Method of preparing a lubricant composition

A method of preparing a lubricant composition comprising at least one base oil component, at least one first additive component and at least one second additive component which method comprises:

- introducing into an elongate mixing vessel comprising at least one static mixer, at least one base oil component, at least one first additive component and at least one second additive component; the at least one first additive component being introduced into the mixing vessel separately from the at least one second additive component;
- mixing the at least one second additive component with a mixture of the at least one first additive component and the at least one base oil component in the elongate mixing vessel using the at least one static mixer.
This invention relates to a method of preparing a lubricant composition and in particular to a method of preparing a lubricant composition comprising a mixture of at least one base oil component, at least one first additive component and at least one second additive component.

Lubricant compositions comprising at least one base oil component and one or more additive components are usually prepared in batch processes. Batch processes for the preparation of lubricant compositions usually involve introducing at least one base oil component and one or more additive components into a vessel and mixing the components using an agitator, paddle stirrer or the like. Batch processes usually require the use of large inventories of components in the vessel to achieve commercially acceptable production rates. This may present problems associated with the energy consumption required for mixing with stirrers, paddles or the like. Large inventories of components may also present safety issues and/or cost implications. Large inventories of components may require large feed lines from component storage to a mixing vessel. Large feed lines may require flushing between production batches and this may contribute to potential waste. Also, large feed lines may require heating.

It is desirable that a prepared lubricant composition is clear and bright and does not contain solids, gels or the like. It has been found that when preparing a lubricant composition comprising a mixture of at least one base oil component, at least one first additive and at least one second additive, incompatibility of some or all of the additive components may result in the undesirable formation in the composition of solids, gels or the like. Therefore, in batch processes, the sequence of introducing the components into a mixing/reaction vessel and/or the duration of mixing between introductions of components is usually controlled to provide adequate mixing of the components and in particular to reduce or mitigate the risk of solids, gels or the like forming during the preparation of the lubricant composition. This may require extended periods of mixing.

Static mixers (sometimes called static mixing devices or motionless mixing devices) are known. For example, according to trade brochure http://www.chemineer.com/images/pdf/bulletin_800.pdf dated 2011, Kenics® Static Mixers available from Chemineer Inc. Ohio, USA include helical mixing elements which direct the flow of material radially towards the pipe walls and back to the centre.

According to the brochure, typical applications in petrochemical and refining are blending gaseous reactants, washing hydrocarbon streams, gas scrubbing, lube oil blending and crude oil sampling.

US patent US3953002 relates to mixing devices for intermixing of a plurality of fluids, and more specifically to motionless type mixing devices which do not employ moving parts. US3953002 relates to a mixing device for intermixing a plurality of fluids which comprises a housing having a cylindrical bore through which the fluids may flow and a diffuser link supported centrally within the housing bore. The mixing device is said to further comprise a right-hand helical baffle secured to one end of the diffusal link and a left-hand helical baffle secured to the other end of the diffusal link.

In US3953002, one embodiment is said to include a means for introducing trace additives into the device. The trace introductory means is said to include a tubular element which transverses the tubular housing of the device and is plugged at one end by a cap. In Figure 5 thereof only a single tubular element is shown. The tube is said to comprise two or more substantially parallel slots located about opposite sides of the axis of the tubular housing and the helical baffle. It is stated that with this configuration trace additives may be introduced into the housing. The fluids are said to enter through the slots and are caused to swirl in opposite directions and change directions of flow as they encounter the adjacent baffle, which is said to result in excellent intermixing.

There remains a need for a method of preparing a lubricant composition which overcomes, or at least mitigates at least some of these problems.

Thus, according to the present invention there is provided a method of preparing a lubricant composition comprising at least one base oil component, at least one first additive component and at least one second additive component which method comprises:

- introducing into an elongate mixing vessel comprising at least one static mixer, at least one base oil component, at least one first additive component and at least one second additive component; the at least one first additive component being introduced into the mixing vessel separately from the at least one second additive component; and
- mixing the at least one second additive component with a mixture of the at least one first additive component and the at least one base oil component in the elongate mixing vessel using the at least one static mixer.

The present invention reduces or at least mitigates at least some of the technical problems identified above by providing a method of preparing a lubricant composition by introducing at least one first additive component and at least one second additive component separately from each other into a mixing vessel which is an elongate mixing vessel comprising at least one static mixer. The first and second additive components are not introduced into the mixing vessel together.

The at least one second additive component is mixed in the elongate mixing vessel with a mixture of the at least one base oil component in the elongate mixing vessel using the at least one static mixer.
least one first additive component and the at least one base oil component using the at least one static mixer. This reduces or mitigates the risk of solid, gels or the like forming in the lubricant composition, for example due to incompatibility between the first and second additive components, especially for example, when the first additive component(s) and the second additive component(s) are mixed together at high relative amounts and/or concentrations, and/or even in neat, undiluted form.

[0012] Furthermore, the use of an elongate mixing vessel comprising at least one static mixer facilitates the use of smaller inventories of components which may reduce the energy costs of the mixing process and/or reduce the costs of component inventories compared to a batch process using for example, a mixing vessel comprising stirrer, paddle or the like.

[0013] The method may permit the use of mixing vessels which are smaller than mixing vessels used in conventional batch mixing processes and this may provide an opportunity to use mixing vessels each dedicated to the production of one or a few lubricant compositions. This may reduce or obviate the need for feed line and/or mixing vessel flushing, which may reduce potential waste when preparing several different lubricant compositions.

[0014] The method may permit the use of feed lines with small inventories and this may (i) reduce potential waste from flushing between production batches and/or (ii) reduce the cost of heating the feed lines.

[0015] The use of static mixers in the mixing vessel may reduce or obviate any requirement to heat the mixing vessel.

[0016] The extent of mixing of the at least one second additive component and the mixture of at least one base oil component and the at least one first additive component may be controlled by adjusting the flow rate of components through the mixing vessel and/or the configuration and/or type of static mixers in the mixing vessel.

[0017] In a first aspect, the at least one base oil component and the at least one first additive component are introduced as a mixture of the at least one base oil component and the at least one first additive component. This mixture is introduced into the mixing vessel through the at least one first inlet.

