(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 516 913 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
23.03.2005 Bulletin 2005/12

(21) Application number: **04019106.6**

(22) Date of filing: **12.08.2004**

(51) Int Cl.^{7}: **C10M 169/04**, C10M 171/02
// (C10M169/04, 145:14),
(C10N20/02, 30:02, 40:04)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

(30) Priority: **22.08.2003 US 497245 P**
20.07.2004 US 894705

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(54) **Shear stable functional fluid with low Brookfield viscosity**

(57) A functional fluid of low Brookfield Viscosity comprising a mixture of at least two different base stocks with shear stable viscosity modifier polymers, and also containing performance additives.

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The invention relates to shear stable functional fluids having low Brookfield viscosities comprising a mixture of base stocks, with shear stable viscosity modifier polymers, and also containing performance additives.

BACKGROUND OF THE INVENTION

[0002] Functional fluids comprise a broad range of lubricants that are used in automotive and industrial hydraulic systems, automatic transmissions, power steering systems, shock absorber fluids, and the like. These fluids transmit and control power in mechanical systems, and thus must have carefully controlled viscometric characteristics. In addition, these fluids may sometimes be formulated to provide multigrade performance so as to ensure year round operation in variable climates.

[0003] Automatic Transmission Fluid (ATF) is one of the most common functional fluids, and an integral part of all automatic transmissions. Automatic transmissions are used in about 80% to 90% of all vehicles in North America and Japan and their use is becoming more commonplace in other parts of the world. They are the most complex and costly sub-assemblies of a vehicle and the major Original Equipment Manufacturers (OEMs) have stringent specifications to control all aspects of the components that go into their manufacture, including the functional fluid.

[0004] An automatic transmission comprises a torque converter or clutch assemblies, gear assemblies, output drives and hydraulic systems. The ATF acts as a hydraulic fluid to transfer power from the engine via the torque converter or clutch assembly, and to actuate complex controls to engage the gears to give the correct vehicle speed.

[0005] The fluid must have the right viscometrics at ambient start-up temperatures, which can be as low as -40°C, while maintaining sufficient viscosity at higher operating temperatures of 100°C or more. ATF must also be oxidation stable since it is subjected to high temperatures and is expected to remain in service for up to 100,000 miles in some cases. In addition, frictional characteristics are important so as to provide smooth control of shifting with the clutch plates.

[0006] Great strides have been made in ATF additive formulation science to meet these viscometric and oxidation requirements using solvent extracted mineral oils, commonly referred to as Group I base stocks. However, over the past few years, with the increasing performance demands being made on automatic transmission fluids, the use of hydrocracked base stocks, commonly referred to as Group II or Group III base stocks, have become more widespread. These base stocks give improved low temperature performance and longer oxidation life.

[0007] However most recently, the major automotive manufacturers have again increased the demands on ATFs by moving to smaller and higher power-density designs that have increased the need for improved viscometrics. In particular, lower viscosity at lower operating temperatures is required to ensure proper hydraulic operation of the components.

TABLE 1:

Brookfield Viscosity Limits of Major OEM ATFs		
	Previous Limits	New or Pending Limits
General Motors	20,000 cP max	15,000 cP max
Ford	20,000 cP max	13,000 cP max
Chrysler	22,000 cP max	10,000 cP max
Toyota	20,000 cP max	15,000 cP max

[0008] In addition, it is expected that ATFs do not undergo excessive viscosity reduction through shearing during severe service. It is quite common for current fluids to undergo 30% to 50%, or more viscosity loss during use, resulting in a kinematic viscosity for aged fluids of less than 4.5 mm^2/sec at 100°C. Such low viscosities can have a detrimental affect on transmission operation because they are generally designed to operate over the life of the transmission with a fluid with substantially constant viscosity at 100°C.

SUMMARY OF THE INVENTION

[0009] The present invention is directed to a functional fluid comprising:

(A) a mixture of at least two base stocks, said mixture comprising

(i) at least one first base stock having a kinematic viscosity of about 4.5 to about 8.0 mm^2/sec at 100°C, a viscosity index of at least 120 to about 160, a pour point of about -12°C maximum, a saturates content of greater than about 98 mass %;

(ii) at least one second base stock having a kinematic viscosity of about 2.0 to about 4.5 mm^2/sec at 100°C, a viscosity index of about 100 to about 120, a pour point of about -12°C maximum, a saturates content of greater than about 98 mass %;

wherein the first base stock is present in the amount of about 40 vol% to about 90 vol% based on the stock, wherein the second base stock is present in the amount of about 10 vol% to about 60 vol% based on the stock, wherein the first base stock (i) and second base stock (ii) are not the same; and

(B) said base oil mixture (being a blend of base stocks as defined above) has a kinematic viscosity of about 4.0 to about 5.5 mm^2/sec at 100°C, a viscosity index of about 120 to about 150, a pour point of about -12°C maximum;

