

Description

Title: Method for purifying at least partially re-refined lubricating oils

Technical field

The present invention relates to the field of rerefining or regenerating used lubricating compositions. More precisely, the present invention relates to a method for purifying an at least partially rerefined lubricating oil, making it possible to obtain a lubricating oil having in particular a reduced silicon content tailored to the use of said oil as a base oil for the formulation of a new lubricating composition.

Prior art

Lubricating compositions, referred to even more simply as “lubricants”, are commonly used in mechanical systems for the primary purposes of reducing frictional forces between the various moving metal parts and to prevent premature wear or even damage to these parts, particularly to their surface. For example, they are used in various mechanical systems of vehicles, including the engine, transmission or hydraulics system.

During their use, the lubricating compositions are subjected to stresses that result in their degradation and lead to an increase in the level of undesirable elements, which may come from degradation of the base oil itself or of additives generally present in lubricating compositions, from external contaminants such as dust, from elements originating from the wear of parts with which the oil comes into contact during use, or from fractions of fuel coming from the engine.

These various undesirable elements are capable of negatively impacting the properties of the lubricating composition, which after use accordingly becomes what is referred to as a “used”, “spent” or even “degraded” lubricating composition. This is the reason why lubricating compositions need to be replaced after a certain period of use.

In the light of current issues of environmental protection and conservation of resources, a focus of research has been the development of methods for rerefining or reconditioning used lubricating compositions with the aim of regenerating lubricating oils that can be reused for the formulation of new lubricating compositions.

To this end, used lubricating compositions are usually subjected to various operations aimed at removing contaminants and other undesirable elements present therein, and thus undergo

operations similar to those employed in the field of refining petroleum oils. The numerous methods proposed for rerefining used lubricating compositions include for example the method described in document EP 0 708 174, which comprises dewatering, vacuum distillation, extraction with the aid of a solvent, and hydrotreating steps.

A process for preparing a regenerated lubricating oil advantageously having a reduced content of the undesirable polycyclic aromatic hydrocarbons (PAHs) that are present in used lubricating compositions, is likewise described in document WO 2018/109208 and comprises passing the used lubricating composition through activated carbon.

But even though such processes make it possible to obtain rerefined lubricating oils having good performance, these rerefined or regenerated oils usually have silicon contents that are still significantly higher than those of conventional base oils resulting directly from petroleum refining.

However, the presence of silicon in base oils intended for the formulation of lubricants, especially for the lubrication of mobile or stationary drive systems, in particular engine lubricants, is undesirable given the wear problems that it can cause.

This means that the amount of rerefined lubricating oils, or the nature of the rerefined lubricating oils, that can be incorporated for the formulation of lubricating compositions is limited in order to meet the specifications required for the lubricant in terms of silicon content. Consequently, the amount of rerefined lubricating oils introduced is usually kept within limits in favor of new base oils.

There therefore remains a need to optimize the composition of rerefined oils, in particular to reduce their silicon content, in order to be able to fully exploit these regenerated oils for use as base oils in the formulation of lubricating compositions.

Statement of the invention

The present invention aims specifically to overcome the constraint associated with the presence of undesirable elements such as silicon in regenerated oils.

More particularly, it proposes a novel method for purifying at least partially rerefined lubricating oils, advantageously making it possible to reduce the content of undesirable

elements, in particular silicon, in order to obtain regenerated and purified oils that can be used as base oils for the formulation of lubricating compositions.

Thus, according to a first of its aspects, the invention relates to a process or method for purifying an at least partially rerefined lubricating oil, said process comprising at least the following steps:

(a) contacting said at least partially rerefined lubricating oil, referred to as “regenerated lubricating oil”, with from 0.1% to 50% by weight of at least one strong base containing an alkali metal or alkaline earth metal cation; and

(b) recovering said purified lubricating oil by separating the strong base containing the alkali metal or alkaline earth metal cation from the product obtained at the end of step (a).

Preferably, as detailed hereinbelow, step (a) of contacting the regenerated lubricating oil with said strong base is carried out in the presence of water and, preferably, step (b) of separating said strong base is carried out via one or more steps of filtration, distillation, separation by settling and/or liquid/liquid extraction, preferably liquid/liquid extraction, in particular with water.

Such a process has already been proposed for the purposes of purifying feedstocks containing oils from the pyrolysis of plastic wastes with a view to the use thereof in a steam cracking process, in applications filed under the numbers FR2104616, FR2104617, and FR2109395.

On the other hand, as far as the inventors are aware, nobody has yet proposed exploiting this means of purifying oils from the pyrolysis of plastics for the purposes of purifying partially rerefined lubricating oils, and especially with a view to lowering the silicon content.

In the context of the invention, “used lubricating composition” (or more simply “used lubricant” or “used oil”) is understood as meaning any lubricating composition that has been used for lubricating moving parts, in particular metal parts, of a mechanical system, such as bearings, gears or motors.

A used lubricating composition can come from a variety of sources. In particular, as detailed hereinbelow, it may be a lubricant that has been used for the lubrication of a drive system, in particular a “mobile” drive system, or else for the lubrication of a so-called industrial system, in particular a “stationary” industrial system.

It is understood that a used lubricating composition may be a mixture of more than one used lubricating composition from the same source or from more than one different source.

On account of their origin, used lubricants, in particular engine lubricants, comprise a number of degradation products derived from the oil itself or from additives present therein, as well as metal particles, metal oxide particles, and particles of other elements originating for example from the engine. A used oil may in particular contain a high content of undesirable elements, for example of calcium (Ca), iron (Fe), magnesium (Mg), sodium (Na), nickel (Ni), phosphorus (P), silicon (Si), chlorine (Cl), zinc (Zn), etc.

By contrast with a “used lubricating composition”, the expression “new lubricating composition” refers for the purposes of the invention to a lubricating composition that has not yet been used for lubricating moving parts of a mechanical system and that is ready for such use.

In the context of the present invention, the expression “at least partially rerefined lubricating oil”, also referred to more simply hereinbelow as “regenerated oil” or “recycled oil”, means an oil resulting at least in part from a used lubricating composition that has been subjected to one or more steps of treatment known as rerefining treatment.

In other words, an at least partially rerefined lubricating oil is obtained from one or more steps of treatment of a used lubricant intended to at least partially remove a number of contaminants present therein, such as dust, water, fuel fractions, metallic elements, and other residues resulting from the degradation of additives present in the lubricant.

