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(54) LUBRICANT BASE OIL AND METHOD FOR PRODUCING SAME

(57) A lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):
(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,
(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and
(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s.

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Description

Technical Field

[0001] The present invention relates to a lubricant base oil and a method for producing the same.

Background Art

[0002] Conventionally, regarding a lubricant base oil and a lubricant oil composition, satisfaction of both a high viscosity index and a low-temperature viscosity characteristic has been attempted.

[0003] For example, by blending an additive agent such as a pour-point depressant into a lubricant base oil such as a highly-refined mineral oil, improvement of a low-temperature viscosity characteristic of a lubricant oil has been attempted (for example, refer to Patent Literature 1 to 3). Moreover, as a producing method of a high viscosity index base oil, for feedstock containing natural and synthetic normal paraffins, a method of refining a lubricant base oil by hydrocracking/hydroisomerization is known (for example, refer to Patent Literature 4 to 6).

[0004] A pour point is generally as an evaluation index of a low-temperature viscosity characteristic of a lubricant base oil and a lubricant oil. In addition, a technique for evaluating a low-temperature viscosity characteristic based on a lubricant base oil such as the content of normal paraffins and isoparaffins is also known.

Citation List

Patent Literature

[0005]

Patent Literature 1: JP-A-04-036391
Patent Literature 2: JP-A-04-068082
Patent Literature 3: JP-A-04-120193
Patent Literature 4: JP-A-2005-154760
Patent Literature 5: JP-T-2006-502298
Patent Literature 6: JP-T-2002-503754

Summary of Invention

Technical Problem

[0006] As described above, in general, it is considered that lower cold flow property of a lubricant base oil is better, and according to the study of the present inventors, a conventional lubricant base oil having cold flow property has a problem in a sealing property. More specifically, a low viscosity of a lubricant base oil or, moreover, contraction of a sealing material widens a gap, and when a pressure is applied to the site, oil leakage becomes easy to occur.

[0007] The present invention has been made in view of these circumstances, and it is an object of the present invention to provide a lubricant base oil capable of satisfying both a low-temperature viscosity characteristic and a sealing property at a high level, and a method for producing same.

Solution to Problem

[0008] In order to achieve the above-described object, firstly, the present inventors attempted satisfaction of both a low-temperature viscosity characteristic and a sealing property of a lubricant base oil using an SBV viscosity as an index, as an approach different from improvement in a low-temperature viscosity characteristic of a lubricant base oil using a pour point as an index. As a result, it was found that when the kinematic viscosity at 100°C, viscosity index, and SBV viscosity at -20°C of a lubricant base oil satisfy their respective specific requirements, a sealing property can be improved while sufficiently maintaining a low-temperature viscosity characteristic to complete the present invention.

[0009] That is, the present invention provides a lubricant base oil described in the following [1] to [12], and a method for producing a lubricant base oil described in the following [13] to [18].

[1] A lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):

(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,

(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and

(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s.

[2] The lubricant base oil according to [1], in which the hydrocarbon oil satisfies the condition (i) and has an SBV viscosity at - 30°C of 5,000 to 500,000 mPa·s.

[3] The lubricant base oil according to [1] or [2], in which the hydrocarbon oil satisfies the condition (i) and has a freezing point of -20 to -5°C.

[4] The lubricant base oil according to any one of [1] to [3], in which the hydrocarbon oil satisfies the condition (i) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 15% or more in a ^{13}C-NMR analysis.

[5] The lubricant base oil according to any one of [1] to [4], in which the hydrocarbon oil satisfies the condition (i) and has a cycloparaffin content of 50% or less in an FD-MS analysis.

[6] The lubricant base oil according to [1], in which the hydrocarbon oil satisfies the condition (ii) and has an SBV viscosity at - 25°C of 5,000 to 500,000 mPa·s.

[7] The lubricant base oil according to [1] or [6], in which the hydrocarbon oil satisfies the condition (ii) and has a freezing point of-15 to -5 °C.

[8] The lubricant base oil according to any one of [1], [6] and [7], in which the hydrocarbon oil satisfies the condition (ii) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 20% or more in a ^{13}C-NMR analysis.

[9] The lubricant base oil according to any one of [1], [6], [7] and [8], in which the hydrocarbon oil satisfies the condition (ii) and has a cycloparaffin content of 60% or less in an FD-MS analysis.

[10] The lubricant base oil according to [1], in which the hydrocarbon oil satisfies the condition (iii) and has an SBV viscosity at -35°C of 3,000 to 500,000 mPa·s.

[11] The lubricant base oil according to [1] or [10], in which the hydrocarbon oil satisfies the condition (iii) and has a freezing point of -30 to -10°C.

[12] The lubricant base oil according to any one of [1], [10] and [11], in which the hydrocarbon oil satisfies the condition (iii) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 15% or more in a ^{13}C-NMR analysis.

[13] The lubricant base oil according to any one of [1], [10], [11] and [12], in which the hydrocarbon oil satisfies the condition (iii) and has a cycloparaffin content of 30% or less in an FD-MS analysis.

[14] A method for producing a lubricant base oil, the method including

a first step of fractionating, from a hydrocarbon oil containing a base oil fraction and a heavy fraction that is heavier than the base oil fraction, the base oil fraction and the heavy fraction,

a second step of returning a cracked oil obtained by hydrocracking the heavy fraction fractionated in the first step, to the first step,

a third step of obtaining a dewaxed oil by performing hydroisomerization dewaxing of the base oil fraction,

a fourth step of obtaining a refined oil by refining the dewaxed oil, and

a fifth step of obtaining a lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):

(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,

(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and

(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s by fractionation of the refined oil.

[15] The method according to [14], in which the lubricant base oil obtained in the third step satisfies the condition (i) and has a freezing point of -20 to -5°C.

[16] The method according to [14], in which the lubricant base oil obtained in the third step satisfies the condition (ii) and has a freezing point of -15 to -5°C.

[17] The method according to [14], in which the lubricant base oil obtained in the third step satisfies the condition (iii) and has a freezing point of -30 to -10°C.

[18] The method according to any one of [14] to [17], in which the third step is a step of performing hydroisomerization

dewaxing of the base oil fraction in the presence of a hydroisomerization catalyst containing at least one crystalline solid acidic substance selected from the group consisting of ZSM-22-type zeolite, ZSM-23-type zeolite, SSZ32, and ZSM-48-type zeolite and platinum and/or palladium as an active metal.

[19] The method according to any one of [14] to [18], in which the hydrocarbon oil is obtained by using GTL wax obtained by a Fischer-Tropsch synthesis or slack wax obtained by solvent dewaxing, as a raw material.

[0010] Here, the kinematic viscosity and the viscosity index in the present invention mean a kinematic viscosity and a viscosity index measured in conformity with JIS K 2283-1993, respectively.

[0011] Moreover, the SBV viscosity in the present invention means a value measured by a method in which a viscosity is continuously measured by rotating a rotor at 0.3 rpm while cooling at a cooling rate of 1°C/hour, which is a test method defined in ASTM D5133.

[0012] Moreover, the freezing point in the present invention means a value measured according to the following procedure.

[0013] More specifically, a sample charged in a test tube is preheated to 46°C, and then, is cooled at 2.5°C/min, and a cooling rate is changed to 1°C/min at a temperature higher than an expected freezing point (measured once in advance) by 10°C to start the measurement. According to this method, a reproducible freezing point can be obtained compared to JIS. This freezing point is distinguished from a pour point measured by JIS K 2269-1987 (JIS method pour point). In addition, according to the study of the present inventors, the pour point defined in JIS is suitable for measuring a liquid having widely differing crystallization temperatures, such as a petroleum lubricant base oil that is a multicomponent mixture. However, in the case of the present invention, a single component of paraffin does not flow by the JIS measurement method for evaluating fluidity when being inclined, but is confirmed to flow by the application of exogenous force and does not exhibit actual fluidity. The cause is due to the composition and is also affected by a rate of temperature decrease of 2.5°C/min, and determination in a situation where crystallization does not proceed completely is considered to be the cause. Therefore, it is necessary to accelerate fluidity of base oil molecules and to obtain a freezing point close to a true value by slowing a descending rate of temperature.

[0014] Moreover, the ratio of CH_2 carbons constituting the main chain to all carbons constituting the lubricant base oil can be determined, for example, by performing a ^{13}C-NMR analysis under the following analysis conditions.

[0015] More specifically, in the present invention, in the ^{13}C-NMR measurement, a diluted sample obtained by adding 3 g of deuterated chloroform to 0.5 g of a sample was used, the measurement temperature was room temperature, and the resonant frequency was 100 MHz. In addition, a gated decoupling method was used as the measurement method.

[0016] The ratio of CH_2 to the total of the constituent carbons of the lubricant base oil of the present invention means a ratio of the total of integral intensity attributed to the CH_2 main chain with respect to the total of integral intensity of all carbons, which are measured by ^{13}C-NMR, and other methods may be used as long as the equivalent result is obtained.

[0017] Furthermore, the ratio of the cycloparaffin content can be determined, for example, by performing an FD-MS analysis under the following analysis conditions.

[0018] The FD method is an ionization method in which a sample is coated on an emitter, a current is applied to the emitter to heat the coated sample, and a tunneling effect is used in a high electrical field on the emitter surface and in the vicinity of the whisker tip. In the present invention, the measurement was performed using JMS-AX505H by JEOL Ltd. under conditions of an accelerating voltage (cathode voltage) of 3.0 kV and an emitter current of 2 mA/min. Compound types in mass spectrometry are determined by specific ions to be formed, and they are generally classified by a z value. The z value is represented by a general formula C_nH_{2n+z} for all hydrocarbon species. Since the saturated phase is analyzed separately from the aromatic phase, contents of different cycloparaffins having the same stoichiometry can be measured. In addition, cycloparaffins include both of monocyclic cycloparaffms and bicyclic or more cycloparaffins.

Advantageous Effects of Invention

[0019] According to the present invention, a lubricant base oil capable of satisfying both a low-temperature viscosity characteristic and a sealing property at a high level, and a method for producing same are provided.

Description of Embodiments

[0020] Preferred embodiments of the present invention will now be described in more detail.

[First Embodiment: Lubricant Base Oil that is Hydrocarbon Oil that satisfies Condition (i)]

[0021] The lubricant base oil according to the first embodiment of the present invention is a lubricant base oil that is a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s.

[0022] In addition, conventionally, a pour point used as an index of a low-temperature viscosity characteristic of a lubricant base oil evaluates ease of flow, that is to say, a bulk viscosity. In contrast, the SBV viscosity in the present invention can evaluate not a bulk viscosity but mobility of a base oil at the molecular level. For example, a lubricant base oil does not flow at a temperature lower than a pour point, but can move at the molecular level due to distortion between molecules constituting the base oil to impart the SBV viscosity. The lubricant base oil according to the present embodiment is made based on the above-described present inventors' knowledge, and has an unexpected significant effect that, in a lubricant base oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s and a viscosity index of 145 or more, by making the SBV viscosity at -20°C of the lubricant base oil be 3,000 to 60,000 mPa·s, a sealing property can be improved while sufficiently maintaining a low-temperature viscosity characteristic.

[0023] The kinematic viscosity of the lubricant base oil according to the present embodiment at 100°C is 3.0 to 5.0 mm^2/s, preferably 3.0 to 4.5 mm^2/s, more preferably 3.2 to 4.3 mm^2/s, and more preferably 3.4 to 4.1 mm^2/s.

[0024] Moreover, the viscosity index of the lubricant base oil according to the present embodiment is 145 or more, preferably 147 or more, and more preferably 148 to 160. In addition, if the viscosity index is less than the above-described lower limit, an energy saving property is decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature is decreased and the lubricant base oil according to the present embodiment tends to be not able to be used as a lubricant base oil.

[0025] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -20°C is 3,000 to 60,000 mPa·s, preferably 3,000 to 30,000 mPa·s, and more preferably 3,000 to 15,000 mPa·s. If the SBV viscosity at -20°C is less than the above-described lower limit, a sealing property is insufficient, and if it exceeds the above-described upper limit, a low temperature viscosity characteristic is insufficient.

[0026] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -30°C is preferably 50,000 to 500,000 mPa·s, more preferably 50,000 to 400,000 mPa·s, and further preferably 50,000 to 300,000 mPa·s. If the SBV viscosity at -25°C is less than the above-described lower limit, a sealing property becomes insufficient, and if it exceeds the above-described upper limit, a low temperature viscosity characteristic becomes insufficient.

[0027] Moreover, the kinematic viscosity of the lubricant base oil according to the present embodiment at 40°C is preferably 10 to 20 mm^2/s, and more preferably 12 to 16 mm^2/s.

[0028] Moreover, the freezing point of the lubricant base oil according to the present embodiment is preferably -20 to -5°C, more preferably - 18 to -8°C, and further preferably -15 to -10°C. In addition, if the freezing point is less than the above-described lower limit, an energy saving property tends to be decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature tends to be decreased and the lubricant base oil according to the present embodiment cannot be used as a lubricant base oil.

[0029] Furthermore, in the case of performing a ^{13}C-NMR analysis of the lubricant base oil according to the present embodiment, a ratio of CH_2 carbons constituting the main chain to all carbons constituting the lubricant base oil is preferably 15% or more, and more preferably 16% or more. If the ratio is the above-described lower limit or more, a traction coefficient of the lubricant base oil can be decreased (that is, low friction), and it is preferable in terms of an energy saving property.

[0030] Furthermore, in the case of performing an FD-MS analysis of the lubricant base oil according to the present embodiment, a cycloparaffin content is preferably 50% or less, and more preferably 40% or less. If the cycloparaffin content is the above-described upper limit or less, abrasion resistance of the lubricant base oil can be further improved.

[0031] Moreover, from the viewpoint of improving a low-temperature viscosity characteristic without impairing a viscosity-temperature characteristic at high temperature, the urea adduct value of the lubricant base oil according to the present embodiment is preferably 4% by mass or less, more preferably 3.5% by mass or less, further preferably 3% by mass or less, and particularly preferably 2.5% by mass or less. Furthermore, the urea adduct value of the lubricant base oil may be 0% by mass. However, since a sufficient low-temperature viscosity characteristic and a lubricant base oil having a higher viscosity index can be obtained, and furthermore, dewaxing conditions are loosened to result in excellent economic efficiency, it is preferably 0.1% by mass or more, more preferably 0.5% by mass or more, and particularly preferably 0.8% by mass or more.

[0032] Moreover, the content of the saturated content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 90% by mass or more, more preferably 93% by mass or more, further preferably 95% by mass or more, and particularly preferably 99% by mass or more. The content of the saturated content satisfies the above-described condition so that a viscosity-temperature characteristic and thermal-oxidation stability can be achieved, and furthermore, in the case where an additive agent is blended into the lubricant base oil, the additive agent is sufficiently stably dissolved and maintained in the lubricant base oil and functions of the additive agent can be expressed at a high level. Furthermore, a friction characteristic of the lubricant base oil itself can be improved, and as a result, improvement in a friction-reducing effect and therefore improvement in an energy saving property can be achieved. In addition, the content of the saturated content in the present invention means a value (unit: % by mass) measured in conformity with ASTM D 2007-93.

[0033] Moreover, the aromatic content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 5 % by mass or less, more preferably 0.05 to 3% by mass, further preferably 0.1 to 1% by mass, and particularly preferably 0.1 to 0.5% by mass. If the content of the aromatic content exceeds the above-described upper limit, a viscosity-temperature characteristic, thermal-oxidation stability, a friction characteristic, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased. Furthermore, although the lubricant base oil according to the present embodiment may not contain the aromatic content, solubility of the additive agent can be further increased by making the content of the aromatic content be 0.05% by mass or more.

[0034] In addition, the content of the aromatic content in the present invention means a value measured in conformity with ASTM D 2007-93. Generally, the aromatic content includes, in addition to alkylbenzenes and alkylnaphthalenes, anthracene, phenanthrene, alkylated products thereof, and moreover, compounds in which four benzene rings or more are condensed, and aromatic compounds having a hetero atom, such as pyridines, quinolines, phenols, and naphthols.

