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(54) A lubricating oil composition for automatic transmissions

(57) The present invention relates to a lubricating oil composition comprising a major amount of base oil of lubricating viscosity and the following additives in the following amounts based on a total amount of the lubricating oil composition:
(A) 0.1 to 10 wt.% of a succinic acid ester,
(B) 0.01 to 2 wt.% of a phosphorous acid ester,
(C) 0.1 to 5 wt.% of an amide compound which is a reaction product obtained by reaction of a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine,
(D) 0.01 to 2 wt.% of an overbased metal-containing detergent, and
(E) 0.01 to 1 wt.% of a corrosion inhibitor.

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Description

[0001] The present invention relates to a lubricating oil composition. In particular, the invention relates to a lubricating oil composition for automatic transmissions of internal combustion engines, in which the lubricating oil composition shows a high torque transmission capacity and a prolonged shudder inhibition.

BACKGROUND OF THE INVENTION

[0002] Automatic transmissions in automobiles comprise a torque converter, a wet multi-plate clutch, a gear mechanism, and a mechanism controlling these elements. The torque transmission capacity is automatically set according to the speed of automobile and the degree of load. Modern automatic transmissions further comprise a lockup clutch mounted to the torque converter, so as to improve fuel economy. The use of the lockup clutch enables engine torque to be transmitted to the automatic transmission according to driving conditions in addition to the driving force transmitted through a lubricating oil. However, since the torque variation produced by the operation of the lockup clutch sometimes disturbs passengers due to shudder, the lockup clutch is generally set to operate only under high speed driving conditions giving less torque variation.

[0003] Under low speed driving conditions as when an automobile starts, loss of driving force transmission is caused between the engine output revolution and the transmission input revolution. Therefore, enough improvement of fuel economy is not attained. Accordingly, automatic transmissions adopt a slip control system by which the lockup mechanism can operate under the low speed driving conditions and the transmission loss can be reduced. However, when the clutch is subjected to control by the slip control system, abnormal vibration of the body of automobile (i.e., shudder) takes place on the friction surface of the lockup clutch. At low road speeds vehicle operation is rough and engine vibration is transmitted through the drive train. Rough operation and engine vibration are not acceptable to drivers. The lock-up system requires specific automatic transmission fluid characteristics in terms of anti-shudder durability to perform smoothly.

[0004] Shudder is known as a stick-slip phenomenon and is related to the frictional coefficient and velocity called μ-V characteristic. Shudder occurs when the sliding rate (V) in the lockup clutch increases and the coefficient of friction (μ) decreases. Thus, it is desirable to employ a lubricating oil (automatic transmission fluid) which shows a favorable μ-V character, i.e., the friction coefficient increases when the sliding rate increases, and keeps the favorable μ-V character for a prolonged period of time, i.e., prolonged shudder inhibition performance. Positive $d\mu/dV$ in the μ-V characteristics are required to prevent shudder.

[0005] JASO (Japanese Automobile Standard Organization) M349:2001 describes a standard oil T-III which shows standard shudder inhibition performance and torque transmission capacity. However, there is given no information with respect to the formulation of the T-III standard oil.

[0006] Prolonged shudder inhibition can be attained by incorporating a friction modifier (generally, friction decreasing agent). However, if too much friction modifier is incorporated into a lubricating oil, the friction coefficient of the wet clutch extremely decreases and hence enough torque transmission capacity cannot be obtained.

[0007] U.S. Patent No. 4,948,523 discloses a lubricating composition, preferably essentially free of zinc dihydrocarbyldithiophosphate compounds, and optionally free of chlorine containing silver lubricity agents, comprising a major proportion of an oil of lubricating viscosity and a minor amount of a silver protective agent comprising the reaction product of a C_5 to C_{60} carboxylic acid and at least one amine selected from the group consisting of (1) guanidine, urea, and thiourea compounds; (2) C_1 to C_{20} hydrocarbyl or hydroxy-substituted hydrocarbyl mono-amines, alkylene diamines, and (3) polyalkylene polyamines; and N-alkyl glycine.

[0008] U.S. Patent No. 5,395,539 discloses certain hydrocarbon soluble or dispersible amide reaction products (Component-1), and mixtures, and/or acid amine salts of Component-1 and certain acid/esters (Component-2), which are useful as friction modifying additives for oleaginous compositions such as lubricating oils, including power transmitting fluids, particularly automatic transmission fluids (ATF), and to the oleaginous compositions in which they are contained.

[0009] U.S. Patent No. 5,916,852 discloses lubricating fluids which include an additive combination comprising a compound having the general formula $R\text{-}NH_2$ with oil-soluble phosphorus compounds, an ashless dispersant, and, optionally, other amine containing friction modifiers provide lubricating fluids which exhibit excellent break-in characteristics that are capable of preventing "green shudder" in automatic transmissions.

[0010] U.S. Patent No. 6,303,547 discloses lubricant formulations containing the reaction product of at least one C_5 to C_{60} carboxylic acid and at least one amine selected from the group consisting of guanidine, aminoguanidine, urea, thiourea and salts thereof is useful as a gear oil additive. The lubricant formulations exhibit excellent low and high temperature rheology and are particularly suited for use in automotive and industrial gear applications. Lubricants of the present invention exhibit improved performance properties, such as increased axle efficiencies and lower axle temperatures, improved limited slip performance, reduced chatter, improved frictional durability and/or improved power divider performance compared to lubricant formulations that do not contain said reaction products.

