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(54) BASE OIL FOR COOLING DEVICE, DEVICE-COOLING OIL CONTAINING THE BASE OIL, DEVICE TO BE COOLED BY THE COOLING OIL, AND DEVICE COOLING METHOD USING THE COOLING OIL

(57) A base oil for cooling a device contains a hydrocarbon compound at 30 mass% or more and exhibits a kinematic viscosity of 4 mm^2/s to 30 mm^2/s at 40 degrees C. The total number of a terminal methyl group(s) and a methylene group(s) in a main chain of the hydrocarbon compound is 16 or more. The total number of a methyl branch and an ethyl branch in the molecule is one or less. A device-cooling oil provided by blending the base oil is excellent in electrical insulation properties and thermal conductivity, and thus is favorably usable for cooling a motor, a battery, an inverter, an engine, an electric cell or the like in an electric vehicle, a hybrid vehicle or the like.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a base oil for cooling a device, a device-cooling oil using the base oil, a device to be cooled by the device-cooling oil, and a device cooling method using the device-cooling oil.

BACKGROUND ART

[0002] An improvement in the performance of electric vehicles and hybrid vehicles results in an increase in the power density and, consequently, the heat generation of a motor. Accordingly, coil, magnet and the like have been improved in heat resistance and, further, a variety of modifications in motor design have been made for, for instance, reducing the increased heat generation resulting from the improved performance of a motor.

For cooling a motor, there have been suggested three types of methods, i.e., an air-cooling method, a water-cooling method and an oil-cooling method. Among the above, the air-cooling method advantageously does not require any specific coolant to be prepared, but is unlikely to provide a large cooling capacity. The water-cooling method is excellent in cooling performance because water exhibits a high thermal conductivity. However, since a motor coil cannot be directly cooled because of the electrical conductivity of water, a cooling pipe has to be laid out, which, disadvantageously, increases the size of a cooling device.

As compared with the above cooling methods, the oil-cooling method uses oil, which is excellent in cooling efficiency and low in electrical conductivity, so that the oil-cooling method enables directly cooling a motor, resulting in a compact design. Additionally, when lubrication of a rotary member is simultaneously required, an oil for cooling the motor is usable as a dual-purpose oil not only for cooling but also for lubrication (i.e., the same packaging). For instance, hybrid vehicles in practice use a mechanism for circulating a transmission oil to simultaneously cool a motor. Some wheel-driving motors for electric vehicles have been modified in design such that a lubricating oil is circulated not only for lubricating a planetary gear but also for cooling a motor coil.

[0003] As such a dual-purpose oil usable for cooling a motor while lubricating a transmission or the like, there has been suggested, for instance, a lubricating oil composition provided by blending a low-viscosity mineral oil or synthetic oil with at least one of (A) zinc dithiophosphate containing a hydrocarbon group, (B) triaryl phosphate and (C) triaryl thiophosphate (see Patent Literature 1). Additionally, as the dual-purpose oil, there have been suggested: a lubricating oil composition using a base oil that has a urea adduct value of 4 mass% or less, a kinematic viscosity of 25 mm^2/s or less at 40 degrees C and a viscosity index of 100 or more, the lubricating oil composition having a heat transfer coefficient of 720 W/m^2·degrees C or more (see Patent Literature 2); and a lubricating oil composition using a base oil that contains an ester synthetic oil of 10 mass% to 100 mass% of the total amount of the base oil and has a kinematic viscosity of less than 15 mm^2/s at 40 degrees C, a viscosity index of 120 or more and a density of 0.85 g/cm^3 or more at 15 degrees C, the lubricating oil composition having a heat transfer coefficient of 780 W/m^2·degrees C or more (see Patent Literature 3). Each of Patent Literatures 1, 2 and 3 discloses that the suggested lubricating oil composition is excellent in electrical insulation properties, cooling properties and lubricity and is favorably usable for electric motor vehicles such as electric vehicles and hybrid vehicles.

CITATION LIST

PATENT LITERATURE(S)

[0004]

Patent Literature 1: WO20021097017
Patent Literature 2: JP-A-2009-161604
Patent Literature 3: JP-A-2009-242547

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005] In connection with the cooling properties of the lubricating oil composition, Patent Literature 1 does not teach anything but lowering the viscosity of the lubricating oil composition, and does not even show data on cooling properties. Additionally, neopentylglycol 2-ethyl hexanoic acid diester and alkylbenzene, which are used as base oils in Examples of Patent Literature 1, are unlikely to exhibit excellent cooling properties because of their poor thermal conductivity.

Patent Literature 2 teaches in paragraph [0020] that "as an urea adduct, a component that deteriorates thermal conductivity... is accurately and reliably collected." In other words, contrarily to the fact, Patent Literature 2 teaches that a urea adduct component deteriorates thermal conductivity. It is probably wrong that "a component having a long paraffin main chain exhibits a poor thermal conductivity." In view of the above, it is doubtful whether or not Patent Literature 2 discloses a lubricating oil composition excellent in cooling properties. Patent Literature 3 discloses that a base oil is specifically an ester compound, which is low in volume resistivity, i.e., poor in electrical insulation properties, and thus is not so favorably usable as an oil for cooling a motor.

