative Example C.

Figure 5b is a graphical representation of low temperature operability for the cold starting pumpability test (ASTM D4684) for the lubricating oil composition of Example 2 versus a SAE 10W-30 grade oil of Comparative Example C.

DETAILED DESCRIPTION OF THE INVENTION

In a first embodiment of the present invention, a lubricating oil composition is provided which comprises (a) an oil of lubricating viscosity having a kinematic viscosity in the range of about 2 to 10.5 cSt and preferably from about 2 to less than 10 cSt and most preferably from about 3.8 to less than or equal to 9.3 cSt at 100°C and (b) a friction modifying effective amount of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

In formulating the lubricating oil composition of the first embodiment, any suitable oil may be used provided it meets the requirements of having a kinematic viscosity in the range of about 2 to 10.5 cSt and preferably from about 2 to less than 10 cSt and most preferably from about 3.8 to less than or equal to 9.3 cSt at 100°C. In
5 practice, this means that the oil is selected from one or more natural oils, synthetic oils or mixtures thereof which meets the foregoing kinematic viscosity requirements at 100°C. Useful natural oils include mineral lubricating oils such as, for example, liquid petroleum oils, solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types, oils derived from coal or shale, animal oils,
10 vegetable oils (e.g., castor oils and lard oil), and the like.

Useful synthetic lubricating oils include, but are not limited to, hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins, e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes), and the like and
15 mixtures thereof; alkylbenzenes such as dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)-benzenes, and the like; polyphenyls such as biphenyls, terphenyls, alkylated polyphenyls, and the like; alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivative, analogs and homologs thereof and the like.

Other useful synthetic lubricating oils include, but are not limited to, oils made by
20 polymerizing olefins of less than 5 carbon atoms such as ethylene, propylene, butylenes, isobutene, pentene, and mixtures thereof. Methods of preparing such polymer oils are well known to those skilled in the art.

Additional useful synthetic hydrocarbon oils include liquid polymers of alpha olefins having the proper viscosity. Especially useful synthetic hydrocarbon oils are the hydrogenated liquid oligomers of C_6 to C_{12} alpha olefins such as, for example, 1-decene trimer.

5 Another class of useful synthetic lubricating oils include, but are not limited to, alkylene oxide polymers, i.e., homopolymers, interpolymers, and derivatives thereof where the terminal hydroxyl groups have been modified by, for example, esterification or etherification. These oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and amyl ethers of these polyoxyalkylene
10 polymers (e.g., methyl poly propylene glycol ether having an average molecular weight of 1,000, diphenyl ether of polyethylene glycol having a molecular weight of 500-1000, diethyl ether of polypropylene glycol having a molecular weight of 1,000-1,500, etc.) or mono- and polycarboxylic esters thereof such as, for example, the acetic esters, mixed C_3 - C_8 fatty acid esters, or the C_{13} Oxo acid diester of tetraethylene glycol.

15 Yet another class of useful synthetic lubricating oils include, but are not limited to, the esters of dicarboxylic acids e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acids, alkyl malonic acids, alkenyl malonic acids, etc., with a variety of alcohols, e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol,
20 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc. Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl-phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, the

complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

Esters useful as synthetic oils also include, but are not limited to, those made from monocarboxylic acids having from about 5 to about 12 carbon atoms and polyols and
5 polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, and the like.

Silicon-based oils such as, for example, polyalkyl-, polyaryl-, polyalkoxy- or polyaryloxy-siloxane oils and silicate oils, comprise another useful class of synthetic lubricating oils. Specific examples of these include, but are not limited to, tetraethyl
10 silicate, tetra-isopropyl silicate, tetra-(2-ethylhexyl) silicate, tetra-(4-methylhexyl)silicate, tetra-(p-tert-butylphenyl)silicate, hexyl-(4-methyl-2-pentoxo)disiloxane, poly(methyl)siloxanes, poly(methylphenyl)siloxanes, and the like. Still yet other useful synthetic lubricating oils include, but are not limited to, liquid esters of phosphorous containing acids, e.g., tricresyl phosphate, trioctyl phosphate, diethyl ester of decane
15 phosphonic acid, etc., polymeric tetrahydrofurans and the like.

The lubricating oil may be derived from unrefined, refined and rerefined oils, either natural, synthetic or mixtures of two or more of any of these of the type disclosed hereinabove. Unrefined oils are those obtained directly from a natural or synthetic source (e.g., coal, shale, or tar sands bitumen) without further purification or treatment.

20 Examples of unrefined oils include, but are not limited to, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from distillation or an ester oil obtained directly from an esterification process, each of which is then used without further treatment. Refined oils are similar to the unrefined oils except they have been

further treated in one or more purification steps to improve one or more properties.

These purification techniques are known to those of skill in the art and include, for example, solvent extractions, secondary distillation, acid or base extraction, filtration, percolation, hydrotreating, dewaxing, etc. Rerefined oils are obtained by treating used
5 oils in processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

Lubricating oil base stocks derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base
10 stocks. Such wax isomerase oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

Natural waxes are typically the slack waxes recovered by the solvent dewaxing of mineral oils; synthetic waxes are typically the wax produced by the Fischer-Tropsch process.

15 The ashless friction modifier for use in the foregoing lubricating oil composition of the present invention comprises a reaction product of an about C_4 to about C_{75} and preferably about C_6 to about C_{24} fatty acid ester, and an alkanolamine.

The fatty acid ester for use in forming the reaction product herein can be, for example, glycerol fatty acid esters, i.e., glycerides derived from natural sources such as,
20 for example, beef tallow oil, lard oil, palm oil, castor oil, cottonseed oil, corn oil, peanut oil, soybean oil, sunflower oil, olive oil, whale oil, menhaden oil, sardine oil, coconut oil, palm kernel oil, babassu oil, rape oil, soya oil and the like with coconut oil being preferred for use herein.