As detailed hereinbelow, these pretreatment steps to which the lubricating oils have been subjected prior to use in a purification process according to the invention may be selected in particular from steps of dewatering, distillation, filtration, hydrogenation, liquid/liquid extraction, separation by settling and/or of passing the used lubricant through an adsorbent material, in particular through activated carbon.

This distinguishes an at least partially rerefined composition of the invention from a used lubricating composition or oil. Compared to a used lubricant, the at least partially rerefined lubricating oil has in particular a reduced content of certain undesirable contaminants, for example of water or fuel, and advantageously a reduced content of PAHs, and preferably satisfies a number of quality standards required for a lubricating base oil.

An at least partially rerefined lubricating oil according to the invention likewise differs from a virgin or new base oil (i.e. a refined base oil), especially with regard to the silicon content present in the regenerated oil.

In particular, an at least partially rerefined oil used in the treatment process according to the invention may have a silicon content that is particularly high and in any event undesirable for the use of said regenerated oil for the formulation of a lubricating composition.

The silicon content of a regenerated lubricating oil used in the purification process according to the invention may in particular be strictly greater than 2 ppm, preferably greater than or equal to 5 ppm, in particular greater than or equal to 10 ppm, more particularly greater than or equal to 15 ppm, for example greater than or equal to 20 ppm, or even greater than or equal to 30 ppm.

In some cases, the silicon content of a regenerated lubricating oil may be up to 285 ppm, even up to 290 ppm, or even up to 300 ppm.

The silicon content can be evaluated by any method known to those skilled in the art, for example by X-ray fluorescence (XRF), by inductively-coupled plasma atomic emission spectrometry (ICP-AES) or else by inductively-coupled plasma mass spectrometry (ICP-MS).

Advantageously, as illustrated in the examples that follow, the purification process according to the invention for a regenerated lubricating oil makes it possible to significantly reduce the silicon content present in the regenerated oil.

It is advantageous when the silicon content initially present in the regenerated lubricating oil can be reduced by at least 50% by weight of its initial value, in particular by at least 60%, advantageously by at least 70%, preferably by at least 80%, of its initial value.

Advantageously, in particular irrespective of the silicon content of the regenerated lubricating oil initially provided, the process according to the invention makes it possible to reduce the amount of silicon to a content of strictly less than 10 ppm, in particular less than or equal to 7 ppm, in particular less than or equal to 5 ppm.

Thus, the purification process of the invention is found to be particularly advantageous for treating regenerated lubricating oils that, despite the rerefining treatments to which they have

been subjected, have a high residual silicon content that is undesirable for the use thereof as base oils for the formulation of new lubricants.

According to another of its aspects, the invention thus relates to a process or method for reducing the silicon content in an at least partially rerefined lubricating oil, said process employing at least the steps (a) and (b) defined above.

It also relates to the use of at least one purification process according to the invention employing at least the above steps (a) and (b) to reduce the silicon content of an at least partially rerefined lubricating oil.

It also relates to a process for preparing an at least partially rerefined lubricating oil that contains less than 10 ppm, in particular less than 7 ppm, preferably less than 5 ppm, of silicon from at least partially rerefined lubricating oil, said process employing at least the steps (a) and (b) defined above.

A further advantage, as illustrated in the examples that follow, is that, in addition to significantly reducing the silicon content of the regenerated oil, the process of the invention advantageously makes it possible to reduce the content of other elements that may be considered undesirable, especially chlorine, nitrogen and/or oxygen. These elements can be undesirable in the lubricant, especially with regard to the corrosion effects (in the case of chlorine), changes in interfacial properties (in the case of nitrogen), and tendency to oxidation (in the case of oxygen) that they can cause.

In particular, the process of the invention, especially when the regenerated oil has a high chlorine content, advantageously makes it possible to significantly reduce this content. Such a reduction in the chlorine content is advantageous given the undesirable corrosion effects that can be caused by the hydrogen chloride potentially generated by residual chlorine present in the lubricating oil.

It is advantageous when the chlorine content of a regenerated oil treated according to the invention is less than or equal to 30 ppm, in particular less than or equal to 25 ppm, and more particularly less than or equal to 10 ppm, or even less than or equal to 5 ppm.

The invention thus relates to the use of a purification process according to the invention employing at least the above steps (a) and (b) to reduce the silicon, chlorine, oxygen and/or nitrogen content, in particular silicon and/or chlorine content, more particularly silicon content, of an at least partially rerefined lubricating oil.

Advantageously, as illustrated in the examples that follow, the process of the invention also makes it possible to reduce the boron and phosphorus contents present in the regenerated oils.

The invention thus relates to the use of a purification process according to the invention employing at least the above steps (a) and (b) to reduce the silicon, chlorine, oxygen, nitrogen, boron and/or phosphorus contents of an at least partially rerefined lubricating oil.

The regenerated and purified lubricating oil obtained at the end of the treatment process according to the invention is found to be particularly suitable, and without requiring additional purification treatment, for use as a base oil, for example for the purposes of being sold as is, further treated in fractions of different viscosities or else formulated with additives to produce a new lubricating composition.

In particular, the process of the invention advantageously makes it possible to overcome the constraint associated with their silicon content when using regenerated lubricating oils for the formulation of new lubricants.

Thus, lubricating oils regenerated and purified according to the process of the invention may be incorporated on their own or as a mixture with one or more virgin base oils for the formulation of a lubricant, without a limit on the amount, since they do not contribute to an increase in the silicon content of the lubricant.

Thus, the present invention also relates, according to another of its aspects, to the use of a lubricating oil regenerated and purified according to the process according to the invention for the formulation of a new lubricating composition, in particular by additizing it with one or more additives conventionally used in the field of lubricants.

The invention relates in particular to a process or method for preparing a lubricating composition comprising at least the following steps:

- (i) purifying an at least partially rerefined lubricating oil by a purification process according to the invention as defined above, said process preferably including no distillation step subsequent to step (b);
- (ii) optionally mixing said purified lubricating oil from step (i) with one or more further lubricating oils selected in particular from virgin base oils, lubricating oils regenerated and

purified according to the process of the invention, and at least partially rerefined lubricating oils;

(iii) supplementing said purified lubricating oil resulting from step (i) or the mixture of lubricating oils from step (ii) with at least one additive, preferably selected from friction-modifying additives, extreme pressure additives, anti-wear additives, detergents, antioxidants, viscosity index improvers, pour point depressants, dispersants, antifoaming agents, thickeners, and mixtures thereof.

