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(71) Applicants:
- **SK Innovation Co., Ltd.**
  Seoul 03188 (KR)
- **SK Enmove Co., Ltd.**
  Seoul 03188 (KR)

(72) Inventors:
- **JEON, Young Wook**
  34124 Daejeon (KR)
- **PARK, Jun Soo**
  34124 Daejeon (KR)
- **NOH, Kyung Seok**
  34124 Daejeon (KR)

(74) Representative: **Frick, Robert**
Lorenz Seidler Gossel
Rechtsanwälte Patentanwälte
Partnerschaft mbB
Widenmayerstraße 23
80538 München (DE)

(54) METHOD OF RECYCLING WASTE LUBRICANT

(57) The invention relates to a method of recycling waste lubricant. The method includes providing a waste lubricant-derived oil fraction, pretreating the waste lubricant derived oil fraction, and hydrocracking the pretreated waste lubricant-derived oil fraction. The method has economic advantages in that waste lubricant can be recycled into fuel oil and high-grade lube base oil.

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method of recycling waste lubricant.

2. Description of the Related Art

[0002] Waste lubricant undergoes a series of refining processes to obtain refined oil. In some countries, the entire amount of the refined oil is used as fuel oil, while in other countries, a portion of the refined oil is used as fuel oil, and the remainder is used as low-grade regenerated base oil.

[0003] On the other hand, good lube base oils have a high viscosity index, high stability (resistant to oxidation, heat, UV, etc.), and low volatility. The American Petroleum Institute (API) classifies lube base oils according to their quality as shown in Table 1 below.

[Table 1]

Group	Content of sulfur (ppm)		Saturation (%)	Viscosity index (VI)
I	> 300	and/or	< 90	80-120
II	≤ 300	and	≥ 90	80-120
III	≤ 300	and	≥ 90	> 120
IV	All Polyalphaolefins (PAOs)			
V	All stocks not in Groups I-IV			

[0004] In the above classification, the quality of lube base oils increases from Group I to V, of which Group III lube base oils are generally produced by advanced hydrocracking reactions. Typically, unconverted oil, which is a heavy oil fraction that is not converted to fuel oil during a fuel oil hydrocracking process, is used as a feedstock for the production of Group III and higher lube base oils.

SUMMARY OF THE INVENTION

[0005] The present invention provides a method of recycling waste lubricant into fuel oil or lube base oil.

[0006] More specifically, a method of the present invention includes: providing a waste lubricant-derived oil fraction ("WLDOF"); pretreating the waste lubricant-derived oil fraction; and hydrocracking the pretreated waste lubricant-derived oil fraction.

[0007] According to one embodiment, the waste lubricant-derived oil fraction has a kinematic viscosity at 40°C in a range of 20 to 60 cSt (ASTM D445 at 40°C) and a pour point of 0°C (ASTM D97).

[0008] According to one embodiment, the pretreatment step may include performing solvent extraction on the waste lubricant-derived oil fraction. The solvent may be selected from one or more of N-methyl-2-pyrrolidone (NMP), sulfolane, DMSO, furfural, phenol, and acetone. The solvent extraction may be carried out at a temperature of 30°C to 200°C. The solvent extraction may carried out at pressure in a range of atmospheric pressure to 20 kg/cm2. The volume ratio of a solvent with respect to the oil component contained in the waste lubricant-derived oil fraction may be 1:1 to 10:1.

[0009] According to one embodiment, the method may further include a first blending step of blending the waste lubricant-derived oil fraction with a hydrocarbon feedstock prior to the hydrocracking step to produce a first formulation.

[0010] According to one embodiment, the first formulation may include 1% to 10% by volume of the waste lubricant-derived oil fraction with respect to the total volume thereof.

[0011] In one embodiment, the hydrocracking step may performed at a reaction pressure of 25 to 320 atm, preferably 80 to 250 atm. The temperature during hydrocracking may be 200°C to 500°C, preferably 250°C to 400°C). A liquid hourly space velocity (LHSV) during hydrocracking may be 0.1 to 8 hr-1, preferably 0.5 to 5 hr-1

[0012] According to one embodiment, the method may further include recovering a plurality of fractions including a first fraction and a second fraction, from the product of the hydrocracking step.

[0013] According to one embodiment, the first fraction may have a boiling point in a boiling point range of fuel oil, i.e. lower than 400°C.

[0014] According to one embodiment, the boiling point of the second fraction may be higher than the boiling point of the first fraction.

[0015] According to one embodiment, the method may further include a second blending step of blending the second fraction with a separate waste lubricant-derived oil fraction to produce a second formulation.

[0016] According to one embodiment, the separate waste lubricant-derived oil fraction is obtained by providing a waste lubricant-derived oil fraction, which may be the same or a different waste lubricant-derived oil fraction relative to the waste lubricant-derived oil fraction provided to obtain the second fraction; and pretreating that waste lubricant-derived oil fraction; wherein that pretreated waste lubricant derived oil fraction is not subjected to hydrocracking.

[0017] According to one embodiment, the amount of the separate waste lubricant-derived oil used in the second blending step may be 3% to 50%, preferably 5% to 35%, more preferably 7% to 20% by volume with respect to the volume of the second formulation. The separate waste lubricant-derived oil fraction may be obtained by providing a waste lubricant-derived oil fraction, which may be the same or a different waste lubricant-derived oil fraction relative to the waste lubricant-derived oil fraction provided to obtain the second fraction, and pretreating that waste lubricant-derived oil fraction, preferably as described above. Preferably, that pretreated waste lubricant-derived oil fraction is not subjected to hydrocracking.

[0018] According to one embodiment, the method may further include a step of catalytically dewaxing the second formulation, wherein the catalyst preferably comprises a carrier having an acid site selected from molecular sieve, alumina, and silica-alumina, and one or more hydrogenating metals selected from Mo, W, Co, Ni, Pt, and Pd.