[0018] Thus according to at least some embodiments, the mixing vessel is an elongate mixing vessel comprising at least one first static mixer, at least one first inlet which is upstream of the at least one first static mixer, at least one second inlet which is upstream of the at least one first static mixer and at least one outlet which is downstream of the at least one static mixer and the method comprises the steps of:

a) introducing a mixture of the at least one base oil component and the at least one first additive component into the mixing vessel through the at least one first inlet;

b) introducing the at least one second additive component into the mixing vessel through the at least one second inlet upstream of the at least one first static mixer;

c) flowing the at least one second additive component and the mixture of step a, through the mixing vessel and past the at least one first static mixer to mix the at least one second additive component with the mixture of step a to produce a mixture of the at least one base oil component, the at least one first additive component and the at least one second additive component; and

d) removing the mixture produced in step c from the mixing vessel through the at least one outlet downstream of the first static mixer.

[0019] The mixture of the at least one base oil component and the at least one first additive component may be prepared by mixing the components in a mixing vessel before being introduced as a mixture into the elongate mixing vessel through the at least one first inlet. The mixture of the at least one base oil component and the at least one first additive component may be prepared by circulating the at least one base oil component through a mixing vessel, introducing into said mixing vessel the at least one first additive component and mixing the components in said mixing vessel with or without the use of at least one static mixer.

[0020] In a second aspect, the at least one base oil component and the first additive component are mixed together in the elongate mixing vessel before the resulting mixture is mixed with the at least one second additive.

[0021] Thus, according to at least some embodiments, the mixing vessel is an elongate mixing vessel comprising at least one first static mixer, at least one first inlet which is upstream of the at least one first static mixer, at least one second inlet which is upstream of the at least one first static mixer, at least one third inlet which is upstream of the at least one first static mixer and is upstream of the at least one second inlet and at least one outlet which is downstream of the at least one static mixer;

and in which the method comprises the steps of:

a') introducing the at least one base oil component into the mixing vessel through the at least one first inlet, introducing the at least one first additive component into the mixing vessel through the at least one third inlet and mixing together the at least one base oil component and the at least one first additive component in the mixing vessel to produce a mixture of the at least one base oil component and the at least one first additive component;

b') introducing the at least one second additive component into the mixing vessel through the at least one second inlet.
According to at least some embodiments the at least one first inlet is upstream of the at least one third inlet. Additionally or alternatively, a combination of at least one fourth inlet and at least one first static mixer. Additionally or alternatively, a combination of at least one fourth inlet and at least one second static mixer. This combination of at least one fourth inlet and at least one second static mixer may be located downstream of the at least one first static mixer.

In at least some embodiments, the at least one outlet is located at one end of the elongate mixing vessel distal from the end of the elongate mixing vessel comprising the at least one first inlet. The mixing vessel may comprise more than one first inlet. In at least some embodiments, when introduced into the mixing vessel separately from the at least one base oil component, the at least one first additive component is introduced into the mixing vessel through the at least one first inlet in a direction which has a component perpendicular to the direction of the longitudinal axis of the elongate mixing vessel. In at least some embodiments, when introduced into the mixing vessel separately from the at least one base oil component, the at least one first additive component is introduced into the mixing vessel through the at least one first inlet in a direction which has a component perpendicular to the direction of the longitudinal axis of the elongate mixing vessel.
natively, a combination of at least one fourth inlet and at least one third static mixer downstream thereof may be located
5 downstream of the at least one second static mixer and upstream of the second inlet. In the method of the present
invention at least one additive component may be introduced into the mixing vessel through the at least one fourth inlet
and passed by the at least one third static mixer thereby to be mixed with the components and/or mixtures flowing
through the mixing vessel.

[0035] In at least some embodiments, the at least one additive component is introduced into the mixing vessel through the
at least one third inlet in a direction which has a component which is perpendicular to the longitudinal axis of the
elongate mixing vessel, for example in a direction which is perpendicular to the longitudinal axis of the elongate mixing
5 vessel. By introducing the additive components into the mixing vessel in a direction which has a component which is
perpendicular to, the direction of the longitudinal axis of the vessel, the additive components, which may have a viscosity
greater than that of the components and/or mixture flowing through the mixing vessel, may be efficiently mixed therewith.

[0036] According to at least some embodiments, mixing of additive components which are introduced into the elongate
mixing chamber with components and/or mixture flowing through the elongate mixing chamber may be facilitated by
using at least one narrow bore inlet. This may provide a velocity of the additive components which is greater than that
which is achieved using a broader bore inlet, which may enhance or facilitate mixing. However, using a narrow bore
inlet may increase the energy requirement and hence cost of pumping the additive component(s) into the elongate mixing
chamber. Additionally or alternatively, increasing longitudinal distance along the elongate mixing chamber between two
or more static mixers may enhance or facilitate mixing of components.

[0037] In at least some embodiments the at least third additive component is mixed in the mixing vessel with the at
least one base oil component, the at least one first additive components and the at least one second additive component
in the mixing vessel by flowing the components through the mixing vessel and past the at least one third static mixer at
a temperature which is different to the temperature at which the components are flowed past the at least one first static
mixer which is different to the temperature the components are flowed past the at least one second static mixer, if present.
This may be beneficial in at least some embodiments for example, when the at least one third additive which is introduced
into the mixing vessel through the at least one fourth inlet comprises at least one zinc dihydrocarbyl dithiophosphate
(ZDDP). Generally, ZDDP’s should be used in processes for the preparation of lubricant compositions at temperatures
less than 60°C. At temperatures of 60°C or above ZDDP’s may decompose to produce hydrogen sulphide. Thus, in at
least some embodiments when the at least one third additive which is introduced into the mixing vessel through the at
least one fourth inlet comprises at least one zinc dihydrocarbyl dithiophosphate the at least third additive component is
mixed in the mixing vessel with the at least one base oil component, the at least one first additive components and the
at least one second additive component in the mixing vessel by flowing the components through the mixing vessel and
past the at least one third static mixer at a temperature which is less than 60°C, for example less than 55°C or less than
50°C. The temperature may be in the range of 20 to 55°C, for example in the range of 25 to 35 °C.

[0038] Additive components other than ZDDP’s may be used in processes for the preparation of lubricant compositions
at temperatures up to 300°C for example, up to 200°C. Additive components other than ZDDP’s may be used in processes
for the preparation of lubricant compositions at temperatures in the range of ambient temperature to 300°C, for example
in the range of ambient temperature to 200°C. Ambient temperature may be about 10 to 40 °C, for example about 20
to 30 °C.

[0039] The components other than ZDDP’s may be flowed through the elongate mixing vessel at temperatures up to
300°C for example, up to 200°C. Additive components other than ZDDP’s may be flowed through the elongate mixing
vessel at temperatures in the range of ambient temperature to 300°C, for example in the range of ambient temperature
to 200°C. Ambient temperature may be about 10 to 40 °C, for example about 20 to 30 °C.

