



(51) International Patent Classification:
C10M 107/10 (2006.01)

(21) International Application Number:
PCT/US2019/065651

(22) International Filing Date:
11 December 2019 (11.12.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/781,712 19 December 2018 (19.12.2018) US

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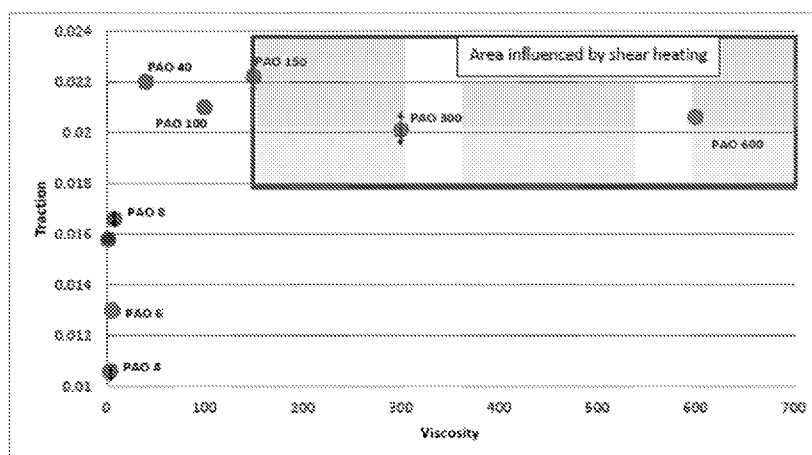
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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,

(54) Title: LUBRICANT COMPOSITIONS WITH IMPROVED WEAR CONTROL

Fig. 1



(57) Abstract: This disclosure provides a method for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces. The method involves using a lubricant composition in the mechanical component having sliding or rolling between contacting surfaces. The lubricant composition has a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend has at least one first base stock having a viscosity from 1 to 50 cSt at 40°C and at least one second base stock having viscosity from 100 to 2000 cSt at 40°C. The first base stock is present in an amount greater than 50 to 95 wt% of the base stock blend, and the second base stock is present in an amount from 5 to less than 50 wt% of the base stock blend. The second base stock is miscible with the first base stock.

MG, MK, MN, 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, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, 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, 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:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

LUBRICANT COMPOSITIONS WITH IMPROVED WEAR CONTROL**FIELD**

[0001] This disclosure relates to lubricating fluids and oil formulations which provide improved wear control. In particular, this disclosure relates to lubricant compositions, methods for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces, methods for controlling traction coefficient (T_c) of lubricant compositions, and methods for controlling film thickness of lubricant compositions. The lubricant compositions of this disclosure are useful as finished gear, transmission, engine or industrial lubricants.

BACKGROUND

[0002] Environmental regulations and increased energy cost have made improvement of energy efficiency one of the most prominent trends among equipment builders and end users of industrial and mobile equipment. Energy efficiency improvements come from modifications in mechanical design, use of advanced materials and changes in the way equipment is operated. Innovative solutions also come from the lubricant industry, as many of the energy loss mechanisms are related to lubrication.

[0003] One of the most prominent functions of a lubricant is keeping the moving mechanical parts apart. Full separation under load leads to a situation called elastohydrodynamic lubrication (EHL).

[0004] EHL is the mode of lubrication that exists in non-conforming concentrated contacts. Examples include the contact between meshing gear teeth used in hypoid axles, worm gears, etc. and between the components in a rolling element bearing. In these contacts the load is supported over a very small contact area which results in very high contact pressures. As lubricants are drawn into the contact zone by the movement of the component surfaces, the lubricant experiences an increase in pressure. Pressures on the order of 1 GPa and above are common in EHL contacts. Most lubricating oils exhibit a large increase in viscosity in response to higher pressures. It is this characteristic that results in the separation of the two surfaces in the contact zone.

[0005] If there is relative sliding between the two contacting surfaces in the central contact region, the lubricant is sheared under these high-pressure conditions. The shearing losses depend on how the oil behaves under these extreme conditions. The properties of the oil under high pressure, in turn, depend on the type of base stocks used in the manufacture of the finished lubricant. The generation of the EHL film is governed by what happens in the inlet region of the contact; however, the energy losses are governed by what happens when the lubricant is sheared in the high-pressure central contact region.

[0006] The resistance of the lubricant to the shearing effects within an EHL contact is referred to as traction. Even though ultimately this force would be classified as friction, the distinct name allows tribologists and lubrication engineers to distinguish it from friction due to surface interactions. The traction response is dominated by the behavior of the lubricant under shear in the central high contact pressure region of an EHL contact. The traction properties generally depend on the base stock type.

[0007] Traction coefficients can be defined as the traction force divided by the normal force. The traction force is the force transmitted across a sheared EHL film. The normal force or contact load is the force of one element (such as a roller) pushing down on a second element. Therefore, the traction coefficient is a non-dimensional measure of the shear resistance imparted by a lubricant under EHL conditions. Lower traction coefficients result in lower shearing forces and hence less energy loss if the two surfaces are in relative motion. Low traction is believed to be related to improved fuel economy, increased energy efficiency, reduced operating temperatures, and improved durability. In certain applications where energy loss is dominated by shearing of a lubricant (such as worm gearbox), energy efficiency directly correlates with the traction coefficient.

[0008] This direct correlation makes traction coefficient very useful for lubricant formulators. Traction is usually measured in a ball-on-disc machine (e.g. MTM) and has been targeted in lubricant development helping advance synthetic base stocks (PAOs, synthetic esters and PAGs) and develop technologies such as extreme modal blending. In a family of fluids with similar chemical composition, traction tends to correlate with viscosity. Lubricating products are sold at a given viscosity point (called a grade). Typically traction increases with viscosity. It has been shown that traction of a blend can be minimized by blending base stocks with different viscosities. Traction coefficient of a blend can be lower than traction predicted as a linear combination of traction coefficient of straight base stocks with corresponding viscosity. It is however, higher than the traction coefficients of its components. When taken to its extreme this approach uses base stocks with highest and lowest practical viscosities and is called extreme modal blending.

[0009] There is a need for lubricating base stocks and additives capable of improving wear control while maintaining or improving energy efficiency, particularly in industrial and automotive applications.

[0010] The present disclosure also provides many additional advantages, which shall become apparent as described below.

SUMMARY

[0011] This disclosure relates to lubricating fluids and oil formulations which provide

improved wear control. In particular, this disclosure relates to lubricant compositions, methods for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces, methods for controlling traction coefficient (Tc) of lubricant compositions, and methods for controlling film thickness of lubricant compositions. The lubricant compositions of this disclosure are useful as finished gear, transmission, engine or industrial lubricants.

[0012] This disclosure also relates in part to a method for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces. The method involves using a lubricant composition in the mechanical component having sliding or rolling between contacting surfaces. The lubricant composition has a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend has at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend. The second base stock is miscible with the first base stock.

[0013] This disclosure further relates in part to a lubricant composition having a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend has at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend. The second base stock is miscible with the first base stock.

[0014] This disclosure yet further relates in part to a method for controlling traction coefficient (Tc) of a lubricant composition. The method involves blending at least one first base stock with at least one second base stock to give a base stock blend. The first base stock has a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and the second base stock has a viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock is miscible with the second base stock. The first base stock is present in the base stock blend in an amount sufficient to control traction coefficient (Tc) of the lubricant composition.

[0015] This disclosure also relates in part to a method for controlling film thickness of a lubricant composition. The method involves blending at least one first base stock with at least one second base stock to give a base stock blend. The first base stock has a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and the second base stock has a viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The second base stock is miscible with the first base stock. The second base stock is present in the base stock blend in an amount sufficient to control film thickness of the lubricant composition.

[0016] This disclosure further relates in part to a method for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces. The method comprises using a lubricant composition in the mechanical component having sliding or rolling between contacting surfaces. The lubricant composition comprises a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend comprises at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445. The first base stock is different from the second base stock. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend. The second base stock is miscible with the first base stock.

[0017] This disclosure yet further relates in part to a lubricant composition comprising a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend comprises at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445. The first base stock is different from the second base stock. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend. The second base stock is miscible with the first base stock.

[0018] It has been surprisingly found that, in a lubricant composition having a unique base stock blend of a low viscosity base stock and a high viscosity base stock, the traction coefficient is dependent on the concentration of the low viscosity base stock, and independent of lubricant composition viscosity. The unique base stock blend has at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least

one second base stock having viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock and second base stock are miscible with each other. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend.

[0019] Also, it has been surprisingly found that, in a mechanical component having sliding or rolling between contacting surfaces lubricated with a lubricant composition having a unique base stock blend of a low viscosity base stock and a high viscosity base stock, traction coefficient (Tc) is controlled by concentration of the first base stock, and film thickness is controlled by the concentration of the second base stock. The unique base stock blend has at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock and second base stock are miscible with each other. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend.

[0020] Other objects and advantages of the present disclosure will become apparent from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Fig. 1 graphically shows traction performance for neat base oils, PAO 4, PAO 8, PAO 40, PAO 100, mPAO 150, mPAO 300, and mPAO 600, in accordance with the Examples.

[0022] Fig. 2 graphically shows traction performance for blends made with constant high viscosity base oil (mPAO 150) and varied low viscosity base oil (i.e., PAO 2, PAO 4, PAO 6 or PAO 8) under conditions 1GPa, 25% SRR at 100°C, in accordance with the Examples.

[0023] Fig. 3 graphically shows traction performance for blends of multiple high molecular weight PAO polymers (PAO 100, mPAO 150, mPAO 300, mPAO 600, mPAO 1000) with PAO 4, in accordance with the Examples.

[0024] Fig. 4 graphically shows traction performance for PAO bimodal blends made by mixing high viscosity base oil (i.e., PAO 40, PAO 100, mPAO 150, mPAO 300, mPAO 600 or mPAO 1000) with a low viscosity base oil PAO 4 under conditions 1GPa, 25% SRR at 100°C, in accordance with the Examples.

[0025] Fig. 5 graphically shows that traction coefficient is controlled by the low viscosity component of bimodal blends and is independent of finish oil viscosity, in accordance with the Examples.

[0026] Fig. 6 graphically shows that, at a low concentration of high viscosity base oils, the traction increased unexpectedly as the concentration of PAO 4 increased (viscosity decreasing), in accordance with the Examples.

[0027] Fig. 7 shows an illustrative mechanical contact zone.

[0028] Fig. 8 shows gears, bearings and other high load/high pressure applications that rely on elastohydrodynamic (EHD) lubrication (EHL) to maintain effective separation between moving parts in equipment leading to reduced friction and enhanced durability.

DETAILED DESCRIPTION

Definitions

[0029] “About” or “approximately.” All numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0030] “Major amount” as it relates to components included within the lubricating oils of the specification and the claims means greater than or equal to 50 wt.%, or greater than or equal to 60 wt.%, or greater than or equal to 70 wt.%, or greater than or equal to 80 wt.%, or greater than or equal to 90 wt.% based on the total weight of the lubricating oil.

[0031] “Minor amount” as it relates to components included within the lubricating oils of the specification and the claims means less than 50 wt.%, or less than or equal to 40 wt.%, or less than or equal to 30 wt.%, or greater than or equal to 20 wt.%, or less than or equal to 10 wt.%, or less than or equal to 5 wt.%, or less than or equal to 2 wt.%, or less than or equal to 1 wt.%, based on the total weight of the lubricating oil.

[0032] “Essentially free” as it relates to components included within the lubricating oils of the specification and the claims means that the particular component is at 0 weight % within the lubricating oil, or alternatively is at impurity type levels within the lubricating oil (less than 100 ppm, or less than 20 ppm, or less than 10 ppm, or less than 1 ppm).

[0033] “Other lubricating oil additives” as used in the specification and the claims means other lubricating oil additives that are not specifically recited in the particular section of the specification or the claims. For example, other lubricating oil additives may include, but are not limited to, antioxidants, detergents, dispersants, antiwear additives, corrosion inhibitors, viscosity modifiers, metal passivators, pour point depressants, seal compatibility agents, antifoam agents, extreme pressure agents, friction modifiers and combinations thereof.

[0034] “Other mechanical component” or “mechanical component” as used in the specification and the claims means an electric vehicle component, a hybrid vehicle component, a

power train, a driveline, a transmission, a gear, a gear train, a gear set, a compressor, a pump, a hydraulic system, a bearing, a bushing, a turbine, a piston, a piston ring, a cylinder liner, a cylinder, a cam, a tappet, a lifter, a gear, a valve, or a bearing including a journal, a roller, a tapered, a needle, and a ball bearing.

[0035] “Hydrocarbon” refers to a compound consisting of carbon atoms and hydrogen atoms.

[0036] “Alkane” refers to a hydrocarbon that is completely saturated. An alkane can be linear, branched, cyclic, or substituted cyclic.

[0037] “Olefin” refers to a non-aromatic hydrocarbon comprising one or more carbon-carbon double bond in the molecular structure thereof.

[0038] “Mono-olefin” refers to an olefin comprising a single carbon-carbon double bond.

[0039] “C_n” group or compound refers to a group or a compound comprising carbon atoms at total number thereof of n. Thus, “C_m-C_n” group or compound refers to a group or compound comprising carbon atoms at a total number thereof in the range from m to n. Thus, a C1-C50 alkyl group refers to an alkyl group comprising carbon atoms at a total number thereof in the range from 1 to 50.

[0040] “Carbon backbone” refers to the longest straight carbon chain in the molecule of the compound or the group in question. “Branch” refer to any substituted or unsubstituted hydrocarbyl group connected to the carbon backbone. A carbon atom on the carbon backbone connected to a branch is called a “branched carbon.”