(C) at least one viscosity index improver having a shear stability index (SSI) less than 35, preferably less than 25, and more preferably less than 15, as measured in the KRL Tapered Roller Bearing Tester according to procedure CEC-L-45-T-93, said SSI being defined by the equation

$$\mathrm{SSI} = \frac{(\mu_i - \mu_f)}{(\mu_i - \mu_0)} * 100$$

where

μ_i - Initial fluid viscosity @ 100°C (fully blended ATF)

μ_f - Final after-shear fluid viscosity @ 100°C (fully blended ATF)

μ_0 - Base oil viscosity @ 100°C (blend of two or more base stocks without any additives)

(D) an additive package

(E) the resulting additized functional fluid having, a kinematic viscosity of about 5.0 to about 6.5 mm^2/sec at 100°C, a viscosity index of about 120 to about 180, a pour point of about less than -42°C maximum, and a Brookfield viscosity of about 15,000 cP or less at -40°C.

(F) the resulting additized functional fluid having, an after KRL shear parameter (SP) of about 4.9 to about 5.6 mm^2/sec at 100°C, preferably about 4.95 to about 5.4 mm^2/sec at 100°C, more preferably about 4.98 to about 5.2 mm^2/sec at 100°C as defined by

$$\mathrm{SP} = \frac{(\mu_f + \mu_0)}{2}$$

where

μ_f - Final after-shear fluid viscosity @ 100°C (fully blended ATF)

μ_0 - Base oil viscosity @ 100°C (blend of two or more base stocks without any additives)

[0010] The base stocks may be prepared by use of any of the process procedures currently used in the art, as well as any processes yet to be developed. It is believed the performance and function of the base stocks in the present invention are independent of the particular procedural techniques employed in the production of the base stocks. Typically base stocks are made starting with distillate from the atmosphere/vacuum pipestills and/or coker distillate, optionally subjecting such distillate to an aromatics removal step using an aromatics selective solvent such as phenol, furfural, NMP, etc. The distillate is then subjected to hydroconversion in at least one hydroconversion zone, more typically two zones wherein the distillate is exposed to a catalyst in the presence of hydrogen at high temperature and pressure to effect the saturation of aromatics, open rings and reduce sulfur and nitrogen content.

[0011] The stream from the hydroconversion stage(s) can now optionally be subject to fractionation, a further aromatics removal step such as solvent extraction employing a selective solvent such as phenol, furfural, NMP, etc, or hydroprocessing. This stream can then be subjected to wax removal employing solvent dewaxing or catalytic dewaxing or isomerization. The stream, either before or after such dewaxing can also be subjected to hydrofinishing to further reduce the aromatic, sulfur and nitrogen contents.

[0012] Examples of suitable processes can be found in "All Hydroprocessing Route for High Viscosity Index Lubes" Zakarian et al Energy Progress, Vol. 7, No. 1, pp. 59-64; "Hydrotreated Lube Oil Base Stocks" Cashmore et al, SAE Paper 821235; "Lube Facility Makes High Quality Lube Oil from Low Quality Feed" Farrell et al, Oil and Gas Journal May 19, 1986, Technology, pp. 47-51; U.S. Patent 5,976,353.

[0013] Other suitable stocks include hydroisomerized waxy stocks. Suitable waxy stocks include waxy petroleum stock such as gas oil, foots oil, slack waxes, waxy raffinates, deasphalted oils, fuels hydrocracker bottoms, etc. Hydroisomerization converts the paraffinic waxy components of these stocks into isoparaffinic hydrocarbons which is lubricating oil. Also suitable as waxy stocks are those produced by the Fischer Tropsch process which catalytically converts synthesis gas, i.e., CO and H_2, into hydrocarbons. The high boiling point residues of the Fischer Tropsch synthesis process products are highly paraffinic waxy stocks of low sulfur content which are also free of nitrogen, aromatics and olefinic hydrocarbons. The hydroisomerization process can be practiced on one or more waxy petroleum stocks, Fischer Tropsch wax stocks or a mixture thereof. Further, other suitable stocks can include polyalphaolefins (PAO) whose viscosities and other characteristics fall within the limits recited above.

[0014] The first base stock (i) and second base stock (ii) are preferably hydrocracked stocks and hydroisomerized stocks.

[0015] The first stock employed is one or more stocks having a kinematic viscosity of at least 4.5 to about 8.0 mm^2/s at 100°C, preferably about 4.5 to about 7.0 mm^2/s at 100°C, more preferably about 5.0 to about 7.0 mm^2/s at 100°C, a viscosity index in the range of at least 120 to about 160, preferably about 125 to about 150, a pour point of less than about -12°C, preferably less than about -15°C, more preferably less than about -18°C, and a saturates content of greater than about 98 mass %.

[0016] The second stock employed is one or more stocks having a kinematic viscosity of about 2.0 to about 4.5 mm^2/s at 100°C, preferably about 2.5 to about 4.0 mm^2/s at 100°C, more preferably about 2.5 to about 3.5 mm^2/s at 100°C, a viscosity index in the range of about 100 to about 120, preferably about 100 to about 115, more preferably about 100 to about 110, a pour point of less than about - 12°C, preferably less than about -15°C, more preferably less than about -18°C, and a saturates content of greater than about 98 mass %.