[0019] According to one embodiment, the method may further include a step of hydrofinishing the catalytically dewaxed second formulation. The product of the hydrofinishing step may be recovered as a fuel oil or lube base oil.

[0020] The invention further relates to a fuel oil or lube base oil made by a method as described above. The oil may have a viscosity index of 120 or more (ASTM D2270) and/ or a degree of saturation of 90% or more. Further, the oil may have a Saybolt color value of 27 or greater (ASTM D156). Yet further, the oil may exhibit a UV 260-350 nm absorbance of 2.5 or less and a UV 325 nm absorbance of 0.7 or less (ASTM D2008).Since waste lubricant can be reclaimed into fuel oil and advanced lube base oils, the present invention has the advantage of being economically beneficial, and an advantage that waste lubricant can be utilized as a feedstock for producing products for various applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIGS. 1 to 3 are simplified flow charts of a method of recycling waste lubricant according to embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The above and other objectives, features, and advantages of the present disclosure will be more clearly understood from the following detailed description.

[0023] According to the present invention, there is provided a method of recycling waste lubricant, the method including providing a waste lubricant-derived oil fraction 10; pretreating the waste lubricant-derived oil fraction 20; and hydrocracking the pretreated waste lubricant-derived oil fraction 30. The recycling waste lubricant, in the broadest sense, means reclaiming waste lubricant as a feedstock for the manufacture of a usable oil, and in the context of this disclosure, it means reusing waste lubricant as a feedstock for the manufacture of fuel oils and lube base oils.

[0024] As used herein, the term "waste lubricant-derived oil fraction" refers to used lubricant. In general, lubricant contains a lube base oil and various additives. The additives include large amounts of impurities that are not suitable for use in a lube base oil. For this reason, the waste lubricant contains large amounts of impurities. For example, waste lubricant may contain 200 to 3000 ppm of sulfur, 200 to 2000 ppm of nitrogen, 20 to 2000 ppm of chlorine, and other metallic impurities that may be introduced during lubrication.

[0025] According to one embodiment, the waste lubricant-derived oil fraction has a kinematic viscosity at 40°C in a range of 20 to 60 cSt and a pour point of lower than 0°C. Preferably, the waste lubricant-derived oil fraction has a kinematic viscosity in a range of 25 to 50 cSt when measured at 40°C and a pour point of -5°C. More preferably, the waste lubricant-derived oil fraction has a kinematic viscosity in a range of 26 to 40 cSt measured at 40°C and a pour point in a range of -21°C to -6°C.

[0026] If reference is made to values of kinematic viscosity herein, reference is made to values as measured according to ASTM D445 at the temperature indicated.

[0027] If reference is made to values of pour point herein, reference is made to values as measured according to ASTM D97.

[0028] In one embodiment, the waste lubricant derived oil fraction may be a refined oil fraction. As used herein, the term "refined oil fraction" refers to an oil component resulting from a process in which waste lubricant undergoes centrifugal separation, atmospheric distillation, vacuum distillation, or any combination thereof. The refined oil fraction has a reduced impurity content compared to the original waste lubricant. For example, the refined oil fraction may have a sulfur content of less than 200 ppm, a nitrogen content of less than 100 ppm, and a chlorine content of less than 2000 ppm.

[0029] The method includes a step of pretreating the waste lubricant-derived oil fraction. The pretreatment refers to the step of treating the waste lubricant-derived oil fraction prior to the hydrocracking process, to minimize the impact of impurities contained in the waste lubricant-derived oil fraction on the process and the catalyst.

[0030] In one embodiment, the pretreatment step may include a step of performing solvent extraction on the waste lubricant-derived oil fraction.

[0031] The solvent extraction of the waste lubricant-derived refined oil fraction is a step of blending the refined oil fraction and a solvent in a blending tank, a step of maintaining the mixture in a stationary state to reach phase separation, thereby obtaining a phase in which oil is a main component, and a step of removing a phase containing a large amount of impurity. The solvent used for the solvent extraction is a solvent having a higher affinity to impurities than the oil component in the waste lubricant-derived refined oil fraction. As the solvent, N-methyl-2-pyrrolidone (NMP), sulfolane, DMSO, furfural, phenol, and acetone are commonly used. As the solvent, any solvent that has a high affinity to impurities and a low affinity to the waste lubricant-derived refined oil fraction so as to be phase-separated from the waste lubricant-derived refined oil fraction can be used. In addition, the solvent may exhibit a different volatility from the oil fraction in the subsequent solvent separation process.

[0032] The solvent extraction of the waste lubricant-derived refined oil fraction is carried out at a temperature of about 30°C to 200°C, preferably about 40°C to 150°C, and more preferably about 60°C to 100°C, and at a pressure in a range of atmospheric pressure to 20 kg/cm^2, preferably in a range of atmospheric pressure to 15 kg/cm^2, more preferably in a range of atmospheric pressure to 10 kg/cm^2.

[0033] In addition, the volume ratio of a solvent used in the solvent extraction step of the waste lubricant-derived refined oil fraction with respect to the oil component contained in the waste lubricant-derived oil fraction is 1:1 to 10:1, preferably 2:1 to 8:1, 2:1 to 7:1,2:1 to 6:1, 2:1 to 5:1, 3:1 to 8:1, 3:1 to 7:1, 3:1 to 6:1, 4:1 to 8:1, 4:1 to 7:1, and 5:1 to 8:1. The volume ratio of the solvent used in the solvent extraction step of the refined oil fraction to the oil component contained in the refined oil fraction may most preferably be in a range of 1:1 to 1.5:1. The above volume ratio is preferable in terms of the balance between the level of impurity removal through the solvent extraction and the yield of the hydrocracking product produced from the pretreated waste lubricant-derived oil fraction.