Other features, alternative forms, and advantages of the process for purifying at least partially rerefined lubricating oils according to the invention will emerge more clearly on reading the description and the examples that follow, which are given as non-limiting illustrations of the invention.

The expressions “between... and...”, “ranging from... to...”, “formed from... to...”, and “varying from... to...” should be understood as being meaning inclusive of limits, unless otherwise stated.

In the description and the examples, percentages are percentages by weight unless otherwise stated. Percentages are thus expressed as weights relative to the total weight of the composition.

Detailed description

Regenerated lubricating oil

The process of the invention makes it possible to purify any at least partially rerefined lubricating oil, referred to as “regenerated oil”, in other words any lubricating oil resulting from a used lubricating composition that has been subjected to one or more refining treatment steps.

The used lubricating compositions and consequently the regenerated lubricating oils comprise as the majority component one or more base oils conventionally used in the field of lubricants, such as synthetic or natural mineral oils, animal oils or vegetable oils or mixtures thereof.

This may be a mixture of more than one base oil, for example a mixture of two, three or four base oils.

These base oils may in particular be oils of mineral or synthetic origin of groups I to V according to the classes defined in the API classification (or their equivalents under the ATIEL classification) and shown in the table below, or mixtures thereof.

[Table 1]

	Content of saturates	Content of sulfur	Viscosity index (VI)
Group I Mineral oils	< 90%	> 0.03%	$80 \leq VI < 120$
Group II Hydrocracked oils	$\geq 90\%$	$\leq 0.03\%$	$80 \leq VI < 120$
Group III Hydrocracked or hydroisomerized oils	$\geq 90\%$	$\leq 0.03\%$	≥ 120
Group IV	Polyalphaolefins (PAO)		
Group V	Esters and other bases not included in groups I to IV		

In particular, the used lubricating composition from which is derived the regenerated lubricating oil used in the process of the invention may comprise at least 50% by weight of base oil(s) relative to its total weight, in particular at least 60% by weight of base oil(s), and more particularly between 60% and 99% by weight of base oil(s).

The purification process according to the invention advantageously makes it possible to purify regenerated lubricating oils comprising one or more base oils of groups I, II, III and/or IV of the API classification, in particular oils of groups II and/or III.

According to a particular embodiment, the regenerated lubricating oil treated according to the invention may result from the treatment of a used lubricating composition that has been used for the lubrication of a drive system, in particular a “mobile” drive system, that is to say including light vehicles, heavy-duty vehicles, “off-road” vehicles or marine vehicles.

According to another particular embodiment, the regenerated lubricating oil treated according to the invention may result from the treatment of a used lubricating composition that has been used for the lubrication of a so-called industrial system, in particular a “stationary” industrial system, that is to say including in a non-limiting manner turbines, compressors, hydraulics systems, and gears, as well as forming and cutting machines.

A used lubricating composition from which is derived the regenerated lubricating oil to be treated according to the invention may contain various additives conventionally used in the field of lubricants, such as friction-modifying additives, extreme pressure additives, anti-wear additives, detergents, antioxidants, viscosity index (VI) improvers, pour point depressants (PPDs), dispersing agents, antifoaming agents, thickeners, and mixtures thereof. As already mentioned above, the properties of the used lubricating composition become degraded through their use for periods of varying length for the lubrication of a mechanical system, in particular a drive system, such as a combustion engine.

As a consequence of their origin, used lubricating compositions can thus contain one or more additives described above and impurities resulting from the degradation of additives originally present in the lubricant or resulting from the wear of moving mechanical parts.

The composition of the used lubricant may of course differ according to the origin of the lubricant, its initial formulation, and the varying nature of its contamination according to how it has been used.

The regenerated lubricating oil according to the invention comes more particularly from a used lubricating composition that has been subjected to one or more prior pretreatment steps known in the field of rerefining used lubricants.

In particular, the aim of these treatment steps is to at least partially remove water, solid particles, fuel and/or other contaminants, such as PAHs, which are undesirable in the formulation of lubricants.

According to a particular embodiment, the regenerated lubricating oil according to the invention comes from a used lubricant that has been subjected to one or more prior steps of dewatering, distillation, filtration, hydrogenation, liquid/liquid extraction, separation by settling and/or passage of the used lubricant through an adsorbent material, preferably as detailed below.

Thus, the invention also relates to a process or method for preparing a regenerated and purified lubricating oil comprising at least the steps of:

- recovering an at least partially rerefined lubricating oil from a used lubricating composition, said lubricating oil being obtained in particular by subjecting said used lubricating composition to at least one or more steps of dewatering, distillation, filtration, hydrogenation, liquid/liquid extraction, separation by settling and/or passage of said used lubricating composition through an adsorbent material, preferably carried out under the conditions detailed below;
- contacting said regenerated lubricating oil with 0.1% to 50% by weight of at least one strong base containing an alkali metal or alkaline earth metal cation; and
- recovering said purified lubricating oil by separating the strong base containing the alkali metal or alkaline earth metal cation.

Preferably, the regenerated lubricating oil used in the process of the invention is obtained by subjecting a used lubricating composition to at least one prior dewatering step. This dewatering step removes any water that may be present in the used lubricant.

It is advantageous when the regenerated lubricating oil used according to the invention thus has a water content of less than or equal to 10% by weight, in particular less than or equal to 5% by weight, in particular less than or equal to 5% by weight, especially less than or equal to 2% by weight, and more particularly less than or equal to 1% by weight, relative to the total weight of said regenerated lubricating oil.

This dewatering may be carried out by any method known to those skilled in the art, for example by distillation, separation by settling, heating or passing a stream of hot air through the used lubricating composition.

According to one embodiment, the dewatering step may be carried out at a temperature of between 50°C and 250°C, preferably between 100°C and 200°C. In particular, it may be carried out at a pressure of between 50 000 and 150 000 Pa, preferably at atmospheric pressure.

Preferably, the regenerated lubricating oil used in the process of the invention is obtained by subjecting a used lubricating composition to at least one prior filtration step. This filtration may be carried out by any method known to those skilled in the art. This filtration step may

or may not be a particulate filtration step. It may for example be carried out using diatomaceous earth type systems.