[0006] An object of the invention is to provide: a base oil having excellent electrical insulation properties and thermal conductivity for cooling a device; a device-cooling oil using the base oil; a device to be cooled by the device-cooling oil; and a device cooling method using the device-cooling oil

MEANS FOR SOLVING THE PROBLEMS

[0007] As a measure of the cooling properties of a fluid, "heat transfer coefficient (heat transfer amount per unit area, unit temperature and unit time)" is usable. A fluid having a higher value of heat transfer coefficient exhibits better cooling properties. Since heat transfer coefficient is not physical properties but is variable depending on conditions such as flow rate and material type, modifications in design for increasing heat transfer coefficient have been made.

For increasing heat transfer coefficient by modifications in terms of a fluid, it should be noted that since heat transfer coefficient is variable in relation to Nusselt number, Reynolds number and Prandt1 number, the cooling properties of a fluid are affected by the physical properties of the fluid such as kinematic viscosity, thermal conductivity, specific heat and density. Specifically, a fluid having smaller kinematic viscosity but larger thermal conductivity, specific heat and density exhibits better cooling properties. Accordingly, it has been considered to lower the viscosity of a fluid (e.g., a lubricating oil) for improving the cooling properties thereof. However, when the viscosity of a lubricating oil is lowered, the cooling properties are improved but a sufficient film thickness of the lubricating oil cannot be provided, thereby causing lubrication failure. In view of the above, the minimum viscosity is determined depending on conditions regarding a portion to be lubricated in a transmission or the like. Thus, among lubricating oils having the same kinematic viscosity, one having larger thermal conductivity, specific heat and density has better cooling properties. For instance, a heat transfer coefficient during forced convection of a plate having a uniform temperature is proportional to the thermal conductivity to the power of two thirds, the specific heat to the power of one third and the density to the power of one third, so that the heat transfer coefficient is the most affected by the thermal conductivity.

[0008] In view of the above, a base oil having a high thermal conductivity is favorable for a cooling oil usable in a device such as a motor. However, a correlation between the molecular structure and the thermal conductivity of a base oil has not been studied. Regarding basic low-molecular compounds, there is only a small amount of information available. Specifically, alcohols such as glycerin, ethyleneglycol and methanol are excellent in thermal conductivity as described in Kagaku Binran ("Handbook of Chemistry"). However, polar compounds such as alcohols exhibit a poor volume resistivity (poor electrical insulation properties), so that they are not usable as a cooling oil for directly cooling a device such as motor. Additionally, they are not expected to be usable as a lubricating oil because of a lack of lubricity.

As a result of concentrated studies in terms of molecular design, the inventor has found that a hydrocarbon compound having a predetermined molecular structure is excellent in cooling properties, electrical insulation properties and lubricity. In other words, according to the invention, there are provided: a base oil for cooling a device; a device-cooling oil using the base oil; a device to be cooled by the device-cooling oil; and a device cooling method using the device-cooling oil, as described below.

[0009]

(1) A base oil for cooling a device, containing a hydrocarbon compound at 30 mass% or more and exhibiting a kinematic viscosity of 4 mm^2/s to 30 mm^2/s at 40 degrees C, in which a total number of a terminal methyl group and a methylene group in a main chain of the hydrocarbon compound is 16 or more, and a total number of a methyl branch and an ethyl branch in a molecule of the hydrocarbon compound is one or less.

(2) In the base oil of (1), it is preferable that a total number of the methylene group in the main chain is 16 or more.

(3) In the base oil of (1) or (2), it is preferable that the hydrocarbon compound has a chain structure.

(4) In the base oil of any one of (1) to (3), it is preferable that the hydrocarbon compound has a saturated structure.

(5) In the base oil of any one of (1) to (3), it is preferable that the hydrocarbon compound has an unsaturated structure.

(6) In the base oil of any one of (1) to (5), it is preferable that a thermal conductivity of the base oil at 25 degrees C is 0.138 W/(m·K) or more.

(7) In the base oil of any one of (I) to (6), it is preferable that a volume resistivity of the base oil at 25 degrees C is $10^{13}\Omega\cdot cm$ or more.

(8) A device-cooling oil containing the base oil of any one of (1) to (7).

(9) A device configured to be cooled by the device-cooling oil of (8).

(10) Preferably, the device of (9) is usable for an electric vehicle or a hybrid vehicle.
(11) Preferably, the device of (9) or (10) is at least one of a motor, a battery, an inverter, an engine and an electric cell.
(12) A device cooling method using the device-cooling oil of (8).