[0035] Furthermore, the content of the sulfur content in the lubricant base oil according to the present embodiment depends on the content of the sulfur content in the raw material. For example, in the case of using a raw material substantially not containing sulfur, such as a synthetic wax constituent obtained by a Fischer-Tropsch reaction or the like, a lubricant base oil substantially not containing sulfur can be obtained. Moreover, in the case of using a raw material containing sulfur, such as slack wax obtained in the refining process of the lubricant base oil and micro wax obtained in the wax refining process, the sulfur content in the obtained lubricant base oil is generally 100 mass ppm or more. In the lubricant base oil of the present invention, in terms of further improvement in thermal-oxidation stability and reduction in the sulfur content, the content of the sulfur content is preferably 10 mass ppm or less, more preferably 5 mass ppm or less, further preferably 3 mass ppm or less, and particularly preferably 1 mass ppm or less.

[0036] Furthermore, in terms of cost reduction, slack wax or the like is preferably used as a raw material, and in this case, the sulfur content in the obtained lubricant base oil is preferably 50 mass ppm or less, and more preferably 10 mass ppm or less. In addition, the sulfur content in the present invention means a sulfur content measured in conformity with JIS K 2541-1996.

[0037] Moreover, the pour point of the lubricant base oil according to the present embodiment is preferably -5°C or less, more preferably-10°C or less, and further preferably -12.5°C or less. If the pour point exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased. Furthermore, the pour point of the lubricant base oil according to the present embodiment is preferably -20°C or more, more preferably - 17.5°C or more, and further preferably -15°C or more. If the pour point is less than -20°C, it becomes difficult for the SBV viscosity at-20°C to be within a range of 3,000 to 60,000 mPa·s, and a sealing property tends to be insufficient. In addition, the pour point in the present invention means a pour point measured in conformity with JIS K 2269-1987.

[0038] Moreover, the CCS viscosity of the lubricant base oil according to the present embodiment at -30°C is preferably 1,500 mPa·s or less, and more preferably 1,200 mPa·s or less. Furthermore, the CCS viscosity of the lubricant base oil at -35°C is preferably 2,500 mPa·s or less, and more preferably 2,000 mPa·s or less. If the CCS viscosity at - 30°C or at -35°C exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased. In addition, the CCS viscosity at -30°C or at -35°C means a viscosity measured in conformity with JIS K 2010-1993.

[0039] Moreover, the density of the lubricant base oil according to the present embodiment at 15°C (ρ_{15}) is preferably a ρ value represented by the following formula (1) or less, that is $\rho_{15} \leq \rho$.

$$\rho = 0.0025 \times kv100 + 0.816 \quad (1)$$

[In the formula, kv100 represents kinematic viscosity of lubricant base oil at 100°C (mm^2/s).]

[0040] In addition, in the case of $\rho_{15} > \rho$, a viscosity-temperature characteristic, thermal-oxidation stability, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased.

[0041] More specifically, ρ_{15} of the lubricant base oil is preferably 0.815 or less, and more preferably 0.810 or less.

[0042] In addition, the density at 15°C in the present invention means a density measured at 15°C in conformity with JIS K 2249-1995.

[0043] Moreover, the NOACK evaporation of the lubricant base oil according to the present embodiment is preferably 8% by mass or more, more preferably 9% by mass or more, further preferably 10 or more, and moreover, preferably 15% by mass or less, more preferably 14% by mass or less, and further preferably 13% by mass or less. When the NOACK evaporation is the above-described lower limit, improvement in a low-temperature viscosity characteristic tends to become difficult. Furthermore, the NOACK evaporation exceeding the above-described upper limit is not preferable because, in the case where the lubricant base oil is used for an internal combustion engine lubricant oil or the like, evaporation loss of the lubricant oil is increased, and therefore, catalyst poisoning is accelerated. In addition, the NOACK evaporation in the present invention means evaporation loss measured in conformity with ASTMD 5800-95.

[Second Embodiment: Lubricant Base Oil that is Hydrocarbon Oil that satisfies Condition (ii)]

[0044] The lubricant base oil according to the second embodiment of the present invention is a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s.

[0045] In addition, conventionally, a pour point used as an index of a low-temperature viscosity characteristic of a lubricant base oil evaluates ease of flow, that is to say, a bulk viscosity. In contrast, the SBV viscosity in the present invention can evaluate not a bulk viscosity but mobility of a base oil at the molecular level. For example, a lubricant base oil does not flow at a temperature lower than a pour point, but can move at the molecular level due to distortion between molecules constituting the base oil to impart the SBV viscosity. The lubricant base oil according to the present embodiment is made based on the above-described present inventors' knowledge, and has an unexpected significant effect that, in a lubricant base oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, by making the SBV viscosity at - 20°C of the lubricant base oil be 3,000 to 30,000 mPa·s, a sealing property can be improved while sufficiently maintaining a low-temperature viscosity characteristic.

[0046] The kinematic viscosity of the lubricant base oil according to the present embodiment at 100°C is 5 to 9 mm^2/s, preferably 5.5 to 8.5 mm^2/s, and more preferably 6 to 8 mm^2/s.

[0047] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -20°C is 3,000 to 30,000 mPa·s, preferably 3,000 to 25,000 mPa·s, and more preferably 3,000 to 20,000 mPa·s. If the SBV viscosity at -20°C is less than the above-described lower limit, a sealing property is insufficient, and if it exceeds the above-described upper limit, a low temperature viscosity characteristic is insufficient.

[0048] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -25°C is preferably 5,000 to 500,000 mPa·s, more preferably 5,000 to 400,000 mPa·s, and further preferably 5,000 to 300,000 mPa·s. If the SBV viscosity at -25°C is less than the above-described lower limit, a sealing property becomes insufficient, and if it exceeds the above-described upper limit, a low temperature viscosity characteristic becomes insufficient.

[0049] Moreover, the kinematic viscosity of the lubricant base oil according to the present embodiment at 40°C is preferably 25 to 40 mm^2/s, and more preferably 28 to 35 mm^2/s.

[0050] Moreover, the viscosity index of the lubricant base oil according to the present embodiment is 155 or more, preferably 157 or more, and more preferably 158 to 165. In addition, if the viscosity index is less than the above-described lower limit, an energy saving property is decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature tends to be decreased and the lubricant base oil according to the present embodiment cannot be used as a lubricant base oil.

[0051] Moreover, the freezing point of the lubricant base oil according to the present embodiment is preferably -15 to -5°C, more preferably - 14 to -7°C, and further preferably -13 to -8°C. In addition, if the freezing point is less than the above-described lower limit, an energy saving property tends to be decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature tends to be decreased and the lubricant base oil according to the present embodiment cannot be used as a lubricant base oil.

[0052] Furthermore, in the case of performing a ^{13}C-NMR analysis of the lubricant base oil according to the present embodiment, a ratio of CH_2 carbons constituting the main chain to all carbons constituting the lubricant base oil is preferably 20% or more, and more preferably 18% or more. If the ratio is the above-described lower limit or more, a traction coefficient of the lubricant base oil can be decreased (that is, low friction), and it is preferable in terms of an energy saving property.

[0053] Furthermore, in the case of performing an FD-MS analysis of the lubricant base oil according to the present embodiment, a cycloparaffin content is preferably 60% or less, and more preferably 65% or less. If the cycloparaffin content is the above-described upper limit or less, abrasion resistance of the lubricant base oil can be further improved.

[0054] Moreover, from the viewpoint of improving a low-temperature viscosity characteristic without impairing a viscosity-temperature characteristic at high temperature, the urea adduct value of the lubricant base oil according to the present embodiment is preferably 4% by mass or less, more preferably 3.5% by mass or less, further preferably 3% by mass or less, and particularly preferably 2.5% by mass or less. Furthermore, the urea adduct value of the lubricant base oil may be 0% by mass. However, since a sufficient low-temperature viscosity characteristic and a lubricant base oil having a higher viscosity index can be obtained, and furthermore, dewaxing conditions are loosened to result in excellent economic efficiency, it is preferably 0.1% by mass or more, more preferably 0.5% by mass or more, and particularly preferably 0.8% by mass or more.

[0055] Moreover, the content of the saturated content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 90% by mass or more, more preferably 93% by mass or more, further preferably 95% by mass or more, and particularly preferably 99% by mass or more. The content of the saturated content satisfies the above-described condition so that a viscosity-temperature characteristic and thermal-oxidation stability can be achieved, and furthermore, in the case where an additive agent is blended into the lubricant base oil, the additive agent is sufficiently stably dissolved and maintained in the lubricant base oil and functions of the additive agent can be expressed at a high level. Furthermore, a friction characteristic of the lubricant base oil itself can be improved, and as a result, improvement in a friction-reducing effect and therefore improvement in an energy saving property can be achieved.

[0056] Moreover, the aromatic content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 5% by mass or less, more preferably 0.05 to 3% by mass, further preferably 0.1 to 1% by mass, and particularly preferably 0.1 to 0.5% by mass. If the content of the aromatic content exceeds the above-described upper limit, a viscosity-temperature characteristic, thermal-oxidation stability, a friction characteristic, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased. Furthermore, although the lubricant base oil according to the present embodiment may not contain the aromatic content, solubility of the additive agent can be further increased by making the content of the aromatic content be 0.05% by mass or more.

[0057] Furthermore, the content of the sulfur content in the lubricant base oil according to the present embodiment depends on the content of the sulfur content in the raw material. For example, in the case of using a raw material substantially not containing sulfur, such as a synthetic wax constituent obtained by a Fischer-Tropsch reaction or the like, a lubricant base oil substantially not containing sulfur can be obtained. Moreover, in the case of using a raw material containing sulfur, such as slack wax obtained in the refining process of the lubricant base oil and micro wax obtained in the wax refining process, the sulfur content in the obtained lubricant base oil is generally 100 mass ppm or more. In the lubricant base oil of the present invention, in terms of further improvement in thermal-oxidation stability and reduction in the sulfur content, the content of the sulfur content is preferably 10 mass ppm or less, more preferably 5 mass ppm or less, further preferably 3 mass ppm or less, and particularly preferably 1 mass ppm or less.

[0058] Furthermore, in terms of cost reduction, slack wax or the like is preferably used as a raw material, and in this case, the sulfur content in the obtained lubricant base oil is preferably 50 mass ppm or less, and more preferably 10 mass ppm or less.

[0059] Moreover, the pour point of the lubricant base oil according to the present embodiment is preferably -5°C or less, more preferably - 10°C or less, and further preferably -12.5°C or less. If the pour point exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased. Furthermore, the pour point of the lubricant base oil according to the present embodiment is preferably -20°C or more, more preferably - 17.5°C or more, and further preferably -15°C or more. If the pour point is less than -20°C, it becomes difficult for the SBV viscosity at - 20°C to be within a range of 3,000 to 30,000 mPa·s, and a sealing property tends to be insufficient.

[0060] Moreover, the CCS viscosity of the lubricant base oil according to the present embodiment at -30°C is preferably 950 mPa·s or less, and more preferably 900 mPa·s or less. Furthermore, the CCS viscosity of the lubricant base oil at -35°C is preferably 1,600 mPa·s or less, and more preferably 1,500 mPa·s or less. If the CCS viscosity at -30°C or at -35°C exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased.

[0061] Moreover, the density of the lubricant base oil according to the present embodiment at 15°C (ρ_{15}) is preferably a ρ value represented by the following formula (1) or less, that is $\rho_{15} \leq \rho$.

$$\rho = 0.0025 \times kv100 + 0.816 \quad (1)$$

[In the formula, kv100 represents kinematic viscosity of lubricant base oil at 100°C (mm^2/s).]

[0062] In addition, in the case of $\rho_{15} > \rho$, a viscosity-temperature characteristic, thermal-oxidation stability, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased.

[0063] More specifically, ρ_{15} of the lubricant base oil is preferably 0.830 or less, and more preferably 0.825 or less.

[Third Embodiment: Lubricant Base Oil that is Hydrocarbon Oil that satisfies Condition (iii)]

[0064] The lubricant base oil according to the third embodiment of the present invention is a lubricant base oil that is a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s.

[0065] In addition, conventionally, a pour point used as an index of a low-temperature viscosity characteristic of a lubricant base oil evaluates ease of flow, that is to say, a bulk viscosity. In contrast, the SBV viscosity in the present invention can evaluate not a bulk viscosity but mobility of a base oil at the molecular level. For example, a lubricant base oil does not flow at a temperature lower than a pour point, but can move at the molecular level due to distortion between molecules constituting the base oil to impart the SBV viscosity. The lubricant base oil according to the present embodiment is made based on the above-described present inventors' knowledge, and has an unexpected significant effect that, in a lubricant base oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s and a viscosity index of 130 or more, by making the SBV viscosity at -30°C of the lubricant base oil be 1,000 to 30,000 mPa·s, a sealing property can be improved while sufficiently maintaining a low-temperature viscosity characteristic.

[0066] The kinematic viscosity of the lubricant base oil according to the present embodiment at 100°C is 2.0 to 3.0 mm^2/s, preferably 2.1 to 2.9 mm^2/s, and more preferably 2.2 to 2.8 mm^2/s.

[0067] Moreover, the viscosity index of the lubricant base oil according to the present embodiment is 130 or more, preferably 131 or more, and more preferably 132 to 140. If the viscosity index is less than the above-described lower limit, an energy saving property is decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature is decreased and the lubricant base oil according to the present embodiment cannot be used as a lubricant base oil.

[0068] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -30°C is 1,000 to 30,000 mPa·s, preferably 1,000 to 20,000 mPa·s, and more preferably 1,000 to 15,000 mPa·s. If the SBV viscosity at -30°C is less than the above-described lower limit, a sealing property is insufficient, and if it exceeds the above-described upper limit, a low temperature characteristic is insufficient.

[0069] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -35°C is preferably 3,000 to 500,000 mPa·s, more preferably 3,000 to 400,000 mPa·s, and further preferably 3,000 to 300,000 mPa·s. If the SBV viscosity at -35°C is less than the above-described lower limit, a sealing property is insufficient, and if it exceeds the above-described upper limit, a low-temperature viscosity characteristic is insufficient.

[0070] Moreover, the SBV viscosity of the lubricant base oil according to the present embodiment at -40°C is preferably 5,000 to 750,000 mPa·s, more preferably 5,000 to 500,000 mPa·s, and further preferably 5,000 to 400,000 mPa·s. If the SBV viscosity at -40°C is less than the above-described lower limit, a sealing property is insufficient, and if it exceeds the above-described upper limit, a low-temperature viscosity characteristic is insufficient.

[0071] Moreover, the kinematic viscosity of the lubricant base oil according to the present embodiment at 40°C is preferably 7 to 12 mm^2/s, and more preferably 8 to 10 mm^2/s.

[0072] Moreover, the freezing point of the lubricant base oil according to the present embodiment is preferably -30 to -10°C, more preferably - 29 to -15°C, and further preferably -28 to -20°C. In addition, if the freezing point is less than the above-described lower limit, an energy saving property tends to be decreased, and if it exceeds the above-described upper limit, fluidity at ordinary temperature tends to be decreased and the lubricant base oil according to the present embodiment cannot be used as a lubricant base oil.

[0073] Furthermore, in the case of performing a ^{13}C-NMR analysis of the lubricant base oil according to the present embodiment, a ratio of CH_2 carbons constituting the main chain to all carbons constituting the lubricant base oil is preferably 15% or more, and more preferably 15% or more. If the ratio is the above-described lower limit or more, a traction coefficient of the lubricant base oil can be decreased (that is, low friction), and it is preferable in terms of an energy saving property.

[0074] Furthermore, in the case of performing an FD-MS analysis of the lubricant base oil according to the present embodiment, a cycloparaffin content is preferably 30% or less, and more preferably 25% or less. If the cycloparaffin content is the above-described upper limit or less, abrasion resistance of the lubricant base oil can be further improved.

[0075] Moreover, from the viewpoint of improving a low-temperature viscosity characteristic without impairing a viscosity-temperature characteristic at high temperature, the urea adduct value of the lubricant base oil according to the present embodiment is preferably 4% by mass or less, more preferably 3.5% by mass or less, further preferably 3% by mass or less, and particularly preferably 2.5% by mass or less. Furthermore, the urea adduct value of the lubricant base oil may be 0% by mass. However, since a sufficient low-temperature viscosity characteristic and a lubricant base oil having a higher viscosity index can be obtained, and furthermore, dewaxing conditions are loosened to result in excellent economic efficiency, it is preferably 0.1% by mass or more, more preferably 0.5% by mass or more, and particularly preferably 0.8% by mass or more.

