(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
14 December 2023 (14.12.2023)

(10) **International Publication Number**
WO 2023/238045 A1

(51) **International Patent Classification:**
C10M 143/04 (2006.01) *C10M 143/12* (2006.01)

(21) **International Application Number:**
PCT/IB2023/055849

(22) **International Filing Date:**
07 June 2023 (07.06.2023)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
63/350,464 09 June 2022 (09.06.2022) US

(71) **Applicant: CHEVRON ORONITE COMPANY LLC** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(72) **Inventors: SEPEHR, Maryam**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **MORGAN, David L.**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **CHOMMELOUX, Claire**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **KLEIJWEGT, Peter**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **ZHANG, Sara Yue**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(74) **Agent: PIO, Michael Sungjoon** et al.; P.O. Box 6006, SAN RAMON, California 94583-0806 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:
- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

(54) Title: LUBRICATING OIL COMPOSITION WITH VISCOSITY MODIFIER WITH LOW SHEAR STABILITY INDEX

(57) **Abstract:** This disclosure describes a method of improving fuel economy of an engine. The method involves lubricating the engine with a lubricating oil composition that includes a) an oil of lubricating viscosity; and b) a viscosity modifier including an olefin copolymer or diene-based copolymer or homopolymer wherein the viscosity modifier has shear stability index of 15 or less. The lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier of b).

LUBRICATING OIL COMPOSITION WITH VISCOSITY MODIFIER WITH LOW SHEAR STABILITY INDEX

INVENTORS**:** Maryam Sepehr, David Morgan, Claire Chommeloux, Peter Kleijwegt, Sara Yue Zhang

TECHNICAL FIELD

[0001] The present disclosure relates to a method of improving fuel economy by formulating a low SSI viscosity modifier in a lubricating oil composition.

BACKGROUND

[0002] Improving fuel economy is a significant driving force in the development of advanced lubricant technology. In general, lubricants with lower viscosities across a range of temperatures and shear conditions provide better fuel economy due to reductions in viscous drag. Viscosity modifiers or viscosity index improvers (particularly those with improved shear stability) can modify the rheological properties of an engine oil to help attain better fuel economy in vehicles.

SUMMARY OF DISCLOSURE

[0003] The present disclosure is concerned with a method of improving fuel economy of an engine, the method comprising: lubricating the engine with a lubricating oil composition comprising: a) an oil of lubricating viscosity; and b) a viscosity modifier comprising an olefin copolymer or diene-based copolymer or homopolymer wherein the viscosity modifier has shear stability index of 15 or less; wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier of b).

[0004] In another aspect, the present disclosure is concerned with a method of increasing the fuel economy of a diesel engine, the method comprising: lubricating the diesel engine with a lubricating oil composition comprising: a) an oil of lubricating viscosity; and b) a viscosity modifier comprising an olefin copolymer or diene-based copolymer or homopolymer, wherein the viscosity modifier has shear stability index of 15 or less; wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier of b).

DETAILED DESCRIPTION

[0005] As used herein, a "polymer" has two or more of the same or different monomer units. A "homopolymer" is a polymer having monomer units that are the same. A "copolymer" is a polymer having two or more monomer units that are different from each other.

[0006] As used herein, the term "substituted" means that a hydrogen has been replaced with a heteroatom, or a heteroatom-containing group. For example, a "substituted hydrocarbyl" is a radical made of carbon and hydrogen where at least one hydrogen is replaced by a heteroatom or heteroatom-containing group.

[0007] As used herein, Mn is number average molecular weight, Mw is weight average molecular weight, and Mz is z average molecular weight, wt. % is weight percent, and mol % is mole percent. Molecular weight distribution (MWD), also referred to as polydispersity (PDI), is defined to be Mw divided by Mn. Unless otherwise noted, all molecular weight units (e.g., Mw, Mn, Mz) are g/mol.

[0008] Shear stability index (SSI) refers to a polymer's resistance to mechanical degradation (polymer coil breakage) under shearing stress as measured by ASTM D6278 or D7109. For example, an SSI of 50 means that the polymer will lose 50% of the viscosity it contributed to a lubricant prior to degradation.

[0009] At least one previous study suggests that polymers with higher SSI are used to improve fuel economy at constant HTHS150 (High Temperature High Shear viscosity at 150°C) or KV100 (Kinematic Viscosity at 100°C). U.S. Publication No. 20130143782 asserts that an increase in the ratio of high/low SSI polymer provides a boost in fuel economy. This may be expected given that shear thinning contribution increases with higher SSI polymer content.

[0010] In the present disclosure, it has been surprisingly discovered that lubricating oil composition comprising low SSI viscosity modifier can improve fuel economy of an internal combustion engine. This improvement can be verified or determined by measuring the Fuel Economy Increase (referred to as "Fuel Economy Improvement") from standardized dynamometer tests such as World Harmonized Transient Cycle or Heavy-Duty Supplemental Emissions test.

[0011] The present disclosure relates to low SSI viscosity modifiers (or viscosity index improvers) in lubricating oil composition and/or methods of using the lubricating oil composition thereof. As used herein, the term "low SSI" or "low shear stability index" indicates an SSI value of 15 or less such as 14 or less, 13 or less, 12 or less, 11 or less, 10 or less, 9 or less, 8 or less, 7 or less, 6 or less, 5 or less, 4 or less, 3 or less, 2 or less, 1 or less, 1 to 15, 1 to 14, 1 to 13, 1 to 12, 1 to 11, 1 to 10, 1 to 9, 1 to 8, 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, 1 to 2, 2 to 15, 2 to 14, 2 to 13, 2 to 12, 2 to 11, 2 to 10, 2 to 9, 2 to 8, 2 to 7, 2 to 6, 2 to 5, 2 to 4, 2 to 3, 3 to 15, 3 to 14, 3 to 13, 3 to 12, 3 to 11, 3 to 10, 3 to 9, 3 to 8, 3 to 7, 3 to 6, 3 to 5, 3 to 4, 4 to 15, 4 to 14, 4 to 13, 4 to 12, 4 to 11, 4 to 10, 4 to 9, 4 to 8, 4 to 7, 4 to 6, 4 to 5, 5 to 15, 5 to 14, 5 to 13, 5 to 12, 5 to 11, 5 to 10, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 6 to 15, 6 to 14, 6 to 13, 6 to 12, 6 to 11, 6 to 10, 6 to 9, 6 to 8, 6 to 7, 7 to 15, 7 to 14, 7 to 13, 7 to 12, 7 to 11, 7 to 10, 7 to 9, 7 to 8, 8 to 15, 8 to 14, 8 to 13, 8 to 12, 8 to 11, 8 to 10, 8 to 9, 9 to 15, 9 to 14, 9 to 13, 9 to 12, 9 to 11, 9 to 10, 10 to 15, 10 to 14, 10 to 13, 10 to 12, 10 to 11, 11 to 15, 11 to 14, 11 to 13, 11 to 12, 12 to 15, 12 to 14, 12 to 13, 13 to 15, 13 to 14, or 14 to 15.

[0012] According to an embodiment, a method for improving fuel economy comprises:

lubricating an internal combustion engine with a lubricating oil composition comprising:

a) a major amount of oil of lubricating viscosity; and

b) a viscosity modifier comprising an olefin copolymer or a diene-based copolymer or homopolymer (e.g., hydrogenated diene-based polymer), wherein the viscosity modifier has an SSI of 15 or less. In general, the lubricating oil composition does not contain viscosity modifiers other than the viscosity modifier of b). In some embodiments, the lubricating oil composition contains less than 0.01 wt.% of other viscosity modifiers. Other viscosity modifiers include poly alkyl methacrylate (PMA) polymer and the like.

