

lubricant compositions usually do not fulfill the requirements for such wear performance or scuffing resistance according to the Caterpillar TO-4 specification because the additive mixtures tend to fail one or more of the wear, friction, and/or scuffing tests. For instance, use of dispersants and/or molybdenum-containing friction modifiers is typically avoided in lubricants destined for off-road driveline or transmission applications since such additives may, for instance, lower the static friction to a level that no longer qualifies under the Caterpillar TO-4 specification. In other instances, heavy duty lubricants having adequate levels of metal, such as zinc and calcium for example, from an antiwear additive and/or detergent may show strong low speed gear wear performance, but then provide less than desirable load stage scuffing resistance.

SUMMARY

[0005] In one approach or example, an off-road lubricant composition, such as a TO-4 lubricant, is described herein and includes one or more base oils of lubricating viscosity; about 200 ppm to about 2,000 ppm of zinc provided by one or more zinc dialkyl dithiophosphate compounds; one or more metal-containing detergents providing about 1,000 to about 5,000 ppm of metal selected from calcium, magnesium and/or sodium and provided from one or more C6 to C30 branched metal salts of phenates, sulfonates, calixarates, salixarates, salicylates, carboxylic acids, or combinations thereof; no more than about 300 ppm of nitrogen provided from one or more nitrogen-containing ashless dispersants; and about 0.01 to about 3.5 weight percent of a low molecular weight diol or triol compound, such as a C2 to C3 diol or triol compound or mixture thereof.

[0006] In other approaches or examples, the off-road lubricant composition described in the previous paragraph may including optional features or examples in any combination. These optional features or examples may include one or more of the following: wherein the C2 to C3 diol or triol compound is trihydroxypropane, wherein the C2 to C3 diol or triol compound, and preferably the trihydroxypropane, is a non-esterified compound; and/or wherein the off-road lubricant composition is substantially free of glycerol monooleate (GMO); and/or wherein the off-road lubricant composition includes about 0.01 to about 2 weight percent of the C2 to C3 diol or triol compound or mixture thereof and, preferably 0.01 to about 2 weight percent of trihydroxypropane; and/or wherein the one or more metal containing detergents include an overbased metal salt of an branched polyolefin substituted phenate, sulfonate, and/or

salicylate detergent; and/or wherein the branched polyolefin is derived from a branched alkene having at least 3, carbon atoms or at least 4 carbon atoms and wherein the branched polyolefin has a number average molecular weight of about 100 to about 800; and/or wherein the branched polyolefin is derived from an isomerized normal alpha olefin having about 6 to about 30 carbons and an isomerization level of about 0.1 to about 0.4; and/or wherein the overbased metal salt of a branched polyolefin substituted phenate, sulfonate, and/or salicylate detergent has a total base number (TBN) of at least about 250 mg KOH/g on an oil-free basis as measured pursuant to ASTM D2896; and/or wherein the one or more overbased detergents is a branched calcium sulfonate; and/or wherein the off-road lubricant composition satisfies the requirements of Caterpillar TO-4 lubricants including at least low speed wear and scuffing tests with no more than 100 mg of wear, preferably no more than 50 mg of wear as measured pursuant to ASTM D4998 and a passing load stage of 9 or higher, 10 or higher, 11 or higher, or 12 pursuant to CEC L-07 (FZG A/8.3/90); and/or wherein the nitrogen-containing ashless dispersant is a succinimide dispersant.

[0006a] In one aspect, the disclosure provides a lubricant composition comprising: one or more base oils of lubricating viscosity; 200 ppm to 2,000 ppm of zinc provided by a zinc dialkyl dithiophosphate compound; one or more metal-containing detergents providing 1,000 to 5,000 ppm of metal selected from calcium, magnesium and/or sodium and provided from one or more C6 to C30 metal salts of phenates, sulfonates, calixarates, salixarates, salicylates, carboxylic acids, or combinations thereof, wherein the one or more metal containing detergents include an overbased metal salt of a branched polyolefin substituted phenate, sulfonate, and/or salicylate detergent; no more than 300 ppm of nitrogen provided from one or more nitrogen-containing ashless dispersants; and 0.01 to 3.5 weight percent of a C2 to C3 diol or triol compound or mixture thereof.

[0007] In other approaches or examples, the disclosure herein provides for a method of providing low speed wear and scuffing protection to gears, bearings, and/or clutches according to Caterpillar TO-4 requirements as measured pursuant to ASTM D4998 and CEC L-07 (FZG A/8.3/90). In some examples, the method includes lubricating the gears, bearings, and/or clutches with a lubricating composition and wherein the lubricating composition includes one or more base oils of lubricating viscosity; about 200 ppm to about 2,000 ppm of zinc provided by a zinc dialkyl dithiophosphate compound; one or more metal-containing detergents providing about 1,000 to about 5,000 ppm of metal selected from calcium, magnesium and/or sodium and provided from one or more C6 to C30 branched metal salts of phenates, sulfonates, calixarates, salixarates, salicylates, carboxylic acids, or combinations thereof; no more than about 300 ppm of nitrogen provided from one or more nitrogen-containing ashless dispersants; and about 0.01 to about 3.5 weight percent of a low molecular weight diol or triol compound and preferably a C2 to C3 diol or triol compound or mixture thereof.