[0017] The base stocks are combined to produce a base oil mixture characterized by having a kinematic viscosity of about 4.0 to about 5.5 mm^2/s at 100°C, preferably at least about 4.5 to about 5.5 mm^2/s at 100°C, more preferably at least about 4.5 to about 5.0 mm^2/s at 100°C, a viscosity index of about 120 to 150, and a pour point of about -12°C maximum. A blend of base stocks is employed so as to insure that the base oil kinematic viscosity target is consistently met.

[0018] A viscosity index improver or mixture of viscosity index improvers may be employed at a treat range of 0.5 vol% to 15 vol%, preferably 0.5 vol% to 10 vol%, more preferably 0.5 to 5 vol%. Viscosity index improver may comprise any of the common chemical types used in lubricating formulations, including, but not limited to polymethacrylates, polyisobutenes, styrene, styrene-isoprene copolymer, polyisomers, polyacylates, etc., and mixtures thereof, preferably polymethacrylate. The only requirement which must be met is that the viscosity index improver used have an SSI meeting the requirement recited below and that the resulting formulated ATF meet the viscometric and performance characteristics established for the ATF as presented hereafter below.

[0019] The viscosity index improvers (VII's) which are useful in the present invention and are preferred are the polyalkylmethacylate (PAMA) viscosity under improvers. Such VII's are typically provided as viscous concentrates of polymer in solvent-refined carrier oil. The aforesaid treat ranges are on an as received basis. Nonlimiting examples of PAMAs include those secured from RohMax® known as Viscoplex®, those formerly known as Acryloid® formerly supplied by Rohm and Haas Corporation, as well as PAMA secured from Sanyo Chemical Industries known as Aclube® or Sanlube®, or from Lubrizol Corp. or other sources. Suitable non-limiting examples include VISCOPLEX® 0-030, VISCOPLEX® 0-050, VISCOPLEX® 0-101, VISCOPLEX® 0-110, VISCOPLEX® 0-111, VISCOPLEX® 0-112, VISCOPLEX® 0-113, VISCOPLEX® 0-120, VISCOPLEX® 0-400, VISCOPLEX® 8-100, VISCOPLEX® 12-291, VISCOPLEX® 12-310, Aclube® 813, Aclube® 806T, Aclube® C-728, Aclube® 975, Aclube® C-813, Aclube® 812 or Lubrizol® 7720C.

[0020] The viscosity index improver will have a shear stability index (SSI) as reported in the manufacturer's literature of less than 35, preferably less than 25, and more preferably less than 15, as measured in the KRL Tapered Roller Bearing Tester according to procedure CEC-L-45-T-93, said SSI being defined by the equation

$$SSI = \frac{(\mu_i - \mu_f)}{(\mu_i - \mu_0)} * 100$$

where

μ_i - Initial fluid viscosity @ 100°C (fully blended ATF)

μ_f - Final after-shear fluid viscosity @ 100°C (fully blended ATF)

μ_0 - Base oil viscosity @ 100°C (blend of two or more base stocks without any additives)

[0021] The finished functional fluid will contain a performance additive package. Such performance additives will be used in an amount of about 4 to about 20 vol%, preferably about 5 to about 15 vol% of the total formulated oil. Performance additives include, but are not limited to, metallic and ashless oxidation inhibitors, metallic and ashless dispersants, metallic and ashless detergents, corrosion and rust inhibitors, metal deactivators, anti-wear agents (metallic and non-metallic, low-ash, phosphorus-containing and non-phosphorus, sulfur-containing and non-sulfur types), extreme pressure additives (metallic and non-metallic, phosphorus-containing and non-phosphorus sulfur-containing and non-sulfur types), anti-seizure agents, pour point depressants, wax modifiers, viscosity index improvers, viscosity modifiers, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, and others. For a review of many commonly used additives see Klamann in *Lubricants and Related Products,* Verlag Chemie, Deerfield Beach, FL; ISBN 0-89573-177-0, and also *Lubricant Additives* by M.W. Ranney, published by Noyes Data Corporation of Parkridge, NJ (1973) both of which are incorporated here by reference.

[0022] Antiwear additives include metal alkylthiophosphate and more particularly a metal dialkyldithiophosphate in which the primary metal constituent is zinc, or zinc dialkyldithiophosphate (ZDDP). ZDDP compounds generally are of the formula $Zn[SP(S)(OR^1)(OR^2)]_2$ where R^1 and R^2 are C_1-C_{18} alkyl groups, preferably C_2-C_{12} alkyl groups. These alkyl groups may be straight chain or branched. These ZDDP type antiwear additives are typically used in amounts of from about 0.4 wt% to about 1.4 wt%, but more or less can be used at the discretion of the practitioner.

[0023] Non-phosphorous antiwear additives can also be used and they include sulfurized olefins.

