

MARINE FUEL BASE COMPRISING A COMPONENT OF RENEWABLE ORIGIN AND METHOD FOR MANUFACTURING SAME

Field of the invention

The present invention relates to a marine fuel base comprising a component of renewable origin of the type methyl ester coming from fatty acids of plant or animal origin (also designated by the acronym FAME). The addition of this component of renewable origin allows to improve the viscosity, the pour point and the stability of an oil residue.

Prior art

Marine fuels are usually manufactured by mixing a residue (atmospheric residue, vacuum residue or visbreaking residue) with one or more fluxants usually of petroleum origin.

In order to reduce the impact of marine fuels on the environment, producers seek to integrate more and more components of renewable origin in their manufacturing. In particular, producers seek to manufacture fuels preferably having a low impact on greenhouse gases such as carbon dioxide, and a low content of sulfur since the goal is to reduce sulfur emissions, in particular in arctic regions.

The document WO2020109653A1 describes a marine fuel mixture comprising a marine fuel having a density of 860 to 960kg/m³ at 15°C and from 0.5 to 50% by volume of a renewable hydrotreated fuel. The addition of this renewable fuel allows to improve the pour point and the storage stability of the mixture. The renewable hydrotreated fuel used comprises at least 70 vol% of C15-C18 paraffins and 0.5 vol% or less of oxygenated hydrocarbon compounds. This renewable compound comes from the hydrotreatment and optionally from the isomerization of fatty acids, triglycerides and other derivatives of the fatty acids contained in a vegetable or animal oil. This document specifies that it is preferable for the marine fuel mixture to not contain FAME in order to obtain good long-term storage stability. It is indeed known that the oxidation of FAMEs has a negative effect on the long-term storage stability of a fuel.

The document WO202118895A1 describes a fuel mixture having an improved stability or compatibility comprising from 5 to 95% m/m of a component of hydrocarbon residue chosen from an atmospheric residue and a vacuum residue coming from the vacuum distillation of an atmospheric residue, from 5 to 50% m/m of a component of fatty acid methyl esters and up to 90% m/m of a hydrocarbon component hydrotreated or not. In order to have the improved properties of stability/compatibility, the methyl esters must be added to the component of hydrocarbon residue before any other component. This document teaches in paragraph 37 that the use of fatty acid alkyl esters allows to increase the compatibility of a fuel composition with the addition of paraffinic compounds, the latter acting as viscosity reducers.

The document US10899983B1 describes a marine fuel composition with a high concentration of naphthenes and a low content of aromatics comprising a residue coming from shale oil and a biodiesel. The shale oil residue has a viscosity at 50°C of 40cSt to 150cSt (i.e. from 40mm²/s to 150mm²/s) and a density at 15°C of at most 920kg/m³.

Although such marine fuel mixtures are satisfactory, the search for new marine fuels is always necessary to satisfy the requirements set by increasingly strict regulations and the needs of consumers.

The document WO2018178402A2 describes a first composition allowing to reduce the viscosity of a crude or of an oil component that is deposited or precipitates during the processes of production, transport or treatment of a crude. It also describes a second composition allowing the restoration of the sand. The first composition comprises 50 %m or more of a fraction of fatty acid esters and 50 %m or less of a fraction of

non-substituted C1-C6 mono-alcohols. The flash point of this first composition is very low (18.5°C in the example of page 38), which is not compatible with a use in a marine fuel that must have a flash point of at least 60°C.

5 The document FR2 894 588 describes a bituminous binder comprising at least one bitumen and at least one fluxant, the fluxant containing castor oil and/or at least one derivative of castor oil, preferably at least one ester. This document does not describe a marine fuel.

10 The document JP2010111720A describes a method for manufacturing a bio-asphalt containing 10 parts or more of vegetable or animal oils and/or of fatty acid esters for 100 parts of a residue derived from a crude oil that is very viscous, or even solid, at ambient temperature. The vegetable and animal oils that can be used are in claim 2 of this document and include the hydrogenated oils. The examples relate only to the mixtures of asphalt and of non-esterified vegetable oil.

Summary

15 The object of the present invention is to provide a base for a renewable marine fuel with a low sulfur content, with improved viscosity and with a good pour point. Another goal is to provide a marine fuel, which can be used in uses in which long-term storage stability is required. Another goal is also to provide a marine fuel with contents of biological origin, which can be used with the current logistics of marine fuels.

Definitions

20 An atmospheric residue comes from the atmospheric distillation of a crude oil (column bottoms of the atmospheric distillation).

A vacuum residue comes from the vacuum distillation of an atmospheric residue (column bottoms of the vacuum distillation).

25 A residue coming from a visbreaking process, also called visbreaking residue or visbroken residue, results from the transformation of a vacuum residue by visbreaking.

The characteristic called S-value or intrinsic stability is defined in the profession as well as in the standard ASTM D7157-18 (2018 Revision) by the following expression:

$S = \text{aromaticity of the maltenes} / \text{aromaticity of the asphaltenes}$, or $S = S_o / (1 - S_a)$, wherein:

30 - S_o represents the power of the medium to dissolve the asphaltenes (solvent power), that is to say the aromatic nature of the medium. The more the latter is aromatic, the higher the S_o ,

- S_a characterizes the intrinsic stability (or peptizability) of the asphaltenes,

- $(1 - S_a)$ represents the aromaticity of the medium necessary to dissolve the asphaltenes present.

If $S > 1$, the asphaltenes are peptized and are thus stable. $S - 1$ represents the stability reserve (the higher this reserve, the less the product will be subject to problems of precipitation or of compatibility).

35 The solvent power S_o , the peptizability of the asphaltenes S_a and the S-value are thus as defined in the standard ASTM D7157-18 (2018 Revision).

The S-value parameters obey mixing rules that are written in the following manner:

$$S_{o_{\text{mélange}}} = \sum x_i \times S_{o_i} \quad (1)$$

$$Sa_{mélange} = \frac{\sum x_i \times ASP_i \times Sa_i}{\sum x_i \times ASP_i} \quad (2)$$

$$S_{mélange} = \frac{So_{mélange}}{1 - Sa_{mélange}} \quad (3)$$

Where:

x_i is the mass fraction of the component i,

5 ASP_i is the content of asphaltenes (%m) of the component i,

So_i is the solvent power of the component i,

Sa_i is the peptizability of the component i.