[0011] Japanese Patent Publication No. 2001-247532 discloses fatty acid amide compounds used for surface lubricant, vehicle component and thermal recording materials, has three or more amide groups in a molecule having the formula $R_1CONH(CH_2)_m((NCOR_2)(CH_2)_n)_1NHCOR_3$, where R_1-R_3 is a C_{12} to C_{50} alkyl or alkenyl group, m and n = 1-3, and l = 1-4.

[0012] U.S. Patent Application Publication No. 2002/0072478A1 discloses a lubricating oil and one or more succinimide-modified compounds having long-lasting anti-shudder property, enhanced transmission torque capacity for wet clutches and/or wet brakes, and excellent shifting property for automatic transmissions and continuously variable transmissions.

[0013] Japanese Patent No. 3330245 discloses lubricating oil compositions for slide guide surfaces containing nitrogen-containing compounds of polyamines and amides in mineral and/or synthetic oil.

[0014] U.S. Patent Application Publication No. 2005/0124506 A1 discloses an additive compound comprising a non-borated and/or borated reaction product, in which the reaction product is obtained by reacting a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine, when employed in a lubricating oil composition is favorably employable as an automatic transmission fluid of internal combustion engines.

[0015] The anti-shudder durability and shifting property and the transmission torque capacity are in a trade-off relation. Therefore, it is desired to develop a lubricant composition having all of these properties.

[0016] In view of this dilemma, the object of the present invention is to provide a novel lubricant composition which can retain anti-shudder durability for extended periods and has high transmission torque capacity and improved shifting property.

SUMMARY OF THE INVENTION

[0017] The present invention provides a lubricating oil composition employable in automatic transmissions of internal combustion engines. The lubricating oil composition of the present invention has a high torque transmission capacity and prolonged shudder inhibition when used as an automatic transmission fluid (ATF) in automatic transmissions of internal combustion engines.

[0018] It is desirable that an automatic transmission fluid not only should show a high shudder inhibiting ability when the transmission fluid is first used, but also should keep the high shudder inhibiting ability for a prolonged period of time without substantial decrease of the inhibiting ability and further should show a high torque transmission capacity.

[0019] Accordingly, the present invention relates to a lubricating oil composition employable as an ATF in internal combustion engines having the beneficial performances mentioned above.

[0020] The present invention relates to a lubricating oil composition comprising a major amount of base oil of lubricating viscosity and the following additives in the following amounts based on a total amount of the lubricating oil composition:

(A) 0.1 to 10 wt.% of a succinic acid ester,

(B) 0.01 to 2 wt.% of a phosphorous acid ester,

(C) 0.1 to 5 wt.% of an amide compound which is a reaction product obtained by reaction of a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine,

(D) 0.01 to 2 wt.% of an overbased metal-containing detergent, and

(E) 0.01 to 1 wt.% of a corrosion inhibitor.

[0021] The present invention further relates to a method of reducing shudder in an automatic transmission of an internal combustion engine by adding the lubricating oil composition of the present invention to an automatic transmission and operating the engine.

[0022] Among other factors, the present invention is based on the surprising discovery that the lubricating oil composition of the present invention provides high transmission torque capacity and prolonged shudder inhibition when employed in an automatic transmission of an internal combustion engine. The lubricating oil composition is useful as a method for reducing shudder when used as an automatic transmission fluid. Accordingly the present invention is also directed to the use of the present additive compound in an automatic transmission fluid to reduce shudder in an automatic transmission of an internal combustion engine. The lubricating oil composition of the present invention has high stability with respect to the shudder inhibition, the torque transmission capacity and the shift performance, which are important properties of an automatic transmission fluid.

DETAILED DESCRIPTION OF THE INVENTION

[0023] As described in U.S. Patent Application Publication No. 2005/0124506 A1, the amide compound employed in the automatic transmission oil shows shudder inhibition performance retention, i.e., prolonged shudder inhibition time. However, the present invention will show that U.S. Patent Application Publication No. 2005/0124506 A1 does not have fully satisfactory characteristics in torque transmission capacity and shift performance despite having better characteristics compared to the standard T-III reference oil used in the JASO M349:2001 test. The torque transmission capacity and the shift performance relate to response depending upon the slide of the clutch and to shock in gear shifting, respectively. Accordingly, if the torque transmission capacity and the shift performance fluctuate, the response of the clutch and the shock in gear shifting are liable to fluctuate, respectively.

[0024] Thus, it is an object of the present invention to provide a lubricating oil composition containing additives for further effectively utilizing the amide compound disclosed in U.S. Patent Application Publication No. 2005/0124506 A1. In particular, the present invention provides a lubricating oil composition which is excellent not only in shudder inhibition performance, i.e., prolonged shudder inhibition time, but also in the stability of the torque transmission capacity and the shift performance.

[0025] The preferred embodiments of the lubricating oil composition according to the present invention will be described in further detail below.

Succinic Acid Ester

[0026] The lubricating oil composition of the present invention contains a succinic acid ester (Component A) in an amount of 0.1 to 10 wt.%, preferably 0.1 to 5 wt.%, based on the total amount of the lubricating oil composition.