Preferably, the regenerated lubricating oil used in the process of the invention is obtained by subjecting a used lubricating composition to at least one prior distillation step, which preferably follows a prior dewatering step. Said distillation step(s) may be carried out by any technique known to those skilled in the art. It may for example be a distillation at atmospheric pressure or a distillation under reduced pressure. The distillations may for example be carried out at a temperature of between 100°C and 500°C, preferably between 200°C and 400°C, more preferably between 300°C and 380°C. In particular, they may be carried out at a pressure of between 25 and 2000 Pa, preferably between 50 and 1000 Pa, more particularly between 50 and 250 Pa.

It is advantageous when the regenerated lubricating oil used in the process of the invention is obtained by subjecting a used lubricating composition to at least one prior step of passing said used lubricating composition through an adsorbent material.

The adsorbent material advantageously permits the selective adsorption of aromatic compounds, in particular polycyclic aromatic hydrocarbons (PAHs).

In particular, the passage through an adsorbent material, preferably through activated carbon, advantageously makes it possible to reduce the content of polycyclic aromatic hydrocarbons (PAHs), selected in particular from chrysene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[e]pyrene, benzo[a]pyrene, dibenz[a,h]anthracene and/or benz[a]anthracene, in the used lubricating composition.

“Passage of the used lubricating composition through an adsorbent material” is understood as meaning the flow of the used lubricating composition through the adsorbent support.

The adsorbent materials may be for example activated carbon, zeolites, clays or functionalized porous compounds. Preferably, it is activated carbon.

For example, the regenerated lubricating oil used in the process of the invention may be obtained from the treatment of a used lubricating composition according to the process described in document WO 2018/109208.

In the case of passage of the used lubricating composition through activated carbon, the amount of activated carbon used is preferably between 0.5 and 60 g of activated carbon per

liter of used lubricating composition, preferably between 0.5 and 50 g/l, preferably from 1 to 50 g/l, preferably between 1 and 30 g/l, for example between 5 and 60 g/l, preferably between 5 and 50 g/l.

The flow rate in the passage of the used lubricating composition may be between 1 m³/h and 15 m³/h, for example between 5 and 10 m³/h.

Preferably, the activated carbon is characterized by a density of between 200 and 500 kg/m³, for example measured according to the standard ASTM D2854.

Preferably, the activated carbon is a carbon from bituminous coal, preferably comprising from 70% to 95%, advantageously from 80% to 90%, by weight of carbon.

The step of passing the used lubricating composition through an adsorbent support, preferably through activated carbon, is advantageously preceded by the following prior steps:

- one or more distillation steps; and
- a filtration step, in particular as defined above.

It is advantageous when the regenerated lubricating oil used in the process of the invention can be obtained by subjecting a used lubricating composition to at least one prior hydrogenation (or hydrotreating) step, which preferably follows a prior dewatering and/or distillation step. Said hydrogenation step(s) may be carried out by any technique known to those skilled in the art and generally consist of treating the lubricating oil with hydrogen, usually in the presence of a hydrotreating catalyst. Such a catalyst may comprise for example at least one oxide or sulfide of at least one group VI metal and/or of at least one group VIII metal, such as molybdenum, tungsten, nickel or cobalt, and a support, for example alumina, silica-alumina or a zeolite.

It is advantageous when the regenerated lubricating oil used in the process of the invention can be obtained by subjecting a used lubricating composition to at least one prior step of liquid/liquid extraction with a solvent, which preferably follows a prior dewatering and/or distillation step. In particular, the liquid/liquid extraction with a solvent advantageously makes it possible to lighten a dark-colored used oil and to at least partially eliminate the bad odor or aromatic compounds, in particular polycyclic aromatic hydrocarbons (PAHs). Said extraction step(s) may be carried out by any technique known to those skilled in the art. The

extraction is usually carried out in a mixer-settler or in an extraction column, using a suitable extraction solvent.

It is advantageous when the regenerated lubricating oil used in the process of the invention can be obtained by subjecting a used lubricating composition to at least one prior separation by settling step. Said separation by settling step(s) may be carried out by any technique known to those skilled in the art.

It is understood that the invention is in no way limited to the use of regenerated oils obtained as described above. The process of the invention can thus be used to purify any at least partially rerefined lubricating oil, especially an oil resulting from prior treatment steps different from those described above.

In a particular embodiment, the purification treatment according to the invention is carried out on a fraction ("cut") of an at least partially rerefined and distilled lubricating oil, said distilled lubricating oil coming in particular from a used lubricant that has been subjected to one or more prior steps of treatment by dewatering, filtration, hydrogenation, liquid/liquid extraction, separation by settling and/or passage of the used lubricant through an adsorbent material. In other words, the regenerated lubricating oil used in step (a) of the purification process according to the invention is a fraction of an at least partially rerefined and distilled lubricating oil.

The regenerated lubricating oil used in the process of the invention generally has a kinematic viscosity measured at 100°C according to the standard ASTM D445 of between 2 and 12 mm²/s⁻¹, in particular between 3 and 10 mm²/s⁻¹.

The regenerated lubricating oil used in a purification process according to the invention is in particular characterized by a high silicon content, in particular a content of strictly greater than 2 ppm, in particular greater than or equal to 5 ppm, more particularly greater than or equal to 10 ppm, especially greater than or equal to 15 ppm, for example greater than or equal to 20 ppm, in particular possibly ranging up to 300 ppm, especially up to 290 ppm, for example up to 285 ppm.

The regenerated lubricating oil used in a purification process according to the invention may also be characterized by a high content of one or more elements selected from chlorine, oxygen, and nitrogen. It may for example have a chlorine content of at least 5 ppm, in particular at least 10 ppm, especially greater than or equal to 20 ppm, in particular greater than or equal to 30 ppm.

The chlorine content may be evaluated for example by any method known to those skilled in the art, for example by X-ray fluorescence (XRF).

The regenerated lubricating oil used in a purification process according to the invention may also be characterized by a high content of boron and/or phosphorus. For example, it may have a phosphorus content of at least 10 ppm, in particular at least 15 ppm, especially greater than or equal to 20 ppm. For example, it may have a boron content of at least 10 ppm, or even at least 20 ppm, especially greater than or equal to 30 ppm, or even greater than or equal to 50 ppm.

Purification of the regenerated lubricating oil

As mentioned above, the process for purifying a regenerated lubricating oil according to the invention comprises at least the steps of:

- (a) contacting said regenerated lubricating oil with from 0.1% to 50% by weight of at least one strong base containing an alkali metal or alkaline earth metal cation, preferably in the presence of water, in particular for a period of at least 1 minute at a temperature of not more than 450°C; and
- (b) recovering said purified lubricating oil by separating the strong base containing the alkali metal or alkaline earth metal cation, preferably by liquid/liquid extraction with water.