[0041] “Epsilon-carbon” in a branched alkane refers to a carbon atom in its carbon backbone that is (i) connected to two hydrogen atoms and two carbon atoms and (ii) connected to a branched carbon via at least four (4) methylene (CH₂) groups. Quantity of epsilon carbon atoms in terms of mole percentage thereof in a alkane material based on the total moles of carbon atoms can be determined by using, e.g., ¹³C NMR.

[0042] “Alpha-carbon” in a branched alkane refers to a carbon atom in its carbon backbone that is with a methyl end with no branch on the first 4 carbons. It is also measured in mole percentage using ¹³C NMR.

[0043] “T/P methyl” in a branched alkane refers to a methyl end and a methyl in the 2 position. It is also measured in mole percentage using ¹³C NMR.

[0044] “P-methyl” in a branched alkane refers to a methyl branch anywhere on the chain, except in the 2 position. It is also measured in mole percentage using ¹³C NMR.

[0045] “SAE” refers to SAE International, formerly known as Society of Automotive Engineers, which is a professional organization that sets standards for internal combustion engine lubricating oils.

[0046] “SAE J300” refers to the viscosity grade classification system of engine lubricating oils established by SAE, which defines the limits of the classifications in rheological terms only.

[0047] “Base stock” or “base oil” interchangeably refers to an oil that can be used as a component of lubricating oils, heat transfer oils, hydraulic oils, grease products, and the like.

[0048] “Lubricating oil” or “lubricant” interchangeably refers to a substance that can be introduced between two or more surfaces to reduce the level of friction between two adjacent surfaces moving relative to each other. A lubricant base stock is a material, typically a fluid at various levels of viscosity at the operating temperature of the lubricant, used to formulate a lubricant by admixing with other components. Non-limiting examples of base stocks suitable in lubricants include API Group I, Group II, Group III, Group IV, and Group V base stocks. PAOs, particularly hydrogenated PAOs, have recently found wide use in lubricants as a Group IV base stock, and are particularly preferred. If one base stock is designated as a primary base stock in the lubricant, additional base stocks may be called a co-base stock.

[0049] All kinematic viscosity values in this disclosure are as determined pursuant to ASTM D445. Kinematic viscosity at 100°C is reported herein as KV100, and kinematic viscosity at 40°C is reported herein as KV40. Unit of all KV100 and KV40 values herein is cSt unless otherwise specified. When describing the kinematic viscosity at 100°C is “essentially” maintained, the kinematic viscosity at 100°C is expected to vary less than 0.2 cSt as measured by ASTM D445.

[0050] All viscosity index (“VI”) values in this disclosure are as determined pursuant to ASTM D2270.

[0051] All Noack volatility (“NV”) values in this disclosure are as determined pursuant to ASTM D5800 unless specified otherwise. Unit of all NV values is wt%, unless otherwise specified.

[0052] All pour point values in this disclosure are as determined pursuant to ASTM D5950 or D97.

[0053] All CCS viscosity (“CCSV”) values in this disclosure are as determined pursuant to ASTM 5293. Unit of all CCSV values herein is millipascal second (mPa·s), which is equivalent to centipoise), unless specified otherwise. All CCSV values are measured at a temperature of interest to the lubricating oil formulation or oil composition in question. Thus, for the purpose of designing and fabricating engine oil formulations, the temperature of interest is the temperature at which the SAE J300 imposes a minimal CCSV.

[0054] All percentages in describing chemical compositions herein are by weight unless specified otherwise. “Wt. %” means percent by weight.

Lubricating Oil Compositions of This Disclosure

[0055] Mainly the job of the base oils within lubricants is to separate the two surfaces via the generation of a lubrication film between them, preventing metal to metal contact. However, under extreme conditions, maintaining a uniform lubricant film can be difficult. Failure to maintain the film can allow metal to metal contact leading to wear and early failure of the machines. Usually, additives were used to provide protection when this event occurs. However, in accordance with this disclosure, it has been found that the solubility of mixture base oils is another property that can be used to prevent metal contact and improve life of the equipment.

[0056] This disclosure relates to a new approach for selecting and blending base oils and co-base oils that can reduce the probability of metal to metal contact under mid to extreme lubrication conditions, thereby increasing durability of equipment and efficiency. Through proper choice of base oils (e.g., using solubility parameter as one of the key criteria), wear protection is improved by inducing a phase transition/separation (e.g. liquid to liquid, or solid to liquid) in the mechanical contact. In one embodiment, this transition allows the formulator to use very low concentrations of a heavy base oil with unexpected film benefits while maintaining a lower bulk viscosity for better efficiency. This work has shown that the film thickness (h) is controlled by very low concentrations of high viscosity base oil while the traction coefficient (T_c) is controlled by the higher concentration of low viscosity base oil. This new approach will provide new technology and formulation design options enabling lubricants with enhance wear protection and improved efficiency.

[0057] The function of a lubricant is to generate a thin film that separates a surface from its moving counterpart with the goal of reducing friction and wear at operating conditions. This disclosure will mitigate wear and frictional losses through the use of carefully selected base oils that will generate a very high viscosity film or solid film via phase separation in the contact zone, thereby improving durability and energy efficiency.

[0058] A major trend is to improve efficiency/fuel economy while maintaining equipment protection. The challenge is that these performance attributes respond differently. Good fuel economy requires lower viscosity lubricants and equipment protection requires the opposite. This disclosure provides a solution to this problem by providing a sacrificial solid film in the contact maintaining or increasing equipment protection while the bulk viscosity of the lubricant is lower.

[0059] The conventional understanding is that traction is dependent upon lubricant viscosity. Surprisingly, the results of this disclosure show that this is not always the case. In accordance with this disclosure, traction was shown to be dependent upon the low viscosity fluid

concentration, and independent of viscosity of the final fluid, particularly within the same bimodal blend family (i.e., PAO). While not wishing to be bound by any particular theory, the analysis of traction performance suggests that other potential mechanisms (e.g., shear thinning, shear or pressure induced phase transition) may be responsible for the traction characteristics that these fluids exhibit. Also, in accordance with this disclosure, characteristics that predominantly control the properties of the fluids in the contact zone have been identified, particularly for a selected group of PAO single-component base fluids and PAO bimodal blends. An illustrative mechanical contact zone is shown in Fig. 7.

[0060] Gears, bearings and other high load/high pressure applications rely on elastohydrodynamic (EHD) lubrication (EHL) to maintain effective separation between moving parts in the equipment leading to reduced friction and enhanced durability and thus lifetime of the machines. See Fig. 8. The EHD lubrication film thickness determines the extent to which opposing surfaces are separated, and is one of the most important features of an EHD contact. The EHD film thickness depends on the oil volume entrained in the inlet, and this is determined by the velocity and rheology of the lubricant.

[0061] The rheology of the lubricant is controlled by the physical properties (e.g., temperature, pressure, molecular structure or composition of the fluid) and the mechanics of the system (e.g., geometry, bodies within contact). The EHD contact can be, for example, a piezoviscous elastic contact. This contact is defined as a system where there is an elastic deformation effect excerpted by the pressure on the lubricant (e.g., viscosity increase) and the solid bodies making the contact (e.g., metal-metal contact), and this effect cannot be neglected. The pressurized fluid within a contact is described by the Reynolds equation, and the pressure profile in the metal surface is described by Hertz equations.

[0062] This is also called a non-conformal contact. See Fig. 8. This effect is seen under high speed and high load conditions, e.g., bearing and gears applications. The non-conforming contact zones, composed of metal-lubricant-metal are under extreme high pressure, up to 4 GPa. See Fig. 8. Under these high pressure conditions, the lubricant significantly increases in viscosity and the slope or profile of viscosity change versus pressure is called the pressure viscosity coefficient, α .

[0063] The pressure viscosity coefficient, α , value depends on the chemistry of the fluids as well as the composition of the blend and is one of the most important parameters that control film thickness (h) in the contact zone. Furthermore, conventional understanding is that film thickness is controlled by viscosity (which varies with temperature and pressure) as well as operation values such as speed, load, surface geometry, roughness, and material properties.

Surprisingly, in accordance with this disclosure, film thickness was shown to be dependent upon the high viscosity fluid concentration, particularly within the same bimodal blend family (i.e., PAO).

[0064] Friction is present in all moving systems. Friction is generated due to the resistance of two sliding surfaces. In accordance with this disclosure, the work in part is with two surfaces separated by a lubricant in the EHD region, therefore, the friction observed is coming from the resistance to flow of the lubricant in the contact area. This friction is often called traction. The term traction is often used to define fluid intermolecular friction within the EHD contacts.

Traction is the friction caused by the molecules moving in adjacent shear planes to each other and traction is defined as the total shear stress over the entire contact area. As used herein, the traction coefficient is defined as shear stress divided by the pressure over the whole contact.

[0065] In the EHD contact (high pressure), the fluid has a viscosity that is so high that it behaves more like a solid than a liquid. Consequently, the traction observed is consistent with the measure of the shearing force of a semi-solidified fluid. These forces are controlled by the high pressure rheology of the fluid which are controlled by the intermolecular friction (i.e., the resistance to flow), which results in generation of heat and loss of efficiency in the system.

[0066] In accordance with this disclosure, lubricants having base oil blends are provided that are suitable for use in machines with various degrees of sliding, i.e., non-conforming concentrated contacts, such as with roller and spherical bearings, hypoid gears, worm gears, and also conforming contacts such as thrust and journal bearings, and the like.

[0067] The disclosure is directed in general to lubricant compositions having a base stock blend. When used in an engine or other mechanical component lubricated with the lubricant composition, film thickness is controlled by the concentration of one base stock, and traction coefficient (T_c) is controlled by concentration of another base stock, in the base stock blend. The lubricant compositions are useful as finished gear, transmission, engine, and industrial lubricants and in a preferred embodiment are used as lubricants for non-conforming concentrated contacts with high sliding such as spur gears, helical gears, hypoid gears, bevel gears, worm gears and the like.

[0068] In an embodiment, the lubricant compositions have a base stock blend as a major component, and at least one lubricant additive, as a minor component. The base stock blend comprises at least one first base stock having a viscosity from about 1 cSt to about 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from about 100 cSt to about 2000 cSt at 40°C as determined by ASTM D-445. The first base stock is present in an amount greater than about 50 to about 95 weight percent of the base stock blend, and the

second base stock is present in an amount from about 5 to less than about 50 weight percent of the base stock blend. The second base stock is miscible with the first base stock.

[0069] In the base stock blends of this disclosure, the first base stock has a viscosity from about 1 cSt to about 50 cSt at 40°C, preferably about 1 cSt to about 40 cSt at 40°C, more preferably about 1.25 cSt to about 30 cSt at 40°C, and even more preferably about 1.5 cSt to about 20 cSt at 40°C, as determined by ASTM D-445.

[0070] In the base stock blends of this disclosure, the second base stock has viscosity from about 100 cSt to about 2000 cSt at 40°C, preferably about 100 cSt to about 1800 cSt at 40°C, more preferably about 125 cSt to about 1600 cSt at 40°C, and even more preferably about 150 cSt to about 1500 cSt at 40°C, as determined by ASTM D-445.

[0071] In the base stock blends of this disclosure, the first base stock is present in an amount greater than about 50 to about 95 weight percent, preferably from about 60 to about 95 weight percent, more preferably from about 70 to about 95 weight percent, even more preferably from about 80 to about 95 weight percent, of the base stock blend. The second base stock is present in an amount from about 5 to less than about 50 weight percent, preferably from about 5 to about 40 weight percent, more preferably from about 5 to about 30 weight percent, even more preferably from about 5 to about 20 weight percent, of the base stock blend. The first and second base stocks are miscible with each other.

[0072] In the lubricant compositions of this disclosure, the base stock blend is present in an amount from about 70 to about 95 weight percent, preferably from about 75 to about 95 weight percent, more preferably from about 80 to about 95 weight percent, even more preferably from about 85 to about 95 weight percent, of the lubricant composition.

[0073] In the base stock blends of this disclosure, the first base stock has a traction coefficient (Tc) from about 0.008 to about 0.015, preferably from about 0.008 to about 0.011, more preferably from about 0.008 to about 0.01, as determined by MTM TC Method. The second base stock has a traction coefficient (Tc) from about 0.008 to about 0.025, preferably from about 0.01 to about 0.02, more preferably from about 0.01 to about 0.02, as determined by MTM TC Method.

[0074] The lubricant compositions of this disclosure have a traction coefficient (Tc) of less than 0.15, preferably from about 0.15 to about 0.0001, preferably from about 0.015 to about 0.001, as determined by MTM TC Method.

[0075] In accordance with this disclosure, traction coefficient (Tc) is independent of viscosity of the lubricant composition.

[0076] In an embodiment, the base stock blend is a bimodal blend.

[0077] It is important that the first and second fluids be miscible with each other to comprise a clear fluid. The term miscible takes its ordinary meaning of the ability to mix in all proportions. For purposes of this disclosure, miscibility is determined at 25°C and 1 atm.

[0078] Fluids (e.g., base stocks) that can meet these criteria according to the present disclosure are varied. They may fall into any of the well-known American Petroleum Institute (API) categories of Group I through Group V as described herein.

[0079] The lubricant compositions of this disclosure may contain other fluids in addition to the first and second base stocks. For example, the lubricant compositions may have a third fluid that can be a high viscosity or low viscosity fluid, or other combinations of fluids.

[0080] In an embodiment, the first base stock can be selected from a Group I, Group II, Group III, Group IV or Group V base oil, and the second base stock can be selected from a Group I, Group II, Group III, Group IV or Group V base oil. Preferably, the first base stock can be a polyalphaolefin (PAO) base oil, and the second base stock can be a polyalphaolefin (PAO) base oil or a metallocene catalyzed polyalphaolefin (PAO) base oil.