The glycerol fatty acid esters will contain from about C₄ to about C₇₅ and preferably contain about C₆ to about C₂₄ fatty acid esters, i.e., several fatty acid moieties, the number and type varying with the source of the oil. Fatty acids are a class of compounds containing a long hydrocarbon chain and a terminal carboxylate group and are characterized as unsaturated or saturated depending upon whether a double bond is present in the hydrocarbon chain. Therefore, an unsaturated fatty acid has at least one double bond in its hydrocarbon chain whereas a saturated fatty acid has no double bonds in its fatty acid chain. Preferably, the acid is saturated. Examples of unsaturated fatty acids include, myristoleic acid, palmitoleic acid, oleic acid, linolenic acid, and the like.

10 Examples of saturated fatty acids include caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, behenic acid, lignoceric acid, and the like.

The acid moiety may be supplied in a fully esterified compound or one which is less than fully esterified, e.g., glyceryl tri-stearate, or glyceryl di-laurate and glyceryl mono-oleate, respectively. Esters of polyols including diols and polyalkylene glycols can also be employed such as, for example, esters of mannitol, sorbitol, pentaerythrol, polyoxyethylene polyol and the like.

The alkanolamine employed in the reaction product herein can be, for example, a primary or secondary amine which possesses at least one hydroxy group. The expression "alkanolamine" is used in its broadest sense to include compounds containing at least one primary or secondary amine and at least one hydroxy group, e.g., monoalkanolamines, dialkanolamines, and so forth. It is believed that any alkanolamine can be used, although preferred alkanolamines are lower alkanolamines, generally having from about two to

about 6 carbon atoms. The alkanolamine can possess O or N functionality in addition to one amino group (that group being a primary or secondary amino group) and at least one hydroxy group. The alkanolamine preferably possesses the general formula



- 5 wherein R is hydrogen or an aminoalkyl group with the alkyl having from one to about six carbon atoms, R' is a lower hydrocarbyl generally having from about two to about six carbon atoms and "a" is 0 or 1. Suitable alkanolamines include, but are not limited to, monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, di-isopropanolamine, butanolamine, aminoethylaminoethanol such as
- 10 2-(2-aminoethylamino) ethanol. Mixtures of two or more alkanolamines can be employed. Diethanolamine is highly preferred for use in accordance with the practice of the present invention.

The reaction may be effected by heating the fatty acid ester and alkanolamine in equivalent quantities to produce the desired product and then added to the oil component.

- 15 Alternatively, the reaction can be effected by heating the fatty acid ester and alkanolamine in the presence of one or more of the aforementioned lubricating oils. The reaction may typically be effected by maintaining the reactants at a temperature of from about 100°C to 200°C, and preferably from about 120°C to about 150°C for about 1 to about 10 hours, and preferably about 4 hours. The reaction can be solventless or carried
- 20 out in a solvent, preferably one which is compatible with the ultimate composition in which the product is to be used. Particularly useful solvents include at least aromatic solvents such as, for example, Aromatic-100, Aromatic-150, Shellsolv AB, Avjet, toluene, xylene, and mixtures thereof.

Typical reaction products which may be employed in the practice of this invention may include those formed from esters having, for example, the following acid moieties and alkanolamines:

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TABLE I

<u>Acid Moiety in Ester</u>	<u>Amine</u>
Lauric Acid	Propanolamine
Lauric Acid	Diethanolamine
Lauric Acid	Ethanolamine
Lauric Acid	Dipropanolamine
Palmitic Acid	Diethanolamine
Palmitic Acid	Ethanolamine
Stearic Acid	Diethanolamine
Stearic Acid	Ethanolamine

Other useful mixed reaction products with alkanolamines may be formed from the acid component of the following oils: coconut, babassu, palm kernel, palm, olive, castor, peanut, rape, beef tallow, lard, whale blubber, corn, tall, cottonseed, etc.

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In one preferred aspect of this invention, the desired reaction product may be prepared by the reaction of (i) a fatty acid ester of a polyhydroxy compound (wherein some or all of the OH groups are esterified) and (ii) diethanolamine.

The preferred fatty acid ester is coconut oil which contains the following acid moieties:

15

TABLE II

<u>Fatty Acid Moiety</u>	<u>Weight Percent</u>
Caprylic	8.0
Capric	7.0
Lauric	48.0
Myristic	17.5
Palmitic	8.2
Stearic	2.0
Oleic	6.0
Linoleic	2.5

Representative of the preparation of the reaction product from fatty acid esters and alkanolamines is the preparation disclosed in Schlict et al. U.S. Patent No. 4,729,769, the contents of which are incorporated herein by reference.

It will be readily understood and appreciated by those skilled in the art that the reaction product constitutes a complex mixture of compounds including at least fatty amides, fatty acid esters, fatty acid ester-amides, unreacted starting reactants, free fatty acids, amines, glycerol, and partial fatty acid esters of glycerol (i.e., mono- and di-glycerides). For example, fatty amides are formed when the amine group of the alkanolamine reacts with the carboxyl group of a fatty acid while fatty acid esters are formed when one or more hydroxyl groups of the alkanolamine react with the carboxyl group of a fatty acid. Fatty acid ester-amides are formed when both the amine and hydroxyl group of alkanolamine react with carboxyl groups of fatty acids. In general, a representation of the various amounts of the various compounds constituting the complex mixture of the reaction product is as follows: about 5-65 mole % of fatty amide, about 3-

30 mole % fatty acid ester, about 5-65 mole % fatty acid ester-amide, about 0.1-50 mole % partial fatty acid ester, about 0.1-30 mole % glycerol, about 0.1-30 mole % free fatty acids, about 0.1-30 mole % charge alkanolamine, about 0.1-30 mole % charge glycerides, etc. It is not necessary to isolate one or more specific components of the product mixture.

- 5 Indeed, the reaction product mixture is preferably employed as is in the additive composition of this invention.

