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(54) **LUBRICATING FORMULATIONS FOR DISPERSANCY AND TEMPERATURE, FRICTION, AND WEAR REDUCTION**

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(57) **ABSTRACT**

The present invention provides a working fluid additive for use in conjunction with a working fluid within an operating system having contact surfaces. The working fluid additive may consist solely of a highly polar material, but preferably includes both a highly polar material and a material that is synergistic to the highly polar material. The highly polar materials have a great affinity for the contact surfaces within the operating system and, therefore, produce film layers on the contact surfaces sufficient to significantly eliminate the frictional losses experience in the boundary regime of lubrication. By including a synergistic polar material, the efficacy as well as the thickness of this film layer is increased to further increase friction reduction. Organo-metallics may be utilized to further decrease wear and friction. An enhancing accelerator may be used to increase the compatibility between the host working fluid and the additive. A dispersion agent may also be employed within to disperse the working fluid additive within the working fluid.
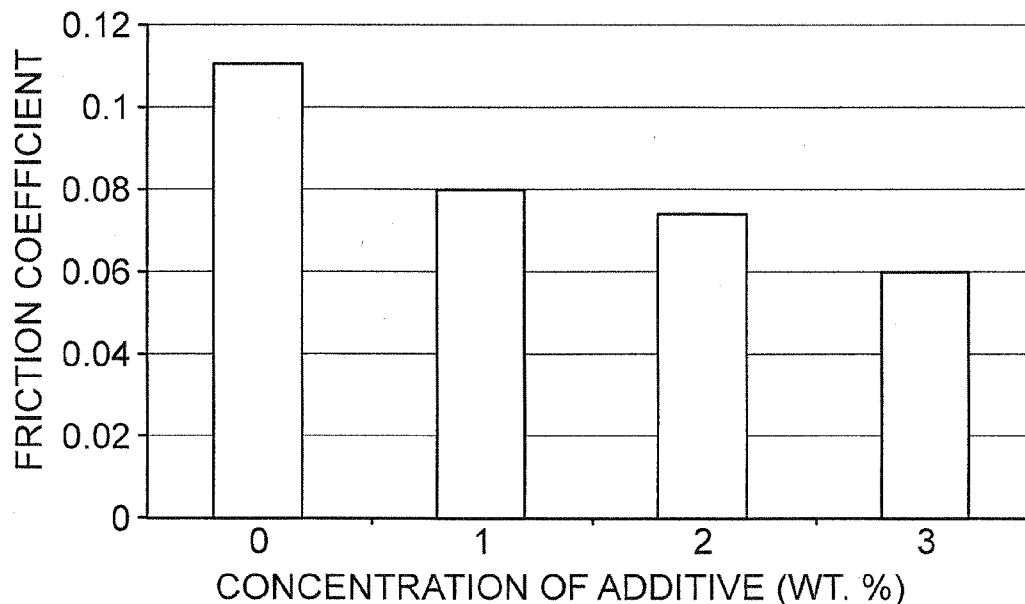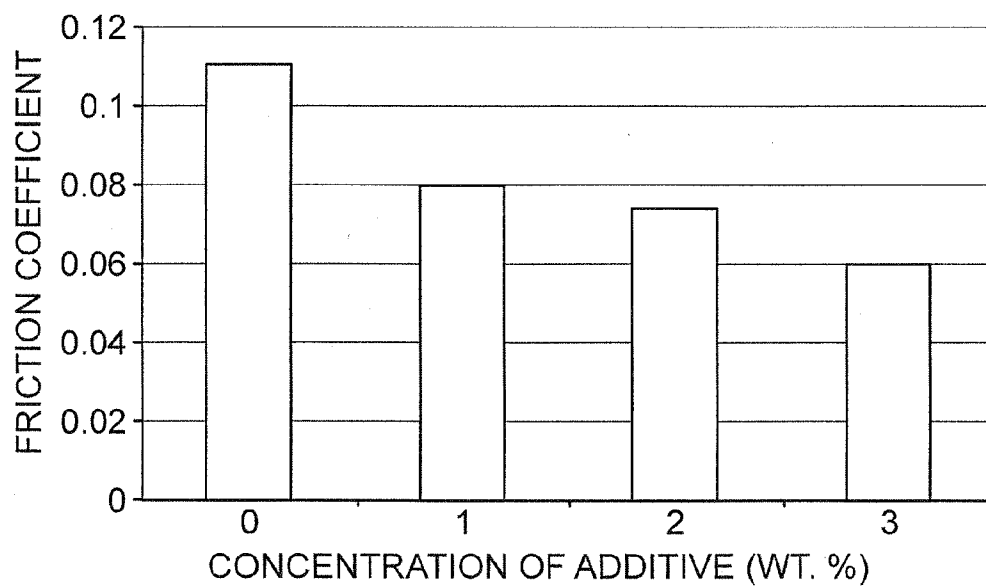
FIG. 1
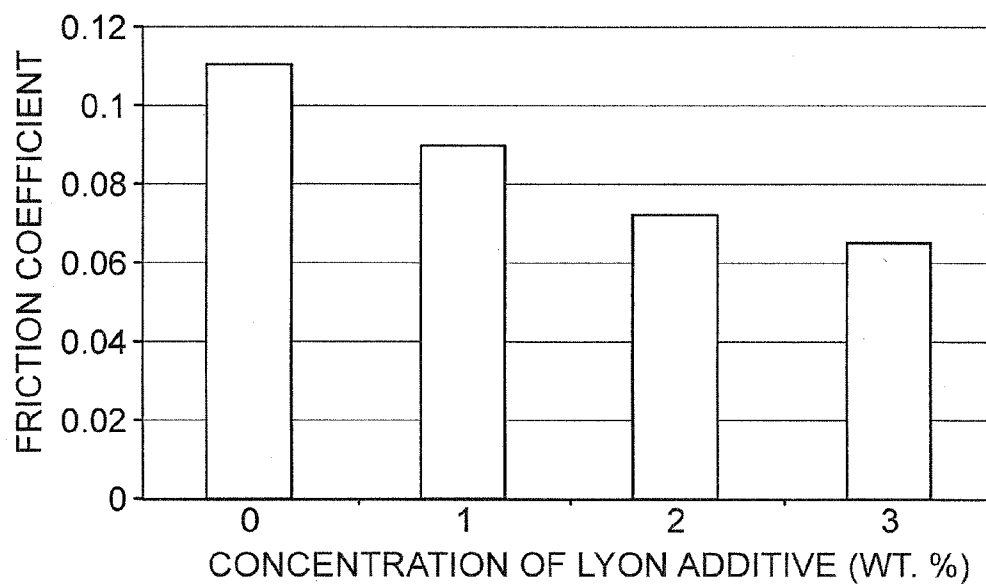
FIG. 2

FIGURE 3

FIGURE 4

FIG. 5

Normal force

driven roll

transmitted torque

tangential force

lubricant

applied torque

driving roll
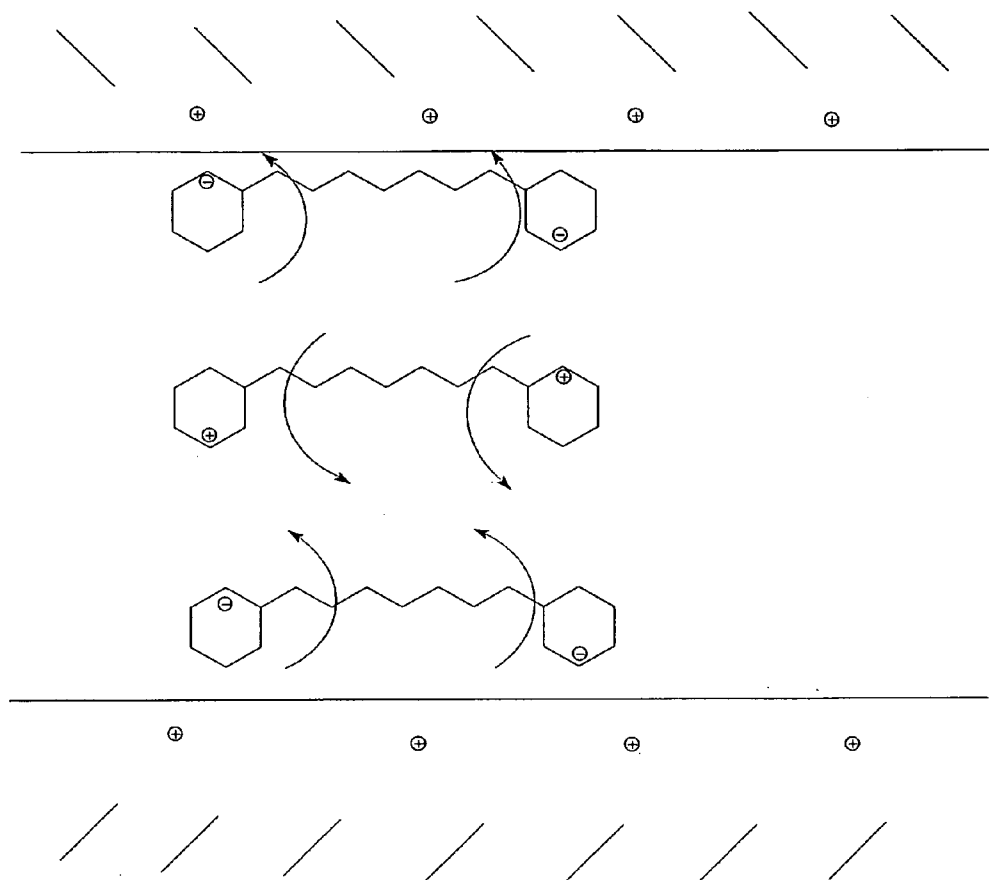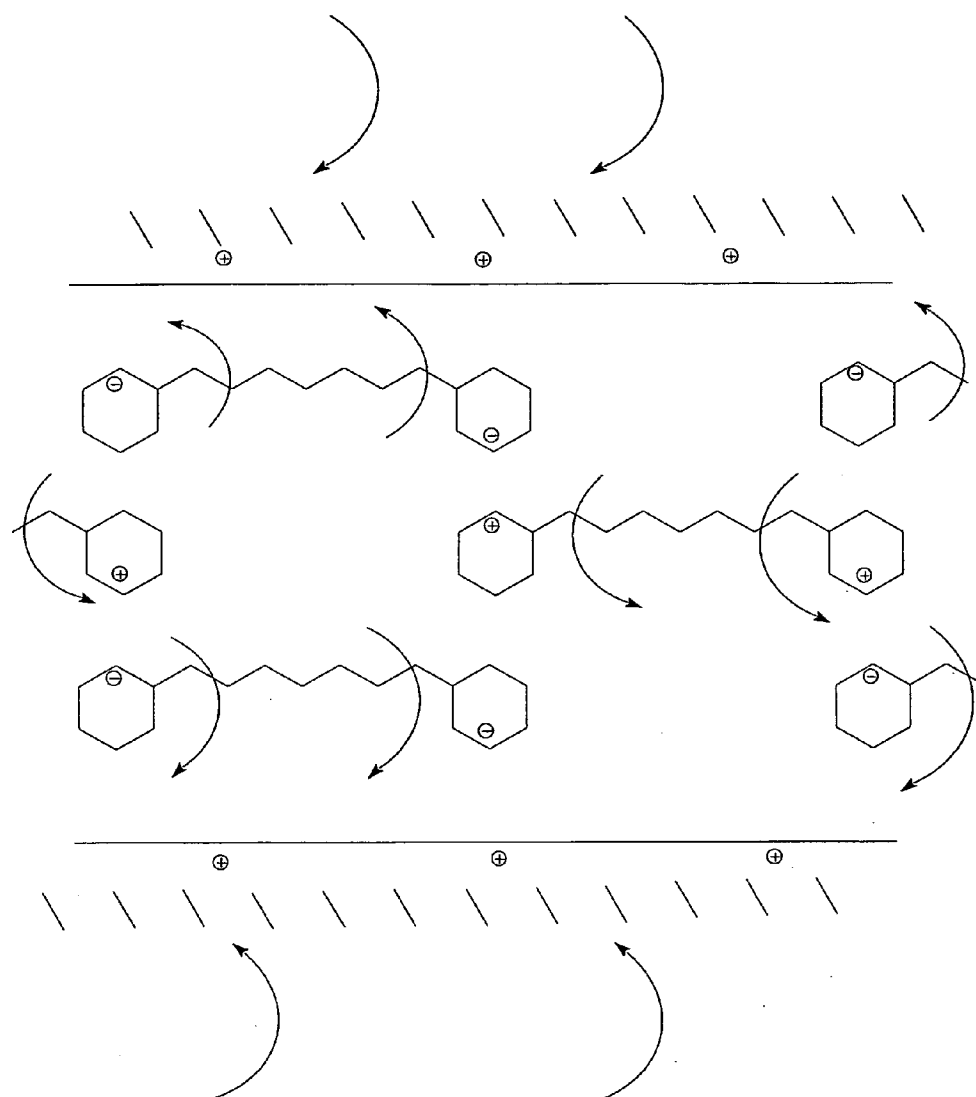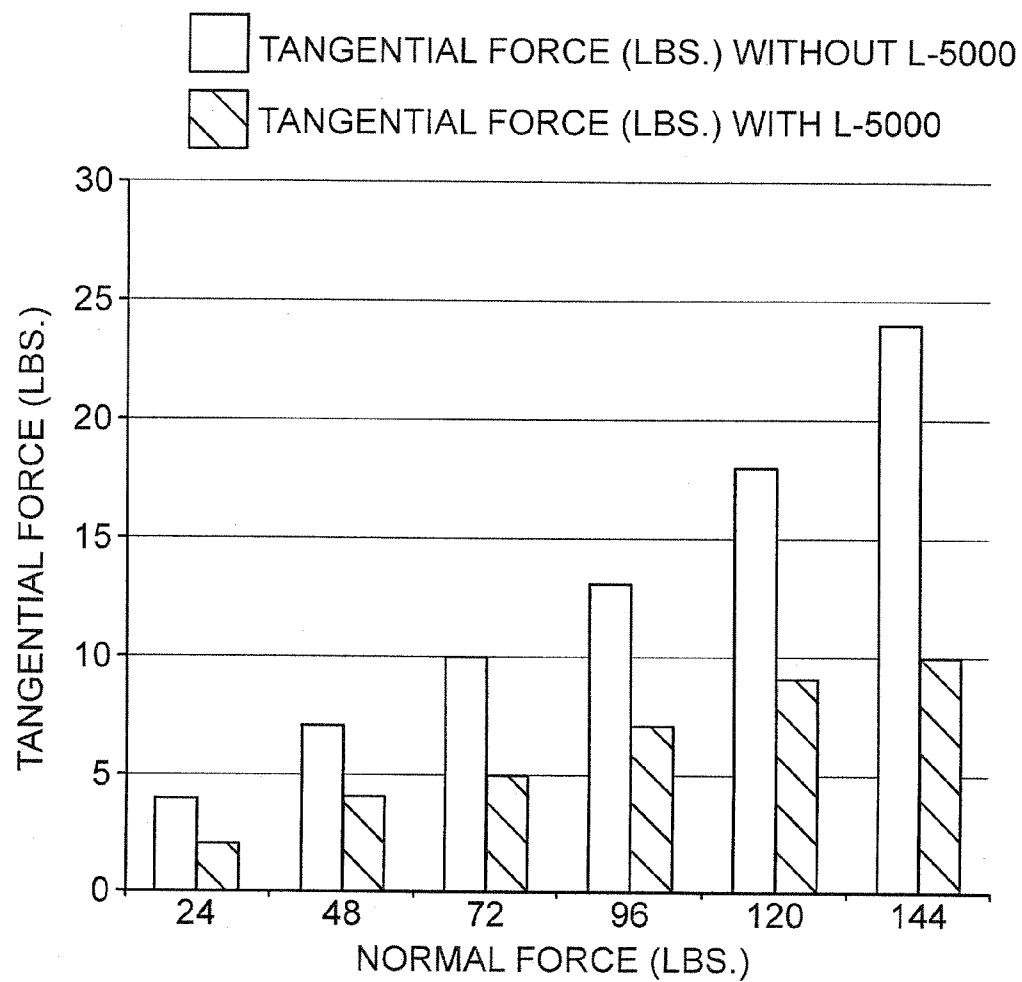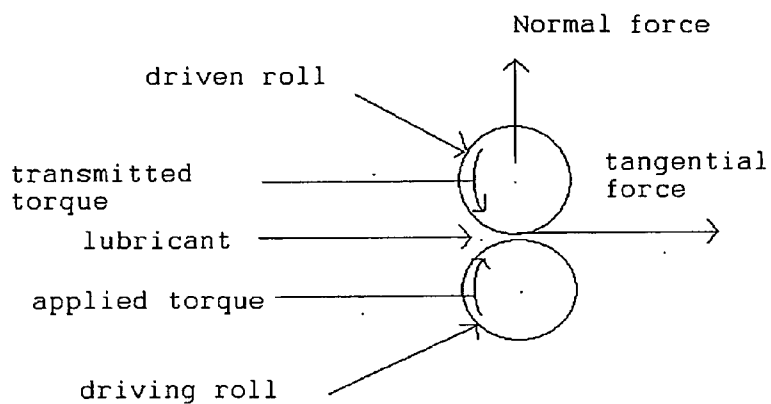
traction coefficient = tangential force/normal force