[0081] The lubricant compositions of this disclosure may contain one or more first base stocks, and/or one or more second base stocks.

[0082] In an embodiment, the lubricant compositions can further include one or more of a viscosity modifier, dispersant, detergent, antioxidant, pour point depressant, corrosion inhibitor, metal deactivator, seal compatibility additive, anti-foam agent, inhibitor, and anti-rust additive.

Base Stocks

[0083] A wide range of lubricating base oils is known in the art. Lubricating base oils that are useful in the present disclosure are both natural oils, and synthetic oils, and unconventional oils (or mixtures thereof) can be used unrefined, refined, or rerefined (the latter is also known as reclaimed or reprocessed oil). Unrefined oils are those obtained directly from a natural or synthetic source and used without added purification. These include shale oil obtained directly from retorting operations, petroleum oil obtained directly from primary distillation, and ester oil obtained directly from an esterification process. Refined oils are similar to the oils discussed for unrefined oils except refined oils are subjected to one or more purification steps to improve at least one lubricating oil property. One skilled in the art is familiar with many purification processes. These processes include solvent extraction, secondary distillation, acid extraction, base extraction, filtration, and percolation. Rerefined oils are obtained by processes analogous to refined oils but using an oil that has been previously used as a feed stock.

[0084] Groups I, II, III, IV and V are broad base oil stock categories developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org) to create guidelines for

lubricant base oils. Group I base stocks have a viscosity index of between about 80 to 120 and contain greater than about 0.03% sulfur and/or less than about 90% saturates. Group II base stocks have a viscosity index of between about 80 to 120, and contain less than or equal to about 0.03% sulfur and greater than or equal to about 90% saturates. Group III stocks have a viscosity index greater than about 120 and contain less than or equal to about 0.03 % sulfur and greater than about 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stock includes base stocks not included in Groups I-IV. The table below summarizes properties of each of these five groups.

	Base Oil Properties		
	Saturates	Sulfur	Viscosity Index
Group I	<90 and/or	>0.03% and	≥ 80 and <120
Group II	≥ 90 and	$\leq 0.03\%$ and	≥ 80 and <120
Group III	≥ 90 and	$\leq 0.03\%$ and	≥ 120
Group IV	Polyalphaolefins (PAO)		
Group V	All other base oil stocks not included in Groups I, II, III or IV		

[0085] Natural oils include animal oils, vegetable oils (castor oil and lard oil, for example), 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, hydrotreated, or solvent extracted.

[0086] Group II and/or Group III hydroprocessed or hydrocracked base stocks, including synthetic oils such as polyalphaolefins, alkyl aromatics and synthetic esters are also well known base stock oils.

[0087] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, for example). Polyalphaolefin (PAO) oil base stocks are commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C₈, C₁₀, C₁₂, C₁₄ olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073.

[0088] The number average molecular weights of the PAOs, which are known materials and generally available on a major commercial scale from suppliers such as ExxonMobil Chemical Company, Chevron Phillips Chemical Company, BP, and others, typically vary from about 250

to about 3,000, although PAO's may be made in viscosities up to about 150 cSt (100°C). The PAOs are typically comprised of relatively low molecular weight hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, C₂ to about C₃₂ alphaolefins with the C₈ to about C₁₆ alphaolefins, such as 1-hexene, 1-octene, 1-decene, 1-dodecene and the like, being preferred. The preferred polyalphaolefins are poly-1-hexene, poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefins. However, the dimers of higher olefins in the range of C₁₄ to C₁₈ may be used to provide low viscosity base stocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers, having a viscosity range of 1.5 to 12 cSt. PAO fluids of particular use may include 3.0 cSt, 3.4 cSt, and/or 3.6 cSt and combinations thereof. Bi-modal mixtures of PAO fluids having a viscosity range of 1.5 to 150 cSt may be used if desired.

[0089] The PAO fluids may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by U.S. Patent Nos. 4,149,178 or 3,382,291 may be conveniently used herein. Other descriptions of PAO synthesis are found in the following U.S. Patent Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the C₁₄ to C₁₈ olefins are described in U.S. Patent No. 4,218,330.

[0090] The alkylated naphthalene can be used as base oil or base oil component and can be any hydrocarbyl molecule that contains at least about 5% of its weight derived from a naphthenoid moiety, or its derivatives. These alkylated naphthalenes include alkyl naphthalenes, alkyl naphthols, and the like. The naphthenoid group can be mono-alkylated, dialkylated, polyalkylated, and the like. The naphthenoid group can be mono- or poly-functionalized. The naphthenoid group can also be derived from natural (petroleum) sources, provided at least about 5% of the molecule is comprised of the naphthenoid moiety. Viscosities at 100°C of approximately 3 cSt to about 50 cSt are preferred, with viscosities of approximately 3.4 cSt to about 20 cSt often being more preferred for the naphthylene component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of naphthalene can be advantageously used. Naphthalene or methyl naphthalene, for example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like.

[0091] Alkylated naphthalenes of the present disclosure may be produced by well-known Friedel-Crafts alkylation of aromatic compounds. See Friedel-Crafts and Related Reactions, Olah, G. A. (ed.), Inter-science Publishers, New York, 1963. For example, an aromatic compound, such as naphthalene, is alkylated by an olefin, alkyl halide or alcohol in the presence of a Friedel-Crafts catalyst. See Friedel-Crafts and Related Reactions, Vol. 2, part 1, chapters 14, 17, and 18, See Olah, G. A. (ed.), Inter-science Publishers, New York, 1964. Many homogeneous or heterogeneous, solid catalysts are known to one skilled in the art. The choice of catalyst depends on the reactivity of the starting materials and product quality requirements. For example, strong acids such as AlCl_3 , BF_3 , or HF may be used. In some cases, milder catalysts such as FeCl_3 or SnCl_4 are preferred. Newer alkylation technology uses zeolites or solid super acids.

[0092] Mixtures of alkylated naphthalene base stocks with other lubricating oil base stocks (e.g., Groups I, II, III, IV and V base stocks) may be useful in the lubricant compositions of this disclosure.

[0093] The alkylated naphthalene can be present in an amount of from about 30 to about 99.8 weight percent, or from about 35 to about 95 weight percent, or from about 40 to about 90 weight percent, or from about 45 to about 85 weight percent, or from about 50 to about 80 weight percent, or from about 55 to about 75 weight percent, or from about 60 to about 70 weight percent, based on the total weight of the formulated oil.

[0094] Other useful lubricant oil base stocks include wax isomerate base stocks and base oils, comprising hydroisomerized waxy stocks (e.g. waxy stocks such as gas oils, slack waxes, fuels hydrocracker bottoms, etc.), hydroisomerized Fischer-Tropsch waxes, Gas-to-Liquids (GTL) base stocks and base oils, and other wax isomerate hydroisomerized base stocks and base oils, or mixtures thereof Fischer-Tropsch waxes, the high boiling point residues of Fischer-Tropsch synthesis, are highly paraffinic hydrocarbons with very low sulfur content. The hydroprocessing used for the production of such base stocks may use an amorphous hydrocracking/hydroisomerization catalyst, such as one of the specialized lube hydrocracking (LHDC) catalysts or a crystalline hydrocracking/hydroisomerization catalyst, preferably a zeolitic catalyst. For example, one useful catalyst is ZSM-48 as described in U.S. Patent No. 5,075,269, the disclosure of which is incorporated herein by reference in its entirety. Processes for making hydrocracked/hydroisomerized distillates and hydrocracked/hydroisomerized waxes are described, for example, in U.S. Patent Nos. 2,817,693; 4,975,177; 4,921,594 and 4,897,178 as well as in British Patent Nos. 1,429,494; 1,350,257; 1,440,230 and 1,390,359. Each of the aforementioned patents is incorporated herein in their entirety. Particularly favorable processes

are described in European Patent Application Nos. 464546 and 464547, also incorporated herein by reference. Processes using Fischer-Tropsch wax feeds are described in U.S. Patent Nos. 4,594,172 and 4,943,672, the disclosures of which are incorporated herein by reference in their entirety.

[0095] Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized (wax isomerase) base oils be advantageously used in the instant disclosure, and may have useful kinematic viscosities at 100°C of about 3 cSt to about 50 cSt, preferably about 3 cSt to about 30 cSt, more preferably about 3.5 cSt to about 25 cSt, as exemplified by GTL 4 with kinematic viscosity of about 4.0 cSt at 100°C and a viscosity index of about 141. These Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized base oils may have useful pour points of about -20°C or lower, and under some conditions may have advantageous pour points of about -25°C or lower, with useful pour points of about -30°C to about -40°C or lower. Useful compositions of Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and wax-derived hydroisomerized base oils are recited in U.S. Patent Nos. 6,080,301; 6,090,989, and 6,165,949 for example, and are incorporated herein in their entirety by reference.

[0096] The hydrocarbyl aromatics can be used as base oil or base oil component and can be any hydrocarbyl molecule that contains at least about 5% of its weight derived from an aromatic moiety such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These hydrocarbyl aromatics include alkyl benzenes, alkyl naphthalenes, alkyl diphenyl oxides, alkyl naphthols, alkyl diphenyl sulfides, alkylated bis-phenol A, alkylated thiodiphenol, and the like. The aromatic can be mono-alkylated, dialkylated, polyalkylated, and the like. The aromatic can be mono- or poly-functionalized. The hydrocarbyl groups can also be comprised of mixtures of alkyl groups, alkenyl groups, alkynyl, cycloalkyl groups, cycloalkenyl groups and other related hydrocarbyl groups. The hydrocarbyl groups can range from about C₆ up to about C₆₀ with a range of about C₈ to about C₂₀ often being preferred. A mixture of hydrocarbyl groups is often preferred, and up to about three such substituents may be present. The hydrocarbyl group can optionally contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least about 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100°C of approximately 3 cSt to about 50 cSt are preferred, with viscosities of approximately 3.4 cSt to about 20 cSt often being more preferred for the hydrocarbyl aromatic component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of aromatics can be advantageously used. Naphthalene or methyl naphthalene, for

example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be about 2% to about 25%, preferably about 4% to about 20%, and more preferably about 4% to about 15%, depending on the application.

[0097] Alkylated aromatics such as the hydrocarbyl aromatics of the present disclosure may be produced by well-known Friedel-Crafts alkylation of aromatic compounds. See Friedel-Crafts and Related Reactions, Olah, G. A. (ed.), Inter-science Publishers, New York, 1963. For example, an aromatic compound, such as benzene or naphthalene, is alkylated by an olefin, alkyl halide or alcohol in the presence of a Friedel-Crafts catalyst. See Friedel-Crafts and Related Reactions, Vol. 2, part 1, chapters 14, 17, and 18, See Olah, G. A. (ed.), Inter-science Publishers, New York, 1964. Many homogeneous or heterogeneous, solid catalysts are known to one skilled in the art. The choice of catalyst depends on the reactivity of the starting materials and product quality requirements. For example, strong acids such as AlCl_3 , BF_3 , or HF may be used. In some cases, milder catalysts such as FeCl_3 or SnCl_4 are preferred. Newer alkylation technology uses zeolites or solid super acids.

[0098] Esters comprise a useful base stock. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

[0099] Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, preferably the hindered polyols (such as the neopentyl polyols, e.g., neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol) with alkanoic acids containing at least about 4 carbon atoms, preferably C_5 to C_{30} acids such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures of any of these materials.

[00100] Suitable synthetic ester components include the esters of trimethylol propane,

trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from about 5 to about 10 carbon atoms. These esters are widely available commercially, for example, the Mobil P-41 and P-51 esters of ExxonMobil Chemical Company.

[00101] Also useful are esters derived from renewable material such as coconut, palm, rapeseed, soy, sunflower and the like. These esters may be monoesters, di-esters, polyol esters, complex esters, or mixtures thereof. These esters are widely available commercially, for example, the Mobil P-51 ester of ExxonMobil Chemical Company.

[00102] Engine oil formulations containing renewable esters are included in this disclosure. For such formulations, the renewable content of the ester is typically greater than about 70 weight percent, preferably more than about 80 weight percent and most preferably more than about 90 weight percent.

[00103] Other useful fluids of lubricating viscosity include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance lubrication characteristics.

[00104] 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 isomerase/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.

[00105] GTL materials are materials that are derived via one or more synthesis, combination, transformation, rearrangement, and/or degradation/deconstructive processes from gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks such as hydrogen, carbon dioxide, carbon monoxide, water, methane, ethane, ethylene, acetylene, propane, propylene, propyne, butane, butylenes, and butynes. GTL base stocks and/or base oils are GTL materials of lubricating viscosity that are generally derived from hydrocarbons; for example, waxy synthesized hydrocarbons, that are themselves derived from simpler gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks. GTL base stock(s) and/or base oil(s) include oils boiling in the lube oil boiling range (1) separated/fractionated from synthesized GTL materials such as, for example, by distillation and subsequently subjected to a final wax processing step which involves either or both of a catalytic dewaxing process, or a solvent dewaxing process, to produce lube oils of reduced/low pour point;

(2) synthesized wax isomerates, comprising, for example, hydrodewaxed or hydroisomerized cat and/or solvent dewaxed synthesized wax or waxy hydrocarbons; (3) hydrodewaxed or hydroisomerized cat and/or solvent dewaxed Fischer-Tropsch (F-T) material (i.e., hydrocarbons, waxy hydrocarbons, waxes and possible analogous oxygenates); preferably hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxing dewaxed F-T waxy hydrocarbons, or hydrodewaxed or hydroisomerized/followed by cat (or solvent) dewaxing dewaxed, F-T waxes, or mixtures thereof.

