

IMPROVED VISCOSITY MODIFIERS FOR LUBRICANT COMPOSITIONS

TECHNICAL FIELD

The following disclosure is directed to lubricants, lubricant compositions and additives, lubricated parts and engines, and methods for lubricating moving parts.

BACKGROUND

Lubricating oils used in gasoline and diesel crankcases include a natural and/or synthetic basestock and one or more additives to impart desired characteristics to the lubricant. Such additives typically include ashless dispersant, metal detergent, antioxidant and antiwear components, which may be combined in a package, sometimes referred to as a detergent inhibitor (or DI) package.

Multigrade oils usually also contain one or more viscosity modifiers which are relatively long chain polymers. Such polymers may be functionalized to provide other properties when they are known as multifunctional viscosity modifiers, but primarily act to improve the viscosity characteristics of the oil over a desired operating temperature range. The viscosity modifier acts to increase viscosity at high temperature to provide more protection to the engine at high speeds, without unduly increasing viscosity at low temperatures which would otherwise make starting a cold engine difficult. High temperature performance is usually measured in terms of the kinematic viscosity (kV) at 100° C. (ASTM D445), while low temperature performance is measured in terms of cold cranking simulator (CCS) viscosity (ASTM D5293, which is a revision of ASTM D2602), mini-rotary viscometer (MRV; ASTM D4684), or scanning brookfield or gel index (ASTM D5133).

Viscosity grades are defined by the SAE Classification system (SAE J300) according to the foregoing temperature measurements. Multigrade oils meet the requirements of both low temperature and high temperature performance and are thus referenced to both the relevant grades.

Shear stability is a measure of the ability of an oil to resist permanent viscosity loss under high shear - the more shear stable an oil the smaller the viscosity loss when subjected to shear. Polymeric viscosity modifiers, which make a significant contribution to kV 100° C., are not entirely shear stable. Such polymeric viscosity modifiers are characterized by a shear stability index (SSI).

An oil or additive that exhibits relatively high shear stability will have an SSI that is relatively low. Typically, higher molecular weight polymers used in

lubricating oil applications have poor shear stability (i.e., high SSI). However, viscosity modifiers with relatively low SSI require higher treat rates due to their relatively lower molecular weights and therefore lead to an increase in total formulation costs. Multigrade oils often have poor shear stability unless they use expensive viscosity modifiers having low SSI. Poor shear stability requires the oils to be blended to a higher initial kV 100 °C, which may result in poor fuel economy. Accordingly, there is a need for improved viscosity modifiers which are relatively shear stable and more cost effective to use in lubricant composition.

10 SUMMARY OF THE EMBODIMENTS

In one embodiment herein is presented a lubricated surface. The lubricated surface includes a thin film coating of a lubricant composition containing a base oil of lubricating viscosity and from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000. The shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8.

In another embodiment, there is provided a vehicle having moving parts and containing a lubricant for lubricating the moving parts. The lubricant contains an oil of lubricating viscosity and from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000. The shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8.

In yet another embodiment there is provided a method of lubricating moving parts. The method includes contacting the moving parts with a lubricant composition containing a lubricant additive. The lubricant additive includes a diluent or carrier oil and from about 5 to about 95 percent by weight of a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000. The shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8. The lubricant composition contains

from about 5 to about 30 percent by weight of the additive based on a total weight of the lubricant composition.

A further embodiment of the disclosure provides a method for improving the viscosity index of a lubricant composition. The method includes mixing with the lubricant composition from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000. The shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8.

An advantage of the shear stable copolymer as described herein is that the polymer exhibits improved thickening efficient at a lower polymer loading. Another advantage of the shear stable copolymer is that it may be made using an amorphous lower ethylene containing copolymer, e.g., a copolymer having an ethylene content in the range of from about 40% to about 55% by weight. In addition to the shear stable olefin copolymers, the disclosure may also be applicable to shear stable star polymers based on styrene-isoprene chemistry.