[0034] After the solvent extraction step, the waste lubricant-derived oil fraction has a specific gravity of 0.8 to 0.9, a kinematic viscosity at 100°C in a range of 4 to 6 cSt (ASTM D445 at 100°C), a viscosity index of 110 to 130 (ASTM D2270), a pour point of -18°C to -3°C (ASTM D97), a sulfur content of less than 150 ppm, a nitrogen content of less than 100 ppm, and a chlorine content of less than 20 ppm. That is, after the solvent extraction, the waste lubricant-derived oil fraction may have improved characteristics and a reduced impurity content, may exhibit a light brown color of about 2 to 4 (ASTM D1500), and may have a reduced sediment content compared to the original refined oil fraction which has not yet undergone the solvent extraction.

[0035] The method includes a step of hydrocracking the pretreated waste lubricant-derived oil fraction. The hydrocracking is a process in which long-chain hydrocarbons in pretreated waste lubricant-derived oils are broken down into shorter-chain hydrocarbons by a catalyzed hydrogenation reaction. For example, in the hydrocracking step, the C30+ hydrocarbon chains contained in the pretreated waste lubricant-derived oil fraction can be broken down into chains having fewer carbons. To this end, the hydrocracking step may be performed at a reaction pressure of about 25 to 320 atm (specifically about 80 to 250 atm) and in a temperature condition of about 200°C to 500°C (more specifically, about 250°C to 400°C). In addition, the hydrocracking step may be performed at a liquid hourly space velocity (LHSV) in a range of, for example, about 0.1 to 8 hr^{-1} and, more specifically, about 0.5 to 5 hr^{-1}.

[0036] In one embodiment, the method may further include a first blending step of blending the waste lubricant-derived oil fraction with a hydrocarbon feedstock prior to the hydrocracking step to produce a first formulation. The first blending step may be performed prior to the pretreatment step, or between the pretreatment step and the hydrocracking step. Preferably, the first blending step may be performed prior to the pretreatment step. As used herein, the term "hydrocarbon feedstock" refers to any material that may be an input for a refining, conversion, or other industrial process in which hydrocarbons are a major component. The hydrocarbon feedstock may be provided at a temperature above its pour point, so that the hydrocarbon feedstock may be in a liquid state. The hydrocarbon feedstock may contain a non-hydrocarbon component such as organic and inorganic materials containing heteroatoms (for example, S, N, O, P, and metals). Crude oil, refinery streams, chemical plant streams (for example, steam cracked tar), and recycling plant streams (for example, pyrolysis oil from tires or municipal solid waste) are examples of the hydrocarbon feedstock. The hydrocarbon feedstock may preferably be a feedstock fed to the hydrocracking step for the generation of a fraction having a boiling point within the boiling point range of fuel oils. Referring to FIG. 2, the hydrocarbon feedstock as described above may be blended with waste lubricant-derived oil in the first blending step 40, after a pretreating step 20 and then introduced into the hydrocracking step 40. Alternatively, the pretreating step 20 may be performed after the first blending step 40. The hydrocarbon feedstock as described above may be blended with waste lubricant-derived oil in the first blending step 40, after a pretreating step 20 and then introduced into the hydrocracking step 40. Hence, alternatively, the hydrocarbon feedstock may be blended with pretreated waste lubricant-derived oil after the waste lubricant pretreatment step and then be introduced into the hydrocracking step. When the first formulation is introduced into the hydrocracking step, oils having a more variety of carbon numbers and a more variety of saturation degrees can be obtained compared to when only oils derived from pretreated waste lubricant are introduced into the hydrocracking step.

[0037] In one embodiment, the first formulation may include 1% to 10% by volume of the waste lubricant-derived oil fraction with respect to the total volume thereof. When the amount of waste lubricant-derived oil that is blended with the hydrocarbon feedstock in the first blending step is less than 1% by volume of the total volume of the first formulation, the proportion of the high-carbon waste lubricant derived oils in the formulation may be relatively low, so that hydrocracking of the high-carbon waste lubricant-derived oil may not be easily performed. When the amount of the waste lubricant-derived oil fraction that is blended with the hydrocarbon feedstock in the first blending step exceeds 10% with respect to the total volume of the first formulation, the feedstock introduced into the hydrocracking step may contain a high proportion of heavy oils containing catalyst deactivating impurities, resulting in increases in hydrocracking temperature and pressure conditions, and consequently, a strain on the hydrocracking catalyst. The first formulation may include the waste lubricant-derived oil fraction in an amount of 2% to 9% by volume and, more preferably, 4% to 8% by volume, with respect to the total volume thereof. The first formulation may include a hydrocarbon feedstock other than the waste lubricant-derived oil fraction.

[0038] According to one embodiment, the method may further include recovering a plurality of fractions including a first fraction and a second fraction, from the product of the hydrocracking step 60. The hydrocracked waste lubricant-derived oil, or the hydrocracked first formulation is separated into components according to boiling point by separation distillation. Specifically, the product of the hydrocracking step is separated by fractional distillation in the order of lower boiling point fractions to higher boiling point fractions. The plurality of fractions thus separated includes at least first and second fractions having different boiling points, which are recovered and used for appropriate purposes.

[0039] In one embodiment, the first fraction may have a boiling point in a boiling point range of fuel oils. For example, fuel oils include liquefied petroleum gas (LPG), gasoline, kerosene, diesel, and heavy fuel oil that are in order of decreasing boiling point. The first fraction may correspond to a fraction having a boiling point within the range of boiling points of fuel oils as described above, and may be further separated as necessary to include a specific fraction of the fuel oil. In one embodiment, the first fraction may have a boiling point lower than 400°C.