[00106] GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxed wax or waxy feed, preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100°C of from about 2 mm²/s to about 50 mm²/s (ASTM D445). They are further characterized typically as having pour points of -5°C to about -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of about 80 to about 140 or greater (ASTM D2270).

[00107] In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than about 10 ppm, and more typically less than about 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this material especially suitable for the formulation of low SAP products.

[00108] The term GTL base stock and/or base oil and/or wax isomerate base stock and/or base oil is to be understood as embracing individual fractions of such materials of wide viscosity range as recovered in the production process, mixtures of two or more of such fractions, as well as mixtures of one or two or more low viscosity fractions with one, two or more higher viscosity fractions to produce a blend wherein the blend exhibits a target kinematic viscosity.

[00109] The GTL material, from which the GTL base stock(s) and/or base oil(s) is/are derived is preferably an F-T material (i.e., hydrocarbons, waxy hydrocarbons, wax).

[00110] Base oils for use in the lubricant compositions useful in the 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.

[00111] The base oil constitutes the major component of the engine oil lubricant composition of the present disclosure and typically is present in an amount ranging from about 50 to about 99 weight percent, preferably from about 70 to about 95 weight percent, and more preferably from about 85 to about 95 weight percent, based on the total weight of the composition. The base oil may be selected from any of the synthetic or natural oils typically used as crankcase lubricating oils for spark-ignited and compression-ignited engines. The base oil conveniently has a kinematic viscosity, according to ASTM standards, of about 2.5 cSt to about 12 cSt (or mm²/s) at 100°C and preferably of about 2.5 cSt to about 9 cSt (or mm²/s) at 100° C. Mixtures of synthetic and natural base oils may be used if desired. Bi-modal mixtures of Group I, II, III, IV, and/or V base stocks may be used if desired.

Lubricant Add

[00112] The lubricant compositions useful in the present disclosure may additionally contain one or more of the commonly used lubricant performance additives including but not limited to antioxidants, dispersants, detergents, antiwear additives, corrosion inhibitors, rust inhibitors, metal deactivators, extreme pressure additives, anti-seizure agents, wax modifiers, viscosity index improvers, viscosity modifiers, fluid-loss additives, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, emulsifiers, densifiers, wetting agents, gelling agents, tackiness agents, colorants, and others. For a review of many commonly used additives, see Klamann in Lubricants and Related Products, Verlag Chemie, Deerfield Beach, FL; ISBN 0-89573-177-0. Reference is also made to “Lubricant Additives” by M. W. Ranney, published by Noyes Data Corporation of Parkridge, NJ (1973); see also U.S. Patent No. 7,704,930, the disclosure of which is incorporated herein in its entirety. These additives are commonly delivered with varying amounts of diluent oil, that may range from 5 weight percent to 50 weight percent.

Antioxidants

[00113] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. One skilled in the art knows a wide variety of oxidation inhibitors that are useful in lubricant compositions. See, Klamann in Lubricants and Related Products, op cite, and U.S. Patent Nos. 4,798,684 and 5,084,197, for example.

[00114] Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics which are the

ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C₆+ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered mono-phenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic propionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the instant disclosure. Examples of ortho-coupled phenols include: 2,2'-bis(4-heptyl-6-t-butyl-phenol); 2,2'-bis(4-octyl-6-t-butyl-phenol); and 2,2'-bis(4-dodecyl-6-t-butyl-phenol). Para-coupled bisphenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

[00115] Effective amounts of one or more catalytic antioxidants may also be used. The catalytic antioxidants comprise an effective amount of a) one or more oil soluble polymetal organic compounds; and, effective amounts of b) one or more substituted N,N'-diaryl-o-phenylenediamine compounds or c) one or more hindered phenol compounds; or a combination of both b) and c). Catalytic antioxidants are more fully described in U.S. Patent No. 8, 048,833, herein incorporated by reference in its entirety.

[00116] Non-phenolic oxidation inhibitors which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula R⁸R⁹R¹⁰N where R⁸ is an aliphatic, aromatic or substituted aromatic group, R⁹ is an aromatic or a substituted aromatic group, and R¹⁰ is H, alkyl, aryl or R¹¹S(O)_xR¹² where R¹¹ is an alkylene, alkenylene, or aralkylene group, R¹² is a higher alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1 or 2. The aliphatic group R⁸ may contain from 1 to about 20 carbon atoms, and preferably contains from about 6 to 12 carbon atoms. The aliphatic group is a saturated aliphatic group. Preferably, both R⁸ and R⁹ are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups R⁸ and R⁹ may be joined together with other groups such as S.

[00117] Typical aromatic amines antioxidants have alkyl substituent groups of at least about 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than about 14 carbon atoms. The general types of amine antioxidants useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of

two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present disclosure include: p,p'-dioctyldiphenylamine; t-octylphenyl-alpha-naphthylamine; phenyl-alphanaphthylamine; and p-octylphenyl-alpha-naphthylamine.

[00118] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants.

[00119] Preferred antioxidants include hindered phenols, arylamines. These antioxidants may be used individually by type or in combination with one another. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent, more preferably zero to less than 1.5 weight percent, more preferably zero to less than 1 weight percent.

Dispersants

[00120] During engine operation, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants used in the formulation of the lubricant may be ashless or ash-forming in nature. Preferably, the dispersant is ashless. So called ashless dispersants are organic materials that form substantially no ash upon combustion. For example, non-metal-containing or borated metal-free dispersants are considered ashless. In contrast, metal-containing detergents discussed above form ash upon combustion.

[00121] Suitable dispersants typically contain a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group typically contains at least one element of nitrogen, oxygen, or phosphorus. Typical hydrocarbon chains contain 50 to 400 carbon atoms.

[00122] A particularly useful class of dispersants are the (poly)alkenylsuccinic derivatives, typically produced by the reaction of a long chain hydrocarbyl substituted succinic compound, usually a hydrocarbyl substituted succinic anhydride, with a polyhydroxy or polyamino compound. The long chain hydrocarbyl group constituting the oleophilic portion of the molecule which confers solubility in the oil, is normally a polyisobutylene group. Many examples of this type of dispersant are well known commercially and in the literature. Exemplary U.S. patents describing such dispersants are U.S. Patent Nos. 3,172,892; 3,215,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,511; 3,787,374 and 4,234,435. Other types of dispersant are described in U.S. Patent Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants may be found, for example, in European Patent Application.

[00123] Hydrocarbyl-substituted succinic acid and hydrocarbyl-substituted succinic anhydride derivatives are useful dispersants. In particular, succinimide, succinate esters, or succinate ester amides prepared by the reaction of a hydrocarbon-substituted succinic acid compound preferably having at least 50 carbon atoms in the hydrocarbon substituent, with at least one equivalent of an alkylene amine are particularly useful.

[00124] Succinimides are formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and amines. Molar ratios can vary depending on the polyamine. For example, the molar ratio of hydrocarbyl substituted succinic anhydride to TEPA can vary from about 1:1 to about 5:1. Representative examples are shown in U.S. Patent Nos. 3,087,936; 3,172,892; 3,219,666; 3,272,746; 3,322,670; and 3,652,616, 3,948,800; and Canada Patent No. 1,094,044.

[00125] Succinate esters are formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and alcohols or polyols. Molar ratios can vary depending on the alcohol or polyol used. For example, the condensation product of a hydrocarbyl substituted succinic anhydride and pentaerythritol is a useful dispersant.

[00126] Succinate ester amides are formed by condensation reaction between hydrocarbyl substituted succinic anhydrides and alkanol amines. For example, suitable alkanol amines include ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines and polyalkenylpolyamines such as polyethylene polyamines. One example is propoxylated hexamethylenediamine. Representative examples are shown in U.S. Patent No. 4,426,305.

[00127] The molecular weight of the hydrocarbyl substituted succinic anhydrides used in the preceding paragraphs will typically range between 800 and 2,500 or more. The above products can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids such as oleic acid. The above products can also be post reacted with boron compounds such as boric acid, borate esters or highly borated dispersants, to form borated dispersants generally having from about 0.1 to about 5 moles of boron per mole of dispersant reaction product.

[00128] Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. See U.S. Patent No. 4,767,551, which is incorporated herein by reference. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of the alkylphenols range from 800 to 2,500. Representative examples are shown in U.S. Patent Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; and 3,803,039.

[00129] Typical high molecular weight aliphatic acid modified Mannich condensation products useful in this disclosure can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or HNR₂ group-containing reactants.

[00130] Hydrocarbyl substituted amine ashless dispersant additives are well known to one skilled in the art; see, for example, U.S. Patent Nos. 3,275,554; 3,438,757; 3,565,804; 3,755,433, 3,822,209, and 5,084,197.

[00131] Preferred dispersants include borated and non-borated succinimides, including those derivatives from mono-succinimides, bis-succinimides, and/or mixtures of mono- and bis-succinimides, wherein the hydrocarbyl succinimide is derived from a hydrocarbylene group such as polyisobutylene having a Mn of from about 500 to about 5000, or from about 1000 to about 3000, or about 1000 to about 2000, or a mixture of such hydrocarbylene groups, often with high terminal vinylic groups. Other preferred dispersants include succinic acid-esters and amides, alkylphenol-polyamine-coupled Mannich adducts, their capped derivatives, and other related components.

[00132] Polymethacrylate or polyacrylate derivatives are another class of dispersants. These dispersants are typically prepared by reacting a nitrogen containing monomer and a methacrylic or acrylic acid esters containing 5 -25 carbon atoms in the ester group. Representative examples are shown in U.S. Patent Nos. 2, 100, 993, and 6,323,164. Polymethacrylate and polyacrylate dispersants are normally used as multifunctional viscosity modifiers. The lower molecular weight versions can be used as lubricant dispersants or fuel detergents.

[00133] Illustrative preferred dispersants useful in this disclosure include those derived from polyalkenyl-substituted mono- or dicarboxylic acid, anhydride or ester, which dispersant has a polyalkenyl moiety with a number average molecular weight of at least 900 and from greater than 1.3 to 1.7, preferably from greater than 1.3 to 1.6, most preferably from greater than 1.3 to 1.5, functional groups (mono- or dicarboxylic acid producing moieties) per polyalkenyl moiety (a medium functionality dispersant). Functionality (F) can be determined according to the following formula:

$$F = (SAP \times M_n) / ((112,200 \times A.I.) - (SAP \times 98))$$

wherein SAP is the saponification number (i.e., the number of milligrams of KOH consumed in the complete neutralization of the acid groups in one gram of the succinic-containing reaction product, as determined according to ASTM D94); M_n is the number average molecular weight of the starting olefin polymer; and A.I. is the percent active ingredient of the succinic-containing reaction product (the remainder being unreacted olefin polymer, succinic anhydride and diluent).

[00134] The polyalkenyl moiety of the dispersant may have a number average molecular weight of at least 900, suitably at least 1500, preferably between 1800 and 3000, such as between 2000 and 2800, more preferably from about 2100 to 2500, and most preferably from about 2200 to about 2400. The molecular weight of a dispersant is generally expressed in terms of the molecular weight

of the polyalkenyl moiety. This is because the precise molecular weight range of the dispersant depends on numerous parameters including the type of polymer used to derive the dispersant, the number of functional groups, and the type of nucleophilic group employed.

[00135] Polymer molecular weight, specifically M_n , can be determined by various known techniques. One convenient method is gel permeation chromatography (GPC), which additionally provides molecular weight distribution information (see W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979). Another useful method for determining molecular weight, particularly for lower molecular weight polymers, is vapor pressure osmometry (e.g., ASTM D3592).

[00136] The polyalkenyl moiety in a dispersant preferably has a narrow molecular weight distribution (MWD), also referred to as polydispersity, as determined by the ratio of weight average molecular weight (M_w) to number average molecular weight (M_n). Polymers having a M_w/M_n of less than 2.2, preferably less than 2.0, are most desirable. Suitable polymers have a polydispersity of from about 1.5 to 2.1, preferably from about 1.6 to about 1.8.

[00137] Suitable polyalkenes employed in the formation of the dispersants include homopolymers, interpolymers or lower molecular weight hydrocarbons. One family of such polymers comprise polymers of ethylene and/or at least one C_3 to C_{26} alpha-olefin having the formula $H_2C = CHR^1$ wherein R^1 is a straight or branched chain alkyl radical comprising 1 to 26 carbon atoms and wherein the polymer contains carbon-to-carbon unsaturation, and a high degree of terminal ethenylidene unsaturation. Preferably, such polymers comprise interpolymers of ethylene and at least one alpha-olefin of the above formula, wherein R^1 is alkyl of from 1 to 18 carbon atoms, and more preferably is alkyl of from 1 to 8 carbon atoms, and more preferably still of from 1 to 2 carbon atoms.

[00138] Another useful class of polymers is polymers prepared by cationic polymerization of monomers such as isobutene and styrene. Common polymers from this class include polyisobutenes obtained by polymerization of a C_4 refinery stream having a butene content of 35 to 75% by wt., and an isobutene content of 30 to 60% by wt. A preferred source of monomer for making poly-n-butenes is petroleum feed streams such as Raffinate II. These feed stocks are disclosed in the art such as in U.S. Pat. No. 4,952,739. A preferred embodiment utilizes polyisobutylene prepared from a pure isobutylene stream or a Raffinate I stream to prepare reactive isobutylene polymers with terminal vinylidene olefins. Polyisobutene polymers that may be employed are generally based on a polymer chain of from 1500 to 3000.