BRIEF DESCRIPTION OF THE DRAWINGS:

Further features and advantages of the embodiments will become apparent by reference to the detailed description of preferred embodiments when considered in conjunction with the following drawings, in which like reference numbers denote like elements throughout the several views, and wherein:

FIG. 1 is a shear stability index profile of a mechanically sheared olefin copolymer according to the disclosure;

FIG. 2 is a polydispersity profile for a mechanically sheared olefin copolymer according to the disclosure;

FIG. 3 is a graphical representation of a viscosity profile for a mechanically sheared olefin copolymer according to the disclosure;

FIG. 4 is a graphical representation of an olefin copolymer according to the disclosure in a process oil illustrating a change in viscosity during mechanical shearing compared to conventional olefin copolymers prepared under a high temperature extruder shearing and direct finishing process; and

FIG. 5 is a thickening efficiency profile for a mechanically sheared olefin copolymer according to the disclosure compared to a thickening efficiency of conventional olefin copolymers prepared under a high temperature extruder shearing and direct finishing process.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

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

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

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

In all of the embodiments of the disclosure, a particular lubricant component or additive is provided. The additive is referred to generally as a multi-functional viscosity index modifier. Specifically, the lubricant additive includes a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 15,000 to about 500,000 or more. The shear stable olefin copolymer may have a shear stability index of less than about 40 and a polydispersity

of less than or equal to about 1.5. As described herein, shear stable olefin copolymer is dissolved in a suitable solvent such as Solvent Neutral 150 to provide the additive component.

5 A wide variety of copolymers and terpolymers may be used as starting materials for making the shear stable copolymer. The copolymers are referred to generally as olefin copolymers, however, the disclosed embodiments may also be applicable to copolymers derived from styrene-isoprene. The copolymers typically have number average molecular weights of from about 15,000 to about 500,000; preferably about 20,000 to about 300,000, and more preferably from about 100,000 to
10 about 200,000. The shear stable copolymers generally have a narrow range of molecular weight, as determined by the ratio of weight-average molecular weight (Mw) to number-average molecular weight (Mn), referred to hereinafter as "polydispersity." Suitable olefin copolymers have a polydispersity of less than 10, preferably less than 7, and more preferably 4 or less. The (Mn) and (Mw/Mn) of the
15 copolymers are measured by the well known techniques of vapor phase osmometry (VPO), membrane osmometry and gel permeation chromatography. The shear stable copolymers derived from the olefin copolymers may have a polydispersity of less than or equal to about 1.5.

In general, shear stable copolymers having a narrow range of molecular
20 weight may be obtained by relatively low temperature mechanical shearing. Conventional copolymer shearing is conducted at temperatures above about 100° C. (212° F.) in an extrusion shearing process. By contrast, shearing of the copolymers according to the disclosure is conducted at a temperature below about 100° C. (212° F.), typically from about 35° C. (95° F.) to about 85° C. (135° F.) in a homogenizer.
25 Accordingly, the term "relatively low temperature" means a temperature below a temperature used in a conventional extrusion shearing process for shearing copolymers.

The homogenizer used in the process may be any type capable of developing a pressure in excess of 500 pounds per square inch wherein the product is subjected to
30 high shearing action upon release of said pressure. Typical of the homogenizers which may be used are those of the type conventionally used in the homogenization of dairy products and in the preparation of emulsions utilized as polishing compounds, cosmetics, pharmaceuticals and liquid soaps. The copolymers may be sheared using

multiple passes through the homogenizer, for example from about 2 to about 10 passes through the homogenizer.

The olefin copolymer sheared in the homogenizer may be prepared from ethylene and ethylenically unsaturated hydrocarbons including cyclic, alicyclic and acyclic, compounds containing from 3 to 28 carbons, e.g. 2 to 18 carbons. The ethylene copolymers may contain from about 15 to about 90 wt. % ethylene, preferably, from about 30 to about 80 wt. % of ethylene, and most preferably less than about 70 wt. % ethylene. The copolymers may also contain from about 10 to about 85 wt. %, preferably 20 to 70 wt. % of one or more C_3 to C_{28} , preferably C_3 to C_{18} more preferably C_3 to C_{10} , unsaturated hydrocarbons, preferably alpha olefins.

Copolymers of ethylene and propylene are most preferred. However, other alpha-olefins suitable in place of propylene to form the copolymer, or to be used in combination with ethylene and propylene, to form a terpolymer, tetrapolymer, etc., include, but are not limited to, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, etc.; also branched chain alpha-olefins, such as 4-methyl-1-pentene, 4-methyl-1-hexene, 5-methylpentene-1, 4,4-dimethyl-1-pentene, and 6-methylheptene-1, etc., and mixtures thereof.