[0076] Moreover, the content of the saturated content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 90% by mass or more, more preferably 93% by mass or more, further preferably 95% by mass or more, and particularly preferably 99% by mass or more. The content of the saturated content satisfies the above-described condition so that a viscosity-temperature characteristic and thermal-oxidation stability can be achieved, and furthermore, in the case where an additive agent is blended into the lubricant base oil, the additive agent is sufficiently stably dissolved and maintained in the lubricant base oil and functions of the additive agent can be expressed at a high level. Furthermore, a friction characteristic of the lubricant base oil itself can be improved, and as a result, improvement in a friction-reducing effect and therefore improvement in an energy saving property can be achieved.

[0077] Moreover, the aromatic content in the lubricant base oil according to the present embodiment is, on the basis of the total amount of the lubricant base oil, preferably 5% by mass or less, more preferably 0.05 to 3% by mass, further preferably 0.1 to 1% by mass, and particularly preferably 0.1 to 0.5% by mass. If the content of the aromatic content exceeds the above-described upper limit, a viscosity-temperature characteristic, thermal-oxidation stability, a friction characteristic, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased. Furthermore, although the lubricant base oil according to the present embodiment may not contain the aromatic content, solubility of the additive agent can be further increased by making the content of the aromatic content be 0.05% by mass or more.

[0078] Furthermore, the content of the sulfur content in the lubricant base oil according to the present embodiment depends on the content of the sulfur content in the raw material. For example, in the case of using a raw material substantially not containing sulfur, such as a synthetic wax constituent obtained by a Fischer-Tropsch reaction or the like, a lubricant base oil substantially not containing sulfur can be obtained. Moreover, in the case of using a raw material containing sulfur, such as slack wax obtained in the refining process of the lubricant base oil and micro wax obtained in the wax refining process, the sulfur content in the obtained lubricant base oil is generally 100 mass ppm or more. In the lubricant base oil of the present invention, in terms of further improvement in thermal-oxidation stability and reduction in the sulfur content, the content of the sulfur content is preferably 10 mass ppm or less, more preferably 5 mass ppm or less, further preferably 3 mass ppm or less, and particularly preferably 1 mass ppm or less.

[0079] Furthermore, in terms of cost reduction, slack wax or the like is preferably used as a raw material, and in this case, the sulfur content in the obtained lubricant base oil is preferably 50 mass ppm or less, and more preferably 10 mass ppm or less.

[0080] Moreover, the pour point of the lubricant base oil according to the present embodiment is preferably -5°C or less, more preferably - 12.5°C or less, and further preferably -15°C or less. If the pour point exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased. Furthermore, the pour point of the lubricant base oil according to the present embodiment is preferably -27.5°C or more, and more preferably -25°C or more. If the pour point is less than -27.5°C, it becomes difficult for the SBV viscosity at -20°C to be within a range of 3,000 to 60,000 mPa·s, and a sealing property tends to be insufficient.

[0081] Moreover, the CCS viscosity of the lubricant base oil according to the present embodiment at -30°C is preferably 1,000 mPa·s or less, and more preferably 750 mPa·s or less. Furthermore, the CCS viscosity of the lubricant base oil at -35°C is preferably 1,300 mPa·s or less, and more preferably 1,000 mPa·s or less. If the CCS viscosity at - 30°C or at -35°C exceeds the above-described upper limit, low temperature fluidity of the entire lubricant oil using the lubricant base oil tends to be decreased.

[0082] Moreover, the density of the lubricant base oil according to the present embodiment at 15°C (ρ_{15}) is preferably a ρ value represented by the following formula (1) or less, that is $\rho_{15} \leq \rho$.

$$\rho = 0.0025 \times kv100 + 0.816 \quad (1)$$

[In the formula, kv100 represents kinematic viscosity of lubricant base oil at 100°C (mm^2/s).]

[0083] In addition, in the case of $\rho_{15} > \rho$, a viscosity-temperature characteristic, thermal-oxidation stability, and furthermore, a volatilization-preventing property, and a low-temperature viscosity characteristic tend to be decreased, and moreover, in the case where an additive agent is blended into the lubricant base oil, an effect of the additive agent tends to be decreased.

[0084] More specifically, ρ_{15} of the lubricant base oil is preferably 0.806 or less, and more preferably 0.8058 or less.

[0085] Moreover, the NOACK evaporation of the lubricant base oil according to the present embodiment is preferably 20% by mass or more, more preferably 25% by mass or more, further preferably 30 or more, and moreover, preferably 50% by mass or less, more preferably 48% by mass or less, and further preferably 46% by mass or less. When the NOACK evaporation is the above-described lower limit, improvement in a low-temperature viscosity characteristic tends to become difficult. Furthermore, the NOACK evaporation exceeding the above-described upper limit is not preferable because, in the case where the lubricant base oil is used for an internal combustion engine lubricant oil or the like, evaporation loss of the lubricant oil is increased, and therefore, catalyst poisoning is accelerated.

[Fourth Embodiment: Method for Producing Lubricant Base Oil]

[0086] The method for producing a lubricant base oil according to the fourth embodiment of the present invention includes

a first step of fractionating, from a hydrocarbon oil containing a base oil fraction and a heavy fraction that is heavier than the base oil fraction, the base oil fraction and the heavy fraction,
a second step of returning a cracked oil obtained by hydrocracking the heavy fraction fractionated in the first step, to the first step,
a third step of obtaining a dewaxed oil by performing hydroisomerization dewaxing of the base oil fraction,
a fourth step of obtaining a refined oil by refining the dewaxed oil, and
a fifth step of obtaining a lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):

(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,
(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and
(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s, by fractionation of the refined oil.

[0087] In the method for producing a lubricant base oil according to the present embodiment, the base oil fraction and the heavy fraction are fractionated from the hydrocarbon oil as a raw material (first step), and the cracked oil obtained by hydrocracking the heavy fraction is returned to the first step (second step). That is, since only the heavy fraction is offered to the subsequent hydroisomerization dewaxing (third step) after passing through the hydrocracking and the base oil fraction is offered to hydroisomerization dewaxing without passing through the hydrocracking, isomerization of the entire treated oil to be offered to hydroisomerization dewaxing becomes difficult to proceed compared to the conventional method for producing a highly-refined mineral oil. Then, with respect to such a treated oil, hydroisomerization dewaxing is performed, the obtained dewaxed oil is refined to obtain the refined oil (fourth step), and furthermore, the refined oil is fractionated (fifth step) so that the intended lubricant base oil can be effectively obtained.

[0088] In addition, as the conventional method for producing a highly-refined mineral oil, hydrocracking and hydroisomerization dewaxing are generally performed for entire feedstock, but in this case, it becomes difficult to obtain a lubricant base oil in which both of a kinematic viscosity at 100°C and an SBV viscosity at -20°C satisfy the above-described conditions. In particular, in the case of a conventional highly-refined mineral oil, if the kinematic viscosity at 100°C is within the range shown in any of the above-described (i), (ii) and (iii), the SBV viscosity at -30°C is less than the lower limit shown in the respective conditions, and a sealing property becomes insufficient.

[0089] The base oil fraction is a fraction for obtaining a lubricant base oil after a dewaxing step, a hydrofinishing step, and a second distillation step, and the boiling point range thereof can be appropriately changed based on the intended product. Examples of the preferred boiling point range of the base oil fraction in the present embodiment include 340 to 520°C.

[0090] The heavy fraction is a fraction that has a higher boiling point than the base oil fraction. It is preferred that a boiling point of the heavy fraction is higher than 520°C.

[0091] The hydrocarbon oil may also contain, other than the base oil fraction and the heavy fraction, a fraction (light fraction) that has a lower boiling point than the base oil fraction. It is preferred that a boiling point of the light fraction is lower than 340°C.

[0092] Examples of the hydrocarbon oil include hydrotreated or hydrocracked gas oil, heavy gas oil, vacuum gas oil, lubricant oil raffinate, lubricant oil raw material, bright stock, slack wax (crude wax), foot's oil, deoiled wax, paraffinic wax, microcrystalline wax, petrolatum, synthetic oils, Fischer-Tropsch synthesis reaction oil (hereinafter referred to as an "FT synthetic oil"), high-pour-point polyolefins, and straight-chain α-olefin waxes. These hydrocarbon oils can be used singly or in combinations of two or more. In particular, the hydrocarbon oil is preferably at least one selected from the group consisting of a vacuum gas oil, a hydrocracked vacuum gas oil, an atmospheric residue, a hydrocracked atmospheric residue, a vacuum residue, a hydrocracked vacuum residue, slack wax, a dewaxed oil, paraffin wax, microcrystalline wax, petrolatum, and Fischer-Tropsch synthetic wax, and further preferably at least one selected from the group consisting of an atmospheric residue, a vacuum residue, a vacuum gas oil, slack wax, and Fischer-Tropsch synthetic wax.

[0093] In one aspect of the present invention, FT (Fischer-Tropsch) synthetic oil is preferred as the hydrocarbon oil. The FT synthetic oil is a hydrocarbon oil synthesized from carbon monoxide and hydrogen by a FT synthesis reaction, and does not contain a nitrogen content. Therefore, when the hydrocarbon oil is the FT synthetic oil, there is no possibility of sulfur poisoning in hydrocracking and isomerization dewaxing described below, and a wide variety of catalysts can be used.

[0094] Further, in another aspect of the present invention, it is preferred to use as the hydrocarbon oil a petroleum-based hydrocarbon oil containing petroleum feedstock-derived hydrocarbons. Examples of the petroleum-based hydrocarbon oil include hydrocracked vacuum gas oil, hydrocracked atmospheric residue, hydrocracked vacuum residue, slack wax, dewaxed oil, paraffinic wax, microcrystalline wax, and petrolatum.

[0095] The first distillation step is a step of fractionating the base oil fraction and the heavy fraction from the hydrocarbon oil. Conditions of the fractionating step can be appropriately changed based on the composition of the hydrocarbon oil. For example, when the hydrocarbon oil contains 20% by volume or more of the light fraction, it is preferred that the fractionating step is carried out by atmospheric distillation for distilling away the light fraction from the hydrocarbon oil, and vacuum distillation for fractionating the base oil fraction and the heavy fraction from the bottom oil of the atmospheric distillation.

[0096] The heavy fraction fractionated in the first distillation step is offered to the hydrocracking step. The hydrocracked oil obtained in the hydrocracking step is returned to the first distillation step.

[0097] The form of a reactor used in the hydrocracking step is not particularly limited, and a fixed-bed flow reactor filled with a hydrocracking catalyst is preferably used. The reactor may be a single apparatus, or an apparatus in which a plurality of reactors are arranged in series or in parallel. Moreover, a catalyst bed in the reactor may be a single bed or a plurality of beds.

[0098] A known hydrocracking catalyst is used as a hydrocracking catalyst and it is preferred to use a catalyst (hereinafter referred to as a "hydrocracking catalyst A") in which a metal of groups 8 to 10 of the periodic table of elements having hydrogenation activity is supported on an inorganic carrier that is a solid acid. Especially, when the hydrocarbon oil is FT synthetic oil, it is preferred to use the hydrocracking catalyst A, because there is no risk of catalyst poisoning due to sulfur content.

[0099] Examples of the inorganic carrier that is a preferred solid acid and constitutes the hydrocracking catalyst A include ones formed from one or more inorganic compounds selected from zeolites, such as ultrastable Y-type (USY) zeolite, Y-type zeolite, mordenite, and β-zeolite, as well as amorphous composite metal oxides having heat resistance such as silica-alumina, silica-zirconia, and alumina-boria. Moreover, the carrier is more preferably a composition formed from USY zeolite and one or more amorphous composite metal oxides selected from silica-alumina, alumina-boria, and silica-zirconia, and further preferably a composition formed from USY zeolite and alumina-boria and/or silica-alumina.

[0100] USY zeolite is one obtained by ultrastabilizing Y-type zeolite by hydrothermally treatment and/or acid treatment, in which newly pores having a pore diameter within a range of 2 to 10 nm are formed in addition to the fine pore structure that Y-type zeolite inherently has and is called micropores having a pore diameter of 2 nm or less. The average particle size of the USY zeolite, which although is not especially limited, is preferably 1.0 μm or less, and more preferably 0.5 μm or less. Further, the silica/alumina molar ratio (molar ratio of silica based on alumina) in the USY zeolite is preferably 10 to 200, more preferably 15 to 100, and even more preferably 20 to 60.

[0101] It is preferred that the carrier of the hydrocracking catalyst A includes 0.1 to 80% by mass of crystalline zeolite and 0.1 to 60% by mass of amorphous composite metal oxide having heat resistance.

[0102] The carrier of the hydrocracking catalyst A can be produced by forming a carrier composition including the above-described inorganic compound that is a solid acid and the binder, and then calcining. It is preferred that the blending ratio of the inorganic compound that is a solid acid is, based on the total mass of the carrier, 1 to 70% by mass, and more preferred is 2 to 60% by mass. Further, if the carrier includes a USY zeolite, it is preferred that the blending ratio of the USY zeolite is, based on the total mass of the carrier, 0.1 to 10% by mass, and more preferred is 0.5 to 5% by mass. Still further, if the carrier includes a USY zeolite and alumina-boria, it is preferred that the blending ratio of the USY zeolite and the alumina-boria (USY zeolite/alumina-boria) is 0.03 to 1 by mass. Moreover, if the carrier includes a USY zeolite and silica-alumina, it is preferred that the blending ratio of the USY zeolite and the silica-alumina (USY zeolite/silica-alumina) is 0.03 to 1 by mass.

[0103] Although a binder is not particularly limited, alumina, silica, titania, and magnesia are preferable, and alumina is more preferable. The amount of the binder blended is, on the basis of the total mass of the carrier, preferably 20 to 98% by mass, and more preferably 30 to 96% by mass.

[0104] It is preferred that the temperature when calcining the carrier composition is in the range of 400 to 550°C, more preferred is in the range of 470 to 530°C, and even more preferred is in the range of 490 to 530°C. By calcining at such a temperature, sufficient solid acidity and mechanical strength can be imparted to the carrier.

[0105] Specifically, examples of a metal of groups 8 to 10 of the periodic table, which is supported by a carrier and has hydrogenation activity, include cobalt, nickel, rhodium, palladium, iridium, and platinum. Among them, it is preferable that metals selected from nickel, palladium, and platinum be used singly or two or more kinds thereof be used in combination. These metals may be supported on the above-described carrier by a conventional method such as impregnation or ion exchange. Although there is no particular limitation on the amount of supported metal, it is preferred that the total amount of metal is 0.1 to 3.0% by mass based on the carrier mass. Here, the term "periodic table of elements" refers to the long form periodic table of elements as stipulated by the IUPAC (the International Union of Pure and Applied Chemistry).

[0106] In the case of using the hydrocracking catalyst A, conditions when the base oil fraction is made to be brought into contact with the hydrocracking catalyst A in the presence of hydrogen are not particularly limited, and the following reaction conditions can be selected. Specifically, examples of the reaction temperature include 180 to 400°C, but the reaction temperature is preferably 200 to 370°C, more preferably 250 to 350°C, and especially preferably 280 to 350°C. If the reaction temperature is more than 400°C, not only does the yield of the base oil fraction decrease due to the base oil fraction being broken down into a light fraction, but the generated product is colored, so that usage as a fuel oil base tends to be limited. On the other hand, if the reaction temperature is less than 180°C, the hydrocracking reaction does not proceed sufficiently, so that the yield of the base oil fraction decreases. Examples of the hydrogen partial pressure include 0.5 to 12 MPa, but the hydrogen partial pressure is preferably 1.0 to 5.0 MPa. If the hydrogen partial pressure is less than 0.5 MPa, the hydrocracking tends not to proceed sufficiently. On the other hand, if the hydrogen partial pressure is more than 12 MPa, a high pressure resistance is required for the apparatus, so that equipment costs tend to increase. Examples of the liquid hourly space velocity (LHSV) of the heavy fraction include 0.1 to 10.0 h^{-1}, but the LHSV is preferably 0.3 to 3.5 h^{-1}. If the LHSV is less than 0.1 h^{-1}, the hydrocracking tends to proceed excessively, and the productivity tends to decrease. On the other hand, if the LHSV is more than 10.0 h^{-1}, the hydrocracking tends not to proceed sufficiently. Examples of the hydrogen/oil ratio include 50 to 1,000 NL/L, but the hydrogen/oil ratio is preferably 70 to 800 NL/L. If the hydrogen/oil ratio is less than 50 NL/L, the hydrocracking tends not to proceed sufficiently. On the other hand, if the hydrogen/oil ratio is more than 1,000 NL/L, large-scale hydrogen supply apparatus and the like tend to be required.