[0024] Polysulfides of thiophosphorous acids and thiophosphorus acid esters, phosphorothenyl desulfides, alkylthiocarbamoyl compounds in combination with molybdenum compounds and a phosphorus ester are also useful antiwear additives as are carbamate, thiocarbamate and thiocarbamate/molybdenum complexes such as moly-sulfur alkyldithiocarbamate complexes, as well as esters of glycerol. Further, mixtures of ZDDP and thiodixanthogen compounds can also improve antiwear properties.

[0025] Antiwear additives may be used in amounts of from about 0.01 to 6 wt%, preferably about 0.01 to 2 wt%.

[0026] Antioxidants include hindered phenols and maybe ashless (metal free) or neutral or basis metal salts of phenolic compounds (ashed). Hindered phenols contain one or more hydroxyl groups of which one or more is sterically hindered. Bis-phenolic antioxidants can also be used, e.g., ortho-coupled bis-phenols such as 2, 2'-bis(6-t-butyl-4-heplyl phenol); 2,2'-bis(6-t-butyl-4-octyl phenyl) and paracoupled bis-phenols such as 4,4'-bis(2-6-di-t-butyl phenol) and 4,4' methylene-bis(2,6-di-t-butyl phenol).

[0027] Non-phenolic antioxidants include aromatic amine antioxidants and these may be used either alone or in combination with phenolic antioxidants. Aminic antioxidants include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more aminic antioxidants can be used.

[0028] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof are also useful antioxidants.

[0029] Oil soluble copper compounds such as copper dihydrocarbyl thio- or dithio-phosphates and copper salts of carboxylic acid are also antioxidants, as are copper dithiocarbamate sulphonates, phenates and acetylacetonates. Basic neutral or acidic copper Cu(I) and or Cu(II) salts derived from alkenyl succinic acids or anhydrides can also be used.

[0030] Antioxidants are typically used in an amount of about 0.01 to 5 wt%, preferably about 0.01 to 2 wt%.

[0031] Useful detergents can be neutral, mildly overbased or highly overbased. At least some overt acid detergent is desirable. The total base number of the detergent can range as high as 450 mgKOH/g or higher. A mixture of detergents of different total base numbers is preferred. Detergents include the alkali or alkaline earth metal salts of sulfates, phenates, carboxylates, phosphates and salicylites and preferred detergents include calcium or magnesium phenates, sulfonates and salicylates, including the borated versions of these materials.

[0032] Detergents are used in an amount of about 0.01 to 6 wt%, preferably about 0.1 to 4 wt%.

[0033] Dispersants function by keeping byproducts and decomposition products in solution, thereby reducing their deposition on metal surfaces. Dispersants may be ashless or ash forming, and may also be borated, the ashless borated or unborated type being preferred.

[0034] Dispersants include phenates, sulfonates, sulfurized phenates, salicylates, naphthenates, stearates, carbamates, thiocarbamates and phosphorus derivatives. A particularly useful class of dispersants are alkenylsuccinic derivatives, typically produced by the reaction of a long chain substituted alkenyl succinic compound, usually a substituted succinic acid or anhydride, preferably the anhydrate, with a polyhydroxy or polyamine compound. The long chain group substituted in the alkenyl succinic compound is normally a polyisobutylene group having anywhere from 35 to 100 to 150 or more carbon atoms, more usually at least about 50 carbon atoms.

[0035] Hydrocarbyl substituted succinic acid/acid anhydride compounds useful as dispersants include the succinimides, succinate esters and succinate ester amides.

[0036] The succinimides are formed by the condensation reaction between alkenyl succinic anhydrides and amines. The succinate esters are formed by the condensation reaction between alkenyl succinic anhydrides and alcohols or polyols. The succinate ester amides are formed by the condensation reaction between alkenyl succinic anhydrides and alkanol amines.

[0037] The hydrocarbyl substituted succinic acid/acid anhydride compounds can be post treated with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids (such as oleic acid) and boron compounds. The dispersants can be borated with from about 0.1 to about 5 moles of boron per mole of dispersant reaction product. Preferred are the borated mono-succinimide, bis-succinimides and mixtures thereof, wherein the hydrocarbyl substitutent is a polyisobutylene having an Mn of from about 500 to 5000, or a mixture of such hydrocarbyl groups.

[0038] Other dispersants are the Mannich base dispersants made by the reaction of alkylphenols, formaldehyde and amines. See US Patent No. 4,767,551 incorporated herein by reference in its entirety.

[0039] Suitable dispersants also include oxygen containing compounds such as polyether compounds, polycarbonate compounds and/or polycarbonyl compounds.

[0040] Dispersants may be used in an amount of about 0.1 to 20 wt%, preferably about 0.1 to 8 wt%.