The term copolymer as used herein, unless otherwise indicated, includes terpolymers, tetrapolymers, interpolymers, etc., of ethylene and C_{3-28} alpha-olefin and/or a non-conjugated diolefin or mixtures of such diolefins which may also be used. Such materials may contain minor amounts of other olefinic monomers so long as the basic characteristics of the olefin copolymers are not materially changed. The amount of the non-conjugated diolefin will generally range from about 0.5 to 20 mole percent, preferably about 1 to about 7 mole percent, based on the total amount of ethylene and alpha-olefin present.

Representative examples of non-conjugated dienes that may be included in a terpolymer include straight chain acyclic dienes such as 1,4-hexadiene; 1,5-heptadiene; 1,6-octadiene; branched chain acyclic dienes such as 5-methyl-1,4-hexadiene; 3,7-dimethyl 1,6-octadiene; 3,7-dimethyl-1,7-octadiene; and the mixed isomers of dihydro-myrcene and dihydro-cymene; single ring alicyclic dienes such as 1,4-cyclohexadiene; 1,5-cyclooctadiene; 1,5-cyclododecadiene; 4-vinylcyclohexene; 1-allyl-4-isopropylidene cyclohexane; 3-allyl-cyclopentene; 4-allyl-cyclohexene and 1-isopropenyl-4-(4-butenyl) cyclohexane; multi-single ring alicyclic dienes such as 4,4-dicyclopentenyl and 4,4-dicyclohexenyl dienes; multi-ring alicyclic fused and

bridged ring dienes such as tetrahydroindene; methyl tetrahydroindene; dicyclopentadiene; bicyclo (2.2.1) hepta-2,5-diene; alkyl, alkenyl, alkylidene, cycloalkenyl and cycloalkylidene norbornenes such as: ethyl norbornene; 5-methylene-6-methyl-2-norbornene; 5-methylene-6,6-dimethyl-2-norbornene; 5-propenyl-2-norbornene; 5-(3-cyclopentenyl)2-norbornene and 5-cyclohexylidene-2-norbornene; norbornadiene; etc.

Specifically, the shear stable olefin copolymer may be derived from the polymerization of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-neoprene monomers, styrene-isoprene monomers, and the like.

Ethylene-propylene or higher alpha-olefin copolymers may consist of from about 15 to about 80 weight percent ethylene and from about 85 to about 20 weight percent C_3 to C_{23} alpha-olefin with the preferred weight ratios being from about 35 to about 75 weight percent ethylene and from about 65 to about 25 weight percent of a C_3 to C_{23} alpha-olefin, with the more preferred proportions being from about 50 to less than about 70 weight percent ethylene and about 50 to about 30 weight percent C_3 to C_{23} alpha-olefin, and the most preferred proportions being from about 55 to about 65 weight percent ethylene and from about 45 to about 35 weight percent C_3 to C_{23} alpha-olefin.

Also included among the olefin copolymers for making the shear stable olefin copolymers as described herein are those olefin copolymers which have been functionalized by means of a free radical graft reaction or a graft polymerization reaction. Such grafted copolymers are themselves well known to those skilled in the art.

Graft monomers for functionalizing olefin copolymers are the derivatives of olefinically unsaturated carboxylic monomers such as, maleic anhydride, acrylic or methacrylic acid, or their esters, graft monomers which are likewise known to those skilled in the art. Typically, acrylic and methacrylic acid derivative contain 4 to 16 carbon atoms. Particularly preferred among the group of acrylic or methacrylic graft monomers are glycidyl methacrylate, methylacrylate, methylmethacrylate, ethylmethacrylate and aminopropylmethacrylate, and acrylamide.

Another group of graft monomers which can be used to functionalize the olefin copolymers are vinyl amines containing 2 to 25 carbon atoms, and preferably heterocyclic vinyl amines. Such amines are themselves known as functionalizing graft monomers and include allylamines, N-vinylpyridines, N-vinylpyrrolidones, vinyl

lactams, vinylcarbazoles, vinylimidazoles and vinylthiazoles as represented by 2-vinylpyridine, N-vinylpyrrolidone, vinyl caprolactam, 1-vinylimidazole, allylamine, 4-methyl-5-vinylthiazole and 9-vinylcarbazole. Such graft monomers are described in detail in U.S. Pat. No. 4,340,689, the disclosure of which is incorporated herein by reference.