Viscosity Modifier

[0013] The viscosity modifier of the present disclosure is a low SSI polymer, wherein the viscosity modifier is i) an ethylene-propylene based olefin copolymer or ii) a diene-based copolymer or homopolymer.

[0014] For purposes of this specification and the claims appended thereto, when a polymer is referred to as comprising an olefin, the olefin present in such polymer is the polymerized form of the olefin. For example, an ethylene-propylene based olefin copolymer is a polymer that is made from the olefin monomers (i.e., ethylene and propylene). In some embodiments, olefin polymers ("polyolefins" or "polyolefin polymers") such as poly-alpha-olefin polymers made from propylene or other C3 or higher alpha-olefin monomers, may include hydrocarbyl groups that are pendent from the polymer backbone chain.

[0015] In some embodiments, the viscosity modifier of the present disclosure may be linear in shape. In some embodiments, the viscosity modifier compatible with the present disclosure may be star-shaped. In some embodiments, the viscosity modifier compatible with the present disclosure may be a random copolymer wherein the monomer residues are located randomly.

[0016] The term "linear" means that the viscosity modifier has few, if any, long chain branches and has a g'vis value of about 0.97 or above, such as about 0.98 or above.

[0017] "Star-shaped" means that the viscosity modifier has a multifunctional center (e.g., polyalkenyl coupling agent nucleus) from which at least three polymer arms radiate. In some embodiments, each polymer arm may be chemically identical (homostars). In some embodiments, each polymer arm is not chemically identical (heteroarm stars). In some embodiments, the polymer arm includes linear copolymer or homopolymer. A star-shaped polymer can be hydrogenated to form a hydrogenated star-shaped polymer. A more detailed discussion of star-shaped polymers can be found in U.S. Pat. No. 4,116,917 and 4,141,847, which are hereby incorporated by reference.

1. Ethylene-propylene based olefin copolymer

[0018] According to an embodiment, the olefin copolymer is an ethylene-propylene based olefin copolymer (OCP). Ethylene-propylene based OCPs are generally produced by the polymerization of ethylene and propylene monomers.

[0019] The ethylene-propylene based olefin copolymer has a weight average molecular weight (Mw) ranging from about 10,000 g/mol to 100,000 g/mol such as from about 20,000 g/mol to 100,000 g/mol, 20,000 g/mol to 90,000 g/mol, 20,000 g/mol to 80,000 g/mol, 20,000 g/mol to 70,000 g/mol, 20,000 g/mol to 60,000 g/mol, 20,000 g/mol to 50,000 g/mol, 20,000 g/mol to 40,000 g/mol, 20,000 g/mol to 30,000 g/mol, 30,000 g/mol to 100,000 g/mol, 30,000 g/mol to 90,000 g/mol, 30,000 g/mol to 80,000 g/mol, 30,000 g/mol to 70,000 g/mol, 30,000 g/mol to 60,000 g/mol, 30,000 g/mol to 50,000 g/mol, 30,000 g/mol to 40,000 g/mol, 40,000 g/mol to 100,000 g/mol, 40,000 g/mol to 90,000 g/mol, 40,000 g/mol to 80,000 g/mol, 40,000 g/mol to 70,000 g/mol, 40,000 g/mol to 60,000 g/mol, 40,000 g/mol to 50,000 g/mol, 50,000 g/mol to 100,000 g/mol, 50,000 g/mol to 90,000 g/mol, 50,000 g/mol to 80,000 g/mol, 50,000 g/mol to 70,000 g/mol, 50,000 g/mol to 60,000 g/mol, 60,000 g/mol to 100,000 g/mol, 60,000 g/mol to 90,000 g/mol, 60,000 g/mol to 80,000 g/mol, 60,000 g/mol to 70,000 g/mol, 70,000 g/mol to 100,000 g/mol, 70,000 g/mol to 90,000 g/mol, 70,000 g/mol to 80,000 g/mol, 80,000 g/mol to 100,000 g/mol, 80,000 g/mol to 90,000 g/mol, or 90,000 g/mol to 100,000 g/mol.

[0020] In some preferred embodiments, the ethylene-propylene based olefin copolymer has a weight average molecular weight (Mw) ranging from about 30,000 g/mol to 80,000 g/mol, such as from 30,000 g/mol to 75,000 g/mol, 30,000 g/mol to 65,000 g/mol, 30,000 g/mol to 55,000 g/mol, 30,000 g/mol to 45,000 g/mol, 30,000 g/mol to 35,000 g/mol, 35,000 g/mol to 80,000 g/mol, 35,000 g/mol to 75,000 g/mol, 35,000 g/mol to 65,000 g/mol, 35,000 g/mol to 55,000 g/mol, 35,000 g/mol to 45,000 g/mol, 45,000 g/mol to 80,000 g/mol, 45,000 g/mol to 75,000 g/mol, 45,000 g/mol to 65,000 g/mol, 45,000 g/mol to 55,000 g/mol, 55,000 g/mol to 80,000 g/mol, 55,000 g/mol to 75,000 g/mol, 55,000 g/mol to 65,000 g/mol, 65,000 g/mol to 80,000 g/mol, 65,000 g/mol to 75,000 g/mol, or 75,000 g/mol to 80,000 g/mol.

[0021] In one embodiment, the ethylene-propylene copolymer is ethylene-based. According to an embodiment, the ethylene-based ethylene-propylene copolymer has a total ethylene content ranging from about 35 wt. % to about 70 wt. %, such as from about 35 wt. % to about 65 wt. %, from about 35 wt. % to about 60 wt. %, from about 35 wt. to about 55 wt. %, from about 35 wt. % to about 50 wt. %, from about 35 wt. % to about 45 wt. %, from about 35 wt. % to about 40 wt. %, from about 40 wt. % to about 70 wt. %, from about 40 wt. % to about 65 wt. %, from about 40 wt. % to about 60 wt. %, from about 40 wt. % to about 55 wt. %, from about 40 wt. % to about 50 wt. %, from about 40 wt. % to about 45 wt. %, from about 45 wt. % to about 70 wt. %, from about 45 wt. % to about 65 wt. %, from about 45 wt. % to about 60 wt. %, from about 45 wt. % to about 55 wt. %, from about 45 wt. % to about 50 wt. %, from about 50 wt. % to about 70 wt. %, from about 50 wt. % to about 65 wt. %, from about 50 wt. % to about 60 wt. %, from about 50 wt. % to about 55 wt. %, from about 55 wt. % to about 70 wt. %, from about 55 wt. % to about 65 wt. %, from about 55 wt. % to about 60 wt. %, from about 60 wt. % to about 70 wt. %, from about 60 wt. % to about 65 wt. %, or from about 65 wt. % to about 70 wt. % based on the total weight of the ethylene-based olefin copolymer. When a copolymer is said to have an “ethylene” content of 35 wt.% to 70 wt.%, it is understood that the monomer unit in the copolymer is derived from ethylene in the polymerization reaction and said derived units are present at 35 wt.% to 70 wt.%, based upon the weight of the copolymer.