ADVANTAGEOUS EFFECT OF THE INVENTION

[0010] A device-cooling oil provided by blending a base oil for cooling a device according to the invention is excellent in electrical insulation properties and thermal conductivity, and thus is favorably usable for cooling a motor, a battery, an inverter, an engine, an electric cell or the like in an electric vehicle, a hybrid vehicle or the like.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

Fig. 1 shows a gaschromatograph of a compound used in Example 2 according to the invention.
Fig. 2 shows a gaschromatograph of a compound used in Comparative Example 1 according to the invention.

DESCRIPTION OF EMBODIMENT(S)

[0012] A base oil for cooling a device according to an exemplary embodiment of the invention (hereinafter also referred to simply as "base oil") contains a hydrocarbon compound at 30 mass% or more and exhibits a kinematic viscosity of 4 mm^2/s to 30 mm^2/s at 40 degrees C. The total number of a terminal methyl group(s) and a methylene group(s) in a main chain of the hydrocarbon compound is 16 or more. The total number of a methyl branch and an ethyl branch in the molecule is one or less. The "main chain" herein means a portion having the longest chain structure in the molecule.
The exemplary embodiment will be explained in detail below.

[0013] For improving the thermal conductivity of liquid molecules, it is important to accelerate the transfer of thermal vibration energy resulting from collision between the molecules and to design the molecules such that the vibration energy is not dispersed in the molecules. In order to increase the frequency of collision between the molecules, it is effective to elongate the main chain of each molecule, thereby increasing the movable range of the molecule end based on a rotation around a carbon-carbon bond. Specifically, in order to keep the vibration energy being concentrated in the main chain of each molecule without dispersing in the molecule, methyl branch and ethyl branch, which are short in length and cause dispersion of the vibration energy, are decreased in number. Additionally, the methyl group and the ethyl group are not favorable for collision with the adjacent molecules (energy transfer) because of a small movable range thereof. A preferable example of the molecule having the above structure is a hydrocarbon compound having a long chain molecule.

[0014] Accordingly, in the exemplary embodiment, a main component of a base oil is provided by a hydrocarbon compound in which the total number of a terminal methyl group(s) and a methylene group(s) in the main chain is 16 or more and the total number of a methyl branch and an ethyl branch in the molecule is one or less. The number of the methylene group in the hydrocarbon compound is preferably 16 or more in terms of an enhancement of cooling properties.
The hydrocarbon compound preferably has a chain structure, more preferably has a straight-chain structure, in terms of an enhancement of the cooling properties of the base oil. The hydrocarbon compound may be saturated or unsaturated.

[0015] The hydrocarbon compound may be provided by a typical alpha-olefin oligomer. The alpha-olefin oligomer may be hydrogenated. As the alpha olefin, 1-octen, 1-decene, 1-dodecene and 1-tetradecene are usable.
As an oligomerization catalyst, a typical BF_3 complex catalyst, a solid acid catalyst or the like may be usable. However, using such catalysts may cause generation of a skeletal isomer having a lot of branches, so that it is unlikely to obtain a product having a desired structure. In view of the above, a metallocene complex catalyst is preferably usable because the catalyst is unlikely to cause skeletal isomerization.
For hydrogenating the oligomer, for instance, typical nickel catalysts such as a sponge nickel and a nickel diatomaceous earth and noble metal catalysts such as a palladium activated carbon and a ruthenium activated carbon are favorably usable. It should be noted that the catalyst used herein is not particularly limited in type and thus may be a supported catalyst, a complex catalyst or the like.

[0016] In the exemplary embodiment, the content of the base oil, which contains the hydrocarbon compound at 30 mass% or more, is preferably 50% or more, more preferably 60 mass% or more, further preferably 70 mass% or more, particularly preferably 80 mass% or more. If the base oil contains the hydrocarbon compound at less than 30 mass%, the cooling performance will not be sufficiently provided. It should be noted that a base oil for cooling a device may be provided only by the base oil of the exemplary embodiment (100 mass%).

[0017] According to the exemplary embodiment, the kinematic viscosity of the base oil at 40 degrees C is in a range from 4 mm^2/s to 30 mm^2/s, preferably in a range from 4 mm^2/s to 20 mm^2/s. If the kinematic viscosity of the base oil at

40 degrees C is less than 4 mm^2/s, for instance, when the base oil is used for a dual-purpose oil not only for a motor but also for a transmission or the like, a lack of lubricity may occur. On the other hand, if the kinematic viscosity of the base oil at 40 degrees C exceeds 30 mm^2/s, the cooling properties may be insufficient. Additionally, when such a base oil is used for a cooling oil for a motor or the like, the cooling oil is unlikely to smoothly circulate within a system or the like.

[0018] According to the exemplary embodiment, the thermal conductivity of the base oil at 25 degrees C is preferably 0.138 W/(m·K) or more, more preferably 0.139 W/(m·K) or more, in consideration of cooling properties.