As it will be appreciated by those skilled in the art, other vinyl monomers described in the prior art as suitable for functionalizing olefin copolymers may likewise be used in the practice of the present invention. Examples of such further vinyl compounds are the vinyl silanes and vinyl-benzyl halides as represented by vinyltrimethoxysilane, vinyl-diethylchlorosilane, vinylbenzylchloride and the like. Further descriptions of suitable silane graft monomers are described in U.S. Pat. No. 4,340,689, the disclosure of which is incorporated herein by reference.

The shear stable olefin copolymer of the embodiments described herein is advantageously incorporated into lubricating compositions. The shear stable olefin copolymer may be added directly to the lubricating oil composition. In one embodiment, however, the copolymer is diluted with a substantially inert, normally liquid organic diluent such as mineral oil, synthetic oil (e.g., ester of dicarboxylic acid), naphtha, alkylated (e.g., C₁₀ -C₁₃ alkyl) benzene, toluene or xylene to form an additive concentrate. The shear stable olefin copolymer concentrate usually contain from about 0% to about 99% by weight diluent oil.

In the preparation of lubricating oil formulations it is common practice to introduce the additives in the form of 1 to 99 wt. % active ingredient concentrates in hydrocarbon oil, e.g. mineral lubricating oil, or other suitable solvent. Usually these concentrates may be added with 0.05 to 10 parts by weight of lubricating oil per part by weight of the additive package in forming finished lubricants, e.g. crankcase motor oils. The purpose of concentrates, of course, is to make the handling of the various materials less difficult and awkward as well as to facilitate solution or dispersion in the final blend.

Lubricant compositions made with the shear stable olefin copolymers described above are used in a wide variety of applications. For compression ignition engines and spark ignition engines, it is preferred that the lubricant compositions meet or exceed published GF-4 or API-CI-4 standards. Lubricant compositions according to the foregoing GF-4 or API-CI-4 standards include a base oil and an oil additive package to provide a fully formulated lubricant. The base oil for lubricants according

to the disclosure is an oil of lubricating viscosity selected from natural lubricating oils, synthetic lubricating oils and mixtures thereof. Such base oils include those conventionally employed as crankcase lubricating oils for spark-ignited and compression-ignited internal combustion engines, such as automobile and truck engines, marine and railroad diesel engines, and the like.

Natural oils include animal oils and vegetable oils (e.g., castor oil, lard oil), liquid petroleum oils and hydrorefined, solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale are also useful base oils. The synthetic lubricating oils used in this invention include one of any number of commonly used synthetic hydrocarbon oils, which include, but are not limited to, poly-alpha-olefins, alkylated aromatics, alkylene oxide polymers, interpolymers, copolymers and derivatives thereof here the terminal hydroxyl groups have been modified by esterification, etherification etc, esters of dicarboxylic acids and silicon-based oils.

Fully formulated lubricants conventionally contain an additive package, referred to herein as a dispersant/inhibitor package or DI package, that will supply the characteristics that are required in the formulations. Suitable DI packages are described for example in U.S. Patent Nos. 5,204,012 and 6,034,040 for example. Among the types of additives included in the additive package are detergents, dispersants, friction modifiers, seal swell agents, antioxidants, foam inhibitors, lubricity agents, rust inhibitors, corrosion inhibitors, demulsifiers, viscosity index improvers, and the like. Several of these components are well known to those skilled in the art and are preferably used in conventional amounts with the additives and compositions described herein.

For example, ashless dispersants include an oil soluble polymeric hydrocarbon backbone having functional groups that are capable of associating with particles to be dispersed. Typically, the dispersants comprise amine, alcohol, amide, or ester polar moieties attached to the polymer backbone often via a bridging group. The ashless dispersants may be, for example, selected from oil soluble salts, esters, amino-esters, amides, imides, and oxazolines of long chain hydrocarbon substituted mono and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of long chain hydrocarbons; long chain aliphatic hydrocarbons having a polyamine attached directly

thereto; and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and a polyalkylene polyamine.