It is noted that the equation (1) is a simplified form of the equation (1bis) below

$$So_{mélange} = \frac{\sum x_i \times (100 - ASP_i) \times So_i}{\sum x_i \times (100 - ASP_i)} \quad (1bis).$$

10 For a mixture containing a component for which the value of So cannot be measured (for example because of the absence of asphaltenes), the value So can be estimated via the method described in document WO 2021/122349 A1, which is incorporated by reference.

Thus, the value So of the first component described in the present invention can be estimated by the following method described in the document WO 2021/122349 A1 by implementing the following steps:

- 15 (a) establishing a correlation expressing the solvent power So of a first component of fatty acid alkyl esters according to the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of said first component,
- (b) using said correlation to estimate the value of the solvent power So of a first component of fatty acid alkyl esters, the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of which were measured,
- 20

the step (a) of establishing the correlation comprising:

- (i) measuring the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of a plurality of first components of fatty acid alkyl esters,
- (ii) providing hydrocarbon streams for which it is possible to measure a solvent power So value according to the standard ASTM D7157, in particular the standard ASTM D7157-18 (2018 Revision) or another version of the standard,
- 25
- (iii) preparing at least two mixtures of various proportions of each of the hydrocarbon streams with each of the first components,
- (iv) for each of the mixtures comprising the same first component, measuring the value of the solvent power So , in particular according to the standard ASTM D7157, in particular according to the standard ASTM D7157-18 (2018 Revision) or another version of the standard, and drawing, for each hydrocarbon stream, a straight line representing said value of the solvent power So according to the proportion of first component in the mixture and, for each straight line drawn, determining a value of the solvent power So of the first component by extrapolation to a proportion of first component of 100%, then calculating an average value of these solvent power So values for each first component,
- 30
- 35

- (v) establishing said correlation by a statistical processing of the average solvent power S_o values, of the values of kinematic viscosity at 50°C, of kinematic viscosity at 100°C and of density at 15°C of all the first components.

The density at 15°C is measured according to the standard ISO 12185 :1996.

- 5 The viscosity here is the kinematic viscosity, measured at 50°C or 100°C or 135°C, for example according to the standard ISO 3104:2020.

The pour point is measured according to the standard ISO 3016:2019.

The content of sulfur can be measured according to the standard ISO 8754 or ASTM D4294.

- 10 The calculated carbon aromaticity index (CCAI) is calculated according to the Lewis equation (recalled in the standard NF ISO 8217-June 2018).

The content of asphaltenes can be measured according to the standard NF T60-115 (January 2020).

The flash point can be measured according to the standard NF EN ISO2719 – 2016.

Detailed description

- 15 A first object of the invention relates to the use of fatty acid alkyl esters to improve the viscosity of a component of at least one hydrocarbon residue, wherein (i) 10 to 70% m/m of a first component of fatty acid alkyl esters of renewable origin is mixed with (ii) 90% to 30% m/m of a second component of at least one hydrocarbon residue, and wherein the mixture obtained has a kinematic viscosity lower than a kinematic viscosity calculated according to the formula:
- $$\vartheta = \exp \left(\exp \left(\frac{VB_{mélange} - 23.097}{33.469} \right) \right) - 0.8 \quad (4)$$

- 20 where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the formula:
 $VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8))$ (5),
where v_i is the kinematic viscosity of the component i expressed in stokes.

- 25 These various formulas (4) (5) correspond to the "Refutas" method (Maples, R.E., 2000, "Petroleum Refinery Process Economics", PennWell, ISBN 978-0-87814-779-3).

- 30 In one embodiment, the mixture obtained can have a measured S-value greater than a calculated S-value $S_{mélange}$, previously defined in reference to equations (1) to (3). The solvent power of the first component is estimated from a correlation expressing the solvent power S_o of said first component according to the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of said first component. This correlation can be established by following the teaching of the document WO 2021/122349 A1.

The fatty acid alkyl esters can thus be used to manufacture a marine fuel base having an improved viscosity. In other words, these fatty acid alkyl esters can be used to manufacture a mixture that can form a marine fuel base or a marine fuel.

- 35 Thus, another object of the invention relates to a marine fuel base comprising:

- (i) 10 to 70 % m/m of a first component of fatty acid alkyl esters of renewable origin,
- (ii) 90 to 30% m/m of a second component of at least one hydrocarbon residue,

said base having a kinematic viscosity lower than a kinematic viscosity calculated according to the formula:

$$\vartheta = \exp\left(\exp\left(\frac{VB_{mélange} - 23.097}{33.469}\right)\right) - 0.8 \quad (4)$$

where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the Refutas formula:

5 $VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8))$ (5) where v_i is the kinematic viscosity of the component i expressed in stokes.

The use of the component of fatty acid alkyl esters can thus allow to obtain a mixture having a kinematic viscosity at 50°C 15 to 75% lower than the calculated viscosity. This lowering of the kinematic viscosity is particularly significant when the component of fatty acid alkyl esters is added to a visbreaking residue or
10 to a mixture of visbreaking residues, with a 20 to 70% reduction in the viscosity with respect to the calculated viscosity whereas it is 15 to 40% for the other residues (at equal content of component of alkyl esters).

The use of the component of fatty acid alkyl esters can also allow to obtain a mixture having a kinematic viscosity at 100°C 5 to 30% lower than the calculated viscosity. This lowering of the kinematic viscosity is also greater when the component of fatty acid alkyl esters is added to a visbreaking residue or to a mixture
15 of visbreaking residues, with a 10 to 30% reduction in the viscosity with respect to the calculated viscosity whereas it is 5 to 20% for the other residues (at equal content of component of alkyl esters).

Thus, surprisingly, the component of fatty acid alkyl esters acts as a fluxant for the second component, producing an effect on the viscosity that is greater than the expected effect. The first component can thus
20 be advantageously used as a fluxant for the preparation of a marine fuel base. In particular, the reduction of the viscosity obtained by addition of the first component is a certain advantage, since the temperatures of use can be significantly reduced.

Moreover, when the second component is at least one hydrocarbon residue chosen from a vacuum residue and a visbreaking residue, it was observed in a surprising manner that the fatty acid alkyl esters
25 have an effect on the pour point of the mixture (typically determined according to the standard ISO 3016-2019) greater than the effect provided by fluxants of petroleum origin usually used. In particular, the difference between the pour point of the first component of fatty acid alkyl esters and the pour point of the mixture increases with the content of first component of the mixture, this difference being greater in absolute value than the difference in absolute value between the pour point of a fluxant of petroleum
30 origin and the pour point of a mixture of this fluxant of petroleum origin with the second component (in other words, for a mixture in which the first component has been replaced by a fluxant of petroleum origin). This effect is greater for the visbreaking residues than for the vacuum residues.