[00139] The dispersant(s) are preferably non-polymeric (e.g., mono- or bis-succinimides). Such dispersants can be prepared by conventional processes such as disclosed in U.S. Patent Application Publication No. 2008/0020950, the disclosure of which is incorporated herein by reference.

[00140] The dispersant(s) can be borated by conventional means, as generally disclosed in U.S. Patent Nos. 3,087,936, 3,254,025 and 5,430,105.

[00141] Such dispersants may be used in an amount of about 0.01 to 20 weight percent or 0.01 to 10 weight percent, preferably about 0.5 to 8 weight percent, or more preferably 0.5 to 4 weight percent. Or such dispersants may be used in an amount of about 2 to 12 weight percent, preferably about 4 to 10 weight percent, or more preferably 6 to 9 weight percent. On an active ingredient basis, such additives may be used in an amount of about 0.06 to 14 weight percent, preferably about 0.3 to 6 weight percent. The hydrocarbon portion of the dispersant atoms can range from C₆₀ to C₁₀₀₀, or from C₇₀ to C₃₀₀, or from C₇₀ to C₂₀₀. These dispersants may contain both neutral and basic nitrogen, and mixtures of both. Dispersants can be end-capped by borates and/or cyclic carbonates. Nitrogen content in the finished oil can vary from about 200 ppm by weight to about 2000 ppm by weight, preferably from about 200 ppm by weight to about 1200 ppm by weight. Basic nitrogen can vary from about 100 ppm by weight to about 1000 ppm by weight, preferably from about 100 ppm by weight to about 600 ppm by weight.

[00142] Dispersants as described herein are beneficially useful with the compositions of this disclosure and substitute for some or all of the surfactants of this disclosure. Further, in one embodiment, preparation of the compositions of this disclosure using one or more dispersants is achieved by combining ingredients of this disclosure, plus optional base stocks and lubricant additives, in a mixture at a temperature above the melting point of such ingredients, particularly that of the one or more M-carboxylates (M = H, metal, two or more metals, mixtures thereof).

[00143] As used herein, the dispersant concentrations are given on an “as delivered” basis. Typically, the active dispersant is delivered with a process oil. The “as delivered” dispersant typically contains from about 20 weight percent to about 80 weight percent, or from about 40 weight percent to about 60 weight percent, of active dispersant in the “as delivered” dispersant product.

Detergents

[00144] Illustrative detergents useful in this disclosure include, for example, alkali metal detergents, alkaline earth metal detergents, or mixtures of one or more alkali metal detergents and one or more alkaline earth metal detergents. A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic

acid such as a sulfur-containing acid, carboxylic acid (e.g., salicylic acid), phosphorus-containing acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal. The detergent can be overbased as described herein.

[00145] The detergent is preferably a metal salt of an organic or inorganic acid, a metal salt of a phenol, or mixtures thereof. The metal is preferably selected from an alkali metal, an alkaline earth metal, and mixtures thereof. The organic or inorganic acid is selected from an aliphatic organic or inorganic acid, a cycloaliphatic organic or inorganic acid, an aromatic organic or inorganic acid, and mixtures thereof.

[00146] The metal is preferably selected from an alkali metal, an alkaline earth metal, and mixtures thereof. More preferably, the metal is selected from calcium (Ca), magnesium (Mg), and mixtures thereof.

[00147] The organic acid or inorganic acid is preferably selected from a sulfur-containing acid, a carboxylic acid, a phosphorus-containing acid, and mixtures thereof.

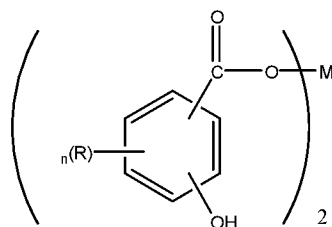
[00148] Preferably, the metal salt of an organic or inorganic acid or the metal salt of a phenol comprises calcium phenate, calcium sulfonate, calcium salicylate, magnesium phenate, magnesium sulfonate, magnesium salicylate, an overbased detergent, and mixtures thereof.

[00149] Salts that contain a substantially stoichiometric amount of the metal are described as neutral salts and have a total base number (TBN, as measured by ASTM D2896) of from 0 to 80. Many compositions are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (a metal hydroxide or oxide, for example) with an acidic gas (such as carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased. These detergents can be used in mixtures of neutral, overbased, highly overbased calcium salicylate, sulfonates, phenates and/or magnesium salicylate, sulfonates, phenates. The TBN ranges can vary from low, medium to high TBN products, including as low as 0 to as high as 600. Preferably the TBN delivered by the detergent is between 1 and 20. More preferably between 1 and 12. Mixtures of low, medium, high TBN can be used, along with mixtures of calcium and magnesium metal based detergents, and including sulfonates, phenates, salicylates, and carboxylates. A detergent mixture with a metal ratio of 1, in conjunction of a detergent with a metal ratio of 2, and as high as a detergent with a metal ratio of 5, can be used. Borated detergents can also be used.

[00150] Alkaline earth phenates are another useful class of detergent. These detergents can be made by reacting alkaline earth metal hydroxide or oxide (CaO, Ca(OH)₂, BaO, Ba(OH)₂, MgO, Mg(OH)₂, for example) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched C₁-C₃₀ alkyl groups, preferably, C₄-C₂₀ or mixtures thereof.

Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched and can be used from 0.5 to 6 weight percent. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (including elemental sulfur, sulfur halides such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

[00151] In accordance with this disclosure, metal salts of carboxylic acids are preferred detergents. These carboxylic acid detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing free water from the reaction product. These compounds may be overbased to produce the desired TBN level. Detergents made from salicylic acid are one preferred class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the formula



where R is an alkyl group having 1 to about 30 carbon atoms, n is an integer from 1 to 4, and M is an alkaline earth metal. Preferred R groups are alkyl chains of at least C₁₁, preferably C₁₃ or greater. R may be optionally substituted with substituents that do not interfere with the detergent's function. M is preferably, calcium, magnesium, barium, or mixtures thereof. More preferably, M is calcium.

[00152] Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

[00153] Alkaline earth metal phosphates are also used as detergents and are known in the art.

[00154] Detergents may be simple detergents or what is known as hybrid or complex detergents. The latter detergents can provide the properties of two detergents without the need to blend separate materials. See U.S. Patent No. 6,034,039.

[00155] Preferred detergents include calcium sulfonates, magnesium sulfonates, calcium salicylates, magnesium salicylates, calcium phenates, magnesium phenates, and other related components (including borated detergents), and mixtures thereof. Preferred mixtures of detergents include magnesium sulfonate and calcium salicylate, magnesium sulfonate and calcium sulfonate, magnesium sulfonate and calcium phenate, calcium phenate and calcium salicylate, calcium

phenate and calcium sulfonate, calcium phenate and magnesium salicylate, calcium phenate and magnesium phenate. Overbased detergents are also preferred.

[00156] The detergent concentration in the lubricant compositions of this disclosure can range from about 0.5 to about 6.0 weight percent, preferably about 0.6 to 5.0 weight percent, and more preferably from about 0.8 weight percent to about 4.0 weight percent, based on the total weight of the lubricant composition.

[00157] As used herein, the detergent concentrations are given on an “as delivered” basis. Typically, the active detergent is delivered with a process oil. The “as delivered” detergent typically contains from about 20 weight percent to about 100 weight percent, or from about 40 weight percent to about 60 weight percent, of active detergent in the “as delivered” detergent product.

Viscosity Modifiers

[00158] Viscosity modifiers (also known as viscosity index improvers (VI improvers), and viscosity improvers) can be included in the lubricant compositions of this disclosure.

[00159] Viscosity modifiers provide lubricants with high and low temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures.

[00160] Suitable viscosity modifiers include high molecular weight hydrocarbons, polyesters and viscosity modifier dispersants that function as both a viscosity modifier and a dispersant. Typical molecular weights of these polymers are between about 10,000 to 1,500,000, more typically about 20,000 to 1,200,000, and even more typically between about 50,000 and 1,000,000.

[00161] Examples of suitable viscosity modifiers are linear or star-shaped polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity modifier. Another suitable viscosity modifier is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity modifiers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 molecular weight.

[00162] Olefin copolymers are commercially available from Chevron Oronite Company LLC under the trade designation “PARATONE®” (such as “PARATONE® 8921” and “PARATONE® 8941”); from Afton Chemical Corporation under the trade designation “HiTEC®” (such as “HiTEC® 5850B”); and from The Lubrizol Corporation under the trade designation “Lubrizol®

7067C". Hydrogenated polyisoprene star polymers are commercially available from Infineum International Limited, e.g., under the trade designation "SV200" and "SV600". Hydrogenated diene-styrene block copolymers are commercially available from Infineum International Limited, e.g., under the trade designation "SV 50".

[00163] The polymethacrylate or polyacrylate polymers can be linear polymers which are available from Evnoik Industries under the trade designation "Viscoplex®" (e.g., Viscoplex 6-954) or star polymers which are available from Lubrizol Corporation under the trade designation Asteric™ (e.g., Lubrizol 87708 and Lubrizol 87725).

[00164] Illustrative vinyl aromatic-containing polymers useful in this disclosure may be derived predominantly from vinyl aromatic hydrocarbon monomer. Illustrative vinyl aromatic-containing copolymers useful in this disclosure may be represented by the following general formula:



wherein A is a polymeric block derived predominantly from vinyl aromatic hydrocarbon monomer, and B is a polymeric block derived predominantly from conjugated diene monomer.

[00165] In an embodiment of this disclosure, the viscosity modifiers may be used in an amount of less than about 10 weight percent, preferably less than about 7 weight percent, more preferably less than about 4 weight percent, and in certain instances, may be used at less than 2 weight percent, preferably less than about 1 weight percent, and more preferably less than about 0.5 weight percent, based on the total weight of the lubricant composition. Viscosity modifiers are typically added as concentrates, in large amounts of diluent oil.

[00166] As used herein, the viscosity modifier concentrations are given on an "as delivered" basis. Typically, the active polymer is delivered with a diluent oil. The "as delivered" viscosity modifier typically contains from 20 weight percent to 75 weight percent of an active polymer for polymethacrylate or polyacrylate polymers, or from 8 weight percent to 20 weight percent of an active polymer for olefin copolymers, hydrogenated polyisoprene star polymers, or hydrogenated diene-styrene block copolymers, in the "as delivered" polymer concentrate.

Pour Point Depressants (PPDs)

[00167] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present disclosure if desired. These pour point depressant may be added to lubricant compositions of the present disclosure to lower the minimum temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. U.S. Patent Nos. 1,815,022; 2,015,748; 2,191,498;

2,387,501; 2,655, 479; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent.

Seal Compatibility Agents

[00168] Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal compatibility agents for lubricants include organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Such additives may be used in an amount of about 0.01 to 3 weight percent, preferably about 0.01 to 2 weight percent.

Antifoam Agents

[00169] Anti-foam agents may advantageously be added to lubricant compositions. These agents retard the formation of stable foams. Silicones and organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide antifoam properties. Anti-foam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers; usually the amount of these additives combined is less than 1 weight percent and often less than 0.1 weight percent.

Inhibitors and Antirust Additives

[00170] Antirust additives (or corrosion inhibitors) are additives that protect lubricated metal surfaces against chemical attack by water or other contaminants. A wide variety of these are commercially available.

[00171] One type of antirust additive is a polar compound that wets the metal surface preferentially, protecting it with a film of oil. Another type of antirust additive absorbs water by incorporating it in a water-in-oil emulsion so that only the oil touches the metal surface. Yet another type of antirust additive chemically adheres to the metal to produce a non-reactive surface. Examples of suitable additives include zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent.

Friction Modifiers

[00172] A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers, also known as friction reducers, or lubricity agents or oiliness agents, and other such agents that change the ability of base oils, formulated lubricant compositions, or functional fluids, to modify the coefficient of friction of a lubricated surface may be effectively used in combination with the base oils or lubricant compositions of the present disclosure if desired. Friction modifiers that

lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this disclosure.

[00173] Illustrative friction modifiers may include, for example, organometallic compounds or materials, or mixtures thereof. Illustrative organometallic friction modifiers useful in the lubricant compositions of this disclosure include, for example, molybdenum amine, molybdenum diamine, an organotungstenate, a molybdenum dithiocarbamate, molybdenum dithiophosphates, molybdenum amine complexes, molybdenum carboxylates, and the like, and mixtures thereof. Similar tungsten based compounds may be preferable.

[00174] Other illustrative friction modifiers useful in the lubricant compositions of this disclosure include, for example, alkoxyated fatty acid esters, alkanolamides, polyol fatty acid esters, borated glycerol fatty acid esters, fatty alcohol ethers, and mixtures thereof.

[00175] Illustrative alkoxyated fatty acid esters include, for example, polyoxyethylene stearate, fatty acid polyglycol ester, and the like. These can include polyoxypropylene stearate, polyoxybutylene stearate, polyoxyethylene isostearate, polyoxypropylene isostearate, polyoxyethylene palmitate, and the like.

[00176] Illustrative alkanolamides include, for example, lauric acid diethylalkanolamide, palmitic acid diethylalkanolamide, and the like. These can include oleic acid diethylalkanolamide, stearic acid diethylalkanolamide, oleic acid diethylalkanolamide, polyethoxylated hydrocarbylamides, polypropoxylated hydrocarbylamides, and the like.

[00177] Illustrative polyol fatty acid esters include, for example, glycerol mono-oleate, saturated mono-, di-, and tri-glyceride esters, glycerol mono-stearate, and the like. These can include polyol esters, hydroxyl-containing polyol esters, and the like.