FIGURE 6

Y

X

Z
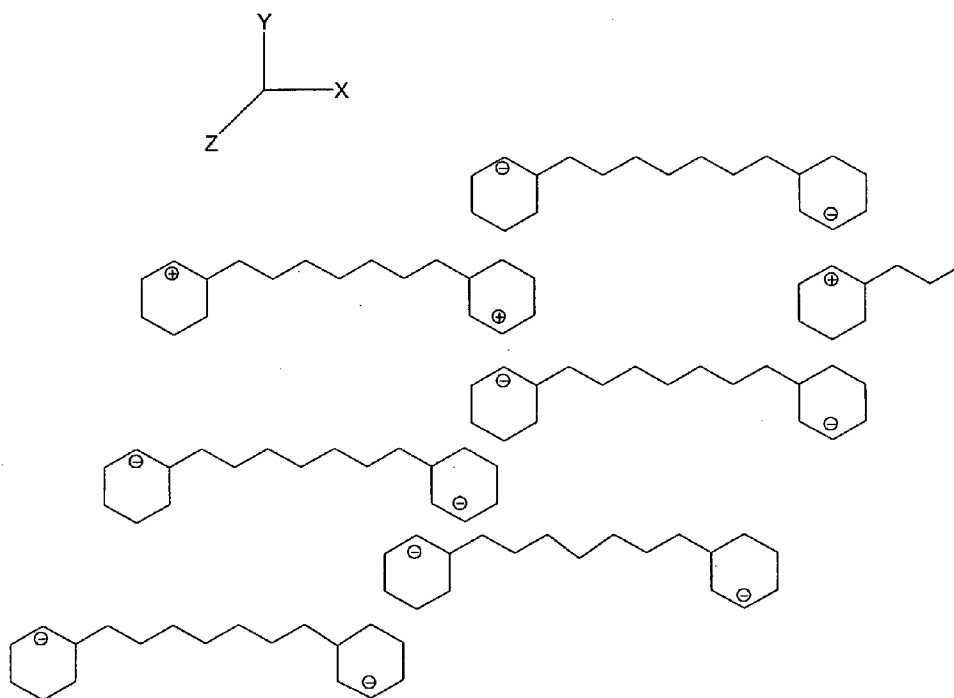
FIGURE 7

FIGURE 8

FIGURE 9

FIG. 10

☐ BEFORE - PLY, ESCORT, DODGE PU, MERC VAN, FORD 150,
CHEV PU, FORD VAN, LINC NAV, MERC MARQ

◩ AFTER - PLY, ESCORT, DODGE PU, MERC VAN, FORD 150,
CHEV PU, FORD VAN, LINC NAV, MERC MARQ
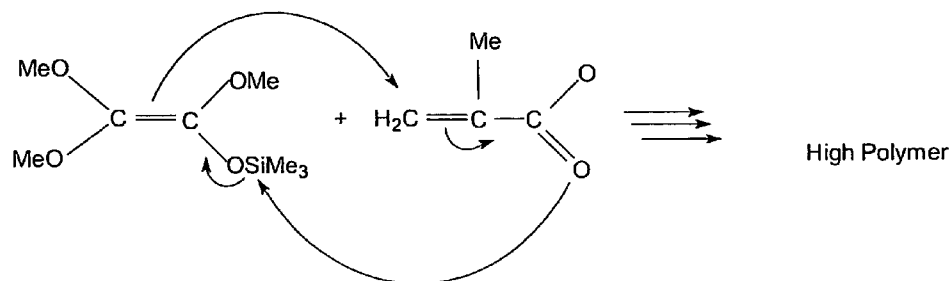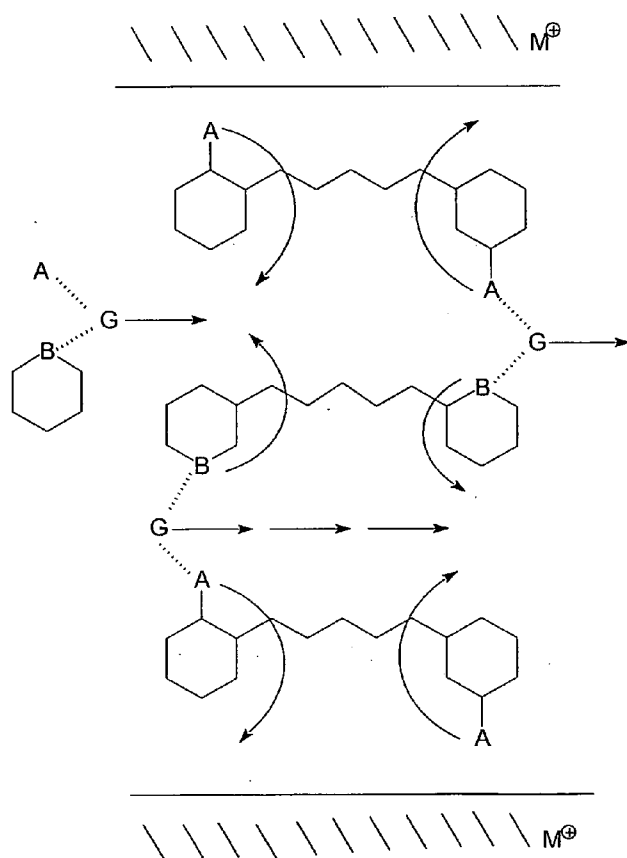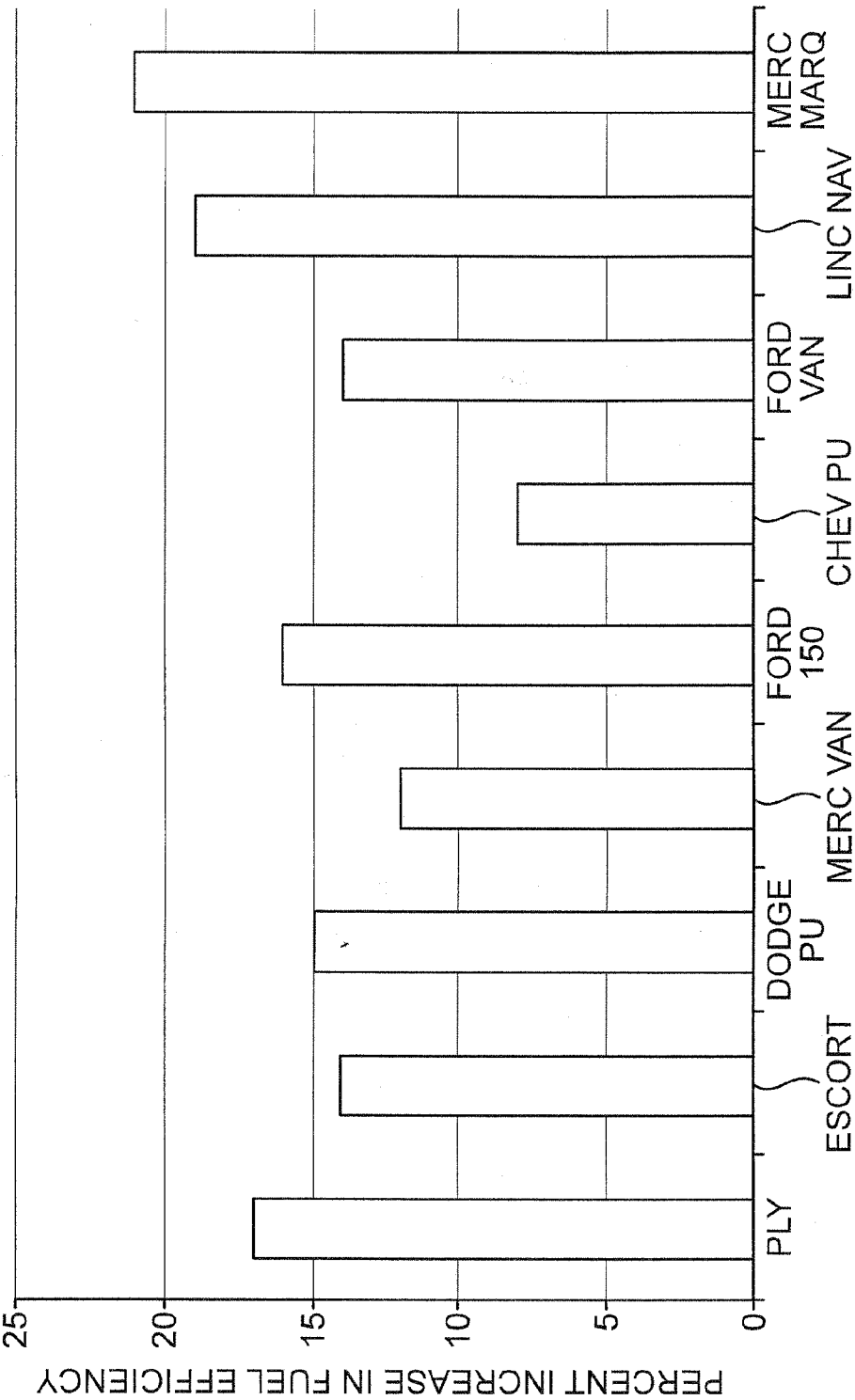
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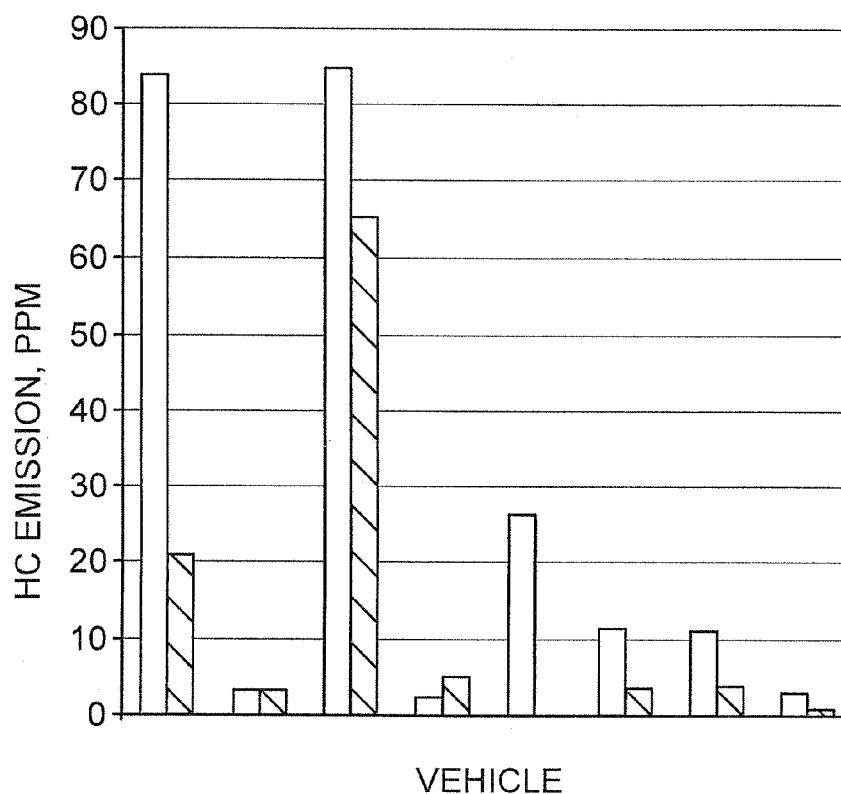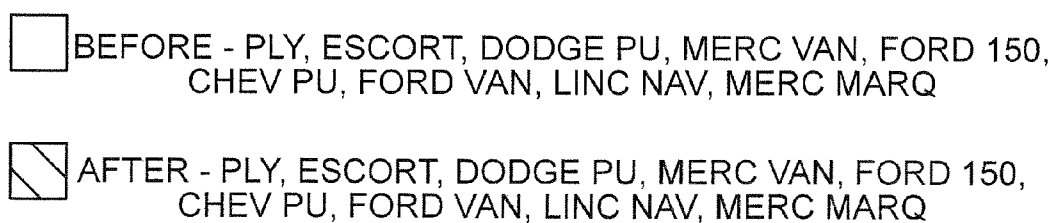
FIG. 11
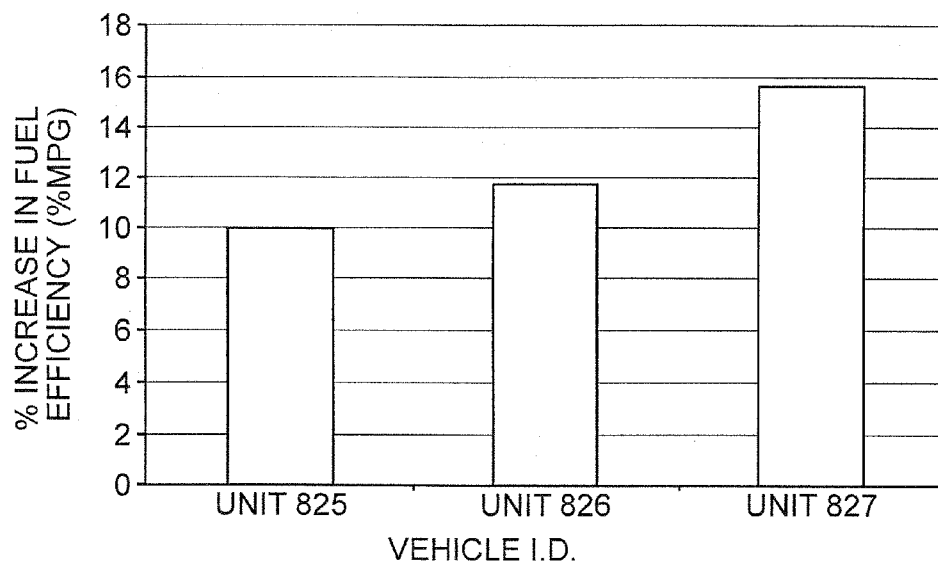
FIG. 12

FIG. 13

FIG. 14

FIG. 15

FIG. 16

LUBRICATING FORMULATIONS FOR DISPERSANCY AND TEMPERATURE, FRICTION, AND WEAR REDUCTION

[0001] This application is a continuation-in-part of U.S. Ser. No. 10/914,568, entitled ADDITIVES FOR LUBRICATING COMPOSITIONS, filed Aug. 9, 2004, and also claims priority to U.S. Ser. No. 60/792,280, entitled LUBRICATING FORMULATIONS FOR DISPERSANCY AND TEMPERATURE, FRICTION, AND WEAR REDUCTION, filed Apr. 14, 2006. Lubricating materials and additives are provided which form low friction, anti-wear, dispersant, corrosion free lubricating compositions.

I. Field of the Invention

[0002] The present invention relates to unique compositions for lubricating metals.

A. BACKGROUND OF THE INVENTION

[0003] When two similar or dissimilar surfaces rub together, progressive loss of material from the operating surfaces may occur. This loss of material, or wear, is accelerated by elevated temperatures and pressures which, for example, occur in internal combustion engines, hypoid gears, transmissions, industrial machines, propulsion engines, wheel bearings, gear oils, turbine oils, cutting fluids, instrument oils, and similar such devices. Lubrication can be achieved by several different methods. One method involves the complete separation of moving parts by a complete film of a viscous liquid. This is termed hydrodynamic lubrication and possesses a coefficient of friction of approximately 0.001. As the operating conditions involving two surfaces become more severe, there is a point where a full-film is no longer sustainable and the higher spots on the mating surfaces must share the load with the film. There is a shift from full-film to mixed-film then to boundary lubrication. In boundary lubrication metal asperities from opposite surfaces may penetrate the film, undergo physical or chemicoadhesion, and tear away from their respective surfaces. Eventually welding and gross seizure may occur. Extreme pressure (EP) additives have been developed to deal with these extreme operating conditions. EP agents are usually sulfur, chlorine, phosphorous, or lead containing compounds that function by one of two mechanisms. Firstly, an EP agent may react 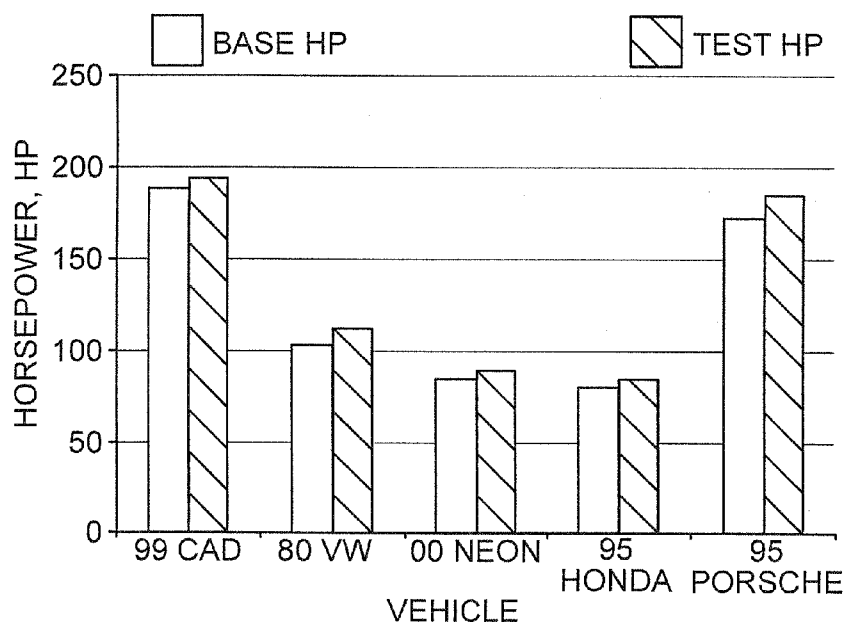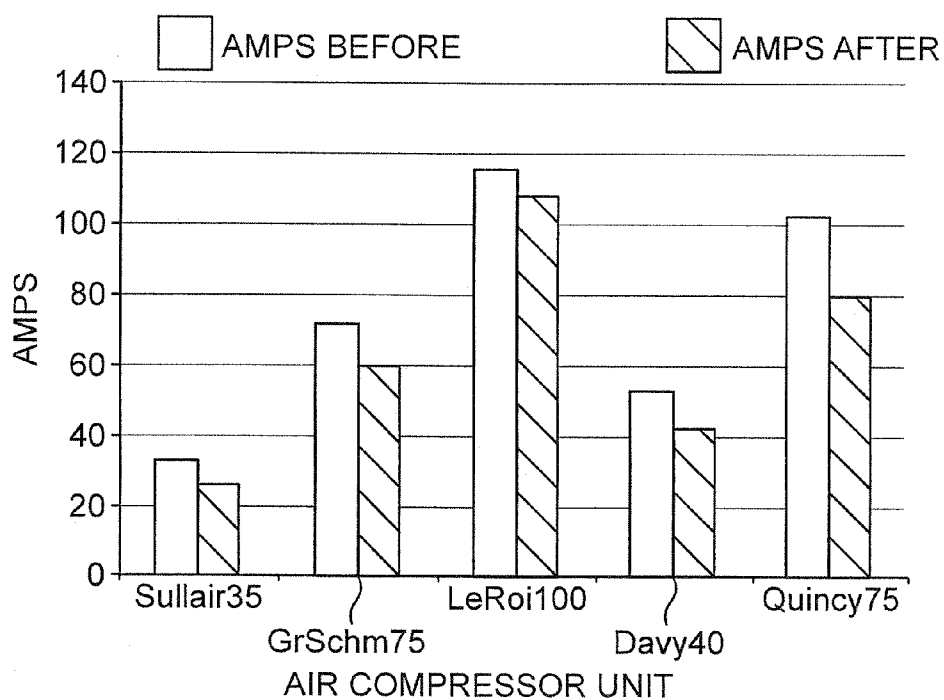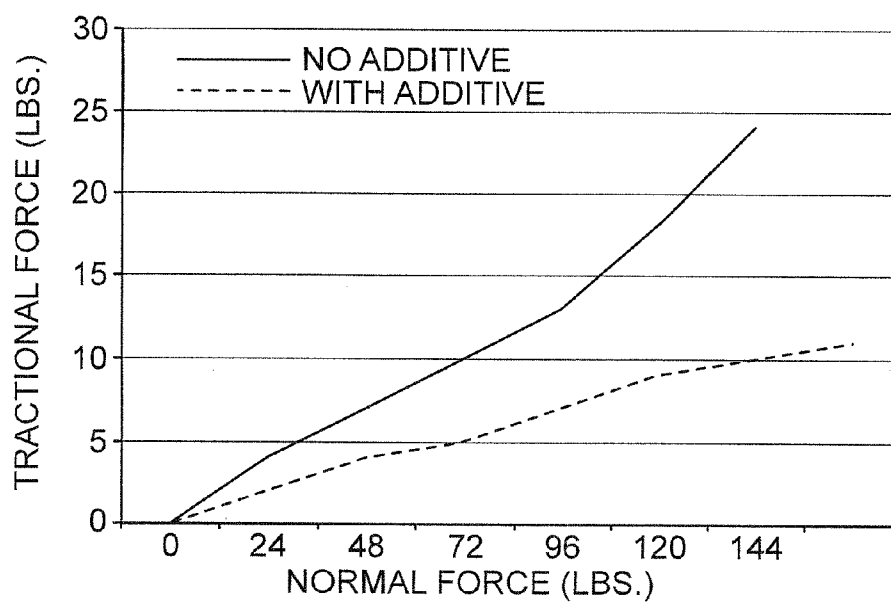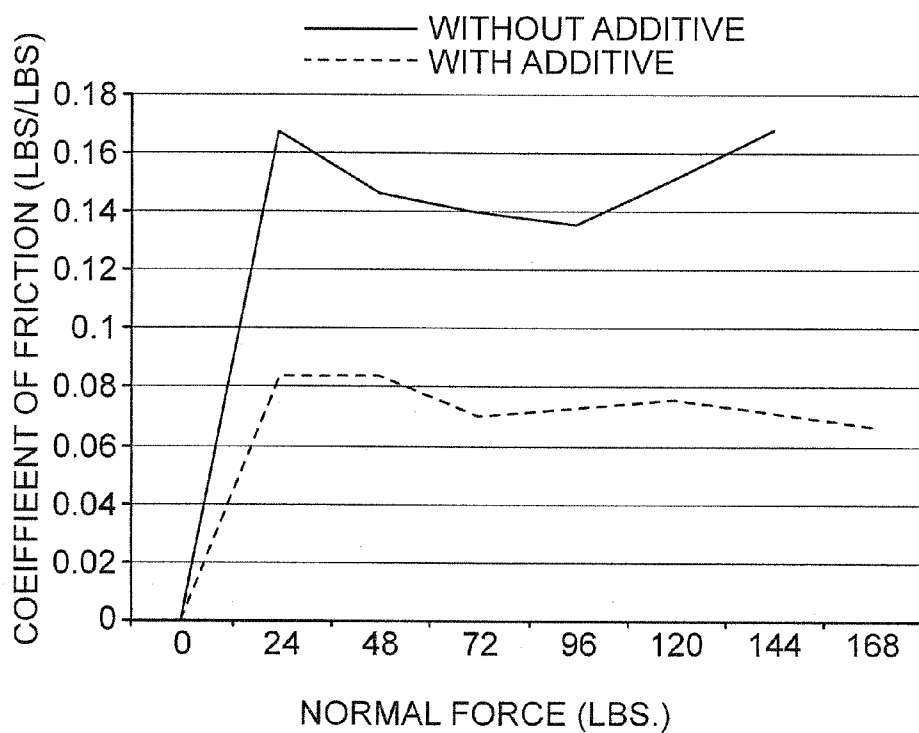at extreme operating conditions to form a low melting temperature, inorganic lubricant film on the metal surface. Secondly, the EP additive may function as a fluxing agent that reacts with, i.e., contaminates, the metal surfaces and prevents welding. This ultimately leads to corrosion of exposed metal surfaces.