[0041] Friction modifiers, also known as lubricity agents or oiliness agents include metal-containing compounds as well as ashless compounds, and mixtures thereof. Metal-containing friction modifiers may include metal salts or metal-ligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivate of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar functional groups containing effective amounts of O, N, S, or P, individually or in combination. Particularly preferred are Mo-dithiocarbamates (Mo (DTC)), Modithiophosphates (Mo(DTFP), Mo-amines (Mo(Am)), Mo-alcoholates, Moalcohol-amides, etc.

[0042] Ashless friction modifiers include hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives and the like, as well as salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, etc. Also useful are fatty organic acids, fatty amines and sulfurized fatty acids.

[0043] Friction modifiers are used in amounts of from about 0.01 to 15 wt%, preferably 0.01 to 10 wt%, more preferably 0.1 to 5 wt%. The amount of molybdenum containing friction modifiers is usually expressed in terms of molybdenum metal concentrations, the amount usually being in the range of about 10 to 3,000 ppm or more, preferably about 20-2,000 ppm, more preferably about 30-1,000 ppm.

[0044] Pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. They have be used in an amount of about 0.01 to 5 wt%, preferably about 0.01 to 1.5 wt%.

[0045] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include thiadizoles and thiadiazoles. They are used in an amount of about 0.01 to 5 wt%, preferably about 0.01 to 1.5 wt%.

[0046] Seal compatibility agents, also known as seal swell agents, include organic phosphates, aromatic esters, aromatic hydrocarbons, esters such as butylbenzyl phthalate, and polybutenyl succinic anhydrides. They are used in an amount of about 0.01 to 3 wt%, preferably about 0.01 to 2 wt%.

[0047] Anti-foam agents include silicones and organic polymers such as polysiloxane, silicone oils or polydimethylsiloxane. They are used in trace amounts, usually less than 1 wt% and preferably less than 0.01 wt%.

[0048] Anti-rust additives, also known as corrosion inhibitors, include polar compounds that wet the metal surface protecting it with a film of oil, compounds that absorb water by incorporating it into a water-in-oil emulsion so that the oil and not the water touches the metal surface, and compounds that chemically adhere to the metal to produce non-reactive surfaces. Examples include zinc dithiophosphate, metal phenalates basic metal sulfonates, fatty acids and amines. They may be used in amounts of about 0.01 to 5 wt%, preferably about 0.01 to 1.5 wt%.

[0049] Additional types of additives may be further incorporated into lubricant compositions or functional fluids of this invention, and may include one or more additives such as, or example, demulsifiers, solubilizers, fluidity agents, coloring agents, chromophoric agents, and the like, as required. Further, each additive type may include individual additives or mixtures of additive.

[0050] The additives either individually or as a package can be marketed either as 100% active ingredient materials or as concentrates in diluent oil. The amount of diluent oil associated with the additive(s), therefore, can range from zero to about 40 vol%. The diluent oil embraces any oil of sufficient viscosity and solvency being such that the final formulated ATF performance characteristics are within the limits recited herein, and would include any naphthenic, paraffinic or aromatic oil, e.g., any suitable Group I, Group II, Group III, Group IV or Group V oil (term of oil known to those skilled in the art).

[0051] The final additized functional fluid is characterized as having a kinematic viscosity of about 5.0 to about 6.5 mm^2/s at 100°C, preferably about 5.3 to about 6.4 mm^2/s at 100°C, a viscosity index of about 120 to about 180, a pour point of less than about -42°C maximum and a Brookfield viscosity about 15,000 cP or less at -40°C.

[0052] The invention will be further explained by and understood by reference to the following non-limiting examples, see Table 2.

[0053] In Table 2 base stocks Q, A, B, C, D, X, Y and Z are hydrocracked base stocks. Base stocks E and F are the products of the hydroisomerization of waxy feed stocks. Base stock E is hydroisomerized waxy stock from a petroleum source, slack wax, while base stock F in hydroisomerized Fischer Tropsch wax. Fischer Tropsch waxes are the waxy, high boiling residue of the Fischer Tropsch process which converts synthesis gas (CO and H_2) into hydrocarbons. Fischer Tropsch waxes are highly paraffinic hydrocarbons with very low sulfur content. The specification for each stock is recited in Table 2.