Advantageously, when the second component is at least one hydrocarbon residue chosen from a vacuum residue and a visbreaking residue, the marine fuel base can have a measured S-value greater than a
35 calculated S-value $S_{mélange}$ as defined above, by using a value of the solvent power of the first component estimated from a correlation expressing the solvent power So of said first component according to the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of said first component.

Finally, the object of the invention is a marine fuel comprising a marine fuel base according to the
40 invention and optionally at least one fluxant of petroleum origin.

Because of the effect on the viscosity of the component of alkyl esters, the base according to the invention allows to manufacture a marine fuel requiring a reduced, or even null, quantity of fluxant of petroleum origin.

The object of the invention is also a method for improving the viscosity of a component of at least one hydrocarbon residue comprising the mixture of (i) 10 to 70% m/m of a first component of fatty acid alkyl esters of renewable origin with (ii) 90% to 30% m/m of a second component of at least one hydrocarbon residue, and wherein the mixture obtained has a viscosity lower than a viscosity calculated according to the formula:

$$\vartheta = \exp \left(\exp \left(\frac{VB_{mélange} - 23.097}{33.469} \right) \right) - 0.8 \quad (4)$$

where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the Refutas formula: $VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8))$ (5), where v_i is the kinematic viscosity of the component i expressed in stokes.

This method thus allows to prepare a mixture forming a marine fuel base having one or more of the features described above.

First component of alkyl esters

Fatty acid alkyl esters are usually produced by the reaction of vegetable oils and/or animal fats with alcohols in the presence of a suitable catalyst. The reaction of the oils/fats with an alcohol to produce a fatty acid ester and glycerin is known by the name transesterification. Alternatively, the fatty acid alkyl esters can be produced by the reaction of a fatty acid with an alcohol (esterification reaction) to form a fatty acid ester.

The first component is thus exclusively of biological origin: this will be called component of renewable origin.

The vegetable oils can be chosen from pine oil, colza oil, sunflower oil, castor oil, peanut oil, linseed oil, babassu oil, hemp oil, linola oil, jatropha oil, peanut oil, rice bran oil, mustard oil, carinata oil, coconut oil, copra oil, olive oil, palm oil, cotton oil, corn oil, palm kernel oil, soybean oil, squash oil, grapeseed oil, argan oil, jojoba oil, sesame oil, walnut oil, hazelnut oil, China wood oil, rice oil, safflower oil, algae oil, used oils, and any combination thereof.

The used oils comprise used cooking oils (used food oils) and oils recovered from wastewater, such as trapped and drained fats/oils, gutter oils, sewer oils, for example from wastewater treatment plants, and used fats from the food industry.

The animal fats can be chosen from tallow, lard, fat (yellow and brown fat), fish oils/fats, the fat of milk and any combination thereof.

The alcohol can be chosen from the linear or branched, aliphatic or aromatic, primary, secondary or tertiary alcohols, and can have a number of carbons from 1 to 22. Advantageously, the alcohol can be chosen from methanol, ethanol, propanol and mixtures thereof, preferably from methanol, ethanol and mixtures thereof.

In a preferred embodiment, the component of alkyl esters comprises, or consists of, methyl esters, ethyl esters, propyl esters, alone or in a mixture, preferably methyl esters, ethyl esters, alone or in a mixture, for example methyl esters. In a preferred embodiment, the component of alkyl esters thus consists only

of alkyl esters, in particular methyl esters, ethyl esters and/or propyl esters, preferably methyl esters and/or ethyl esters, without another component in particular of the alcohol type.

Second component of at least one hydrocarbon residue

5 The at least one hydrocarbon residue of the second component can be chosen from a residue coming from a distillation process or a residue coming from a visbreaking process.

The residue coming from the distillation process can be an atmospheric residue or a vacuum residue.

In one embodiment, the second component is at least one hydrocarbon residue chosen from a vacuum residue and a visbreaking residue.

10 In a preferred embodiment, the at least one hydrocarbon residue of the second component is a visbreaking residue.

The second component is thus exclusively of petroleum origin, coming from a crude oil. In particular, the at least one residue is not a residue coming from shale oil.

Advantageously, the second component can consist of at least one hydrocarbon residue, in particular as described above.

15 Advantageously, the at least one hydrocarbon residue of the second component can have a sulfur content of at most 1.5% m/m, preferably of at most 1% m/m, or even of at most 0.8% m/m.

Advantageously, the at least one hydrocarbon residue of the second component can have a density at 15°C of 845 to 1060kg/m³ and/or a viscosity at 100°C of 10 to 2500mm²/s.

20 In one embodiment, the at least one hydrocarbon residue of the second component can have a density at 15°C of 950 to 1060kg/m³ and/or a viscosity at 100°C of 20 to 2500mm²/s.

When the residue is a vacuum residue, it can have at least one of the following features:

- for a sulfur content of at most 1.5% m/m, preferably of at most 1% m/m:
 - o a content of asphaltenes lower than 3% m/m,
 - o a carbon residue of less than 15% m/m,
- 25 - regardless of the sulfur content, a value Sa greater than 0.75,
- regardless of the sulfur content, a density at 15°C of 950 to 1000kg/m³,
- regardless of the sulfur content, a viscosity at 100°C of 20 to 2500mm²/s,
- regardless of the sulfur content, a viscosity at 50°C of 150 to 600000mm²/s.

When the residue is a visbreaking residue, it can have at least one of the following features:

- 30 - for a sulfur content of at most 1.5% m/m, preferably of at most 1% m/m:
 - o a content of asphaltenes greater than 3% m/m,
 - o a carbon residue greater than 15% m/m,
- regardless of the sulfur content, a value Sa lower than 0.70,
- regardless of the sulfur content, a density at 15°C of 950 to 1060kg/m³,
- 35 - regardless of the sulfur content, a viscosity at 100°C of 80 to 1500mm²/s,
- regardless of the sulfur content, a viscosity at 50°C of 1700 to 300000mm²/s.

When the residue is an atmospheric residue, it can have at least one of the following features:

- a density at 15°C of 845 to 990kg/m³,
- a viscosity at 100°C of 10 to 180mm²/s,

- a viscosity at 50°C of 50 to 6200mm²/s.