5 Oxidation inhibitors or antioxidants reduce the tendency of base stocks to deteriorate in service which deterioration can be evidenced by the products of oxidation such as sludge and varnish-like deposits on the metal surfaces and by viscosity growth. Such oxidation inhibitors include hindered phenols, alkaline earth metal salts of alkylphenol thioesters having preferably C₅ to C₁₂ alkyl side chains, calcium nonylphenol sulfide, ashless oil soluble phenates and sulfurized phenates, phosphosulfurized or sulfurized hydrocarbons, phosphorus esters, metal
10 thiocarbamates and oil soluble copper compounds as described in U.S. Pat. No. 4,867,890.

 Rust inhibitors selected from the group consisting of nonionic polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, and anionic alkyl sulfonic acids may be used.

15 A small amount of a demulsifying component may be used. A preferred demulsifying component is described in EP 330,522. It is obtained by reacting an alkylene oxide with an adduct obtained by reacting a bis-epoxide with a polyhydric alcohol. The demulsifier should be used at a level not exceeding 0.1 mass % active ingredient. A treat rate of 0.001 to 0.05 mass % active ingredient is convenient.

20 Pour point depressants, otherwise known as lube oil flow improvers, lower the minimum temperature at which the fluid will flow or can be poured. Such additives are well known. Typical of those additives which improve the low temperature fluidity of the fluid are C₈ to C₁₈ dialkyl fumarate/vinyl acetate copolymers, polyalkylmethacrylates and the like.

25 Foam control can be provided by many compounds including an antifoamant of the polysiloxane type, for example, silicone oil or polydimethyl siloxane.

 Seal swell agents, as described, for example, in U.S. Patent Nos. 3,974,081 and 4,029,587, may also be used.

30 Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is a corrosion inhibitor, a functionally effective amount of this corrosion inhibitor would be an amount sufficient to impart the desired corrosion inhibition characteristics to the lubricant. Generally, the concentration of each of these additives, when used, ranges up to about 20% by weight based on the weight of the

lubricating oil composition, and in one embodiment from about 0.001% to about 20% by weight, and in one embodiment about 0.01% to about 10% by weight based on the weight of the lubricating oil composition.

Example

5 Four fully formulated lubricant compositions were made and the viscometric and shear strength properties of the compositions were compared. Each of the lubricant compositions contained a conventional DI package providing 11 percent by weight of the lubricant composition. The DI package contained conventional amounts of detergents, dispersants, antiwear additives, friction modifiers, antifoam agents, and
10 antioxidants. The formulations also contained about 0.1 percent by weight pour point depressant, about 58 to 64 percent by weight 150 solvent neutral oil, about 12 to 18 percent by weight 600 solvent neutral oil. Samples 1-3 provide the characteristics of commercially available olefin copolymers as viscosity modifiers. Sample 4 provides the characteristics of a shear stable olefin copolymer made according to the
15 disclosure.

In the tables, the following abbreviations are used:

VII – viscosity index improver

KV – kinematic viscosity

CCS – cold cranking simulator

20 MRV – mini rotary viscometer – tests conducted according to ASTM D4684

HTHS – high temperature high shear – tests conducted according to ASTM D-4683, D-4781, and D-5481.

Table 1

Sample #	1	2	3	4
Viscosity Grade	15W50	15W50	15W50	15W50
Components	Wt. %	Wt. %	Wt. %	Wt. %
HiTEC [®] 9386 ¹	11.00	11.00	11.00	11.00
HiTEC [®] 672 ²	0.10	0.10	0.10	0.10
ESSO 150 solvent neutral	63.60	63.00	58.20	63.50
ESSO 600 solvent neutral	12.40	13.50	17.30	12.00
Viscosity Index Modifier				
HiTEC [®] 5748 ³	12.90	0.00	0.00	0.00
LUBRIZOL 7077 ⁴	0.00	12.40	0.00	0.00
PARATONE 8006 ³	0.00	0.00	13.40	0.00
Shear Stable ethylene/propylene Copolymer (50 wt. % ethylene)	0.00	0.00	0.00	13.40
Total	100.00	100.00	100.00	100.00