TABLE 2: SHEAR STABLE FUNCTIONAL FLUID WITH LOW BROOKFIELD VISCOSITY

	First Base Stock					Second Base Stock					Base Stock Blend				ATF Blend			
	Code	KV100 (mm^2/s)	KV40 (mm^2/s)	VI	vol%	Code	KV100 (mm^2/s)	KV40 (mm^2/s)	VI	vol%	Code	KV100 (mm^2/s)	KV40 (mm^2/s)	VI	KV100 (mm^2/s)	KV40 (mm^2/s)	VI	BF (cP@-40°C)
Comparative Example																		
A	Q	4.593	22.88	117	100.000	---	---	---	---	0.000	Q	4.593	22.88	117	6.174	---	---	41,391
B	A	5.362	29.26	118	73.579	X	3.109	12.56	107	26.421	AX	4.588	22.93	116	---	---	---	16,297
C	A	5.362	29.26	118	81.275	Y	2.557	9.373	101	18.725	AY	4.585	22.93	116	6.199	32.20	144	16,836
D	A	5.362	29.26	118	74.530	Z	3.052	12.21	107	25.470	AZ	4.588	22.92	116	---	---	---	17,436
E	C	5.053	25.74	126	100.000	---	---	---	---	0.000	C	5.053	25.74	126	6.189	32.57	141	17,466
F	D	6.433	36.29	130	56.858	X	3.109	12.56	107	43.142	DX	4.582	22.08	124	6.292	33.58	140	22,245
Inventive Example																		
1	B	6.047	33.34	129	61.554	X	3.109	12.56	107	38.446	BX	4.585	22.17	124	6.204	31.37	151	13,357
2	B	6.047	33.34	129	71.392	Y	2.557	9.373	101	28.608	BY	4.580	22.06	124	6.222	31.46	151	14,317
3	B	6.047	33.34	129	62.722	Z	3.052	12.21	107	37.278	BZ	4.585	22.16	124	---	---	---	14,657
4	C	5.053	25.74	126	81.722	X	3.109	12.56	107	18.278	CX	4.590	22.32	122	6.149	31.20	149	13,117
5	C	5.053	25.74	126	87.448	Y	2.557	9.373	101	12.552	CY	4.588	22.28	123	6.189	31.40	150	12,927
6	C	5.053	25.74	126	82.455	Z	3.052	12.21	107	17.545	CZ	4.590	22.31	123	---	---	---	14,377
7	D	6.433	36.29	130	56.813	X	3.109	12.56	107	43.187	DX	4.580	22.07	124	6.269	31.53	153	11,798
8	D	6.433	36.29	130	67.223	Y	2.557	9.373	101	32.777	DY	4.574	21.92	125	6.284	31.54	154	12,197
9	D	6.433	36.29	130	58.027	Z	3.052	12.21	107	41.973	DZ	4.580	22.04	125	6.252	31.66	151	12,907
10	E	6.621	35.05	147	55.014	X	3.109	12.56	107	44.986	EX	4.583	21.29	134	6.302	30.75	161	10,898
11	E	6.621	35.05	147	65.608	Y	2.557	9.373	101	34.392	EY	4.577	21.00	137	6.305	30.48	163	11,098
12	E	6.621	35.05	147	56.251	Z	3.052	12.21	107	43.749	EZ	4.583	21.25	134	6.273	30.81	159	11,967
13	F	6.062	30.83	148	61.336	X	3.109	12.56	107	38.664	FX	4.585	21.19	135	---	---	---	11,018
14	F	6.062	30.83	148	71.208	Y	2.557	9.373	101	28.792	FY	4.580	20.93	138	6.213	29.95	163	9,758
15	F	6.062	30.83	148	62.516	Z	3.052	12.21	107	37.484	FZ	4.584	21.16	136	---	---	---	10,138

[0054] ATF blends were made using various "first base stocks" and "second base stocks", along with a VI improver secured from an independent source and is believed to be RohMax VISCOPLEX® 0-050 having a SSI measured by the technique recited herein of about 8 and performance additives. The kinematic viscosity of the blended mixture of the "first and second base stocks" was targeted to be about 4.6 mm^2/s at 100°C, except where otherwise indicated as in Comparative Example E. The VI improver treat rate was 5 vol% as received, active ingredient level ~40-75%, except in Comparative Example E wherein the VI improver treat rate was 2.75 vol% as received, and the treat rate of the performance additives was about 8 vol% as received and were kept constant in the examples and comparative examples unless otherwise indicated. In Comparative Example F a different type of VI improver was used, a polyisobutylene VI improver employed at a treat rate of 3.5% vol%, as received (90% active ingredient).

Comparative Example A

[0055] ATF blend "A" comprised only a "first base stock" having a viscosity index (VI) of 117. The Brookfield was 41,391 mPa.s at -40°C. The Brookfield was well above the specification target of 15,000 cP.

Comparative Examples B, C, D

[0056] ATF blends "B", "C" and "D" comprised a "first base stock" having a viscosity index (VI) of 118 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 116, 116 and 116 respectively. The Brookfield for the three ATFs were 16,297 and 16,836 and 17,436 cP respectively. The Brookfields were above the specification target of 15,000 cP.

Comparative Example E

[0057] ATF blend "E" comprises a single "first base stock" having a viscosity index of 126 and a KV at 100°C of 5.053. On its face, therefor, this single base stock would appear to meet the viscometric requirements established for the base stock blend of the present invention (the target KV at 100°C and VI for blended oils being 4.0 to about 5.5 mm^2/s and about 120 to 150 respectively). The ATF made using only the single base stock had Brookfield Viscosity at -40°C of 17,466 cP, well above the specification target of 15,000 cP. This demonstrates that a blend of base stocks is necessary to achieve a final ATF formulation meeting the taught viscometric specification.