[0027] The succinic acid ester is preferably an ester derived from a polyol and an alkenyl-substituted succinic anhydride prepared by reaction between maleic anhydride and polyolefin having a number average molecular weight of 450 to 5,000. The polyolefin preferably is polybutene. The polyol preferably is a polyhydric alcohol having 12 or less carbon atoms such as glycerol, erythritol, pentaerythritol, dipentaerythritol, heptanediol, hexanetriol, or butanetriol. Particularly preferred is pentaerythritol.

[0028] The process for preparing the polybutenylsuccinic anhydride by the reaction between polybutene and maleic anhydride is generally performed by a chlorination method utilizing chlorine. While this reaction is advantageous in giving a high reaction yield, it has disadvantageous feature in that a large amount (for instance, approx. 2,000 ppm) of chlorine remains in the finally obtained succinimide product. In contrast, a thermal reaction process utilizing no chlorine gives a final reaction product having an extremely low chlorine content (such as 40 ppm or less). It is known that an improved thermal reaction process employing a highly reactive polybutene (containing at least approx. 50% of methylvinylidene structure) in place of the conventional polybutene (containing mainly β-olefin structure) gives a high reaction yield. The improved thermal reaction process is further advantageous because the reaction ratio of the polybutene increases, and the resulting dispersant contains the effective product (succinimide) in a high concentration. Accordingly, it is preferred that the polybutenylsuccinic anhydride is produced from the highly reactive polybutene by a thermal process and the resulting polybutenylsuccinic anhydride is reacted with a polyhydric alcohol such as pentaerythritol to prepare the succinic acid ester.

[0029] In the lubricating oil composition of the present invention, the succinic acid ester can be used in combination with a polybutenyl-substituted succinic imide having a number average molecular weight of 300 to 5,000 or a modified succinic imide obtained by reacting the polybutenyl-substituted succinic imide with boric acid, alcohol, aldehyde, ketone, alkylphenol, cyclic carbonate, organic acid or inorganic acid such as phosphoric acid.

Phosphorous Acid Ester

[0030] The lubricating oil composition of the present invention contains a phosphorous acid ester (Component B) in an amount of 0.01 to 2 wt.%, preferably 0.05 to 0.5 wt.%, based on the total amount of the lubricating oil composition.

[0031] The phosphorous acid ester serves as a friction modifier and an anti-wear agent in the lubricating oil composition of the present invention.

[0032] The phosphorous acid ester preferably is an aliphatic secondary phosphite or an aromatic secondary phosphite. Examples of the aliphatic secondary phosphites include a secondary phosphite having a hydrocarbon group of 3 to 18 carbon atoms (e.g., dipropyl hydrogen phosphite, dibutyl hydrogen phosphite, dioctyl hydrogen phosphite, didecyl hydrogen phosphite, dilauryl hydrogen phosphite, dioleyl hydrogen phosphite) and a mixed dialkyl hydrogen phosphite having a hydrocarbon group of 12 carbon atoms and a hydrocarbon group of 14 carbon atoms. Examples of the aromatic secondary phosphites include diphenyl hydrogen phosphite. The phosphorous acid ester may be in the form of an amine salt. Examples of the amine salts include a linear or branched chain aliphatic amine having 8 to 18 carbon atoms such as octyl amine, decyl amine, lauryl amine, capryl amine, coconut amine, tallow amine or oleyl amine.

Amide Compound

[0033] The lubricating oil composition of the present invention contains a non-borated (I) and/or borated (II) amide compound (Component C) which is a reaction product in which the reaction product is obtained by reacting a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine. The additive compounds I and II of Compound C can be employed singly or in combination. The amount of Component C employed in the lubricating oil composition of the present invention will be in an amount of 0.1 to 5 wt.%, preferably 0.2 to 4 wt.%, based on the total amount of the lubricating oil composition.

[0034] Additive compound I comprises the reaction product of a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine.

[0035] Additive compound II comprises the borated reaction product in which the reaction product is obtained by reacting a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine with boric acid compound.

Monovalent Aliphatic Acid

[0036] The monovalent aliphatic acid is a compound which is represented by the formula:

$$R_4\ (COOH)y$$

or anhydride thereof, wherein R_4 represents a hydrocarbyl group having about 2 to 50 carbon atoms, and y represents an integer of 1 to 4.

[0037] The monovalent aliphatic acid employed for the preparation of the amide compound of the present invention is a linear or branched, saturated or unsaturated monovalent aliphatic acid containing 8 to 22 carbon atoms. Examples of the aliphatic acids include octanoic acid, lauric acid, myristic acid, palmitic acid, stearic acid, isostearic acid, oleic acid, and behenic acid. Particularly preferred is isostearic acid.

Urea

[0038] Any ordinarily employable urea such as urea of industrial purity grade can be employed.

Polyalkylenepolyamine

[0039] Preferred is a polyalkylenepolyamine containing 2 to 30 carbon atoms and 2 to 15 nitrogen atoms, each of at least two nitrogen atoms constituting primary amine. Preferably, the alkylene groups of such polyalkylenepolyamines will contain form 2 to 6 carbon atoms, more preferably form 2 to 4 carbon atoms. The nitrogen atom other than the nitrogen atoms constituting primary amine generally constitutes secondary amine.