[0040] In one embodiment, the second fraction may have a boiling point higher than the boiling point of the first fraction. For example, the second fraction may have a boiling point of 450°C or higher. Aside from the fuel oil, which is the oil fraction cracked in the hydrocracking step, the product of the hydrocracking step also includes an uncracked oil fraction. "Unconverted oil" (UCO) refers to heavy oil that remains from the hydrocracking step and which is not converted to fuel oil as described above. The unconverted oil (UCO) has a higher boiling point than fuel oil. The unconverted oil may be separated from the first fraction having a boiling point in the boiling point range of the fuel oil upon fractional distillation, and may be recovered. In other words, the second fraction may be a fraction including unconverted oil and may have a higher boiling point than the first fraction described above. The second fraction including the unconverted oil as described above may be recovered and introduced into the process steps for the preparation of the lube base oil. In one embodiment, the second fraction may exhibit a high pour point of 30°C to 45°C due to the high wax content of the unconverted oil but may contain impurities such as sulfur and nitrogen in a low content of less than 10 ppm.

[0041] Referring to FIG. 3, in one embodiment, the method may further include a second blending step 70 of blending the second fraction with a separate waste lubricant-derived oil fraction to produce a second formulation. As described above, the separate waste lubricant-derived oil fraction blended with the second fraction containing the unconverted oil is subjected to the pretreatment step for the removal of impurities but is not introduced into the hydrocracking step. Preferably, the waste lubricant-derived oil fraction may be pretreated waste lubricant-derived oil. The second blending step may include a stirring step of blending the second fraction with the separate waste lubricant-derived oil fraction. The second formulation resulting from the second blending step can be further processed and reclaimed as a lube base oil through additional treatment. As described above, since a lube base oil is generated from a blended formulation including unconverted oil after the hydrocracking stage of a waste lubricant-derived oil fraction and a separate waste lubricant-derived oil, the cost of manufacturing a lube base oil can be reduced. In addition, there are also environmental benefits because waste lubricant is not disposed of but is recycled.

[0042] In one embodiment, the amount of the separate waste lubricant-derived oil used in the second blending step may be 3% to 50% by volume with respect to the volume of the second formulation. For example, the amount of the separate waste lubricant-derived oil fraction introduced into the second blending may be about 5% to 45%, about 5% to 40%, about 5% to 35%, about 5% to 30%, about 5% to 25%, about 5% to 20%, about 5% to 15%, about 5% to 10%, about 7% to 40%, about 7% to 35%, about 7% to 25%, about 7% to 20%, preferably about 7% to 15%, and more preferably about 7% to 10% of the volume of the second formulation. The pretreated waste lubricant-derived oil fraction contains almost no wax component. Therefore, as described above, the pour point of the pretreated waste lubricant-derived oil fraction is as low as -18°C to -3°C. When the pretreated waste lubricant-derived oil fraction is blended with the second formulation containing unconverted oil having a high pour point of about 42°C, the fluidity of the blended raw material is increased, so that the raw material can be easily transported even at low temperatures. When the blending amount of the pretreated waste lubricant-derived oil fraction is lower than 3% by volume, the effect of increasing the fluidity is not significant, so that the blended raw material cannot be easily transported from one step to another. When the blending amount of the pretreated waste lubricant-derived oil fraction exceeds 20% by volume, the blended raw material is not suitable as a raw material for producing a high-grade lube base oil due to impurities contained in the pretreated waste lubricant-derived oil fraction and a low viscosity index.

[0043] Referring to FIG. 3, in one embodiment, the method may further include a step 80 of catalytically dewaxing the second formulation. The catalytic dewaxing selectively isomerizes the wax component contained in the second formulation to improve low-temperature properties (to ensure a low pour point) and to maintain a high viscosity index (VI). In the present invention, it is intended to achieve improvement in efficiency and yield through improvement of the catalyst used in the catalytic dewaxing process.

[0044] In general, the main reaction of the catalytic dewaxing is to convert N-paraffine to isoparaffin through an isomerization reaction to improve low-temperature properties, and it is reported that the catalyst used here is mainly a bi-functional catalyst. A bi-functional catalyst is composed of two active components: a metal active component (metal site) for hydrogenation/dehydrogenation reaction and a carrier (acid site) for skeletal isomerization using carbynium ions. A catalyst having a zeolite structure is generally composed of an aluminosilicate carrier and at least one metal selected from Group 8 metals and Group 6 metals.

[0045] The dewaxing catalyst used includes a carrier having an acid site selected from molecular sieve, alumina, and silica-alumina, and one or more hydrogenating metals selected from elements of Groups 2, 6, 9 and 10 of the Periodic table. In particular, among the metals in Group 9 and Group 10 (i.e., Group VIII), Co, Ni, Pt, and Pd are preferably used, and among the metals in Group 6 (i.e., Group VIB), Mo and W are preferably used.

[0046] The types of carriers having acid sites include molecular sieves, alumina, silica-alumina, and the like. Among these, the molecular sieves refer to crystalline aluminosilicates (zeolite), SAPO, ALPO, and the like. A medium pore molecular sieve with a 10-membered oxygen ring, such as SAPO-11, SAPO-41, ZSM-11, ZSM-22, ZSM-23, ZSM-35, and ZSM-48 is used, and a large pore molecular sieve with a 12-membered oxygen ring may be used.

[0047] In particular, EU-2 zeolite having a controlled phase transition degree may be preferably used as the carrier. After pure zeolite is generated, the synthesis conditions are likely to change, or the synthesized zeolite crystal is likely to gradually transition to a more stable phase if the synthesis continues over a predetermined period time. This phenomenon is referred to as phase transformation of zeolite. It was confirmed that isomerization selection performance was improved according to the degree of phase transformation of the zeolite, and excellent performance was also exhibited in the catalytic dewaxing reaction using the same.