Table 2

Sample #	1	2	3	4
Lubricant Properties				
Polymer content in VII (weight %)	13.12	12.61	10.27	9.88
Polymer loading in blend (grams)	1.69	1.56	1.38	1.32
KV at 100 °C. (cSt)	18.98	19.06	19.02	18.96
KV at 40° C. (cSt)	144.80	146.2	144.4	146.6
Viscosity index	149	149	150	147
CCS at -20° C. (cP) (7000 cP max.)	6776	6897	6653	6840
MRV TP-1@-25°C, cP	44900	47300	0	40800
MRV Yield Stress	<35	<35	<140	<35
Noack Volatility, %	11.4	10.6	10.1	10.4
HTHS at 150°C. (cP)	4.89	4.95	4.63	4.79
KV at 100° C. after 30 cycle Bosch shear	16.29	16.55	16.03	16.16
KV at 100° C. % viscosity loss (15% max.)	14.17	13.14	15.72	14.77
Shear stability Index (SSI, %)	23.60	20.60	24.20	24.90

¹HiTEC® 9386 is a commercially available DI package available from Afton Chemical Corporation of Richmond, Virginia

²HiTEC® 672 is a commercially available pour point depressant available from Afton Chemical Corporation

³HiTEC® 5748 is a olefin copolymer made by an extrusion shearing process and is available from Afton Chemical Corporation

⁴LUBRIZOL 7077 is an olefin copolymer having an ethylene content of about 50 weight percent and is available from Lubrizol Corporation of Wickliffe, Ohio. (The table results are from an average of two batches of LUBRIZOL 7077)

⁵PARATONE 8006 is an olefin copolymer having an ethylene content of about 70 weight percent and is available from Chevron Oronite Company LLC of Houston, Texas.

As seen in the foregoing Tables 1 and 2, sample 4 provides a highly efficient viscosity modifier. Compared with samples 1-3, sample 4 had the lowest polymer loading in the lubricant composition (1.32 versus 1.38 to 1.69 for samples 1-3). Sample 4 also had the highest shear stability index (SSI) and passed the MRV tests and CCS test, whereas, sample 3 failed the MRV test and viscosity loss test. Overall, sample 4 exhibited improved viscometric and shear strength properties over commercially available ethylene-based olefin copolymer products.

In order to make shear stable olefin copolymers according to the disclosure, 10 parts by weight ethylene/propylene copolymer having a number average molecular weight as determined by gas phase chromatography (GPC) of 179,192 and a weight average molecular weight of 332,930 was mixed with 90 parts by weight of process oil. The oil and copolymer mixture was cycled through a GAULIN homogenizer

from 1 to 10 times to provide a shear stable olefin copolymer having a polydispersity of less than 1.5.

Properties of the olefin copolymer after zero to ten passes through the homogenizer are provided in the following table and FIGS. 1-3. FIGS. 4-5 provide a visual comparison of the thickening efficiency and kinematic viscosity of the olefin copolymer after zero to ten passes with the same properties of HiTEC® 5748 and LUBRIZOL 7077 (LZ 7077) (Samples 6 and 7, respectively). The comparisons were conducted with one percent olefin copolymer in a reference oil having a viscosity as indicated in the table. The kinematic viscosity at 100° C. of the samples was estimated by thermogravimetric analysis (TGA) by dissolving one weight percent of each sample in about a five centistokes reference oil (FIG. 4).

Table 3

Sample No.	1	2	3	4	5	6	7
No. of passes through Homogenizer	0	4	6	8	10	----	----
KV at 100° C. (cSt)	5422	1685	1299	1176	1048	1010	1212
KV at 40° C. (cSt)	78489	21084	17234	14878	13109	13290	15153
VI	385.9	332.8	321.0	309.3	303.4	295.4	313.0
% Crystallinity	2.47	2.32	2.63	2.79	2.59	2.30	2.68
TGA/N2 (wt. % Polymer)	9.635	9.638	9.668	9.568	9.627	12.97	12.80
Wt. % process oil	89.77	89.77	89.59	89.38	89.43	86.49	86.59
Mn	179192	163277	152061	153749	139436	72972	93130
Mw	332930	231655	209057	202834	183335	147926	147853
Pd	1.86	1.42	1.37	1.32	1.31	2.03	1.59