Marine fuel base

5 The marine fuel base according to the invention contains from 10 to 70% m/m of the first component of fatty acid alkyl esters and from 90% to 30% m/m of the second component of at least one hydrocarbon residue. These contents are given relative to the total composition of the base. Typically, the sum of the contents of first component and second component is equal to 100%. In other words, the base can consist only of the first and second components, and thus without any other component in particular of the alcohol type.

10 In one embodiment, the base can contain the first component in a content of 10 to 60% m/m, of 10 to 50% m/m, of 10 to 50% m/m or in any range defined by two of these limits, the rest of the base consisting of the second component.

The content of first component in the base according to the invention, and in particular of methyl esters, can be determined by the testing methods IP579 or ASTM D7963, as described in the standard ISO 8217-2018.

15 The base according to the invention can be obtained by simple mixture of the first and second components described above.

In order to facilitate their mixture, the two components, or at least the second component, can be preheated, for example to a temperature lowering the viscosity of the second component. A person skilled in the art will be able to determine a suitable preheating temperature.

20 The marine fuel base can have one or more of the following features:

- a density of 860 to 991kg/m³ at 15°C,
- a sulfur content less than or equal to 0.7% by mass,
- a pour point of at most 42°C,
- a CCAI of at most 870,
- 25 - a kinematic viscosity at 50°C of at most 2000mm²/s,
- a flash point of at least 60°C.

When the second component of the marine fuel base comprises only, or even consists of, one or more atmospheric residues, the base can have one or more of the following features:

- 30 - a density at 15°C of 900 to 980kg/m³ or of 920 to 960kg/m³, or in any interval defined by two of these limits,
- a sulfur content less than or equal to 0.7% by mass,
- a pour point of at most 42°C, typically from 25 to 42°C,
- a CCAI of at most 870,
- a kinematic viscosity at 50°C of at most 80mm²/s, typically from 25 to 80mm²/s,
- 35 - a flash point of at least 60°C.

When the second component of the marine fuel base comprises only, or even consists of, one or more vacuum residues, the base can have one or more of the following features:

- 40 - a density at 15°C of 930 to 980kg/m³ or of 940 to 970kg/m³, or in any interval defined by two of these limits,
- a sulfur content less than or equal to 0.7% by mass,
- a pour point of at most 12°C or of at most 0°C, for example from -6° to -30°C,

- a CCAI of at most 860,
- a kinematic viscosity at 50°C of at most 380 mm²/s, for example from 50 to 380mm²/s,
- an S-value greater than 3, typically from 3 to 7,
- a flash point of at least 60°C.

5 When the second component of the marine fuel base comprises only, or even consists of, one or more visbreaking residues, the base can have one or more of the following features:

- a density at 15°C of 910 to 991kg/m³,
- a sulfur content less than or equal to 0.7% by mass,
- a pour point of at most 12°C, for example from 12° to -42°C, or from 6° to -36°C, or in any interval defined by two of these limits,
- a CCAI of at most 870 or of at most 840, for example from 820 to 870,
- a kinematic viscosity at 50°C of at most 2000mm²/s, for example from 25 to 2000mm²/s,
- an S-value greater than 1.5, for example from 1.5 to 4 or from 1.5 to 3, or in any interval defined by two of these limits,
- a flash point of at least 60°C.

Marine fuel

The base according to the invention can be used as a base for manufacturing a marine fuel. Marine fuel means a fuel having specifications suitable for a use in the diesel engines and boilers of ships, before any conventional treatment on board (settling, centrifugation, filtration) before its use. This type of fuel can also be used in stationary diesel engines, of a type identical or similar to those used for marine uses.

For this purpose, the base according to the invention is typically mixed with a fluxant of petroleum origin. However, it can also be used alone as a marine fuel. The marine fuel according to the invention can in particular respect all the specifications of the marine fuels presented in the standard ISO 8217-June 2018, except for the content of FAME or other methyl esters.

25 The marine fuel can in particular respect the specifications of the fuels of the type RMD, RME, RMG, RMK of the standard (except for the content of methyl esters).

This fluxant of petroleum origin is for example chosen from:

- the gasoils coming from the direct distillation of petroleum: kerosene, lamp oil, light gasoil, medium gasoil, heavy gasoil,
- the products of vacuum distillation of the atmospheric residue: vacuum light gasoil, vacuum medium gasoil, vacuum heavy gasoil, distillate,
- the products of atmosphere or vacuum distillation of the effluents of the conversion units: visbreaking gasoil, visbreaking distillate,
- the products coming from the catalytic cracking units and from the desulfurization and hydrodesulfurization units: catalytic cracker gasoil (LCO), heavy catalytic cracker gasoils (HCO, bright oil, Slurry), desulfurized gasoil, gasoil and bleed (residue) from the hydrodesulfurization units,
- the products coming from the steam-cracking units: pyrolysis oil or gasoline.

40 The characteristics of the marine fuel such as its viscosity, its density and its sulfur content can be adjusted by varying the proportions of fluxant of petroleum origin and of marine fuel base according to the invention.

Typically, the content of fluxant of petroleum origin of the marine fuel can be from 0 to 30% m/m, preferably from 0 to 20% m/m, the rest consisting of the marine fuel base according to the invention.

In one embodiment, the marine fuel according to the invention can have a content of first component of fatty acid alkyl esters of 7 to 38% m/m, a content of second component of at least one residue of 42 to 85.5% m/m and a content of fluxant of petroleum origin of 0 to 30% m/m.

In another embodiment, the marine fuel according to the invention can have a content of first component of fatty acid alkyl esters of 8 to 38% m/m, a content of second component of at least one residue of 48 to 72% m/m and a content of fluxant of petroleum origin of 0 to 20% m/m.

The marine fuel according to the invention can in particular have one or more of the following features:

- a sulfur content less than or equal to 1.5% m/m, preferably less than or equal to 1% m/m, more preferably less than or equal to 0.5% m/m, for example from 0.05 to 0.5% m/m or in any interval defined by two of these limits,
- a density at 15°C of at most 1010kg/m³, of at most 991kg/m³, of at most 975kg/m³, of at most 960kg/m³, of at most 920kg/m³, of at most 900kg/m³ or of at most 890kg/m³, in particular greater than 900kg/m³, or in any interval defined by two of these limits,
- a pour point of at most 30°C, of at most 6°C, of at most 0°C or of at most -6°C, in particular greater than -42 °C, or in any interval defined by two of these limits,
- a kinematic viscosity at 50°C of at most 700mm²/s, of at most 500mm²/s, of at most 380mm²/s, of at most 180mm²/s, of at most 80mm²/s, of at most 30mm²/s or of at most 10mm²/s, in particular greater than 2mm²/s, or in any interval defined by two of these limits,
- a flash point of at least 60°C.