[0048] In one embodiment, the method may further include a step 90 of hydrofinishing the catalytically dewaxed second formulation and a step of recovering the product of the hydrofinishing step as a lube base oil. The hydrofinishing 90 is a step of removing aromatics, olefins, and solvents from the blended raw material to improve the oxidative stability and UV stability of the second formulation. The catalytically dewaxed second formulation is hydrofinished in the presence of a hydrofinishing catalyst. The hydrofinishing catalyst has the function of saturating the unsaturated hydrocarbons contained in the catalytically dewaxed second formulation, thereby improving color and storage stability. In one embodiment, the hydrofinishing catalyst may be the same as the dewaxing catalyst described above. The products of the hydrofinishing step can be separated according to their viscosity, and among the products, a lube base oil with the desired properties can be recovered.

[0049] Specifically, the lube base oil produced by the method described above may be a high-grade lube base oil in Group III or higher according to the API classification described above. More specifically, the lube base oil has a viscosity index of 120 or more, preferably 120 to 140, 120 to 135, 120 to 130, 120 to 125, 125 to 140, 125 to 135, 125 to 130, 130 to 140, or 130 to 135, and the degree of saturation is 90% or more, preferably 91% or more, 92% or more, 93% or more, 94% or more, 95% or more, 96% or more, 97% or more, 98% or more, or 99 % or more.

[0050] In addition, the lube base oil may contain almost no impurities since the content of each of the impurities such as sulfur, nitrogen, and chlorine is 1 ppm or less.

[0051] The lube base oil may have a Saybolt color value of 27 or greater, when measured by ASTM D 156. When the lube base oil has a Saybolt color value is 27 or greater, it is considered that this lube base oil is a lube base oil having stability corresponding to Water White grade. Water White grade lube base oils have a sulfur content of less than 1 ppm, a nitrogen content of less than 1 ppm, a saturation degree of 99% or more, and an aromatic content of less than 1%. These lube base oils are more stable than conventional API Group III lube base oils.

[0052] The lube base oil may exhibit a UV 260-350 nm absorbance of 2.5 or less and a UV 325 nm absorbance of 0.7 or less, as measured by ASTM D 2008. Here, the absorbance at a wavelength of 260 to 350 nm indicates that the test material contains a component having 3 or more aromatic rings, and the absorbance at a wavelength of 325 nm indicates that the test material contains a component having 3 to 7 aromatic rings. The lube base oil exhibits a low absorbance at these wavelengths. That is, the lube base oil has a low aromatic content, thereby having high stability.

[0053] Hereinafter, the preferred examples are presented to aid understanding of the present invention.

Example

[0054] Measurement of behavior and properties of fuel oil and lube base oil produced according to one embodiment.

[0055] Waste lubricant having a sulfur content of about 2000 ppm, a nitrogen content of about 1500 ppm, and a chlorine content of about 1500 ppm was centrifuged at a speed of about 300 rpm, followed by atmospheric distillation and vacuum distillation, to obtain a refined oil fraction. The resulting refined oil fraction was hydrotreated and subjected to hydrocracking.

[0056] Subsequently, the hydrocracked refined oil fraction was introduced into fractional distillation to obtain fuel oil and unconverted oil with different boiling points.

[0057] Like the refined oil fraction, a separate waste lubricant-derived oil fraction having undergone atmospheric distillation and vacuum distillation was subj ected to hydrotreatment, and the hydrotreated oil was blended with the unconverted oil in a volume ratio of 25 (separate waste lubricant-derived oil fraction):75 (unconverted oil), and the blended oil was subjected to vacuum distillation, catalytic dewaxing, and hydrofinishing to produce a lube base oil. Here, the atmospheric distillation was performed at a temperature of 50°C to 350°C and at atmospheric pressure. The process conditions of the vacuum distillation are shown in Table 2 below.

[Table 2]

Process conditions of vacuum distillation	
Temperature	100°C to 350°C
Pressure	10 torr

[0058] Process conditions of the hydrotreatment are shown in Table 3 below.

[Table 3]

Process conditions of hydrotreatment	
Temperature	350°C
Pressure	150 kg/cm^2
Catalyst	Ni-Mo catalyst

[0059] In addition, the catalytic dewaxing is carried out at a temperature of 300°C and a pressure of 150 kg/cm^2, in the presence of a hydrogenation catalyst with EU-2 zeolite as a carrier. The lube base oil prepared by the above-described production processes was measured for various properties, and as a result of the measurements, the lube base oil had a specific gravity of 0.84, a kinematic viscosity at 100°C of 7.3 cSt, a viscosity index (VI) of 129, a kinematic viscosity of -33°C, a sulfur content of less than 1 ppm, and a nitrogen content of less than 1 ppm, and contained almost no impurities except for unavoidable trace amounts of impurities. In addition to the properties described above, other properties of the lube base oil were measured, and the measurement results are shown in Table 4 below.

[Table 4]

Classification	Test method	Specification
Appearance	Visual	Bright & Clear
Saybolt Color	ASTM D 156	Min. +27
Saturation %	ASTM D 7419	Min. 99
UV 260 to 250 nm	ASTM D 2008	Max. 3.0
UV 325 nm	ASTM D 2008	Max. 1.0
Viscosity index	ASTM D 2270	Min. 120

[0060] The lube base oil had a viscosity index of at least 120 and a saturation degree of at least 95%, indicating that the lube base oil satisfies the conditions required for Group III lube base oil shown in Table 1. The base oil had a bright and clean color when visually evaluated by eye. The color was a Saybolt color value of 27 or more, when measured according to ASTM D 156. That is, the lube base oil is a lube base oil having a water white grade, and the lube base oil has high thermal stability at high temperatures.