[0040] Thus, in at least some embodiments zinc dihydrocarbyl thiophosphates (ZDDP’s) is mixed with the components
of the lubricant composition at a temperature which is lower than the temperature at which other components (for example
dispersants and/or metal-containing detergents) are mixed with the components of the lubricant composition.

[0041] Thus, according to at least some embodiments the elongate mixing vessel comprises at least one fourth inlet
downstream of the at least one first static mixer and at least one third static mixer which is downstream of the at least
one first static mixer and which is downstream of the at least one fourth inlet, and the method further comprises introducing
at least one third additive component which comprises at least one zinc dihydrocarbyl dithiophosphate, into the mixing
evessel through the at least one fourth inlet; and mixing the at least one third additive component in the mixing vessel
with the at least one base oil component, the at least one first additive component and the at least one second additive
component in the mixing vessel by flowing them through the mixing vessel and past the at least one third static mixer
at a temperature which is different to the temperature at which the components are flowed past the at least one first
static mixer and which is different to the temperature at which the components are flowed past the at least one second
static mixer, if present, to produce a mixture of the at least one base oil component and the at least one first additive
component, the at least one second additive component and the at least one third additive component.

[0042] The mixing vessel may comprise more than one first static mixer. The mixing vessel may comprise more than
one second static mixer. The mixing vessel may comprise more than one third static mixer.
[0043] The mixing vessel may comprise at least one additional static mixer. This at least one additional static mixer may be located upstream of the at least one second inlet. In use in the method of the present invention this further static mixer introduces turbulent flow into the mixture of at least one base oil component and at least one first additive component prior to mixing with the at least one second additive in the first static mixer. This at least one additional static mixer may be located downstream of the at least one first inlet and upstream of the at least one third inlet. In use in the method of the present invention this further static mixer introduces turbulent flow into the at least one base oil component prior to mixing with the at least one additive in the at least one second static mixer.

[0044] The elongate mixing vessel may be cylindrical. The elongate mixing vessel may have a circular transverse cross-section. The elongate mixing vessel may be cylindrical with a circular transverse cross-section. The elongate mixing vessel may have a uniform transverse cross-section. The elongate mixing vessel may be cylindrical with a uniform, circular transverse cross-section.

[0045] In at least some embodiments the elongate mixing vessel has a circular transverse cross-section which has a diameter of at least 1mm, for example at least 5mm or at least 10mm. In at least some embodiments the elongate mixing vessel has a circular transverse cross-section which has a diameter of up to 100 mm. In at least some embodiments the elongate mixing vessel has a circular transverse cross-section which has a diameter of 1mm to 100mm, for example 10 mm to 100mm.

[0046] The elongate mixing vessel may have a transverse cross-section which is other than circular, for example an oval transverse cross section.

[0047] The elongate mixing vessel may have a non-uniform cross-section. The non-uniform cross-section may vary continuously along the axis of the elongate mixing vessel. The non-uniform cross-section may vary discontinuously along the axis of the elongate mixing vessel.

[0048] In at least some embodiments, the elongate mixing vessel is cylindrical with a uniform, circular transverse cross-section.

[0049] In at least some embodiments, the elongate mixing vessel has a length of at least 10mm, for example at least 100mm. In at least some embodiments, the elongate mixing vessel has a length of up to 5000mm, for example up to 1000mm. In at least some embodiments, the elongate mixing vessel has a length of 10mm to 5000mm, for example 100mm to 1000mm, typically 300mm.

[0050] In at least some embodiments, the elongate mixing vessel is cylindrical with a length of 10mm to 5000mm, for example 100mm to 1000mm and having a uniform, circular transverse cross-section with a diameter of 1mm to 100mm, for example 10mm to 100mm.

[0051] In at least some embodiments more than one elongate mixing vessel is used. When more than one elongate mixing vessel is used, the elongate mixing vessels may be used in parallel and/or in series.

[0052] In at least some embodiments the components are recirculated through the elongate mixing vessel.

[0053] The static mixers may each independently comprise a discontinuous, non-uniform cross-section of the elongate mixing vessel. A discontinuous, non-uniform cross-section may provide at least one shearing boundary to induce turbulent flow of mixtures and/or components flowing through the mixing vessel to thereby mix them.

[0054] The static mixers may each independently comprise a plate having at least one orifice and/or slot and being located transverse to the longitudinal axis of the elongate mixing vessel. The at least one orifice provides at least one shearing boundary surface to induce turbulent flow of components and/or mixtures flowing through the mixing vessel to thereby mix them.

[0055] The static mixers may each independently comprise a plate having at least one orifice and/or slot and being located transverse to the longitudinal axis of the elongate mixing vessel. The at least one orifice provides at least one shearing boundary surface to induce turbulent flow of components and/or mixtures flowing through the mixing vessel to thereby mix them.

[0056] The static mixers may each independently comprise one or more baffles. Suitable baffles include motionless mixing devices for example as described in US3953002 in particular a motionless mixing device comprising a diffusion link supported centrally within a housing bore, and further comprising a right-hand helical baffle secured to one end of the diffusal link and a left-hand helical baffle secured to the other end of the diffusal link. Suitable motionless mixing devices include Kenics® Static Mixers which are available from Chemineer Inc, Ohio USA. Suitable static mixers may comprise helical static mixers.

[0057] The method may further comprise rotating the elongate mixing vessel about its longitudinal axis. This may be beneficial in aiding mixing of components which have largely differing densities, which may facilitate higher throughputs.

[0058] In at least some embodiments, the method is performed at a pressure in the range of atmospheric to 10 barg. The operating temperature may be determined by the operating pressure of the mixing vessel.

[0059] In at least some embodiments the pressure drop between the inlets and outlets of the elongate mixing vessel is up to 5 bar, for example in the range of 1 to 3 bar.

[0060] In at least some embodiments the total flow rate of the components through one or more mixing vessels is up
to 1000 litres per minute.

[0061] In at least some embodiments the total flow rate of the components through the mixing vessel is at least 10 litres per minute, for example at least 20 litres per minute, at least 50 litres per minute or at least 100 litres per minute.

[0062] In at least some embodiments the total flow rate of the components through the mixing vessel is in the range of 1 litre per minute to 150 litres per minute. In at least some embodiments the total flow rate of the components through the mixing vessel is in the range of 3 litres per minute to 40 litres per minute.

[0063] A conventional large batch method for preparing a lubricant composition might use a 26000 litre mixing vessel and a mixing time of 6 hours, which corresponds to only 72 litres per minute. The elongate mixing vessel on the other hand, may have a volume of less than about 1 litre, for example about 500 ml. Thus, the use of an elongate mixing vessel comprising at least one static mixer facilitates the use of smaller inventories of components which may reduce the energy costs of the mixing process and/or reduce the costs of component inventories compared to a batch process using for example, a mixing vessel comprising stirrer, paddle or the like.