[0004] The formulation of an oil lubricant begins with the base stock, which unformulated possesses poor lubricating properties. This base stock tends to foam, undergo oxidation, and degrade under load, all resulting in surface to surface contact with high rates of wear and frictional losses. The friction associated with the relative motion of the operating surfaces can be divided into two categories: friction resulting from wear, and friction resulting from shear stresses in the oil, i.e., viscous losses. The petroleum oils are examples of base stock and are complex mixtures of hydrocarbons with an approximate molecular weight range of 250 to 1000 g/mol.

[0005] The physical properties of these oils are a function of the relative amounts of paraffinic, aromatic, and alicyclic (naphthenic) components. The paraffins have relatively low viscosities, densities, and higher freezing points compared to other petroleum oils of a similar molecular weight. The paraffinics are prone to oxidation and consequently need to be properly stabilized to prevent sludging. The aromatics are relatively resistant to oxidation but tend to fuse and form insoluble black sludge at high temperatures. Aromatics tend to have a relatively high viscosity, dark color, and demonstrate a rapid change in viscosity as the temperature changes. The alicyclics demonstrate characteristics that are intermediate between the paraffins and the aromatics, as well as possessing poor oxidative stability, and a low pour point. Most of the commercially available paraffinic oils are actually a mixture of paraffinic and alicyclic oils.

[0006] Turbine oils are used to lubricate steel mills, steam turbines, paper mills electric motors, and hydroelectric generators. Hydraulic oils usually contain a zinc dithiophosphate additive to reduce wear in high pressure hydraulic pumps.

[0007] For automotive and industrial gear applications, SAE lubricants classified between 5 W and 50 W are utilized. Grade 2EP through 8A EP are used for industrial gears. They contain a myriad of phosphorous, lead, chlorine, sulfur and tallow additives to reduce wear and scuffing.

[0008] In addition to the attempt to develop an ideal lubricating composition there is a continuing search for methods of improving the operating efficiency of power transmission and generating equipment. This has traditionally centered on refining hydrocarbon materials to providing better film-forming characteristics and the addition of various chemical compounds to provide stability, operating life under high load, and operating efficiency. Crankcase oils and power transmission and hydraulic fluids are cases in point, which have seen the greatest amount of attention, especially those involved in automotive applications.

[0009] Early attempts to provide extra pressure agents were made by the inclusion of chlorinated paraffins. These were rejected by the industry, primarily on the basis of corrosion of seals. Zinc dialkyldithiophosphate was the first real breakthrough in extra pressure technology and is in general use today in most premium oils. By carefully balancing the amount of ZDDPT with anti-corrosion agents, the EP function in the design of lubricating oils and working fluids is achieved. However, ZDDTP suffers from a number of disadvantages:

[0010]   1. It attacks the surface to form a chemical bond, thereby increasing the surface roughness.

[0011]   2. It diminishes the ability of the oil to form a film.

[0012]   3. It is corrosive, and once the anti-corrosion agent has been expended, it destroys the finish of the working surfaces.

[0013]   4. It attacks the seals.

[0014]   5. It has a high friction coefficient.

[0015] A colloidal suspension of graphite was introduced as an EP agent, as was molybdenum disulfide, with some degree of success, but were ultimately rejected because of their characteristic to permanently stain rather than cost or performance.

[0016] Polytetrafluoroethylene has been tried and found wanting, having no EP characteristics at all. Polyalphaolefins are the subject of much investigation and show promise in many applications in conjunction with other materials.

[0017] The problem of friction and wear of hypoid gearing used in trucks and cars has been widely addressed, primarily by the use of sulfurous, highly viscous compounds.

[0018]   The work on automatic transmission fluids, since the banning of the use of sperm whale oil, has been largely directed toward duplicating the physical characteristics of whale oil instead of addressing the friction, wear, and bulk temperature problem head on. The result has been a history of transmission failures over the last two decades.

[0019]   In summary, the wear rate of working fluids has traditionally been addressed by the addition of EP agents, which attack and form a chemical compound with the working surfaces; friction has been addressed by the addition of friction reducing agents and the control of the viscosity of the host fluid.

[0020]   The need for this invention is axiomatic. With 500 million cars on the road, the average age being 8-10 years old, the gas consumption of these cars can be reduced 25 to 35 percent and the pollution by 50 to 60 percent by the addition of a small amount of this material to the working fluids now in use.

[0021]   By the addition of polar compounds to the host materials, it has been found that the friction factors of premium oils and working fluids can be reduced significantly and the wear coefficients improved by orders of magnitude, producing a resultant decrease in operating temperature. This is produced not by forming a chemical reaction with the working surfaces, but by the attraction and adhesion of these materials to the working surfaces. The film produced is a stable, low friction coating which eliminates the dependency of viscosity to form a film and which has a greater attraction for the surface than the soils and wear particles, which tend to collect on the surface and cause greater wear.

[0022]   This current work began by addressing the automotive lubrication problem, because most of the current work on lubricants is being directed toward the automotive industry.

[0023]   A survey of the technical transactions and patent literature on lubrication developments for automobiles revealed that there is a list of problem areas that must be addressed satisfactorily before a lubricant can be formulated to meet government-mandated requirements and API standards for automotive applications. This list includes sludge and varnish formation, emissions, particulate matter suspension, fuel economy, contaminant control, corrosion, oil life and additive depletion. Other researchers have demonstrated that each item is caused or is heavily influenced by wear particles. If wear can be significantly reduced, hypothetically these problems would disappear or at least be contained at a more manageable level.

[0024]   Rocker-arm sludge and engine sludge are made up of wear particles and precipitants of chemicals introduced to handle the wear problem.

[0025]   Engine varnish and sticky valves and rings are caused by over temperature and oxidation of the oil, which are again caused by wear. The energy it takes to plastically deform or rip off the asperities of the working surfaces goes into increasing the temperature of the oil and thus the engine or transmission. At higher temperatures, varnish precipitates out of the lubricant and deposits on the working surfaces. This is one of the major causes of emissions increases during the functioning time span of an engine.

[0026]   Catalytic converter life is almost entirely dictated by the amount of ZDDP (zinc dialkyl dithiophosphate, a heavy metal containing compound) used as an anti-wear agent. The greater the content of ZDDP, the shorter the lifetime of the converter.

[0027]   Oil aging, which is related to temperature increase, causes accelerated oxidation and nitration with the accompanying problems of oil thickening, hence less pump ability and less cooling of working parts.

[0028]   Focusing their efforts on the automobile, lubrication experts have given primary importance to the function of viscosity as the controlling factor in the formulation of a lubricant and treat the instance of wear as an intrinsic value of the internal combustion engine, transmission and gearboxes which cannot be improved by any significant amount. It is, as will be explained in what follows, the other way around. The improvements in thermal efficiency of a machine that can be obtained by optimizing viscosity are but a few percent. Whereas by reducing the wear rate, mechanical losses can be reduced by as much as 50 percent.

[0029]   There is a large and on-going body of work by the automotive and lubrication industries aimed at improving fuel economy without jeopardizing the durability of the engine and emission systems or useful life of the lubricants. The development of these lubricants takes place in the laboratory and it is based on the application of classical elastohydrodynamic (EHD) theory wherein viscosity is thought to be the principal controlling factor. A protective film between the working surfaces is formed at sufficient velocities to separate them. As velocity approaches zero, a mixed flow regime exists before degenerating into boundary lubrication regime when surfaces actually touch. During the mixed flow and boundary lubrication regimes is when wear presumably occurs.

[0030]   Also an empirical relationship has been determined which relates fuel economy to three independent variables—the viscosity of the oil, its pressure-viscosity and its boundary friction coefficients. This relationship takes the form

$$FE = A + Bv + Cf + Dp \qquad (1)$$

[0031]   Where v is the high temperature-high shear (HTHS) viscosity, f is the boundary friction coefficient, and p is the pressure-viscosity coefficient. A, B, C and D are coefficients derived by statistical analysis of data from Standard Sequence Engine tests.

[0032]   The HTHS viscosities are measured using an ASTM procedure (D4683).

[0033]   Boundary friction coefficients are typically arrived at by measuring the tangential force on a steel ball oscillating over a 1 mm path at a frequency of 20 Hertz at a controlled temperature.

[0034]   The pressure-viscosity coefficient can be computed from an empirical relationship between dimensionless parameters of film thickness, viscosity and pressure-viscosity coefficient:

$$Hs/Hr = (Vs/Vr)^{0.67} \times (Ps/Pr)^{0.53} \qquad (2)$$

[0035]   Where Hr, Vr and Pr are previously calculated reference values of film thickness, viscosity and pressure-viscosity coefficient. The thickness of the boundary layer of the test sample, Hs is measured in pure rolling contact using optical interferometry, as a function of entrainment velocity and temperature. Making these substitutions into the above equation, the pressure-viscosity coefficient of the sample can be calculated and FE can thus be determined for the sample oil.

[0036]   By varying each independent variable separately, the relative contribution of each of the parameters can be ascertained.

[0037] There is a loose correlation between the data that is predicted in the laboratory and that recorded on automobile engines. The conclusions generally reached are as follows:

[0038] 1. Fuel economy is improved as each of the viscosity, boundary friction coefficient and pressure-viscosity coefficients are improved.

[0039] 2. Viscosity has the greatest effect on fuel economy for city driving.

[0040] 3. Boundary friction coefficient and pressure-viscosity coefficient are equally effective in improving fuel economy for highway driving.

[0041] 4. Sequence Test Engines give varying results, not always agreeing with the data recorded on actual automotive tests.

[0042] 5. Fuel efficiency improvements of the order of a few percent can be obtained by improving the viscosity, friction and pressure-viscosity parameters.

[0043] Various additives are mixed into the base stock to formulate a lubricant. Each constituent of the additive package has an effect on the performance of the oil, particularly the fuel efficiency, engine durability and the useful life of the oil. These constituents, i.e., detergent, friction modifier, extra pressure additive, antioxidant, viscosity index improver, acid neutralizer, antifoamant, pour point depressant, metal deactivators, corrosion inhibitors, etc. comprise about 10 percent of the total lubricant and must be in balance with the base stock. Implicit within this formulation are pressure-viscosity coefficient, HTHS viscosity and boundary friction coefficient, all of which are subject to change by the extent of oxidation, nitration, precipitation and volatilization of the oil due to aging.

[0044] Thus additive packages have been formulated and blended with mineral or synthetic oils to perform the mission of a lubricant, i.e., to cool, reduce wear and friction, control contaminants and not to contribute to pollution. These constituents are consumed during the life of the oil and at the end of its useful life, are no longer capable of performing their mission.

[0045] Some of the constituents of choice at the present state of the art attack one another and this must be accounted for in the design of the package. The present anti-scuffing agent of choice for the foreseeable future is zinc dialkyl-dithiophosphate (ZDDP), an aggressive chemical which attacks the working surfaces to form a phosphorus compound to prevent welding and galling of the working surfaces under extreme operating pressure. Not only does it attack the working surfaces, it also attacks the anti-wear and extra-pressure constituents as well. Additional agents must be supplied to prevent the destruction of these constituents. A substitute for ZDDP has been sought for years but its continued use is projected beyond 2006.

[0046] The government-mandated improvements in fuel efficiency (5 percent) and catalytic converter life (150,000 miles) present a formidable problem for the industry since ZDDP must be reduced because it is a pollutant. Gains in fuel efficiency generated by improving viscosity, boundary friction and pressure-viscosity coefficients appear to be limited. Clearly these goals must be obtained by another avenue.

[0047] In the classical literature wear is most often treated as a separate subject from lubrication and this has led to some confusion. The lubricant community has more or less concluded that wear has been reduced to a non-problem, only capable of a few percent of improvement in the performance of machines. This has been accomplished presumably by the replacement of sliding contact with rolling contact, improvement in bearing surface finishes, better alignment and improved lubricants.

[0048] Elastohydrodynamic theory has been proposed which postulates that the bearing surfaces in contact deflect under Hertzian pressure loads to form cavities that are filled with oil of sufficient thickness to prevent opposing asperities from touching one another thus preventing the incidence of wear from taking place.

[0049] Furthermore, under extreme pressure, especially in lubricants with high pressure-viscosity coefficients, the oil instantaneously solidifies and in some cases at the extreme, turn into glassy substances before being instantaneously returned to the bulk liquid form, thus assuring that squeeze-out of the oil is not happening, and further assuring that wear is not taking place.

[0050] Also, boundary layer thickness under rolling has been measured to be of finite thickness and at velocities greater than 1.5 meters per second are thicker than the combined height of the asperities of the mating surfaces.

[0051] Contrary to these generalizations, in sliding contact a "Squeeze-out Phenomenon" has been observed which sufficiently squeezes out the lubricant to a one molecular diameter of lubricant between the surfaces, hardly enough to prevent the asperities of the working surfaces from interacting.

[0052] The friction coefficient for sliding contact has been estimated to be two orders of magnitude greater than for rolling contact and thus for practical considerations rolling friction can be considered zero.

[0053] Considering the kinematics of a gear set designed for use with conventional bearings, an allowance for backlash must be included in the gear profiles to permit movement without interference.

[0054] The teeth come into initial contact in pure sliding motion. As they approach the addendum the slip-to-roll ratio is reduced to zero, where pure rolling contact takes place at the addendum. As the teeth recede away from the addendum the slip-to-roll ratio increases. Thus, in most of the travel from engagement to disengagement, the teeth are in sliding contact to some degree.

[0055] The boundary layer, separating the teeth is subject to at least some measure of squeeze-out, beginning initially as the teeth engage.

[0056] The foregoing discussion assumes zero tolerances in the supporting bearings. When bearing tolerances and alignments are considered, another degree of freedom is introduced which must be taken into consideration to assess this additional component of sliding motion.

[0057] This can best be ascertained by examining the wear patterns of spherical gear sets in spindle designs. The offset of the input axis to the output axis by design, represents an exaggeration of the tolerances of gear sets in real-world designs supported by conventional bearings.

[0058] With a significant number of teeth being in constant contact under load, an X-pattern is formed whereby the point of contact at the gear faces travel in a diagonally forward direction and back again in one revolution, representing a component in the direction of motion of the gears and a component in a transverse direction. The resulting wear pattern repeats itself at a lesser angle as the gears wear in, progressing to a diagonally rearward direction completing the X-pattern, i.e., simultaneous lateral and longitudinal creepage. Smaller perturbations of this pattern are generated by the bearing tolerances but are not noticeable.