[0022] In another embodiment, the ethylene-propylene based copolymer is propylene-based. According to another embodiment, the propylene-based ethylene-propylene copolymer has a total ethylene content of about 1 wt. % to about 20 wt. %, such as from about 1 wt. % to 19 wt. %, from about 1 wt. % to about 18 wt. %, from about 1 wt. % to about 17 wt. %, from about 1 wt. % to about 16 wt. %, from about 1 wt. % to about 15 wt. %, from about 1 wt. % to about 14 wt. %, from about 1 wt. % to about 13 wt. %, from about 1 wt. % to about 12 wt. %, from about 1 wt. % to about 11 wt. %, from about 1 wt. % to about 10 wt. %, from about 1 wt. % to about 9 wt. %, from about 1 wt. % to about 8 wt. %, from about 1 wt. % to about 7 wt. %, from about 1 wt. % to about 6 wt. %, from about 1 wt. % to about 5 wt. %, from about 1 wt. % to about 4 wt. %, from about 1 wt. % to about 3 wt. %, from about 1 wt. % to about 2 wt. %, from about 2 wt. % to about 19 wt. %, from about 2 wt. % to about 18 wt. %, from about 2 wt. % to about 17 wt. %, from about 2 wt. % to about 16 wt. %, from about 2 wt. % to about 15 wt. %, from about 2 wt. % to about 14 wt. %, from about 2 wt. % to about 13 wt. %, from about 2 wt. % to about 12 wt. %, from about 2 wt. % to about 11 wt. %, from about 2 wt. % to about 10 wt. %, from about 2 wt. % to about 9 wt. %, from about 2 wt. % to about 8 wt. %, from about 2 wt. % to about 7 wt. %, from about 2 wt. % to about 6 wt. %, from about 2 wt. % to about 5 wt. %, from about 2 wt. % to about 4 wt. %, from about 2 wt. % to about 3 wt. %, from about 3 wt. % to about 20 wt. %, from about 3 wt. % to about 19 wt. %, from about 3 wt. % to about 18 wt. %, from about 3 wt. % to about 17 wt. %, from about 3 wt. % to about 16 wt. %, from about 3 wt. % to about 15 wt. %, from about 3 wt. % to about 14 wt. %, from about 3 wt. % to about 13 wt. %, from about 3 wt. % to about 12 wt. %, from about 3 wt. % to about 11 wt. %, from about 3 wt. % to about 10 wt. %, from about 3 wt. % to about 10 wt. %, from about 3 wt. % to about 9 wt. %, from about 3 wt. % to about 8 wt. %, from about 3 wt. % to about 7 wt. %, from about 3 wt. % to about 6 wt. %, from about 3 wt. % to about 5 wt. %, from about 3 wt. % to about 4 wt. %, from about 4 wt. % to about 20 wt. %, from about 4 wt. % to about 19 wt. %, from about 4 wt. % to about 18 wt. %, from about 4 wt. % to about 17 wt. %, from about 4 wt. % to about 16 wt.

%, from about 4 wt. % to about 15 wt. %, from about 4 wt. % to about 14 wt. %, from about 4 wt. % to about 13 wt. %, from about 4 wt. % to about 12 wt. %, from about 4 wt. % to about 11 wt. %, from about 4 wt. %, to about 10 wt. %, from about 4 wt. % to about 9 wt. %, from about 4 wt. % to about 8 wt. %, from about 4 wt. % to about 7 wt. %, from about 4 wt. % to about 6 wt. %, from about 4 wt. %, to about 5 wt. %, from about 5 wt. % to about 20 wt. %, from about 5 wt. % to about 19 wt. %, from about 5 wt. % to about 18 wt. %, from about 5 wt. % to about 17 wt. %, from about 5 wt. % to about 16 wt. %, from about 5 wt. % to about 15 wt. %, from about 5 wt. % to about 14 wt. %, from about 5 wt. % to about 13 wt. %, from about 5 wt. % to about 12 wt. %, from about 5 wt. % to about 11 wt. %, from about 5 wt. % to about 10 wt. %, from about 5 wt. % to about 9 wt. %, from about 5 wt. % to about 8 wt. %, from about 5 wt. % to about 7 wt. %, from about 5 wt. % to about 6 wt. %, from about 6 wt. % to about 20 wt. %, from about 6 wt. % to about 19 wt. %, from about 6 wt. % to about 18 wt. %, from about 6 wt. % to about 17 wt. %, from about 6 wt. % to about 16 wt. %, from about 6 wt. % to about 15 wt. %, from about 6 wt. % to about 14 wt. %, from about 6 wt. % to about 13 wt. %, from about 6 wt. % to about 12 wt. %, from about 6 wt. % to about 11 wt. %, from about 6 wt. % to about 10 wt. %, from about 6 wt. % to about 10 wt. %, from about 6 wt. % to about 9 wt. %, from about 6 wt. % to about 8 wt. %, from about 6 wt. % to about 7 wt. %, from about 7 wt. % to about 20 wt. %, from about 7 wt. % to about 19 wt. %, from about 7 wt. % to about 18 wt. %, from about 7 wt. % to about 17 wt. %, from about 7 wt. % to about 16 wt. %, from about 7 wt. % to about 16 wt. %, from about 7 wt. % to about 15 wt. %, from about 7 wt. % to about 14 wt. %, from about 7 wt. % to about 13 wt. %, from about 7 wt. % to 12 wt. %, from about 7 wt. % to about 11 wt. %, from about 7 wt. % to about 10 wt. %, from about 7 wt. % to about 9 wt. %, from about 7 wt. % to about 8 wt. %, from about 8 wt. % to about 20 wt. %, from about 8 wt. % to about 19 wt. %, from about 8 wt. % to about 18 wt. %, from about 8 wt. % to about 17 wt. %, from about 8 wt. % to about 16 wt. %, from about 8 wt. % to about 15 wt. %, from about 8 wt. % to about 14 wt. %, from about 8 wt. % to about

13 wt. %, from about 8 wt. % to about 12 wt. %, from about 8 wt. % to about 12 wt. %, from about 8 wt. % to about 11 wt. %, from about 8 wt. % to about 10 wt. %, from about 8 wt. % to about 9 wt. %, from about 9 wt. % to about 20 wt. %, from about 9 wt. % to about 19 wt. %, from about 9 wt. % to about 18 wt. %, from about 9 wt. % to about 17 wt. %, from about 9 wt. % to about 16 wt. %, from about 9 wt. % to about 15 wt. %, from about 9 wt. % to about 14 wt. %, from about 9 wt. % to about 13 wt. %, from about 9 wt. % to about 12 wt. %, from about 9 wt. % to about 11 wt. %, from about 9 wt. % to about 10 wt. %, from about 10 wt. % to about 20 wt. %, from about 10 wt. % to about 19 wt. %, from about 10 wt. % to about 18 wt. %, from about 10 wt. % to about 17 wt. %, from about 10 wt. % to about 16 wt. %, from about 10 wt. % to about 16 wt. %, from about 10 wt. % to about 15 wt. %, from about 10 wt. % to about 14 wt. %, from about 10 wt. % to about 13 wt. %, from about 10 wt. % to about 12 wt. %, from about 10 wt. % to about 11 wt. %, from about 11 wt. % to about 20 wt. %, from about 11 wt. % to about 19 wt. %, from about 11 wt. % to about 18 wt. %, from about 11 wt. % to about 17 wt. %, from about 11 wt. % to about 16 wt. %, from about 11 wt. % to about 15 wt. %, from about 11 wt. % to about 14 wt. %, from about 11 wt. % to about 13 wt. %, from about 11 wt. % to about 12 wt. %, from about 12 wt. % to about 20 wt. %, from about 12 wt. % to about 19 wt. %, from about 12 wt. % to about 18 wt. %, from about 12 wt. % to about 17 wt. %, from about 12 wt. % to about 16 wt. %, from about 12 wt. % to about 15 wt. %, from about 12 wt. % to about 14 wt. %, from about 12 wt. % to about 13 wt. %, from about 13 wt. % to about 20 wt. %, from about 13 wt. % to about 19 wt. %, from about 13 wt. % to about 18 wt. %, from about 13 wt. % to about 17 wt. %, from about 13 wt. % to about 16 wt. %, from about 13 wt. % to about 15 wt. %, from about 13 wt. % to about 14 wt. %, from about 14 wt. % to about 20 wt. %, from about 14 wt. % to about 19 wt. %, from about 14 wt. % to about 18 wt. %, from about 14 wt. % to about 17 wt. %, from about 14 wt. % to about 16 wt. %, from about 14 wt. % to about 15 wt. %, from about 15 wt. % to about 20 wt. %, from about 15 wt. % to about 19 wt. %,