The foregoing ashless friction modifiers can be utilized in the lubricating oil compositions of the present invention in effective amounts which impart significant friction modifying credit characteristics to the oils. Accordingly, concentration of
10 additive ordinarily ranging from about 0.5 to about 5.0 weight percent and preferably from 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, can be used herein.

An alternative embodiment of the present invention is a lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity in
15 the range of about 2 to 10.5 cSt and preferably from about 2 to less than 10 cSt and most preferably from about 3.8 to less than or equal to 9.3 cSt at 100°C and comprising from about 55 to about 85 weight percent of a first lubricating oil, and about 15 to about 45 weight percent of a second lubricating oil wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C;
20 and (b) from about 0.5 to about 5 weight percent and preferably from 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of the foregoing ashless friction modifier.

The first and second lubricating oils of the alternative embodiment can be any of the aforementioned natural oils, synthetic oils or mixtures thereof, provided that the resulting oil of lubricating viscosity has a kinematic viscosity in the range of about 2 to 10.5 cSt, preferably from about 2 to less than 10.0 cSt and most preferably from about 3.8 to less than or equal to 9.3 cSt at 100°C as well as the requirement that the second lubricating oil has a lower kinematic viscosity at 100°C than the kinematic viscosity at 100°C of the first lubricating oil. In general, the first lubricating oil will be an oil of lubricating viscosity having a kinematic viscosity of at least 9.3 cSt at 100°C, preferably from 9.3 to about 16.3 cSt and most preferably from 9.3 to about 12.5 cSt at a temperature of 100°C. Accordingly, the first lubricating oil can be any of the aforementioned natural oils, synthetic oils or mixtures thereof, provided it meets the foregoing kinematic viscosity requirements at 100°C. It is particularly advantageous that the first lubricating oil is selected so that the oil meets the requirements of a SAE 10W, SAE 15W, SAE 20W, SAE 25W and SAE 40W grades (e.g., SAE 10W, SAE 10W-20, SAE 10W-30, SAE 10W-40 and/or SAE 10W-50 and/or SAE 15W, SAE 15W-20, SAE 15W-30, SAE 15W-40 and/or SAE 15W-50) and the like and mixtures thereof. Preferably, the first lubricating oil is selected so that the oil meets the requirements of the SAE 10W and/or SAE 15W grades with a SAE 10W-30 being most preferred.

The second lubricating oil of the alternative embodiment can be an oil of lubricating viscosity having a kinematic viscosity of from about 2 cSt to less than or equal to 9.3 cSt, preferably from about 2 to less than 9.3 cSt and most preferably from about 5.6 to less than 9.3 cSt at 100°C. Accordingly, the second lubricating oil can be any of the aforementioned natural oils, synthetic oils or mixtures thereof, provided it

meets the foregoing kinematic viscosity requirements at 100°C. Preferably the second lubricating oil is selected so that the oil meets the requirements of the SAE 0W or SAE 5W grades (e.g., SAE 0W, SAE 0W-20, SAE 0W-30, SAE 0W-40, SAE 0W-50 and/or SAE 0W-60, and/or SAE 5W, SAE 5W-20, SAE 5W-30, SAE 5W-40, SAE 5W-50 and/or SAE 5W-60) or mixtures thereof with a SAE 5W-20 being most preferred.

The foregoing alternative lubricating oil composition can be formed by adding the first lubricating oil, second lubricating oil and the foregoing ashless friction modifier either sequentially or simultaneously. Preferably, the alternative lubricating oil composition is formed by first mixing the foregoing ashless friction modifier in an effective amount ranging from about 1.5 to about 15 weight percent and preferably from 4 to about 12.5 weight percent, based on the total weight of the mixture with the second lubricating oil and then adding the mixture to the first lubricating oil composition.

Yet another alternative embodiment of the present invention is a lubricating oil composition comprising (a) an oil of lubricating viscosity and (b) from 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of the foregoing ashless friction modifier. The oil of lubricating viscosity can be any of the aforementioned natural oils, synthetic oils or mixtures thereof.

If desired, all of the lubricating oil compositions disclosed herein can be admixed with other conventional additives to enhance performance. For example, the lubricating oil compositions can be blended with metal detergents, antioxidants, anti-wear agents, rust inhibitors, dehazers, demulsifiers, metal deactivators, viscosity index improvers, pour point depressants, antifoaming agents, co-solvents, package compatibilisers, deodorants and metallic-based additives such as metallic combustion improvers, anti-knock

compounds, anti-icing additives, corrosion-inhibitors, dyes, and the like, at the usual levels in accordance with well known practice. The following non-limiting examples are of some of the additives that can be favorably employed in the lubricating oil compositions of the present invention.

- 5 1. Metal detergents: sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl aromatic sulfonates, sulfurized or unsulfurized metal salts of multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl naphthenates, metal salts of alkanolic acids, metal salts of an alkyl or alkenyl multiacid, and chemical and physical mixtures thereof.
- 10 2. Antioxidants: Antioxidants reduce the tendency of mineral oils to deteriorate in service which deterioration is evidenced by the products of oxidation such as sludge and varnish-like deposits on the metal surfaces and by an increase in viscosity. Examples of anti-oxidants useful in the present invention include, but are not limited to, phenol type (phenolic) oxidation inhibitors, such as 4,4'-methylene-bis(2,6-di-tert-butylphenol), 4,4'-
15 bis(2,6-di-tert-butylphenol), 4,4'-bis(2-methyl-6-tert-butylphenol), 2,2'-methylene-bis(4-methyl-6-tert-butyl-phenol), 4,4'-butylidene-bis(3-methyl-6-tert-butylphenol), 4,4'-isopropylidene-bis(2,6-di-tert-butylphenol), 2,2'-methylene-bis(4-methyl-6-nonylphenol), 2,2'-isobutylidene-bis(4,6-dimethylphenol), 2,2'-methylene-bis(4-methyl-6-cyclohexylphenol), 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,4-
20 dimethyl-6-tert-butyl-phenol, 2,6-di-tert-I-dimethylamino-p-cresol, 2,6-di-tert-4-(N,N'-dimethylaminomethylphenol), 4,4'-thiobis(2-methyl-6-tert-butylphenol), 2,2'-thiobis(4-methyl-6-tert-butylphenol), bis(3-methyl-4-hydroxy-5-tert-butylbenzyl)-sulfide, and bis(3,5-di-tert-butyl-4-hydroxybenzyl). Other types of oxidation inhibitors

include metal dithiocarbamate (e.g., zinc dithiocarbamate), and methylenebis(dibutyldithiocarbamate).