[00178] Illustrative borated glycerol fatty acid esters include, for example, borated glycerol mono-oleate, borated saturated mono-, di-, and tri-glyceride esters, borated glycerol mono-stearate, and the like. In addition to glycerol polyols, these can include trimethylolpropane, pentaerythritol, sorbitan, and the like. These esters can be polyol monocarboxylate esters, polyol dicarboxylate esters, and on occasion polyoltricarboxylate esters. Preferred can be the glycerol mono-oleates, glycerol dioleates, glycerol trioleates, glycerol monostearates, glycerol distearates, and glycerol tristearates and the corresponding glycerol monopalmitates, glycerol dipalmitates, and glycerol tripalmitates, and the respective isostearates, linoleates, and the like. On occasion the glycerol esters can be preferred as well as mixtures containing any of these. Ethoxylated, propoxylated, butoxylated fatty acid esters of polyols, especially using glycerol as underlying polyol can be preferred.

[00179] Illustrative fatty alcohol ethers include, for example, stearyl ether, myristyl ether, and the like. Alcohols, including those that have carbon numbers from C₃ to C₅₀, can be ethoxylated, propoxylated, or butoxylated to form the corresponding fatty alkyl ethers. The underlying alcohol portion can preferably be stearyl, myristyl, C₁₁ – C₁₃ hydrocarbon, oleyl, isosteryl, and the like.

[00180] The lubricant compositions of this disclosure exhibit desired properties, e.g., wear control, in the presence or absence of a friction modifier.

[00181] Useful concentrations of friction modifiers may range from 0.01 weight percent to 5 weight percent, or about 0.1 weight percent to about 2.5 weight percent, or about 0.1 weight percent to about 1.5 weight percent, or about 0.1 weight percent to about 1 weight percent. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 25 ppm to 700 ppm or more, and often with a preferred range of 50-200 ppm. Friction modifiers of all types may be used alone or in mixtures with the materials of this disclosure. Often mixtures of two or more friction modifiers, or mixtures of friction modifier(s) with alternate surface active material(s), are also desirable.

Antiwear Additives

[00182] A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) can be a useful component of the lubricant compositions of this disclosure. ZDDP can be derived from primary alcohols, secondary alcohols or mixtures thereof. ZDDP compounds generally are of the formula



where R¹ and R² are C₁-C₁₈ alkyl groups, preferably C₂-C₁₂ alkyl groups. These alkyl groups may be straight chain or branched. Alcohols used in the ZDDP can be propanol, 2-propanol, butanol, secondary butanol, pentanols, hexanols such as 4-methyl-2-pentanol, n-hexanol, n-octanol, 2-ethyl hexanol, alkylated phenols, and the like. Mixtures of secondary alcohols or of primary and secondary alcohol can be preferred. Alkyl aryl groups may also be used.

[00183] Preferable zinc dithiophosphates which are commercially available include secondary zinc dithiophosphates such as those available from for example, The Lubrizol Corporation under the trade designations “LZ 677A”, “LZ 1095” and “LZ 1371”, from for example Chevron Oronite under the trade designation “OLOA 262” and from for example Afton Chemical under the trade designation “HITEC 7169”.

[00184] The ZDDP is typically used in amounts of from about 0.3 weight percent to about 1.5 weight percent, preferably from about 0.4 weight percent to about 1.2 weight percent, more preferably from about 0.5 weight percent to about 1.0 weight percent, and even more preferably from about 0.6 weight percent to about 0.8 weight percent, based on the total weight of the

lubricant, although more or less can often be used advantageously. Preferably, the ZDDP is a secondary ZDDP and present in an amount of from about 0.6 to 1.0 weight percent of the total weight of the lubricant composition.

[00185] The types and quantities of performance additives used in combination with the instant disclosure in lubricant compositions are not limited by the examples shown herein as illustrations.

[00186] When lubricant compositions contain one or more of the additives 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 disclosure are shown in Table 1 below.

[00187] It is noted that many of the additives are shipped from the additive manufacturer as a concentrate, containing one or more additives together, with a certain amount of base oil diluents. Accordingly, the weight amounts in the table below, as well as other amounts mentioned herein, are directed to the amount of active ingredient (that is the non-diluent portion of the ingredient). The weight percent (wt%) indicated below is based on the total weight of the lubricant composition.

Table 1
Typical Amounts of Other Lubricant Components

Compound	Approximate wt% (Useful)	Approximate wt% (Preferred)
Antiwear	0.1-2	0.5-1
Dispersant	0.1-20	0.1-8
Detergent	0.1-20	0.1-8
Antioxidant	0.1-10	0.1-5
Friction Modifier	0.01-5	0.01-1.5
Pour Point Depressant (PPD)	0.0-5	0.01-1.5
Anti-foam Agent	0.001-3	0.001-0.15
Viscosity Index Improver (pure polymer basis)	0.0-8	0.1-6
Inhibitor and Antirust	0.01-5	0.01-1.5

[00188] The foregoing additives are all commercially available materials. These additives may be added independently but are usually precombined in packages which can be obtained from suppliers of lubricant oil additives. Additive packages with a variety of ingredients,

proportions and characteristics are available and selection of the appropriate package will take the requisite use of the ultimate composition into account.

[00189] The concentrations of the low and high viscosity base stock blends described herein have the ability to control traction coefficient and film thickness in the lubricant compositions incorporating the blends. The use of these fluid blends is desirable in lubricant compositions in the presence of salicylate, sulfonate and phenate detergents, along with antioxidants and ashless antioxidants, along with succinimide based dispersants, along with zinc dialkyldithiophosphates, along with organic and metallic friction modifiers, along with corrosion inhibitors, and along with defoamants. The low and high viscosity base stock blends are useful in all lubricant applications.

[00190] The disclosure is directed to base stock blends useful in the preparation of finished gear, transmission, engine, and industrial lubricants, and in a preferred embodiment are used as lubricants for non-conforming concentrated contacts with high sliding such as spur gears, helical gears, hypoid gears, bevel gears, worm gears and the like.

[00191] Lubricant compositions according to the present disclosure are particularly useful in applications wherein there are EHL contacts that have a component of sliding. Examples include spherical roller bearings, deep groove ball bearings, angular contact bearings among others. Additionally, most gear systems contain multiple sliding EHL contacts between meshing gear teeth. Examples include spur gears, helical gears, hypoid gears, bevel gears, worm gears, and the like.

[00192] For industrial gears, one common type of gearing is worm gears. Worm gears form an extended elliptical contact against the wheel and operate under high sliding EHL conditions. Therefore, there is a significant benefit to the lubricant compositions of this disclosure in terms of energy savings.

[00193] Quantifying the amount of efficiency that can be expected is difficult because it is dependent on many factors, in worm gears for example, the amount of efficiency seen will depend on many factors including the shaft bearings, seals, churning losses, gear meshing, gear reduction ratios, etc. However, it is estimated that the gains may be substantial due to the high sliding and generally high energy losses. Steel gears are generally more efficient than bronze worm gears, and therefore, the absolute efficiency gains will be lessened.

[00194] Nevertheless, one of ordinary skill in the art can quantify fuel efficiency of a gear system by numerous methods and more particularly can determine an improvement in such system for embodiments of compositions according to the present disclosure compared with

lubricant composition that do not show an improvement. Likewise, the energy efficiency of a machine operating the gear system can be readily determined and comparisons made.

[00195] Rolling element bearings have many configurations and depending on the type of configuration, there may or may not be a benefit to having a lubricant composition of this disclosure. This may also be determined by one of ordinary skill in the art in possession of the present disclosure. Where there is sliding between the ball and the raceway, the oil is being sheared such that the lubricants described in this disclosure will reduce the energy losses.

[00196] The present disclosure is particularly beneficial in any system that includes machine elements that contain gears of any kind and rolling element bearings. Examples of such systems include electricity generating systems, industrial manufacturing equipment such as paper, steel and cement mills, hydraulic systems, automotive drive trains, aircraft propulsion systems, etc. It will be recognized by one of ordinary skill in the art in possession of the present disclosure that the various embodiments set forth herein, including preferred and more preferred embodiments, may be combined in a manner consistent with achieving desired lubricant properties.

[00197] The following non-limiting examples are provided to illustrate the disclosure.

EXAMPLES

[00198] The Examples focus are directed to traction and pressure viscosity coefficient behaviors of PAO lubricant base fluids and their blends. The Examples are separated into two parts, selected single-component lubricant base stocks and selected two-component binary blends of these same lubricants. The lubricants were tested in a Mini-Traction Machine (MTM).

[00199] As used herein, traction coefficient was determined by a PCS Instruments MTM using standard steel specimens, a lubricant temperature of 100°C, a 1.0 GPa peak contact pressure, a lubricant entraining velocity of 2 ms, and a 25% slide-to-roll ratio (hereinafter "MTM TC Method"). Suitable MTM testing properties include, for example, 0.1 to 3.5 GPa, peak contact pressure, -40°C to 200°C lubricant temperature, and a lubricant entraining velocity of from 0.25 to 10.0 m/s. Other methods can be used to determine traction coefficient provided the measurements are consistent with a given method in making any comparisons. As used herein, viscosity was determined by ASTM D-445.

[00200] A listing of base oils used in the Examples is set forth in Table 2 below. As used herein and Figs. 1-8, mPAO 150 is SpectraSyn Elite® 150, mPAO 300 is SpectraSyn Elite® 300, mPAO 600 is 600 cSt Alpha Olefin, and mPAO 1000 is 1000 cSt Alpha Olefin.

Table 2

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Low molecular base oils	High molecular base oil
PAO 2	PAO 100
PAO 4	mPAO 150
PAO 6	mPAO 300
PAO 8	mPAO 600
	mPAO 1000

[00201] A further listing of base oils used in the Examples is set forth in Table 3 below.

Bimodal blends were done in two ways as shown in Table 3. First, a series of low viscosity base oil (i.e., PAO 2, PAO 4, PAO 6 or PAO 8) were blended with the high viscosity base oil mPAO150. Second, a series of high viscosity base oil (i.e., PAO 100, mPAO 150, mPAO 300, mPAO 600 or mPAO 1000) were blended with a low viscosity base oil PAO 4. Table 4 shows bimodal blend results for kinematic viscosity determined by ASTM D-445, and traction coefficient determined by MTM TC Method.

Table 3

Low molecular base oils	High molecular base oil	Low molecular base oil Concentration %
PAO 2	mPAO 150	10,25,50,75,90
PAO 4	mPAO 150	25,50,65,75
PAO 6	mPAO 150	10,25,50,75,90
PAO 8	mPAO 150	30,50,75,90
PAO 4	PAO 100	25,50,75,90
PAO 4	mPAO 150	25,50,75
PAO 4	mPAO 300	25,50,75
PAO 4	mPAO 600	25, 50,75
PAO 4	mPAO 1000	25,50,75, 90

Table 4

	KV @100C	Traction		KV @100C	Traction
mPAO150/PAO2 blends			PAO100 blends		
7171/90%PAO2	1.366	0.0097	PAO100/PAO4 25%	46.38	0.0171
7171/75%PAO2	4.451	0.0086	PAO100/PAO4 50%	20.92	0.014
7171/50%PAO2	12.55	0.0153	PAO100/PAO4 75%	9.313	0.0114
7171/25%PAO2	49.22	0.015			
7171/10%PAO2	59.45	0.0121	mPAO300 blends		
			PAO300/75%PAO4	11.85	0.0114
			PAO300/50%PAO4	11.6	0.0132
			PAO300/25%PAO4	93.13	0.0124
mPAO150/PAO6 blends					
7171/25%PAO6	61.72	0.018			
7171/50%PAO6	26.73	0.0157	mPAO 500 blends		
7171/75%PAO6	12.51	0.0148	PAO500/50%PAO4	7.283	0.01205
7171/100%PAO6	110.9	0.0136	PAO500/75%PAO4	16.12	0.0113
7171/90%PAO6	7.829	0.013	PAO500/90%PAO4	7.401	0.0115
			PAO500/15%PAO4	167.4	0.0176
			PAO500/30%PAO4	93.18	0.0139
			PAO500/10%PAO4	134.1	0.0156
mPAO150/PAO8 blends					
7171/90%PAO8	10.56	0.0132			
7171/50%PAO8	32.13	0.012			
7171/25%PAO8	58.55	0.0123	mPAO 1000 blends		
7171/75%PAO8	16.03	0.0137	mPAO1000/25%PAO4	236.4	0.016
			mPAO1000/50%PAO4	74.63	0.0131
			mPAO1000/75%PAO4	30.71	0.0117
			mPAO1000/90%PAO4	2.482	0.0133
mPAO150/PAO4 Blends					
7171/75%PAO4	8.1	0.0115			
7171/63%PAO4	13	0.0124			
7171/50%PAO4	21.88	0.0134			
7171/25%PAO4	34.29	0.0127			

[00202] A summary of the traction responses for the base oils is shown in Fig. 1.

Reproducibility errors have been calculated for some of the base oils, and they are represented by arrow lines in Fig. 1. In particular, Fig. 1 graphically shows traction performance for neat base oils, PAO 4, PAO 8, PAO 40, PAO 100, mPAO 150, mPAO 300, and mPAO 600.

[00203] Fig. 1 shows the following: tractions increase as the viscosity of the base oils increase up to a KV 40; neat oil traction responses reach a plateau around PAO40 or before; variability of the test increases as traction increases (arrow lines); and after viscosity surpasses mPAO 150, shear heating effects contribution (shear heating) has a substantial effect on traction performance.