[0107] When the hydrocarbon oil is a petroleum-based hydrocarbon oil, sulfur content can be contained in the base oil fraction. In such a case, it is preferred to use, as a hydrocracking catalyst, a catalyst (hereinafter referred to as a "hydrocracking catalyst B") having a porous inorganic oxide that includes two or more elements selected from aluminum, silicon, zirconium, boron, titanium, and magnesium, and one or more metals selected from the elements of group 6A and group 8 of the periodic table that are supported on the porous inorganic oxide. According to the hydrocracking catalyst B, decrease in the catalytic activity due to sulfur poisoning is sufficiently suppressed.

[0108] As the carrier of the hydrocracking catalyst B, as described above, a porous inorganic oxide formed from two or more selected from aluminum, silicon, zirconium, boron, titanium, and magnesium can be used. Such a porous inorganic oxide is, from the perspective of enabling a much greater improvement in the hydrocracking activity, preferably an inorganic oxide that includes two or more selected from aluminum, silicon, zirconium, boron, titanium, and magnesium, and more preferably an inorganic oxide (a composite oxide of an aluminum oxide and another oxide) that includes aluminum and another element.

[0109] If the porous inorganic oxide contains aluminum as a constituent element, the content of aluminum is preferably 1 to 97% by mass, more preferably 10 to 97% by mass, and even more preferably 20 to 95% by mass in terms of alumina, based on the total amount of the porous inorganic oxide. If the content of aluminum is less than 1% by mass in terms of alumina, physical properties such as the carrier acid properties are not preferable, and a sufficient hydrocracking activity tends not to be exhibited. On the other hand, if the content of aluminum is more than 97% by mass in terms of alumina, the catalyst surface area is insufficient and the activity tends to decrease.

[0110] The method for introducing silicon, zirconium, boron, titanium, and magnesium, which are constituent elements of the carrier other than aluminum, into the carrier is not especially limited. A solution containing these elements or the like may be used as a raw material. For example, there may be used, for silicon, silicon, liquid glass, and silica sol; for boron, boric acid; for phosphorus, phosphoric acid and an alkali metal salt of phosphoric acid; for titanium, titanium sulfide, titanium tetrachloride, and various alkoxide salts; and for zirconium, zirconium sulfate and various alkoxide salts.

[0111] Further, the porous inorganic oxide preferably contains phosphorus as a constituent element. The content of phosphorus is preferably 0.1 to 10% by mass, more preferably 0.5 to 7% by mass, and even more preferably 2 to 6% by mass based on the total amount of the porous inorganic oxide. If the content of phosphorus is less than 0.1% by mass, sufficient hydrocracking activity tends not to be exhibited, and if the content of phosphorus is more than 10% by mass, excessive cracking can proceed.

[0112] It is preferred to add the raw materials for the constituent components of the carrier other than the above-described aluminum oxide in a step before the calcining of the carrier. For example, the raw materials are added to an aluminum aqueous solution in advance and then an aluminum hydroxide gel containing these constituent components may be prepared or the raw materials may be added to the prepared aluminum hydroxide gel. Alternatively, the raw materials may be added in a step in which water or an acidic aqueous solution is added to a commercially available aluminum oxide intermediate or a boehmite powder, and the resulting mixture is kneaded. However, it is preferred that the raw materials are allowed to coexist during the stage of preparing the aluminum hydroxide gel. Although the mechanism for exhibiting the effect of the constituent components of the carrier other than aluminum oxide is not entirely understood, it is thought that the constituent components form a complex oxide state with aluminum, and that this causes an increase in the carrier surface area and interactions with the active metals to occur, thereby influencing the activity.

[0113] One or more metals selected from the elements of group 6A and group 8 of the periodic table is supported on the above-described porous inorganic oxide acting as a carrier. Among these metals, it is preferred to use a combination of two or more metals selected from cobalt, molybdenum, nickel, and tungsten. Examples of preferred combinations include cobalt-molybdenum, nickel-molybdenum, nickel-cobalt-molybdenum, and nickel-tungsten. Among these, more preferred is a combination of nickel-molybdenum, nickel-cobalt-molybdenum, and nickel-tungsten. During the hydrocracking, these metals are converted into a sulfide state to use.

[0114] As the content of the active metal based on the catalyst mass, the range of the total amount of tungsten and molybdenum supported is preferably 12 to 35% by mass, and more preferably 15 to 30% by mass, in terms of the oxide. If the total amount of tungsten and molybdenum supported is less than 12% by mass, the active sites decrease and sufficient activity tends not to be obtained. On the other hand, if the total amount of tungsten and molybdenum supported is more than 35% by mass, the metals are not effectively dispersed and sufficient activity tends not to be obtained. The range of the total amount of cobalt and nickel supported is preferably 1.0 to 15% by mass and more preferably 1.5 to 12% by mass in terms of the oxide. If the total amount of cobalt and nickel supported is less than 1.0% by mass, a sufficient co-catalyst effect is not obtained and the activity tends to decrease. On the other hand, if the total amount of cobalt and nickel supported is more than 15% by mass, the metals are not effectively dispersed and sufficient activity tends not to be obtained.

[0115] The method for incorporating these active metals into the catalyst is not especially limited. A known method that is applied when producing a general hydrocracking catalyst may be employed. Generally, it is preferred to employ a method in which a solution containing a salt of the active metal is impregnated into the catalyst carrier. In addition, an equilibrium adsorption method, a pore-filling method, an incipient-wetness method and the like can also be preferably employed. For example, a pore-filling method is a method in which the pore volume of a carrier is measured in advance and then the carrier is impregnated with the same volume of a metal salt solution. In addition, the impregnation method is not especially limited. The carrier may be impregnated by a suitable method based on the amount of the metal supported and the physical properties of the catalyst carrier.

[0116] In the present embodiment, the number of the hydrocracking catalyst B types to be used is not especially limited. For example, one type of catalyst may be used singly or a plurality of catalysts with different active metal species or carrier constituent components may be used. Examples of a suitable combination when using a plurality of different catalysts include a catalyst containing cobalt-molybdenum following on from a catalyst containing nickel-molybdenum, a catalyst containing nickel-cobalt-molybdenum following on from a catalyst containing nickel-molybdenum, a catalyst containing nickel-cobalt-molybdenum following on from a catalyst containing nickel-tungsten, and a catalyst containing cobalt-molybdenum following on from a catalyst containing nickel-cobalt-molybdenum. Prior to and/or following these combinations, a nickel-molybdenum catalyst may be further combined.

[0117] When combining a plurality of catalysts with different carrier components, a catalyst may be used that, for example, has an aluminum oxide content in the range of 80 to 99% by mass following on from a catalyst having an aluminum oxide content of 30% by mass or more and less than 80% by mass based on the total mass of the carrier.

[0118] Further, other than the hydrocracking catalyst B, a guard catalyst, a demetallization catalyst, and an inactive filler may optionally be used for the purpose of trapping the scale content which flows in along with the base oil fraction and supporting the hydrocracking catalyst B at the partition part of the catalyst bed as necessary. These may be used singly or in combinations thereof.

[0119] It is preferred that the pore volume of the hydrocracking catalyst B as measured by a nitrogen adsorption BET method is 0.30 to 0.85 ml/g, and more preferred is 0.45 to 0.80 ml/g. If the pore volume is less than 0.30 ml/g, the dispersibility of the supported metals is insufficient, and the active sites may decrease. In addition, if the pore volume is more than 0.85 ml/g, the catalyst strength is insufficient, so that the catalyst may turn into a powder and break up during use.

[0120] Further, it is preferred that the average pore size of the catalyst determined by a nitrogen adsorption BET method is 5 to 11 nm, and more preferred is 6 to 9 nm. If the average pore size is less than 5 nm, the reaction substrate is not sufficiently dispersed in the pores, and the reactivity may decrease. In addition, if the average pore size is more than 11 nm, the pore surface area decreases and the activity may become insufficient.

[0121] In addition, in the hydrocracking catalyst B, in order to maintain effective catalyst pores and exhibit sufficient activity, it is preferred that the ratio of the pore volume derived from pores having a pore diameter of 3 nm or less to the total pore volume is 35% by volume or less.

[0122] When the hydrocracking catalyst B is used, the hydrocracking conditions can be set to, for example, a hydrogen pressure of 2 to 13 MPa, a liquid hourly space velocity (LHSV) of 0.1 to 3.0 h^{-1}, and a hydrogen-oil ratio (hydrogen/oil ratio) of 150 to 1,500 NL/L, are preferably a hydrogen pressure of 4.5 to 12 MPa, a liquid hourly space velocity of 0.3 to 1.5 h^{-1}, and a hydrogen-oil ratio of 380 to 1,200 NL/L, and more preferably a hydrogen pressure of 6 to 15 MPa, a liquid hourly space velocity of 0.3 to 1.5 h^{-1}, and a hydrogen-oil ratio of 350 to 1,000 NL/L. All of these conditions are factors having an influence on the reaction activity. For example, if the hydrogen pressure and the hydrogen-oil ratio are less than the above lower limits, the reactivity tends to decrease and the activity tends to rapidly decrease. On the other hand, if the hydrogen pressure and the hydrogen-oil ratio are more than the above upper limits, an excessive investment in equipment such as a compressor tends to be required. In addition, the lower the liquid hourly space velocity is, the more advantageous it tends to be for the reaction. However, if the liquid hourly space velocity is less than the above lower limit, a reactor having an extremely large internal volume is required and an excessive investment in equipment tends to be required. On the other hand, if the liquid hourly space velocity is more than the above upper limit, the reaction tends not to sufficiently proceed. Further, the reaction temperature may be 180 to 400°C, is preferably 200 to 370°C, more preferably 250 to 350°C, and especially preferably 280 to 350°C. If the reaction temperature is more than 400°C, not only does the yield of the base oil fraction decrease due to the base oil fraction being broken down into a light fraction, but the generated product is colored, so that usage as a fuel oil base tends to be limited. On the other hand, if the reaction temperature is less than 180°C, the hydrocracking reaction does not proceed sufficiently, so that the yield of the base oil fraction decreases.

[0123] In the hydrocracking step, the heavy fraction is, due to the hydrocracking, converted into hydrocarbons having a boiling point of about 520°C or less. On the other hand, a part of the heavy fraction is not sufficiently hydrocracked, and remains as an uncracked heavy fraction having a boiling point of 520°C or more.

[0124] The composition of the hydrocracked oil is determined based on the hydrocracking catalyst to be used and the hydrocracking reaction conditions. Here, unless otherwise stated, the "hydrocracked oil" refers to all the products of hydrocracking, including the uncracked heavy fraction. If the hydrocracking reaction conditions are severer than necessary, although the content of the uncracked heavy fraction in the hydrocracked oil decreases, a light fraction having a boiling point of 340°C or less increases, and the yield of the preferred base oil fraction (340 to 520°C fraction) decreases. On the other hand, if the hydrocracking reaction conditions are milder than necessary, the content of the uncracked heavy fraction increases, and the base oil fraction yield decreases. In the case where the ratio M2/M1 of the mass M2 of the cracking products having a boiling point of 25 to 520°C to the mass M1 of all the cracking products having a boiling point of 25°C or more is referred to as a "cracking ratio", generally, the reaction conditions are preferably selected such that the cracking ratio M2/M1 is 5 to 70%, preferably 10 to 60%, and further preferably 20 to 50%.

[0125] Next, the dewaxing step will be described. In the dewaxing step, the base oil fraction fractionated in the first distillation step is brought into contact with a hydrocracking catalyst in the presence of hydrogen (molecular hydrogen). Accordingly, the base oil fraction is dewaxed by hydroisomerization to obtain a dewaxed oil.

[0126] As a tube reactor for the dewaxing step, a known fixed-bed tube reactor can be used. More specifically, for example, hydroisomerization can be performed by filling a fixed-bed flow reactor with a hydroisomerization catalyst and making hydrogen (molecular hydrogen) and the base oil fraction flow through the reactor.

[0127] As the hydroisomerization catalyst, a catalyst that is generally used for hydroisomerization, namely, a catalyst in which a metal having a hydrogenation activity is supported on an inorganic carrier, can be used.

[0128] As the metal having a hydrogenation activity and constituting the hydroisomerization catalyst, one or more metals selected from the group consisting of metals of group 6, group 8, group 9, and group 10 of the periodic table of elements are used. Specific examples of these metals include noble metals such as platinum, palladium, rhodium, ruthenium, iridium, and osmium, or cobalt, nickel, molybdenum, tungsten, and iron. Preferred are platinum, palladium, nickel, cobalt, molybdenum, and tungsten, and more preferred are platinum and palladium. In addition, it is also preferred to use these metals in combinations of a plurality of species. In this case, examples of preferred combinations include platinum-palladium, cobalt-molybdenum, nickel-molybdenum, nickel-cobalt-molybdenum, and nickel-tungsten.

[0129] Examples of inorganic carriers constituting the hydroisomerization catalyst include metal oxides such as alumina, silica, titania, zirconia, and boria. These metal oxides may be one kind, a mixture of two or more kinds, or a composite metal oxide such as silica-alumina, silica-zirconia, alumina-zirconia, and alumina-boria. From the perspective of efficiently promoting the hydroisomerization of normal paraffins, the inorganic carrier is preferably a composite metal oxide that is a solid acid, such as silica-alumina, silica-zirconia, alumina-zirconia, and alumina-boria. Further, a small amount of zeolite may be included in the inorganic carrier. In order to improve the moldability and mechanical strength of the carrier, the inorganic carrier may be blended with a binder. Examples of preferred binders include alumina, silica, and magnesia.

[0130] As the content of the metal having a hydrogenation activity in the hydroisomerization catalyst, if this metal is the above-described noble metal, it is preferred that the content is about 0.1 to 3% by mass based on the mass of the carrier as metal atoms. Further, if this metal is a metal other than the above-described noble metals, it is preferred that the content is about 2 to 50% by mass based on the mass of the carrier as a metal oxide. If the content of the metal having a hydrogenation activity is less than the above-described lower limit, hydrorefining and hydroisomerization tend not to proceed sufficiently. On the other hand, if the content of the metal having a hydrogenation activity is more than the above-described upper limit, dispersion of the metal having a hydrogenation activity deteriorates, so that the activity of the catalyst tends to decrease, and the catalyst cost increases.

[0131] Further, the hydroisomerization catalyst may be a catalyst in which one or more metals selected from the elements of group 8 of the periodic table that is supported on a carrier including a porous inorganic oxide that is formed from a substance selected from aluminum, silicon, zirconium, boron, titanium, magnesium, and zeolite.

[0132] Examples of the porous inorganic oxide used as a carrier of such a hydroisomerization catalyst include alumina, titania, zirconia, boria, silica, or zeolite, and of these, preferred is a porous inorganic oxide formed from alumina and at least one of titania, zirconia, boria, silica, and zeolite. The production method is not especially limited, but an arbitrary preparation method may be employed that uses raw materials in the form of various sols or salt compounds corresponding to the respective elements. Furthermore, the carrier may be prepared by once preparing a composite hydroxide or a composite oxide, such as silica-alumina, silica-zirconia, alumina-titania, silica-titania, and alumina-boria, and then adding the composite hydroxide or composite oxide in the form of an alumina gel or other hydroxide, or in the form an appropriate solution, at an arbitrary stage of the preparation step. The proportion of alumina to the other oxide may be any ratio based on the carrier, but the content of alumina is preferably 90% by mass or less, more preferably 60% by mass or less, even more preferably 40% by mass or less, and preferably 10% by mass or more, and more preferably 20% by mass or more.

[0133] Examples of the zeolite, which is a crystalline alumino silicate, include faujasite, pentasil, mordenite, TON, MTT, and MRE. A zeolite that has been ultrastabilized by a predetermined hydrothermal treatment and/or acid treatment, or a zeolite whose alumina content has been adjusted may be used. It is preferred to use faujasite or mordenite, and especially preferred to use a Y or beta type. The Y type is preferably ultrastabilized. A zeolite ultrastabilized by a hydrothermal treatment has, in addition to its inherent pore structure, called micropores, of 20 angstroms or less, newly formed pores in the range of 20 to 100 angstroms. The hydrothermal treatment may be carried out under known conditions.