Comparative Example F

[0058] ATF blend F comprised a "first base stock" having a viscosity index (VI) of 130 and a "second base stock" having a VI of 107. The resulting "base oil" had a VI of 124 and a KV at 100°C of 4.582. A PIB VI improver was employed at a treat rate of 3.5 vol%, as received (90% active ingredient). The VI improver had an SSI, as measured by the KRL technique recited herein, of about 9, and a molecular weight of about 2,000. The Brookfield viscosity of the ATF was 22,245 cP @ -40°C, well above the specification target of 15,000 cP.

Inventive Examples 1, 2, 3

[0059] ATF blends "1", "2" and "3" comprised a "first base stock" having a viscosity index (VI) of 129 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 124, 124 and 124 respectively. The Brookfield for the three ATFs were 13,357 and 14,317 and 14,657 cP respectively. The Brookfields met the specification target of 15,000 cP.

Inventive Examples 4, 5, 6

[0060] ATF blends "4", "5" and "6" comprised a "first base stock" having a viscosity index (VI) of 126 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 122, 123 and 123 respectively. The Brookfield for the three ATFs were 13,117 and 12,927 and 14,377 cP respectively. The Brookfields met the specification target of 15,000 cP.

Inventive Examples 7, 8, 9

[0061] ATF blends "7", "8" and "9" comprised a "first base stock" having a viscosity index (VI) of 130 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 124, 125 and 125 respectively. The Brookfield for the three ATFs were 11,798 and 12,197 and 12,907 cP respectively. The Brookfields met the specification target of 15,000 cP.

Inventive Examples 10, 11, 12

[0062] ATF blends "10", "11" and "12" comprised a "first base stock" having a viscosity index (VI) of 147 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 134, 137 and 134 respectively. The Brookfield for the three ATFs were 10,898 and 11,098 and 11,967 cP respectively. The Brookfields met the specification target of 15,000 cP.

Inventive Examples 13, 14, 15

[0063] ATF blends "13", "14" and "15" comprised a "first base stock" having a viscosity index (VI) of 148 and three different "second base stocks" having a VI of 107, 101 and 107 respectively. The resulting "base oil" blends had a VI of 135, 138 and 136 respectively. The Brookfield for the three ATFs were 11,018 and 9,758 and 10,138 cP respectively. The Brookfields met the specification target of 15,000 cP.

[0064] Comparative Examples A to D demonstrate that a blend of various "first base stocks" and "second base stocks", having a resultant "base oil" viscosity index of less than about 120 gave a finished ATF Brookfield of greater than the target of 15,000 cP at -40°C.

[0065] Comparative Example E demonstrates that an ATF formulated from a single base stock, even a stock which by itself meets the viscometric properties required of the base stock blend (KV100 between 4.0-5.5, VI of 120-150, pour point of -12°C maximum), does not meet the viscometric property requirement for the finished AFT, having a finished ATF Brookfield Viscosity of greater than the target of 15,000 cP at -40°C.

[0066] Inventive Examples 1 to 15 demonstrate that a blend of various "first base stocks" and "second base stocks", having a resultant "base oil" viscosity index of about 120 or greater gave a finished ATF Brookfield of less than 15,000 cP at -40°C.

[0067] The shear stability attributes of this invention can be illustrated by the following non-limiting examples. A blend was made according to the recipe shown in Table 3 below. The kinematic viscosity before shear was 5.58 mm^2/s at 100°C. The after shear viscosity was 5.50 mm^2/s at 100°C. Using the Shear Stability Index equation presented above, the SSI of the viscosity index improver was determined to be 8. The Shear Parameter using the SP equation above was calculated to be 5.05.

TABLE 3

	Vol%
First base stock ("D")	51.8
Second base stock ("X")	39.3
Viscosity Index Improver	1.5
Additive Package	7.4
	Result
Kinematic Viscosity, mm^2/s at 100°C (fluid before KRL shear)	5.58
Kinematic Viscosity, mm^2/s at 100°C (fluid after 40 hours KRL shear)	5.50
Shear Stability Index (SSI) (measured)	8
Base Oil Viscosity, mm^2/s at 100°C	4.59
Shear Parameter, mm^2/s at 100°C	5.05
Brookfield Viscosity, cP at mm^2/s at 100°C	12,750

[0068] The SSI equation given above can be algebraically rearranged to give

$$\mu_f = \mu_i - [\frac{SSI}{100} * (\mu_i - \mu_0)]$$

Thus the ATF after shear viscosity can be calculated by knowing the ATF initial viscosity, the base oil viscosity, and the shear stability index (SSI) for a given viscosity index improver polymer. Calculations using this equation are shown in Table 4.

[0069] The first row in Table 4 is the actual experimental data from Table 3, recorded here for comparative purposes for the calculations that are given in the following rows.

[0070] Assuming an SSI of 15, and using the ATF before shear viscosity (5.58) and base oil viscosity (4.59) from Table 3, the after shear viscosity of the oil if one used a viscosity index improver having a SSI of 15 can be calculated to be 5.43 cSt. Using the SP equation above, the shear parameter is calculated to be 5.01 cSt.