According to the exemplary embodiment, the volume resistivity of the base oil at 25 degrees C is preferably 10^{13} Ω·cm or more in terms of insulation, more preferably 10^{14} Ω·cm or more

[0019] The base oil of the exemplary embodiment may be provided by blending the hydrocarbon compound with an additional component (base oil). In this case, the additional component is not particularly limited in type. However, even after blending the additional component, the viscosity range, the cooling properties, the insulation properties and the lubricity should be maintained as described above and the advantages of the invention should be achieved.

Preferable examples of the additional component are a mineral oil and a synthetic oil. Examples of the mineral oil are a naphthenic mineral oil, a paraffinic mineral oil, a GTL mineral oil and a WAX-isomerized mineral oil. Specifically, the mineral oil is exemplified by a light neutral oil, a medium neutral oil, a heavy neutral oil and a bright stock, which are provided by solvent refining or hydrogenation refining.

Examples of the synthetic oil are polybutene and a hydrogenated product thereof, poly-alpha-olefin (e.g., 1-octene oligomer and 1-decene oligomer) and a hydrogenated product thereof, alpha-olefin copolymer, alkylbenzene, polyol ester, dibasic ester, polyoxyalkylene glycol, polyoxyalkylene glycol ester, polyoxyalkylene glycol ether, hindered ester, and silicone oil.

[0020] A device-cooling oil using the base oil of the exemplary embodiment is favorably usable for cooling a motor, a battery, an inverter, an engine and an electric cell or the like in an electric vehicle, a hybrid vehicle or the like. Since the viscosity of the base oil at 40 degrees C is in the above predetermined range, the device-cooling oil is excellent in lubricity, and thus is favorably usable as a dual-purpose oil not only for cooling but also for lubricating a planetary gear, a transmission or the like.

A variety of additives may be blended in the device-cooling oil of the exemplary embodiment as long as an object of the invention is attainable. For instance, a viscosity index improver, an antioxidant, a detergent dispersant, a friction modifier (e.g., an oiliness agent and an extreme pressure agent), an antiwear agent, a metal deactivator, a pour point depressant, and an antifoaming agent can be blended as needed. It should be noted that when the device-cooling oil is used as a dual-purpose oil, the respective blending ratios of the additives should be determined such that the device-cooling oil can exhibit lubricating properties while maintaining electrical insulation properties. In view of the above, the respective blending ratios are preferably determined such that the device-cooling oil has a thermal conductivity at 25 degrees C of 0.138 W/(m·K) or more, a volume resistivity at 25 degrees C of 10^{13}Ω·m or more, and a kinematic viscosity at 40 degrees C of 4 mm^2/s to 30 mm^2/s.

[0021] Examples of the viscosity index improver are a non-dispersive polymethacrylate, a dispersive polymethacrylate, an olefin copolymer (e.g., an ethylene-propylene copolymer), a dispersive olefin copolymer, and a styrene copolymer (e.g., a styrene-diene copolymer hydride). When the dispersive or non-dispersive polymethacrylate is used as the viscosity index improver, the mass average molecular weight of the viscosity index improver is preferably in a range from 5,000 to 300,000. When the olefin copolymer is used, the mass average molecular weight is preferably in a range from 800 to 100,000. One of these viscosity index improvers may be singularly blended or a combination thereof may be blended. The content of the viscosity index improver(s) is preferably in a range from 0.1 mass% to 20 mass% of the total amount of the cooling oil.

[0022] Examples of the antioxidant are: amine antioxidants such as alkylated diphenylamine, phenyl-alpha-naphthylamine, and alkylated phenyl-alpha-naphthylamine; phenol antioxidants such as 2,6-di-t-butylphenol, 4,4'-methylenebis (2,6-di-t-butylphenol), isooctyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, and n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate; sulfur-based antioxidants such as dilauryl-3,3'-thiodipropionate; phosphorus-based antioxidants such as phosphite; and molybdenum-based antioxidants. One of these antioxidants may be singularly blended or a combination thereof may be blended. Preferably, two or more of these antioxidants are blended in combination and the content thereof is in a range from 0.01 mass% to 5 mass% of the total amount of the cooling oil.

[0023] Examples of the detergent dispersant are: metal-based cleaners such as alkaline earth metal sulfonate, alkaline earth metal phenate, alkaline earth metal salicylate, and alkaline earth metal phosphonate; and ashless dispersants such as alkenyl succinimide, benzylamine, alkylpolyamine, and alkenyl succinimide ester.

One of these detergent dispersants may be singularly blended or a combination of two or more thereof may be blended. The content of the detergent dispersant(s) is preferably in a range from 0.1 mass% to 30 mass% of the total amount of the cooling oil.