[0134] As the active metal of such a hydroisomerization catalyst, one or more metals selected from the elements of group 8 of the periodic table can be used. Among these metals, preferably used are one or more metals selected from Pd, Pt, Rh, Ir, Au and Ni, and more preferably used is a combination thereof. Examples of a preferred combination include Pd-Pt, Pd-Ir, Pd-Rh, Pd-Au, Pd-Ni, Pt-Rh, Pt-Ir, Pt-Au, Pt-Ni, Rh-Ir, Rh-Au, Rh-Ni, Ir-Au, Ir-Ni, Au-Ni, Pd-Pt-Rh, Pd-Pt-Ir, and Pt-Pd-Ni. Among these, more preferred combinations are Pd-Pt, Pd-Ni, Pt-Ni, Pd-Ir, Pt-Rh, Pt-Ir, Rh-Ir, Pd-Pt-Rh, Pd-Pt-Ni, and Pd-Pt-Ir, and even more preferred combinations are Pd-Pt, Pd-Ni, Pt-Ni, Pd-Ir, Pt-Ir, Pd-Pt-Ni, and Pd-Pt-Ir.

[0135] The total content of the active metals is preferably 0.1 to 2% by mass, more preferably 0.2 to 1.5% by mass, and even more preferably 0.5 to 1.3% by mass, in terms of metal, based on catalyst mass. If the total amount of metals supported is less than 0.1% by mass, the number of active sites is reduced, so that sufficient activity tends not to be obtained. On the other hand, if the total amount of metals supported is more than 2% by mass, the metals are not dispersed effectively, so that sufficient activity tends not to be obtained.

[0136] For any of the above-described hydroisomerization catalysts, the method for supporting the active metal on the carrier is not especially limited. A known method that is applied when producing a general hydroisomerization catalyst may be employed. Generally, it is preferred to employ a method in which a solution containing a salt of the active metal is impregnated into the catalyst carrier. In addition, an equilibrium adsorption method, a pore-filling method, an incipient-wetness method and the like can also be preferably employed. For example, a pore-filling method is a method in which the pore volume of a carrier is measured in advance and then the carrier is impregnated with the same volume of a metal salt solution. Although the impregnation method is not especially limited, the carrier may be impregnated by a suitable method based on the amount of the metal supported and the physical properties of the catalyst carrier.

[0137] As the hydroisomerization catalyst, the following catalyst can also be used.

<Specific Aspect of the Hydroisomerization Catalyst>

[0138] The hydroisomerization catalyst according to this aspect is imparted with its characteristics as a result of being produced by a specific method. The hydroisomerization catalyst according to the present aspect will now be described with reference to a preferred production aspect thereof.

[0139] The method for producing the hydroisomerization catalyst according to the present aspect includes a first step of obtaining a carrier precursor by heating a mixture that includes an ion-exchanged zeolite obtained by ion-exchanging an organic template-containing zeolite that contains an organic template and has a one-dimensional, 10-membered ring pore structure in a solution containing ammonium ions and/or protons, and a binder, in a N_2 atmosphere at a temperature of 250 to 300°C, and a second step of obtaining a hydroisomerization catalyst in which platinum and/or palladium is supported on a carrier including zeolite by calcining a catalyst precursor incorporating a platinum salt and/or palladium salt in the carrier precursor in an atmosphere containing molecular oxygen at a temperature of 350 to 400°C.

[0140] From the perspective of achieving a high level of both high isomerization activity and suppressed cracking activity in the hydroisomerization reactions of normal paraffins, the organic template-containing zeolite used in the present aspect has a one-dimensional pore structure formed from a 10-membered ring. Examples of such zeolites include AEL, EUO, PER, HEU, MEL, MFI, NES, TON, MTT, WEI, *MRE, and SSZ-32. The above three-lettered acronyms represent framework-type codes assigned to various structures of classified molecular sieve-type zeolites by the Structure Commission of the International Zeolite Association. It is also noted that zeolites having the same topology are collectively designated by the same code.

[0141] Among the above-described zeolites having a one-dimensional, 10-membered ring pore structure, from the perspective of high isomerization activity and low cracking activity, preferred as the organic template-containing zeolite are zeolites having a TON or an MTT structure, zeolite ZSM-48, which is a zeolite having a *MRE structure, and zeolite SSZ-32. Zeolite ZSM-22 is more preferred among zeolites having the TON structure, and zeolite ZSM-23 is more preferred among zeolites having the MTT structure.

[0142] The organic template-containing zeolite is hydrothermally synthesized according to a known method from a silica source, an alumina source, and an organic template that is added to build the above-described predetermined pore structure.

[0143] The organic template is an organic compound having an amino group, an ammonium group and the like, and is selected according to the structure of the zeolite to be synthesized. However, it is preferred that the organic template is an amine derivative. Specifically, the organic template is preferably at least one selected from the group consisting of alkylamines, alkyldiamines, alkyltriamines, alkyltetramines, pyrrolidine, piperazine, aminopiperazine, alkylpentamines, alkylhexamines, and their derivatives.

[0144] The molar ratio of the silicon element to aluminum element ([Si]/[Al]; hereinafter referred to as a "Si/Al ratio") that constitute the organic template-containing zeolite having a one-dimensional, 10-membered ring pore structure is preferably 10 to 400, and more preferably 20 to 350. If the Si/Al ratio is less than 10, although the activity for the conversion of normal paraffins increases, the isomerization selectivity to isoparaffins decreases, and cracking reactions caused by an increase in the reaction temperature tend to sharply increase, which is undesirable. Conversely, if the Si/Al ratio is more than 400, the catalytic activity needed for the conversion of normal paraffins cannot be easily obtained, which is undesirable.

[0145] The synthesized organic template-containing zeolite, which has preferably been washed and dried, typically has alkali metal cations as counter cations, and incorporates the organic template in its pore structure. The zeolite containing an organic template, which is used for producing the hydroisomerization catalyst according to the present invention, is preferably in such a synthesized state, i.e., preferably, the zeolite has not been subjected to a calcining treatment for removing the organic template incorporated therein.

[0146] The organic template-containing zeolite is next ion-exchanged in a solution containing ammonium ions and/or protons. By the ion-exchange treatment, the counter cations contained in the organic template-containing zeolite are exchanged for ammonium ions and/or protons. Further, at the same time, a portion of the organic template incorporated in the organic template-containing zeolite is removed.

[0147] The solution used for the ion-exchange treatment is preferably a solution that uses a solvent containing at least 50% by volume of water, and more preferably is an aqueous solution. Examples of compounds for supplying ammonium ions into the solution include various inorganic and organic ammonium salts, such as ammonium chloride, ammonium sulfate, ammonium nitrate, ammonium phosphate, and ammonium acetate. On the other hand, mineral acids such as hydrochloric acid, sulfuric acid, and nitric acid are typically used as compounds for supplying protons into the solution. The ion-exchanged zeolite (here, an ammonium-form zeolite) obtained by ion exchange of the organic template-containing zeolite in the presence of ammonium ions releases ammonia during subsequent calcination, and the counter cations are converted into protons to form Bronsted acid sites. Ammonium ions are preferred as the cationic species used for the ion exchange. The amount of ammonium ions and/or protons contained in the solution is preferably set to 10 to 1,000 equivalents based on the total amount of the counter cations and organic template contained in the organic template-containing zeolite used.

[0148] The ion-exchange treatment may be performed on the organic template-containing zeolite simple substance in powder form, or alternatively, prior to the ion-exchange treatment, the organic template-containing zeolite may be blended with an inorganic oxide, which is a binder, and molded, and the ion-exchange treatment may be performed on the resulting molded body. However, if the molded body is subjected to the ion-exchange treatment in an uncalcined state, problems such as the molded body collapsing and turning into a powder tend to occur. Therefore, it is preferred to subject the organic template-containing zeolite in powder form to an ion-exchange treatment.

[0149] The ion-exchange treatment is preferably performed based on a standard method, i.e., a method in which the zeolite containing an organic template is dipped in a solution, preferably an aqueous solution, containing ammonium ions and/or protons, and the solution is stirred or fluidized. It is preferred to perform the stirring or fluidization under heating to increase the ion-exchange efficiency. In the present aspect, especially preferred is a method in which the aqueous solution is heated, boiled, and ion-exchanged under reflux.

[0150] Further, from the perspective of increasing the ion-exchange efficiency, during the ion exchange of the zeolite in a solution, it is preferred to exchange the solution with a fresh one once or twice or more, and more preferably exchanged with a fresh one once or twice. When exchanging the solution once, the ion-exchange efficiency can be improved by, for example, dipping the organic template-containing zeolite in a solution containing ammonium ions and/or protons, and heating the solution under reflux for 1 to 6 hours, followed by exchanging the solution with a fresh one, and further heating under reflux for 6 to 12 hours.

[0151] By the ion-exchange treatment, substantially all of the counter cations such as an alkali metal in the zeolite can be exchanged for ammonium ions and/or protons. On the other hand, regarding the organic template incorporated in the zeolite, although a portion of the organic template is removed by the ion-exchange treatment, it is generally difficult to remove all of the organic template even if the ion-exchange treatment is repeatedly performed, so that a portion of the organic template remains inside the zeolite.

[0152] In the present aspect, a carrier precursor is obtained by heating a mixture in which the ion-exchanged zeolite and the binder are included in a nitrogen atmosphere at a temperature of 250 to 350°C.

[0153] The mixture in which the ion-exchanged zeolite and the binder are included is preferably obtained by blending an inorganic oxide, which is a binder, with the ion-exchanged zeolite obtained by the above-described method, and molding the resulting composition to form a molded body. The purpose of blending an inorganic oxide with the ion-exchanged zeolite is to increase the mechanical strength of the carrier (in particular, a particulate carrier) obtained by calcining the molded body to a degree that can withstand practical applications. However, the present inventor found that the selection of the type of inorganic oxide affects the isomerization selectivity of the hydroisomerization catalyst. From this perspective, at least one inorganic oxide selected from alumina, silica, titania, boria, zirconia, magnesia, ceria, zinc oxide, phosphorus oxide, and a composite oxide containing a combination of two or more of these oxides can be used as the inorganic oxide. Among the above, silica and alumina are preferred, and alumina is more preferred, from the perspective of further improving the isomerization selectivity of the hydroisomerization catalyst. The phrase "composite oxide containing a combination of two or more of these oxides" refers to a composite oxide containing at least two components from alumina, silica, titania, boria, zirconia, magnesia, ceria, zinc oxide, and phosphorus oxide, but is preferably an alumina-based composite oxide containing 50% by mass or more of an alumina component based on the composite oxide, and among those, is more preferably alumina-silica.

[0154] The blending ratio of the ion-exchanged zeolite and the inorganic oxide in the above-described composition is preferably 10:90 to 90:10, and more preferably 30:70 to 85:15, in terms of the mass ratio of the ion-exchanged zeolite to the inorganic oxide. If this ratio is less than 10:90, the activity of the hydroisomerization catalyst tends to be insufficient, which is undesirable. Conversely, if the ratio is more than 90:10, the mechanical strength of the carrier obtained by molding and calcining the composition tends to be insufficient, which is undesirable.

[0155] Although the method for blending the inorganic oxide with the ion-exchanged zeolite is not especially limited, a general method can be employed, such as, for example, a method in which a suitable amount of a liquid such as water is added to the powders of both components to form a viscous fluid, and the fluid is kneaded in a kneader or the like.

[0156] The composition containing the ion-exchanged zeolite and inorganic oxide, or a viscous fluid including the composition, is molded by a method such as extrusion molding, and is preferably dried, to form a particulate molded body. Although the shape of the molded body is not especially limited, examples of the shape include a cylindrical shape, a pellet shape, a spherical shape, and an irregular tubular shape having a three leaf shaped or a four leaf shaped cross-section. Although the size of the molded body is not especially limited, the molded body is preferably, for example, about 1 to 30 mm in the long axis, and about 1 to 20 mm in the short axis, from the perspective of the ease of handling, the load density in the reactor and the like.

[0157] In the present aspect, it is preferred to form the carrier precursor by heating the thus-obtained molded body in a N_2 atmosphere at a temperature of 250 to 350°C. Regarding the heating time, preferred is 0.5 to 10 hours, and more preferred is 1 to 5 hours.

[0158] In the present aspect, if the above-described heating temperature is less than 250°C, a large amount of organic template remains, and the zeolite pores become blocked with the remaining template. The isomerization active sites are thought to exist near the pore mouth. Thus, in the above case, the reaction substrate cannot disperse into the pores due to the pore blockage, so that the active sites become covered, the isomerization reaction does not easily proceed, and a normal paraffin conversion rate tends not to be sufficiently obtained. On the other hand, if the heating temperature is more than 350°C, the isomerization selectivity of the obtained isomerization catalyst does not sufficiently improve.

[0159] It is preferred that the lower limit for the temperature when forming the carrier precursor by heating the molded body is 280°C or more, and that the upper limit for the temperature is 330°C or less.

[0160] In the present aspect, it is preferred to heat the above-described mixture so that a portion of the organic template included in the molded body remains. Specifically, it is preferred to set the heating conditions so that the micropore volume per unit mass of the hydroisomerization catalyst obtained by calcining after the below-described metal supporting is 0.02 to 0.11 cc/g, and the micropore volume per unit mass of the zeolite that is contained in that catalyst is 0.04 to 0.12 cc/g.

[0161] Next, the catalyst precursor incorporating a platinum salt and/or palladium salt in the above-described carrier precursor is calcined in an atmosphere containing molecular oxygen at a temperature of 350 to 400°C, preferably 380 to 400°C, and more preferably 400°C, to obtain a hydroisomerization catalyst in which a platinum and/or palladium is supported on a carrier including zeolite. Here, "in an atmosphere containing molecular oxygen" means bringing into contact with a gas including oxygen gas, and of those preferably air. The calcining time is preferably 0.5 to 10 hours, and more preferably 1 to 5 hours.

[0162] Examples of the platinum salt include chloroplatinic acid, tetraammineplatinum dinitrate, dinitroaminoplatinum, and tetraamminedichloroplatinum. Since chloride salts can produce hydrochloric acid during a reaction, which may cause apparatus corrosion, tetraammineplatinum dinitrate, which is a platinum salt that is not a chloride salt and in which a high level of platinum is dispersed, is preferred.

[0163] Examples of the palladium salt include palladium chloride, tetraammine palladium nitrate, and diaminopalladium nitrate. Since chloride salts can produce hydrochloric acid during a reaction, which may cause apparatus corrosion, tetraammine palladium nitrate, which is a palladium salt that is not a chloride salt and in which a high level of palladium is dispersed, is preferred.

[0164] The amount of the active metal supported on the carrier including zeolite according to the present aspect is preferably 0.001 to 20% by mass, and more preferably 0.01 to 5% by mass, based on the mass of the carrier. If the amount supported is less than 0.001% by mass, it is difficult to impart a predetermined hydrogenation/dehydrogenation function to the catalyst. Conversely, if the amount supported is more than 20% by mass, conversion on the active metal of hydrocarbons into lighter products by cracking tends to proceed, so that the yield of the intended fraction tends to decrease, and the catalyst costs tend to increase, which are undesirable.

[0165] Further, when the hydroisomerization catalyst according to the present aspect is used for hydroisomerization of a hydrocarbon oil containing many sulfur-containing compounds and/or nitrogen-containing compounds, from the perspective of the durability of catalytic activity, it is preferred that the active metals are a combination such as nickel-cobalt, nickel-molybdenum, cobalt-molybdenum, nickel-molybdenum-cobalt, or nickel-tungsten-cobalt. It is preferred that the amount of these metals supported is 0.001 to 50% by mass, and more preferably 0.01 to 30% by mass, based on the mass of the carrier.

[0166] In the present aspect, it is preferred to calcine the above-described catalyst precursor so that the organic template remaining in the carrier precursor remains. Specifically, it is preferred to set the heating conditions so that the micropore volume per unit mass of the obtained hydroisomerization catalyst is 0.02 to 0.11 cc/g, and the micropore volume per unit mass of the zeolite that is contained in that catalyst is 0.04 to 0.12 cc/g.

[0167] The micropore volume per unit mass of the hydroisomerization catalyst is calculated by a method called nitrogen adsorption measurement. Namely, for the catalyst, the micropore volume per unit mass of the catalyst is calculated by analyzing a physical adsorption and desorption isotherm of nitrogen measured at the temperature of liquid nitrogen (-196°C), specifically, analyzing an adsorption isotherm of nitrogen measured at the temperature of liquid nitrogen (-196°C) by a t-plot method. Further, the micropore volume per unit mass of the zeolite contained in the catalyst is also calculated by the above-described nitrogen adsorption measurement.