[0071] Similarly, Table 4 shows the calculated after shear viscosities and shear parameters for different VII having a range of assumed SSI values of 25, 35, 55 and 75.

[0072] The data in Table 4 shows that an SSI less than 35, more preferably less than 25 and most preferably less than 15 is necessary to meet the target shear parameter requirements for the ATF.

TABLE 4

Shear Stability Index (SSI)	ATF After Shear Viscosity @ 100°C	ATF Shear Parameter @ 100°C
8	5.50	5.05
15	5.43	5.01
25	5.33	4.96
35	5.23	4.91
55	5.04	4.81
75	4.84	4.71
ATF Before Shear Viscosity @ 100°C (mm^2/s) = 5.58 Base Oil Blend Viscosity @ 100°C (mm^2/s) = 4.59		

Claims

1. A functional fluid comprising:

(A) a mixture of at least two base stocks, said mixture comprising

(i) at least one first base stock having a kinematic viscosity of at least 4.5 to about 8.0 mm^2/sec at 100°C, a viscosity index of at least 120 to about 160, a pour point of about -12°C maximum, a saturates content of greater than about 98 mass %;

(ii) at least one second base stock having a kinematic viscosity of about 2.0 to about 4.5 mm^2/sec at 100°C, a viscosity index of about 100 to about 120, a pour point of about -12°C maximum, a saturates content of greater than about 98 mass %;

wherein the first base stock is present in the amount of about 40 vol% to about 90 vol% based on the stock, wherein the second base stock is present in the amount of about 10 vol% to about 60 vol% based on the stock, wherein the first base stock (i) and second base stock (ii) are not the same; and

(B) said base oil mixture (being a blend of base stocks as defined above) has a kinematic viscosity of about 4.0 to about 5.5 mm^2/sec at 100°C, a viscosity index of about 120 to about 150, a pour point of about -12°C maximum;

(C) at least one viscosity index improver having a shear stability index (SSI) less than 35, as measured in the KRL Tapered Roller Bearing Tester according to procedure CEC-L-45-T-93, said SSI being defined by the equation

$$\text{SSI}=\frac{(\mu_i - \mu_f)}{(\mu_i - \mu_0)} * 100$$

where

μ_i - Initial fluid viscosity @ 100°C (fully blended ATF)

μ_f - Final after-shear fluid viscosity @ 100°C (fully blended ATF)

μ_0 - Base oil viscosity @ 100°C (blend of two or more base stocks without any additives);

(D) an additive package;

(E) the resulting additized functional fluid having, a kinematic viscosity of about 5.0 to about 6.5 mm^2/sec at 100°C, a viscosity index of about 120 to about 180, a pour point of about less than -42°C maximum, and a Brookfield viscosity of about 15,000 cP or less at -40°C;

(F) the resulting additized functional fluid having, an after KRL shear parameter (SP) of about 4.9 to about 5.6 mm^2/sec at 100°C as defined by

$$SP = \frac{(\mu_f + \mu_0)}{2}$$

where

μ_f - Final after-shear fluid viscosity @ 100 °C (fully blended ATF)

μ_0 - Base oil viscosity @ 100 °C (blend of two or more base stocks without any additives).

2. The functional fluid of claim 1 wherein base stock (i) has a kinematic viscosity of about 4.5 to about 7.0 mm^2/s at 100°C, a viscosity index in the range of about 125 to about 150, a pour point of less than about -15°C.

3. The functional fluid of claim 1 wherein base stock (i) has a kinematic viscosity of about 5.0 to about 7.0 mm^2/s at 100°C, a viscosity index in the range of about 125 to about 150, a pour point of less than -18°C.

4. The functional fluid of claim 1, 2 or 3 wherein base stock (ii) has a kinematic viscosity of about 2.5 to about 4.0 mm^2/s at 100°C, a viscosity index in the range of about 100 to about 115, a pour point of less than -15°C.

5. The functional fluid of claim 1, 2 or 3 wherein base stock (ii) has a kinematic viscosity of about 2.5 to about 3.5 mm^2/s at 100°C, a viscosity index in the range of about 100 to about 110 and a pour point of less than -18°C.

6. The functional fluid of any preceding claim wherein the viscosity index improver has a shear stability index (SSI) of less than 25.

7. The functional fluid of any preceding claim wherein the viscosity index improver has a shear stability index (SSI) of less than 15.

8. The functional fluid of any preceding claim wherein the additized functional fluid has an after KRL shear parameter (SP) of about 4.95 to about 5.4 mm^2/s at 100°C.

9. The functional fluid of any preceding claim wherein the additized functional fluid has an after KRL shear parameter (SP) of about 4.98 to about 5.2 mm^2/s at 100°C.

10. The functional fluid of any preceding claim wherein the base oil mixture (B) has a kinematic viscosity of at least about 4.5 to about 5.5 mm^2/s at 100°C.

11. The functional fluid of claim 1 wherein the viscosity index improver is a PAMA.