[0024] Examples of the friction modifier or the antiwear agent are: sulfur compounds such as olefin sulfide, dialkyl polysulfide, diarylalkyl polysulfide, and diaryl polysulfide; phosphorus compounds such as phosphate, thiophosphate, phosphite, alkyl hydrogen phosphite, phosphate amine salt, and phosphite amine salt; chloride compounds such as chlorinated fat and oil, chlorinated paraffin, chlorinated fatty acid ester, and chlorinated fatty acid; ester compounds such as alkyl or alkenyl maleate, and alkyl or alkenyl succinate; organic acid compounds such as alkyl or alkenyl maleic acid, and alkyl or alkenyl succinic acid; and organic metal compounds such as naphthenic acid salt, zinc dithiophosphate (ZnDTP), zinc dithiocarbamate (ZnDTC), sulfurized oxymolybdenum organophosphorodithioate (MoDTP), and sulfurized oxymolybdenum dithiocarbamate (MoDTC). The content of the friction modifier or the antiwear agent is preferably in a range from 0.1 mass% to 5 mass% of the total amount of the cooling oil.

[0025] Examples of the metal deactivator are benzotriazole, triazole derivative, benzotriazole derivative, and thiadiazole derivative. The content of the metal deactivator is preferably in a range from 0.01 mass% to 3 mass%.

Examples of the pour point depressant are an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and naphthalene, a condensate of chlorinated paraffin and phenol, polymethacrylate, and polyalkylstyrene, among which polymethacrylate is preferably usable. The content of the pour point depressant is preferably in a range from 0.01 mass% to 5 mass% of the total amount of the cooling oil.

As the antifoaming agent, a liquid silicone is suitable and, specifically, methylsilicone, fluorosilicone, polyacrylate and the like are preferably usable. The content of the antifoaming agent is preferably in a range from 0.0005 mass% to 0.01 mass% of the total amount of the cooling oil.

Examples

[0026] Next, the invention will be further described in detail based on Examples, which by no means limit the invention. Specifically, base oils shown in Table 1 were prepared and evaluated. A preparation method and an evaluation method (a physical properties measuring method) for the base oils are as follows.

[0027]

Table 1

	Ex. 1	Ex. 2	Ex. 3	Comp. 1	Comp.2	Comp. 3	Comp. 4	Comp. 5
Base Oil (Compound Name)	Decene Dimer	Hydrogenated Decene Dimer	Hydrogenated Decene Trimer/ Hydrogenated Decene Dimer (72/28) Mixture	Commercially Available PAO Durasyn 162	Purified Mineral Oil of Gr. II	Soft Dodecylbenzene	n-dodecane	Neopentyl Glycol 2-Ethyl Hexanoic Acid Diester
Total Number of Terminal Methyl Group & Methylene Group in Main Chain	18	18	18.7 (Average)	Mixture (app. 16 to 17)	Mixture	Mixture (<12)	12	10
Total Number of Methyl Branch & Ethyl Branch in Molecule	0	1	1	Mixture (app. 2 to 3)	Mixture (Many)	Mixture (Many)	0	4
Thermal Conductivity (25°C), W/m·K	0.141	0.139	0.142	0.133	0.130	0.124	0.129	0.123
Volume Resistivity (25°C), W·cm	4.6E+14	1.9E+15	1.9E+15	4.9E+14	1.28+15	9.8E+14	1.3E+15	2.9E+12
Kinematic Viscosity (40°C), mm^2/s	4.456	5.026	10.39	5.380	9.898	4.256	1.448	7.486
Kinematic Viscosity (100°C), mm^2/s	1.684	1.799	2.889	1.776	2.722	1.438	0.7414	2.076
Viscosity Index	-	-	132	-	116	-	-	58
Density (15°C), g/cm^3	0.8019	0.7922	0.8074	0.7982	0.8265	0.8605	0.7529	0.9185
Flash Point, °C	-	178	-	145	-	-	-	-

Example 1

[0028] A 1-decene dimer manufactured using a metallocene catalyst (manufactured by IDEMITSU KOSAN CO., LTD., trade name: LINEALENE DIMER™ A-20) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, density and volume resistivity).

Example 2

[0029] A hydrogenated 1-decene dimer manufactured using a metallocene catalyst (manufactured by IDEMITSU KOSAN CO., LTD., trade name: LINEALENE PAO™ A-20H) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, density, volume resistivity and flash point). Fig. 1 shows a gaschromatograph. Referring to Fig. 1, the hydrogenated 1-decene dimer is obviously a highly pure single composition.

Example 3

[0030] A hydrogenated 1-decene dimer (manufactured by IDEMITSU KOSAN CO., LTD., trade name: LINEALENE PAO™ A-20H) and a hydrogenated 1-decene trimer (manufactured by IDEMITSU KOSAN CO., LTD., trade name: LINEALENE PAO™ A-30H), both being manufactured using a metallocene catalyst, were blended together at a mass ratio of 28/72, and the resulting mixture was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, viscosity index, density and volume resistivity). In the hydrogenated trimer, the total number of a terminal methyl group(s) and a methylene group(s) in the main chain is 19 and the total number of a methyl branch and an ethyl branch group is one. In the hydrogenated dimer, the total number of a terminal methyl group(s) and a methylene group(s) in the main chain is 18 and the total number of a methyl branch and an ethyl branch group is one.