[0064] In at least some embodiments the total residence time of all the components in the elongate mixing vessel is less than about 1 minute, for example about 2 to 10 seconds. The flow rate and residence time will depend upon the time required to mix the components to the desired amount.

[0065] Usually the flow rate of components through the elongate mixing vessel is a uniform flow rate, but other flow patterns may be used.

[0066] The ratio of cross section to length of the elongate mixing vessel is such that it may facilitate heat exchange to/from the components, for example to heat or cool the components and/or mixtures thereof.

[0067] More than one mixing vessel may be used in the method of the present invention. The multiple mixing vessels may be used in parallel or in sequence or in a combination arrangement of both parallel and sequential mixing vessels.

[0068] The relatively small size of the elongate mixing vessel compared to conventional batch stirred mixing vessels means that several such elongate mixing vessels may be used in a manufacturing site in an area equivalent to a large conventional stirred mixing vessel. This may have an advantage of facilitating the use of dedicated mixing vessels to preparation of particular lubricant compositions or classes of lubricant compositions, thereby reducing equipment turn-around times and costs of cleaning and the like.

[0069] Suitable base oil components may be base stocks defined as Group I, II, III, IV and V base stocks according to API standard 1509, "ENGINE OIL LICENSING AND CERTIFICATION SYSTEM", April 2007 version 16th edition Appendix E.

[0070] Group I, Group II and Group III base stocks may be derived from mineral oils. Group I base stocks are typically manufactured by known processes comprising solvent extraction and solvent dewaxing, or solvent extraction and catalytic dewaxing. Group II and Group III base stocks are typically manufactured by known processes comprising catalytic hydrogenation and/or catalytic hydrocracking, and catalytic hydrosomeration. Suitable Group I and Group II base stocks are available from Indian Oil Corporation Limited (IOCL), Hindustan Petroleum Corp. Ltd. (HPCL) or Exxon. Suitable Group III base stocks include Yubase 4 and Yubase 6 available for example, from SK Lubricant. Suitable Group V base stocks include for example ester base stocks. Suitable Group IV base stocks include hydrogenated oligomers of alpha olefins. The oligomers may be made by free radical processes, Zeigler catalysis or by cationic Friedel-Crafts catalysis. Polyalpha olefin base stocks may be derived from C8, C10, C12, C14 olefins and mixtures of one or more thereof.

[0071] Suitable base oil components include natural oils, mineral oils (sometimes called petroleum-derived oils or petroleum-derived mineral oils), non-mineral oils and mixtures thereof. Natural oils include animal oils, fish oils, and vegetable oils. Mineral oils include paraffinic oils, naphthenic oils and paraffinic-naphthenic oils. Mineral oils may also include oils derived from coal or shale.

[0072] Suitable base oil components may be derived from processes such as chemical combination of simpler or smaller molecules into larger or more complex molecules (for example polymerisation, oligomerisation, condensation, alkylation, acylation).

[0073] Suitable base oil components may be derived from gas-to-liquids materials, coal-to-liquids materials, biomass-to-liquids materials and combinations thereof.

[0074] Gas-to-liquids materials (sometimes also referred to as GTL materials) may be obtained by one or more process steps of synthesis, combination, transformation, rearrangement, degradation and combinations of two or more thereof applied to gaseous carbon-containing compounds. GTL derived base oil components may be obtained from the Fischer-Tropsch synthesis process in which synthesis gas comprising a mixture of hydrogen and carbon monoxide is catalytically converted to hydrocarbons, usually waxy hydrocarbons that are generally converted to lower-boiling materials hydrosomeration and/or dewaxing (see for example, WO 2008/124191).

[0075] Biomass-to-liquids materials (sometimes also referred to as BTL materials) may be manufactured from compounds of plant origin for example by hydrogenation of carboxylic acids or triglycerides to produce linear paraffins, followed by hydrosomeration to produced branched paraffins (see for example, WO-2007-068799-A).

[0076] Coal-to-liquids materials may be made by gasifying coal to make synthesis gas which is then converted to hydrocarbons.
The at least one base oil component may have a kinematic viscosity at 100 °C in the range of 2 to 100 cSt, for example in the range of 3 to 50 cSt or in the range 3.5 to 25 cSt. Pour point depressants and dispersant viscosity modifiers. It has been found that in some cases when a dispersant viscosity modifier comes into contact with a pour point depressant, a highly viscous mixture may be formed. This may block inlets to a mixing vessel used to prepare a lubricant composition. In some cases, gelation may occur and this may result in an unacceptable increase in viscosity. The method of the present invention overcomes, or at least mitigates this problem. Thus, in at least some embodiments the at least one first additive comprises at least one dispersant viscosity modifier and the at least one second additive comprises at least one pour point depressant.

Alternatively, the at least one first additive comprises at least one pour point depressant and the at least one second additive comprises at least one dispersant viscosity modifier.

Pour point depressants (also called pour point depressant additives, lube oil improvers or lube oil flow improvers), lower the minimum temperature at which a lubricant composition will flow and can be poured. Examples of suitable pour point depressants include C_8 to C_{18} dialkyl fumarate/vinyl acetate copolymers, methacrylates, polyacrylates, polyarylates, polymethacrylates, polyalkyl methacrylates, vinyl fumarates, styrene esters, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, terpolymers of dialkyfumarates, vinyl esters of fatty acids and allyl vinyl ethers, wax naphthalene and the like.

More than one pour point depressant may be used.

Dispersant viscosity modifiers (also called dispersant viscosity modifier additives) may provide both viscosity index improving properties and dispersancy to a lubricant composition. Such compounds are also known as dispersant viscosity improver additives or multifunctional viscosity improvers. Examples of suitable dispersant viscosity modifiers may be prepared by chemically attaching functional moieties (for example amines, alcohols and amides) to polymers which tend to have number average molecular weights of at least 15000, for example in the range 20000 to 600000 (for example as determined by gel permeation chromatography or light scattering methods). Examples of suitable dispersant viscosity modifiers and methods of making them are described in WO 99/21902, WO2003/099890, WO2006/099250, WO2006/11663 and WO2011/062914. More than one dispersant viscosity modifier may be used.

The dispersant viscosity modifier may have a Kg of about 1000 cSt.

The dispersant viscosity modifier may be HiTec5777 (Trade Mark). This is available from Afton.