[00204] The base oil mPAO 150 was mixed with a variety of low viscosity (LV) base oils (i.e., PAO 2, PAO 4, PAO 6 or PAO 8) to make the fluids in Table 3. The results have showed that when high concentration of the LV molecules is used, meaning final blends have lower viscosity; the traction decreases. An important observation is as the molecular weight of the LV component used to make the blends (lower viscosity fluids- PAO 8 > PAO6 > PAO4 > PAO 2) is decreased, the traction of the final blend decreases as well. This is conventional behavior. The conventional wisdom is that traction is completely dependent on lubricant viscosity (see Fig. 2).

This behavior has been well explored and observed with other LV base oils and it is attributed to a lower pressure viscosity coefficient meaning lower viscosity at pressure in the EHL contact zone.

[00205] Fig. 2 graphically shows traction performance for blends made with constant high viscosity base oil (mPAO 150) and varied low viscosity base oil (i.e., PAO 2, PAO 4, PAO 6 or PAO 8) under conditions 1GPa, 25% SRR at 100°C. Traction coefficient shows a clear dependency on oil viscosity and type of low viscosity component.

[00206] In particular, Fig. 2 shows the following: as the concentration of the low viscosity component is increased, the viscosity of the fluid decreases and traction also decreases; a significant decrease in traction also observed when the LV fluid was replaced with a lower molecular weight fluid; at the same concentration of LV component, traction trend behave as follows: PAO 8 > PAO6 > PAO4 > PAO 2; and in the case of PAO 2 and PAO 8, minimum traction points were observed lower than the neat LV component. The PAO 2 mixtures and PAO 2 neat are situated outside of the EHL region (mix boundary region), hence having higher traction due to metal-metal contact.

[00207] The base oil PAO 4 was blended with a variety of high viscosity (HV) base oils at different ratios (i.e., PAO 100, mPAO 150, mPAO 300, mPAO 600 or mPAO 1000) with the traction subsequently measured. The data is summarized in Fig. 3.

[00208] Fig. 3 graphically shows traction performance for blends of multiple high molecular weight PAO polymers (PAO 100, mPAO 150, mPAO 300, mPAO 600, mPAO 1000) with PAO 4. Fig. 3 shows traction increase as viscosity of the bimodal blends increase.

[00209] In particular, Fig. 3 shows the following: the expected behavior of traction being controlled by viscosity; and extreme bimodal behavior confirmed, meaning the more separation of the viscosities of the components used to make the final fluids, the lower the traction at the same viscosity.

[00210] The same data in Fig. 3 was plotted against the concentration of the LV component in the fluid, in this case PAO 4 (see Fig. 4). The expected behavior was to observe something similar to Fig. 2, where the viscosity of the fluids control the traction performance of the fluids, however in these experiments a different response was observed. Unresponsiveness was observed to changes in traction as the viscosities of the fluids was significantly increased for all fluids with similar PAO 4 compositions (compare Figs. 2 and 4). These means that at a given PAO 4 concentration, these blends showed equivalent traction performance despite the lubricant viscosity being varied and high viscosity fluids used. For example, similar traction performance was observed at 25% PAO 4 independently of the use of HV materials, e.g., PAO 100, mPAO

150, 300, 600 or 1000. This performance is totally contradicted to the conventional knowledge of bimodal blends. In addition, initial data confirmed a similar phenomena if PAO 4 is replaced with PAO 6.

[00211] While not wishing to be bound by any particular theory, potential explanations for this performance include the following: shear thinning; inlet size separation; induced phase transition; and induced phase separation.

[00212] Fig. 4 graphically shows traction performance for PAO bimodal blends made by mixing high viscosity base oil (i.e., PAO 40, PAO 100, mPAO 150, mPAO 300, mPAO 600 or mPAO 1000) with a low viscosity base oil PAO 4 under conditions 1GPa, 25% SRR at 100°C. Fig. 4 shows that traction coefficients are predominantly controlled by PAO4 concentration, and are independent of the high viscosity component and finished oil KV.

[00213] Fig. 5 graphically shows that traction coefficient is controlled by the low viscosity component of bimodal blends and is independent of finish oil viscosity.

[00214] Fig. 6 graphically shows that traction coefficient is controlled by high viscosity base oil (i.e., Lucant base oil) at concentration higher than 15 percent by weight. At a low concentration of high viscosity base oils, the traction increased unexpectedly as the concentration of PAO 4 increased (viscosity decreasing).

[00215] The Examples show that the bimodal blend traction coefficient is independent of lubricant viscosity and is instead dependent upon the low viscosity (LV) fluid concentration.

[00216] All patents and patent applications, test procedures (such as ASTM methods, UL methods, and the like), and other documents cited herein are fully incorporated by reference to the extent such disclosure is not inconsistent with this disclosure and for all jurisdictions in which such incorporation is permitted.

[00217] When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated. While the illustrative embodiments of the disclosure have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the disclosure. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as encompassing all the features of patentable novelty which reside in the present disclosure, including all features which would be treated as equivalents thereof by those skilled in the art to which the disclosure pertains.

[00218] The present disclosure has been described above with reference to numerous embodiments and specific examples. Many variations will suggest themselves to those skilled in

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this art in light of the above detailed description. All such obvious variations are within the full intended scope of the appended claims.

CLAIMS:

1. A method for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces, said method comprising using a lubricant composition in the mechanical component having sliding or rolling between contacting surfaces, the lubricant composition comprising a base stock blend as a major component, and at least one lubricant additive, as a minor component; wherein the base stock blend comprises at least one first base stock having a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from 100 cSt to 2000 cSt at 40°C as determined by ASTM D-445; wherein the first base stock is present in an amount greater than 50 to 95 weight percent of the base stock blend, and the second base stock is present in an amount from 5 to less than 50 weight percent of the base stock blend; and wherein the second base stock is miscible with the first base stock.
2. The method of claim 1 wherein, in the mechanical component having sliding or rolling between contacting surfaces lubricated with the lubricant composition, traction coefficient (Tc) is controlled by concentration of the first base stock, and film thickness is controlled by the concentration of the second base stock.
3. The method of claims 1 and 2 wherein the first base stock is present in an amount from 60 to 95 weight percent of the base stock blend, and the second base stock is present in an amount from 5 to 40 weight percent of the base stock blend.
4. The method of claims 1-3 wherein the first base stock comprises a Group I, Group II, Group III, Group IV or Group V base oil, and the second base stock comprises a Group I, Group II, Group III, Group IV or Group V base oil.
5. The method of claims 1-4 wherein the first base stock comprises a polyalphaolefin (PAO) base oil, and the second base stock comprises a polyalphaolefin (PAO) base oil or a metallocene catalyzed polyalphaolefin (PAO) base oil.
6. The method of claims 1-5 wherein the base stock blend is present in an amount from 70 to 95 weight percent of the lubricant composition.
7. The method of claims 1-6 wherein the first base stock has a traction coefficient (Tc) of from 0.008 to 0.015 as determined by MTM TC Method, the second base stock has a traction coefficient (Tc) of from 0.008 to 0.025 as determined by MTM TC Method, and the lubricant composition has a traction coefficient (Tc) of less than 0.15 as determined by MTM TC Method.
8. The method of claims 1-7 wherein traction coefficient (Tc) is independent of viscosity of the lubricant composition.
9. The method of claims 1-8 wherein the base stock blend is a bimodal blend.

10. The method of claims 1-9 wherein, in the mechanical component having sliding or rolling between contacting surfaces lubricated with the lubricant composition, a phase separation or transition is induced in a mechanical contact zone.

11. A lubricant composition comprising a base stock blend as a major component, and at least one lubricant additive, as a minor component; wherein the base stock blend comprises at least one first base stock having a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from 100 cSt to 2000 cSt at 40°C as determined by ASTM D-445; wherein the first base stock is present in an amount greater than 50 to 95 weight percent of the base stock blend, and the second base stock is present in an amount from 5 to less than 50 weight percent of the base stock blend; and wherein the second base stock is miscible with the first base stock.

12. A method for controlling traction coefficient (T_c) of a lubricant composition, said method comprising blending at least one first base stock with at least one second base stock to give a base stock blend; wherein the first base stock has a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and the second base stock has a viscosity from 100 cSt to 2000 cSt at 40°C as determined by ASTM D-445; wherein the first base stock is miscible with the second base stock; and wherein the first base stock is present in the base stock blend in an amount sufficient to control traction coefficient (T_c) of the lubricant composition.

13. A method for controlling film thickness of a lubricant composition, said method comprising blending at least one first base stock with at least one second base stock to give a base stock blend; wherein the first base stock has a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and the second base stock has a viscosity from 100 cSt to 2000 cSt at 40°C as determined by ASTM D-445; wherein the second base stock is miscible with the first base stock; and wherein the second base stock is present in the base stock blend in an amount sufficient to control film thickness of the lubricant composition.

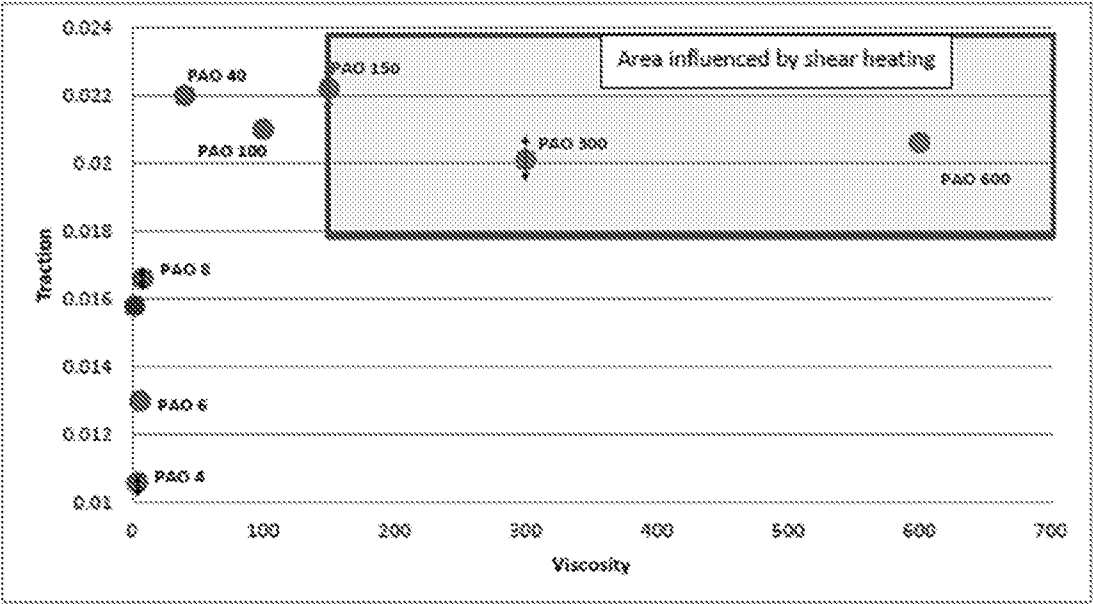
14. A method for improving wear control, while maintaining or improving energy efficiency, in a mechanical component having sliding or rolling between contacting surfaces, said method comprising using a lubricant composition in the mechanical component having sliding or rolling between contacting surfaces, the lubricant composition comprising a base stock blend as a major component, and at least one lubricant additive, as a minor component; wherein the base stock blend comprises at least one first base stock having a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445; wherein the first base stock is different from the second base stock; wherein the first base stock is present in an amount greater than 50 to 95

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weight percent of the base stock blend, and the second base stock is present in an amount from 5 to less than 50 weight percent of the base stock blend; and wherein the second base stock is miscible with the first base stock.