Step (a): Contacting with a strong base

The contacting of said regenerated lubricating oil with said strong base may consist of adding said strong base to said regenerated lubricating oil, preferably in an autoclave.

Preferably, said regenerated lubricating oil is contacted with said strong base for a period of at least 1 minute, in particular a period ranging from 1 minute to 48 hours, preferably from 5 minutes to 2 hours.

It is advantageous when the contacting is carried out at a temperature of not more than 450°C, in particular not more than 400°C, preferably not more than 350°C.

Thus, the contacting may be carried out at a temperature of between 50°C and 450°C, in particular between 90°C and 350°C, more preferably between 150°C and 350°C, especially between 200°C and 250°C, for example about 225°C.

According to a particular embodiment, the contacting of said regenerated lubricating oil with said strong base is carried out for a period of from 1 minute to 1 hour, in particular from 5 minutes to 40 minutes, and more particularly from 20 minutes to 40 minutes, for example about 30 minutes, in particular at a temperature of not more than 450°C, especially between 200°C and 250°C, for example about 225°C.

It is likewise advantageous when the contacting is carried out at an absolute pressure of from 0.1 to 100 bar, preferably from 1 to 50 bar, in particular from 1 to 10 bar, especially from 1 to 5 bar.

It is advantageous when the regenerated lubricating oil is contacted with 0.1% to 40% by weight, in particular from 0.5% to 30% by weight, especially from 1.0% to 20% by weight, and more particularly from 1.0% to 5.0% by weight, of strong base containing an alkali metal or alkaline earth metal cation.

The content by weight of strong base is understood as meaning the content by weight of strong base relative to the total weight of the mixture comprising the regenerated lubricating oil and the strong base in step (a).

“Strong base” is for the purposes of the present invention understood to mean a compound that is capable of capturing one or more protons and that is completely protonated in the presence of water. Thus, one mole of strong base gives rise to the release of one mole of hydroxide ion. Said strong bases are in particular oxides and hydroxides of alkali metals or alkaline-earth metals.

The strong base used in the process of the invention may be selected for example from lithium hydroxide (LiOH), sodium hydroxide (NaOH), cesium hydroxide (CsOH), barium dihydroxide (Ba(OH)₂), sodium oxide (Na₂O), potassium hydroxide (KOH), potassium oxide (K₂O), calcium oxide (CaO), calcium dihydroxide (Ca(OH)₂), magnesium oxide (MgO), magnesium dihydroxide (Mg(OH)₂), and mixtures thereof.

The strong base is preferably selected from NaOH, KOH, and mixtures thereof and is more preferably NaOH.

The strong base may be contacted with the regenerated lubricating oil in the solid state or in solution, in particular in water or in a polar solvent containing an alcohol function and/or an ether function.

According to a particularly preferred alternative embodiment, the contacting step (a) of the purification process of the invention may be carried out in the presence of water. This alternative is particularly preferred, given its ease of performance and since it does not require the use of a solvent that is costly or difficult to recycle.

The strong base added in step (a) is preferably in solution in water. Thus, during step (a), the regenerated lubricating oil may be contacted with an aqueous solution of a strong base containing an alkali metal or alkaline earth metal cation. Those skilled in the art are capable of choosing an amount of water sufficient to dissolve/solubilize the strong base.

In particular, the ratio by volume of the strong base in solution in water to the regenerated lubricating oil, i.e. the volume ratio (strong base+water)/oil, may range from 0.1/99.9 to 80/20, in particular from 1/99 to 80/20, especially from 1/99 to 70/30, preferably from 1/99 to 65/35, in particular from 1/99 to 60/40, and more particularly from 1/99 to 50/50.

In this alternative, the contacting in step (a) is carried out preferably for a period of from 1 minute to 1 hour, in particular from 5 minutes to 40 minutes, especially from 20 minutes to 40 minutes, for example about 30 minutes. In particular, this contacting step (a) is carried out at a temperature of from 50 to 450°C, preferably from 90 to 350°C, more preferably from 150 to 350°C, for example about 225°C, and at an absolute pressure of from 0.1 to 100 bar, preferably from 1 to 50 bar.

Other alternative embodiments of step (a) of the process of the invention may be envisaged. In particular, according to another alternative embodiment, the contacting of said regenerated oil with said strong base may be carried out in the presence of a polar solvent containing an alcohol function and/or an ether function.

Preferably, the ratio between the volume of polar solvent and the volume of regenerated lubricating oil and of the strong base may range from 1/99 to 95/10, from 1/99 to 90/10, from 2/98 to 90/10, from 2/98 to 85/15, from 2/98 to 80/20, from 2/98 to 75/25, from 2/98 to

70/30, from 2/98 to 65/35, from 2/98 to 60/40, from 2/98 to 55/45, from 2/98 to 50/50, from 2/98 to 45/55, or from 1/99 to 40/60, or within any range defined by any two of the above limits.

The polar solvent may more particularly be selected from (i) C₁ to C₄ alcohols, preferably from methanol, ethanol, propan-1-ol, propan-2-ol, butan-1-ol, butan-2-ol, 2-methylpropan-1-ol, ethylene glycol or propylene glycol, (ii) alcohols containing an ether function, preferably diethylene glycol, triethylene glycol, polyethylene glycol or polypropylene glycol, and (iii) cyclic ethers, preferably tetrahydrofuran, 2-methyltetrahydrofuran, cyclopentyl methyl ether, tetrahydropyran, 1,4-dioxane or eucalyptol; and mixtures thereof. In this alternative, the contacting in step (a) is carried out preferably for a period of from 1 minute to 48 hours, preferably from 5 minutes to 2 hours. In particular, this contacting step (a) is carried out at a temperature of from 50 to 450°C, preferably from 90 to 350°C, more preferably from 150 to 350°C, and at an absolute pressure of from 0.1 to 100 bar, preferably from 1 to 50 bar.

According to yet another alternative embodiment, the contacting of said regenerated oil with said strong base may be carried out in the absence of addition of solvent; in other words, the strong base is then added in solid form and not in solution.

In this alternative, the contacting in step (a) is carried out preferably for a period of from 1 minute to 48 hours, preferably from 5 minutes to 2 hours. In particular, this contacting step (a) is carried out at a temperature of from 50 to 450°C, preferably from 90 to 350°C, more preferably from 150 to 350°C, and at an absolute pressure of from 0.1 to 100 bar, preferably from 1 to 50 bar.