Comparative Example 1

[0031] A commercially available polyalphaolefin (manufactured by INEOS Group Limited, trade name: Durasyn 162) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, density, volume resistivity and flash point). Fig. 2 shows a gaschromatogram.

Comparative Example 2

[0032] A purified mineral oil of Group II (manufactured by IDEMITSU KOSAN CO., LTD.) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, viscosity index, density and volume resistivity).

Comparative Example 3

[0033] A soft dodecylbenzene (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, density and volume resistivity).

Comparative Example 4

[0034] n-dodecane (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent) was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, density and volume resistivity).

Comparative Example 5

[0035] In a 500 mL four-necked flask with a Dean-Stark apparatus, 173 g of 2-ethyl hexanoic acid (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent), 52 g of neopentyl glycol (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent), 0.1 g of titanium tetraisopropoxide (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent) and 100 cc of xylene (manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD., reagent) were mixed, and reacted together under a nitrogen gas stream at 160 degrees C for four hours while water was distilled away. Subsequently, after being cleansed with saturated saline for three times and with 0.1N sodium hydroxide for three times, the reactant was dried with anhydrous magnesium sulfate. After the magnesium sulfate was filtered away, unreacted 2-ethyl hexanoic acid was distilled away under reduced pressure to obtain 155 g of neopentyl glycol diester of 2-ethyl hexanoic acid. The obtained compound was measured in terms of the physical properties thereof (i.e., thermal conductivity, kinematic viscosity, viscosity index, density and volume resistivity).

Physical Properties Measuring Method

(1) Thermal Conductivity

[0036] Using a thermal properties analyzer KD2 Pro manufactured by DECAGON DEVICES, Inc. thermal conductivity was measured was measured by a single needle sensor at room temperature (25 degrees C).

(2) Volume Resistivity

[0037] Volume resistivity was measured at room temperature (25 degrees C) in accordance with JIS (Japanese Industrial Standards) C2101, 24 (Volume Resistivity Test).

(3) Kinematic Viscosity

[0038] Kinematic viscosity was measured in accordance with "Test Method for Petroleum Products Kinematic Viscosity" defined in JIS K2283.

(4) Viscosity Index

[0039] Viscosity index was measured in accordance with "Test Method for Petroleum Products Kinematic Viscosity" defined in JIS K2283.

(5) Density

[0040] Density was measured in accordance with JIS K2249, "Crude Oil and Petroleum Product-Density Test Method".

(6) Flash Point

[0041] Flash point was measured by the C. O. C. method in accordance with JIS K2265. (7) Total Number of Terminal Methyl Group and Methylene Group in Main Chain and Total Number of Methyl Branch and Ethyl Branch in Molecule Using AL-400 NMR manufactured by JEOL Ltd., each of total numbers was obtained from the integrated intensity of a proton signal of the relevant functional group.

Evaluation Result

[0042] As is obvious from the results shown in Table 1, in each of the base oils (compounds) of Examples 1 to 3 according to the invention, the total number of a terminal methyl group(s) and a methylene group(s) in the main chain was 16 or more and the total number of a methyl branch and an ethyl branch in the molecule was one or less, so that these base oils were excellent in thermal conductivity (cooling properties) and electrical insulation properties. Further, these base oils were excellent in lubricating properties because the kinematic viscosities thereof were within the predetermined range. Thus, it is understandable that a cooling oil using the base oil according to the invention is favorably usable as a dual-purpose oil not only for cooling a motor, a battery, an inverter, an engine, an electric cell or the like in an electric vehicle or a hybrid vehicle but also for lubricating a transmission or the like.
In contrast, as shown in Fig. 2, the base oil of Comparative Example 1, which was a commercially available PAO, had a lot of isomers and, further, the total number of methyl branch and ethyl branch therein obtained from ^{1}H-NMR was large, so that the thermal conductivity was degraded and the flash point was lowered. The base oil of Comparative Example 2, which was a purified mineral oil, had a poor thermal conductivity because the mineral oil was a mixture of a lot of components. The base oil of Comparative Example 3 was the soft dodecylbenzene, i.e., a mixture with a lot of isomers, so that the thermal conductivity was degraded because of the short main chain thereof and the large total number of the methyl branch and ethyl branch in the molecule. The base oil of Comparative Example 4, which was an n-dodecane, had neither a methyl branch nor an ethyl branch, but had a poor thermal conductivity because of a short main chain thereof. The base oil of Comparative Example 5, which was an ester of a polyhydric alcohol, had a poor thermal conductivity because of the large total number of the methyl branch and the ethyl branch in the molecule. Further, the base oil of Comparative Example 5 had poor electrical insulation properties. It should be noted that the base oils (compounds) used in Comparative Examples 1, 3 and 5 were the same as the base oils used in Examples of Patent Literature 1 mentioned in the Background Art.