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[0059] Since the surfaces cannot be ground with standard grinding machines due to the restrictive nature of its geometry, the gear-teeth surfaces have a finish of 60 to 120 micro-inches. It is hoped that at some point during the wear-in cycle, the surface finishes will approach a ground finish such that a lubricant can support the Hertzian pressure forces without undue wear.

[0060] The point here is that gear sets go through the same process in microcosm, but starting with less misalignment and a finer finish.

[0061] Another example will serve to quantize the frictional losses contributed by the sliding motion accompanying rolling contact. In about 1970 scientists at TRW built a 30-to-1 gearbox, which minimized the incidence of sliding motion. The gears were supported by OD-ground rollers, which were ground to a tolerance of 0.0001 in instead of conventional bearings with a tolerance of 0.003 in. These rollers were pre-loaded to minimize slip-skid. By this measure, an epicyclic gear profile could be used requiring no backlash, employing near-pure rolling contact, thus eliminating the slip-roll zones, i.e., intermittent longitudinal creepage, encountered with conventional designs. Also, the transverse, or lateral sliding components of gear contact were eliminated along with the friction and wear associated with it.

[0062] The thermal efficiency of this gearbox was measured to be greater than 99 percent, which compares to the efficiency of a conventional thirty-to-one gearbox of 90 percent. This recovery of energy loss is attributed to a reduction of sliding contact and of the friction and wear associated with it.

[0063] From this it was concluded that the friction and wear of rolling contacts are very nearly zero, and that virtually all wear and friction are due to sliding contact, i.e., longitudinal creepage. It also points out that more emphasis should be placed on lubricants that are more resistant to squeeze-out and which have lower rates of wear and friction in sliding contact.

[0064] High-performance bearing surfaces are usually ground and honed to a finish of 8 micro-inches. These surfaces have a roughness profile in excess of the effective boundary layer, which is insufficient to keep the bearing surfaces separated, and are subject to a fair amount of wearing-in. The asperities are always in contact with one another. This accounts for the particles of surface materials and their oxides, which have sheared off, melted or oxidized into extremely hard particles that are suspended in the working lubricant.

[0065] The conventional way of dealing with this wear is to use corrosive chemistry to form compounds with the working surfaces. This measure introduces less active chemistry at the surface thereby gaining a temporary reprieve. The problem with this approach is that the newly formed surface compounds are themselves subject to wear and must be replaced by additional chemical reactions with the surfaces. These reactions continue until the chemistry is expended. Sludge is continually being precipitated and must be suspended in the lubricant along with the wear particles. The continual erosion and reformation of these surface compounds limit the formation of smoother bearing surfaces with lower frictional losses.

[0066] Providing a more effective protective layer irrespective of the viscous boundary layer and without the use of corrosive chemistry is the direction the development of lubricants should go rather than in the refinement of corrosive chemistry. This would permit the working surfaces to wear in less aggressively, permitting the asperities to gradually reduce in height to the same order as the effective boundary layer, thus minimizing the wear and the friction due to wear. The continual erosion and reformation of the surfaces caused by chemical attack could be avoided altogether, producing a smoother finish and lower frictional losses.

[0067] This approach would reduce the number and severity of collisions between asperities, thus reducing the size and number of iron trioxide and tetraoxide particles usually observed in working lubricants (which are associated with high rates of abrasive wear and oxidative degeneration due to catalytic reactions caused by metallic debris), and without the precipitation of sludge caused by chemical attack on the bearing surfaces.

[0068] Instead of emphasizing the importance of reducing viscosity in order to reduce friction and having to rely on corrosive chemistry to prevent scuffing and high rates of wear, it was found more prudent to emphasize wear reduction through more effective boundary lubrication by providing a thicker boundary layer. In this manner viscosity can be used in a more constructive way and corrosive chemistry can be reduced or avoided altogether.

[0069] The chemistry used in the tests that are reported herein after, are such materials consisting of molecular designs, i.e., MMC, which provide this protection without the use of corrosive chemistry. While capable of forming the basis of new formulations, it is capable of superimposing an additive effect on current lubricants.

[0070] Recognizing that this chemistry is in its infancy, more effective molecular formulations can be designed to lessen the incidence of wear and increase the thermal efficiency of virtually any mechanical system without sacrificing the positive contribution of viscosity.

B. DESCRIPTION OF RELATED ART

[0071] U.S. Pat. No. 2,247,046 teaches the use of the reaction products of perchloromethyl mercaptan as EP additives. Some of theses compounds contain a disulfide linkage attached to an aromatic group and tend to be reduced during use and in turn oxidize other components in the lubrication system. Some of the mercaptans have low flash points and tend to evaporate at utilization temperature

[0072] U.S. Pat. No. 3,984,599 teaches a coating composition useful in metal working processes comprises a major amount of a mineral oil having a viscosity of 100° F. of at least 100 SUS and (a) 1.0 to 20.0 parts by weight of a paraffin wax, (b) 0.1 to 10.0 parts by weight of a polymeric wax modifier and (c) 0.1 to 10.0 parts by weight of an extreme pressure agent. The compositions can also contain one or more rust inhibitors. Particularly preferred classes of extreme pressure agents for use in this comparison are sulfur containing agents and zinc salts of dialkyl dithiophosphates.

[0073] U.S. Pat. No. 4,116,874 discloses a compressor oil composition comprising a major portion of a lubricating base oil selected from a group of mineral lubricating oils or synthetic hydrocarbon oils having a viscosity of 20 to 100 centistokes at 37.8° C. Also included in the invention is an aromatic amine selected from the group consisting of diphenylamine, phenyl-α-naphthylamine, phenyl-α-naphthylamine among others, an alkylphenol selected from the group consisting of 2,6-di-tert-butyl-para-cresol, 4,4'-methylenebis(2,6-di-tert-butylphenol), 4,4'-dihydroxy-3,3',5,5'-tetra-tert-butyl biphenyl, 4,4'-thiobis(2,6-di-tert-butylphenol), bis(3,5-di-tert-butyl-4-hydroxybenzyl)sulfide, and 2,2'-

methylenebis(4-methyl-6-tert-butylphenol). Also included in the composition is a triester of dithiophosphoric acid selected from the group consisting of S-dodecyl O,O'-dipropyl dithiophosphate, O,O-bis(propylphenyl)-S-benzyl dithiophosphate, and O,O'-bis(propylphenyl)-S-styryl dithiophosphate.

[0074] U.S. Pat. No. 4,131,551 describes a composition comprising (A) a lubricant mineral oil base, (B) a Mannich condensation reaction product comprising the reaction product of an alkyl phenol, a polyamine and formaldehyde, (C) an alkaline earth metal salt of a Mannich condensation reaction product comprising the reaction product of alkyl phenol, formaldehyde and a polyamine, (D) an alkylbenzene alkaline earth metal sulfonate of low total base number, and (E) the alkaline earth metal salts of a bis-alkylphenol sulfide, (F) chlorinated paraffin, and (G) dimethyl siloxane polymer.

[0075] U.S. Pat. No. 4,228,021 states that compounds suitable as extreme pressure additives for lubricating oils are of the general formula CX_3—S—S—R where X is a halogen and R is a hydrocarbyl, and that the performance of the compounds is improved by the addition of a stabilizer.

[0076] U.S. Pat. No. 4,360,438 discloses synergistic antiwear compositions comprising a sulfurized molybdenum dialkyldithiocarbamate and an organic sulfur compound selected from the group consisting of dithiocarbamate acid esters, sulfurized oils and polysulfurized olefins. Lubricating compositions containing the synergistic compositions possess good antiwear properties and improved extreme pressure and oxidation stability.

[0077] U.S. Pat. No. 4,369,119 discloses an antioxidant combination for lubricating oils comprising an oil soluble sulfurized molybdenum compound and an organic sulfur compound.

[0078] U.S. Pat. No. 4,529,526 claims a lubricating oil composition consisting of 53 to 98.6% by weight of a base oil possessing a kinematic viscosity of 3 to 20 centistokes at 100° C., 0.2 to 5% by weight of at least one compound selected from a sulfurized oxymetal organophosphorodithioate such as sulfurized oxymolybdenum diisopropylphosphorodithioate, sulfurized oxytungsten diisopropylphosphorodithioate, sulfurized oxymolybdenumdiisobutylphosphoroditioate and similar compounds and/or a sulfurized oxymetal dithiocarbamate selected from the group consisting of sulfurized oxymolybdenum dibutyldithiocarbamate, sulfurized oxytungsten dibutyldithiocarbamate and similar compounds.

[0079] U.S. Pat. No. 4,601,838 claims improved anti-wear, lubricity, and EP properties in metalworking fluids by using mono and dibasic acids that contain 8 to 36 carbon atoms and have been chlorinated to a weight percent of 10 to 50% chlorine by weight.

[0080] U.S. Pat. No. 4,692,256 discloses a lubricant composition comprising a sulfur compound and an oil soluble molybdenum compound, synthesized by reacting a hexavalent molybdenum compound with a reducing agent and an amine. These lubricant additives are claimed to possess antioxidant, anti-wear, friction reducing, and reduced metal corrosion properties. The oil soluble molybdenum compound is obtained by reacting a hexavalent molybdenum compound such as molybdenum trioxide, molybdic acid, and alkali salts of molybdic acid with a secondary amine such that the ratio of molybdenum to amine is 1:1 to 1:4. Examples of the secondary amine are di(2-ethylhexyl)amine, dibenzylamine, ditridecylamine,

[0081] U.S. Pat. No. 4,832,867 discloses a lubricating oil composition which comprises: lubricating base oil, (A) at least one organophosphorus compound represented by the general formula (I), (II), (III), (IV), (V), (VI), (VII) or (VIII) and (B) at least one organomolybdenum compound selected from the group consisting of molybdenum oxysulfide alkylphosphorodithioates and molybdenum oxysulfide alkyldithiocarbamates. The lubricating oil composition is excellent in antiwear properties, anti-seizure properties, and corrosion resistance, and is suitable for gear oils, and bearing oils, also for internal combustion engine oils and automatic transmission fluids, and further for hydraulic fluids, metal working fluids.

[0082] U.S. Pat. No. 4,844,825 discloses that it is known to use chlorinated paraffins as an extreme pressure lubricant additive in lubricating metals. Such additives are highly corrosive, however, and for that reason are not suitable for a number of uses, such as in the lubrication of internal combustion engines. The present invention overcomes the corrosive problems of the previous chlorinated paraffin additives. The present invention involves the mixing of a substantial portion of chlorinated paraffins with a smaller portion of an alkaline earth metal sulfonate, such as calcium or barium sulfonate, and preferably a base mineral oil and solvent. The resulting additive can be added to standard motor oil to improve its extreme pressure performance in internal combustion engines.

[0083] U.S. Pat. No. 5,064,547 teaches the use of a lubricating composition particularly suited for automobile engine lubrication that comprises at least one dicarboxylic acid with a carbon chain preferably between 20 and 32 carbon atoms in length, and a carrier for the acids such as paraffin oil. The dimer acids are present in the amount of 60 to 80% by weight and the carrier is present in the amount between 20 t 40%.

[0084] U.S. Pat. No. 5,783,528 claims an improved lubricant is created by combining an ester lubricant, such as a polyester, natural or modified seed ester oils, C5-C18 adipate esters, C5-C18 azelate esters, C3-C22 trimethylol propane esters, C3-C22 pentaerythritol esters,3 C3-C22 dipentaerythritol esters, C3-C22 tripentaerythritol esters, mC3-C22 neopentyl glycol esters, C3-C18 phthalate esters, C3-C18 trimellitate esters, and C3-C22 esters of C36 dimer acid with an aromatic lubricant selected from the group consisting of C5-C22 alkylnaphthenic lubricants and C5-C22 alkoxynaphthenic lubricants.

[0085] U.S. Pat. No. 5,880,072 discloses an antiwear composition, comprising a cyclic amide, and a monoester formed by reaction of a dicarboxylic acid and a polyol in substantially equimolar amounts, wherein said dicarboxylic acid is a dimer of an unsaturated fatty acid.

[0086] U.S. Pat. No. 5,925,600 discloses a lubricant composition e.g. for engine oils comprises (i) a base oil, (ii) an antiwear additive combination comprising (a) an organo-molybdenum compound and (b) an ashless organo-phosphorus compound, and (iii) an antioxidant additive combination comprising (d) an aminic antioxidant and (e) a phenolic antioxidant, the weight ratio of aminic antioxidant to phenolic antioxidant being greater than 1:1, preferably from 1.5:1 to 20:1. The antiwear additive combination (ii) may further comprise (c) a zinc thiophosphate compound selected from zinc dialkyldithiophosphate, zinc diaryldithiophosphate and zinc alkylaryldithiophosphate and zinc arylalkyldithiopoosphate and mixtures thereof.

[0087] U.S. Pat. No. 6,150,309 discloses a method for improving the dispersancy retention of a crankcase lubricant composition comprising including in the crankcase lubricant

composition an oil-soluble, organomolybdenum compound and a phenolic and aminic antioxidant, the molybdenum and antioxidant being present in a weight ratio in the range of about 80:20 to about 20:80.

II. SUMMARY OF THE INVENTION

Definitions

[0088] To assist the reader in understanding the description of this invention, the definitions of the following terms should be noted.

[0089] Boundary Lubrication—Lubrication between two rubbing surfaces without the development of a full lubricating film.

[0090] Corrosion resistant—Protected against aggressive attack from oxygen, water and numerous chemicals by a natural oxide layer.

[0091] Highly Polar—a material that has a functional group that is capable of being polarized and has a dipole moment of 15 Debye or greater.

[0092] Hydrodynamic Lubrication—When a viscous film completely separates moving surfaces. It is affected solely by the 'pumping' action developed by the sliding of one surface over another in contact with lubricating oil. Adhesion to the moving surface draws the oil into a high-pressure wedge shape area between the surfaces, and viscosity retards the tendency to squeeze the oil out.

[0093] Low Friction—a force that approaches the viscous friction force of the base oil.

[0094] Low Wear—a wear rate that is significantly less than wear rates measured in premium grade oils and greases available on the open market.

[0095] Polar—a material that has the capability of developing oppositely charged poles, either via an inductive or conjugated mechanism.

[0096] Replenishable—a rate of replenishment which is equal to or greater than the rate of wear of a protective film. Replenishment refers to the rate of reaction of additive materials that form the protective film of conventional lubricants.

[0097] Sacrificial—refers to the rate of wear of protective films which are continuously being sacrificed and replaced by reaction with additive chemistry of conventional lubricants.

[0098] Stable Coating—a coating in which the rate of replenishment equals the rate of attrition, and is not destroyed under operating conditions.

[0099] Synergist—something (as a chemical or a muscle) that enhances the effectiveness of an active agent; receiving an unexpected result from two or more constituents; a greater result from two or more constituents than would be expected by the added effect of each constituent.

[0100] Working fluid refers to any fluid employed as a lubricant between contact surfaces or, more generally, between moving parts of operating systems. Such operating systems may include, by way of non-limiting example, internal combustion engines, hypoid gears, transmissions, industrial machines, propulsion engines, wheel bearings, and the like.

[0101] In one embodiment, the present invention focuses on the boundary and mixed-flow regimes of operation of a working fluid, rather than the hydrodynamic operating regime. In fact the incorporation of one or any combination of the ingredients of this invention eliminates the need for what is classically regarded as hydrodynamic lubrication. Lubrication can be achieved by several different methods. One

method involves the complete separation of moving parts by a film of a viscous liquid or working fluid. This lubrication, known as hydrodynamic lubrication, or full fluid lubrication, typically possesses a coefficient of friction of approximately 0.001. As the operating conditions between the contact surfaces become more severe, there is a point where a complete film is no longer sustainable, and the high points on the mating surfaces must share the load with the film. Thus, there is a shift, first from a complete film to a mixed film, then to boundary lubrication. The mixed film, sometimes called the mixed lubrication region, is a translational region where wear and friction possess larger magnitudes than they do in the hydrodynamic region but smaller magnitudes than in boundary lubrication. Within this range, the coefficient of friction may vary from approximately 0.0001 to 0.09.

[0102] In boundary lubrication, metal asperities from opposite surfaces may penetrate the film, undergo physical or chemical adhesions, and tear away from their respective surfaces. Eventually, welding and gross seizure may occur. Extreme pressure (EP) additives have been developed to deal with these extreme operating conditions. EP agents are typically sulfur-, chlorine-, phosphorous-, or lead-containing compounds that function by one of two mechanisms. Firstly, an EP agent may react at extreme operating conditions to form a low melting temperature, inorganic lubricant film on the metal surface. Secondly, the EP additive may function as a fluxing agent that reacts with the metal surfaces and prevents welding. Notably, reaction with the metal surfaces ultimately leads to corrosion of the surfaces. Thus, it is desirable that an additive for working fluids not chemically react with the contact surfaces.

[0103] The present invention operates on the understanding that virtually all of the wear and high friction occur in the boundary and mixed regimes, whereas, in the hydrodynamic regime, friction and wear are, for the most part, inconsequential because the operating surfaces never make contact. The present invention focuses on providing a lubricous film upon the contact surfaces within an operating system containing a working fluid, working fluid additive, or a working fluid/working fluid additive combination, and eliminates the need for a high viscosity working fluid having increased film forming characteristics. This beneficially enables the designer of an operating system to use a lower viscosity fluid and, thus, reduce the viscous friction component within the system. The end result is a more efficient operating system.

[0104] This invention involves the addition of highly polar lubricating materials and enhancers, which, by their nature, form a low friction, low wear, corrosion resistant, sacrificial, replenishable, stable coating that does not chemically combine with the contact surfaces but is still attracted thereto to protect the polished nature of the surfaces. These highly polar materials exhibit a chelating effect that prevents varnishes, lacquers, and carbonaceous formations, as well as wear particles, usually associated with lubricants and working fluids, from forming on the surfaces.

[0105] These highly polar materials are materials that have a greater affinity for the contact surfaces. Hence, they produce film layers on the contact surfaces that prevent the working surfaces from making contact and eliminate the friction losses experienced in the boundary regime. The highly polar materials serve to separate the contact surfaces under the extremes of high load and low speed to obtain a step improvement in friction coefficients and an orders-of-magnitude reduction in wear coefficients. These reductions lead to a

reduction of operating temperatures, thereby significantly reducing the boiling off of lower molecular weight materials within the working fluid to prolong the life of the working fluid, enhance its cooling function, and retard oxidation and the resulting formation of lacquers and varnishes on the contact surfaces.