Dispersants and metal-containing detergents

It has been found that dispersant additives, for example those with low base number dispersants, may be difficult to mix with metal-containing detergent additives when preparing lubricant compositions. This may be due to difficulty in forming the appropriate sized micelles of detergent in the composition. Thus, in at least some embodiments the at least one first additive component comprises at least one dispersant and the at least one second additive component comprises at least one metal-containing detergent, or alternatively, the at least one first additive component comprises at least one metal-containing detergent and the at least one second additive component comprises at least one dispersant.

Dispersants (also called dispersant additives) help hold solid and liquid contaminants for example resulting from oxidation of the lubricant composition during use, in suspension and thus reduce sludge flocculation, precipitation and/or deposition for example on lubricated surfaces. They generally comprise long-chain hydrocarbons, to promote oil-solubility, and a polar head capable of associating with material to be dispersed. Examples of suitable dispersant additive components include oil soluble polymeric hydrocarbonyl backbones each having one or more functional groups which are capable of associating with particles to be dispersed. The functional groups may be amine, alcohol, amine-alcohol, amine or ester groups. The functional groups may be attached to the hydrocarbonyl backbone through bridging groups. More than one dispersant may be used.

Examples of suitable ashless dispersants include oil soluble salts, esters, amino-esters, amides, imides and oxazolines of long chain hydrocarbon-substituted mono- and polycarboxylic acids or anhydrides thereof; thiocarboxylate derivatives of long chain hydrocarbons; long chain aliphatic hydrocarbons having polyamine moieties attached directly thereto; Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine; Koch reaction products and the like. Examples of suitable dispersant additive components include derivatives of long chain hydrocarbonyl-substituted carbonylic acids, for example in which the hydrocarbonyl group has a number average molecular weight of up to 20000, for example 300 to 20000, 500 to 10000, 700 to 5000 or less than 15000. Examples of suitable dispersant additive components include hydrocarbonyl-substituted succinic acid compounds, for example succinimide, succinate esters or succinate ester amides and in particular, polyisobutenyl succinimide dispersants. The dispersants may be borated or non-borated. Dispersant additive components may be provided in DI (detergent inhibitor) additive packs. DI packs typically comprise detergent(s), dispersant(s), antiwear additive(s), antioxidant(s) and surfactant(s). Suitable DI packs include for example, Lubrizol 890, Lubrizol 6406 and Infineum C9268 (trade marks).

Additionally or alternatively, dispersancy may be provided by polymeric compounds capable of providing vis-
cosity index improving properties and dispersancy. Such compounds are generally known as dispersant viscosity improver additives or multifunctional viscosity improvers. Examples of suitable dispersant viscosity modifiers are described herein.

More than one dispersant may be used.

The at least one additive component comprising at least one dispersant may have a viscosity of about 1000 cSt or more. The at least one additive component comprising at least one dispersant may have a Kv100 of less than 1000cSt, for example of about 500cSt.

Detergents (also called detergent additives) may help reduce high temperature deposit formation for example on pistons in internal combustion engines, including for example high-temperature varnish and lacquer deposits, by helping to keep finely divided solids in suspension in the lubricating composition. Detergents may also have acid-neutralising properties. Metal-containing detergent comprises at least one metal salt of at least one organic acid, which is called soap or surfactant. Detergents may be overbased in which the detergent comprises an excess of metal in relation to the stoichiometric amount required to neutralise the organic acid. The excess metal is usually in the form of a colloidal dispersion of metal carbonate and/or hydroxide. Examples of suitable metals include Group I and Group 2 metals, more suitably calcium, magnesium and combinations thereof, especially calcium. More than one metal may be present.

Examples of suitable organic acids include sulphonic acids, phenols (sulphurised or preferably sulphurised and including for example, phenols with more than one hydroxyl group, phenols with fused aromatic rings, phenols which have been modified for example alkylene bridged phenols, and Mannich base-condensed phenols and saligenin-type phenols, produced for example by reaction of phenol and an aldehyde under basic conditions) and sulphurised derivatives thereof, and carboxylic acids including for example, aromatic carboxylic acids (for example hydrocarbyl-substituted salicylic acids and sulphurised derivatives thereof, for example hydrocarbyl substituted salicylic acid and derivatives thereof). More than one type of organic acid may be present.

Examples of suitable metal-containing detergents include 400 BN calcium sulphonate (e.g. Lubrizol 6464, trade mark), 300 BN calcium sulphate (e.g. Lubrizol 6446C, trade mark), 250 BN calcium phenate (e.g. Lubrizol 6499, trade mark), 400 TBN magnesium sulphate (e.g. Lubrizol 6465A, trade mark), 400 BN magnesium sulphate (e.g. Infineum C9340, trade mark), 300 TBN calcium sulphate (e.g. Infineum C9330, trade mark), 300 BN calcium sulphate (e.g. HiTec 611, trade mark) and 400 BN magnesium sulphate (e.g. HiTec 7637, trade mark).

Additionally, non-metallic detergents may be used to prepare the lubricant composition. Suitable non-metallic detergents are described for example in US7622431.

More than one detergent may be used.

The at least one additive component comprising at least one metal-containing detergent may have a viscosity of about 1000 cSt or more. The at least one additive component comprising at least one metal-containing detergent may have a Kv100 of less than 1000cSt, for example of about 500cSt.

In at least some embodiments, the at least one base oil and the at least one first component and the at least one second additive component are mixed in the absence of any zinc dihydrocarbyl dithiophosphate when the at least one first additive component comprises at least one dispersant and the at least one second additive component comprises at least one metal-containing detergent or when the at least one first additive component comprises at least one metal-containing detergent and the at least one second additive component comprises at least one dispersant. In this aspect, mixing of the at least one first additive component and the at least one second additive component in the absence of any zinc dialkyl thiophosphate is performed at a temperature different (for example higher) than the temperature at which any zinc dialkyl thiophosphate is subsequently mixed with the components. The at least one dispersant and the at least one metal-containing detergent may be mixed at a temperature in the range of ambient temperature to 300 °C, for example in the range of ambient temperature to 200 °C. Ambient temperature may be about 10 to 40 °C, for example about 20 to 30 °C.

In at least some embodiments, the at least one dihydrocarbyl dithiophosphate is mixed with the other components at a temperature which is not greater than 60 °C, for example less than 55 °C or less than 50 °C. The at least one dihydrocarbyl dithiophosphate may be mixed with the other components at a temperature in the range of 20 to 55 °C, for example in the range of 25 to 35 °C.