[0040] Examples of suitable polyalkylenepolyamines include ethylenediamine, propylenediamine, isopropylenediamine, butylenediamine, pentylenediamine, hexylenediamine, diethylenetriamine, dipropylenetriamine, dimethylaminopropylamine, diisopropylenetriamine, dibutylenetriamine, di-sec-butylenetriamine, triethylenetetraamine, tripropylenetetraamine, triisobutylenetetraamine, tetraethylenepentamine, pentaethylenehexamine, hexaethyleneheptamine, dimethylaminopropylamine, and mixtures thereof.

[0041] Particularly suitable polyalkylenepolyamines are those having the formula:

$$H_2N\text{-}(R_5NH)_z\text{-}H$$

wherein R_5 is a straight- or branched-chain alkylene group having 2 to 6 carbon atoms, preferably 2 to 4 carbon atoms, most preferably about 2 carbon atoms, i.e., ethylene ($-CH_2CH_2-$); and z is an integer from 1 to 4, preferably 1 to 2.

[0042] Particularly preferred polyalkylenepolyamines are ethylenediamine, diethylenetriamine, triethylenetetraamine, tetraethylenepentamine, pentaethylenehexamine, and hexaethyleneheptamine. Particularly preferred is hexaethyleneheptamine.

[0043] Many of the polyamines suitable for use in the present invention are commercially available and others may be prepared by methods that are well known in the art. For example, methods for preparing amines and their reactions are detailed in Sidgewick's "The Organic Chemistry of Nitrogen", Clarendon Press, Oxford, 1966; Noller's "Chemistry of Organic Compounds", Saunders, Philadelphia, 2nd Ed., 1957; and Kirk-Othmer's "Encyclopedia of Chemical Technology", 2nd Ed., especially Volume 2, pp. 99-116.

[0044] The amide compound of the present invention can be obtained by reacting the acid compound (i.e., monovalent aliphatic acid), urea, the amine compound (i.e., polyalkylenepolyamine) in such conditions (i.e., ratio and nature) that the resulting reaction compound shows an oil-soluble property. The amide compound of the present invention is preferably obtained by reacting one mole of the monovalent aliphatic acid, 0.01 to 2 moles (preferably 0.03 to 0.5 moles) of urea, and 0.1 to 1 mole (preferably 0.125 to 0.5 moles) of polyalkylenepolyamine. The reaction can be performed generally at 100-250°C, preferably at 150-200°C, generally for 1-30 hours, preferably for 2-6 hours. Since the reaction is a condensation reaction, it is preferred that the produced water is removed continuously. The progress of the reaction can be checked by measuring the production of water.

[0045] The above-mentioned reaction product can be preferably borated by the reaction using a boric acid compound to yield the borated amide compound (B). The reaction can be carried out by adding to the above-mentioned reaction product a solid boric acid compound in such amount that the amount of boron in the boric acid compound is 0.001 to 0.25 weight part based one weight part of nitrogen in the above-mentioned reaction product, and heating the mixture to 100-160°C at an atmospheric pressure or a reduced pressure (reduced to 6.7 kPa) for 5-12 hours. The reaction is preferably continued until the solid boric acid compound diminishes in the reaction mixture.

Overbased Metal-Containing Detergent

[0046] The lubricating oil composition of the present invention contains an overbased metal-containing detergent (Component D) in an amount of 0.01 to 2 wt.%, preferably 0.01 to 1 wt.%, based on the total amount of the lubricating oil composition.

[0047] The overbased metal-containing detergent generally has a total base number of 10 to 500 mg•KOH/g. Examples of the overbased metal-containing detergents include alkali or alkaline earth metal salts or overbased products of petroleum sulfonic acids, alkylbenzenesulfonic acids, and alkyloxybenzenesulfonic acids. They are preferably used singly or in combination. As the alkaline earth metal salts, Mg or Ca salts are preferred. The sulfonates thereof having a total base number of 10 to 500 mg•KOH/g are generally used. Further, a sulfurized phenate or unsulfurized salicylate can be employed singly or in combination.

Corrosion Inhibitor

[0048] The lubricating oil composition of the present invention contains a corrosion inhibitor (Component E) in an amount of 0.01 to 1 wt.%, preferably 0.01 to 0.5 wt.%, based on the total amount of the lubricating oil composition.

[0049] The corrosion inhibitor preferably is a copper corrosion inhibitor. The copper corrosion inhibitor can be a thiazole compound, a triazole compound or a thiadiazole compound. Examples of these compounds include benzotriazole, tolyltriazole, octyltriazole, decyltriazole, dodecyltriazole, 2-mercaptobenzothiazole, 2,5-dimercapto-1,3,4-thiadiazole, 2-mercapto-5-hydrocarbyldithio-1,3,4-thiadiazole, and 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazole.

[0050] In order to protect copper from corrosion, two or more corrosion inhibitors having different chemical structures are preferably used in combination rather than one corrosion inhibitor is singly used. For example, a triazole compound and a thiadiazole are preferably used in combination. Particularly preferred is a combination of tolyltriazole and 2,5-bis (hydrocarbyldithio)-1,3,4-thiadiazole in a weight ratio of 1:10 to 10:1.

[0051] Other employable corrosion inhibitors include alkenylsuccinic acid and its anhydride. Examples of these compounds include tetrapropenylsuccinic acid, tetrapropenylsuccinic anhydride, tetradocenylsuccinic acid, tetradocenylsuccinic anhydride, octadecenylsuccinic acid, and octadecenylsuccinic anhydride. Otherwise, an alkenylsuccinic acid having an alkenyl group of 8 to 24 carbon atoms, and a half ester of this alkenylsuccinic acid with an alcohol such as polyglycol can be employed as the corrosion inhibitor. In addition, an amine compound, an acidic phosphoric acid ester, an ethoxylated amine compound, an imidazoline compound, an aminosuccinic acid, or their derivatives can be employed as the corrosion inhibitor.