[0106] In general, the present invention provides a combination working fluid and working fluid additive for use in an operating system comprising 0 to 99.99 weight percent working fluid and 0.01 to 100 weight percent working fluid additive. The working fluid additive consists of 0 to 100 percent by weight of a highly polar material possessing at least one, and often times multiple, polarizable functional group(s) that has a great attraction for the metal contact surfaces. The highly polar material itself is sufficient to form the desired film on the contact surfaces and thereby protect the same and reduce the friction within the operating system. However, optional materials that will be termed herein synergists are employed because certain highly polar material will undergo proton exchange with or form charged complexes with such materials. Consequently the layers of lubricating composition are attracted to the metal surfaces as well as to each other by electrostatic attraction. This is a completely novel approach because heretofore conventional lubrication industry wisdom invariably discusses the need for a lubricating composition that possesses suitably large viscosity in order to be efficient. In this invention, the lubricant's electronic qualities help determine its efficacy as a lubricant; large viscosity is not the primary prerequisite for a good lubricant. The result of a build up of partially charged or ionized compounds on the working surfaces will increase the thickness of the films formed on the contact surfaces.

[0107] The working fluid may contain one or more secondary polar materials, referred to hereafter as synergistic highly polar compounds, which act in a synergistic manner with the first polar material. This second polar material may be present in amounts of 0.1% to 99.9% of the working fluid additive. The working fluid additive may contain one or more organometallic components, present in amounts from 0.1% to 99% of the working fluid additive. The working fluid additive may also include from 0 to 95 weight percent of one or more of enhancing accelerators and/or from 0 to 95 weight percent of one or more dispersion agents. The "enhancing accelerator," which includes but is not limited to the general class of organic compounds known as the glycol ethers, serves to enhance the compatibility between the host working fluid and the additive of the present invention, and, thus, would be employed when compatibility is required. The present invention is utilized as a working fluid additive, and thus would be employed in working fluid additives used in operating systems such as spark-ignited and compression-ignited internal combustion engines, including truck and automobile engines, two-cycle engines, aviation piston engines, marine and low load diesel engines, hypoid gears, transmissions, industrial machines, propulsion engines, wheel bearings, gear oils, turbine oils, cutting fluids, instrument oils, and the like.

[0108] The use of small amounts of glycol materials serves to improve the anti-wear, anti-friction, and antioxidative properties of any lubricating composition containing this invention and, thus, would be employed in working fluid additives used in operating systems requiring a water infiltrateable environment.

[0109] In accordance with one aspect of the present invention, a lubricant additive includes at least a first polar material

and at least a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

[0110] In accordance with one aspect of the present invention, the ratio of the first polar material to the second polar material is from about 5:1 to about 1:5 by weight.

[0111] In accordance with one aspect of the present invention, the first polar material is a highly polar material.

[0112] In accordance with one aspect of the present invention, the second polar material is a highly polar material.

[0113] In accordance with one aspect of the present invention, one of the polar materials is an organic acid.

[0114] In accordance with one aspect of the present invention, the first polar material is an ester and the second polar material is a dimer acid.

[0115] In accordance with one aspect of the present invention, the ratio of the first polar material to the second polar material is from about 4:3 to about 3:4 by weight.

[0116] In accordance with one aspect of the present invention, the combination of polar materials increases a boundary layer without increasing the viscosity of an associated oil or working fluid.

[0117] In accordance with one aspect of the present invention, the lubricant further includes approximately 0.1 to 99 percent by weight of an organometallic compound, approximately 0 to 95% by weight of at least one enhancing accelerators, and approximately 0 to 95% by weight of at least one dispersion agent.

[0118] In accordance with one aspect of the present invention, the highly polar material is chosen from the group comprising: fatty esters, halogenated fatty esters, carboxylic acids, halogenated carboxylic acids, alcohols, amines, amides, anhydrides, lactams, lactones, phenols, urethanes polyurethanes, carbamates, sulfonamides, sulfones, sulfoxides, polysulfones, thiazoles, oxazoles, polyesters, polyacrylates, polymethacrylates, polycarbonates, mono and poly functional carboxylic acids, polyhydroxylated aliphatic and unsaturated compounds, mono and polyhydroxylated esters, mono and polyhydroxylated ketones, mono and polyhydroxylated baldheads, sulfonic acids, polymerized carboxylic acids, aromatic carboxylic acids, alkyl and alkenyl carboxylic acids, alkyl and alkenyl dicarboxylic acids, fatty acids, unsaturated carboxylic acids, dimer, trimer, and oligomeric carboxylic acids and mixtures thereof; the organometallic compound is chosen from the group comprising: organomolybdenum carboxylates, organomolybdenum dithiocarbamate, organomolybdenum xanthate, molybdic acid, molybdenum ditridecyldithiocarbamate, sulfurized organomolybdenum carboxylates, sulfurized organomolybdenum dithiocarbamate, sulfurized organomolybdenum xanthate, sulfurized molybdic acid, sulfurized molybdenum ditridecyldithiocarbamate, boric acid, boric acid monoethanolamine esters, boron nitride powders, and amidized boron complexes, and mixtures thereof; the enhancing accelerator is a carbodiimide; and the dispersion agent is chosen from the group comprising: polyamides, thiadiazoles, polyisobutenyl-succinimide, esters, diesters, polyol esters, polyols, ethoxy-propoxy-ethanol, ethoxy-propoxy-propanol, 22-(2-aminoethoxy)-ethanol, and oleyl/cetyl alcohols.

[0119] In accordance with one aspect of the present invention, the additive further comprises at least one of the following: anti-wear/extreme pressure additive, antioxidant, metal deactivator, detergent, corrosion inhibitor, defoamer, and dye.

[0120] In accordance with one aspect of the present invention, the additive further includes an anti-wear/extreme pressure additive, an antioxidant, a metal deactivators, a detergent, a corrosion inhibitors, a defoamer, and a dye.

[0121] In accordance with one aspect of the present invention, the first highly polar material comprises: at least one hydrophilic functional group and at least one hydrophobic structure.

[0122] In accordance with one aspect of the present invention, the first highly polar material is chosen from the group comprising: aliphatic esters, aliphatic di, tri, tetra, and polyesters, methyl palmitate, hydroxy substituted esters, dimer acid, trimer acid, valeric acid, isopentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, isooctanoic acid, 2-ethylhexanoic acid, pelargonic acid, isononanoic acid, decanaoic acid, stearic acid, trimellitic acid, isostearic acid, lauric acid, myristic acid, palmitic acid, oxalic acid, malonic acid, maleic acid, fumeric acid, succinic acid, adipic acid, glutaric acid, oleic acid, hydrogenated dimer acid, salicyclic acid, acetosalicylic acid, toluic acid, cyclohexanecarboxylic acid, alkyl malonic acids, alkenyl malonic acids, cyclopentane carboxylic acid, cycloheptanoic acid, cyclopentenoic acid, cyclohexenoic acid, cycloheptenoic acid, formic acid, acetic acid, propionic acid, butyric acid, valeric acid, caproic acid, enanthic acid, caprylic acid, capric acid, glutaric acid, pimelic acid, benzoic acid, ortho-phthalic acid, meta-phthalic acid, para-phthalic acid, pyromellitic acid, ethylmalonic acid, methylmalonic acid, fatty acids such as coconut oil, soybean oil, cottonseed oil, rapeseed oil, linseed oil, castor oil, sunflower seed oil, olive oil, neat's foot oil, peanut oil, herring oil, cod liver oil, shark liver oil, whale oil, tallow fat, lard, dioleic dioic acid, dilinoleic dioic acid, didodecadiendioic acid, dicyclopentadiene dioic acid, the mixed dimer of oleic and linoleic acids, and combinations of these mixed dimer acids.

[0123] In accordance with one aspect of the present invention, the lubricant consists essentially of a first polar material and a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

[0124] In accordance with one aspect of the present invention, a method for improving lubrication, the method comprising the steps of increasing a boundary layer without increasing the viscosity, the increase being accomplished by adding a composition to oil or a working fluid, the composition comprising: at least a first polar material and at least a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

[0125] In accordance with one aspect of the present invention, the first polar material is an ester and the second polar material is a dimer acid.

[0126] In accordance with one aspect of the present invention, the ratio of the first polar material to the second polar material is from about 4:3 to about 3:4 by weight.

[0127] In accordance with one aspect of the present invention, the composition is added at about 0.5% by weight to the oil or working fluid.

[0128] In accordance with one aspect of the present invention, a lubricant compound includes approximately 95% to approximately 99.9% by weight working fluid and approximately 0.1% to approximately 5% by weight of an additive, the additive comprising approximately 1% to 100% by weight of a highly polar material, approximately 0.4% to approximately 95% by weight of a second, synergistic highly polar material, and approximately 0.02% to approximately 20% by weight organometallic material.

III. BRIEF DESCRIPTION OF THE DRAWINGS

[0129] The invention may take physical form in certain parts and arrangement of parts, at least one embodiment of which will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof and wherein:

[0130] FIG. 1 shows a graph representing the concentration of the present invention versus the friction coefficient of a typical industrial gear oil;

[0131] FIG. 2 shows a graph representing the concentration of the present invention versus the friction coefficient of a typical hydraulic oil;

[0132] FIG. 3 shows the electrostatic attraction and repulsion amongst working surfaces and lubricating layers;

[0133] FIG. 4 shows minimization of lateral slip via the inclusion of tie-in molecules;

[0134] FIG. 5 shows a graph of the normal force versus tangential force with and without the present invention;

[0135] FIG. 6 shows the forces associated with the present invention;

[0136] FIG. 7 shows a three-dimensional representation of FIG. 6;

[0137] FIG. 8 shows the process of living polymerization;

[0138] FIG. 9 shows a side view of a boundary layer using the present invention;

[0139] FIG. 10 shows a graph of the percent increase in fuel efficiency for several test vehicles utilizing the present invention;

[0140] FIG. 11 shows a graph of vehicle hydrocarbon emissions before and after addition of the present invention;

[0141] FIG. 12 shows a graph of fuel efficiency for buses after addition of the present invention;

[0142] FIG. 13 shows a graph of horsepower before and after addition of the present invention;

[0143] FIG. 14 shows a graph of amperage usage of industrial air compressors before and after the addition of the present invention;

[0144] FIG. 15 shows a graph of tractional forces versus normal force for a grease formulated with and without the present invention; and,

[0145] FIG. 16 shows a graph of the coefficient of friction versus the normal force for grease with and without the present invention.

IV. DESCRIPTION OF THE INVENTION

[0146] This invention provides a working fluid additive of highly polar lubricating materials and enhancers, which, by their nature, form a low friction, low wear, corrosion resistant, sacrificial, replenishable, stable coating upon contact surfaces within an operating system. This coating does not chemically combine with the contact surfaces, but has an attraction for the contact surfaces that is greater than its attraction for itself, this attraction preferably being stronger than a van der Waal bond. This coating protects the polished nature of the contact surfaces and, by virtue of the chelating effect of these polar compounds, varnishes, lacquers, and carbonaceous formations, as well as wear particles, usually associated with lubricants and working fluids, are removed and are prevented from forming on the contact surface.

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[0147] In addition to the highly polar material, the working fluid additive may optionally include any one or more of additional polar materials that act as a synergist to the first polar materials, one or more organometallic components, one or more enhancing accelerators, and one or more dispersion agents. The optional polar component(s) is chosen such that the highly polar material has a great affinity for the synergist (s) at the contact surfaces. This phenomenon creates an electrostatically bound lubricating layer or layers which increases the efficiency of the boundary film and thereby decreases the wear and the friction at the contact surfaces. We call this action matched molecular chemistry (MMC). The anti-friction, wear, and antioxidative properties of this invention are enhanced by the addition of enhancing accelerators. The inclusion of dispersing agents will enhance the already formidable chelating power of the highly polar materials and will thus decrease the likelihood of varnish, lacquer, or particulate build-up on the operating surfaces.

[0148] The working fluid additive, whether or not it is inclusive of the optional materials, provides a protective film at the contact surfaces that is not viscosity dependent. Thus, the working fluid additive of the present invention permits the use of lower viscosity working fluids, which use results in a reduction of the friction due to viscous action, thereby yielding an additional gain in system efficiency. We also have demonstrated that the reduction in wear achieved by this invention translates into significant reductions in viscous losses. Additionally, because less friction is generated, there is less temperature build-up, and the necessity of the working fluid's function as a heat sink is minimized and the rate of oil degradation is consequently decreased.

A. Highly Polar Material

[0149] The "highly polar materials" as they are to be understood in the present invention, are molecules that are relatively inert, lubricous, and stable at elevated temperatures of about 105° F. and above. The highly polar materials are chosen for their ability to form bonds with the contact surfaces within an operating system as well as with other amorphous, highly lubricous materials, such as the aforementioned synergistic component. Non-limiting examples of useful highly polar materials include: fatty esters, halogenated fatty esters, carboxylic acids, halogenated carboxylic acids, alcohols, amines, amides, anhydrides, lactams, lactones, phenols, urethanes polyurethanes, carbamates, sulfonamides, sulfones, sulfoxides, polysulfones, thiazoles, oxazoles, polyesters, polyacrylates, polymethacrylates, polycarbonates, mono and poly functional carboxylic acids, polyhydroxylated aliphatic and unsaturated compounds, mono and polyhydroxylated esters, mono and polyhydroxylated ketones, mono and polyhydroxylated baldheads, sulfonic acids, polymerized carboxylic acids, aromatic carboxylic acids, alkyl and alkenyl carboxylic acids, alkyl and alkenyl dicarboxylic acids, fatty acids, unsaturated carboxylic acids, dimer, trimer, and oligomeric carboxylic acids and mixtures thereof are suitable materials for this primary highly polar material. In addition to at least one hydrophilic functional group, the highly polar material can contain one or more hydrophobic structures, which render the material soluble in typical working fluids. One would select a highly polar material suitable in this invention by selecting a compound with at least one polar functional group and at least one hydrophobic group. In one embodiment, the material has relatively low volatility.

[0150] Examples of highly polar primary compounds include: aliphatic esters, aliphatic di, tri, tetra, and polyesters, methyl palmitate, hydroxy substituted esters, dimer acid, trimer acid, valeric acid, isopentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, isooctanoic acid, 2-ethylhexanoic acid, pelargonic acid, isononanoic acid, decanoic acid, stearic acid, trimellitic acid, isostearic acid, lauric acid, myristic acid, palmitic acid, oxalic acid, malonic acid, maleic acid, fumeric acid, succinic acid, adipic acid, glutaric acid, oleic acid, hydrogenated dimer acid, salicyclic acid, acetosalicylic acid, toluic acid, cyclohexanecarboxylic acid, alkyl malonic acids, alkenyl malonic acids, cyclopentane carboxylic acid, cycloheptanoic acid, cyclopentenoic acid, cyclohexenoic acid, cycloheptenoic acid, formic acid, acetic acid, propionic acid, butyric acid, valeric acid, caproic acid, enanthic acid, caprylic acid, capric acid, glutaric acid, pimelic acid, benzoic acid, ortho-phthalic acid, meta-phthalic acid, para-phthalic acid, pyromellitic acid, ethylmalonic acid, methylmalonic acid, fatty acids such as coconut oil, soybean oil, cottonseed oil, rapeseed oil, linseed oil, castor oil, sunflower seed oil, olive oil, neat's foot oil, peanut oil, herring oil, cod liver oil, shark liver oil, whale oil, tallow fat, lard, dioleic dioic acid, dilinoleic dioic acid, didodecadiendioic acid, dicyclopentadiene dioic acid, the mixed dimer of oleic and linoleic acids and combinations of these mixed dimer acids. While the invention is described using a dimer acid, it is common knowledge and understood that the dimer acid need not be 100% dimer acid because commercially available dimer acids will contain trimer acids and monomer acids. Commercially available dimer acids contain anywhere from approximately 75-99% dimer acid. Several non-limiting examples of Uniqema dimer acid products include Pripol 1009 (96.5% dimer acid, 1% trimer acid, 0.1% monomer acid), Pripol 1017 (75-80% dimer acid, 18-22% trimer acid, 1-3% monomer acid), Pripol 1013 (95-98% dimer acid, 3-4% trimer acid, 0.2% monomer acid). Also aliphatic fatty acid compounds containing no unsaturated fatty acids or with a reduced content of unsaturated fatty acids are applicable to this invention.

B. Synergistic Highly Polar Components

[0151] In one embodiment, materials may be added to the primary highly polar material to increase the lubricating and anti-wear properties of the working fluid additive. These materials are selected for being relatively stable and polar, and are herein called the "synergistic highly polar component" or "synergistic highly polar components" when combinations of secondary synergists are utilized. These components add a synergistic lubricating effect not predicted in any literature dealing with lubrication. We postulate that the highly polar synergistic materials are drawn to the contact surfaces and the synergistic material forms an interface with the primary highly polar material, thus producing electrostatically charged layers of lubricant which prevent the working surfaces from making contact. The net effect is a thickening of the boundary layer which offers greater protection than the polar material by itself.

[0152] Non-limiting examples of useful ester, fatty esters, and halogenated fatty esters include chlorinated ethyl esters, chlorinated methyl ester (CME), mono and dichlorinated esters made from C_5 to C_{50} monocarboxylic acids, fatty esters, halogenated fatty esters, carboxylic acids, halogenated carboxylic acids, alcohols, amines, amides, anhydrides, lactams, lactones, phenols, urethanes polyurethanes, carbam-

ates, sulfonamides, sulfones, sulfoxides, polysulfones, thiazoles, oxazoles, polyesters, polyacrylates, polymethacrylates, polycarbonates, mono and poly functional carboxylic acids, polyhydroxylated aliphatic and unsaturated compounds, mono and polyhydroxylated esters, mono and polyhydroxylated ketones, mono and polyhydroxylated baldheads, sulfonic acids, polymerized carboxylic acids, aromatic carboxylic acids, alkyl and alkenyl carboxylic acids, alkyl and alkenyl dicarboxylic acids, fatty acids, unsaturated carboxylic acids, dimer, trimer, and oligomeric carboxylic acids and mixtures thereof are suitable materials; aromatic carboxylic acids, aromatic polycarboxylic acids such as phthalic, trimellitic, pyromellitic, or mellitic acid and alcohols and polyols and polyol ethers such as dodecyl alcohol, hexyl alcohol, butyl alcohol, ethylene glycol, 2-ethylhexyl alcohol, propylene glycol, diethylene glycol monoether, neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, the pentaerythritol ester of heptanoic, caprylic, capric, and adipic acids, dipentaerythritol hexaester with 3,5,5-trimethylhexanoic acid, dipentaerythritol esters of linear and branched fatty acids, the dipentaerythritol esters of valeric, caprylic, and capric acids, the pentaerythritol esters of caprylic and capric acids, the mixed diesters of decanoic acid with 2,2-dimethyl-1,3-propanediol, isooctadecanoic acid, and octanoic acid, pentaerythritol tetrapentanoate, polyethylene glycol ester of sebacic acid and 2-ethylhexanol, the pentaerythritol ester of oleic acid, di-2-ethylhexyldimerate, triisodecyl tridecyl trimellic ester, the poly(pentaerythritol esters of heptanoic, caprylic, and capric acids, isodecyl sebacate, glyceryl monooleate, di-2-ethylhexylsebacate, the sucrose esters of fatty acids soyate, sorbitan monooleate, sebacic acid and neopentyl glycol dissolved in sorbitan monooleate, and poly (neopentyl glycol sebacate) dissolved in sorbitan monooleate. Another useful class of compounds that can be used in the present invention are the mono and di chlorinated esters made from dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, alkyl malonic acids, alkenyl malonic acids, suberic acid, sebacic acid, maleic acid, fumeric acid, azelaic acid, adipic acid, malonic acid, alkyl malonic acid, alkenyl malonic acid, linoleic acid dimer etc. with a variety of alcohols (e.g., propyl alcohol, butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, propylene glycol, diethylene glycol monoether, etc.).