Thus according to this aspect, the elongate mixing vessel may comprise at least one fourth inlet downstream of the at least one first static mixer and at least one third static mixer which is downstream of the at least one first static mixer and is downstream of the at least one fourth inlet and the method further comprises:

introducing the at least one third additive component into the mixing vessel through the at least one fourth inlet; and mixing the at least one third additive component in the mixing vessel with the at least one base oil component, the at least one first additive component and the at least one second additive component in the mixing vessel by flowing them through the mixing vessel and past the at least one third static mixer to produce a mixture of the at least one base oil component and the at least one first additive component, the at least one second additive component and
the at least one third additive component.

[0100] In this embodiment, the at least one third additive component may be mixed in the mixing vessel with the at least one base oil component, the at least one first additive component and the at least one second additive component in the mixing vessel by flowing them through the mixing vessel and past the at least one third static mixer at a temperature which is different to the temperature at which the components are flowed past the at least one first static mixer and which is different to the temperature at which the components are flowed past the at least one second static mixer, if present.

[0101] Thus, the components that are mixed by the at least one third static mixer may be mixed at a temperature which is not greater than 60°C, for example less than 55°C or less than 50°C. This temperature may be in the range of 20 to 55°C, for example in the range of 25 to 35°C.

[0102] The components that are mixed by the at least one first static mixer may be mixed at a temperature in the range of ambient temperature to 300°C, for example in the range of ambient temperature to 200°C. Ambient temperature may be about 10 to 40°C, for example about 20 to 30°C.

[0103] The components that are mixed by the at least one second static mixer if present, may be mixed at a temperature in the range of ambient temperature to 300°C, for example in the range of ambient temperature to 200°C. Ambient temperature may be about 10 to 40°C, for example about 20 to 30°C.

[0104] The use of different temperatures for mixing the components by the third static mixer and the first (and second, if present) mixers has a benefit, for example when the at least one third additive component comprises at least one zinc dialkyl thiophosphate, of being able to operate the first and second static mixers (for example to mix together at least one dispersant and at least one metal-containing detergent) at a higher temperature than the temperature of operation of the third static mixer, which may be used to mix in at least one dialkyl thiophosphate. In this way, at least one zinc dialkyl thiophosphate may be mixed with the other components for example after the dispersant and the metal-containing detergent have been mixed together, suitably at a higher temperature.

[0105] The temperatures of the components may be maintained by the use of one or more heat exchangers which may be external to the elongate mixing vessel. The heat exchangers may introduce heat into the components as they are mixed by the respective static mixers and/or may remove heat from the components if the mixing is exothermic.

[0106] Zinc dihydrocarbyl dithiophosphates are often referred to as ZDDP’s. The ZDDP’s may comprise hydrocarbyl groups independently having 1 to 18 carbon atoms, suitably 2 to 13 carbon atoms or 3 to 18 carbon atoms, more suitably 2 to 12 carbon atoms or 3 to 13 carbon atoms, for example 3 to 8 carbon atoms. Examples of suitable hydrocarbyl groups include alkyl, cycloalkyl and alkaryl groups which may contain ether or ester linkages and also which may contain substituent groups for example, halogen or nitro groups. The hydrocarbyl groups may be alkyl groups which are linear and/or branched and suitably may have from 3 to 8 carbon atoms. Particularly suitable ZDDP’s have hydrocarbyl groups which are a mixture of secondary alkyl groups and primary alkyl groups for example, 90 mol. % secondary alkyl groups and 10 mol. % primary alkyl groups.

Detergents and Detergent Boosters

[0107] When preparing a lubricant composition by mixing at least one base oil component with at least one additive component comprising at least one detergent (for example metal-containing detergent) and at least one additive component comprising at least one detergent booster haziness of the mixture might result if the first and second additive components are not introduced into the mixture in a correct sequence.

[0108] Thus, in at least some embodiments, the at least one first additive component comprises at least one detergent and the at least one second additive component comprises at least one detergent booster, or alternatively, the at least one first additive component comprises at least one detergent booster and the at least one second additive component comprises at least one detergent.

[0109] Examples of suitable detergents are described herein.

[0110] Detergent boosters are over based metal salts which may increase the total base number (TBN) of the lubricant composition. They may be provided as components in one or more DI (detergent inhibitor) additive packs. DI packs typically comprise detergent(s), dispersant(s), antioxidant(s), anti-oxidant(s) and surfactant(s). Examples of detergent boosters include calcium and/or magnesium salts or sulphonates, phenates, salicylates and/or phosphates.

[0111] More than one detergent booster may be used.

Anti-foam Additives and additives other than anti-foam additives.

[0112] Anti-foam additives (sometimes called anti-foams or anti-foaming agents) retard the formation of stable foams. Examples of suitable anti-foam agents include silicones, organic polymers, siloxanes (including poly siloxanes and (poly) dimethyl siloxanes, phenyl methyl siloxanes), acrylates and the like. Anti-foams may be provided as components in DI (detergent inhibitor) additive packs. More than one anti-foam may be used.
When preparing a lubricant composition comprising at least one base oil component, at least one additive component comprising at least one anti-foam additive and at least one additive component comprising at least one lubricant additive other than an anti-foam additive haziness may result. Anti-foam additives in general may be difficult to mix with other components of a lubricant composition. It is generally beneficial to introduce the additive components comprising at least one anti-foam additive after other additive components have been mixed with the at least one base oil component. The present invention may help mitigate the difficulties of mixing anti-foam additive components with other components of lubrication compositions.

Thus, in at least some embodiments, the at least one second additive component comprises at least one anti-foam additive and the at least one first additive component is at least one lubricant additive which is other than an anti-foam additive.

Friction Modifier Additives and additives other than friction modifiers.

Friction modifiers and additives other than friction modifiers may be mixed together in at least some embodiments.

Thus in some embodiments at least, the at least one second additive component comprises at least one friction modifier additive and the at least one first additive component is at least one lubricant additive which is other than a friction modifier additive.

Suitable friction modifiers may be ash-producing additives or ashless additives. Examples of such friction modifiers include fatty acid derivatives including for example, other fatty acid esters, amides, amines, and ethoxylated amines. Examples of suitable ester friction modifiers include esters of glycerol for example, mono-, di-, and tri-oleates, mono-palmitates and mono-myristates. A particularly suitable fatty acid ester friction modifier is glycerol monooleate. Examples of friction modifiers also include molybdenum compounds for example, organo molybdenum compounds, molybdenum dialkyldithiocarbamates, molybdenum dialkyliithiophosphates, molybdenum disulphide, tri-molybdenum cluster dialkyldithiocarbamates, non-sulphur molybdenum compounds and the like. Suitable molybdenum-containing compounds are described for example, in EP-1533362-A1 for example in paragraphs [0101] to [0117].