3. Anti-wear agents: As their name implies, these agents reduce wear of moving metallic parts. Examples of such agents include, but are not limited to, phosphates, phosphites, carbamates, esters, sulfur containing compounds, and molybdenum complexes.

4. Rust inhibitors (Anti-rust agents)

a) Nonionic polyoxyethylene surface active agents: polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonyl phenyl ether, polyoxyethylene octyl phenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol mono-oleate, and polyethylene glycol mono-oleate.

b) Other compounds: stearic acid and other fatty acids, dicarboxylic acids, metal soaps, fatty acid amine salts, metal salts of heavy sulfonic acid, partial carboxylic acid ester of polyhydric alcohol, and phosphoric ester.

5. Demulsifiers: addition product of alkylphenol and ethylene oxide, polyoxyethylene alkyl ether, and polyoxyethylene sorbitan ester.

6. Extreme pressure agents (EP agents): zinc dialkyldithiophosphate (primary alkyl, secondary alkyl, and aryl type), sulfurized oils, diphenyl sulfide, methyl trichlorostearate, chlorinated naphthalene, fluoroalkylpolysiloxane, and lead naphthenate.

7. Friction modifiers: fatty alcohol, fatty acid, amine, borated ester, and other esters.

8. Multifunctional additives: sulfurized oxymolybdenum dithiocarbamate, sulfurized oxymolybdenum organo phosphorodithioate, oxymolybdenum monoglyceride, oxymolybdenum diethylate amide, amine-molybdenum complex compound, and sulfur-containing molybdenum complex compound.

5 9. Viscosity index improvers: polymethacrylate type polymers, ethylene-propylene copolymers, styrene-isoprene copolymers, hydrated styrene-isoprene copolymers, polyisobutylene, and dispersant type viscosity index improvers.

10. Pour point depressants: polymethyl methacrylate.

11. Foam inhibitors: alkyl methacrylate polymers and dimethyl silicone
10 polymers.

The lubricating oil compositions of the present invention are particularly useful when added to an internal combustion engine including both gasoline engines, e.g., spark-ignition engines, and diesel engines, e.g., compression-ignition engines, for lubricating the engine, e.g., the high wear areas of the engine such as, for example, wear
15 interfaces or contacts of such as, for example, piston rings/cylinder liner region, valve train components such as cam lobes, tappets, followers, valve tips, rocker arms, rocker arm mechanisms, and the like. However, it will be understood that the lubricating oil compositions containing the ashless friction modifier of this invention can be used to operate a variety of engines and in any other application where lubrication is needed,
20 provided it meets the requirements of that application.

The following non-limiting examples are illustrative of the present invention.

Experimental Section

I. Preparation of Ashless Friction Modifier

Example 1

Crude coconut oil (525.6 g – 0.8 moles) was heated to about 60°C. Diethanolamine (151.2 g – 1.44 moles) was added with stirring. The mixture was then heated under nitrogen to 120°C and held at 120°C for 4 hours and polish-filtered at 100–120°C. The product was quantitatively isolated as a yellow semi-solid containing a nitrogen content of 2.9% and base number TBN target of 9.

II. Preparation of Lubricating Oil Compositions

Example 2

15 A mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C was formed. Next, a lubricating oil composition was prepared containing 25% by volume of the above mixture and 75 % by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 11.25 cSt at 100°C. The kinematic viscosity of the resulting lubricating oil composition at 100°C was 10.27 cSt.

Example 3

A mixture of 12% by weight of the ashless friction modifier of Example 1 with 88% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C was formed. Next, a lubricating oil composition was prepared containing 25%
5 by volume of the above mixture and 75% by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 11.25 at 100°C. The kinematic viscosity of the resulting lubricating oil composition at 100°C was 10.38 cSt.

Example 4

10 A mixture of 1% by weight of the ashless friction modifier of Example 1 with 99% by weight of the SAE 10W-30 API SL motor oil of Example 2 having a kinematic viscosity of 11.25 cSt at 100°C was formed.

Example 5

15 A mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C was formed. Next, a lubricating oil composition was prepared containing 25% by volume of the above mixture and 75 % by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity at 100°C of 10.41 cSt. The kinematic viscosity of the
20 resulting lubricating oil composition at 100°C was 9.73 cSt.

Example 6

A mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C was formed. Next, a lubricating oil composition was prepared containing 25%
5 by volume of the above mixture and 75 % by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 10.33 cSt at 100°C. The kinematic viscosity of the resulting lubricating oil composition at 100°C was 9.75 cSt.

Example 7

10 A mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C was formed. Next, a lubricating oil composition was prepared containing 25%
by volume of the above mixture and 75 % by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 10.77 cSt at 100°C. The kinematic viscosity of the
15 resulting lubricating oil composition at 100°C was 10.01 cSt.

Comparative Example A

A mixture of 4% by weight of Molybdenum Dithiocarbamate (MoDTC) with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt
20 at 100°C was formed. Next, a lubricating oil composition was prepared containing 25% by volume of the above mixture and 75% by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 11.23 cSt at 100°C. The kinematic viscosity of the resulting lubricating oil composition at 100°C was 10.21 cSt.