The invention allows in particular to formulate a marine fuel with a very low sulfur content (less than 0.50% sulfur), comprising a renewable component.

Examples:

Various bases for a marine fuel were prepared, each comprising a residue (atmospheric residue, vacuum residue or visbreaking residue according to the trials) and a fluxant of petroleum origin or of biological origin.

The residues used are visbreaking residues (noted as RVR), a vacuum residue (noted as RSV) and an atmospheric residue (noted as RAT). The fluxants of renewable origin tested are fatty acid methyl esters coming from the transesterification of vegetable oils (noted as FAME 0, FAME 1 and FAME 2) and fatty acid methyl esters coming from the transesterification of cooking oils (noted as UCOME). The fluxant of petroleum origin is a diesel (noted as GO).

The characteristics of the various components used for the bases are grouped together in tables 1 (residues) and 2 (fluxants).

All the analyses presented in tables 2 to 8 were carried out by following the standards in tables 1 and 3. It is noted that the values S_o of the fluxants in table 2 were estimated from a correlation established according to the method described in the document WO 2021/122349 A1. The correlation used for the various fluxants is the same and has the form:

$$S_o = A + B \cdot \nu_{50} + C \cdot \nu_{100} + D \cdot CCAI \quad (6)$$

where:

A, B, C, D : coefficients determined by statistical processing as described in WO 2021/122349 A1,

ν_{50} : Kinematic viscosity (in mm²/s) at 50°C,

ν_{100} : Kinematic viscosity (in mm²/s) at 100°C,

$CCAI$: "Calculated Carbon Aromaticity Index", defined by:

$$5 \quad CCAI = \rho_{15} - 81 - 141 \cdot \text{Log}[\text{Log}(\nu_{50} + 0.85)] - 483 \cdot \text{Log} \frac{T+273}{323} \quad (7)$$

where

ρ_{15} : density at 15°C (in kg/m³), T : temperature (in °C).

Table 1: Characteristics of the residues

Product			RVR 1 (411-392)	RVR 2 (411-445)	RSV (411-669)	RAT 411-338)
Characteristic	Unit	Standard	Analysis			
Viscosity at 50°C	mm ² /s	ISO 3104:2020	4435	8900	2848	219.5
Viscosity at 100°C	mm ² /s	ISO 3104:2020	139.9	227.6	118	21.36
Viscosity at 135°C	mm ² /s	ISO 3104:2020	35.81	50.64		
Density at 15°C	kg/m ³	ISO 12185:1996	995.4	998.2	984.4	951.0
CCAI	-	-	835	833	827	818
Sulfur	%m	ASTM D2622: 16	1.094	0.698	0.711	0.683
Pour point	°C	ISO 3016:2019				36
Asphaltenes	%m	NF T 60-115 (January 2020)	8.33	7.35	2.29	
CCR	%m	ISO 10370:2014	18.37	19.52	12.58	
S-Value	S	ASTM D7157-18	1.66	2.06	6.42	
	Sa		0.56	0.62	0.88	
	So		0.73	0.78	0.77	

10 Table 2: Characteristics of the fluxants

Product		GO 411-393	FAME 0 410-321	FAME 1 410-308	FAME 2 410-182	UCOME 410-241
Characteristic	Unit	Analysis				
Viscosity at 50°C	mm ² /s	3.274	3.665	3.424	3.667	3.819
Viscosity at 100°C	mm ² /s	1.482	1.744	1.667	1.743	1.794

Density at 15°C	kg/m ³	857.5	882.0	885.5	882.7	884.9
CCAI	-	806	827			828
Sulfur	%m	0.00455	0			
Pour point	°C	0	-12	0	-6	3
Asphaltenes	%m	0	0	0	0	0
S-Value	So	0.31	0.38			0.38

Table 3: Base comprising a visbroken residue

Product (pour point)			Mass composition of the mixtures	
RVR 1 (non-measurable)	411-392		80	80
FAME 0 (-12°C)	410-321		20	-
GO (0°C)	411-393		-	20
Characteristic	Unit	Standard	Analysis	
Measured viscosity at 50°C	mm²/s	ISO 3104-2020	234.9	329.2
Calculated V50			399.5	372.8
difference in % vs measurement			-70	-13
Reproducibility (%)			7.4	7.4
Measured viscosity at 100°C	mm²/s	ISO 3104-2020	28.15	31.61
Calculated V100			35.7	32.6
difference in % vs measurement			-27	-3
Reproducibility (%)			5	5
Density at 15°C	kg/m³	ISO 12185: 1996	970.2	965.0
CCAI	-	-	836	827
Pour point	°C	ISO 3016:2019	-18	
Measured S-value	S	ASTM D7157-18	1.77	
	Sa		0.55	
	So		0.79	
Calculated S-value	S		1.50	1.46
	Sa		0.56	0.56
	So		0.66	0.64

Table 4: RVR Bases + petroleum fluxant

Product (pour point)	Mass composition of the mixtures					
RVR 2 (non-measurable)	441-445	90	80	70	60	45
GO (0°C)	411-393	10	20	30	40	55
Characteristic	Unit	Analysis				

Measured viscosity at 50°C	mm²/s	1743	480.8	164.5	67.54	24.46
Calculated V50		1889	521.9	179.1	73.49	25.13
difference in % vs measurement		-8	-9	-9	-9	-3
Reproducibility (%)		7.4	7.4	7.4	7.4	7.4
Measured viscosity at 100°C	mm²/s	85.51	40.76	21.14	12.1	6.133
Calculated V100		89.06	40.70	21.09	12.08	6.07
difference in % vs measurement		-4	0	0	0	1
Reproducibility (%)		4	5	6	7	9
Measured density at 15°C	kg/m³	981.0	966.1	950.9	936.6	916
CCAI	-	828	825	821	818	814
Pour point	°C	3	-9	-12	-15	-15
Difference relative to pour point of the flux		3	-9	-12	-15	-15
Measured S-value	S	1.89	1.86	1.75	1.67	1.52
	Sa	0.62	0.61	0.62	0.61	0.62
	So	0.72	0.73	0.67	0.64	0.58
Calculated S-value	S	1.92	1.79	1.66	1.54	1.35
	Sa	0.62	0.62	0.62	0.62	0.62
	So	0.73	0.68	0.63	0.58	0.51
Difference between measured and calculated S-value		-0.03	0.07	0.09	0.13	0.17
Reproducibility of the method for the measured S-value		0.31	0.31	0.30	0.29	0.27