Friction modifiers may also include a combination of an alkoxylated hydrocarbyl amine and a polyol partial ester of a saturated or unsaturated fatty acid or a mixture of such esters, for example as described in WO 93/21288.

Friction modifiers which are fatty acid derivative friction modifiers may be introduced into the mixing vessel to produce a lubricant composition in which the friction modifiers are present at a concentration of 0.01 to 5% by weight actives, for example in the range of 0.01 to 1.5% by weight actives.

Molybdenum containing friction modifier additives may be introduced into the mixing vessel to produce a lubricant composition in which the friction modifiers are present at a concentration of 10 to 1000 ppm by weight molybdenum, for example in the range of 400 to 600 ppm by weight.

Other additive components.

The method of the present invention may be used to prepare lubricant compositions comprising additive components which may suitably include: dispersant viscosity modifiers, pour point depressants, dispersants, metal-containing detergents, detergent boosters, anti-foam additives, friction modifiers, anti-wear additives, viscosity index improvers, viscosity modifiers, rust inhibitors, corrosion inhibitors, anti-oxidants (sometimes also called oxidation inhibitors), seal swell agents (sometimes also called compatibility agents), extreme pressure additives (metallic, non-metallic, phosphorus containing, non-phosphorus containing, sulphur containing and non-sulphur containing), surfactants, demulsifiers, anti-seize agents, wax modifiers, lubricity agents, anti-staining agents, chromophoric agents and metal deactivators. Such additive components may be first additive components, second additive components or third additive components as herein described or may be other additive components. Some additive components may exhibit more than one function. The method of the present invention may be used to prepare a lubricant composition which comprises at least two additive components. The method of the present invention may be used to prepare a lubricant composition which comprises up to 18 additive components, for example up to 6 additive components. The method of the present invention may be used to prepare a lubricant composition which comprises typically up to about 20% by weight in total of additive components, for example up to about 10% by weight in total of additive components. The method of the present invention may be used to prepare a lubricant composition which comprises typically at least about 80% by weight in total of base oil components, for example, at least about 90% by weight in total of base oil components.

The method of the present invention may be used to prepare a lubricant composition in which the additive components have a viscosity which is typically in the range of 10 to 15 times more than that of the base oil components. The method of the present invention may be used to prepare a lubricant composition in which the additive components have a $K_v100$ of 1000 cSt or more. The limitation may be determined by the limit of the pump(s) available for introducing the component into the mixing vessel.
[0123] The method of the present invention may be used to prepare a lubricant composition in which during the preparation of the components react with each other. The use of an elongate mixing vessel in the method of the present invention may facilitate temperature control by heat removal or heat addition to the components in the mixing vessel.

[0124] Suitable anti-wear additives may be ash-producing additives or ashless additives. Examples of such anti-wear additives include non-phosphorus containing additives for example, sulphurised olefins. Examples of such anti-wear additives also include phosphorus-containing anti-wear additives. Examples of suitable phosphorus-containing anti-wear additives include triaryl phosphite and triphenylphosphorothonate and those disclosed in paragraph [0036] of US2005/0198894. Examples of suitable ash-forming, phosphorus-containing anti-wear additives include dihydrocarbyl diithiophosphate metal salts. Examples of suitable metals of the dihydrocarbyl diithiophosphate metal salts include alkali and alkaline earth metals, aluminium, lead, tin, molybdenum, manganese, nickel, copper and zinc. Particularly suitable dihydrocarbyl diithiophosphate metal salts are zinc dihydrocarbyl dithiophosphates (ZDDP). The ZDDP's may have hydrocarbyl groups independently having 1 to 18 carbon atoms, suitably 2 to 13 carbon atoms or 3 to 18 carbon atoms, more suitably 2 to 12 carbon atoms or 3 to 13 carbon atoms, for example 3 to 8 carbon atoms. Examples of suitable hydrocarbyl groups include alky, cycloalkyl and alkaryl groups which may contain ether or ester linkages and also which may contain substituent groups for example, halogen or nitro groups. The hydrocarbyl groups may be alkyl groups which are linear and/or branched and suitably may have from 3 to 8 carbon atoms. Particularly suitable ZDDP's have hydrocarbyl groups which are a mixture of secondary alkyl groups and primary alkyl groups for example, 90 mol. % secondary alkyl groups and 10 mol. % primary alkyl groups.

[0125] Phosphorus-containing anti-wear additives may be introduced into the mixing vessel to produce a lubricant composition in which the phosphorus-containing anti-wear additives are present at a total concentration of 10 to 6000 ppm by weight of phosphorus, suitably 10 to 1000 ppm by weight of phosphorus, for example 200 to 1400 ppm by weight of phosphorus, or 200 to 800 ppm by weight of phosphorus or 200 to 6000 ppm by weight of phosphorus.

[0126] Viscosity index improvers (also called viscosity modifiers, viscosity improvers or VI improvers) impart high and low temperature operability to a lubricant composition and facilitate it remaining shear stable at elevated temperatures whilst also exhibiting acceptable viscosity and fluidity at low temperatures.

[0127] Examples of suitable viscosity modifiers include high molecular weight hydrocarbon polymers (for example polyisobutylene, copolymers of ethylene and propylene and higher alpha-olefins); polyesters (for example polymethacrylates); hydrogenated poly(styrene-co-butadiene or isoprene) polymers and modifications (for example star polymers); and esterified poly(styrene-co-maleic anhydride) polymers. Oil-soluble viscosity modifying polymers generally have number average molecular weights of at least 15000 to 1000000, preferably 20000 to 600000 as determined by gel permeation chromatography or light scattering methods.

[0128] Viscosity modifiers may have additional functions as multifunction viscosity modifiers. More than one viscosity index improver may be used.

[0129] Rust inhibitors generally protect lubricated metal surfaces against chemical attack by water or other contaminants. Examples of suitable rust inhibitors include non-ionic polyoxyalkylene polyls and esters thereof, polyoxyalkylene phenols, polyoxyalkylene polyls, anionic alkyl sulphonlic acids, zinc dithiophosphates, metal phenolates, basic metal sulphonates, fatty acids and amines.

[0130] More than one rust inhibitor may be present.

[0131] Corrosion inhibitors (also called anti-corrosive agents) reduce the degradation of metallic parts contacted with the lubricating composition. Examples of corrosion inhibitors include phosphosulphurised hydrocarbons and the products obtained by the reaction of phosphosulphurised hydrocarbon with an alkaline earth metal oxide or hydroxide, non-ionic polyoxyalkylene polyls and esters thereof, polyoxyalkylene phenols, thiaadiazoles, triazoles and anionic alkyl sulphonlic acids. Examples of suitable epoxidised ester corrosion inhibitors are described in US2006/0090393.