[0153] Non-limiting examples of useful carboxylic acids and halogenated carboxylic acids include C_5 to C_{50} monocarboxylic acids (e.g., hexanoic acid, dodecanoic acid, stearic acid, etc.), polycarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, alkyl malonic acids, alkenyl malonic acids, polycarboxylated fatty acids, dimer acid, trimer acid, valeric acid, isopentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, isooctanoic acid, 2-ethylhexanoic acid, pelargonic acid, isononanoic acid, decanaoic acid, stearic acid, trimellitic acid, isostearic acid, lauric acid, myristic acid, palmitic acid, oxalic acid, malonic acid, maleic acid, fumeric acid, succinic acid, adipic acid, glutaric acid, oleic acid, hydrogenated dimer acid, salicyclic acid, acetosalicyclic acid, toluic acid, cyclohexanecarboxylic acid, alkyl malonic acids, alkenyl malonic acids, cyclopentane carboxylic acid, cycloheptanoic acid, cyclopentenoic acid, cyclohexenoic acid, cycloheptenoic acid, formic acid, acetic acid, propionic acid, butyric acid, valeric acid, caproic acid, enanthic acid, caprylic acid,

capric acid, glutaric acid, pimelic acid, benzoic acid, orthophthalic acid, meta-phthalic acid, para-phthalic acid, pyromellitic acid, ethylmalonic acid, methylmalonic acid, fatty acids such as coconut oil, soybean oil, cottonseed oil, rapeseed oil, linseed oil, castor oil, sunflower seed oil, olive oil, neat's foot oil, peanut oil, herring oil, cod liver oil, shark liver oil, whale oil, tallow fat, lard, dioleic dioic acid, dilinoleic dioic acid, didodecadiendioic acid, dicyclopentadiene dioic acid, the mixed dimer of oleic and linoleic acids and combinations of these mixed dimer acids. While the invention is described using a dimer acid, it is common knowledge and understood that the dimer acid need not be 100% dimer acid because commercially available dimer acids will contain trimer acids and monomer acids, etc.)

[0154] Non-limiting examples of useful aromatic carboxylic and aromatic polycarboxylic acids such as phthalic, trimellitic, pyromellitic, or mellitic acid and alcohols and polyols and polyol ethers such as dodecyl alcohol, hexyl alcohol, butyl alcohol, ethylene glycol, 2-ethylhexyl alcohol, propylene glycol, diethylene glycol monoether, neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, etc.

[0155] Non-limiting useful examples of alcohols include sec-dodecyl alcohol, pelargonic alcohol, lauryl alcohol, stearyl alcohol, behenyl alcohol, ceryl alcohol, melissyl alcohol, geddyl alcohol and the like.

[0156] Non-limiting examples of useful amines include cyclohexylamine, stearylamine, dicyclohexylamine, N-ethyl-2-pentylamine, N-propyl-3-laurylamine, 2-ethylpiperidine, 2-methylpyridine, tributylamine, N-ethyl-N-propylstearamide, piperidine, pyridine, etc.

[0157] Non-limiting examples of useful amides include, ethanamide, butanamide, N-methylbenzamide, N,N-dimethylformamide, stearamide, N-methylstearamide, N,N-dimethylstearamide, erucamide, erucyl erucamide, etc.

[0158] Non-limiting examples of useful anhydrides include benzoic anhydride, ethanoic anhydride, ethanoic propanoic anhydride, benzoic ethanoic anhydride, etc.

[0159] Non-limiting examples of useful lactams include 2-azetidinone, butyrolactam, 2-azacyclohexanone, caprolactam, 2-azacyclooctanone, 2-azacyclononanone, 2-azacyclotridecanone, etc.

[0160] Non-limiting examples of useful lactones include ascorbic acid, nepetalactone, α-butyrolactone, 5-hydroxypentanoic acid lactone, 2-methylcaprolactone, 3-ethylcaprolactone, etc.

[0161] Non-limiting examples of phenols include 4-tert butylphenol, 4-phenylphenol, methylene bis(2-phenylphenol), α-naphthol, etc.

[0162] Non-limiting examples of useful carbamates include ethyl-3-dimethylaminophenylcarbamate, ethyl-3-methoxy-4-methylphenylcarbamate, 1-naphthyl-N-methylcarbamate, phenyl-N-phenylcarbamate, etc.

[0163] Non-limiting examples of poly(urethanes) include the polymerization product of one or more diols such as ethylene glycol, propylene glycol, and/or a polydiol, such as diethylene glycol, triethylene glycol, and/or tetraethylene glycol, and the like, with a diisocyanate such as 2,4-tolylene diisocyanate, 2,6-tolylene diisocyanate, 4,4'-diphenylmethane diisocyanate, 1,6-hexamethylene diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, and the like.

[0164] Non-limiting examples of useful sulfonamides include benzenesulfonamide, p-toluenesulfonamidebenzysulfonamide, p-bromobenzenesulfonamide, m-nitrobenzenesulfonamide, α-naphthylsulfonamide, methanesulfona-

mide, N-methylbenzenesulfonamide, N,N-dimethylbenzenesulfonamide, N-ethyl, N-methyl-p-toluenesulfonamide, and the like.

[0165] Non-limiting examples of sulfones include dimethyl sulfone, methyl p-tolyl sulfone, benzyl phenyl sulfone, as well as the sulphonates such as oil soluble calcium sulphonate, overbased, and the like.

[0166] Non-limiting examples of sulfoxides include dimethyl sulfoxide, methyl p-toly sulfoxide, benzyl phenyl sulfoxide and the like.

[0167] Non-limiting examples of polysulfones such as the reaction product of the sodium salt of 2,2-bis(4-hydroxyphenyl)propane and 4,4'-dichlorodiphenyl sulfone.

[0168] Non-limiting examples of useful thiazoles include thiazol, benzthiazol, alpha and beta benzylthiazole and the like.

[0169] Non-limiting examples of useful oxazoles include benzoxazole and the like.

[0170] Non-limiting examples of useful polyesters include polyethlene terephthalate, polybutyleneterephthalate, poly-1,4-cyclohexane dimethylene terephthalate, poly(ethylene azelate), poly(ethylene-1,5-naphthalate), poly(ethylene oxybenzoate), poly(p-hydroxy benzoate) and the like.

[0171] Non-limiting examples of polyamides include poly (4-aminobutyric acid), poly(hexamethylene adipamide), poly (6-aminohexanoic acid), poly(m-xylylene adipamide), poly (xylylene sebacamide), poly(2,2,2-trimethyl hexamethylene terephthalamide), poly(metaphenylene isophthalimide), poly (p-phenylene terephthalamide) and the like.

[0172] Non-limiting examples of useful polyacrylates and polymethacrylates and their copolymers include poly(ethyl acrylate), poly(n-butyl acrylate), poly(methylmethacrylate), poly(ethyl methacrylate), poly(n-butyl methacrylate), poly (n-propyl methacrylate), ethylene-acrylic acid copolymers, methyl methacrylate-styrene copolymers ethylene-ethyl acrylate copolymers, methacrylated butadiene-styrene copolymers and the like.

[0173] Non-limiting examples of useful polycarbonates include poly(4,4'-dioxydiphenol-2,2-propane), which is sold under the trademark LEXAN, diethylene glycol bis(allyl carbonate), which is sold under the trademark CR-39, as well as all of the copolymers and blends of these materials such as with vinyl acetate, cellulose acetate, cellulose butyrate, cellulose propionate and acrylonitrile and the like.

[0174] Non-limiting examples of useful ketones include acetophenone, benzophenone, (4-hydroxyphenyl)phenyl ketone, butanone, benzoin, 2-pentanone, 3-pentanone, 2-hexanone, 3-hexanone, 2-heptanone, 3-heptanone, 4-heptanone, 2-octanone, 3-octanone, 4-octanone, 3-methyl-2 pentanone, 3-alkyl-2-penatanone, 3-alkenyl-2-pentanone, 2-alkyl-3-pentanone, 2-alkenyl-3-pentanone, 3-alkyl-2-hexanone, 4-alkyl-2-hexanone, 5-alkyl-2-hexanone, 3-alkenyl-2-hexanone, 4-alkenyl-2-hexanone, 5-alkenyl-2-hexanone, 2-alkyl-3-hexanone, 2-alkenyl-3-hexanone, 4-alkyl-3-hexanone, 5-alkenyl-3-hexanone, 3-alkyl-2-heptanone, 4-alkyl-2-heptanone, 5-alkyl-2-heptanone, 6-alkyl-2-heptanone, 2-alkenyl-3-heptanone, 4-alkenyl-3-heptanone, 5-alkenyl-3-heptanone, 6-alkenyl-3-heptanone, 2-alkyl-4-heptanone, 3-alkyl-4-heptanone, 2-alkenyl-4-heptanone, 3-alkenyl-4-heptanone, cyclopentanone, cyclohexanone, cyclopentanone, cycloheptanone, cyclooctanone, cyclononanone, cyclodecanone, 2-alkylcyclopenanone, 2-alkenylcyclopentanone, 3-alkylcyclopentanone, 3-alkenylcyclopentanone, 2-alkylcyclohexanone, 2-alkenylcyclohexanone, 3-alkylcy-clohexanone, 3-alkenycyclohexanone, 4-alkylcyclohexanone, 3-alkenylcyclohexanone, 2-alkylcycloheptanone, 4-methoxyacetophenone, 4-(methylsulfonyl)acetophenone, 2-hydroxyacetophenone, 2"-hydroxyacetophenone, 2-hydroxy-2-phenylacetophenone

[0175] In addition to the primary and synergistic polar compounds, the present invention can incorporate the following additives in well known standard amounts: metal deactivators, detergents, dispersants, antioxidants, defoamers, corrosion inhibitors or such additives as may be required for the lubricant application.

C. Organometallic Components

[0176] Non-limiting examples of useful organometallic compounds include organomolybdenum compounds such as: organomolybdenum carboxylates, organomolybdenum dithiocarbamate, organomolybdenum xanthate, molybdic acid, molybdenum ditridecyldithiocarbamate, and molybdenum-sulfur compounds. Non-limiting examples of useful sulfurized organometallic compounds include organomolybdenum compounds such as: sulfurized organomolybdenum carboxylates, sulfurized organomolybdenum dithiocarbamate, sulfurized organomolybdenum xanthate, sulfurized molybdic acid, sulfurized molybdenum ditridecyldithiocarbamate, and molybdenum-sulfur compounds. Non-limiting examples of boron materials include boric acid, boric acid monoethanolamine esters, boron nitride powders, and amidized boron complexes.

[0177] Non-limiting examples of useful polymeric materials include polytetrafluoroethylene (PTFE), poly(ethylene), poly(propylene), and the like.

D. Enhancing Accelerator

[0178] These peterioliate compounds aid the working fluid additive in the rate of dispersing into the base oil. The incorporation of one or more of any combination of enhancing accelerators further improves the additive of this invention in some applications by increasing the anti-friction, anti-wear, and antioxidant properties the additive of this invention imparts to a working fluid.

[0179] Non-limiting examples are the carbodiimides.

E. Dispersion Agent

[0180] Dispersion agents prevent deposits of sludge and varnish from adhering to working surfaces. They also improve additive solubility in the base lubricant. Typical dispersants include polyamides, thiadiazoles, polyisobutenyl-succinimide, esters, diesters, and polyol esters.

[0181] Non-limiting examples include: alcohols, polyols, ethoxy-propoxy-ethanol, ethoxy-propoxy-propanol, 22-(2-aminoethoxy)-ethanol, oleyl/cetyl alcohols In addition to the aforementioned highly polar materials, synergistic highly polar materials, organometallic components, enhancing accelerator, and dispersant, the present invention can incorporate the following additives in various amounts: anti-wear/extreme pressure additives, antioxidants, metal deactivators, detergents, corrosion inhibitors, defoamers, dyes, or such additives as required for the lubricant application.

F. EXAMPLES

[0182] All of the laboratory friction and wear tests of lubricant formulas were performed on a modified McMillan Test

Machine. The data was initially verified by the Falex Corporation using ASTM D-2670 test procedures, only modified D ran for 3 hours.

[0183] The modified McMillan Tester employs a 52100 steel ball 12.25 mm in diameter in sliding contact with the cylindrical surface of a Timken tapered roller bearing (part number A4138 being rotated at 320 rpm). The steel ball was cantilevered to provide a mechanical advantage of 24 to 1. Load was applied in increments of 24 pounds for a duration of 1 minute up to a total of 240 pounds. At the end of 10 minutes, the ball was removed and the wear scar measured. The friction of each stage was measured by a wattmeter based on current draw. The wear scar was converted to wear mass and to wear rate mathematically. The data was then reduced to the standard wear relationship, mm^3/Nm (millimeters cubed divided by Newtons times meters). The wattage reading was converted to frictional force, and the coefficient of friction was found by dividing the frictional force by the normal force.

[0184] The formulations tested in the laboratory using the test described above were in some cases, tested in real-world machines as reported herein after. There is a remarkable degree of correlation between the laboratory experiments and the data from the real-world machines.

Experiment 1

[0185] Initially, a control and a first sample, embodying the technology of the present invention, were subjected to the modified McMillan test. The control included a conventional, petroleum based 5W-30 motor oil (BP); the sample embodying the present invention included the same motor oil and an additive package consisting of a 1.5 percent concentration by weight of the overall composition. Results are shown in Table 1.

TABLE 1

	Coef. Of Friction	Wear Rate
Control 1	0.10	2.5×10^{-6} mm^3/Nm
Sample 1	0.067	1.0×10^{-8} mm^3/Nm

Experiment 2

[0186] Compositions identical to control 1 and sample 1 were subjected to ASTM D 2670 (modified) by Falex Corporation. This data is presented in Table 2.

TABLE 2

	Break-in tooth loss	Test tooth loss	Friction factor	Final oil temperature (° F.)
Control 1	50	48	0.12	235
Sample 1	8	7	0.08	157

[0187] The Falex test apparatus placed a rotating cylinder between V-blocks in a container filled with the fluid being tested. The test was run in 2 phases, i.e., a break in period of one minute, wherein the cylinder works in uniformly between the V-blocks, followed by a three hour test where the wear, temperature, and torque are monitored. The tooth loss is an

indication of the wear and the friction factor is computed from the friction and applied forces.

Experiment 3

[0188] A master batch composed of 95 to 100 wt % working fluid (Mobil Super Syn 5W-20) and 0.1 to 5 wt % working fluid additive including: 1 to 100 wt % of an highly polar primary component, 0.4 to 95 wt % of a highly polar secondary material, and 0.02 to 20% organometallic material. The results are presented in Table 3.

TABLE 3

	Friction factor	Wear scar
Control (neat)	0.094	0.75
Test sample	0.073	0.60

Experiment 4

[0189] The same working fluid additive used in Experiment 3 was mixed with another premium oil (Honda API Grade 0W-20). The results are presented in Table 4.

TABLE 4

	Friction factor	Wear scar
Control (neat)	0.083	0.65
Test sample	0.067	0.50

Experiment 5

[0190] A master batch composed 0.1 to 5 wt % working fluid additive including: 1 to 100 wt % of an highly polar primary component, 0.4 to 95 wt % of a highly polar secondary material, and 0.02 to 20% organometallic material was mixed with an industrial gear oil (Shell BMALA 220) and an industrial hydraulic oil (Shell Tellus Plus 32) in varying concentrations. The results are given in Table 5.

TABLE 5

	Concentration	Friction Coef	Wear rate mm^3/Nm
Industrial Gear Oil	0.0	0.110	8.5×10^{-9}
	1%	0.080	1.1×10^{-9}
	2%	0.074	7.0×10^{-10}
	3%	0.063	5.0×10^{-10}
Industrial hydraulic oil	0.0	0.011	8.5×10^{-9}
	1%	0.090	5.0×10^{-9}
	2%	0.072	2.0×10^{-9}
	3%	0.065	9.0×10^{-10}

Experiment 6

[0191] 10 different automobiles were road tested for 100 miles at 60 mph. The MPG (miles per gallon) for each vehicle was recorded and the emissions tested. A master batch consisting of 1 to 100 wt % of an highly polar primary component, 0.4 to 95 wt % of a highly polar secondary material, and 0.02 to 20% organo-metallic material was prepared. 0.5% of the additive was added to the engine and transmission oils of the 10 different automobiles previously tested which were then tested again for 100 miles at 60 mph. The MPG and

emissions tests were repeated for each vehicle. The results are summarized in Table 6 and show the mileage and emissions, in most every case, improved.