Comparative Example B

A lubricating oil mixture was formed containing 25% by volume of SAE 5W-20 API SL motor oil having a kinematic viscosity of 8.8 cSt at 100°C and 75% by volume of SAE 10W-30 API SL motor oil having a kinematic viscosity of 11.25 cSt at 100°C, and no friction modifier. The kinematic viscosity of the resulting lubricating oil composition at 100°C was 10.29 cSt.

Comparative Example C

A lubricating oil was prepared containing the SAE 10W-30 API SL motor oil of Example 2 having a kinematic viscosity of 11.25 cSt at 100°C, and no friction modifier.

III. Vehicle Fuel Economy Test

The vehicle fuel economy test was conducted to evaluate the fuel economy performance of lubricating oil compositions within the scope of the present invention versus lubricating oil compositions outside the scope of this invention. Vehicles representative of those found in the U.S. market were run on a chassis dynamometer using the EPA-75 cold start test cycle and the Highway Fuel Economy Test (HWFET) cycle testing protocols. Emissions were measured and fuel economy calculated for each vehicle using the carbon balance method as prescribed by the Federal Test Procedure set forth at the web sites <http://www.epa.gov/otaq/mpg.htm> and <http://www.epa.gov/otaq/mpg/40p0600.pdf>.

The testing vehicles used in the examples consisted of vehicles manufactured from two different car manufacturers from North America set forth below in Table III.

TABLE III

Make	Model	Year	Engine
Toyota	Camry	1997	2.2L I-4
Chevrolet	Impala	2001	3.4L V-6

5 Prior to being used for testing, each vehicle had to be prepared to nullify the possible confounding effects of any friction modifier additive that may have been present in the vehicle's previous oil charges. To accomplish this, a series of oil flushes were performed using a high detergent diesel oil formulation. The final oil charge for each
10 vehicle before testing was with a commonly used viscosity grade, SAE 10W-30. The oil was conditioned by driving the test vehicle for a minimum of 50 miles.

The EPA-75 test (cold engine start) and the HWFET test (normal operating temperature) were used to evaluate all vehicles for this program. These tests are described in the Code of Federal Regulations (CFR), Title 40. The test cycles were used
15 to define the city (EPA-75) and highway fuel economy used for new vehicle fuel economy certification. The EPA-75 test cycle consisted of about 11.1 miles of driving at an average speed of about 21.3 mph and a maximum speed of about 56.7 mph as depicted graphically in Figure 1. The HWFET test cycle consisted of about 10.2 miles of driving at an average speed of about 48.1 mph and a maximum speed of about 60 mph as
20 depicted graphically in Figure 2.

Testing was performed on a Clayton chassis dynamometer in conjunction with a Horiba emissions bench utilizing a constant volume sampling (CVS) unit. Fuel economy was calculated via emissions analysis using the carbon balance methods outlined in the

CFR as discussed above. Before taking emissions data on the vehicles, the engines were run for one hour at 50 mph to allow the oil and transmission fluid temperatures to stabilize. In addition, the hood was lowered and the external cooling fan was adjusted in order to control the oil temperature at or near 245°F. Once a vehicle was fully warmed up, the evaluation sequence began.

Two testing protocols were applied. A one day "HWFET only" program consisted of eight HWFETs using the vehicle's normal oil charge followed by four HWFETs in which the oil charge contained the respective lubricating oil composition of Examples 2 and 3 and the lubricating oil compositions of Comparative Examples A and B. The second protocol was a three day evaluation that consisted of an EPA-75 with eight HWFETs conducted each of the three days.

The immediate fuel economy improvements for the one day program were calculated from the average fuel economy (MPG) of the first eight HWFETs with the initial oil charge relative to the average fuel economy of the last four HWFETs in which the oil charge contained the respective lubricating oil composition of Examples 2 and 3 and the lubricating oil compositions of Comparative Examples A and B. The three day evaluation was used to determine immediate cold start fuel economy and immediate highway fuel economy.

The procedure was otherwise designed using standard engineering practices to minimize variability and provide a true measure of the effect on fuel economy using the oil composition of the present invention. Important features of this testing procedure included minimizing engine restarts, ensuring that the vehicle was adequately prepared

prior to running evaluations, performing the complete fuel economy test in one single event, and multiple oil flushes.

IV. Vehicle Fuel Economy Test Results

- 5 Fuel economy test results for the respective lubricating oil compositions of Examples 2 and 3 and the lubricating oil compositions of Comparative Examples A and B are set forth below in Table IV. While the vehicle test program was intended to minimize experimental degrees of freedom, the observed variation in performance data may reflect test reproducibility/repeatability as well as differences in engine response
- 10 sensitivity to the invention.

TABLE IV

<u>Vehicle Number</u>	<u>Sample</u>	<u>HWFET (Avg.)</u>	<u>EPA-75 Cold Start</u>
Toyota Camry T81	Comp. Ex. A	2.05%	Not Conducted
Toyota Camry T82	Comp. Ex. A	2.32%	Not Conducted
Toyota Camry T81	Example 2	2.05%	Not Conducted
Toyota Camry T82	Example 2	0.96%	Not Conducted
Toyota Camry T81	Comp. Ex. B	0.24%	Not Conducted
Toyota Camry T82	Comp. Ex. B	0.64%	Not Conducted
Toyota Camry T82	Example 3	2.74%	2.82%
Chevy Impala L55	Example 3	3.37% ^a	No Change
Toyota Camry T82	Example 3	1.71%	0.83%

^a Instantaneous within day 2.

- As these data demonstrate, the respective lubricating oil compositions of
- 15 Examples 2 and 3 (within the scope of this invention) provided significantly improved fuel economy benefits over the lubricating oil composition of Comparative Example B which contained only a mixture of a SAE 10W-30 and SAE 5W-20 oil with no additional ashless friction modifier.