Table 4

Sample No.	1	2	3	4	5	6	7
No. of passes through Homogenizer	0	4	6	8	10	----	----
KV at 100° C. in Ref. Oil (Est. by TGA)	13.784	11.305	10.822	10.614	10.501	8.79	9.05
Thickening Power (by TGA)	8.81	6.33	5.85	5.64	5.53	3.82	4.07
Thickening Efficiency (by TGA)	2.941	2.369	2.243	2.187	2.156	1.717	1.713
KV at 100° C. in Ref. oil before shearing	11.06	10.92	10.47	10.31	10.11	-----	10.86
KV at 100° C. in Ref. oil after shearing	7.99	9.00	8.95	8.94	8.91	-----	9.72
KV at 100° C. of Ref. Oil	4.89	4.95	4.95	4.95	4.95	-----	4.95
% Viscosity Loss	26.76	17.58	14.52	13.29	11.87	-----	10.5
SSI %	49.76	32.16	27.54	25.56	23.26	24	19.29

As shown by the foregoing tables and FIGS. 1-5, a shear stable copolymer made by passing the copolymer through ten or more passes of a homogenizer can be tailored to provide a viscosity modifier that meets the shear stability index (SSI) requirement of about 23 (Sample 5), and has significantly higher thickening efficiency (Sample 5) compared to conventional olefin copolymer viscosity modifiers (Samples 6 and 7). Mechanical shearing of an olefin copolymer has an added benefit of providing a shear stable olefin copolymer having a polydispersity of less than 1.5 (Sample 5, Table 3).

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

The foregoing embodiments are susceptible to considerable variation in its practice. Accordingly, the embodiments are not intended to be limited to the specific exemplifications set forth hereinabove. Rather, the foregoing embodiments are within the spirit and scope of the appended claims, including the equivalents thereof available as a matter of law.

The patentees do not intend to dedicate any disclosed embodiments to the public, and to the extent any disclosed modifications or alterations may not literally fall within the scope of the claims, they are considered to be part hereof under the doctrine of equivalents.

What is claimed is:

1. A lubricated surface comprising a thin film coating of a lubricant composition containing a base oil of lubricating viscosity and from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer
5 derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of additive in the lubricant composition is based on a total weight of the lubricant composition.

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2. The lubricated surface of claim 1, wherein the lubricated surface comprises an engine drive train.

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3. The lubricated surface of claim 1, wherein the lubricated surface comprises an internal surface or component of an internal combustion engine.

4. The lubricated surface of claim 1, wherein the lubricated surface comprises an internal surface or component of a compression ignition engine.

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5. The lubricated surface of claim 1, wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

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6. The lubricated surface of claim 1, wherein the shear stable copolymer is derived from a relatively low temperature, homogenized copolymer.

7. The lubricated surface of claim 1, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

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8. The lubricated surface of claim 1, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight of the copolymer.

9. A motor vehicle comprising the lubricated surface of claim 1.

10. A vehicle having moving parts and containing a lubricant for lubricating the moving parts, the lubricant comprising an oil of lubricating viscosity and from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of additive in the lubricant is based on a total weight of the lubricant.

11. The vehicle of claim 10, wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

12. The vehicle of claim 10, wherein the shear stable copolymer comprises an olefin copolymer mechanically sheared in a homogenizer.

13. The vehicle of claim 10, wherein the moving parts comprise a heavy duty diesel engine including exhaust gas recirculation and a lubricating system for the engine.

14. The vehicle of claim 10, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

15. The vehicle of claim 10, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight of the copolymer.

16. A fully formulated lubricant composition comprising a base oil component of lubricating viscosity and from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the shear stable olefin copolymer has a shear stability index of less

than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of additive in the lubricant composition is based on a total amount of lubricant composition.

5 17. The lubricant composition of claim 16, wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

10 18. The lubricant composition of claim 16, wherein the shear stable copolymer comprises an olefin copolymer mechanically sheared in a homogenizer.

 19. The lubricant composition of claim 16, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

15 20. The lubricant composition of claim 16, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight.