Step (b): Recovery of the purified lubricating oil

As indicated above, in a step (b) of the process for purifying a regenerated lubricating oil according to the invention, the strong base is separated in order to recover said purified lubricating oil.

The separation of the strong base at the end of the contacting in step (a) may be carried out for example by filtration, distillation, extraction with a solvent, for example with water, separation by settling or by a combination of two, three or four of these steps.

The way in which step (b) is carried out is more particularly selected with regard to the conditions selected for carrying out step (a).

Preferably, step (b) is carried out via one or more steps of filtration, distillation, separation by settling and/or liquid/liquid extraction, preferably liquid/liquid extraction, in particular with water.

According to a particularly preferred alternative embodiment, especially when step (a) of contacting the regenerated lubricating oil with the strong base containing an alkali metal or alkaline earth metal cation is carried out in the presence of water, step (b) may as described above be carried out by liquid/liquid extraction with water of the product resulting from step (a).

“Liquid/liquid extraction with water” or more simply “extraction with water” is understood as meaning one or more steps of liquid/liquid extraction with water.

Thus, in a particularly preferred alternative embodiment, the process for purifying an at least partially rerefined lubricating oil according to the invention comprises at least the following steps:

- (a) contacting said at least partially rerefined lubricating oil with from 0.1% to 50% by weight of at least one strong base containing an alkali metal or alkaline earth metal cation in the presence of water, in particular for a period of at least 1 minute at a temperature of not more than 450°C; and
- (b) separating the strong base containing the alkali metal or alkaline earth metal cation from the product obtained at the end of step (a) via one or more steps of liquid/liquid extraction with water.

Water of neutral ($\text{pH} = 0$), basic ($\text{pH} > 7$) or acidic pH ($\text{pH} < 7$) may be used.

In particular, the water used does not contain base and especially does not contain strong base containing an alkali metal or alkaline earth metal cation. An acidic pH can be obtained by adding one or more organic or inorganic acids. Examples of employable organic acids include citric acid ($\text{C}_6\text{H}_8\text{O}_7$), formic acid (CH_2O_2), acetic acid (CH_3COOH), and sulfamic acid (H_3NSO_3). Examples of inorganic acids are hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4), and phosphoric acid (H_3PO_4).

Step (b) is preferably carried out with water of neutral pH.

Step (b) of extraction with water may be carried out at a temperature of from 0° to 80°C, for example from 0° to 60°C, preferably from 0° to 40°C, more preferably from 0° to 30°C, especially without external heating. Step (b) is typically carried out at atmospheric pressure. During step (b), the volume ratio of water to product from step (a) may range from 10/90 to 90/10, from 20/80 to 80/20, from 30/70 to 70/30, from 35/65 to 65/35, from 35/65 to 60/40, from 40/60 to 60/40, or within any range defined by any two of the above limits.

For example, the product from step (a) and the water may be introduced into tanks, reactors or mixers commonly used in the profession and the two components may be mixed. The contacting may comprise vigorous stirring of the two components by a mixing device. For example, the two components may be mixed together by stirring or shaking. Alternatively, the contacting may be carried out in a chamber in which the two components circulate in countercurrent. This contacting may occur more than once, especially under the conditions presented above.

Step (b) of extraction with water may optionally be preceded by one or more prior steps of separating the strong base containing the alkali metal or alkaline earth metal cation in solution in water, for example by filtration, centrifugation, separation by settling or a combination of these steps.

It is advantageous when the strong base in solution in the water that is separated at the end of step (b) can be partly or completely returned (recycled) to step (a).

Other alternative embodiments of step (b) for separating the regenerated and purified oil from the product obtained at the end of step (a) may also be considered.

In particular, when step (a) of contacting the regenerated oil with the strong base is carried out in the absence of addition of solvent (where the base is introduced in the solid state), step (b) of separating the strong base and the purified oil may be carried out by extraction with a polar solvent immiscible with the product obtained at the end of step (a).

“Polar solvent immiscible with the product from step (a)” is for the purposes of the present invention understood to mean a polar solvent forming a heterogeneous mixture with said product. A solvent may be considered immiscible with the product when a value of greater

than or equal to 0.95 is obtained for the ratio of the volume of the polar solvent after extraction to the initial volume of the polar solvent, the volume of polar solvent after extraction corresponding to a phase containing said polar solvent immiscible with the product from step (a) and recovered after stirring and then separation by settling of a mixture of one part by volume of polar solvent and twenty-five parts by volume of said product at atmospheric pressure and a temperature of 20°C.

The polar solvent(s) may be selected from glycol ethers, including in particular polyethylene glycol of chemical formula $\text{HO}-(\text{CH}_2-\text{CH}_2-\text{O})_n-\text{H}$ having a weight-average molar mass of 90 to 800 g/mol, for example diethylene glycol and tetraethylene glycol, polypropylene glycol of chemical formula $\text{H}[\text{OCH}(\text{CH}_3)\text{CH}_2]_n\text{OH}$ having a weight-average molar mass of 130 to 800 g/mol, for example dipropylene glycol and tetrapropylene glycol; dialkyl formamides in which the alkyl group may contain from 1 to 8 or from 1 to 3 carbon atoms, especially N,N-dimethylformamide (DMF); dialkyl sulfoxides in which the alkyl group may contain from 1 to 8 or from 1 to 3 carbon atoms, especially dimethyl sulfoxide (DMSO) and sulfolane; compounds containing a furan ring; cyclic carbonate esters containing especially 3 to 8 or 3 to 4 carbon atoms, especially propylene carbonate and ethylene carbonate; water and mixtures thereof.

Again, the extraction is preferably carried out with water. The water may have an acidic, basic or neutral pH.

The liquid/liquid extraction step removes all or nearly all of the alkali metal or alkaline earth cation content.

In particular, step (b), preferably carried out by one or more steps of extraction with water, affords a purified oil having a content by weight of alkali metal or alkaline earth metal cation of less than or equal to 2 ppm.

Use of regenerated and purified oil

Advantageously, as mentioned above, the regenerated oil obtained at the end of step (b) of the process of the invention has a silicon content that is significantly reduced compared with the regenerated lubricating oil before the treatment according to the invention introduced in step (a).

Advantageously, the content of silicon in the purified lubricating oil resulting from step (b) is strictly less than 10 ppm, in particular less than or equal to 7 ppm, in particular less than or equal to 5 ppm.