[0061] In addition, the lube base oil exhibits a low absorbance of up to 3.0 (up to 1.0 at a wavelength of 325 nm) when measured according to ASTM D 2008 for UV having a wavelength of 260 to 350 nm, and especially for UV having a wavelength of 325 nm. It was confirmed that the lube base oil had high stability against UV.

[0062] As described above, blending waste lubricant-derived oil with unconverted oil and using the blended oil as a feedstock for the production of lube base oil can increase the stability and yield of the final product lube base oil.

Claims

1. A method of recycling waste lubricant into fuel oil or lube base oil, the method comprising:

providing a waste lubricant-derived oil fraction;
pretreating the waste lubricant-derived oil fraction; and
hydrocracking the pretreated waste lubricant-derived oil fraction.

2. The method of claim 1, wherein the waste lubricant-derived oil fraction has a kinematic viscosity at 40°C in a range of 20 to 60 cSt (ASTM D445 at 40°C) and a pour point of lower than 0°C (ASTM D97).

3. The method of any preceding claim, wherein the pretreating comprises performing solvent extraction on the waste lubricant-derived oil fraction, wherein preferably the solvent is selected from one or more of N-methyl-2-pyrrolidone (NMP), sulfolane, DMSO, furfural, phenol, and acetone, and/or the solvent extraction is carried out at a temperature of 30°C to 200°C, and/or the solvent extraction is carried out at pressure in a range of atmospheric pressure to 20 kg/cm2, and/or the volume ratio of a solvent with respect to the oil component contained in the waste lubricant-derived oil fraction is 1:1 to 10:1.

4. The method of any preceding claim, further comprising a first blending step of blending the waste lubricant-derived oil fraction with a hydrocarbon feedstock to produce a first formulation, prior to the hydrocracking, wherein preferably the first formulation comprises 1% to 10% by volume of the waste lubricant-derived oil fraction with respect to the total volume thereof.

5. The method of any preceding claim, wherein the hydrocracking step is performed at a reaction pressure of 25 to 320 atm, preferably 80 to 250 atm, and/or at a temperature of 200°C to 500°C, preferably 250°C to 400°C), and/or at a liquid hourly space velocity (LHSV) of 0.1 to 8 hr-1, preferably 0.5 to 5 hr-1.

6. The method of any preceding claim, wherein the method further comprises recovering a plurality of fractions including a first fraction and a second fraction, from the product of the hydrocracking, wherein preferably the first fraction has a boiling point lower than 400°C and the second fraction has a boiling point higher than the boiling point of the first fraction.

7. The method of claim 6, further comprising a second blending step of blending the second fraction with a separate waste lubricant-derived oil fraction to produce a second formulation.

8. The method of claim 7, wherein the separate waste lubricant-derived oil fraction is obtained by

providing a waste lubricant-derived oil fraction, which may be the same or a different waste lubricant-derived oil fraction relative to the waste lubricant-derived oil fraction provided to obtain the second fraction; and
pretreating that waste lubricant-derived oil fraction, wherein pretreatment is preferably as described in claim 3;
wherein that pretreated waste lubricant-derived oil fraction is not subjected to hydrocracking.

9. The method of claim 7 or 8, wherein the separate waste lubricant-derived oil fraction used in the second blending is introduced in an amount of 3% to 50%, preferably 5% to 35%, more preferably 7% to 20% by volume with respect to the volume of the second formulation.

10. The method of any of claims 7 to 9, further comprising catalytically dewaxing the second formulation, wherein the catalyst preferably comprises a carrier having an acid site selected from molecular sieve, alumina, and silica-alumina, and one or more hydrogenating metals selected from Mo, W, Co, Ni, Pt, and Pd.

11. The method of claim 9, further comprising hydrofinishing the catalytically dewaxed second formulation.

12. A fuel oil or lube base oil made by a method of any preceding claim.

13. The fuel oil or lube base oil of claim 12, wherein the oil has a viscosity index of 120 or more (ASTM D2270), and/ or a degree of saturation of 90% or more.

14. The fuel oil or lube base oil of claim 12 or 13, wherein the oil has a Saybolt color value of 27 or greater (ASTM D156).

15. The fuel oil or lube base oil of any one of claims 12 to 14, wherein the oil exhibits a UV 260-350 nm absorbance of 2.5 or less and a UV 325 nm absorbance of 0.7 or less (ASTM D2008).