[0052] The lubricating oil composition of the present invention is prepared by adding the above-described amounts of components A to E into a base oil of lubricating viscosity.

Lubricating Oil Composition

[0053] The lubricating oil composition of the present invention will comprise a major amount of base oil of lubricating viscosity and the components (A-E) as described above.

[0054] Base oil as used herein is defined as a base stock or blend of base stocks which is a lubricant component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location); that meets the same manufacturer's specification; and that is identified by a unique formula, product identification number, or both. Base stocks may be manufactured using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. Rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use. The base oil of this invention may be any natural or synthetic lubricating base oil fraction particularly those having a kinematic viscosity at 100°

Centigrade (C) and about 4 centistokes (cSt) to about 20 cSt. Hydrocarbon synthetic oils may include, for example, oils prepared from the polymerization of ethylene, polyalphaolefin or PAO, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases such as in a Fisher-Tropsch process. A preferred base oil is one that comprises little, if any, heavy fraction; e.g., little, if any, lube oil fraction of viscosity about 20 cSt or higher at about 100 C. Oils used as the base oil will be selected or blended depending on the desired end use and the additives in the finished oil to give the desired grade of engine oil, e.g. a lubricating oil composition having an SAE Viscosity Grade of 0W, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W-50, 5W-60, 10W, 10W-20, 10W-30, 10W-40, 10W-50, 15W, 15W-20, 15W-30, or 15W-40.

[0055] There are no specific conditions with respect to the base oil, provided that the base oil is selected from the base stocks generally employed for preparing lubricating oil compositions. The base oil may be derived from natural lubricating oils, synthetic lubricating oils or mixtures thereof. Suitable base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocrackate base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. Suitable base oils include those in all API categories I, II, III, IV and V as defined in API Publication 1509, 14th Edition, Addendum I, December 1998. Saturates levels and viscosity indices for Group I, II and III base oils are listed in Table 1. Group IV base oils are polyalphaolefins (PAO). Group V base oils include all other base oils not included in Group I, II, III, or IV. Group III base oils are preferred.

TABLE 1

Saturates, Sulfur and Viscosity Index of Group I, II, III, IV and V Base Stocks		
Group	Saturates (As determined by ASTM D2007) Sulfur (As determined by ASTM D2270)	Viscosity Index (As determined by ASTM D4294, ASTM D4297 or ASTM D3120)
I	Less than 90 % saturates and/or Greater than to 0.03 % sulfur	Greater than or equal to 80 and less than 120
II	Greater than or equal to 90 % Greater saturates and less than or equal to 0.03 % sulfur	than or equal to 80 and less than 120 less than 120
III	Greater than or equal to 90 % saturates and less than or equal to 0.03% sulfur	Greater than or equal to 120
IV	All Polyalphaolefins (PAOs)	
V	All others not included in Groups I, II, III, or IV	

[0056] Natural lubricating oils may include animal oils, vegetable oils (e.g., rapeseed oils, castor oils and lard oil), petroleum oils, mineral oils, and oils derived from coal or shale.

[0057] Synthetic oils may include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. Synthetic lubricating oils also include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups have been modified by esterification, etherification, etc. Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids with a variety of alcohols. Esters useful as synthetic oils also include those made from C_5 to C_{12} monocarboxylic acids and polyols and polyol ethers. Tri-alkyl phosphate ester oils such as those exemplified by tri-n-butyl phosphate and tri-iso-butyl phosphate are also suitable for use as base oils.

[0058] Silicon-based oils (such as the polyalkyl-, polyaryl-, polyalkoxy-, or polyaryloxysiloxane oils and silicate oils) comprise another useful class of synthetic lubricating oils. Other synthetic lubricating oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0059] The base oil may be derived from unrefined, refined, rerefined oils, or mixtures thereof. Unrefined oils are obtained directly from a natural source or synthetic source (e.g., coal, shale, or tar sand bitumen) without further purification or treatment. Examples of unrefined oils include a shale oil obtained directly from a retorting operation, a petroleum oil obtained directly from distillation, or an ester oil obtained directly from an esterification process, each of which may then be used without further treatment. Refined oils are similar to the unrefined oils except that refined oils have been treated in one or more purification steps to improve one or more properties. Suitable purification techniques include distillation, hydrocracking, hydrotreating, dewaxing, solvent extraction, acid or base extraction, filtration, and percolation, all of which are known to those skilled in the art. Rerefined oils are obtained by treating used oils in processes similar to those used to obtain the refined oils. These rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques for removal of spent additives and oil breakdown products.

[0060] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil.

[0061] Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0062] It is preferred to use a major amount of base oil of lubricating viscosity in the lubricating oil of the present invention. A major amount of base oil as defined herein comprises 40 wt % or more. Preferred amounts of base oil of lubricating viscosity comprise 40 to 99.9 wt %, preferably greater than 50 to 97 wt %, more preferably 60 to 97 wt % of the lubricating oil composition. (When weight percent is used herein, it is based on the total weight percent of the lubricating oil composition unless otherwise specified.)