It is advantageous when the regenerated oil obtained at the end of step (b) of the process of the invention also has a reduced content of phosphorus and boron.

In particular, the content of phosphorus in the purified lubricating oil resulting from step (b) is strictly less than 5 ppm, in particular less than or equal to 3 ppm, and more particularly less than or equal to 1 ppm.

The content of boron in the purified lubricating oil resulting from step (b) may be advantageously strictly less than 5 ppm, in particular less than or equal to 3 ppm, and more particularly less than or equal to 1 ppm.

It is advantageous when the process for purifying a regenerated lubricating oil according to the invention does not employ any distillation step subsequent to step (b).

In a particular embodiment, no step subsequent to step (b) is required. In other words, the very low silicon content of the lubricating oil recovered at the end of step (b) of the process according to the invention means that the oil is suitable as a base oil for the formulation of lubricants, in particular lubricants for mobile drive systems or industrial systems, in the same way as a virgin base oil, without requiring further purification steps.

It is thus advantageous when the lubricating oil recovered at the end of step (b) has properties substantially comparable to those of virgin oils and in particular meets the quality standards of base oils.

According to a particular embodiment, the purified lubricating oil resulting from the process of the invention may be employed as a base oil for the formulation of a new lubricating composition.

Thus, according to another of its aspects, the invention relates to a process or method for preparing a new lubricating composition comprising at least the steps of: (i) recovering a lubricating oil purified through the treatment of an at least partially rerefined lubricating oil by a process according to the invention as detailed above; (ii) optionally mixing said purified lubricating oil from step (i) with one or more further lubricating oils; and (iii) supplementing said purified lubricating oil resulting from step (i) or the mixture of lubricating oils from step (ii) with at least one additive.

The additive(s) may be of any type suitable for use in a lubricant and selected according to the intended use of the lubricant.

The regenerated and purified base oil may be used on its own or be mixed with one or more further lubricating oils, especially with one or more virgin base oils (that is to say newly refined lubricating oils that have not previously been used in lubricants), with one or more further base oils regenerated and purified by a process according to the invention, or else with one or more regenerated lubricating oils resulting from known rerefining treatments.

The regenerated and purified base oil can be used for the formulation of lubricants for the lubrication of various mechanical systems.

According to one embodiment, the regenerated and purified base oil can be used for the formulation of lubricants for the lubrication of a drive system, in particular a “mobile” drive system, that is to say including light vehicles, heavy-duty vehicles, “off-road” vehicles or marine vehicles.

According to another embodiment, the regenerated and purified base oil can be used for the formulation of lubricants for the lubrication of a so-called industrial system, in particular a “stationary” industrial system, that is to say including in a non-limiting manner turbines, compressors, hydraulics systems, and gears, as well as forming and cutting machines.

In particular, it can be used for lubricating bearings, gears or the various mechanical parts of an engine. In particular, the rerefined and purified base oil according to the invention can be used for the formulation of lubricants for drive systems, such as the transmission or engine in a drive system, especially for heavy or light vehicles or marine engines.

Additives may be introduced individually and/or in the form of a mixture, such as those already sold for commercial lubricant formulations for vehicle engines, having a performance level as defined by the ACEA (European Automobile Manufacturers' Association) and/or the API (American Petroleum Institute), which are well known to those skilled in the art.

These additives may be selected in particular from friction-modifying additives, extreme-pressure additives, anti-wear additives, detergents, antioxidants, viscosity index (VI) improvers, pour point depressants (PPDs), dispersants, antifoaming agents, thickeners, and mixtures thereof.

These additives may be added to a regenerated and purified base oil according to the invention in an appropriate amount determined by a person skilled in the art.

The invention will now be described by means of the examples that follow, which are given by way of illustration and without limitation of the invention.

Example

Methods for measuring elemental contents

The silicon content of the lubricating oils was determined by an analysis method based on X-ray fluorescence (XRF), after filtration of the sample.

The chlorine, boron, and phosphorus contents of the lubricating oils were quantified by an analysis method based on XRF measurement, after filtration of the sample.

The nitrogen content of the lubricating oils was quantified by chemiluminescence.

Lastly, the oxygen content of the lubricating oils was quantified according to the standard ASTM D-5622.

Example 1

The three lubricating oils treated are regenerated (or rerefined) commercially available lubricating oils.

These regenerated oils contain in particular silicon, the removal of which is desirable.

The regenerated lubricating oils were subjected to a purification process according to the invention under the conditions detailed below.

Protocol for regenerated oil 1:

A 1.5 L autoclave made of grade AISI-316L stainless steel and equipped with a mechanical stirrer unit is charged with regenerated lubricating oil 1 (493.2 g), a strong base in the form of NaOH (13.93 g), and water (13.87 g), the strong base being dissolved in water before being introduced into the autoclave.

The autoclave is closed and the headspace is flushed with nitrogen for 30 minutes at 1 bar. Once the nominal temperature has been reached, the autoclave is then heated under autogenous pressure with stirring at a speed of approximately 1500 rpm at a temperature of 225°C for a period of 30 minutes. The pressure at the end of the experiment is 3 bar.

At the end of the reaction, the autoclave is cooled to room temperature, then the contents are discharged and extracted with two 400 mL portions of Millipore water to remove residues of strong base and residual impurities.

Protocol for regenerated oil 2:

The autoclave used for the first experiment is charged with regenerated lubricating oil 2 (497.33 g), a strong base in the form of NaOH (13.73 g), and water (13.71 g), the strong base being dissolved in water before being introduced into the autoclave.

The autoclave is closed and the headspace is flushed with nitrogen for 30 minutes at 1 bar. Once the nominal temperature has been reached, the autoclave is then heated under autogenous pressure with stirring at a speed of approximately 1500 rpm at a temperature of 225°C for a period of 30 minutes. The pressure at the end of the experiment is 5 bar.

At the end of the reaction, the autoclave is cooled to room temperature, then the contents are discharged and extracted with three 400 mL portions of Millipore water.

Protocol for regenerated oil 3:

The autoclave used for the first experiment is charged with regenerated lubricating oil 3 (496.87 g), a strong base in the form of NaOH (13.98 g), and water (13.72 g), the strong base being dissolved in water before being introduced into the autoclave.

The autoclave is closed and the headspace is flushed with nitrogen for 30 minutes at 1 bar. Once the nominal temperature has been reached, the autoclave is then heated under autogenous pressure with stirring at a speed of approximately 1500 rpm at a temperature of 225°C for a period of 30 minutes. The pressure at the end of the experiment is 6 bar.