Table 5: RVR Bases + renewable fluxant

Product (pour point)		Mass composition of the mixtures				
RVR 2 (non-measurable)		90	80	70	60	35
FAME 0 (-12°C)		10	20	30	40	65
Characteristic	Unit	Analysis				
Measured viscosity at 50°C	mm²/s	1361	347.5	124.2	54.43	13.08
Calculated V50		1982	565.2	198.0	82.15	15.90
difference in % vs measurement		-46	-63	-59	-51	-22
Reproducibility (%)		7.4	7.4	7.4	7.4	7.4
Measured viscosity at 100°C	mm²/s	80.13	36.61	19.52	11.62	4.391
Calculated V100		94.24	44.76	23.79	13.87	4.84
difference in % vs measurement		-18	-22	-22	-19	-10
Reproducibility (%)		4	5	6	7	11
Measured density at 15°C	kg/m³	984.4	971.6	959.5	947.5	919.6
CCAI	-	833	833	833	832	830
Pour point	°C	0	-18	-30	-33	-30
Measured S-value	S	2.05	2.28	2.26	2.36	2.42

	Sa	0.62	0.61	0.61	0.61	0.62
	So	0.77	0.89	0.89	0.93	0.93
Calculated S-value	S	1.94	1.83	1.72	1.61	1.35
	Sa	0.62	0.62	0.62	0.62	0.62
	So	0.74	0.69	0.65	0.61	0.50
Difference between measured and calculated S-value		0.11	0.45	0.54	0.75	1.07
Reproducibility of the method for the measured S-value		0.33	0.35	0.35	0.36	0.36

Table 6: Bases containing RSV

Product (pour point)	Mass composition of the mixtures					
RSV (non-measurable)	411-469	80.0	80.0	70.0	70.0	70.0
FAME 0 (-12°C)	410-321	20.0	0.0	30.0	0.0	0.0
GO (0°C)	411-393	0.0	20.0	0.0	30.0	0.0
UCOME (3°C)	411-241					30.0
Characteristic	Unit	Analysis				
Viscosity at 50°C (measured)	mm²/s	223.4	269.5	95.11	113.3	98.69
Calculated V50		297	276	123	112.3	127.1
difference in % vs measurement		-33	-2	-29	1	-29
Reproducibility (%)		7.4	7.4	7.4	7.4	7.4
Viscosity at 100°C (measured)	mm²/s	28.29	30.28	16.69	17.37	16.96
Calculated V100		30.6	28.1	17.9	16	18.2
difference in % vs measurement		-8	7	-7	8	-7
Reproducibility (%)		5	5	6	6	6
Density at 15°C	kg/m³	961.9	956.6	951.4	943.1	952.1
CCAI	-	829	821	829	818	829
Pour point	°C	-24	-3	-24	-9	-9
Measured S-value	S	5.84	4.88	5.50	4.88	6.01
	Sa	0.87	0.86	0.88	0.85	0.85
	So	0.75	0.67	0.67	0.72	0.89
Calculated S-value	S	5.75	5.64	5.50	5.25	5.43
	Sa	0.88	0.88	0.88	0.88	0.88
	So	0.69	0.68	0.65	0.63	0.65
Difference between measured and calculated S-value		0.09	-0.76	0.08	-0.37	0.58
Reproducibility of the method for the measured S-value		0.70	0.61	0.67	0.61	0.72

Table 7: Bases containing RAT

Product (pour point)		Mass composition of the mixtures
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RAT (36°C)	411-338	80.0	80.0	70.0	70.0	70.0	70.0
FAME 0 (-12°C)	410-321	20.0	0.0	30.0	0.0		
FAME 1 (0°C)	410-308					30.0	
FAME 2 (-6°C)	410-182						30.0
GO (0°C)	411-393	0.0	20.0	0.0	30.0		
Characteristic	Unit	Analysis					
Viscosity at 50°C (measured)	mm²/s	50.09	57.1	29.44	33.34	28.17	29.55
Calculated V50		64.3	60.9	38.6	35.9	36.93	38.54
difference in % vs measurement		-28	-7	-31	-8	-31	-30
Viscosity at 100°C (measured)	mm²/s	9.535	9.814	6.937	7.066	6.759	6.925
Calculated V100		10.6	10	7.9	7.2	7.703	7.7886
difference in % vs measurement		-11	-2	-14	-2	-14	-12
Density at 15°C	kg/m³	936.6	931.3	929.4	921.6	930.2	929.3
CCAI	-						
Pour point	°C	36	33	33	30	33	33
Calculated pour point		33	33	31	31	32	31

Tables 3 to 7 show differences between the measured and calculated viscosities (at 50°C and 100°C) higher for the bases containing FAME or UCOME than the bases containing GO as a fluxant. Moreover, this difference is much higher for the bases containing a visbroken residue than for the bases containing the other residues.

It should be noted that the reproducibility of the measurement of viscosity is 7.4% at 50°C. The differences in percentage between the measured and calculated viscosities are of this order of magnitude for the bases containing the GO and greater for the bases containing FAME or ECOME, and much greater for the bases containing a visbroken residue relative to the bases containing other types of residues.

Similarly for the viscosity at 100°C, it is observed that the differences in percentage between the measured and calculated viscosities are less than the reproducibility for the bases containing the GO, greater for the bases containing FAME or ECOME, and much greater for the bases containing a visbroken residue relative to the bases containing other types of residues.

With regard to the pour point, it is noted that the pour point of an RVR is not measurable. Nevertheless, the difference between the pour point of the base and that of the fluxant contained in the base is greater in absolute value for the RVR bases with FAME than for the RVR bases with GO. Moreover, it is observed that this difference increases with the content of fluxant, and is greater for the contents of FAME from 30 to 40% m/m. For the bases containing an RSV, a similar, but less pronounced, behavior is observed, with a difference between the pour point of the base and that of the fluxant contained in the base greater in absolute value for the RSV bases with FAME or UCOME than for the RSV bases with GO.

The mixing rule allows to correctly predict the S-value parameters of the RVR / GO bases. However, the measured S-value of the bases with FAME increases with the % of FAME, which should not be the case since the FAMEs are paraffinic compounds. Moreover, the mixing rule predicts a decrease in the S-value. These differences are much greater than the reproducibility of the method and come from the aromaticity

So of the matrix: the measurements indeed show that the Sa is constant regardless of the mixture (the Sa of the RVR is not modified since the fluxants do not introduce asphaltenes).