V. Bench Friction Test

Although known as a diesel fuel lubricity test, the High Frequency Reciprocating Rig (HFRR) testing method may be used to evaluate the friction modifying characteristics and anti-wear capability of new and used lubricants by modifying the operating conditions of the testing method. As shown in Figure 3, the HFRR testing method used herein consisted of a flat steel disc immersed in a bath of the test fluid. A load was applied to a 6 mm steel ball that oscillated across the steel disc at a selected frequency for a specified test time. The friction coefficient was monitored during the course of test. It is to be understood that the standard deviation of the friction coefficient results in the Bench Friction Test equals 0.0187. Examples have been assessed with the modifications of this bench technique described below.

Bench Test Details

HFRR wear test conditions were chosen in order to enhance friction modifying performance discrimination. Lubricant test samples were blended with 50% by volume ISOPAR M (a reference HFRR solvent). The load was set at 600 grams. The stroke length was 2000 microns and the frequency was 50 Hertz. The test was conducted at 60°C for 3 hours. The friction coefficients were obtained for the respective lubricating oil compositions of Examples 2 and 4 and the respective lubricating oil compositions of Comparative Examples B and C and are shown in Figure 4. According to these results, the friction modifying capability of the oil compositions of Examples 2 and 4 versus Comparative Examples B and C, respectively, were significantly improved.

VI. Low Temperature Operability Improvement

The low temperature operability of the lubricating oil composition of Example 2 compared to a SAE 10W-30 API SL motor oil having a kinematic viscosity of 11.25 cSt at 100°C (Comparative Example C) was measured using the industry standard test methods described in ASTM D5293 (Cold Cranking Simulator) and ASTM D4684 (Mini Rotary Viscometer). As depicted in Figures 5a and 5b, the low temperature properties of the lubricating oil composition of Example 2, relative to the SAE 10W-30 alone, was significantly improved.

VII. Vehicle Acceleration And Power Tests

Acceleration and power measurements were obtained for the lubricating oil composition of Example 2 versus the lubricating oil composition of Comparative Example C using a chassis dynamometer, a 2002 Jeep Grand Cherokee having a 4.7 liter engine, and a 2002 Honda Accord having a 3.0 liter VTEC engine. The vehicle test procedure was modeled after the Coordinating Research Counsel method CRC Project No. CM-137-99 as discussed below. The vehicles were accelerated through ¼ mile distances at a part throttle setting while time and power measurements were obtained.

A set of reference tests were first conducted in which the engine sumps contained the SAE 10W-30 motor oil as described in Example 2. At the end of the reference accelerations, 25% (volume) of the oil was removed from the crankcase, replaced with the equivalent amount of the mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a kinematic

viscosity of 8.8 cSt at 100°C (described in Example 2) and acceleration data was then acquired for this oil charge under the same vehicle operating conditions.

The sequence of testing and results are shown in Table V. The four tests described were conducted on four separate days. Performance differences that are statistically significant are noted in the table.

TABLE V
Power and Acceleration Measurements

Test Number	Vehicle	Test Description	Percent Improvement in Acceleration 10-35 mph	Percent Improvement in ¼ mile Acceleration	Percent Improvement in ¼ mile Average Horsepower
1	2002 Jeep Grand Cherokee (4.7L)	Example 2 versus 100% SAE 10W-30 Motor Oil	2.7 (statistically significant)	0.6 (statistically significant)	2.0 (statistically significant)
2	2002 Jeep Grand Cherokee (4.7L)	100% SAE 10W-30 Motor Oil versus 100% SAE 10W-30 Motor Oil	0.3 (not statistically significant)	0.0	0.3 (not statistically significant)
3	2002 Jeep Grand Cherokee (4.7L)	Example 2 versus 100% SAE 10W-30 Motor Oil	1.5 (statistically significant)	0.4 (statistically significant)	1.4 (statistically significant)
4	2002 Honda Accord (3.0L VTEC)	Example 2 versus 100% SAE 10W-30 Motor Oil	0.3 (not statistically significant)	0.1 (statistically significant)	0.3 (statistically significant)

Testing Procedure

A test to measure power and acceleration was modeled after a procedure developed by the Coordinating Research Counsel (CRC) workshop, (CRC Project No. CM-137-99) which is discussed hereinbelow. An indoor vehicle chassis dynamometer
5 equipped with a data acquisition system allowed for the absorption of power transmitted by the driving wheels of the test vehicle. The rate of power absorption varies with speed and simulates a real road driving experience. The data acquisition system collects speed, distance, and power data. The rate of data collection was 100 samples per second.

The vehicle's on board self-diagnostics were examined for stored or current
10 trouble codes before initiating the test. If required, the necessary repairs were made before proceeding. Engine preparation continued with oil flushing, followed by a fresh charge of test oil. The oil flushing process used to thoroughly purge the engine oil system consisted of draining and changing the oil and filter a number of times. Upon
15 each introduction of flush oil, a distance of 50 miles is driven to circulate the oil before draining. The last oil flush is conducted using the test oil. The final charge of test oil 100% SAE 10W-30 Motor Oil (as described in example 2) followed the oil flushes. The test oil is then broken in by driving the vehicle 100 miles.

A mechanical stop was installed in the vehicle to ensure repeatable throttle positioning during the dynamometer test. For this work, the throttle stop was set such
20 that the maximum opening was approximately 25% as recorded using a scan tool. The vehicle and chassis dynamometer were warmed up together on the day of testing. The tires were examined and their pressure set to the maximum recommended by the manufacturer. A series of acceleration conditioning runs were conducted, followed by

the reference test accelerations and oil additive test accelerations. Warm-up consisted of driving the vehicle on the dynamometer between the speeds of 50 and 60 mph for one hour. This yielded a uniform operation temperature for the vehicle and test equipment.