FIG.1

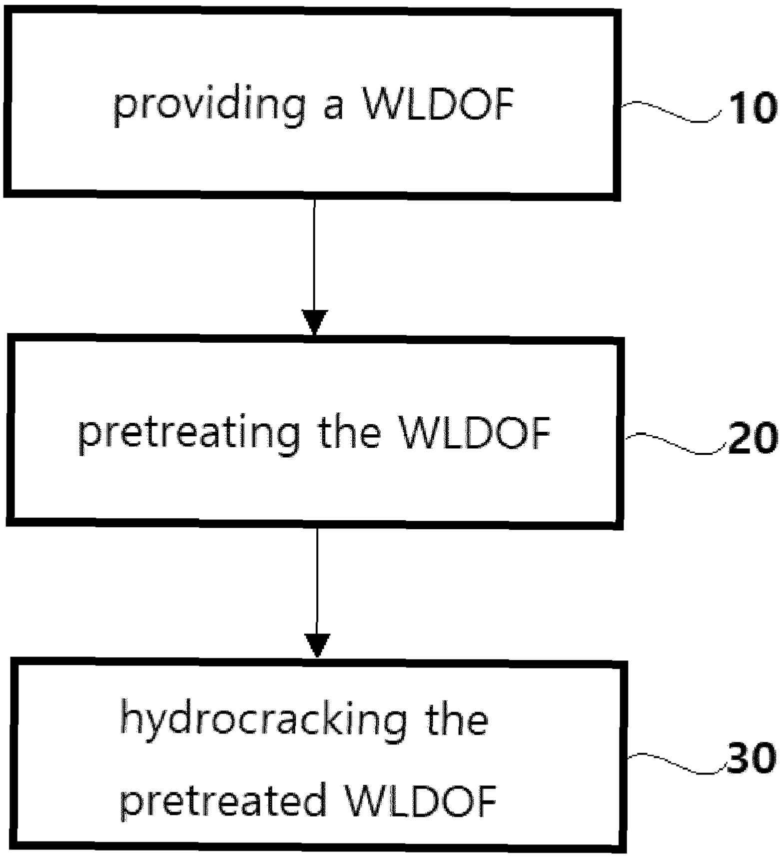

providing a WLDOF
10
pretreating the WLDOF
20
hydrocracking the pretreated WLDOF
30

FIG.2

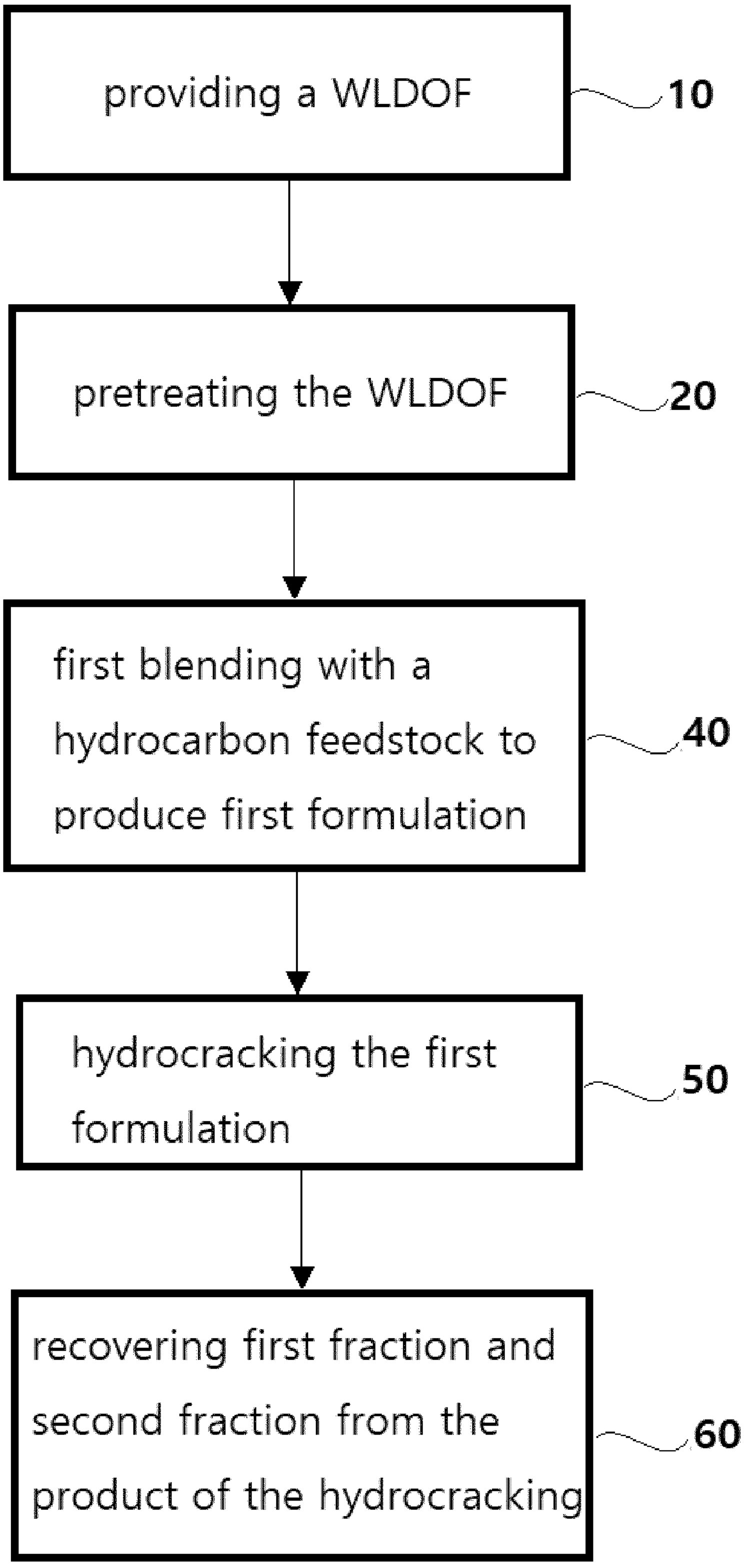
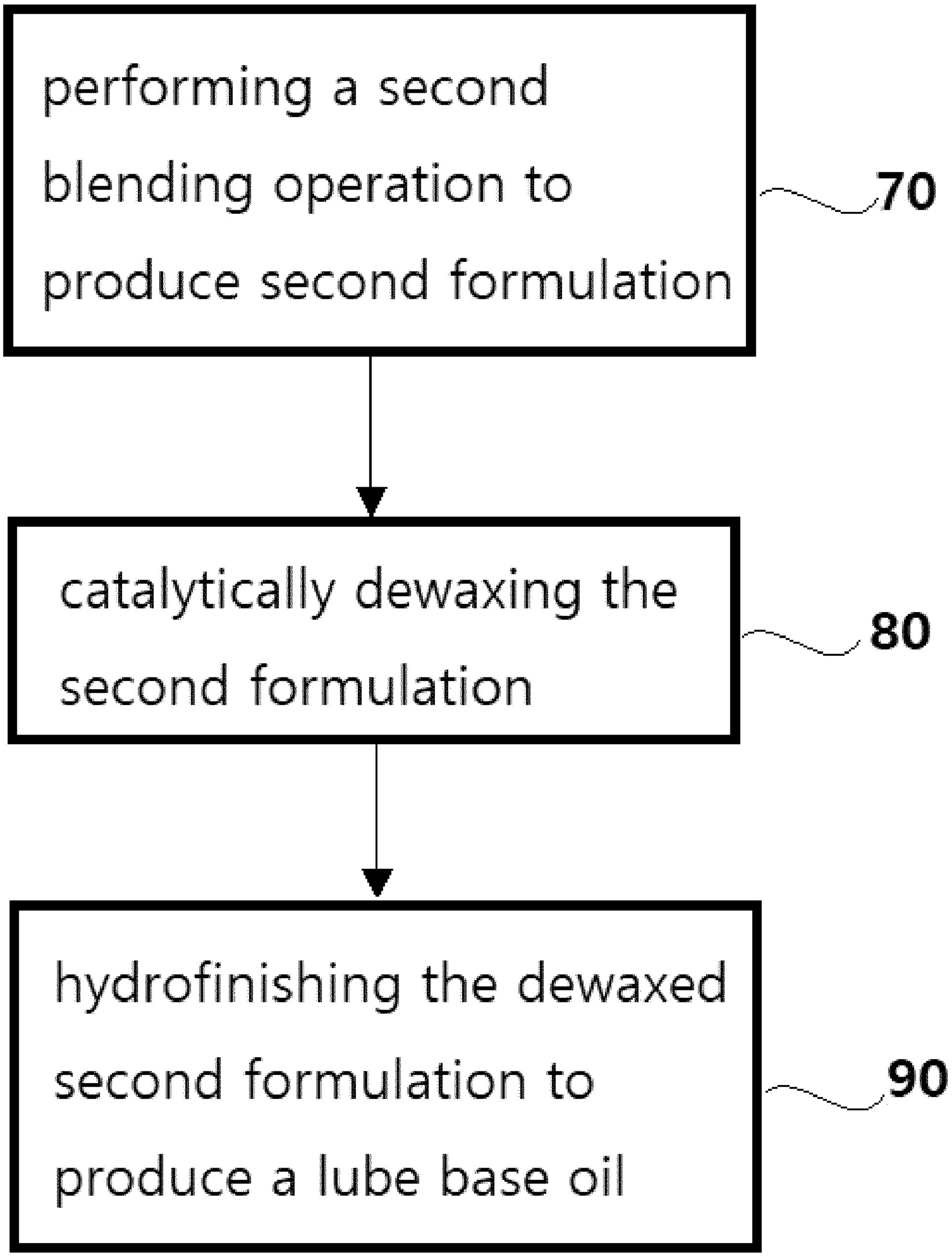