Good agreement between measured and calculated S-value and So is observed for the RVR / GO bases whereas for the RVR / FAME bases the S-value and the aromaticity So increase while the mixing rule predicts a decrease.

The examples of tables 4 and 5 with a visbroken residue thus show that the difference between the measured and calculated S-value is less than the reproducibility for the mixtures with GO and much greater for the mixture with FAME (except for the 90% RVR / 10% FAME mixture).

The examples of table 6 show that the difference between the measured and calculated S-value is less than the reproducibility for all the mixtures except for the 80% RSV / 20% GO mixture. However, the measured S-value of the mixtures with GO is less than the calculated S-value whereas once again the measured S-value of the mixtures with FAME is greater than the calculated S-value.

These observations lead to attributing to the FAME a booster effect on the viscosity (reduction), the pour point (reduction) and the stability (increase) of a mixture with a residue. Moreover, this booster effect is more pronounced for the bases containing visbroken residues.

Table 8 below groups together the properties of fuel mixtures that can be used as marine fuels. A difference between the measured viscosity and the calculated viscosity is observed, the measured viscosity being much lower than the calculated viscosity, even more so for the mixtures containing a visbroken residue.

Table 8: Fuel mixtures

Product (pour point)	Mass composition of the mixtures					
RVR 1 (non-measurable)	411-392	85.0	70.0	60.0		
RSV (non-measurable)					70.0	
RAT (36°C)						70.0
FAME 0 (-12°C)	410-321	10.0	20.0	20.0	20.0	20.0
GO (0°C)	411-393	5.0	10.0	20.0	10.0	10.0
UCOME (3°C)	410-241					
Analysis	Unit					
Viscosity at 50°C (measured)	mm²/s	428.3	98.92	48.05	98.16	30.53
Calculated V50		675.1	149.0	65.0	119	37.7
difference in % vs measurement		-58	-51	-35	-21	-23
Reproducibility (%)		7.4	7.4	7.4	7.4	-
Viscosity at 100°C (measured)	mm²/s	39.91	16.18	10.07	16.33	6.948
Calculated V100		48.1	19.3	11.5	17.2	7.7
difference in % vs measurement		-21	-19	-14	-5	-11
Reproducibility (%)		5	6	7	6	-
Density at 15°C	kg/m³	974.8	955.6	941.6	948	926.7
CCAI	-	835	832	828	825	
Pour point	°C	-12	-21	-15	-18	30
Measured S-value	S	1.70	1.73	1.62	5.78	

	Sa	0.56	0.55	0.55	0.85	
	So	0.75	0.78	0.73	0.86	
Calculated S-value	S	1.53	1.40	1.30	4.73	
	Sa	0.56	0.56	0.56	0.88	
	So	0.67	0.62	0.57	0.57	
Difference between measured and calculated S-value		0.17	0.23	0.32	1.05	

Comparative example 1: mixture of a vacuum residue and a hydrogenated vegetable oil

A mixture comprising 70% m/m of a vacuum residue and 30% m/m of a hydrogenated vegetable oil.

The measured and calculated viscosities of the mixture are presented in table 9. It is observed that the addition of hydrogenated vegetable oils to a residue does not have the booster effect observed with the addition of a FAME.

Table 9

Analysis	Unit	
Viscosity at 50°C (measured)	mm²/s	71.15
Calculated V50		74.69
difference in % vs measurement		-5%

Comparative example 2: mixture of a shale oil residue and a biodiesel

Tables 7 and 8 of the document US10899983B1 were reproduced and completed with the calculated viscosities according to the invention and the differences between the measurements. The results are grouped together in tables 10 and 11. The density, the sulfur content and the MCR were calculated in order to verify that the proportions used for the calculations of viscosity were correct.

With regard to the “35% LCO, 60% VRFO3” mixture, the calculations were carried out with 65% VRFO3, which is consistent with the calculated density, sulfur content and MCR.

The calculated viscosities and the differences between the calculated and measured viscosities show that the booster effect is not observed with a biodiesel when the residue is a residue coming from shale oil.

Table 10: Completed table 7 of US10899983B1

	ISO8217 RMD80 Spec	55% LCO, 45% VRFO1, VLSFO, high ratio	35% LCO, 60% [65%] VRFO3, VLSFO, low ratio	35% Gas Oil, 65% VRFO2, ECA, low ratio	75% Gas Oil, 25% VRFO5, ECA, high ratio
Density at 15°C (kg/m ³)	<990	901.8	936.9	877.1	870.3
Calculated density		901.5	936.7	877	869.5
Kine. viscosity at 50°C (cSt)	<80	28	202	112	11.6

Calculated kine. viscosity at 50°C		27	197	111	11.5
difference in % vs measurement		2.2%	2.5%	1.2%	0.8%
Sulfur content (%m)	<0.50	0.4808	0.4950	0.0403	0.0593
Calculated sulfur content		0.47	0.495	0	0.059
CCAI	<860	798	805	752	784
BHCI	-	42	54	25	31
TE	-	6	4	0	0
Insoluble N-Heptane (%m)	-	0.15	0.16	0.15	0.02
MCR (%m)	<14	0.18	4.58	0.34	0.74
Calculated MCR		0.21	4.55	0.33	0.71
Pour point (°C)	<30	21	24	29	14

Table 11: Completed table 8 of US10899983B1

	ISO8217 RMD80 Spec	25% Biodiesel, 75% VRFO5, ECA, low ratio	50% Biodiesel, 50% VRFO1, ECA, high ratio	30% Biodiesel, 70% VRFO3, VLSFO, low ratio	70% Biodiesel, 30% VRFO3, VLSFO, low ratio
Density at 15°C (kg/m3)	<990	907.0	880.9	926.9	0.8999
Calculated density		906.7	880.8	926	898.8
Kine. viscosity at 50°C (cSt)	<80	366	33.0	298	13.8
Calculated kine. viscosity at 50°C		362	32.62	295	13.6
difference in % vs measurement		1.1%	1.2%	1.0%	1.4%
Sulfur content (%m)	<0.50	0.0592	0.0148	0.2269	0.1004
Calculated sulfur content		0.0586	0.0148	0.2220	0.0955
CCAI	<860	768	774	790	810