TABLE 6

Vehicle	Odometer (miles)	MPG gain (%)	HC before/ after (ppm)	CO before/ after (ppm)	CO2 before/ after
1991 Plymouth	111437	17	84/21	0.46/0.18	14.14/14.78
1996 Ford Escort	37492	14.3	3.4/3.4	0.00/0.03	NR
1989 Dodge Pick up truck	129293	15	84.9/65.4	1.41/1.79	12.32/12.08
1993 Mercury van	101692	12	2.2/5.1	NR	15.21/14.98
1992 Ford 150	19195	16	NR	NR	9.59/11.28
1997 Lincoln Navigator	75844	19	2.8/0.5	0.01/0.00	15.04/15.10
2000 Chevrolet pick up truck	5315	8	11.1/3.6	0.01/0.00	15.12/14.90
1995 Ford van	72655	14	11.9/1.5	0.01/0.12	15.49/14.70
1985 Mercury Marquis	138654	21	231/178	3.41/1.04	NR
2004 Honda Instep	12472	20	NR	NR	NR
Average increase (reduction)	NA	15.63%	35.40%	40.50%	NA

Experiment 7

[0192] In a seventh experiment, the same masterbatch as was used in Experiment 6 was placed in the engine crankcase and transmissions of 3 interurban buses driven on the streets of Cleveland for several months. These buses were powered by GMAC gasoline engines and had a gross weight of approximately 20000 pounds. The MPG for all buses was recorded before and after the addition the masterbatch additive. The results are tabulated in Table 7 and show an average gain of 12.7 percent in fuel mileage (MPG gain).

TABLE 7

Vehicle	Odometer (miles)	Test (miles)	Before (MPG)	After (MPG)	Gain (%)
Unit 825	253800	20800	4.95	5.45	10.10
Unit 826	252200	23400	5.10	5.71	11.96
Unit 827	2021000	20700	5.75	6.65	15.65
Average	NA	NA	NA	NA	12.71

Experiment 8

[0193] In an eighth experiment, the same master batch as in Experiment 7 was placed into the engine crankcases and transmissions of three 18 wheel tractor-trailor rigs at a concentration of 1.5 percent and driven over 25000 miles. The results are given in Table 8 and show an average gain of 23.9 percent in fuel economy.

TABLE 8

Vehicle	Odometer (miles)	Idle Hors	Test (miles)	Before (MPG)	After (MPG)	Gain (%)
584	230934	2528	31078	6.818	8.806	29.16
485	263078	2005	35918	7.260	8.901	22.60
606	211112	1651	27736	7.322	8.804	20.24
Average	NA	NA	NA	NA	NA	23.90

Experiment 9

[0194] In another experiment, 5 different automobiles were tested on a chassis dynamometer at a speed of 70 mph, establishing the baseline deliver power and fuel economy of each vehicle. The same master batch used in Experiment 6 was placed into the engine crankcases and transmissions of each vehicle at a concentration of 1.5% by weight. The average fuel economy of these vehicles was increased by 20.3 percent and the average gain in horsepower was 6 percent. This would indicate a combined reduction in friction losses in the engine and transmission of approximately 30 percent. These results are shown in Table 9.

TABLE 9

Vehicle	Base-line (HP)	Test (HP)	Gain (%)	Base-line (MPG)	MPG (200 miles)	MPG (600 miles)	Gain (%)
1999 Cadillac	188.4	194.9	3.5	32.0	35.7	42.2	31.9
1980 VW (Diesel)	103.9	112.7	8.5	41.0	NR	51.4	25.4
2000 Dodge Neon	84.7	89.5	5.7	33.6	38.8	NR	15.5
1995 Honda	79.9	84.0	5.1	36.6	39.7	NR	8.5
1995 Porsche	172.0	185.2	7.7	NR	NR	NR	NA
Average	NA	NA	6.0	NA	NA	NA	20.3

Experiment 10

[0195] The same master batch as in Experiment 6 was placed into the oil sumps of 5 industrial air compressors at a concentration of 1.5 percent after having established the baseline power draw of each compressor at 100% load. The compressors were of varying designs, i.e., sliding vane, reciprocating and rotary screw. The results are shown in table 10 and demonstrate that the power required to produce rapid output was reduced an average of 16.7 percent.

TABLE 10

Unit	Before (amps)	After (amps)	Power reduction (%)
Sullair 35	32.7	26.3	19.6
Gr-Schm 75	72.0	60.0	16.7
LeRoi 100	115.0	108.0	5.98
Davy 40	52.7	42.2	19.9
Quincy 75	102.0	80.1	21.5
Average	NA	NA	16.7

Experiment 11

[0196] In an eleventh experiment, a masterbatch of MMC was produced by mixing a primary highly polar material with a highly polar secondary material. The additive was placed into a premium motor oil (Mobil 1 SuperSyn 5W-20) at a concentration of 0.6 percent by weight. The coefficient of friction and wear rate of the base oil and the modified base oil were tested and are tabulated in Table 11.

TABLE 11

	Friction coefficient	Wear scar	Wear rate (mm³/Nm)
Control (neat)	0.083	0.8	5×10^{-9}
Test sample	0.075	0.6	1×10^{-9}

[0197] Road tests were conducted using: a 2003 Honda Hybrid 27000 miles), a 96 Saturn L-2 (152000 miles), and a 2004 Honda SUV by first recording mileage over a 100 mile course at 60 mph with a fresh change of Mobil 1 SuperSyn 5W-20 and then adding 0.6 percent of master batch to the engine only. The results are shown in Table 11A below and show a 14 percent average increase in mileage.

TABLE 11A

Vehicle	Baseline mileage (MPG)	Mileage with additive (MPG)	Reduction (%)
1996 Saturn	37.0	44.2	16
2003 Honda Hybrid	64.5	72.6	11
2004 Honda SUV	22.1	26.3	16

Experiment 12

[0198] Shell ATF lubricating material was tested neat and with a concentration of 0.75 percent by weight of the master batch material from Experiment 11. The results are presented in Table 12.

TABLE 12

	Friction coefficient	Wear scar (mm)	Wear rate mm³/Nm
Control (neat ATF)	0.079	0.7	3×10^{-9}
Test sample	0.071	0.6	1×10^{-9}

Experiment 13

[0199] The thirteenth experiment shows a lubricant that reduces the frictional torque required to drill an oil well. A driller's mud is employed to float the cuttings to the surface via the annulus created by the casing and the pipe which is used to drive the drill bit. The driller's mud is pumped down the inner pipe and returns to the surface through the annulus between the pipe and the casing. The cuttings are removed and the mud is reused. Friction is generated by the mud rubbing against the casing and pipe surfaces, by the pipe rubbing against the casing, and the drill bit cutting the earth's crust. The speed of drilling and the depth that can be drilled is dependent upon these frictional sources. Water is used to form the mud slurry during the early stages of drilling and oil is used in the final stages to reduce the frictional forces. It is

expedient to use water because of environmental considerations and because it is cheaper. The thirteenth experiment is directed toward providing a lubricant which would benefit both, but may eliminate oil slurry altogether. A master batch of MMC was produced by mixing a primary highly polar material with a highly polar secondary material. The additive produced was added to the water based slurry at a concentration of approximately 0.5%. An additional test was run using the MMC plus 0.5% graphite. The coefficients of friction and the wear rates were recorded against the performance of the neat mud alone. The results are tabulated in Table 13 below.

TABLE 13

	Friction Coef N/N	Wear Scar mm	Wear Rate mm³/Nm
Control	0.290	3.0	1×10^{-4}
0.5% MMC	0.0866	0.8	5×10^{-9}
0.5% MMC + 0.5% graphite	0.0633	0.7	1×10^{-9}

[0200] The coefficient of friction was reduced by 10 percent and the wear rate by 200 percent.

[0201] When two surfaces rub together, progressive loss of material from the surfaces may occur. This loss of material, or wear, is accelerated by elevated temperatures and pressures such as those found in internal combustion machines, hypoid gears, transmissions, industrial machines, propulsion engines, wheel bearings, gears, turbines, cutting instruments, and other similar devices. Traditional lubricants operate by several methods. One method involves separation of moving parts by a film of viscous liquid. Under extreme operating conditions extreme pressure (EP) agents are utilized. Our unique approach is to dissolve small amounts of an electrophilic, highly polar material and a matched nucleophilic secondary highly polar material into a base oil. Under catalytic action of surface interference energy, conjugate acid-base pairs are formed which have affinity for metallic surfaces. As a consequence the matched molecules are pulled into the boundary layer and form a coherent, cohesive, non-corrosive, boundary layer between working surfaces which significantly reduces friction and wear. The concept of living-lubrication is also explained.

[0202] Using a wear tester similar to the Rolls Royce device in general use by the Air Force and other agencies, friction and wear data was catalogued for formulations of commercially available premium lubricants. The tests were performed using a wet sump in the boundary lubrication regime. The results are summarized in Table 13 in the following section.

[0203] Torque, coefficient of friction, load, and fluid temperature were determined by an independent laboratory via ASTM D 2670, the Pin and Vee Block test. The baseline test material was British Petroleum Nitrex 5W30 engine oil. The formula entitled Performance contained primarily BP Nitrex 5W30 oil with approximately 1% of MMC additive content.

[0204] In order to obtain real-world data involving highway fuel efficiency and emissions, our group conducted a series of road tests involving a variety of passenger cars and light trucks prior to conducting chassis dynamometer testing. The same driver, route, speed, and conditions were kept constant, Shell brand fuel and engine oil were used throughout.

[0205] The dynamometer testing was performed by an independent laboratory. All vehicles tested were conditioned

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at 65° F. for 24 hours. All tire pressures and fluid levels were optimized and new oil and oil filters were installed. First baseline tests were performed in order to determine a) resistance, i.e., parasitic loss, b) horsepower, c) torque, and d) fuel economy. All motor and transmission oils utilized were manufacturer specified. Shell fuel was utilized for all vehicles throughout the test. The vehicles were provided by an independent laboratory. All service work and road tests were performed by independent laboratory personnel. The duration of the test was 90-100 miles on a computerized road course. The test apparatus was a Dynojet 248H Chassis Dynamometer. At the end of the test, oil temperature and all other data was collected. The oil and filter were changed and the MMC material was installed. All vehicles were driven for 300 road miles then subjected to the performance test.

[0206] The MMC material was added to the oil reservoirs of industrial air compressors in order to examine its effect on amperage consumption.

Results and Discussion

[0207] Our novel approach to the problems associated with traditional lubrication strategies is to: lubricate employing non-corrosive matched molecular chemistry, increase traction via photon exchange, create "living" nano-bearings to maximize the lubricating fluid thickness and reduce lateral creepage, and maximize working surface separation via electrostatic repulsion.

[0208] The work energy theorem states that:

$$W = \Delta KE \tag{3}$$

where
W=work
KE=kinetic energy

$$\text{And } W = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2 + \tfrac{1}{2}I\omega^2 \tfrac{1}{2}I\omega_o^2 - \text{nonconservative forces} \tag{4}$$

where
I=moment of inertia
m=mass
v=velocity
ω=angular velocity

[0209] The non-conservative forces involve energy loss due to any one or combination of the following mechanisms:

[0210] 1. asperity collision

[0211] 2. asperity bonding and debonding

[0212] 3. coulombic friction

[0213] The causative mechanisms of nonconservative force may be subdivided into 4 types:

[0214] 1. longitudinal creepage

[0215] 2. lateral creepage

[0216] 3. spin creepage

[0217] 4. a conformity term

[0218] Wear is associated with slip of the working surfaces relative to one another. It is generally accepted that:

$$St = w\tau - v\{du_\tau/dx_i + du_\tau/dt\} \tag{5}$$

where
St=local slip
τ=x,y
i=x,y,z
uτ=$u_{1\tau} - u_{2\tau}$
u=displacement

[0219] Coulombs Law states

$$[p_\tau] \leqq g \tag{6}$$

where
g=traction bound
pτ=tangential traction exerted on body 1
g=1 μN
μ=coefficient of friction
N=normal force

[0220] Longitudinal creepage is given by the following formula:

$$\Xi = \{h_{1x} - h_{2x} - (r_{1x}\omega_{iy} + r_{2x}\omega_{2y})\}/v \tag{7}$$

where
v=rolling velocity
$h_{1x} - h_{2x}$=sliding of upper body 1 over lower body 2
$r_{ax}\omega_{ay}$=velocity of a body due to rotation ω_{ay} about the y axis with radius r_{ax}

[0221] It is true that

$$v = \omega_1/\omega_2/\phi \tag{8}$$

where φ=spin
and

$$v = Gc^3C_{23}/\psi\mu F_2 \tag{9}$$

therefore

$$\Xi = \{h_{1x} - h_{2x} - (r_{1x}\omega_{iy} + r_{2x}\omega_{2y})\}/Gc^3C_{23}/\psi\mu F_2 \tag{10}$$

and as the coefficient of friction decreases, longitudinal creepage will decrease also.

[0222] Lateral creepage is described in the following formula:

$$\zeta = \{h_{1y} - h_{2y} + (\omega_{1x}/\omega_{1y} - \omega_{2x}/\omega_{2y})V\}/v \tag{1}$$

[0223] Substituting the derived expression for rolling velocity, the equation becomes:

$$\zeta = \{h_{1y} - h_{2y} + (\omega_{1x}/\omega_{1y} - \omega_{2x}/\omega_{2y})\omega_1/\omega_2)(\psi\mu F_2/Gc^3C_{23}) \}/(\psi\mu F_2/Gc^3C_{23}) \tag{12}$$

[0224] where

$h_{1y} - h_{2y}$ is the lateral sliding of body 1 over 2

ω_{ax}/ω_{ay} is the angle between the axis of rotation and lateral direction, y

[0225] Differentiation of this equation with respect to the coefficient of friction shows that the lateral creepage is minimized at large values of μ

[0226] Spin creepage, φ, has been described by the following equation:

$$\phi = (\omega_{1z} - \omega_{2z})/v \tag{13}$$

[0227] Which may be rearranged to:

$$\phi = (\omega_{2z} - \omega_{1z})(Gc^3C_{23}/\psi\mu F_2) \tag{14}$$

[0228] Differentiation shows that spin creepage decreases with increasing μ.

[0229] Laboratory tests have been conducted on premium industrial lubricants and are presented in Table 14. These tests were run in boundary friction at loads below the accelerated wear rates that precede catastrophic failure. Using a concentration of 2 percent additive reduces wear by an order of magnitude at a friction coefficient that is 30 percent less.

TABLE 14

Concentration	Friction Coef	Wear Rate - mm³/NM
Industrial Gear Oil		
Zero	.11	8.5×10^{-9}
1%	.08	1.1×10^{-9}
2%	.074	7.0×10^{-10}
3%	.063	5.0×10^{-10}
Hydraulic Oil		
Zero	.11	8.5×10^{-9}
1%	.09	5.0×10^{-9}
2%	.072	2.0×10^{-9}
3%	.065	9.0×10^{-10}

[0230] FIG. 1 shows a plot of the concentration of the present invention versus the friction coefficient of a typical gear oil. As can be seen in FIG. 1, as the concentration of the invention increases the coefficient of friction decreases. FIG. 2 shows a plot of the concentration of the present invention versus the friction coefficient of a typical hydraulic oil. As can be seen in FIG. 2, as the concentration of the invention increases the coefficient of friction decreases.

[0231] It appears that the present invention has succeeded in reducing longitudinal creepage. At boundary lubrication, the extreme pressures and temperatures increase the polarity of certain populations, at least in the system presently under study, which facilitates proton and photon transfer between lubricating layers and working surfaces. This leads to electrostatic attraction (as well as repulsion) amongst working surfaces and lubricating layers (FIG. 3).

[0232] The alternating electric field vectors envisioned in FIG. 3 would enhance traction yet maintain a lubricating layer, simultaneously increasing Horsepower and minimizing wear. Although yet to be experimentally proven, another conceivable benefit of such a structure is that suitably small free metal asperities may fit into the middle layer and act as electropositive gears in the nano-bearing instead of participating in 3-body erosion. FIG. 3 shows the molecular chemistry between two metallic layers 10. The layers 12, 14 attached to the metallic layers 10 are repulsing each other because both carry a negative charge. When the molecules become polarized, they will fall out of viscosity and bond to the metallic surfaces 10. The middle layer 16 has a positive charge to enable layers 12, 14 to bond to layer 16.

[0233] One may also envision the minimization of lateral slip via the inclusion of "tie-in molecules", i.e., molecules possessing the matched molecular chemistry protocol whose one polar terminus is part of one molecular bearing while the other terminus is part of another (FIG. 4).

[0234] In FIG. 4, the charged species spinning in the designated directions would create magnetic fields with alternating poles, generating another cohesive mechanism between neighboring metallic/molecular and molecular/molecular layers.

[0235] One outcome of the electrostatic attraction scenario between additive(s) and working surfaces is an increase in the traction coefficient, C_t. The coefficient of traction is given by the following formula:

$$C_t = f_t/N \qquad (15)$$

where:
f_t=tangential force
N=normal force

[0236] The dynamic frictional force between two bodies is given by:

$$f_k = \mu_k N \qquad (16)$$

where:
f_k=dynamic frictional force
μ_k=dynamic coefficient of friction
Solving both equations for the normal force, one obtains:

$$f_k/\mu_k = f_t/C_t \qquad (17)$$

[0237] Therefore as f_t increases, μ_k must decrease because one observes an overall decrease in f_k. A benefit from the electrostatic repulsive condition depicted in Scheme 1 is decreased wear. By judiciously selecting the correct functionality and molar ratios, one can achieve the best of both worlds, i.e., increased C_t and decreased μ without the use of corrosive chemistry. A lubricant should be able to wet out working surfaces. As the lubricant is placed in a position to be hydrodynamically removed from the boundary layer, properly selected oils will spread out over the working surfaces and provide protection. The data plotted in FIG. 5 was generated during the wet sump experiments.

[0238] Momentarily disregarding nonconservative forces and assuming constant linear velocity:

$$F_t = \mu_k N \qquad (18)$$

[0239] Where Ft=tractional force
If the slip, s≠0 then

$$Ft = -\mu_k N/|s| \qquad (19)$$

[0240] Therefore as the magnitude of s increases, the magnitude of Ft will decrease, however this prediction is reversed with an over compensating reduction in μ_k.

And

[0241]

$$dFt/ds = -\mu N ln|s| \qquad (20)$$

[0242] Experiments show a linear relationship amongst load, τ, and coefficient of friction for the baseline lubricant. The same relationships for the performance material are a natural log function amongst load, torque, and coefficient of friction, suggesting a minimization of slip which appears validates our theory of this particular lubrication mechanism.

[0243] Utilizing a normal force of 11.9N, oil without the MMC additive demonstrated a frictional force of 4.27 N. Under the exact test conditions, the same base oil with MMC additive exhibited a frictional force of 3.14 N. Calculation of the coefficients of friction for the performance and baseline oils yielded coefficients of friction of 0.264 and 0.359, respectively. The change in Ft for the above data is 1.12 N

[0244] These results indicate that the matched molecular additive has reduced the coefficient of friction, or increased the electrostatic contribution to the traction coefficient thus minimizing force transfer via asperity contact, or some combination of both.