[0168] In addition, in the present description, a micropore indicates a "pore having a diameter of 2 nm or less" defined in IUPAC (International Union of Pure and Applied Chemistry).

[0169] A micropore volume V_Z per unit mass of the zeolite contained in the catalyst can be calculated, for example, if the binder does not have a micropore volume, based on the following expression from a value V_c of the micropore volume per unit mass of the hydroisomerization catalyst and the content M_Z (% by mass) of zeolite in the catalyst.

$$V_Z = V_c / M_Z \times 100$$

[0170] It is preferred that, subsequent to the calcination treatment, the hydroisomerization catalyst of the present aspect is subjected to a reduction treatment after the catalyst is loaded in the reactor for conducting the hydroisomerization reaction. Specifically, it is preferred that the hydroisomerization catalyst is subjected to the reduction treatment for about 0.5 to 5 hours in an atmosphere containing molecular hydrogen, and preferably under a stream of hydrogen gas, preferably at 250 to 500°C, and more preferably at 300 to 400°C. By performing this step, it can be further ensured that high activity for the dewaxing of the hydrocarbon oil can be imparted to the catalyst.

[0171] The hydroisomerization catalyst according to the present aspect is a hydroisomerization catalyst containing a carrier that includes a zeolite having a one-dimensional, 10-membered ring pore structure and a binder, and platinum and/or palladium supported on the carrier, in which the micropore volume per unit mass of the catalyst is 0.02 to 0.11 cc/g. Further, this zeolite is preferably a zeolite derived from ion-exchanged zeolite obtained by ion-exchanging an organic template-containing zeolite that contains an organic template and has a one-dimensional, 10-membered ring pore structure in a solution containing ammonium ions and/or protons, in which the micropore volume per unit mass of the zeolite contained in the catalyst is 0.04 to 0.12 cc/g.

[0172] The above-described hydroisomerization catalyst can be produced by the method described above. The micropore volume per unit mass of the catalyst and the micropore volume per unit mass of the zeolite contained in the catalyst can be set to be within the above-described ranges by appropriately adjusting the amount of ion-exchanged zeolite blended in the mixture including the ion-exchanged zeolite and a binder, the heating conditions of the mixture in a N_2 atmosphere, and the heating conditions of the catalyst precursor in the atmosphere containing molecular oxygen.

[0173] The reaction temperature in the dewaxing step is preferably 200 to 450°C, and more preferably 220 to 400°C. If the reaction temperature is less than 200°C, the isomerization of the normal paraffins contained in the base oil fraction tends not to easily proceed, so that the reduction and removal of the wax component tend to be insufficient. Conversely, if the reaction temperature is more than 450°C, cracking of the base oil fraction is significant, so that the yield of the lubricant base oil tends to decrease.

[0174] The reaction pressure in the dewaxing step is preferably 0.1 to 20 MPa, and more preferably 0.5 to 15 MPa. If the reaction pressure is less than 0.1 MPa, catalyst degradation due to the formation of coke tends to be accelerated.

Conversely, if the reaction pressure is more than 20 MPa, construction costs for the apparatus increase, so that it tends to become difficult to realize an economical process.

[0175] In the dewaxing step, the liquid hourly space velocity of the base oil fraction based on the catalyst is preferably 0.01 to 100 hr^{-1}, and more preferably 0.1 to 50 hr^{-1}. If the liquid hourly space velocity is less than 0.01 hr^{-1}, the cracking of the base oil fraction tends to proceed excessively, so that production efficiency tends to decrease. Conversely, if the liquid hourly space velocity is more than 100 hr^{-1}, the isomerization of the normal paraffins contained in the base oil fraction tends not to proceed easily, so that the reduction and removal of the wax component tend to be insufficient.

[0176] The supply ratio of hydrogen to base oil fraction is preferably 100 to 1,000 Nm^3/m^3, and more preferably 200 to 800 Nm^3/m^3. If the supply ratio is less than 100 Nm^3/m^3, for example, when the base oil fraction contains sulfur or nitrogen content, hydrogen sulfide and ammonia gas produced by desulfurization and denitrification reactions that accompany the isomerization reaction are adsorbed onto and poison the active metal on the catalyst, which tends to make it difficult to achieve a predetermined catalytic performance. Conversely, if the supply ratio is more than 1,000 Nm^3/m^3, hydrogen supply equipment having an increased capacity is required, which tends to make it difficult to realize an economical process.

[0177] The dewaxed oil obtained in the dewaxing step is offered to the hydrofinishing step, and hydrofinishing treatment (hydrorefining treatment) is performed.

[0178] A reactor used in the hydrofinishing step is not particularly limited, and the hydrofinishing treatment (hydrorefining treatment) can be suitably performed by filling a fixed-bed flow reactor with a predetermined hydrorefining catalyst and making molecular hydrogen and the above-described dewaxed oil flow through the reactor. The hydrofinishing treatment (hydrorefining treatment) described in the present invention means improvement in oxidation stability and a hue of the lubricant oil, and olefin hydrogenation and aromatic hydrogenation of the dewaxed oil are performed.

[0179] Examples of the hydrorefining catalyst include catalysts that include a carrier including one or more inorganic solid acidic substances selected from alumina, silica, zirconia, titania, boria, magnesia, and phosphorus, and one or more active metals selected from the group consisting of platinum, palladium, nickel-molybdenum, nickel-tungsten, and nickel-cobalt-molybdenum that is supported on the carrier.

[0180] A preferred carrier is an inorganic solid acidic substance that includes at least two or more of alumina, silica, zirconia, or titania.

[0181] As the method for supporting the active metals on the carrier, a conventional method such as impregnation or ion exchange may be employed.

[0182] The amount of the active metals supported in the hydrorefining catalyst is preferably such that the total amount of metal is 0.1 to 25% by mass based on the carrier.

[0183] The average pore size of the hydrorefining catalyst is preferably 6 to 60 nm, and more preferably 7 to 30 nm. If the average pore size is less than 6 nm, a sufficient catalytic activity tends not to be obtained, while if the average pore size is more than 60 nm, catalytic activity tends to decrease due to a decrease in the level of dispersion of the active metals. Further, it is preferred that the pore volume of the hydrorefining catalyst is 0.2 mL/g or more. If the pore volume is less than 0.2 mL/g, degradation of the activity of the catalyst tends to occur earlier. In addition, it is preferred that the specific surface area of the hydrorefining catalyst is 200 m^2/g or more. If the specific surface area of the catalyst is less than 200 m^2/g, the dispersibility of the active metals is insufficient, so that activity tends to decrease. The pore volume and the specific surface area of the catalyst can be measured and calculated by a BET method using nitrogen adsorption.

[0184] It is preferred that the reaction conditions in the hydrofinishing step are set to a reaction temperature of 200 to 300°C, a hydrogen partial pressure of 3 to 20 MPa, an LHSV of 0.5 to 5 h-1, and a hydrogen/oil ratio of 1000 to 5000 scfb, and more preferred are a reaction temperature of 200°C to 300°C, a hydrogen partial pressure of 4 to 18 MPa, an LHSV of 0.5 to 4 h-1, and a hydrogen/oil ratio of 2000 to 5000 scfb.

[0185] In the present embodiment, it is preferred to adjust the reaction conditions so that the sulfur and nitrogen content in the hydrorefined oil is 5 ppm by mass or less and 1 ppm by mass or less, respectively.

[0186] The refined oil obtained by the hydrofinishing step is offered to the second fractionating step. Then, a desired lubricant oil fraction is obtained by setting a plurality of cut points and performing vacuum distillation of the hydrorefined oil.

[0187] In addition, the hydrorefined oil may contain light fractions such as naphtha and kerosene and gas oil produced as a byproduct by the hydroisomerization and the hydrofinishing treatment (hydrorefining treatment), and these light fractions can be collected as a fraction having a boiling point of 350°C or less, for example.

[0188] The method for producing a lubricant base oil of the present invention is not limited to the above-described embodiments, and can be appropriately changed. For example, the method for producing a lubricant base oil of the present invention may include a distillation step of obtaining a lubricant oil fraction by fractionating the dewaxed oil obtained by the above-described producing method of the dewaxed oil, and a hydrofinishing step of performing hydrofinishing treatment (hydrorefining treatment) of the lubricant oil fraction obtained in the distillation step.

[0189] The lubricant base oils according to the above-described first to third embodiments and the lubricant base oil obtained by the production method according to the fourth embodiment excel in a low-temperature viscosity characteristic and a sealing property, and can be suitably used as lubricant base oils for various applications. Specifically, examples of the applications of the lubricant base oil include lubricant oils used for internal combustion engines such as passenger vehicle gasoline engines, two-wheel vehicle gasoline engines, diesel engines, gas engines, gas heat pump engines, marine engines, and power-generating engines (internal combustion engine lubricant oil), lubricant oils used for driving transmission devices such as automatic transmissions, manual transmissions, non-stage transmissions, and final reduction gears (driving transmission device oil), hydraulic oils used for hydraulic systems such as dampers and construction machines, compressor oils, turbine oils, industrial gear oils, refrigerant oils, rust preventing oils, heating medium oils, gas holder seal oils, bearing oils, paper machine oils, machine tool oils, sliding guide surface oils, electrical insulating oils, cutting oils, press oils, rolling oils, and heat treating oils, and by using the lubricant base oil according to the present embodiment for these applications, both a low-temperature viscosity characteristic and a sealing property can be satisfied at a high level.

[0190] In the above-described applications, the lubricant base oil according to each embodiment may be used alone, or the lubricant base oil according to each embodiment may be used in combination with one, or two or more other base oils. In addition, when the lubricant base oil according to each embodiment is used in combination with other base oils, a ratio of the lubricant base oil of the present invention in the mixed-base oil is preferably 30% by mass or more, more preferably 50% by mass or more, and further preferably 70% by mass or more.

[0191] Other base oils used in combination with the lubricant base oil according to each embodiment are not particularly limited, and examples of mineral base oils include solvent refined mineral oils, hydrocracked mineral oils, hydrorefined mineral oils, and solvent dewaxed base oils having a kinematic viscosity at 100°C of 1 to 100 mm^2/s, for example.

[0192] Moreover, examples of synthetic base oils include poly-α-olefms or hydrides thereof, isobutene oligomers or hydrides thereof, isoparaffins, alkylbenzenes, alkylnaphthalenes, diesters (ditridecyl glutarate, di-2-ethylhexyl adipate, diisodecyl adipate, ditridecyl adipate, di-2-ethylhexyl sebacate and the like), polyol esters (trimethylolpropane caprylate, trimethylolpropane pelargonate, pentaerythritol 2-ethylhexanoate, pentaerythritol pelargonate and the like), polyoxyalkylene glycols, dialkyldiphenyl ethers, and polyphenyl ethers, and among them, poly-α-olefins are preferable. Typically, examples of the poly-α-olefins include α-olefin oligomers or co-oligomers having a carbon number of 2 to 32, and preferably 6 to 16 (1-octene oligomer, decene oligomer, ethylene-propylene co-oligomer and the like) and hydrides thereof.

[0193] Although a producing method of poly-α-olefins is not particularly limited, examples thereof include a method in which α-olefin is polymerized in the presence of a polymerization catalyst such as a Friedel-Crafts catalyst including a complex of aluminum trichloride or boron trifluoride with water, an alcohol (ethanol, propanol, butanol and the like), a carboxylic acid, or ester.

[0194] Furthermore, various additive agents may be blended into the lubricant base oil according to each embodiment or the mixed-base oil of the lubricant base oil and other lubricant base oils, if necessary. Such additive agents are not particularly limited, and arbitrary additive agents that are conventionally used in the field of lubricant oils can be blended. Specifically, examples of the lubricant oil additive agents include antioxidants, ashless dispersants, metal-based detergents, extreme pressure agents, antiwear agents, viscosity index improvers, pour-point depressants, friction modifiers, oiliness agents, corrosion inhibitors, rust-preventive agents, demulsifying agents, metal deactivating agents, seal swelling agents, antifoaming agents, and coloring agents. These additive agents may be used singly or two or more kinds thereof may be used in combination.

[0195] For example, the lubricant base oil according to each embodiment can effectively exhibit the addition effect of a pour-point depressant. Therefore, when the lubricant base oil according to each embodiment or the mixed-base oil of the lubricant base oil and other lubricant base oils contains a pour-point depressant, an excellent low-temperature viscosity characteristic (MRV viscosity at -40°C is preferably 20,000 mPa·s or less, more preferably 15,000 mPa·s or less, and further preferably 10,000 mPa·s or less) can be achieved. In addition, the MRV viscosity at -40°C described in the present invention means an MRV viscosity at -40°C measured in conformity with JPI-5S-42-93.

[0196] Further, when a pour-point depressant is blended into the lubricant base oil according to the first embodiment or the lubricant base oil according to the second embodiment, the MRV viscosity at-40°C can be 12,000 mPa·s or less, and a lubricant oil composition having an extremely excellent low-temperature viscosity characteristic of more preferably 10,000 mPa·s or less, further preferably 8,000 mPa·s, and particularly preferably 6,500 mPa·s or less can be obtained. In this case, the amount of the pour-point depressant blended is, on the basis of the total amount of the composition, 0.05 to 2% by mass, and preferably 0.1 to 1.5% by mass, in particular, in terms of capable of decreasing the MRV viscosity, the range of 0.15 to 0.8% by mass is the best, as the pour-point depressant, one having the weight-average molecular weight of preferably 10,000 to 300,000, and more preferably 50,000 to 200,000 is particularly preferable, and moreover, as the pour-point depressant, polymethacrylate-based one is particularly preferable.

Examples

[0197] Hereinafter, the present invention will be described more specifically based on examples and comparative examples, but the present invention is not limited to the following examples.

[Examples 1-1 to 1-3, Comparative Examples 1-1 and 1-2]

[0198] In Examples 1-1 to 1-3 and Comparative Examples 1-1 and 1-2, lubricant base oils shown in Table 1 were each prepared. The lubricant base oils in Examples 1-1 to 1-3 are obtained based on the method for producing a lubricant base oil according to the above-described fourth embodiment. In contrast, the lubricant base oils in Comparative Examples 1-1 and 1-2 are obtained by the conventional method for producing a lubricant base oil. Various characteristics of the respective base oils, and the traction coefficients measured under conditions of a load of 50 N (average hertz pressure 0.60 GPa), a sample oil temperature of 50°C, a circumferential velocity of 1 m/s, and a slip ratio of 3%, and using a 27.4 mm steel ball and a steel disc are shown in Table 1.