BMCI	-	46	50	59	71
TE	-	0	0	0	0
Insoluble N-Heptane (%m)	-	0.05	0.11	0.14	0.06
MCR (%m)	<14	2.14	0.11	4.93	2.18
Calculated MCR		2.12	0.11	4.82	2.07
Pour point (°C)	<30	29	27	28	15

Claims

1. Use of fatty acid alkyl esters to improve the viscosity of a component of at least one hydrocarbon residue and obtain a marine fuel base, wherein (i) 10 to 70% m/m of a first component consisting of fatty acid alkyl esters of renewable origin is mixed with (ii) 90% to 30% m/m of a second component consisting of at least one hydrocarbon residue coming from a crude oil chosen from an atmospheric residue, a vacuum residue and a visbreaking residue, and the mixture obtained forms a marine fuel base that has a kinematic viscosity at 50°C 15 to 75% lower than a kinematic viscosity calculated according to the formula:

$$\vartheta = \exp\left(\exp\left(\frac{VB_{mélange} - 23.097}{33.469}\right)\right) - 0.8 \quad (4),$$
where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the formula:

$$VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8)) \quad (5),$$
where v_i is the kinematic viscosity of the component i expressed in stokes.
2. Use according to claim 1, wherein the mixture obtained has a kinematic viscosity at 100°C 5 to 30% lower than the calculated viscosity.
3. Use according to claim 1, wherein the at least one hydrocarbon residue chosen from a vacuum residue and a visbreaking residue.
4. Use according to claim 1, wherein the at least one hydrocarbon residue is a visbreaking residue.
5. Use according to claim 3 or 4, to obtain a mixture having an S-value measured according to the standard ASTM D7157-18 (2018 Revision) greater than a calculated S-value $S_{mélange}$, defined as being equal to:

$$S_{mélange} = \frac{So_{mélange}}{1 - Sa_{mélange}} \quad (3),$$
with,

$$So_{mélange} = \sum x_i \times So_i \quad (1)$$
or
$$So_{mélange} = \frac{\sum x_i \times (100 - ASP_i) \times So_i}{\sum x_i \times (100 - ASP_i)} \quad (1bis),$$

$$Sa_{mélange} = \frac{\sum x_i \times ASP_i \times Sa_i}{\sum x_i \times ASP_i} \quad (2)$$
where:
the parameters So and Sa are as defined in the standard ASTM D7157-18 (2018 Revision), and
 x_i is the mass fraction of the component i,
 ASP_i is the content of asphaltenes (%m) of the component i,
 So_i is the solvent power of the component i,
 Sa_i is the peptizability of the component i,
and the solvent power of the first component is estimated from a correlation expressing the solvent power So of said first component according to the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of said first component.

6. Use according to any one of claims 1 to 5, wherein the first component comprises methyl esters, ethyl esters, propyl esters and the mixtures thereof.

7. Marine fuel base comprising:

- (i) 10 to 70 % m/m of a first component consisting of fatty acid alkyl esters of renewable origin,
- (ii) 90 to 30% m/m of a second component consisting of at least one hydrocarbon residue coming from a crude oil chosen from an atmospheric residue, a vacuum residue and a visbreaking residue,

said base having a kinematic viscosity at 50°C 15 to 75% lower than a kinematic viscosity calculated according to the formula:

$$\vartheta = \exp \left(\exp \left(\frac{VB_{mélange} - 23.097}{33.469} \right) \right) - 0.8 \quad (4)$$

where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the formula:

$$VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8)) \quad (5),$$

where v_i is the kinematic viscosity of the component i expressed in stokes.

8. Base according to any one claim 7, having a kinematic viscosity at 100°C 5 to 30% lower than the calculated viscosity.

9. Base according to any one claim 7, wherein the at least one hydrocarbon residue of the second component is chosen from a vacuum residue and a visbreaking residue.

10. Base according to any one claim 7, wherein the at least one hydrocarbon residue of the second component is a visbreaking residue.

11. Base according to claim 9 or 10 having an S-value measured according to the standard ASTM D7157-18 (2018 Revision) greater than a calculated S-value $S_{mélange}$, defined as being equal to:

$$S_{mélange} = \frac{So_{mélange}}{1 - Sa_{mélange}} \quad (\text{equation 3}),$$

with,

$$So_{mélange} = \sum x_i \times So_i \quad (\text{equation 1})$$

$$\text{or } So_{mélange} = \frac{\sum x_i \times (100 - ASP_i) \times So_i}{\sum x_i \times (100 - ASP_i)} \quad (\text{equation 1bis}),$$

$$Sa_{mélange} = \frac{\sum x_i \times ASP_i \times Sa_i}{\sum x_i \times ASP_i} \quad (\text{equation 2})$$

where:

the parameters So and Sa are as defined in the standard ASTM D7157-18 (2018 Revision), and

x_i is the mass fraction of the component i,

ASP_i is the content of asphaltenes (%m/m) of the component i,

So_i is the solvent power of the component i,

Sa_i is the peptizability of the component i,

and the solvent power of the first component is estimated from a correlation expressing the solvent power So of said first component according to the kinematic viscosity at 50°C, the kinematic viscosity at 100°C and the density at 15°C of said first component.

12. Base according to any one of claims 7 to 11, wherein the component of fatty acid alkyl esters of renewable origin comprises methyl esters, ethyl esters, propyl esters and the mixtures thereof.

13. Marine fuel comprising a base according to any one of claims 7 to 12, and optionally at least one fluxant of petroleum origin.

14. Method for improving the viscosity of a component of at least one hydrocarbon residue for the preparation of a marine fuel base comprising the mixture of (i) 10 to 70% m/m of a first component consisting of fatty acid alkyl esters of renewable origin with (ii) 90% to 30% m/m of a second component consisting of at least one hydrocarbon residue coming from a crude oil chosen from an atmospheric residue, a vacuum residue and a visbreaking residue, and for obtaining a mixture forming a marine fuel base that has a kinematic viscosity at 50°C 15 to 75% lower than a kinematic viscosity calculated according to the formula:

$$\vartheta = \exp \left(\exp \left(\frac{VB_{mélange} - 23.097}{33.469} \right) \right) - 0.8 \quad (4),$$

where $VB_{mélange}$ is the weighted average of the viscosity indices of the first component and of the second component, these viscosity indices being calculated via the formula: $VB_i = 23.097 + 33.469 \times \ln(\ln(v_i + 0.8))$ (5),

where v_i is the kinematic viscosity of the component i expressed in stokes.