Four sets of part throttle accelerations were conducted to stabilize the vehicle for acceleration style running. Each set consisted of eight accelerations. A vehicle "Key off"/ "Key on" event occurred at the start of each set. At the conclusion of the acceleration conditioning runs, a "Key off"/ "Key on" event was executed and the vehicle traveled for one mile at speeds between 50 and 60 mph. Once the vehicle was at rest, a "Key off"/ "Key on" event occurred, followed by the reference test accelerations. The first phase of a test acceleration set consisted of three accelerations in order for initial stabilization to occur. If the fourth acceleration time was greater than the third acceleration time, four additional accelerations were carried out. The last six of these eight accelerations constituted the data set for the analysis. If the fourth acceleration time was less than the third, then the stabilization process continued until an acceleration was greater than that just preceding it. Once this occurred, four additional accelerations were acquired to complete the test sequence. As before, the last six accelerations constitute the data set for the analysis.

Once the reference acceleration tests were completed, the vehicle's engine was turned off. In this case, 25% of the vehicle's oil charge was replaced to form the oil composition of Example 2. The acceleration data for this test oil were acquired using the same protocol described for the reference runs. A section from a procedural run sheet used for this type of work follows to better illustrate the engine test method.

Test

- 1) Warm up chassis dynamometer and test vehicle by running test vehicle for one hour at 50 to 60 mph at chassis load.
- 5 Acceleration conditioning
- 2) Key off / Key on
- 10 3) Do 8 accelerations
- 4) Key off / Key on
- 5) Do 8 accelerations
- 15 6) Key off / Key on
- 7) Do 8 accelerations
- 20 8) Key off / Key on
- 9) Do 8 accelerations
- 10) Key off / Key on
- 25 11) Drive one mile at 50 - 60 mph, chassis load
- 12) Key off / Key on
- 30 Test Accelerations
- 13) Conduct test acceleration set (base fuel and test oil). Record oil sump temperature at start and end of test set.
- 35 14) Key off
- 15) Draw one quart of oil from test vehicle, (save as sample, see sample labeling), and replace with 25% (volume) of the mixture of 4% by weight of the ashless friction modifier of Example 1 with 96% by weight of SAE 5W-20 API SL motor oil having a
- 40 kinematic viscosity of 8.8 cSt at 100°C (described in Example 2)
- 16) Key on
- 17) Drive one mile at 50 - 60 mph, chassis load.
- 45 18) Key off / Key on

19) Conduct test acceleration set

20) Draw one quart oil sample from test vehicle and label. See sample labeling.

Test complete

Test acceleration criteria

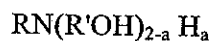
Three initial accelerations were conducted and if the time for the fourth acceleration measured greater than the time for the third acceleration, four additional accelerations were conducted. If the time for the fourth acceleration measured less than the time for the third acceleration, accelerations were repeated until the time for the most recent acceleration was greater than the time for the previous acceleration. When this occurred, an additional four accelerations were conducted.

It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. For example, the functions described above and implemented as the best mode for operating the present invention are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this invention. Moreover, those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

CLAIMS:

1. A lubricating oil composition comprising (a) an oil of lubricating viscosity
5 having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and (b) a friction modifying effective amount of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.
2. The lubricating oil composition of claim 1 wherein component (a) further
comprises (i) a first lubricating oil comprising an oil of lubricating viscosity having a
10 kinematic viscosity of 9.3 to about 16.3 cSt at a temperature of 100°C and (ii) a second lubricating oil comprising an oil of lubricating viscosity having a kinematic viscosity of about 2 to less than or equal to 9.3 cSt at a temperature of 100°C, wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C.
- 15 3. The lubricating oil composition of claim 1 or 2 wherein the fatty acid ester is an about C₆ to about C₂₄ fatty acid ester.
4. The lubricating oil composition of claim 1 or 2 wherein the fatty acid ester is a glycerol fatty acid ester.
- 20 5. The lubricating oil composition of claim 4 wherein the glycerol fatty acid ester is selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof.

6. The lubricating oil composition of any one of the preceding claims wherein the alkanolamine possesses the general formula



wherein R is hydrogen or an aminoalkyl group with the alkyl having from one to about six carbon atoms, R' is a hydrocarbyl having from about two to about six carbon atoms and "a" is 0 or 1.

7. The lubricating oil composition of claim 6 wherein the alkanolamine is selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

8. The lubricating oil composition of any one of the preceding claims wherein the friction modifier is the reaction product of a glycerol fatty acid ester and an alkanolamine.

9. The lubricating oil composition of any one of the preceding claims wherein the friction modifier is the reaction product of a fatty acid ester selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof and an alkanolamine selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

10. The lubricating oil composition of any one of the preceding claims wherein component (a) is an oil of lubricating viscosity having a kinematic viscosity of about 2 to less than 10.0 cSt at 100°C.

11. The lubricating oil composition of any one of the preceding claims wherein
5 component (a) is an oil of lubricating viscosity having a kinematic viscosity of about 3.8 to less than or equal to 9.3 cSt at 100°C.

12. The lubricating oil composition of any one of the preceding claims wherein the amount of the ashless friction modifier present in the lubricating oil composition is 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition.

10

13. A method of improving the fuel economy of an internal combustion engine which comprises operating the engine with a lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and (b) a friction modifying effective amount of an ashless friction modifier comprising a
15 reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

14. The method of claim 13 wherein component (a) further comprises (i) a first lubricating oil comprising an oil of lubricating viscosity having a kinematic viscosity of 9.3 to about 16.3 cSt at a temperature of 100°C and (ii) a second lubricating oil comprising an
20 oil of lubricating viscosity having a kinematic viscosity of about 2 to less than or equal 9.3 cSt at a temperature of 100°C, wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C.

15. The method of claim 13 or 14 wherein the fatty acid ester is an about C₆ to about C₂₄ fatty acid ester.

16. The method of claim 13 or 14 wherein the fatty acid ester is a glycerol fatty
5 acidester.

17. The method of claim 16 wherein the glycerol fatty acid ester is selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof.