from about 15 wt. % to about 18 wt. %, from about 15 wt. % to about 17 wt. %, from about 15 wt. % to about 16 wt. %, from about 16 wt. % to about 20 wt. %, from about 16 wt. % to about 19 wt. %, from about 16 wt. % to about 18 wt. %, from about 16 wt. % to about 18 wt. %, from about 16 wt. % to about 17 wt. %, from about 17 wt. % to about 20 wt. %, from about 17 wt. % to about 19 wt. %, from about 17 wt. % to about 18 wt. %, from about 18 wt. % to about 20 wt. %, from about 18 wt. % to about 19 wt. %, or from about 19 wt. % to about 20 wt. % based on the total weight of the ethylene-based olefin copolymer.

[0023] In some preferred embodiments, the propylene-based ethylene-propylene copolymer has an ethylene content ranging from 4 to 10 wt. %. In some preferred embodiments, the propylene-based ethylene-propylene copolymer has an ethylene content ranging from 6.5 to 8.5 wt. %.

[0024] The ethylene-propylene based olefin copolymer can be prepared by any compatible polymerization process. For example, the polymerization may proceed in a homogeneous, bulk, solution (including supercritical) phase, slurry- and gas-phase type reaction.

[0025] A solution polymerization means a polymerization process in which the monomers are dissolved in a liquid polymerization medium, such as an inert solvent or monomer(s) or their blends. A solution polymerization can be homogeneous. A homogeneous polymerization is one where the polymer product is dissolved in the polymerization medium. Such systems are not turbid as described in J. Vladimir Oliveira, C. Dariva and J. C. Pinto, Ind. Eng. Chem. Res., 2000, Vol. 29, p. 4627. A bulk polymerization means a polymerization process in which the monomers and/or comonomers being polymerized are used as a solvent or diluent using little or no inert solvent as a solvent or diluent. A small fraction of inert solvent might be used as a carrier for catalyst and scavenger. A bulk polymerization system contains less than about 25 wt. % of inert solvent or diluent, such as less than about 10 wt.%, such as less than about 1 wt.%, such as about 0 wt. %.

[0026] In some embodiments, the polymerization process can be run in a batch, semi-batch or continuous mode. Moreover, the polymerization process may proceed in systems with single reactor or multiple reactors (in series and/or in parallel configurations).

[0027] Suitable diluents/solvents for polymerization include non-coordinating, inert liquids. Examples include straight and branched-chain hydrocarbons, such as isobutane, butane, pentane, isopentane, hexanes, isohexane, heptane, octane, dodecane, and mixtures thereof; cyclic and alicyclic hydrocarbons, such as cyclohexane, cycloheptane, methylcyclohexane, methylcycloheptane, and mixtures thereof, such as can be found commercially (Isopar™); perhalogenated hydrocarbons, such as perfluorinated C4-C10 alkanes, chlorobenzene, and aromatic and alkylsubstituted aromatic compounds, such as benzene, toluene, mesitylene, and xylene. Suitable solvents also include liquid olefins which may act as monomers or comonomers including ethylene, propylene, 1-butene, 1-hexene, 1-pentene, 3-methyl-1-pentene, 4-methyl-1-pentene, 1-octene, 1-decene, and mixtures thereof. In at least one embodiment, aliphatic hydrocarbon solvents are used as the solvent, such as isobutane, butane, pentane, isopentane, hexanes, isohexane, heptane, octane, dodecane, and mixtures thereof; cyclic and alicyclic hydrocarbons, such as cyclohexane, cycloheptane, methylcyclohexane, methylcycloheptane, and mixtures thereof. In at least one embodiment, the solvent is not aromatic, such as aromatics are present in the solvent at less than about 1 wt%, such as less than about 0.5 wt%, such as less than about 0 wt% based upon the weight of the solvents.

[0028] Suitable polymerizations can be run at any temperature and/or pressure suitable to obtain the desired polymers. In at least one embodiment, temperatures and/or pressures include a temperature in the range of from about 0°C to about 300°C, such as about 30°C to about 200°C, such as about 60°C to about 195°C, such as from about 75°C to about 190°C, such as from about 80°C to about 100°C; and at a pressure in the range of from about 0.35 MPa to about 1500 MPa, such as from about 0.45 MPa to about 100 MPa, such as from about 0.5 MPa to about 50 MPa, such as from about 1.7 MPa to about 30 MPa. In at least one embodiment, suitable run time of the polymerization reaction is up to about 300 minutes, such as in the range of from about 0 to about 250 minutes, such as from about 0 to about 120 minutes, such as in the range of from about 0 to about 30 minutes, such as about 0 to about 10 minutes.

[0029] In some embodiments, the olefin copolymers of this disclosure are obtained by visbreaking in order to controllably reduce the molecular weight. Visbreaking typically involves an extruder and may involve visbreaking agents. The process is described in, for example, U.S. Patent Pub. No. 2021024789, and U.S. Pat. No. 3,697,429; 5,391,617; 6,753,381; 5,837,773; 5,068,047, which are hereby incorporated by reference.

Additional monomers

[0030] In some embodiments, the polymerization of ethylene-propylene based olefin copolymers can include at least one additional monomer. Suitable examples of the at least one additional monomer include substituted or unsubstituted C2 to C40 alpha olefins, such as C2 to C20, C2 to C15, C2 to C10, C5 to C40, C5 to C20, C5 to C10, C10 to C40, C10 to C20, or C10 to C15 alpha olefins. The C2 to C40 olefin monomers may be linear, branched, or cyclic. The C2 to C40 cyclic olefins may be strained or unstrained, monocyclic, or polycyclic, and may optionally include heteroatoms and/or one or more functional groups.

[0031] Specific examples of the additional monomers include butene, pentene, hexene, heptene, octene, nonene, decene, undecene, dodecene, norbornene, norbornadiene, dicyclopentadiene, cyclopentene, cycloheptene, cyclooctene, cyclooctadiene (e.g., 1,5-cyclooctadiene), cyclododecene, 7-oxanorbornene, 7-oxanorbornadiene, substituted derivatives thereof, and isomers thereof. Derivatives include, for example, 1-hydroxy-4-cyclooctene, 1-acetoxy-4-cyclooctene, 5-methylcyclopentene, and dicyclopentadiene.

2. Diene-based Copolymer/Homopolymer

[0032] In some embodiments, the viscosity modifier is a diene-based homopolymer or copolymer. Copolymers can be derived from the polymerization of two or more conjugated diene monomers. Homopolymers can be derived from the polymerization of a single conjugated diene monomer. In some embodiments, the diene-based copolymer or homopolymer is at least partially or fully hydrogenated.