[Table 1]

Raw materials	Example 1-1	Example 1-2	Example 1-3	Comp. Example 1-1	Comp. Example 1-2
General physical properties					
Density, g/cm^3	0.8182	0.8181	0.8083	0.8180	0.8184
Flash point, °C	232	234	228	238	220
Kinematic viscosity, mm^2/s (40°C)	16.6	17.0	17.1	16.9	17.0
(100°C)	4.09	4.13	4.10	4.16	4.10
Viscosity index	154	151	146	157	141
Pour point, °C	-5	-12.5	-17.5	-2.5	-25
Freezing point, °C	-5	-15	-20	-4	-26
NOACK, mass% (250°C)	11.5	12.0	12.8	12.2	11.8
Sulfur content, mass ppm	<1	<1	<1	<1	<1
Chromatography analysis					
Saturated content, mass%	99.4	99.3	99.5	99.4	99.6
Resin content, mass%	0.4	0.3	0.2	0.4	0.2
Aromatic content, mass%	0.2	0.4	0.3	0.3	0.2
Recovery rate, mass%	100	100	100	100	100
Urea adduct					
Adduct amount, mass%	3.18	2.72	2.08	4.05	1.15
Low-temperature characteristics					
CCS viscosity (-30°C), mPa·s	870	880	630	990	141
(-35°C), mP·s	1,650	1,600	1,590	1,950	1,530
SBV viscosity (-20°C), mPa·s	57,600	12,000	3,200	62,000	810
(-30°C), mPa·s	478,000	156,000	51,000	880,000	3,370
(-35°C), mPa·s	783,000	492,000	118,000	>1,000,000	9,150
^{13}C-NMR					
CH	6.6	6.8	7.2	6.4	7.4
CH2	79.1	78.8	78.3	79.5	78.1
CH3	14.3	14.4	14.5	14.1	14.5
CH2 main chain	19.8	18.6	15.2	22.0	14.7
EI-MS					
Paraffins	92.2	92.3	92.1	92.0	92.8
Monocyclic cycloparaffin	3.8	4.5	4.2	4.6	4.0
Bicyclic cycloparaffin	3.1	2.3	2.7	2.3	2.5
Tricyclic cycloparaffin	0.3	0.2	0.1	0.3	0.2
Tetracyclic cycloparaffin	0.0	0.0	0.0	0.2	0.0

(continued)

Raw materials	Example 1-1	Example 1-2	Example 1-3	Comp. Example 1-1	Comp. Example 1-2
Pentacyclic cycloparaffin	0.2	0.1	0.1	0.0	0.1
Hexacyclic cycloparaffin	0.4	0.6	0.5	0.6	0.4
Alkylbenzenes	0.0	0.0	0.0	0.0	0.0
FD-MS					
Paraffins	61.1	58.1	50.2	65.3	65.2
Monocyclic cycloparaffin	31.4	34.6	39.9	28.5	29.2
Bicyclic cycloparaffins	6.3	6.6	7.1	5.5	4.4
Tricyclic cycloparaffin	0.5	0.6	2.3	0.4	0.4
Tetracyclic cycloparaffin	0.3	0.0	0.2	0.0	0.0
Pentacyclic cycloparaffin	0.1	0.0	0.0	0.0	0.0
Hexayclic cycloparaffin	0.3	0.1	0.3	0.3	0.8
Traction coefficient 50N, 50°C, 1m/s, Slip ratio 3%	0.012	0.013	0.015	0.011	0.018

[Examples 1-4 to 1-9, Comparative Examples 1-3 to 1-5]

[0199] In Examples 1-4, 1-6, and 1-8, and Comparative Examples 1-3 and 1-5, the lubricant base oils of Examples 1-1 to 1-3, or Comparative Examples 1-1 and 1-2, respectively, were used as a sample oil. Furthermore, in Examples 1-5, 1-7, and 1-9, and Comparative Examples 1-4 and 1-6, lubricant oil compositions were prepared by adding 10% by mass of a package additive (breakdown: 40% by mass of ashless dispersant, 40% by mass of metal-based detergent, 10% by mass of antiwear agent, 8 % by mass of antioxidant, and 2% by mass of metal deactivating agent) and 5% by mass of a viscosity index improver (polymethacrylate-based, Mw 350,000, effective concentration 50%) to the respective lubricant base oils of Examples 1-1 to 1-3 or Comparative Examples 1-1 and 1-2, respectively, to be used as a sample oil. Moreover, as Comparative Example 1-7, a commercial 0W-20 oil was prepared. The kinematic viscosities and the viscosity indexes of the respective lubricant oil compositions are shown in Table 2.

[Oil Leakage Test]

[0200] With respect to the sample oils of Examples 1-4 to 1-9, and Comparative Examples 1-3 to 1-6, an oil leakage test was performed according to the following procedure.

[0201] 100 ml of the sample oil is charged in a 200 ml autoclave and an NBR packing is used to be assembled with a tightening torque of 250 N·m using a torque wrench. A two-way cock is used at the upper part and, as a sealing material, a teflon (registered trademark) packing is used to be assembled with a tightening torque of 250 N·m using a torque wrench. After assembling, a pressure is increased to 200 kPa with nitrogen gas. The respective sample oils are subjected to the same operation and are set upside down in a low-temperature thermostat bath that is controlled to be -30±1C°. Results are evaluated by oil leakage from the NBR packing after 48 hours, and with leakage is evaluated as presence and without leakage is evaluated as absence.

[0202] The obtained results are shown in Tables 2 and 3.

[JC08 Hot Mode Fuel Consumption Evaluation Test]

[0203] With respect to the lubricant oil compositions of Examples 1-5, 1-7, and 1-9, and Comparative Examples 1-4 and 1-6, a JC08 hot mode fuel consumption evaluation test was performed according to the following procedure.

[0204] JC08 mode is a method for measuring fuel consumption of vehicles, established by Ministry of Land, Infrastructure, Transport and Tourism (for details, refer to Ministry of Land, Infrastructure, Transport and Tourism, Announcement that Prescribes Details of Safety Standards for Road Trucking Vehicles [2009.07.30] Attachment 42 Measurement Method of Exhaust Gas of Light and Middle Vehicles). JC08 is classified into a cold mode that starts in an engine cold state and a hot mode that measures fuel consumption in an engine warm state. In the test, a 2.5 L, FF gasoline engine vehicle (Toyota ESTIMA) was selected, the engine was washed and filled with a newly-prepared sample oil before the start of the test, the test vehicle was made to warm up at a constant rate of 60±2 km/h for 15 minutes or more on a chassis dynamometer, and then, was quickly returned to the idling state, the vehicle was driven in a predetermined running pattern, and consumed fuel was calculated from exhaust gas to determine fuel consumption. The obtained results are shown in Tables 2 and 3.

[Table 2]

		Example 1-4	Example 1-5	Example 1-6	Example 1-7	Example 1-8	Example 1-9
Base oil	Kind	Example 1	Example 1	Example 2	Example 2	Example 3	Example 3
	Content (% by mass)	100	Balance	100	Balance	Balance	Balance
Package additive (% by mass)		-	10	-	10	-	10
Viscosity index improver (% by mass)		-	5	-	5	-	5
Characteristics of sample oil (0W-20)							
Kinematic viscosity, mm^2/s (100°C)		4.09	8.19	4.13	8.22	4.10	8.18
Viscosity index		154	244	151	240	146	242
SBV viscosity (mPa·s)							
-20°C		57,600	59,000	3,200	3,450	3,200	3,380
-30°C		478,000	520,000	51,000	53,000	51,000	52,000
Oil leakage test (-20°C)							
Presence or absence of leakage		Absence	Absence	Absence	Absence	Absence	Absence
JC08 hot mode fuel consumption							
Fuel consumption improving ratio, %		-	1.85	-	1.71	-	1.52

[Table 3]

		Comp. Example 1-3	Comp. Example 1-4	Comp. Example 1-5	Comp. Example 1-6	Comp. Example 1-7
Base oil	Kind	Comp. Example 1	Comp. Example 1	Comp. Example 2	Comp. Example 2	Commercial 0W-20 oil
	Content (mass%)	100	Balance	100	Balance	
Package additive (mass%)		-	10	-	10	
Viscosity index improver (mass%)		-	5	-	5	
Characteristics of sample oil (0W-20)						
Kinematic viscosity, mm^2/s (100°C)		4.16	8.28	4.04	8.33	8.42
viscosity index		157	245	141	237	230
SBV viscosity (mPa·s)						
-20°C		62,000	68,000	810	3,500	-
-30°C		880,000	>1,000,000	3,370	4,800	-

(continued)

	Comp. Example 1-3	Comp. Example 1-4	Comp. Example 1-5	Comp. Example 1-6	Comp. Example 1-7
Oil leakage test (-20°C) Presence or absence of leakage	Absence	Absence	Presence	Presence	-
JC08 hot mode fuel consumption Fuel consumption improving ratio, %	-	0.11	-	0.05	-

[Examples 2-1 and 2-2, Comparative Examples 2-1 to 2-3]

[0205] In Examples 2-1 and 2-2 and Comparative Examples 2-1 to 2-3, lubricant base oils shown in Table 4 were each prepared. The lubricant base oils in Examples 2-1 and 2-2 are obtained based on the method for producing a lubricant base oil according to the above-described fourth embodiment. In contrast, the lubricant base oils in Comparative Examples 2-1 to 2-3 are obtained by the conventional method for producing a lubricant base oil. Various characteristics of the respective base oils, and the traction coefficients measured under conditions of a load of 50 N (average hertz pressure 0.60 GPa), a sample oil temperature of 50°C, a circumferential velocity of 1 m/s, and a slip ratio of 3%, and using a 27.4 mm steel ball and a steel disc are shown in Table 4.

[Table 4]

Raw materials	Example 2-1	Example 2-2	Comp. Example 2-1	Comp. Example 2-2	Comp. Example 2-3
General physical properties					
Density, g/cm^3	0.8273	0.8272	0.8270	0.8260	0.8288
Flash point, °C	262	260	264	250	254
Kinematic viscosity, mm^2/s (40°C)	30.3	28.2	29.4	26.0	30.8
(100°C)	6.30	5.92	6.20	5.48	6.07
Viscosity index	165	162	167	154	148
Pour point, °C	-5	-12.5	-2.5	-15	-30
Freezing point, °C	-5	-14	-4	-17	-32
Sulfur content, mass ppm	<1	<1	<1	<1	<1
Chromatography analysis					
Saturated content, mass%	99.2	99.2	99.3	99.5	99.4
Resin content, mass%	0.4	0.3	0.3	0.2	0.2
Aromatic content, mass%	0.4	0.5	0.4	0.3	0.4
Recovery rate, mass%	100	100	100	100	100
Urea adduct					
Adduct amount, mass%	1.25	0.77	2.33	0.11	0.13
Low-temperature characteristics					
CCS viscosity (-30°C), mPa·s	790	880	1,070	995	1,020
(-35°C), mP·s	1,210	1,320	1,780	1,625	1,850
SBV viscosity (-20°C), mP·s	29,000	3,200	122,000	2,100	1,030
(-25°C), mP·s	470,000	5,300	>1,000,000	4,300	1,700
^{13}C-NMR					
CH	6.2	6.5	6.0	7.1	6.8
CH2	82.0	81.5	83.2	79.8	80.0
CH3	11.2	12.0	10.8	13.1	13.2

(continued)

Raw materials	Example 2-1	Example 2-2	Comp. Example 2-1	Comp. Example 2-2	Comp. Example 2-3
CH2 main chain	25.3	20.3	25.9	18.0	16.0
EI-MS					
Paraffins	81.2	80.1	82.6	83.2	80.0
Monocyclic cycloparaffin	12.9	13.4	11.8	11.0	12.7
Bicyclic cycloparaffins	4.8	5.0	3.9	4.3	5.3
Tricyclic cycloparaffin	0.9	1.0	0.8	0.6	1.1
Tetracyclic cycloparaffin	0.1	0.1	0.1	0.1	0.2
Pentacyclic cycloparaffin	0.0	0.0	0.2	0.2	0.2
Hexacyclic cycloparaffin	0.1	0.4	0.6	0.6	0.5
Alkylbanzenes	0.0	0.0	0.0	0.0	0.0
FD-MS					
Paraffins	36.8	39.7	35.9	47.2	49.4
Monocyclic cycloparaffin	46.9	44.1	47.2	41.2	39.5
Bicyclic cycloparaffin	13.8	13.0	14.1	9.7	8.7
Tricyclic cycloparaffin	2.1	24	2.2	1.4	1.2
Tetracyclic cycloparaffin	0.1	0.2	0.2	0.1	0.1
Pentacyclic cycloparaffin	0.0	0.0	0.0	0 1	0.2
Hexacyclic cycloparaffin	0.3	0.6	0.4	0.3	0.9
Traction coefficient 50N, 25°C, 0.5m/s, Slip ratio 3%	0.017	0.016	0.014	0.018	0.022

[Examples 2-3 to 2-6, Comparative Examples 2-4 to 2-9]

[0206] In Examples 2-3 and 2-5, and Comparative Examples 2-4, 2-6, and 2-8, the lubricant base oils of Examples 2-1 and 2-2, or Comparative Examples 2-1 to 2-3, respectively, were used as a sample oil. Furthermore, in Examples 2-4, 2-6, and Comparative Examples 2-5, 2-7, and 2-9, lubricant oil compositions were prepared by adding 0.8 mass% of a package additive (breakdown: 60 mass% of antiwear agent, 25 mass% of antioxidant, 10 mass% of rust inhibitor, and 5 mass% of metal deactivating agent) to the respective lubricant base oils of Examples 2-1 and 2-2, or Comparative Examples 2-1 to 2-3, respectively, to be used as a sample oil.

[Oil Leakage Test]

[0207] With respect to the sample oils of Examples 2-3 to 2-6, and Comparative Examples 2-4 to 2-9, an oil leakage test was performed according to the following procedure.

[0208] 100 ml of the sample oil is charged in a 200 ml autoclave and an NBR packing is used to be assembled with a tightening torque of 250 N·m using a torque wrench. A two-way cock is used at the upper part and, as a sealing material, a teflon (registered trademark) packing is used to be assembled with a tightening torque of 250 N·m using a torque wrench. After assembling, a pressure is increased to 300 kPa with nitrogen gas. The respective sample oils are subjected to the same operation and are set upside down in a low-temperature thermostat bath that is controlled to be -30±1C°. Results are evaluated by oil leakage from the NBR packing after 48 hours, and with leakage is evaluated as presence and without leakage is evaluated as absence.

[0209] The obtained results are shown in Tables 5 and 6.

[Storage Stability Test]

[0210] With respect to the sample oils of Examples 2-3 to 2-6, and Comparative Examples 2-4 to 2-9, a storage stability test was performed according to the following procedure.

[0211] In a 100 ml screw vial, an oil is charged to two thirds or more thereof, and each of the test tube is put in a refrigerator of 0±1°C, and the appearance is confirmed after 48 hours. Without change in the appearance is evaluated as without change, and generation of condensation is evaluated as condensation.

[Energy Saving Property Evaluation Test]

[0212] With respect to the lubricant oil compositions of Examples 2-4 and 2-6, and Comparative Examples 2-5, 2-7, and 2-9, an energy saving property evaluation test was performed according to the following procedure.

[0213] The energy saving property was evaluated by using a compact hydraulic unit. A variable capacity piston pump was used for a pump in the compact hydraulic unit, the oil amount was 15 L, the oil temperature was 80±2°C and 0°C that considers the time of low-temperature starting, and the input power of a motor when the discharge pressure is varied from 0.8 to 2.4 MPa using a commercial hydraulic oil (0W-20, kinematic viscosity at 40°C: 32.8 mm^2/s, viscosity index: 125) was measured. Next, the input power of a motor was measured by using each of the lubricant oil compositions of Examples 3, 4 and Comparative Examples 4 to 6 as a sample oil, and the energy saving property was evaluated based on a difference of power consumption from a sample oil of Comparative Example 7.

[0214] The obtained results are shown in Tables 5 and 6.

[Table 5]

		Example 2-3	Example 2-4	Example 2-5	Example 2-6
Base oil	Kind	Example 2-1	Example 2-1	Example 2-2	Example 2-2
	Content (mass%)	100	Balance	100	Balance
Package additive (mass%)		-	0.8	-	0.8
Characteristics of sample oil Kinematic viscosity. mm^2/s (40°C) Viscosity index		 30.3 165	 30.5 164	 28.2 162	 28.4 162
SBV viscosity (mPa·s) -20°C -30°C		 29,000 470,000	 29,500 490,000	 3,200 5,300	 3,300 5,500
Oil leakage test (-20°C) Presence or absence of leakage		Absence	Absence	Absence	Absence
Storage stability (0°C)		Without change	Without change	Without change	without change
Energy saving property 80°C 0°C		 - -	 +6.5 +3.5	 - -	 +4.9 +3.1

[Table 6]

		Comp. Example 2-4	Comp. Example 2-5	Comp. Example 2-6	Comp. Example 2-7	Comp. Example 2-8	Comp. Example 2-9
Base oil	Kind	Comp. Example 2-1	Comp. Example 2-1	Comp. Example 2-2	Comp. Example 2-2	Comp. Example 2-3	Comp. Example 2-3
	Content (mass%)	100	Balance	100	Balance	100	Balance
Package additive (mass%)		-	0.8	-	0.8	-	0.8
Characteristics of sample oil Kinematic viscosity, mm^2/s (40°C) Viscosity index		 29.4 167	 29.7 166	 26.0 154	 26.3 152	 30.8 148	 31.0 146
SBV viscosity (mPa·s)							

(continued)

	Comp. Example 2-4	Comp. Example 2-5	Comp. Example 2-6	Comp. Example 2-7	Comp. Example 2-8	Comp. Example 2-9
-20°C	122,000	123,000	2,100	2,300	1,030	1,100
-30°C	>1,000,000	>1,000,000	4,300	4,500	1,700	1,800
Oil leakage test (-20°C) Presence or absence of leakage	Absence	Absence	Presence	Presence	Presence	Presence
Storage stability test (0°C)	Condensation	Condensation	Without change	Without change	Without change	Without change
Energy saving property						
80°C	-	+6.2	-	+0.6	-	+0.8
0°C	-	-0.3	-	+1.4	-	+1.2

[Examples 3-1 to 3-3, Comparative Examples 3-1 to 3-3]

[0215] In Examples 3-1 to 3-3 and Comparative Examples 3-1 to 3-3, lubricant base oils shown in Table 7 were each prepared. The lubricant base oils in Examples 3-1 to 3-3 are obtained based on the method for producing a lubricant base oil according to the above-described fourth embodiment. In contrast, the lubricant base oils in Comparative Examples 3-1 to 3-3 are obtained by the conventional method for producing a lubricant base oil. Various characteristics of the respective base oils, and the traction coefficients measured under conditions of a load of 50 N (average hertz pressure 0.60 GPa), a sample oil temperature of 50°C, a circumferential velocity of 1 m/s, and a slip ratio of 3%, and using a 27.4 mm steel ball and a steel disc are shown in Table 7.