[0063] The lubricating oil composition of the present invention has high stability with respect to shudder inhibition, torque transmission capacity and shift performance, which are important properties of automatic transmission fluids. It is known that lubricating oils are nowadays required not to need replacement from the time when they are once installed in new cars to the cars are abandoned, i.e., "fill-for-life" is required of the lubricating oils. From this viewpoint, the lubricating oil composition of the present invention is also advantageous.

[0064] The lubricating oil composition of the present invention can further contain various lubricating oil additives available in the art. Examples of the optionally incorporable additives include viscosity index improvers, anti-wear agents, friction modifiers, oxidation inhibitors, seal swelling agents, dyes, and pour point depressants. Particularly preferred additive is diphenyl hydrogen phosphite which is known as an anti-wear agent.

[0065] A number of the above-mentioned optionally incorporable additives are well known. Details of such additives are described below.

Viscosity Index Improver

[0066] Examples of the viscosity index improvers include non-dispersant type viscosity index improvers such as copolymers of various methacrylic acid esters and one or more other monomers and their hydrogenated products and dispersant type viscosity index improvers such as copolymers of various methacrylic acid esters and nitrogen-containing monomers. Other non-dispersant type or dispersant type viscosity index improvers such as copolymers of ethylene and α-olefins (e.g., propylene, 1-butene, and 1-pentene) and their hydrogenated products, and polyacrylic acid esters are also useful in the present invention.

[0067] The lubricating oil composition of the present invention generally contains a viscosity index improver in an amount of 1 to 20 wt. %, preferably 1 to 8 wt. %, based on the total amount of the lubricating oil composition.

Anti-Wear Agent and Friction Modifier

[0068] If desired, zinc dialkyldithiophosphate, which is a known additive serving as an anti-wear agent, an oxidation inhibitor, and an extreme-pressure agent, can be incorporated into the lubricating oil composition of the present invention.

Oxidation Inhibitor

[0069] It is preferred that the lubricating oil composition of the present invention further contains an oxidation inhibitor such as a hindered phenol compound, a diarylamine compound, or a molybdenum compound in an amount of 0.01 to 5 wt. % based on the total amount of the lubricating oil composition.

[0070] Examples of the hindered phenol compounds include 2,6-di-t-butyl-p-cresol, 4,4'-methylenebis(2,6-di-t-butylphenol), 4,4'-methylenebis(6-t-butyl-o-cresol), 4,4'-isopropylidenebis(2,6-di-t-butylphenol), 4,4'-bis(2,6-di-t-butylphenol), 2,2'-methylenebis(4-methyl-6-t-butylphenol), 4,4'-thiobis(2-methyl-6-t-butylphenol), 2,2-thiodiethylenebis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate], octyl 3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, octadecyl 3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate and octyl 3-(5-t-butyl-4-hydroxy-3-methylphenyl)propionate.

[0071] Examples of the diarylamine compounds include an alkyldiphenylamine containing a mixture of alkyl groups having 4 to 9 carbon atoms, p,p'-dioctyldiphenylamine, phenyl-α-naphthylamine, phenyl-β-naphthylamine, alkylated α-naphthylamine, and alkylated phenyl-α-naphthylamine. Each of the hindered phenol compounds and diarylamine compounds can be used singly or in combination. Other oil soluble oxidation inhibitors can be employed in combination.

[0072] The oxidation inhibitor can be a molybdenum-containing compound which is a multi-functional additive. The molybdenum-containing compound is preferably contained in the lubricating oil composition in an amount of 30 to 1,000 ppm in terms of the molybdenum content.

[0073] Examples of the molybdenum-containing compounds are molybdenum-containing imide, amide or amine compounds. Sulfur-containing oxymolybdenum-succinimide complex compound can improve high temperature detergency and oxidation inhibition, and hence is favorably employed. Sulfated oxymolybdenum dithiocarbamate and sulfated oxymolybdenum dithiophosphate can improve oxidation inhibition, wear inhibition, and reduction of friction coefficient, and hence are favorably employed.

Dye

[0074] When the lubricating oil composition of the present invention is employed as an ATF, the oil composition is preferably colored by a dye such as red dye.

Pour Point Depressant

[0075] Examples of the pour point depressants include polymethacrylic acid esters, polyacrylic acid esters, polyacrylamides, condensation products of paraffin wax and aromatic compounds.

Seal Swelling Agent

[0076] When the lubricating oil composition of the present invention is used as an ATF, a seal swelling agent which swells elastomer sealing material placed in the automatic transmission system may be used. Examples of the seal swelling agents include oil-soluble dialkylesters of dibasic acids such as adipic acid, azelaic acid, sebacic acid, or phthalic acid. Examples of preferred seal swelling agents include an adipic acid ester, an azelaic acid ester or a sebacic acid ester of an alkanol having 8 to 13 carbon atoms, and a phthalic acid ester of an alkanol having 4 to 13 carbon atoms.

EXAMPLES

[0077] The invention will be further illustrated by the following examples, which set forth particularly advantageous method embodiments. While the Examples are provided to illustrate the present invention, they are not intended to limit it.

Example 1

Preparation of the Amide Compound

[0078] In one aspect, the amide compound employed in the lubricating oil composition of the present invention is a reaction product prepared from monovalent aliphatic acid, urea and polyalkylenepolyamine.