[0245] The force of attraction between metallic surfaces and selective lubricant may be calculated by Coulombs Law.

$$= \delta q_1 q_2/r^2 \qquad (21)$$

where F is force
q is charge, 1.60×10^{-19} amp s
r is the distance separating the poles

[0246] If one assumes that the lubricant additive is the dominant specie present (electrostatic attractions predomi-

nating), and it acquires a polar, thermodynamically favored cyclohexagonal configuration during moments of intense pressure and temperature, i.e., during boundary lubrication, the thickness of the boundary layer should be an integral of approximately 5.33×10^{-10} m.

[0247] When one gear drives another, or when a roller turns another, there is angular motion created, which of course has centripetal acceleration, therefore there must be a force transfer between, for example, two rolls.

[0248] When equilibrium conditions are achieved utilizing MMC technology, assume that angular momentum is very nearly conserved.

[0249] The angular momentum of each layer involved in the boundary layer is:

$$L = pr = \sqrt{me^2 r / 4\pi\epsilon_0} \quad (22)$$

[0250] Utilizing Bohr's approach

$$L = nh/2\pi, \ n = 1, 2, 3, \quad (23)$$

[0251] Combining the above two equations one may write:

$$r = n^2 h^2 \epsilon_0 / \pi m e^2 \quad (24)$$

[0252] The total energy of the system is given by:

$$E = -e^2 / 8\pi\epsilon_0 r \quad (25)$$

[0253] And may also be described by:

$$E = -me^4 / 8\epsilon_0^2 h^2 n^2 \quad (26)$$

[0254] Utilizing Newton's second law:

$$F = ma \quad (27)$$

or

$$e^2 / 4\pi\epsilon r^2 = mv^2 / r \quad (28)$$

[0255] This force becomes torque and is given by the following equation:

$$\tau = Ft \times 1 \quad (29)$$

where
τ=torque
1=moment arm=r

$$F = e^2 / 4\pi\epsilon r^2 \quad (30)$$

or

$$\tau = e^2 / 4\pi\epsilon r \quad (31)$$

[0256] At very low rates of wear, i.e.; near equilibrium conditions, the MMC material exhibited a wear scar of 0.70 mm. Calculating r when n is equal to 6 utilizing Equation (24) one obtains a value of 1.91×10^{-9} m. Dividing by the mean diameter of our matched molecular structures, one obtains a value close to 3, which is consistent with the prediction of the formation of six-membered, polar, matched molecular chemical species forming Buckeyball type structures (which will be referred to as matched molecular components or molecular bearings or nano-bearings, hereafter) consisting of quasi-oligo or polymeric complexes of three to six, six-membered heterocyclic and possibly acyclic components working in conjunction. Three molecular (or multiples thereof) diameters (cyclic case), or multiples of three mean radii of gyration (acyclic case) comprise two dimensions of the lubricating component, and the third dimension completes the group transfer or "living" matched molecular polymeric structure forming immediately before and possibly existing after boundary lubrication. This is a dynamic process; initially,

upon establishment of boundary lubrication, the components form complete matched molecular "bearings" within the zone of boundary lubrication, and before exiting boundary lubrication, pass on their matched molecular chemistry to other matched molecular components just entering the zone (this may be considered a quasi-static polymerization process). FIG. 7 is a three dimensional representation of FIG. 6 and depicts the 3-dimensional, "living" component of the lubricant composition. Only one bottom layer in the z-direction is shown. The z-direction is the working direction, x marks the boundary direction, and y is lateral creepage. By "living" it is meant that the reactive ends are maintained. This process is akin to the method of macromolecular construction known as living polymerization, i.e., the process continues indefinitely until terminated by some other reactive functionality (FIG. 8).

[0257] In FIG. 8 the trimethylsilyl group is transferred, although in some embodiments of this invention, this group may possess many identities. FIG. 9 represents a side view of a boundary layer utilizing MMC technology. "G" represents the transfer group, "A" and "B" polarized functional groups.

[0258] In the present invention the structures are "living nano-bearings" or "living lubricants." The three layer (or multiple thereof) mechanism is also consistent with the molar ratios of the components of our living nano-bearing formulas. It appears that, by judicious selection of components, traction is maintained, spin and lateral creepage are eliminated (or at least nearly so) and longitudinal creep is minimized.

[0259] The first series of tests of real-world machines were conducted on ten automobiles in over-the-road tests of different model years and mileage using a concentration of 1.5 percent of additive material in the engine and transmission. No other change was made in the test configuration during the tests. In these tests the emissions were tested before and after the test run. The results are presented in FIG. 10 and Table 15. There was an average improvement of 20 percent in mileage. The effect on emissions was favorable with most of the vehicles studied showing a decrease in hydrocarbon (HC), carbon monoxide (CO), and carbon dioxide (CO_2) emissions.

TABLE 15

Vehicle	Odometer	MPG Gain %	HC B/A	CO B/A	CO2 B/A
91 Ply	111,437	17	84/21	.46/.18	14.14/14.78
96 Escort	37,492	14.3	3.4/3.4	00/.03	26.9/14.7
89 Dodge PU	129,293	15	84.9/65.4	1.41/1.79	12.32/12.08
93 Merc Van	101,692	12	2.2/5.1	0/0	15.21/14.98
92 Ford 150	19,195	16	26.4/0	37/0	9.59/11.28
00 Chev PU	5,315	8	11.1/3.6	.01/0	15.12/14.9
95 Ford Van	72,655	14	11.9/1.5	.01/.12	15.49/14.7
97 Linc Nav	75,844	19	2.8/.5	.01/0	15.04/15.1
85 Merc Marq	138,654	21	231/178	3.41/1.04	12.67/27.2
04 Hon Instep	12,472	20	N/R	N/R	N/R

[0260] Tests were run on interurban buses driven on the streets of Cleveland over a period of several months. These vehicles had a gross weight of 20,000 lbs and were powered by GMAC gasoline engines. Engines, transmissions, differentials and steering components were treated in these tests, which were run over 20,000 miles. The results are given in Table 16 and FIG. 12 and show an average mileage improvement of 12.5 percent.

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TABLE 16

Vehicle	Odometer	Test Miles	Before MPG	After MPG	% Gain
Unit 825	253,800	20,800	4.95	5.45	10.1
Unit 826	252,200	23,400	5.10	5.71	11.76
Unit 827	202,100	20,700	5.75	6.65	15.65

[0261] The engines, transmissions and differentials of three 18 wheel tractor-trailer rigs were treated with 1.5 percent MMC additive and driven over 25,000 miles. The recorded mileage improved by an average of 22 percent. The results are shown in Table 17.

TABLE 17

Vehicle	Odometer	Idle Hours	Test Miles	Prior MPG	Treated MPG	% Gain
584	230,934	2,528	31,078	6.818	8.806	29.16
485	263,078	2,005	35,918	7.26	8.901	22.6
606	211,112	1,651	27,736	7.322	8.804	14.82

[0262] Chassis dynamometer tests were run on five automobiles running at a speed of 70 MPH. A concentration of 1.5 percent of additive was used in each test in the engines and transmissions. The power results are shown in Table 18. The power was increased by an average of 4½ percent and, when data was available, the fuel mileage by 21 percent.

TABLE 18

Vehicle	Baseline H/P	Test HP	Baseline MPG	MPG (200 Mi)	MPG (600 Mi)
99 Cad	188.4	194.9	32	35.7	42.2
80 VW(D)	103.9	112.7	41	N/R	51.4
00 Neon	84.7	89.5	33.6	38.8	N/R
95 Honda	79.9	84.0	36.6	39.7	N/R
95 Porsche	172	185.2	N/R	N/R	N/R

[0263] Five industrial air compressors were tested using 1.5 percent concentration of additive, representing sliding vane, reciprocating and rotary screw designs. The results are shown in Table 19 and FIG. 14. The average improvement was 16.7 percent. The LeRoi unit had just been overhauled by non-factory maintenance and is subject to doubt as to its true representation.

TABLE 19

Unit	Amps Before	Amps After	% Power Reduction
Sullair 35	32.7	26.3	19.6
Gr-Schm 75	72.0	60.0	16.67
LeRoi 100	115.0	108.0	5.98
Davy 40	52.7	42.2	19.92
Quincy 75	102.0	80.1	21.47

[0264] The results show that significant improvements can be made beyond the few percentage points predicted by the lubrication industry. These tests were run on the ultimate testing machine, real-world equipment in the field.

[0265] While all of the test data was obtained using automotive equipment, save the industrial air compressors, the same technology is applicable to industrial equipment as well. Virtually every piece of mechanical equipment in industry can benefit by the application of this technology. As an example the same type additive material was added to the lubrication system of a 5000 horsepower gearbox with a gear ratio of 5 to 1. The power required to drive this gearbox was reduced by 5 percent, which represents a savings of $167,000 per year, not to mention the improvement in the life of the machine.

[0266] Turbine gears have been known to run constantly for 25 years without completely erasing the initial surface finishing marks. These gears have ultra smooth teeth running at high pitch line speeds of 200 meters per second, have a high viscous film thickness and low sliding contact. This corresponds to a wear rate of about 4.9×10^{-13} mm/Nm. Even under these ideal conditions, there is wear. This is a far cry from the usual gear set running at 25 to 50 meters per second under less than ideal conditions.

[0267] Greases are subject to the same mechanics as are fluid lubricants. They are largely composed of industrial oils in combination with metallic soaps to hold them in place. They too are subject to boundary lubrication and exhibit high rates of wear and friction. By the addition of similar additive chemistry, the wear and friction can be reduced to a manageable level. As shown in FIGS. 15 and 16, by the addition of 3 percent of additive, to premium grease, the point of failure can be postponed and the wear rate can be reduced by orders of magnitude, lowering friction accordingly.

[0268] Gear sets lubricated with grease such as spindle designs, are particularly subject to more extreme incidents of wear, i.e. scuffing and accelerated rates of adhesion and abrasion. In these applications, in addition to using effective anti-scuffing chemistry, as low an NLGI number as is feasible can be used to provide as much recovery of grease on the denuded surfaces as possible without having the grease leak out the seals. In these applications a film of grease must be in place ahead of the point of contact if catastrophic failure rates of wear are to be avoided.

[0269] Laboratory tests of a premium grease versus a test of a similar grease containing chemistry designed to reduce wear is presented in Table 20. The friction is cut in half and the wear is reduced by orders of magnitude.

TABLE 20

	Normal Force Lbs	Tangential Force Lbs	Friction Coef Lbs/Lbs
Premium Grease	0	0	0
	24	4	.167
	48	7	.146
	72	10	.139
	96	13	.135
	120	18	.150
	144	24	.167
Premium Grease + L-5000	0	0	0
	24	2	.0833
	48	4	.0833
	72	5	.0694
	96	7	.0729
	120	9	.0750
	144	10	.0694
	168	11	.0655

Premium Grease Wear Scar - 1.8 mm
Wear Rate - 1×10^{-7} mm³/Nm
MMC Grease Wear Scar - .65 mm
Wear Rate - 3×10^{-9} mm³/Nm

[0270] These results demonstrate that it is possible to facilitate oil, grease, and hydraulic fluid lubrication employing halogen, phosphorous, and heavy-metal free non-corrosive

matched molecular chemistry, increase traction via photon exchange, create nano-bearings to maximize the lubricating fluid thickness and reduce lateral creepage, and maximize working surface separation via electrostatic repulsion.

[0271] In light of the foregoing, it should thus be evident that the process of the present invention, providing a working fluid additive, substantially improves the art. Although several embodiments of the present invention have been described in detail hereinabove, the present invention is not to be limited thereto or thereby. Rather, the scope of the invention shall include all modifications and variations that fall within the scope of the attached claims.

[0272] Other than in the operating examples, or where otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0273] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

[0274] Having thus described the invention, it is now claimed:

We claim:

1. A lubricant additive comprising:
at least a first polar material; and,
at least a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

2. The lubricant additive of claim 1, wherein the ratio of the first polar material to the second polar material is from about 5:1 to about 1:5 by weight.

3. The lubricant additive of claim 2, wherein the first polar material is a highly polar material.

4. The lubricant additive of claim 3, wherein the second polar material is a highly polar material.

5. The lubricant additive of claim 4, wherein one of the polar materials is an organic acid.

6. The lubricant additive of claim 5, wherein the first polar material is an ester and the second polar material is a dimer acid.

7. The lubricant additive of claim 2, wherein the ratio of the first polar material to the second polar material is from about 4:3 to about 3:4 by weight.

8. The lubricant additive of claim 1, wherein the combination of polar materials increases a boundary layer without increasing the viscosity of an associated oil or working fluid.

9. The lubricant additive of claim 4, wherein the lubricant further comprises:
approximately 0.1 to 99 percent by weight of an organometallic compound;

approximately 0 to 95% by weight of at least one enhancing accelerators; and,
approximately 0 to 95% by weight of at least one dispersion agent.

10. The lubricant additive of claim 9, wherein
the highly polar material is chosen from the group comprising: fatty esters, halogenated fatty esters, carboxylic acids, halogenated carboxylic acids, alcohols, amines, amides, anhydrides, lactams, lactones, phenols, urethanes polyurethanes, carbamates, sulfonamides, sulfones, sulfoxides, polysulfones, thiazoles, oxazoles, polyesters, polyacrylates, polymethacrylates, polycarbonates, mono and poly functional carboxylic acids, polyhydroxylated aliphatic and unsaturated compounds, mono and polyhydroxylated esters, mono and polyhydroxylated ketones, mono and polyhydroxylated baldheads, sulfonic acids, polymerized carboxylic acids, aromatic carboxylic acids, alkyl and alkenyl carboxylic acids, alkyl and alkenyl dicarboxylic acids, fatty acids, unsaturated carboxylic acids, dimer, trimer, and oligomeric carboxylic acids and mixtures thereof;
the organometallic compound is chosen from the group comprising: organomolybdenum carboxylates, organomolybdenum dithiocarbamate, organomolybdenum xanthate, molybdic acid, molybdenum ditridecyldithiocarbamate, sulfurized organomolybdenum carboxylates, sulfurized organomolybdenum dithiocarbamate, sulfurized organomolybdenum xanthate, sulfurized molybdic acid, sulfurized molybdenum ditridecyldithiocarbamate, boric acid, boric acid monoethanolamine esters, boron nitride powders, and amidized boron complexes, and mixtures thereof;
the enhancing accelerator is a carbodiimide; and,
the dispersion agent is chosen from the group comprising: polyamides, thiadiazoles, polyisobutenylsuccinimide, esters, diesters, polyol esters, polyols, ethoxy-propoxyethanol, ethoxy-propoxy-propanol, 22-(2-aminoethoxy)-ethanol, and oleyl/cetyl alcohols.

11. The lubricant additive of claim 10, wherein the additive further comprises at least one of the following: anti-wear/extreme pressure additive, antioxidant, metal deactivator, detergent, corrosion inhibitor, defoamer, and dye.

12. The lubricant additive of claim 11, wherein the additive further comprises:
an anti-wear/extreme pressure additive;
an antioxidant;
a metal deactivators;
a detergent;
a corrosion inhibitors;
a defoamer; and,
a dye.

13. The lubricant additive of claim 4, wherein the first highly polar material comprises:
at least one hydrophilic functional group; and,
at least one hydrophobic structure.

14. The lubricant additive of claim 13, wherein the first highly polar material is chosen from the group comprising: aliphatic esters, aliphatic di, tri, tetra, and polyesters, methyl palmitate, hydroxy substituted esters, dimer acid, trimer acid, valeric acid, isopentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, isooctanoic acid, 2-ethylhexanoic acid, pelargonic acid, isononanoic acid, decanoic acid, stearic acid, trimellitic acid, isostearic acid, lauric acid, myristic acid, palmitic acid, oxalic acid, malonic acid, maleic acid, fumeric

acid, succinic acid, adipic acid, glutaric acid, oleic acid, hydrogenated dimer acid, salicyclic acid, acetosalicylic acid, toluic acid, cyclohexanecarboxylic acid, alkyl malonic acids, alkenyl malonic acids, cyclopentane carboxylic acid, cyclo-heptanoic acid, cyclopentenoic acid, cyclohexenoic acid, cycloheptenoic acid, formic acid, acetic acid, propionic acid, butyric acid, valeric acid, caproic acid, enanthic acid, caprylic acid, capric acid, glutaric acid, pimelic acid, benzoic acid, ortho-phthalic acid, meta-phthalic acid, para-phthalic acid, pyromellitic acid, ethylmalonic acid, methylmalonic acid, fatty acids such as coconut oil, soybean oil, cottonseed oil, rapeseed oil, linseed oil, castor oil, sunflower seed oil, olive oil, neat's foot oil, peanut oil, herring oil, cod liver oil, shark liver oil, whale oil, tallow fat, lard, dioleic dioic acid, dili-noleic dioic acid, didodecadiendioic acid, dicyclopentadiene dioic acid, the mixed dimer of oleic and linoleic acids, and combinations of these mixed dimer acids.

15. The lubricant additive of claim **1**, wherein the lubricant consists essentially of:

a first polar material; and,

a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

16. A method for improving lubrication, the method comprising the steps of:

increasing a boundary layer without increasing the viscosity, the increase being accomplished by adding a composition to oil or a working fluid, the composition comprising:

at least a first polar material; and,

at least a second, synergistic polar material, wherein the ratio of the first polar material to the second polar material is from about 10:1 to about 1:10 by weight.

17. The method of claim **16**, wherein the ratio of the first polar material to the second polar material is from about 5:1 to about 1:5 by weight.

18. The method of claim **17**, wherein the first polar material is a highly polar material.

19. The method of claim **18**, wherein the second polar material is a highly polar material.

20. The method of claim **19**, wherein one of the polar materials is an organic acid.

21. The method of claim **20**, wherein the first polar material is an ester and the second polar material is a dimer acid.

22. The method of claim **17**, wherein the ratio of the first polar material to the second polar material is from about 4:3 to about 3:4 by weight.

23. The method of claim **22**, wherein the composition is added at about 0.5% by weight to the oil or working fluid.

24. A lubricant compound comprising:

approximately 95% to approximately 99.9% by weight working fluid; and,

approximately 0.1% to approximately 5% by weight of an additive, the additive comprising:

approximately 1% to 100% by weight of a highly polar material;

approximately 0.4% to approximately 95% by weight of a second, synergistic highly polar material; and,

approximately 0.02% to approximately 20% by weight organometallic material.

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