[Table 7]

	Example 3-1	Example 3-2	Example 3-3	Comp. Example 3-1	Comp. Example 3-2	Comp. Example 3-3
General physical properties						
Density, g/cm^3	0.8054	0.8055	0.8056	0.8057	0.8058	-
Flash point, °C	204	202	200	205	197	-
Kinematic viscosity, mm^2/s (40°C)	9.23	8.10	9.16	9 19	9.22	8.48
(100°C)	2.70	2.45	2.66	2.70	2.65	2.51
Viscosity index	138	133	131	140	129	127
Pour point, °C	-11	-22.5	-27.5	-7.5	-30	-40
Freezing point, °C	-15	-24	-28	-8	-31	-43
NOACK, mass% (250°C)	44.8	46.2	48.6	52.8	56.2	55.1
Sulfur content, mass ppm	<10	<10	<10	<10	<10	<10
Iodine value	0.08	0.07	0.08	0 07	0.09	0.07
Aniline point, °C	111.1	110.6	110.7	112.5	111.8	112.0
Chromatography analysis						
Saturated content, mass%	99.6	99.4	99.5	99.6	99.6	99.3
Resin content, mass%	0.3	0.3	0.3	0.2	0.2	0.3
Aromatic content, mass%	0.1	0.3	0.2	02	0.2	0.4
Recovery rate, mass%	100	100	100	100	100	100
Urea adduct amount, mass%	9.68	4.25	4.02	12.5	0.58	0.11
nP, mass%	15.2	23.9	22.2	14.8	32.8	37.5

(continued)

	Example 3-1	Example 3-2	Example 3-3	Comp. Example 3-1	Comp. Example 3-2	Comp. Example 3-3
nP Base oil conversion amount, mass%	1.47	1.02	0.89	1.85	0.19	0.04
Low-temperature characteristics						
SBV viscosity, mP·s (-20°C)	1,500	100	110	4,500	130	<1000
(-25°C)	3,100	430	240	37,000	200	-
(-30°C)	19,200	2,120	1,050	49,000	780	270
(-35°C)	290,000	13,300	3,300	900,000	1,970	1,040
(-40°C)	720,000	29,000	5,300	>1,000,000	3,830	2,110
^{13}C-NMR						
CH	7.6	7.8	7.7	7.4	7.7	7.6
CH2	76.4	76.1	75.9	76.6	76.0	75.6
CH3	16.0	16.1	16.2	16.0	16.3	16.8
CH2 main chain	16.9	16.4	15.1	17.1	13.3	10.1
EI-MS						
Paraffins	98.2	98.1	97.9	98.3	98.0	97.7
Monocyclic cycloparaffin	0.0	0.0	0.0	0.0	0.0	0.0
Bicyclic cycloparaffins	1.3	1.5	1.4	1.5	1.7	1.7
Tricyclic cycloparaffin	0.3	0.4	0.3	0.1	0.3	0.3
Tetracyclic cycloparaffin	0.1	0.0	0.2	0.0	0.0	0.0
Pentacyclic cycloparaffin	0.0	0.0	0.0	0.1	0.0	0.0
Hexacyclic cycloparaffin	0.1	0.0	0.2	0.0	0.0	0.3
Alkylbenzenes	0.0	0.0	0.0	0.0	0.0	0.0
FD-MS						
Paraffins	79.9	76.2	70.4	82.1	68.5	67.9
Monocyclic cycloparaffin	18.5	20.1	25.8	16.3	26.4	27.3
Bicyclic cycloparaffin	1.2	2.9	3.0	1.1	4.0	4.1
Tricyclic cycloparaffin	0.2	0.3	0.5	0.3	0.5	0.4
Tetracyclic cycloparaffin	0.0	0.0	0.0	0.0	0.0	0.0
Pentacyclic cycloparaffin	0.1	0.0	0.1	0.0	0.1	0.0
Hexacyclic cycloparaffin	0.1	0.5	0.2	0.2	0.5	0.3
Traction coefficient	0.013	0.014	0.015	0.011	0.016	0.019

[Examples 3-4 to 3-6, Comparative Examples 3-4 to 3-6]

[0216] In Examples 3-4 to 3-6 and Comparative Examples 3-4 to 3-6, lubricant oil compositions were prepared by adding 8% by mass of a package additive (breakdown: antiwear agent: 12% by mass, ashless dispersant: 50% by mass, pour-point depressant: 1% by mass, antioxidant: 12% by mass, metal-based detergent: 25% by mass) and 5% by mass of a viscosity index improver (polymethacrylate-based, Mw 350,000, effective concentration 50% by mass) to the lubricant base oils of Examples 3-4 to 3-6 and Comparative Examples 3-4 to 3-6, respectively.

[Oil Leakage Test]

[0217] With respect to the sample oils of Examples 3-4 to 3-9, and Comparative Examples 3-4 to 3-9, an oil leakage test was performed according to the following procedure.

[0218] More specifically, as a low-temperature leakage test, an actual transmission was used, the sample oil was encapsulated in the transmission to be stored at low temperature, and oil leakage (bleed) was evaluated. The obtained results are shown in Tables 8 and 9.

[Storage Stability Test]

[0219] With respect to the sample oils of Examples 3-4 to 3-9, and Comparative Examples 3-4 to 3-9, a storage stability test was performed according to the following procedure.

[0220] In a 100 ml screw vial, an oil is charged to two thirds or more thereof, and each of the test tube is put in a refrigerator of 0±1°C, and the appearance is confirmed after 48 hours. Without change in the appearance is evaluated as without change, and generation of condensation is evaluated as condensation.

[Low-Temperature Roller Bearing Test]

[0221] With respect to the lubricant oils of Examples 3-4, 3-6, and 3-8, and Comparative Examples 3-4, 3-6, and 3-8, a low-temperature roller bearing test was performed using a high-pressure friction tester. More specifically, a measurement site is cooled to 0°C by a cooling jacket under the ordinary pressure condition and the temperature is kept for 4 hours. A cylindrical roller bearing was used as a test piece, and a friction coefficient was evaluated. The obtained results are shown in Tables 8 and 9. The smaller friction coefficient in Table 7 means an excellent reduction in the friction coefficient at the beginning of rolling, in particular, and has a correlation with cold startability by a real machine.

[Table 8]

		Example 3-4	Example 3-5	Example 3-6	Example 3-7	Example 3-8	Example 3-9
Base oil	Kind	Example 3-1	Example 3-1	Example 3-2	Example 3-2	Example 3-3	Example 3-3
	Content (mass%)	100	Balance	100	Balance	Balance	Balance
Package additive (mass%)		-	8	-	8	-	8
Viscosity index improver (mass%)		-	5	-	5	-	5
SBV viscosity mPa·s -40°C		720,000	320,000	29,000	16,000	5,300	5,500
Oil leakage test (-30°C) Presence or absence of leakage		Absence	Absence	Absence	Absence	Absence	Absence
Low-temperature storage stability		Without change	Without change	Without change	Without change	Without change	Without change
Low-temperature roller bearing test Friction coefficient		0.020	-	0.021	-	0.022	-

[Table 9]

		Comp. Example 3-4	Comp. Example 3-5	Comp. Example 3-6	Comp. Example 3-7	Comp. Example 3-8	Comp. Example 3-9
Base oil	Kind	Comp. Example 3-1	Comp. Example 3-1	Comp. Example 3-2	Comp. Example 3-2	Comp. Example 3-3	Comp. Example 3-3
	Content (mass%)	100	Balance	100	Balance	Balance	Balance

(continued)

	Comp. Example 3-4	Comp. Example 3-5	Comp. Example 3-6	Comp. Example 3-7	Comp. Example 3-8	Comp. Example 3-9
Package additive (mass%)	-	8	-	8	-	8
Viscosity index improver (mass%)	-	5	-	5	-	5
SBV viscosity mPa·s -40°C	>1,000,000	560,000	3,830	4,200	2,110	1,980
Oil leakage test (-30°C) Presence or absence of leakage	Absence	Absence	Presence	Presence	Presence	Presence
Low-temperature storage stability	Condensation	Condensation	Without change	Without change	Without change	Without change
Low-temperature roller bearing test friction coefficient	0.052	-	0.028	-	0.030	-

Claims

1. A lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):

(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,
(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and
(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s.

2. The lubricant base oil according to claim 1, wherein the hydrocarbon oil satisfies the condition (i) and has an SBV viscosity at - 30°C of 5,000 to 500,000 mPa·s.

3. The lubricant base oil according to claim 1 or 2, wherein the hydrocarbon oil satisfies the condition (i) and has a freezing point of -20 to -5°C.

4. The lubricant base oil according to any one of claims 1 to 3, wherein the hydrocarbon oil satisfies the condition (i) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 15% or more in a ^{13}C-NMR analysis.

5. The lubricant base oil according to any one of claims 1 to 4, wherein the hydrocarbon oil satisfies the condition (i) and has a cycloparaffin content of 50% or less in an FD-MS analysis.

6. The lubricant base oil according to claim 1, wherein the hydrocarbon oil satisfies the condition (ii) and has an SBV viscosity at - 25°C of 5,000 to 500,000 mPa·s.

7. The lubricant base oil according to claim 1 or 6, wherein the hydrocarbon oil satisfies the condition (ii) and has a freezing point of - 15 to -5°C.

8. The lubricant base oil according to any one of claims 1, 6 and 7, wherein the hydrocarbon oil satisfies the condition (ii) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 20% or more in a ^{13}C-NMR analysis.

9. The lubricant base oil according to any one of claims 1, 6, 7 and 8, wherein the hydrocarbon oil satisfies the condition (ii) and has a cycloparaffin content of 60% or less in an FD-MS analysis.

10. The lubricant base oil according to claim 1, wherein the hydrocarbon oil satisfies the condition (iii) and has an SBV viscosity at -35°C of 3,000 to 500,000 mPa·s.

11. The lubricant base oil according to claim 1 or 10, wherein the hydrocarbon oil satisfies the condition (iii) and has a freezing point of - 30 to -10°C.

12. The lubricant base oil according to any one of claims 1, 10 and 11, wherein the hydrocarbon oil satisfies the condition (iii) and has a ratio of CH_2 carbons constituting a main chain to all carbons constituting the lubricant base oil of 15% or more in a ^{13}C-NMR analysis.

13. The lubricant base oil according to any one of claims 1, 10, 11 and 12, wherein the hydrocarbon oil satisfies the condition (iii) and has a cycloparaffin content of 30% or less in an FD-MS analysis.

14. A method for producing a lubricant base oil, the method comprising:

a first step of fractionating, from a hydrocarbon oil containing a base oil fraction and a heavy fraction that is heavier than the base oil fraction, the base oil fraction and the heavy fraction;
a second step of returning a cracked oil obtained by hydrocracking the heavy fraction fractionated in the first step, to the first step;
a third step of obtaining a dewaxed oil by performing hydroisomerization dewaxing of the base oil fraction;
a fourth step of obtaining a refined oil by refining the dewaxed oil; and
a fifth step of obtaining a lubricant base oil that is a hydrocarbon oil that satisfies any of the following conditions (i), (ii) and (iii):

(i) a hydrocarbon oil having a kinematic viscosity at 100°C of 3.0 to 5.0 mm^2/s, a viscosity index of 145 or more, and an SBV viscosity at -20°C of 3,000 to 60,000 mPa·s,
(ii) a hydrocarbon oil having a kinematic viscosity at 100°C of 5 to 9 mm^2/s, a viscosity index of 155 or more, and an SBV viscosity at -20°C of 3,000 to 30,000 mPa·s, and
(iii) a hydrocarbon oil having a kinematic viscosity at 100°C of 2.0 to 3.0 mm^2/s, a viscosity index of 130 or more, and an SBV viscosity at -30°C of 1,000 to 30,000 mPa·s, by fractionation of the refined oil.

15. The method according to claim 14, wherein the lubricant base oil obtained in the third step satisfies the condition (i) and has a freezing point of -20 to -5°C.

16. The method according to claim 14, wherein the lubricant base oil obtained in the third step satisfies the condition (ii) and has a freezing point of -15 to -5°C.

17. The method according to claim 14, wherein the lubricant base oil obtained in the third step satisfies the condition (iii) and has a freezing point of -30 to -10°C.

18. The method according to any one of claims 14 to 17, wherein the third step is a step of performing hydroisomerization dewaxing of the base oil fraction in the presence of a hydroisomerization catalyst containing at least one crystalline solid acidic substance selected from the group consisting of ZSM-22-type zeolite, ZSM-23-type zeolite, SSZ32, and ZSM-48-type zeolite and platinum and/or palladium as an active metal.

19. The method according to any one of claims 14 to 18, wherein the hydrocarbon oil is obtained by using GTL wax obtained by a Fischer-Tropsch synthesis or slack wax obtained by solvent dewaxing, as a raw material.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/059947

A. CLASSIFICATION OF SUBJECT MATTER
See extra sheet.

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)
C10M171/00, C10G45/46, C10G45/64, C10G47/12, C10G65/08, C10G65/12, C10M101/02, C10M105/04, C10M177/00, C10N20/00, C10N20/02, C10N30/00, C10N30/02, C10N40/00, C10N40/02, C10N40/04, C10N40/06, C10N40/08,

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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
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A	JP 2006-521416 A (Exxonmobil Research and Engineering Co.), 21 September 2006 (21.09.2006), paragraph [0143]; examples & US 2004/0154958 A1 & EP 1570035 A1 & WO 2004/053030 A2 & CA 2508029 A & KR 10-2005-0084206 A & AU 2003286541 A & CA 2638427 A	1-19

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

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Date of the actual completion of the international search 10 June, 2013 (10.06.13)	Date of mailing of the international search report 18 June, 2013 (18.06.13)
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/059947

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

International application No.
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Continuation of A. CLASSIFICATION OF SUBJECT MATTER
(International Patent Classification (IPC))

C10M171/00(2006.01)i, *C10G45/46*(2006.01)i, *C10G45/64*(2006.01)i, *C10G47/12*(2006.01)i, *C10G65/08*(2006.01)i, *C10G65/12*(2006.01)i, *C10M101/02*(2006.01)i, *C10M105/04*(2006.01)i, *C10M177/00*(2006.01)i, *C10N20/00*(2006.01)n, *C10N20/02*(2006.01)n, *C10N30/00*(2006.01)n, *C10N30/02*(2006.01)n, *C10N40/00*(2006.01)n, *C10N40/02*(2006.01)n, *C10N40/04*(2006.01)n, *C10N40/06*(2006.01)n, *C10N40/08*(2006.01)n, *C10N40/12*(2006.01)n, *C10N40/16*(2006.01)n, *C10N40/20*(2006.01)n, *C10N40/22*(2006.01)n, *C10N40/24*(2006.01)n, *C10N40/25*(2006.01)n, *C10N40/30*(2006.01)n, *C10N70/00*(2006.01)n

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

Continuation of B. FIELDS SEARCHED
Minimum documentation searched (International Patent Classification (IPC))

C10N40/12, C10N40/16, C10N40/20, C10N40/22, C10N40/24, C10N40/25, C10N40/30, C10N70/00

Minimum documentation searched (classification system followed by classification symbols)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 4036391 A **[0005]**
- JP 4068082 A **[0005]**
- JP 4120193 A **[0005]**
- JP 2005154760 A **[0005]**
- JP 2006502298 T **[0005]**
- JP 2002503754 T **[0005]**