[0033] Conjugated diene monomers contain at least two double bonds located in conjugation with each other such as in a 1,3 relationship. Conjugated diene monomers compatible with this disclosure include conjugated dienes containing from 4 to 20 carbon atoms such as, for example, 1,3-butadiene, isoprene, piperylene, 4-methylpenta-1,3-diene, 2-phenyl-1,3-butadiene, 3,4-dimethyl-1,3-hexadiene and 4,5-diethyl-1,3-octadiene. In some embodiments, the conjugated diene monomers may be incorporated in more than one configuration. For example, isoprene monomers can be incorporated as 1,4- or 3,4-units, or mixtures thereof. In some embodiments, the majority of the isoprene is incorporated into the polymer as 1,4-units, such as greater than about 60 mass %, more preferably greater than about 80 mass %, such as about 80 to 100 mass %, most preferably greater than about 90 mass %, such as about 93 mass % to 100 mass %.

[0034] Similarly, butadiene monomers can be incorporated as 1,2- or 1,4- units. In some embodiments, the majority of butadiene is incorporated into the polymer as 1,4 units such as at least about 70 mass %, such as at least about 75 mass %, at least about 80 mass %, at least about 85 mass %, at least about 90, such as 95 to 100 mass %.

Linear Diblock Copolymer (Styrene Hydrogenated Diene)

[0035] In some embodiments, the viscosity modifier is a linear polymer, such as a linear diblock copolymer.

[0036] A non-limiting example of a linear diblock copolymer is polymer comprising one block derived predominantly from a vinyl aromatic hydrocarbon monomer and another block derived predominantly from the one or more conjugated diene monomers. An example of this is a styrene hydrogenated diene (sometimes referred to as "hydrogenated styrene diene"). Useful vinyl aromatic hydrocarbon monomers include those containing from 8 to 16 carbon atoms such as, for example, styrene, alkyl-substituted styrene, alkoxy-substituted styrene, vinyl naphthalene, and alkyl-substituted vinyl naphthalene. The amount of vinyl aromatic content of the copolymer can be between 5% and 40% by mass of the copolymer.

[0037] Diblock copolymers generally have two distinct blocks, wherein each block is different from the adjacent block. For example, a diblock copolymer may comprise 2 homopolymer subunits linked by covalent bond(s). In some instances, the diblock copolymer may require a non-repeating subunit.

[0038] Diblock structures are consistent with, among others, the following generalized formula: $–(A)_x-(B)_y-$ wherein x and y are integers such that the diblock polymer has a molecular weight consistent with the disclosure herein. Non-limiting examples of diblock structures include the following: -A-A-B-B- or -A-A-B- or -A-B-B- wherein A and B represent repeating units.

[0039] Linear copolymers compatible with the present disclosure may have a weight average molecular weight ranging from 40,000 g/mol and 150,000 g/mol, such as from 40,000 g/mol to 125,000 g/mol, from 40,000 g/mol to 100,000 g/mol, from 40,000 g/mol to 75,000 g/mol, from 40,000 g/mol to 50,000 g/mol, from 50,000 g/mol to 150,000 g/mol, from 50,000 g/mol to 125,000 g/mol, from 50,000 g/mol to 100,000 g/mol, from 50,000 g/mol to 75,000 g/mol, from 75,000 g/mol to 150,000 g/mol, from 75,000 g/mol to 1250,000 g/mol, from 75,000 g/mol to 100,000 g/mol, from 100,000 g/mol to 150,000 g/mol, from 100,000 g/mol to 125,000 g/mol, or from 125,000 g/mol to 150,000 g/mol. The term "weight average molecular weight", as used herein, refers to the weight average weight as measured by Gel Permeation Chromatography ("GPC") with a polystyrene standard, subsequent to hydrogenation.

[0040] In some preferred embodiments, linear copolymer may have a weight average molecular weight ranging from 40,000 g/mol to 80,000 g/mol, such as 40,000 to 75,000, 40,000 g/mol to 65,000 g/mol, 40,000 g/mol to 55,000 g/mol, 40,000 g/mol to 45,000 g/mol, 45,000 g/mol to 80,000 g/mol, 45,000 g/mol to 75,000 g/mol, 45,000 g/mol to 65,000 g/mol, 45,000 g/mol to 55,000 g/mol, 55,000 g/mol to 80,000 g/mol, 55,000 g/mol to 75,000 g/mol, 55,000 g/mol to 65,000 g/mol, 65,000 g/mol to 80,000 g/mol, or 65,000 g/mol to 75,000 g/mol.

[0041] Useful block copolymers include those prepared in bulk, suspension, solution or emulsion. Polymerization can be accomplished using free-radical, cationic and anionic initiators or polymerization catalysts, such as transition metal catalysts used for Ziegler-Nana and metallocene type (also referred to as "single-site") catalysts.

[0042] Non-limiting examples of linear diblock copolymers include copolymer comprising a polystyrene block and a block derived from conjugated diene monomers, such as isoprene, butadiene, or a mixture thereof. In some embodiments, the linear diblock copolymer may be at least partially hydrogenated.

[0043] In some embodiments, the block derived from a vinyl aromatic hydrocarbon monomer (e.g., styrene) in the linear diblock copolymer may be present in an amount of up to 35%, such as up to 25%, such as from 5 to 25%, by mass based on the total mass of the linear diblock copolymer. In some embodiments, the block derived from the conjugated diene monomers is present in an amount of greater than 65%, even more preferably greater than or equal to 75%, most preferably 75 to 95%, by mass based on the total mass of the linear diblock copolymer.

[0044] Examples of commercially available styrene/hydrogenated diene linear diblock copolymers include Infineum SV140™, Infineum SV150™, and Infineum SV160™, available from Infineum USA L.P. and Infineum UK Ltd.; LZ® 7408A, available from The Lubrizol Corporation; and Septon 1001™ and Septon 1020™, available from Kuraray Company of America (Kuraray Group). Suitable styrene/1,3-butadiene hydrogenated block copolymers are sold under the tradename Glissoviscal™ by BASF.

Star-Shaped Polymer

[0045] In some embodiments, the viscosity modifier of the present disclosure is star-shaped wherein the star-shaped polymer is at least partially hydrogenated. In some embodiments, the star-shaped polymer comprises or is derived, at least in part, from the polymerization of one or more conjugated diene monomers. The star-shaped polymer includes multiple arms extending from a central core. In some embodiments, the polymer arms include the diene-based copolymer or homopolymer.

[0046] The arms of the star-shaped polymer may be a homopolymer derived from the polymerization of a single conjugated diene monomer, such as isoprene or 1,3-butadiene.

[0047] Alternatively, the arms of the star-shaped polymer may be a copolymer derived from the polymerization of two or more conjugated diene monomers, such as an isoprene and 1,3-butadiene copolymer, or a copolymer derived essentially from the polymerization of one or more conjugated diene monomers and a vinyl aromatic hydrocarbon monomer, such as an isoprene-styrene copolymer, a butadiene-styrene copolymer, or an isoprene-butadiene-styrene copolymer.