[0007a] In one aspect, the disclosure provides a method for providing low speed wear and scuffing protection to gears, bearings, and/or clutches according to Caterpillar TO-4 requirements as measured pursuant to ASTM D4998 and CEC L-07 (FZG A/8.3/90), the method comprising: lubricating the gears, bearings, and/or clutches with a lubricating composition as disclosed herein.

[0008] In other approaches or examples, the method described in the previous paragraph may be combined with optional features, steps, and/or examples in any combination. These optional features, steps, or examples include one or more of the following: wherein the C2 to C3 diol or triol compound is trihydroxypropane; and/or wherein the C2 to C3 diol or triol

compound and preferably the trihydroxypropane is non-esterified; and/or wherein the lubricating composition includes about 0.01 to about 2 weight percent of the C2 to C3 diol or triol compound or mixture thereof; and/or wherein the C2 to C3 diol or triol compound is trihydroxypropane; and/or wherein the one or more metal containing detergents include an overbased metal salt of an branched polyolefin substituted phenate, sulfonate, and/or salicylate detergent; and/or wherein the branched polyolefin is derived from a branched alkene having at least 4 carbon atoms and wherein the branched polyolefin has a number average molecular weight of about 100 to about 800; and/or wherein the branched polyolefin is derived from an isomerized normal alpha olefin having about 4 to about 100 carbons and an isomerization level of about 0.1 to about 0.4; and/or wherein the overbased metal salt of a branched polyolefin substituted phenate, sulfonate, and/or salicylate detergent has a total base number (TBN) of at least about 250 mg KOH/g on an oil-free basis as measured pursuant to ASTM D2896; and/or wherein the one or more overbased detergents is a branched calcium sulfonate; and/or wherein the one or more one or more metal containing detergents includes one or more overbased metal-containing detergents having a total base number (TBN) of at least about 250 mg KOH/g on an oil-free basis as measured pursuant to ASTM D2896; and/or wherein the one or more overbased detergent is a branched calcium sulfonate; and/or wherein the lubricating composition exhibits no more than 100 mg of wear, preferably no more than 50 mg of wear as measured pursuant to ASTM D4998 and a passing load stage of 9 or higher, 10 or higher, 11 or higher, or 12 pursuant to CEC L-07 (FZG A/8.3/90); and/or wherein the nitrogen-containing ashless dispersant is a succinimide dispersant.

[0009] In one aspect, the disclosure provides a use of the lubricating composition as disclosed herein as an off-road lubricant composition and/or a heavy-duty lubricant composition. In yet other approaches or examples, the use of a lubricating composition of any example of this summary is described or disclosed herein for achieving no more than 100 mg of wear, preferably no more than 50 mg of wear, as measured pursuant to ASTM D4998 and a passing load stage of 9 or higher, 10 or higher, 11 or higher, or 12 as measured pursuant to CEC L-07 (FZG A/8.3/90).

[00010] Other examples of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

[00011] The terms “gear oil,” “gear fluid,” “gear lubricant,” “base gear lubricant,”

hydroxyl, alkoxy, halo substituents, and/or heteroatoms including, but not limited to, nitrogen, and oxygen.

[00016] As used herein, the molecular weight is determined by gel permeation chromatography (GPC) using commercially available polystyrene standards (with a M_n of about 180 to about 18,000 as the calibration reference). The molecular weight (M_n) for any example herein may be determined with a gel permeation chromatography (GPC) instrument obtained from Waters or the like instrument and the data processed with Waters Empower Software or the like software. The GPC instrument may be equipped with a Waters Separations Module and Waters Refractive Index detector (or the like optional equipment). The GPC operating conditions may include a guard column, 4 Agilent PLgel columns (length of 300×7.5 mm; particle size of 5 μ , and pore size ranging from 100-10000 Å) with the column temperature at about 40 °C. Unstabilized HPLC grade tetrahydrofuran (THF) may be used as solvent, at a flow rate of 1.0 mL/min. The GPC instrument may be calibrated with commercially available polystyrene (PS) standards having a narrow molecular weight distribution ranging from 500 – 380,000 g/mol. The calibration curve can be extrapolated for samples having a mass less than 500 g/mol. Samples and PS standards can be dissolved in THF and prepared at concentration of 0.1-0.5 weight percent and used without filtration. GPC measurements are also described in US 5,266,223, which is incorporated herein by reference. The GPC method additionally provides molecular weight distribution information; *see, for example*, W. W. Yau, J. J. Kirkland and D. D. Bly, “Modern Size Exclusion Liquid Chromatography”, John Wiley and Sons, New York, 1979, also incorporated herein by reference.

[00017] It is to be understood that throughout the present disclosure, the terms “comprises,” “includes,” “contains,” etc. are considered open-ended and include any element, step, or ingredient not explicitly listed. The phrase “consists essentially of” is meant to include any expressly listed element, step, or ingredient and any additional elements, steps, or ingredients that do not materially affect the basic and novel examples of the disclosure. The present disclosure also contemplates that any composition described using the terms, “comprises,” “includes,” “contains,” is also to be interpreted as including a disclosure of the same composition “consisting essentially of” or “consisting of” the specifically listed components thereof.