20 21. A method for improving the viscosity index of a lubricant composition comprising mixing with the lubricant composition from about 5 to about 30 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the shear stable olefin copolymer has a shear stability index
25 of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of shear stable olefin copolymer in the lubricant composition is based on a total weight of the lubricant composition.

30 22. The method of claim 21, wherein the lubricant composition comprises a multi-viscosity lubricating oil.

23. The method of claim 21, wherein the wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

5 24. The method of claim 21, wherein the shear stable copolymer comprises an olefin copolymer mechanically sheared in a homogenizer.

25. The method of claim 21, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

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26. The method of claim 21, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight of the copolymer.

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27. A lubricant additive concentrate comprising a diluent or carrier oil and from about 5 to about 90 percent by weight of an additive comprising a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not
20 more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of shear stable olefin copolymer in the lubricant composition is based on a total weight of the additive concentrate.

25 28. The additive concentrate of claim 27, wherein the wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

29. The additive concentrate of claim 27, wherein the shear stable copolymer
30 comprises an olefin copolymer mechanically sheared in a homogenizer.

30. The additive concentrate of claim 27, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

31. The additive concentrate of claim 27, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight of the copolymer.

5 32. A lubricant composition comprising a base oil and the additive concentrate of claim 27.

33. A method of lubricating moving parts of a vehicle, the method comprising using as a lubricating oil for one or more moving parts of the vehicle a lubricant composition containing a base oil and a lubricant additive, the lubricant additive comprising a diluent or carrier oil and an amount of shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000 sufficient to provide from about 5 to about 30 weight percent of the shear stable olefin copolymer in the lubricant composition, wherein the
10 shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, and wherein the amount of shear stable olefin copolymer in the lubricant composition is based on a total weight of the lubricant composition.

20 34. The method of claim 33, wherein the wherein the shear stable copolymer is derived from the group consisting of ethylene-propylene monomers, ethylene-propylene-diene monomers, styrene-isoprene, and styrene-neoprene monomers.

35. The method of claim 33, wherein the shear stable copolymer comprises an
25 olefin copolymer mechanically sheared in a homogenizer.

36. The method of claim 33, wherein each monomeric unit of the shear stable copolymer contains from about 2 to about 10 carbon atoms.

30 37. The method of claim 33, wherein the shear stable copolymer comprises an amorphous ethylene containing copolymer having an ethylene content below about 70 percent by weight of the copolymer.

38. The method of claim 33 wherein the vehicle includes a diesel engine and wherein the moving parts include moving parts of the engine.

39. The method of claim 33 wherein the vehicle includes a marine vehicle
5 having an engine, and wherein the moving parts include moving parts of the engine.

40. The method of claim 33, wherein the vehicle includes a spark ignition engine, and wherein the moving parts include moving parts of the engine

10 41. The method of claim 33, wherein the vehicle includes a drive train, and wherein the moving parts include moving parts of the drive train.

42. The method of claim 33 wherein the vehicle includes an internal combustion engine having a crankcase and wherein the lubricant composition
15 comprises a crankcase oil present in the crankcase of the vehicle.

43. The method of claim 33 wherein the lubricant composition comprises a drive train lubricant present in an automotive drive train of the vehicle.

20 44. A method of lubricating moving parts comprising contacting the moving parts with a lubricant composition containing a lubricant additive, the lubricant additive comprising a diluent or carrier oil and from about 5 to about 95 percent by weight of a shear stable olefin copolymer derived from a copolymer having a number average molecular weight ranging from about 50,000 to about 250,000, wherein the
25 shear stable olefin copolymer has a shear stability index of less than about 40, a polydispersity of not more than about 1.5, and a thickening efficiency of greater than about 1.8, wherein the lubricant composition contains from about 5 to about 30 percent by weight of the additive based on a total weight of the lubricant composition.

30 45. The method of claim 44 wherein the moving parts comprise moving parts of a vehicle.

46. The method of claim 44 wherein the vehicle includes a marine vehicle having an engine, and wherein the moving parts include moving parts of the engine.

47. The method of claim 44 wherein the moving parts include an internal combustion engine having a crankcase and wherein the lubricant composition comprises a crankcase oil present in the crankcase of the vehicle.

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48. The method of claim 44 wherein the lubricant composition comprises a drive train lubricant present in an automotive drive train of the vehicle.

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