[0048] The arms of the star-shaped polymer can be formed via anionic polymerization to form a living polymer. Anionic polymerization has been found to provide polymers having a narrow molecular weight distribution (Mw/Mn), such as a molecular weight distribution of less than about 1.2

[0049] The star-shaped polymers useful in the practice of the present invention can have a weight average molecular weight of from about 300,000 g/mol to 1,000,000 g/mol,such as from 300,000 g/mol to 900,000 g/mol, 300,000 g/mol to 800,000 g/mol, 300,000 g/mol to 700,000 g/mol, 300,000 g/mol to 600,000 g/mol, 300,000 g/mol to 500,000 g/mol, 300,000 g/mol to 400,000 g/mol, 400,000 g/mol to 1,000,000 g/mol, 400,000 g/mol to 900,000 g/mol, 400,000 g/mol to 800,000 g/mol, 400,000 g/mol to 700,000 g/mol, 400,000 g/mol to 600,000 g/mol, 400,000 g/mol to 500,000 g/mol, 500,000 g/mol to 1,000,000 g/mol, 500,000 g/mol to 900,000 g/mol, 500,000 g/mol to 800,000 g/mol, 500,000 g/mol to 700,000 g/mol, 500,000 g/mol to 600,000 g/mol, 600,000 g/mol to 1,000,000 g/mol, 600,000 g/mol to 900,000 g/mol, 600,000 g/mol to 800,000 g/mol, 600,000 g/mol to 700,000 g/mol, 700,000 g/mol to 1,000,000 g/mol, 700,000 g/mol to 900,000 g/mol, 700,000 g/mol to 800,000 g/mol, 800,000 g/mol to 1,000,000 g/mol, 800,000 g/mol to 900,000 g/mol, or 900,000 g/mol to 1,000,000 g/mol. The term "weight average molecular weight", as used herein, refers to the weight average weight as measured by Gel Permeation Chromatography ("GPC") with a polystyrene standard, subsequent to hydrogenation.

Hydrogenated Star-Shaped Polymers

[0050] Hydrogenation of star-shaped polymers involves hydrogenating olefinic unsaturation. This process is generally known and described in, for example, U.S. Patent No. 4,141,847, which is hereby incorporated by reference.

[0051] The degree of hydrogenation may vary. In some embodiments, at least 80% of the original olefinic unsaturation is hydrogenated, such as at least 85%, at least 90%, at least 95%, or at least 98%.

[0052] Hydrogenation is typically carried out in a suitably inert solvent using a hydrogenation catalyst such as copper or molybdenum compound and noble-metal compounds.

[0053] Examples of commercially available styrene hydrogenated diene star polymers include Infineum SV200™, Infineum SV250™, Infineum SV260™, Infineum SV270™, Infineum SV300™, from Infineum USA L.P. and Infineum UK Ltd.; LZ® 5994A, available from The Lubrizol Corporation.

Lubricating Oil Compositions

[0054] The low SSI copolymer or homopolymer of the present disclosure may be useful as additives in lubricating oil. The concentration of the viscosity modifier in the lubricating oil composition may range from 0.01 to 5 wt. % (e.g., 0.5 to 5 wt. %, 0.5 to 4 wt. %, 0.5 to 3 wt. %, 0.5 to 2 wt. %, 0.5 to 1 wt. %, 1 to 5 wt. %, 1 to 4 wt. %, 1 to 3 wt. %, 1 to 2 wt. %, 2 to 5 wt. %, 2 to 4 wt. %, 2 to 3 wt. %, 3 to 5 wt. %, 3 to 4 wt. %, 4 to 5 wt. %, etc.), based on the total weight of the lubricating oil composition.

[0055] The oil of lubricating viscosity (sometimes referred to as “base stock” or “base oil”) is the primary liquid constituent of a lubricant, into which additives and possibly other oils are blended, for example to produce a final lubricant (or lubricant composition). A base oil, which is useful for making concentrates as well as for making lubricating oil compositions therefrom, may be selected from natural (vegetable, animal or mineral) and synthetic lubricating oils and mixtures thereof.

[0056] Definitions for the base stocks and base oils in this disclosure are the same as those found in American Petroleum Institute (API) Publication 1509 Twenty-First Edition (February 2022). Group I base stocks contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group II base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group III base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120 using the test methods specified in Table E-1. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0057] Natural oils include animal oils, vegetable oils (e.g., castor oil and lard oil), and mineral oils. Animal and vegetable oils possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils derived from coal or shale are also useful. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrorefined, or solvent extracted.

[0058] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers). Polyalphaolefin (PAO) oil base stocks are commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C_8 to C_{14} olefins, e.g., C_8, C_{10}, C_{12}, C_{14} olefins or mixtures thereof, may be utilized.

[0059] Other useful fluids for use as base oils include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance characteristics.

[0060] Non-conventional or unconventional base stocks/base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as isomerate/isodewaxate base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks.

[0061] Base oils for use in the lubricating oil compositions of present disclosure are any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils, and mixtures thereof, preferably API Group II, Group III, Group IV, and Group V oils, and mixtures thereof, more preferably the Group III to Group V base oils due to their exceptional volatility, stability, viscometric and cleanliness features.

[0062] Typically, the base oil will have a kinematic viscosity at 100°C (ASTM D445) in a range of 1.4 to 20 mm^2/s (e.g., 3 to 12 mm^2/s, 4 to 10 mm^2/s, or 4.5 to 8 mm^2/s).

[0063] The present lubricating oil compositions also contain conventional lubricant additives for imparting auxiliary functions to give a finished lubricating oil composition in which these additives are dispersed or dissolved. For example, the lubricating oil compositions can be blended with antioxidants, dispersants such as ashless dispersants, anti-wear agents, detergents such as metal detergents, rust inhibitors, dehazing agents, demulsifying agents or demulsifiers, friction modifiers, metal deactivating agents, pour point depressants, viscosity modifiers, antifoaming agents or defoamers, co-solvents, package compatibilizers, corrosion-inhibitors, dyes, extreme pressure agents, oiliness improver, and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, can be employed for the preparation of the lubricating oil compositions of the invention by the usual blending procedures.

[0064] 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 an ashless dispersant, a functionally effective amount of this ashless dispersant would be an amount sufficient to impart the desired dispersancy characteristics to the lubricant. Generally, the concentration of each of these additives, when used, may range, unless otherwise specified, from about 0.001 to about 20 wt. %, such as about 0.01 to about 10 wt. %, about 0.1 to about 5 wt. %, and about 1 to about 4 wt. %.

[0065] The lubricating oil comprising the polymer composition can have a kinematic viscosity at 100°C, as measured by ASTM D445, of at least 2 cSt (e.g., at least 3 cSt, at least 4 cSt, at least 6 cSt, at least 8 cSt, at least 10 cSt, at least 12 cSt, or at least 15 cSt). Likewise, the lubricating oil comprising the polymer composition can have a kinematic viscosity at 40°C, as measured by ASTM D445, of 200 cSt or less (e.g., 150 cSt or less, 100 cSt or less, 50 cSt or less, 40 cSt or less, 30 cSt or less, or even 20 cSt or less).

[0066] In one embodiment, the lubricating oil composition of this disclosure can be identified by viscosity standards of the Society of Automotive Engineers (SAE) for automotive lubricants. As one example, the lubricating composition is identified by the SAE J300 standard, a viscosity classification for engine oils. The J300 viscosity grades of this disclosure are summarized in Table A.