providing a WLDOF
10
pretreating the WLDOF
20
first blending with a hydrocarbon feedstock to produce first formulation
40
hydrocracking the first formulation
50
recovering first fraction and second fraction from the product of the hydrocracking
60

FIG.3


performing a second blending operation to produce second formulation
70
catalytically dewaxing the second formulation
80
hydrofinishing the dewaxed second formulation to produce a lube base oil
90

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EUROPEAN SEARCH REPORT

Application Number
EP 24 16 3169

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2023/054666 A1 (JEON YOUNG WOOK [KR] ET AL) 23 February 2023 (2023-02-23) * paragraph [0031] - paragraph [0076] * * figures 1-7 * -----	1-15	INV. C10G47/00 C10G67/04 C10G71/00 C10L1/00 C10M101/00 C10G21/12
X	US 2023/193145 A1 (RAMASESHAN VINOD [SA] ET AL) 22 June 2023 (2023-06-22) * paragraph [0013] - paragraph [0133] * * figures 1-3 * -----	1-15	
X	US 2018/187092 A1 (FRUCHEY KENDALL S [US] ET AL) 5 July 2018 (2018-07-05) * paragraph [0023] - paragraph [0224] * * figures 1-14 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

C10G
C10M
C10L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 August 2024	Bernet, Olivier

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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&: member of the same patent family, corresponding document

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 16 3169

22-08-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023054666 A1	23-02-2023	CN 115895771 A	04-04-2023
		EP 4137553 A1	22-02-2023
		JP 2023027759 A	02-03-2023
		KR 102442618 B1	14-09-2022
		US 2023054666 A1	23-02-2023
		US 2023416621 A1	28-12-2023
US 2023193145 A1	22-06-2023	CN 118414408 A	30-07-2024
		US 2023193145 A1	22-06-2023
US 2018187092 A1	05-07-2018	CA 3045636 A1	05-07-2018
		CA 3045779 A1	05-07-2018
		CA 3045781 A1	05-07-2018
		CA 3046185 A1	05-07-2018
		CN 110121545 A	13-08-2019
		EP 3562917 A1	06-11-2019
		EP 3562918 A1	06-11-2019
		EP 3562919 A1	06-11-2019
		EP 3562920 A1	06-11-2019
		KR 20190102039 A	02-09-2019
		SG 10201912578S A	27-02-2020
		SG 10201912580V A	27-02-2020
		US 2018187089 A1	05-07-2018
		US 2018187092 A1	05-07-2018
		US 2018187102 A1	05-07-2018
		US 2018187116 A1	05-07-2018
		US 2019218465 A1	18-07-2019
		US 2019359898 A1	28-11-2019
		WO 2018125281 A1	05-07-2018
		WO 2018125282 A1	05-07-2018
		WO 2018125283 A1	05-07-2018
		WO 2018125284 A1	05-07-2018