10 18. The method of any one of claims 13 to 17 wherein the alkanolamine possesses the general formula



wherein R is hydrogen or an aminoalkyl group with the alkyl having from one to about six
15 carbon atoms, R' is a hydrocarbyl having from about two to about six carbon atoms and "a" is 0 or 1.

19. The method of claim 18 wherein the alkanolamine is selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine,
20 dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

20. The method of any one of claims 13 to 19 wherein the friction modifier is the reaction product of a fatty acid ester selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof and an alkanolamine selected from the group consisting of
5 monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, diisopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

21. The method of any one of claims 13 to 20 wherein component (a) is an oil of lubricating viscosity having a kinematic viscosity of about 2 to less than 10.0 cSt at 100°C.

10 22. The method of any one of claims 13 to 21 wherein the amount of the ashless friction modifier present in the lubricating oil composition is 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition.

23. A lubricating oil composition comprising (a) an oil of lubricating viscosity having a kinematic viscosity of about 2 to 10.5 cSt at 100°C and comprising about 55 to
15 about 85 weight percent of a first lubricating oil, and about 15 to about 45 weight percent of a second lubricating oil wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C; and (b) about 0.5 to about 5.0 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester
20 and an alkanolamine.

24. The lubricating oil composition of claim 23 wherein the first lubricating oil is an oil of lubricating viscosity having a kinematic viscosity of 9.3 to about 16.3 cSt at a temperature of 100°C and the second lubricating oil is an oil of lubricating viscosity having a kinematic viscosity about 2 to less than or equal to 9.3 cSt at a temperature of 100°C.

5 25. The lubricating oil composition of claim 23 or 24 wherein the fatty acid ester is an about C₆ to about C₂₄ fatty acid ester.

26. The lubricating oil composition of claim 23 or 24 wherein the fatty acid ester is a glycerol fatty acid ester.

27. The lubricating oil composition of claim 26 wherein the glycerol fatty acid
10 ester is selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof.

28. The lubricating oil composition of any one of claims 23 to 27 wherein the alkanolamine possesses the general formula

15
$$\text{RN(R'OH)}_{2-a} \text{H}_a$$

wherein R is hydrogen or an aminoalkyl group with the alkyl having from one to about six carbon atoms, R' is a hydrocarbonyl having from about two to about six carbon atoms and "a" is 0 or 1.

29. The lubricating oil composition of claim 28 wherein the alkanolamine is selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

5 30. The lubricating oil composition of any one of claims 23 to 29 wherein the friction modifier is the reaction product of a glycerol fatty acid ester and an alkanolamine.

31. The lubricating oil composition of any one of claims 23 to 30 wherein the friction modifier is the reaction product of a fatty acid ester selected from the group
10 consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof and an alkanolamine selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine; dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

15 32. The lubricating oil composition of any one of claims 23 to 31 wherein component (a) is an oil of lubricating viscosity having a kinematic viscosity of about 2 to less than 10.0 cSt at 100°C.

33. The lubricating oil composition of any one of claims 23 to 32 wherein
20 component (a) is an oil of lubricating viscosity having a kinematic viscosity of about 3.8 to less than or equal to 9.3 cSt at 100°C

34. The lubricating oil composition of any one of claims 23 to 33 wherein the amount of the ashless friction modifier present in the lubricating oil composition is 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition.

35. The lubricating oil composition of any one of claims 23 to 34 wherein the first lubricating oil of component (a) is selected from the group consisting of a SAE 10W multigrade oil, a SAE 15W multigrade oil and mixtures thereof and the second lubricating oil of component (a) is selected from the group consisting of a SAE 0W multigrade oil, a SAE 5W multigrade oil and mixtures thereof.

36. The lubricating oil composition of claim 35 wherein the first lubricating oil of component (a) is a SAE 10W-30 multigrade oil and the second lubricating oil of component (a) is a SAE 5W-20 multigrade oil.

37. A lubricating oil composition comprising (a) an oil of lubricating viscosity comprising a first lubricating oil selected from the group consisting of a SAE 10W multigrade oil, a SAE 15W multigrade oil and mixtures thereof and a second lubricating oil selected from the group consisting of a SAE 0W multigrade oil, a SAE 5W multigrade oil and mixtures thereof and (b) 1 to about 4.5 weight percent, based on the total weight of the lubricating oil composition, of an ashless friction modifier comprising a reaction product of a C₄ to about C₇₅ fatty acid ester and an alkanolamine.

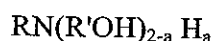
38. The lubricating oil composition of claim 37 wherein the oil of component (a) comprises about 55 to about 85 weight percent of a first lubricating oil, and about 15 to about 45 weight percent of a second lubricating oil wherein the kinematic viscosity of the second lubricating oil is lower than the kinematic viscosity of the first lubricating oil at 100°C.

39. The lubricating oil composition of claim 37 or 38 wherein the friction modifier is the reaction product of a glycerol fatty acid ester and an alkanolamine.

40. The lubricating oil composition of claim 39 wherein the glycerol fatty acid ester is selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof.

41. The lubricating oil composition of any one of claims 37 to 40 wherein the alkanolamine possesses the general formula

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wherein R is hydrogen or an aminoalkyl group with the alkyl having from one to about six carbon atoms, R' is a hydrocarbyl having from about two to about six carbon atoms and "a" is 0 or 1.

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42. The lubricating oil composition of any one of claims 37 to 41 wherein the friction modifier is the reaction product of a fatty acid ester selected from the group consisting of palm, olive, cotton seed, castor, peanut, tallow, lard, whale, sunflower, soybean, coconut, palm kernel oils and combinations thereof and an alkanolamine selected from the group consisting of monoethanolamine, diethanolamine, propanolamine, isopropanolamine, dipropanolamine, di-isopropanolamine, butanolamines, aminoethylaminoethanol and combinations thereof.

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43. A method of improving the fuel economy of an internal combustion engine which comprises operating the engine with the lubricating oil composition of any one of claims 1 to 12 and 23 to 42.