Table A

SAE Viscosity Grade	Low Temp. (°C) Cranking Viscosity(1), mPa-s Max	Low Temp. (°C) Pumping Viscosity(2), mPa-s Max with No Yield Stress	Low Shear Rate Kinematic Viscosity(3) (mm^2/s) at 100°C Min	Low Shear Rate Kinematic Viscosity(3) (mm^2/s) at 100°C Max	High Shear Rate Viscosity(4), (mPa-s) at 150°C Min
0W	6200 at -35	60000 at -40	3.8	-	-
5W	6600 at -30	60000 at -35	3.8	-	-
10W	7000 at -25	60000 at -30	4.1	-	-
15W	7000 at -20	60000 at -25	5.6	-	-
20W	9500 at -15	60000 at -20	5.6	-	-
25W	13000 at -10	60000 at -15	9.3	-	-
8	-	-	4.0	<6.1	1.7
12	-	-	5.0	<7.1	2.0
16	-	-	6.1	<8.2	2.3
20	-	-	6.9	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	3.5(5)
40	-	-	12.5	<16.3	3.7(6)
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

(1) ASTM D5293

(2) ASTM D4684

(3) ASTM D445

(4) ASTM D4683, ASTM D4741, ASTM D5481 or CEC L-36-90

(5) For 0W-40, 5W-40 and 10W-40 grades

(6) For 15W-40, 20W-40, 25W-40 and 40 grades

[0067] When lubricating oil compositions contain one or more of the components discussed above, the additive(s) are blended into the composition in an amount sufficient for it to perform its intended function. Typical amounts of such additives useful in the present invention are shown in Table B below.

TABLE B

Typical Amounts of Various Lubricating Oil Components	
Component	**Approximate wt%**
Detergents	0.01 – 8
Dispersants	0.1 – 20
Antiwear agents	0.01 – 6
Friction Modifiers	0 – 15
Antioxidants	0.01 – 5
Pour Point Depressants	0.01 – 5
Anti-foam Agents	0.001 – 1
Corrosion Inhibitors	0.001 – 5

EXAMPLES

[0068] Lubricating oils containing low SSI viscosity modifier were tested for fuel economy performance and compared against lubricating oils containing high SSI viscosity modifiers.

[0069] Tables 1 and 2 below summarize the contents of Comparative Examples 1-3 and Inventive Examples 1-5 as well as results of fuel economy tests using 3 different engines. The Fuel Economy Improvement (FEI) against the baseline oil (sometimes referred to as “reference oil”) is calculated using fuel consumption or specific fuel consumption measured for each example or comparative example. The baseline oil was used to eliminate the effect of drift in engines during testing.

[0070] Each sample contains a viscosity modifier in the form of Polymer A, B, C, D, E, or F defined herein.

Polymer A: 24 SSI ethylene-based ethylene-propylene copolymer with Mw of about 83,000 g/mol

Polymer B: 24 SSI ethylene-based ethylene-propylene copolymer with Mw of about 135,000 g/mol

Polymer C: 13 SSI propylene-based ethylene-propylene copolymer with Mw of about 63,000 g/mol

Polymer D: 8 SSI propylene-based ethylene-propylene copolymer with Mw of about 53,000 g/mol

Polymer E: 6 SSI ethylene-based ethylene-propylene copolymer with Mw about of 44,000 g/mol obtained by visbreaking

Polymer F: 5 SSI star-shaped hydrogenated isoprene polymer with Mw of about 500,000 g/mol (commercially available as SV 200)

[0071] Referring to Table 1, the comparative and inventive examples contain 17.06% of additive package, 0.3 wt% of pour point depressant, and remainder Gr III/IV base oil to make 0W-20 oil. Oils have been blended to the same HTHS 150°C of 2.6 cP. These SAE 0W-20 oils tested in 2 different engines with modal and transient driving cycles, representative of hydrodynamic, mixed and boundary conditions.

DD13 Fuel Economy Test (Modal Mode)

[0072] The DD13 modal mode fuel economy test quantifies fuel efficiency benefit of an engine over a prescribed test cycle as set forth in the Heavy-Duty Supplemental Emissions Test (SET) which is an engine dynamometer test introduced by U.S. Environmental Protection Agency (EPA). The standard test cycle consists of 13 discrete modes (i.e., specific engine load and RPM) run for seven minutes to stabilize temperatures and pressures to a high level of consistency. The cycle is repeated a total of eight times with the last seven used for statistical evaluations of operation. A flush process between lubricants ensures no carryover occurs. The test fixture is a modified Detroit diesel DD13 engine. FEI results are given as a percentage improvement in fuel consumption between a baseline oil (SAE 10W-30) and candidate lubricants. Weighting Factor B (developed to account for downspeeding trend in heavy-duty engines) of the SET was used.

OM501LA Fuel Economy Test (WHTC)

[0073] The OM501LA FE test is a World Harmonized Transient Cycle (WHTC) test using OM501 LA Daimler engine. WHTC test is a transient engine dynamometer schedule defined by the proposed Global Technical Regulation (GTR) developed by United Nations Economic Commission for Europe Group of Rapporteurs on Pollution and Energy (UN ECE GRPE) group. The test procedure for WHTC can be found in GTR No. 4

[0074] Two representative test cycles, a transient test cycle (WHTC) with both cold and hot start requirements, have been created covering typical driving conditions in the EU, USA, Japan and Australia. WHTC testing requirements were adopted for the first time by the Euro VI emission regulation for heavy-duty engines.

[0075] The WHTC is a transient test of 1800 s duration, with several motoring segments. The test procedure consists of a cold start test following either natural or forced cool-down of the engine, a hot soak period and a hot start test. FEI results are given as a percentage improvement in fuel consumption between a baseline oil (SAE 10W-40) and candidate lubricants.

Table 1. SAE 0W-20 oils made with viscosity modifiers A, E and F, tested in 2 different engines (DD13 and OM 501 LA) with modal or transient driving cycles.

	Comparative Ex 1	Inventive Ex 1	Inventive Ex 2
Polymer A	0.38 wt%		
Polymer E		0.52 wt %	
Polymer F			0.45 wt %
KV 100 (cSt)	7.94	7.58	8.16
HTHS 150 (cP)	2.62	2.56	2.63
FEI-Modal Mode (%)	0.79	0.86	1.01
FEI-WHTC (%)	1.41	1.51	1.47

Referring to Table 2 below, the comparative and inventive examples contain 17.06% of additive package, 0.3 wt% of pour point depressant, and remainder Gr III/IV base oil to make 5W-30 oil. Oils have been blended to comparable KV100 after 30 cycle Bosch of 9.3 cSt. Table 2 also summarizes the results of OM471 Fuel Economy Test.

OM471 Fuel Economy Test (WHTC)

[0076] The OM471 FE test is a World Harmonized Transient Cycle (WHTC) test using OM471 Daimler engine. WHTC test is a transient engine dynamometer schedule defined by the proposed Global Technical Regulation (GTR) developed by United Nations Economic Commission for Europe Group of Rapporteurs on Pollution and Energy (UN ECE GRPE) group. The test procedure for WHTC can be found in GTR No. 4.

[0077] Two representative test cycles, a transient test cycle (WHTC) with both cold and hot start requirements, have been created covering typical driving conditions in the EU, USA, Japan and Australia. WHTC testing requirements were adopted for the first time by the Euro VI emission regulation for heavy-duty engines.

[0078] The WHTC is a transient test of 1800 s duration, with several motoring segments. The test procedure consists of a cold start test following either natural or forced cool-down of the engine, a hot soak period and a hot start test. FEI results are given as a percentage improvement in fuel consumption between a baseline oil (SAE 10W-30) and candidate lubricants.

Table 2. SAE 5W-30 oils made with viscosity modifiers A, B, C, D and F, tested in engine (OM 471 LA) operated with transient driving cycles.