[0079] In a four-necked flask equipped with a stirrer, a thermometer, and a dehydrating device were placed 1,034 g (3.5 mol) of isostearic acid and 15 g (0.25 mol) of urea. The resulting mixture was heated to 100°C, and 137.5 g (0.5 mol) of hexaethyleneheptamine was dropwise added to the heated mixture under replacement of the reaction atmosphere with nitrogen gas. After the addition was complete, the reaction mixture in the flask was gradually heated to reach 160°C within 3 hours. Water produced by the reaction in the course of heating was removed from the flask. Finally, the pressure of inside of the flask was reduced to 6.7 kPa, so as to completely remove the produced water. The finally obtained reaction product (reaction product A) was a brown liquid having a nitrogen content of 4.3 wt.%.

Example 2

[0080] The lubricating oil composition of the present invention was prepared by blending the following components in the designated amounts.

	Weight part(s)
Succinic acid ester	3.0
Succinimide	0.5
Borated succinimide	0.5
Overbased calcium sulfonate (TBN = 320)	0.15
Amide compound	1.0
Oleic acid	0.25
Tertiary alkyl (C_{12}-$_{14}$) primary amine	0.1
Diphenyl hydrogen phosphite	0.15
Tolyltriazole	0.1
2,5-Bis(hydrocarbyldithio)-1,3,4-thiadiazole	0.03

(continued)

	Weight part(s)
Dioctyldiphenylamine	0.4
2,6-Di-t-butylphenol	0.25
Silicone oil (anti-foaming agent)	0.002
Nitrogen-containing polymethacrylate (viscosity index improver)	5.7
Base oil (refined mineral oil)	87.768

Comparative Example A

[0081] The lubricating oil composition of Comparative Example A was prepared as described in Example 2 except no succinic acid ester was used and the amounts of succinimide and borated succinimide were 3.0 weight parts and 1.5 weight parts, respectively. This is essentially the lubricating oil composition described in U.S. Patent Application Publication No. 2005/0124506 A1.

Comparative Example B

[0082] As a reference, the standard oil T-III was prepared as Comparative Example B. According to JASO M348:2002 (SAE No. 2 test) and JASO M349:2001 (LVFA test), the T-III standard oil shows standards for the torque transmission capacity, the shift performance and the shudder inhibition performance.

[0083] Each of the lubricating oil compositions of Example 2 and Comparative Examples A and B were examined for its shudder inhibition performance retention and torque transmission capacity according to the following measuring procedures. The results are set forth in Table 2.

(1) Shudder inhibition performance retention

[0084] The shudder inhibition was measured according to Shudder Inhibition Performance Test Method for Automobiles and Automobile Automatic Transmission Fluid (defined in JASO M349.2001). In the measurements, an LVFA (Low Velocity Friction Apparatus) tester was employed, and $d\mu/dV$ (0.3) and $d\mu/dV$ (0.9) were determined under the following test conditions:

- Test conditions

[0085] Friction material: ZDR 522. OK, Steel plate (FZ132-8Y2)

[0086] Oil volume: 150 mL

- Break-in operation

[0087] Oil temperature: 80°C, Surface pressure: 1 MPa,

[0088] Sliding rate: 0.6 m/s, Period: 30 min.

[0089] After the break-in operation was complete, the friction character was measured according to the below-stated μ-V character-measuring conditions.

- μ-V Character-measuring conditions

[0090] Oil temperature: 40°C, 80°C, 120°C,

[0091] Surface pressure: 1 MPa, Sliding rate: 0 to 1.5 m/s

[0092] After the first measurement of μ-V character was complete, the retention ability was evaluated by measuring μ-V character at the lapse of the predetermined period of time by repeating the same measuring procedure.

- Retention ability conditions

[0093] Oil temperature: 120°C, Surface pressure: 1 MPa,

[0094] Sliding rate: 0.9 m/s, Sliding period: 30 min.

[0095] Rest: one min., Measurement: Every 24 hours

- Measurements

[0096] $d\mu/dV$ (0.3): $d\mu/dV$ (m/s) at sliding rate of 0.3 m/s
[0097] $d\mu/dV$ (0.9): $d\mu/dV$ (m/s) at sliding rate of 0.9 m/s
[0098] Shudder life: period of time until one of $d\mu/dV$ (0.3) and $d\mu/dV$ (0.9) became a minus value. A shorter period was adopted as the shudder life.

(2) Transmissive torque capacity

[0099] Dynamic friction test and static friction test were carried out by means of SAE No.2 Tester according to Friction Test Method for Automobiles and Automobile Automatic Transmission Fluid (defined in JASO M348.2002).

- Friction material

[0100] Friction material: FZ127-24-Y12, Steel plate (FZ132-8Y2)

- Dynamic friction measurement

[0101] Inertial moment of inertia disc: 0.343 kg•m^2
[0102] Oil temperature: 100°C
[0103] Rotation: 3,600 rpm
[0104] Surface pressure of friction plate: 785 MPa
[0105] Test cycle: 30 sec./cycle, Test number: 5,000 cycles

- Static friction measurement

[0106] Rotation: 0.7 rpm
[0107] Oil temperature: 100°C
[0108] Surface pressure of friction plate: 785 MPa
[0109] Test period: 3 min. after initiation of rotation
[0110] Test cycle: after 1, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 3000, 4000 and 5000 cycles

- Measurement

[0111] Static friction coefficient (μs) at the maximum torque caused when the rotation at 0.7 rpm starts and static coefficient (μt) at the lapse of 2 seconds.
[0112] Transmission torque capacity was evaluated by the value of μt. The μt value larger than 0.100 means that the transmission torque capacity is high, and a further larger μt value means a higher transmission torque capacity.