At the end of the reaction, the autoclave is cooled to room temperature, then the contents are discharged and extracted with three 400 mL portions of Millipore water.

Results

The regenerated lubricating oils are analyzed before purification and after purification and extraction as described above, to measure the silicon, chlorine, oxygen and nitrogen contents according to the measurement protocols described above.

The results are shown in the table below.

[Table 2]

Composition	Silicon content [ppm]	Chlorine content [ppm]	Oxygen content [% by weight]
Regenerated oil 1	32	< 5	< 0.09
Purified oil 1	3	< 5	0.04
Regenerated oil 2	33	< 5	0.02
Purified oil 2	< 2	< 5	0.02
Regenerated oil 3	11	51	0.26
Purified oil 3	< 2	21	0.05

The purification treatment significantly reduced the silicon content in the three regenerated oils. Thus, irrespective of the silicon content of the regenerated oil initially provided, there is an almost total removal of silicon in the three regenerated oils treated according to the invention.

In the case of regenerated oil 3, which had a high chlorine content prior to treatment, the treatment according to the invention also significantly reduced the chlorine content.

Example 2

The regenerated oil 3 used in example 1, and also two other regenerated commercially available lubricating oils, were subjected to a purification process according to the invention under the conditions described in example 1 for regenerated oil 3.

Results

The regenerated lubricating oils are analyzed before purification and after purification as described above, to measure the silicon, phosphorus, and boron contents according to the measurement protocols described above.

The results are shown in the table below.

[Table 3]

Composition	Silicon content [ppm]	Phosphorus content [ppm]	Boron content [ppm]
Regenerated oil 3	11	17	11
Purified oil 3	< 1	< 1	< 1
Regenerated oil 4	12	35	62

Purified oil 4	< 1	< 1	< 1
Regenerated oil 5	12	17	28
Purified oil 5	< 1	< 1	< 1

The purification treatment significantly reduced the silicon, phosphorus and boron contents in the three regenerated oils.

Claims

1. A process for purifying an at least partially rerefined lubricating oil comprising at least the following steps:
 - (a) contacting said at least partially rerefined lubricating oil with from 0.1% to 50% by weight of at least one strong base containing an alkali metal or alkaline earth metal cation; and
 - (b) recovering said purified lubricating oil by separating the strong base containing the alkali metal or alkaline earth metal cation from the product obtained at the end of step (a).
2. The process as claimed in claim 1, said process comprising no step subsequent to step (b) of distilling said lubricating oil recovered at the end of step (b).
3. The process as claimed in claim 1 or 2, wherein said at least partially rerefined lubricating oil used in step (a) comes from a used lubricating composition that has been subjected to one or more pretreatment steps selected from steps of dewatering, distillation, filtration, hydrogenation, liquid/liquid extraction, separation by settling and/or passage of the used lubricant through an adsorbent material, in particular through activated carbon.
4. The process as claimed in any one of the preceding claims, wherein said at least partially rerefined lubricating oil used in step (a) has a silicon content of strictly greater than 2 ppm, preferably greater than or equal to 5 ppm, in particular greater than or equal to 10 ppm, more particularly greater than or equal to 15 ppm, for example greater than or equal to 20 ppm, or even greater than or equal to 30 ppm.
5. The process as claimed in any one of the preceding claims, wherein the contacting of said at least partially rerefined lubricating oil with said strong base in step (a) is carried out for a period of at least 1 minute, in particular a period ranging from 1 minute to 48 hours, in particular from 5 minutes to 2 hours, preferably for a period of from 20 minutes to 40 minutes, for example about 30 minutes.
6. The process as claimed in any one of the preceding claims, wherein the contacting of said at least partially rerefined lubricating oil with said strong base in step (a) is carried out at a temperature of not more than 450°C, in particular not more than 400°C, more particularly not more than 350°C, for example ranging from 50°C to 450°C, in particular between 90°C and 350°C, more preferably between 150°C and 350°C, especially between 200°C and 250°C, for example about 225°C, in particular at a pressure ranging from 0.1 to 100 bar, preferably from 1 to 50 bar, in particular from 1 to 10 bar, especially from 1 to 5 bar.

7. The process as claimed in any one of the preceding claims, wherein the at least partially rerefined lubricating oil is contacted in step (a) with 0.1% to 40% by weight, preferably 0.5% to 30% by weight, in particular 1.0% to 20% by weight, more particularly 1.0% to 5.0% by weight, of strong base containing an alkali metal or alkaline earth metal cation.
8. The process as claimed in any one of the preceding claims, wherein said strong base containing an alkali metal or alkaline earth metal cation is selected from lithium hydroxide, sodium hydroxide, cesium hydroxide, barium dihydroxide, sodium oxide, potassium hydroxide, potassium oxide, calcium oxide, calcium dihydroxide, magnesium oxide, magnesium dihydroxide, and mixtures thereof, preferably sodium hydroxide.
9. The process as claimed in any one of the preceding claims, wherein said regenerated lubricating oil is contacted in step (a) with said strong base in the presence of water.
10. The process as claimed in any one of the preceding claims, wherein step (b) is carried out via one or more steps of filtration, distillation, separation by settling and/or liquid/liquid extraction, preferably liquid/liquid extraction, in particular with water.
11. The use of a purification process as defined in any one of claims 1 to 10 for reducing the silicon content of an at least partially rerefined lubricating oil.
12. The use as claimed in the preceding claim, for reducing the amount of silicon to a content of strictly less than 10 ppm, in particular less than or equal to 7 ppm, more particularly less than or equal to 5 ppm.
13. A process for preparing a lubricating composition comprising at least the steps of:
 - (i) purifying an at least partially rerefined lubricating oil by a purification process as defined in any one of claims 1 to 10;
 - (ii) optionally mixing said purified lubricating oil from step (i) with one or more further lubricating oils selected in particular from virgin base oils, lubricating oils regenerated and purified by a purification process as defined in any one of claims 1 to 10; and at least partially rerefined lubricating oils; and
 - (iii) supplementing said purified lubricating oil resulting from step (i) or the mixture of lubricating oils from step (ii) with at least one additive, preferably selected from friction-modifying additives, extreme pressure additives, anti-wear additives, detergents, antioxidants, viscosity index (VI) improvers, pour point depressants (PPDs), dispersants, antifoaming agents, thickeners, and mixtures thereof.