	Comparative Ex 2	Comparative Ex 3	Inventive Ex 3	Inventive Ex 4	Inventive Ex 5
Polymer A	0.83 wt %				
Polymer B		0.86 wt %			
Polymer C			1.00 wt %		
Polymer D				1.16 wt %	
Polymer F					0.72 wt %
KV 100 (cSt)	10.02	10.21	9.52	9.69	9.5
HTHS 150 (cP)	3.03	2.99	2.99	3.08	2.90
KV 100 after 30 cycles in Bosch (cSt)	9.31	9.36	9.22	9.37	9.48
FEI-WHTC (%)	0.68	0.61	0.99	0.91	1.10

[0079] Overall, the Fuel Economy Improvement (FEI) of the examples made with VM with low SSI show a clear benefit compared to comparative examples with higher SSI VMs.

[0080] All documents described herein are incorporated by reference herein, including any priority documents and/or testing procedures to the extent they are not inconsistent with this text. As is apparent from the foregoing general description and the specific embodiments, while forms of the present disclosure have been illustrated and described, various modifications can be made without departing from the spirit and scope of the present disclosure. Accordingly, it is not intended that the present disclosure be limited thereby.

[0081] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0082] The phrases, unless otherwise specified, "consists essentially of" and "consisting essentially of" do not exclude the presence of other steps, elements, or materials, whether or not, specifically mentioned in this specification, so long as such steps, elements, or materials, do not affect the basic and novel characteristics of the present disclosure, additionally, they do not exclude impurities and variances normally associated with the elements and materials used.

[0083] Likewise, the term “comprising” is considered synonymous with the term “including.” Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase “comprising,” it is understood that we also contemplate the same composition or group of elements with transitional phrases “consisting essentially of,” “consisting of,” “selected from the group of consisting of,” or “is” preceding the recitation of the composition, element, or elements and vice versa.

[0084] The terms "a" and "the" as used herein are understood to encompass the plural as well as the singular.

[0085] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[0086] The foregoing description of the disclosure illustrates and describes the present disclosure. Additionally, the disclosure shows and describes only the preferred embodiments but, as mentioned above, it is to be understood that the disclosure is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the relevant art. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

[0087] The embodiments described hereinabove are further intended to explain best modes known of practicing it and to enable others skilled in the art to utilize the disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the description is not intended to limit it to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.

CLAIMS

What is claimed is:

1. A method of improving fuel economy of an engine, the method comprising:

   lubricating the engine with a lubricating oil composition comprising:

   a) an oil of lubricating viscosity; and

   b) a viscosity modifier comprising an olefin copolymer or diene-based copolymer or homopolymer wherein the viscosity modifier has shear stability index of 15 or less;

   wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier of b).

2. The method of claim 1, wherein the lubricating oil composition is substantially free of poly alkyl methacrylate (PMA) viscosity modifier.

3. The method of claim 1, wherein the viscosity modifier is linear or star-shaped.

4. The method of claim 3, wherein the star-shaped diene polymer has a weight average molecular weight of about 300,000 g/mol to 1,000,000 g/mol.

5. The method of claim 1, wherein the olefin copolymer is an ethylene-propylene copolymer.

6. The method of claim 5, wherein the ethylene-propylene based copolymer has a weight average molecular weight of about 10,000 g/mol to about 100,000 g/mol.

7. The method of claim 5, wherein the ethylene-propylene based copolymer has an ethylene content of 35 to 70 wt % or 2 to 20 wt. %based on weight of the copolymer.

8. The method of claim 1, wherein the diene-based copolymer or homopolymer is hydrogenated.

9. The method of claim 1, wherein the viscosity modifier is a styrene hydrogenated diene copolymer.

10. The method of claim 1, wherein the improvement in fuel economy is determined according to Fuel Economy Improvement (FEI) as measured from World Harmonized Transient Cycle or Heavy-Duty Supplemental Emissions Test modal mode dynamometer testing.

11. A method of increasing the fuel economy of a diesel engine, the method comprising:

lubricating the diesel engine with a lubricating oil composition comprising:

a) an oil of lubricating viscosity; and

b) a viscosity modifier comprising an olefin copolymer or diene-based copolymer or homopolymer, wherein the viscosity modifier has shear stability index of 15 or less;

wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier of b).

12. The method of claim 11, wherein the lubricating oil composition is substantially free of poly alkyl methacrylate (PMA) viscosity modifier.

13. The method of claim 11, wherein the viscosity modifier is linear or star-shaped.

14. The method of claim 11, wherein the viscosity modifier is an ethylene-propylene based copolymer.

15. The method of claim 11, wherein the hydrogenated diene polymer has a weight average molecular weight of about 300,000 g/mol to 1,000,000 g/mol.

16. The method of claim 14, wherein the ethylene-propylene based copolymer has a weight average molecular weight of about 10,000 g/mol to about 100,000 g/mol.

17. The method of claim 14, wherein the ethylene-propylene based copolymer has an ethylene content of 35 to 70 wt % based on weight of the copolymer.

18. The method of claim 14, wherein the ethylene-propylene based copolymer has an ethylene content of 2 to 20 wt % based on weight of the copolymer.

19. The method of claim 11, wherein the hydrogenated diene polymer is a styrene hydrogenated diene copolymer.

20. The method of claim 11, wherein the improvement in fuel economy is determined according to Fuel Economy Improvement (FEI) as measured from World Harmonized Transient Cycle or Heavy-Duty Supplemental Emissions Test modal mode dynamometer testing.

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/055849

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10M143/04 C10M143/12

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/029892 A1 (YAMADA RYOU [JP]) 31 January 2013 (2013-01-31) paragraphs [0070], [0094]; examples 1,3; table 1 -----	1-3,5,7, 10
X	US 2012/190601 A1 (IKEDA SATOSHI [JP] ET AL) 26 July 2012 (2012-07-26) paragraphs [0095], [0155]; tables 2, 5 -----	1-3,5-7, 10-14, 16-18,20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 10 August 2023	Date of mailing of the international search report 13/10/2023
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Klaes, Daphne

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2023/055849

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
5-7, 14, 16-18(completely); 1-3, 10-13, 20(partially)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 5-7, 14, 16-18(completely); 1-3, 10-13, 20(partially)

   A method for improving fuel economy of a (diesel) engine, the method comprising lubricating the engine with a lubricating oil composiiton comprising a viscosity modifier b) comprising an olefin copolymer wherein the viscosity modifier has a shear stability index of 15 or less, wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier b).

   ---

2. claims: 4, 8, 9, 15, 19(completely); 1-3, 10-13, 20(partially)

   A method for improving fuel economy of a (diesel) engine, the method comprising lubricating the engine with a lubricating oil composiiton comprising a viscosity modifier b) comprising a diene copolymer or homopolymer wherein the viscosity modifier has a shear stability index of 15 or less, wherein the lubricating oil composition is substantially free of viscosity modifiers other than the viscosity modifier b).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2023/055849

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013029892 A1	31-01-2013	BR 112012023571 A2	02-08-2016
		CN 102782107 A	14-11-2012
		JP 5727713 B2	03-06-2015
		JP 2011195734 A	06-10-2011
		TW 201144427 A	16-12-2011
		US 2013029892 A1	31-01-2013
		WO 2011115265 A1	22-09-2011
US 2012190601 A1	26-07-2012	AU 2010298066 A1	10-05-2012
		BR 112012006950 A2	14-06-2016
		CA 2775584 A1	31-03-2011
		CN 102549126 A	04-07-2012
		EP 2483377 A1	08-08-2012
		JP 5584766 B2	03-09-2014
		JP 2013506036 A	21-02-2013
		KR 20120073285 A	04-07-2012
		US 2012190601 A1	26-07-2012
		WO 2011037585 A1	31-03-2011
		WO 2011038331 A1	31-03-2011