INDUSTRIAL APPLICABILITY

[0043] The invention is applicable to a base oil for cooling a device, a device-cooling oil using the base oil, a device to be cooled by the device-cooling oil, and a device cooling method using the device-cooling oil.

Claims

1. A base oil for cooling a device, comprising a hydrocarbon compound at 30 mass% or more and exhibiting a kinematic viscosity of 4 mm^2/s to 30 mm^2/s at 40 degrees C, wherein
   a total number of a terminal methyl group and a methylene group in a main chain of the hydrocarbon compound is 16 or more, and
   a total number of a methyl branch and an ethyl branch in a molecule of the hydrocarbon compound is one or less.

2. The base oil according to claim 1, wherein a total number of the methylene group in the main chain is 16 or more.

3. The base oil according to claim 1 or 2, wherein the hydrocarbon compound has a chain structure.

4. The base oil according to any one of claims 1 to 3, wherein the hydrocarbon compound has a saturated structure.

5. The base oil according to any one of claims 1 to 3, wherein the hydrocarbon compound has an unsaturated structure.

6. The base oil according to any one of claims 1 to 5, wherein a thermal conductivity of the base oil at 25 degrees C is 0.138 W/(m·K) or more.

7. The base oil according to any one of claims 1 to 6, wherein a volume resistivity of the base oil at 25 degrees C is $10^{13}\Omega\cdot cm$ or more.

8. A device-cooling oil comprising the base oil according to any one of claims 1 to 7.

9. A device configured to be cooled by the device-cooling oil according to claim 8.

10. The device according to claim 9, wherein the device is usable for an electric vehicle or a hybrid vehicle.

11. The device according to claim 9 or 10, wherein the device is at least one of a motor, a battery, an inverter, an engine and an electric cell.

12. A device cooling method using the device-cooling oil according to claim 8.

FIG. 1

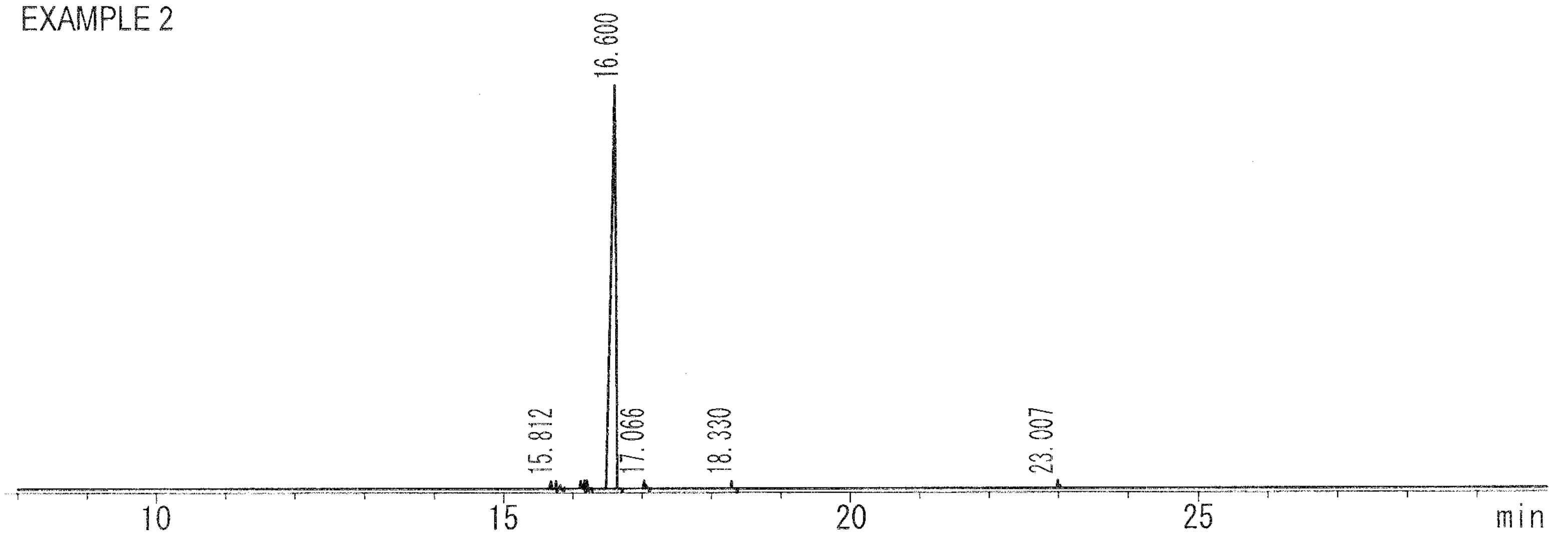
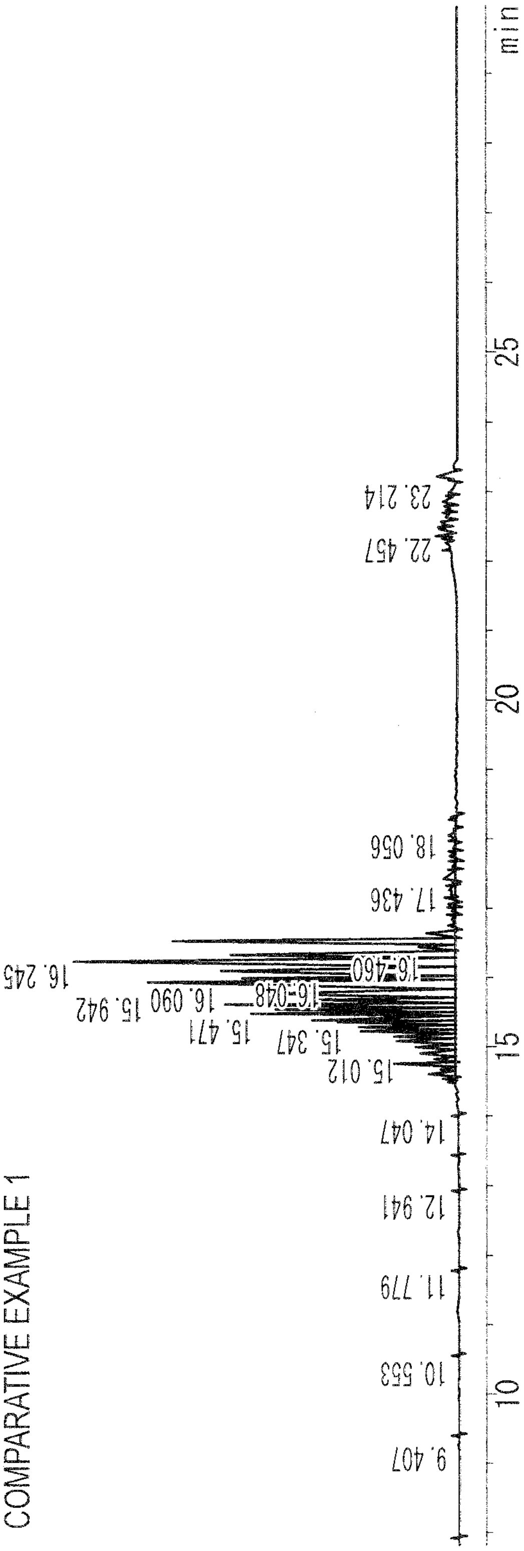