Table 2. Test Results

	Shudder Inhibition Performance	Torque Transmission Capacity					
	Shudder Inhibition Life (hr.)	μt after 50 cycles	μt after 500 cycles	μt after 1000 cycles	μt after 2000 cycles	μt after 3000 cycles	μt after 5000 cycles
Ex. 1	264	0.118	0.120	0.120	0.121	0.121	0.121
Comp. Ex. A	192	0.131	0.131	0.129	0.125	0.123	0.121
Comp. Ex. B	48	0.141	0.142	0.139	0.135	0.132	0.133

[0113] The JASO M318 specification requires a minimum of 85% of μt against the T-III reference oil (Comp. Ex. B). This means μt should be 0.112 (0.132 x 0.85). Example 1 meets this JASO M318 specification requirement as the μt is 0.118. Another important performance feature is stability (durability) over a prolonged time period as indicated by the variation of μt (max-min at 50-5,000cycles) over time. For Example 1, the μt variation is <0.004 while Comparative Example A and Comparative Example B were each ≥0.010. As can be seen by the torque transmission capacity results the variation over time is very low indicating excellent retention of torque transmission capacity throughout the life of the lubricating oil composition of the present invention. This is an important property reflecting the ability of the lubricating oil composition to maintain its function for a prolong period of operation.

[0114] Another aspect of the lubricating oil composition of the present invention is shudder inhibition performance which reflects the smoothness of the engagement of the slip control lock-up clutch. This impacts the comfort of the passenger during operation without vibration or shuddder. The results indicate a longer retention of shudder inhibition performance by the lubricating oil composition of the present invention. The shudder inhibition life of the lubricating oil composition of the present invention (Example 1) was about 1.4 times longer than Comparative Example A and about 5.5 times longer than the Comparative Example B (T-III reference oil).

[0115] The above results demonstrate that, as compared with the lubricating oil composition of U.S. Patent Application Publication No. 2005/0124506 A1 (Comparative Example A) which comprises the amide compound in combination with succinic imide, overbased calcium sulfonate (overbased metal-containing calcium alkylsulfonate), diphenyl hydrogen phosphite (phosphorous acid ester) and tolyltriazole (corrosion inhibitor), a lubricating oil composition using succinic acid ester, as in the case of the present invention, in place of the succinic imide not only has improved long-term stability of both the torque transmission capacity and the shift performance but also has prolonged retention of shudder inhibition performance.

Claims

1. A lubricating oil composition comprising a major amount of base oil of lubricating viscosity and the following additives in the following amounts based on a total amount of the composition:

    (A) 0.1 to 10 wt.% of a succinic acid ester,
    (B) 0.01 to 2 wt.% of a phosphorous acid ester,
    (C) 0.1 to 5 wt.% of an amide compound which is a reaction product obtained by reaction of a linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, urea, and polyalkylenepolyamine,
    (D) 0.01 to 2 wt.% of an overbased metal-containing detergent, and
    (E) 0.01 to 1 wt.% of a corrosion inhibitor.

2. The lubricating oil composition of claim 1, wherein the amide compound is a borated amide compound obtained by borating the reaction product.

3. The lubricating oil composition of claim 1, wherein the amide compound is a reaction product obtained by reacting one mole of the linear or branched, saturated or unsaturated monovalent aliphatic acid having 8 to 22 carbon atoms, 0.01 to 2 moles of urea, and 0.1 to 1 mole of polyalkylenepolyamine.

4. The lubricating oil composition of claim 1, wherein the polyalkylenepolyamine contains 2 to 30 carbon atoms and 2 to 15 nitrogen atoms, each of at least two nitrogen atoms forming primary amine.

5. The lubricating oil composition of claim 4, wherein the polyalkylenepolyamine is at least one compound selected from the group consisting of ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, and hexaethyleneheptamine.

6. The lubricating oil composition of claim 5, wherein the polyalkylenepolyamine is hexaethyleneheptamine.

7. The lubricating oil composition of claim 1, wherein the monovalent aliphatic acid is isostearic acid.

8. The lubricating oil composition of claim 1, wherein the succinic acid ester is an ester derived from a polyol and an alkenyl-substituted succinic anhydride prepared by a reaction between maleic anhydride and polyolefin having a number average molecular weight of 450 to 5,000.

9. The lubricating oil composition of claim 8, wherein the polyolefin is polybutene.

10. The lubricating oil composition of claim 9, wherein the reaction between maleic anhydride and polyolefin is performed

by a thermal reaction process utilizing no chlorine.

11. The lubricating oil composition of claim 1, wherein the phosphorous acid ester is diphenyl hydrogen phosphite.

12. The lubricating oil composition of claim 1, wherein the overbased metal-containing detergent is an overbased calcium alkylbenzenesulfonate detergent having a total base number of 10 to 500 mg•KOH/g.

13. A method for reducing shudder in an automatic transmission of an internal combustion engine, said method comprising adding the lubricating oil composition of claim 1 to the automatic transmission and operating the engine.

REFERENCES CITED IN THE DESCRIPTION

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