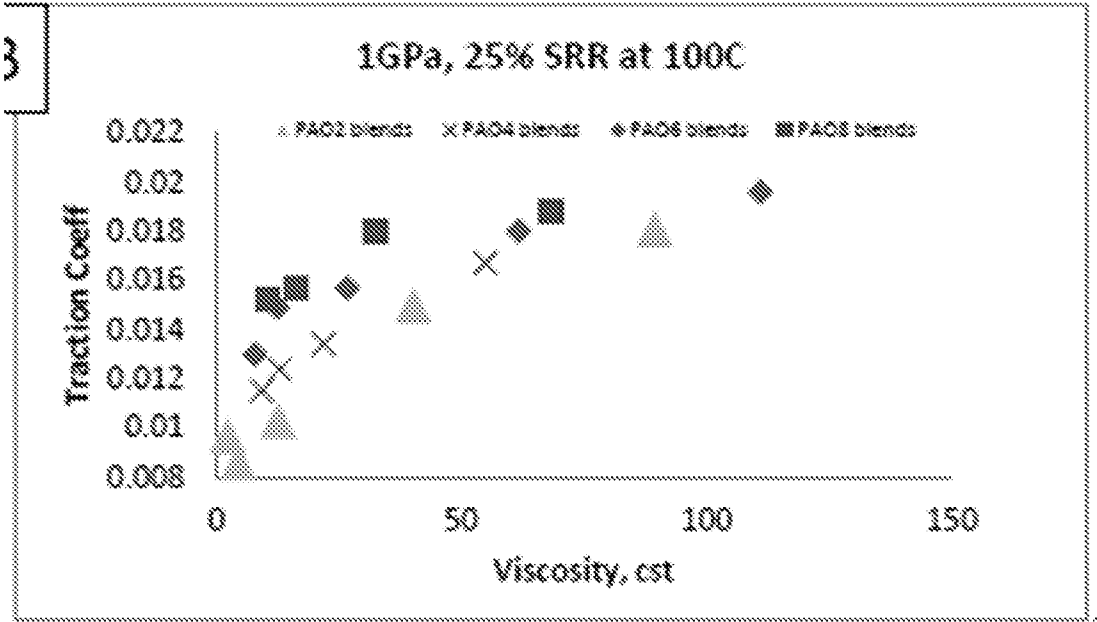
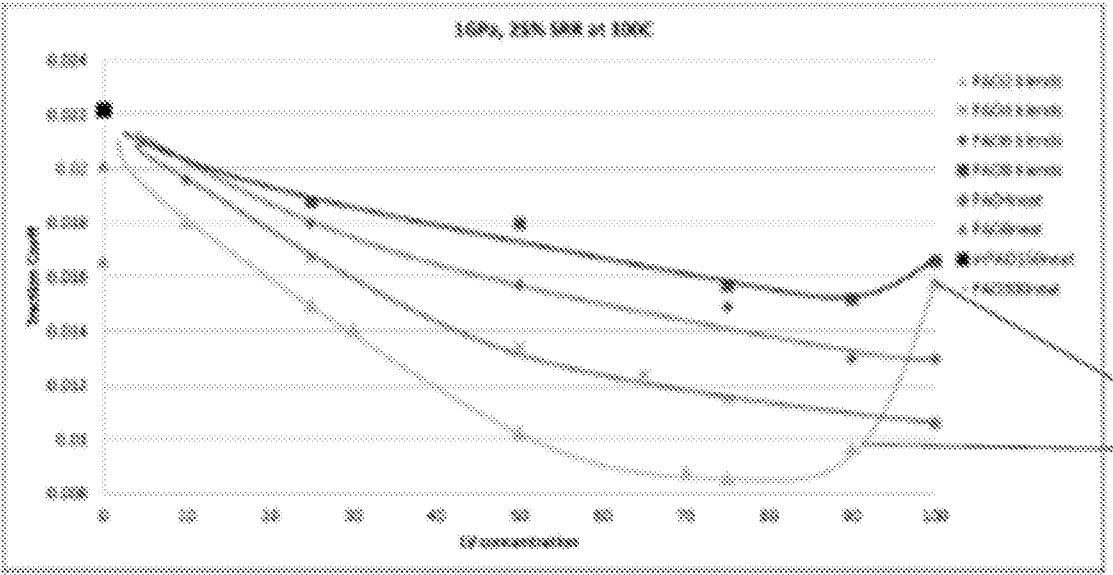
15. A lubricant composition comprising a base stock blend as a major component, and at least one lubricant additive, as a minor component; wherein the base stock blend comprises at least one first base stock having a viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445, and at least one second base stock having viscosity from 1 cSt to 50 cSt at 40°C as determined by ASTM D-445; wherein the first base stock is different from the second base stock; wherein the first base stock is present in an amount greater than 50 to 95 weight percent of the base stock blend, and the second base stock is present in an amount from 5 to less than 50 weight percent of the base stock blend; and wherein the second base stock is miscible with the first base stock.

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Fig. 1



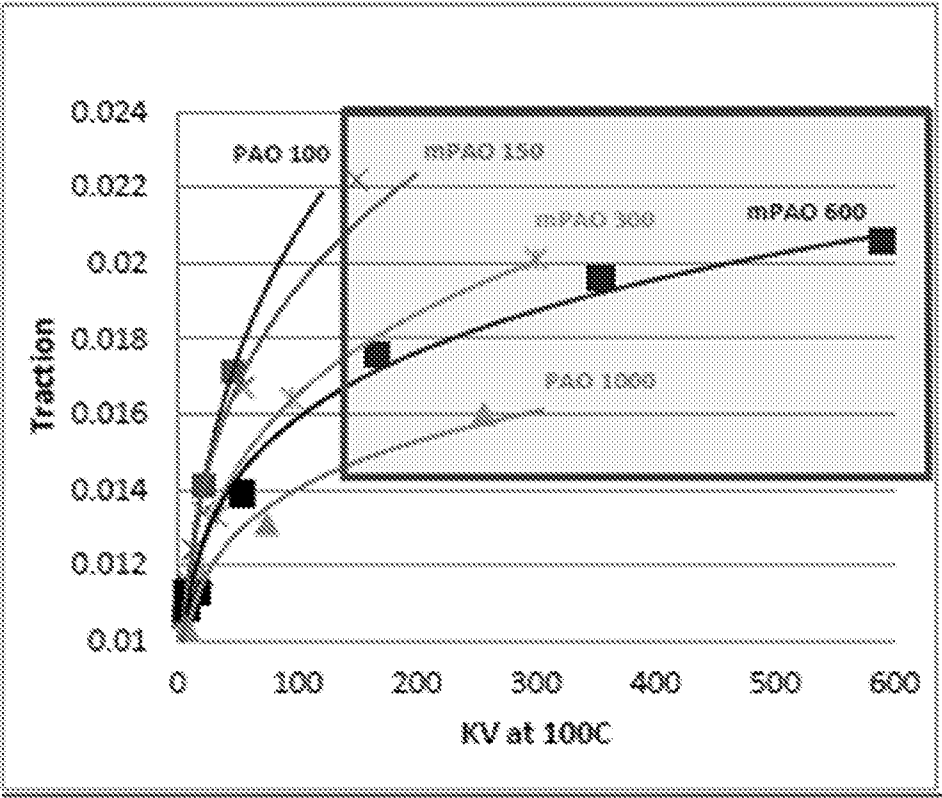
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Fig. 2



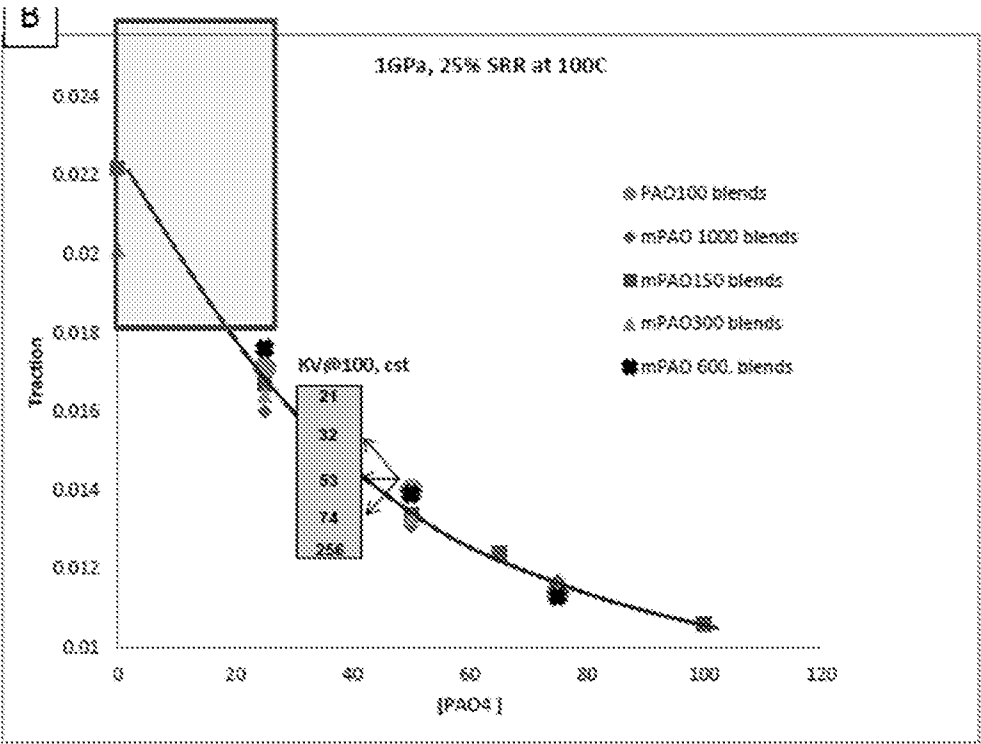
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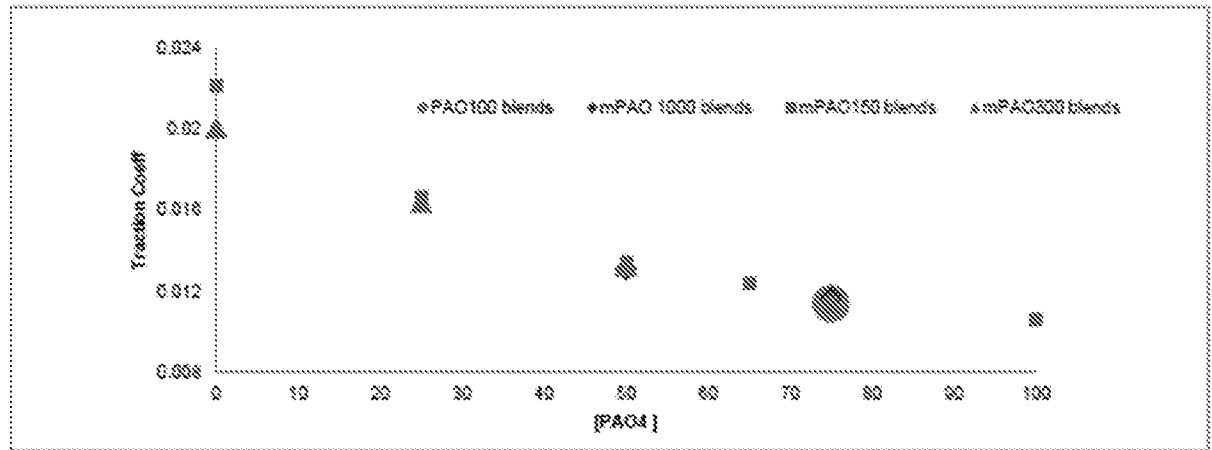
Fig. 3



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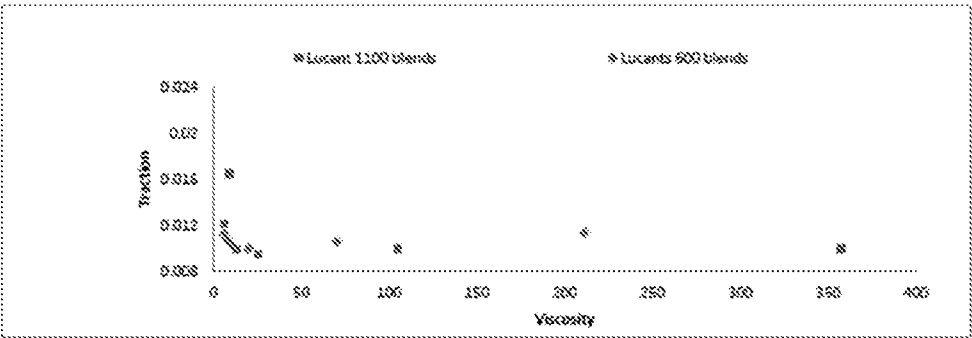
Fig. 4



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Fig. 5

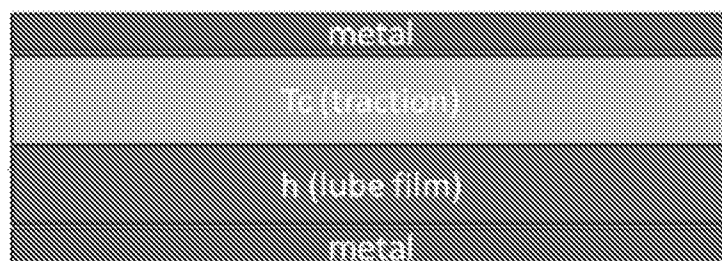
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Fig. 6



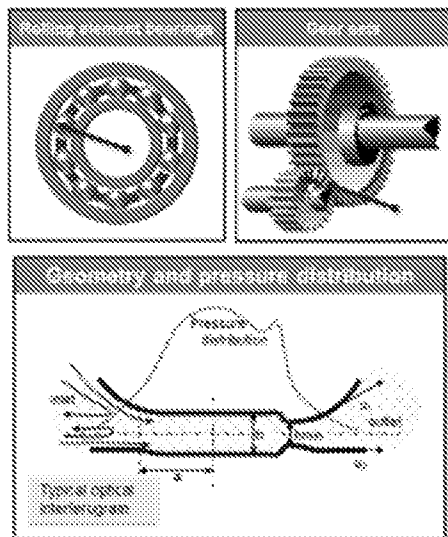
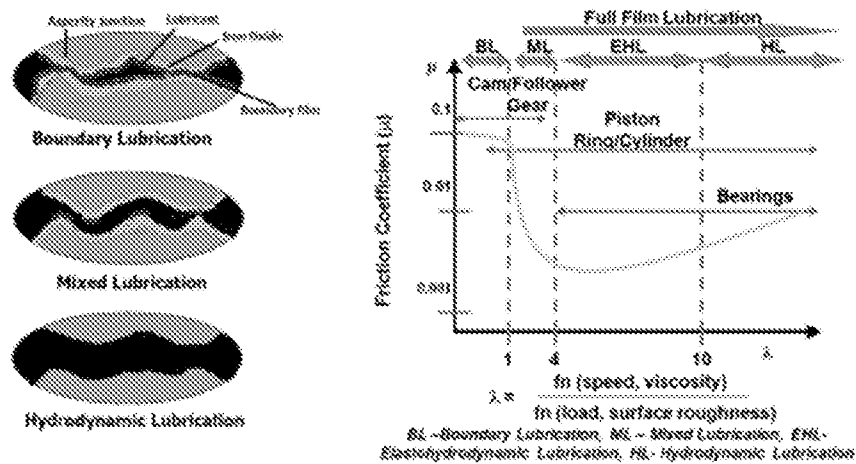
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Fig. 7



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Fig. 8



Elastohydrodynamic lubrication (EHL) – complete separation of loaded moving machine elements by a layer of lubricant

- Lubricant cushion:
 - Separates surfaces
 - Removes (reduces) wear
 - Reduces friction

Film thickness – less than 20% of the distortion of the surface

Thickness depends on:

- entrainment speed U
- ambient viscosity η_0
- pressure-viscosity coefficient α_p