FIG. 2


COMPARATIVE EXAMPLE 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069664

A. CLASSIFICATION OF SUBJECT MATTER
C10M107/10(2006.01)i, *C10N20/00*(2006.01)n, *C10N20/02*(2006.01)n, *C10N30/00*(2006.01)n, *C10N40/00*(2006.01)n, *C10N40/06*(2006.01)n, *C10N40/14*(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M107/10, C10N20/00, C10N20/02, C10N30/00, C10N40/00, C10N40/06, C10N40/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2007-137951 A (Idemitsu Kosan Co., Ltd.), 07 June 2007 (07.06.2007), claims; examples & US 2009/0116771 A1 & WO 2007/058186 A1 & CN 101305082 A	1-9,11-12 1-12
X Y	JP 2007-137952 A (Idemitsu Kosan Co., Ltd.), 07 June 2007 (07.06.2007), claims; examples & US 2009/0181872 A1 & EP 1950278 A1 & WO 2007/058171 A1 & CN 101310002 A	1-9,11-12 1-12

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"&" document member of the same patent family

Date of the actual completion of the international search 01 December, 2010 (01.12.10)	Date of mailing of the international search report 14 December, 2010 (14.12.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069664

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2002/097017 A1 (Nissan Motor Co., Ltd., Nippon Mitsubishi Oil Corp.), 05 December 2002 (05.12.2002), claims; examples & US 2004/0209786 A1 & EP 1405897 A1 & CN 1535307 A	1-12
A	JP 2009-242547 A (Nippon Oil Corp.), 22 October 2009 (22.10.2009), entire text (Family: none)	1-12
A	JP 2009-161604 A (Nippon Oil Corp.), 23 July 2009 (23.07.2009), entire text (Family: none)	1-12
A	JP 7-507077 A (Albemarle Corp.), 03 August 1995 (03.08.1995), entire text & US 5210346 A & EP 625180 A & WO 1993/016152 A1	1-12
A	JP 4-226511 A (Ethyl Corp.), 17 August 1992 (17.08.1992), entire text & US 5068487 A	1-12

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 20021097017 A **[0004]**
- JP 2009161604 A **[0004]**
- JP 2009242547 A **[0004]**