[0132] More than one corrosion inhibitor may be used.

[0133] Antioxidants (sometimes also called oxidation inhibitors) reduce the tendency of oils to deteriorate in use. Evidence of such deterioration might include for example the production of varnish-like deposits on metal surfaces, the formation of sludge and viscosity increase. ZDDP's exhibit some antioxidant properties.

[0134] Examples of suitable antioxidants other than ZDDP's include alkylated diphenylamines, N-alkylated phenylene-diamines, phenyl-α-naphthylamine, alkylated phenyl-α-naphthylamines, dimethyldiquinolines, trimethylhydroquinoline and oligomeric compositions derived therefrom, hindered phenolics (including ashless (metal-free) phenolic compounds and neutral and basic metal salts of certain phenolic compounds), aromatic amines (including alkylated and non-alkylated aromatic amines), sulphurised alkyl phenols and alkaline earth metal salts thereof, alkylated hydroquinones, hydroxylated thiophenyl ethers, alklyldienephenols, tripheorphionate, metallic dithiocarbamates, 1,3,4-dimercaptotriazole and derivatives, oil soluble copper compounds (for example, copper dihydrocarbyl thio- or thio-phosphate, copper salts of a synthetic or natural carboxylic acids, for example a C8 to C18 fatty acid, an unsaturated acid or a branched carboxylic acid, for example basic, neutral or acidic CuI and/or CuII salts derived from alkenyl succinic acids or anhydrides), alkaline earth metal salts of alkylphenolthioesters, suitably having C5 to C12 alkyl side chains,
calcium nonylphenol sulphide, barium t-octylphenyl sulphide, dioctylphenylamine, phosphosulphised or sulphurised hydrocarbons, oil soluble phenates, oil soluble sulphurised phenates, calcium dodecylphenol sulphide, phosphosulphised hydrocarbons, sulphurised hydrocarbons, phosphorus esters, low sulphur peroxide decomposers and the like.

More than one anti-oxidant may be used. More than one type of anti-oxidant may be used.

Seal swell agents (sometimes also called seal compatibility agents or elastomer compatibility aids) help to swell elastomeric seals for example by causing a reaction in the fluid or a physical change in the elastomer. Examples of suitable seal swell agents include long chain organic acids, organic phosphates, aromatic esters, aromatic hydrocarbons, esters (for example butylbenzyl phthalate) and polybutenyl succinic anhydride.

More than one seal swell agent may be used.

The additive components (first, second, third or other) may comprise solvent. Examples of suitable solvents include highly aromatic, low viscosity base stocks, for example 100N, 60 N and 100SP base stocks. The additive components (first, second, third or other) may comprise Group I base stock as solvent.

More than one seal swell agent may be used.

The representative suitable and more suitable independent amounts of additives (if present) in the lubricant composition produce by the method of the invention are given in Table 1, although any effective amounts may be used. The concentrations expressed in Table 1 are by weight of active additive compounds that is, independent of any solvent or diluent.

More than one of each type of additive may be present. Within each type of additive, more than one class of that type of additive may be present. More than one additive of each class of additive may be present. Additives may suitably be supplied by manufacturers and suppliers in solvent or diluents.

According to a further aspect of the present invention there is provided a lubricant composition obtainable by the method as herein described. According to a further aspect of the present invention there is provided a lubricant composition prepared by the method as herein described.

The method of the present invention may be used to prepare lubricant compositions which may be used for a range of applications including:

- as a metalworking fluid which may be used to lubricate metals during machining, rolling and the like;
- as a power transmission fluid for example useful as an automatic transmission fluid, a fluid in a clutch (for example a dual clutch), a gear lubricating composition, or in other automotive applications and the like;
- as an aviation lubricant composition;

### Table 1

<table>
<thead>
<tr>
<th>ADDITIVE TYPE</th>
<th>Suitable amount (actives), if present (by weight)</th>
<th>More suitable amount (actives), if present (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction modifiers</td>
<td>0.01 to 5%</td>
<td>0.01 to 1%</td>
</tr>
<tr>
<td>Phosphorus-containing anti-wear additives</td>
<td>corresponding to 10 to 6000 ppm P</td>
<td>corresponding to 10 to 1000 ppm P</td>
</tr>
<tr>
<td>Molybdenum-containing anti-wear additives</td>
<td>corresponding to 10 to 1000 ppm Mo</td>
<td>corresponding to 40 to 600 ppm Mo</td>
</tr>
<tr>
<td>Boron-containing anti-wear additives</td>
<td>corresponding to 10 to 250 ppm B</td>
<td>corresponding to 50 to 100 ppm B</td>
</tr>
<tr>
<td>Molybdenum-containing friction modifiers</td>
<td>corresponding to 10 to 1000 ppm Mo</td>
<td>corresponding to 400 to 600 ppm Mo</td>
</tr>
<tr>
<td>Dispersants</td>
<td>0.1 to 20 %</td>
<td>0.1 to 8 %</td>
</tr>
<tr>
<td>Detergents</td>
<td>0.01 to 6 %</td>
<td>0.01 to 4 %</td>
</tr>
<tr>
<td>Viscosity index improvers</td>
<td>0.01 to 20 %</td>
<td>0.01 to 15%</td>
</tr>
<tr>
<td>Pour point depressants</td>
<td>0.01 to 5 %</td>
<td>0.01 to 1.5 %</td>
</tr>
<tr>
<td>Corrosion and/or rust inhibitors</td>
<td>0.01 to 5 %</td>
<td>0.01 to 1.5%</td>
</tr>
<tr>
<td>Anti-oxidants</td>
<td>0.1 to 10 %</td>
<td>0.5 to 5 %</td>
</tr>
<tr>
<td>Antifoams containing silicon</td>
<td>corresponding to 1 to 20 ppm Si</td>
<td>corresponding to 1 to 10 ppm Si</td>
</tr>
</tbody>
</table>
- as a lubricant composition suitable for lubricating a turbine;
- as a lubricant composition for lubricating a solid surface, including for example metallic surfaces and non-metallic surfaces;
- as a lubricant for an internal combustion engine, for example a compression ignition engine or a spark-ignition engine; or
- as a lubricant for a marine or power engine, for example as trunk piston oil lubricant composition;

The invention will now be described with respect to the following examples in which Figures 1 to 8 represent in simplified schematic form apparatus in use in the method of the present invention. Figure 9 represents in elevated schematic form a set of static mixers in the form of plugs which may be located in a cylindrical mixing vessel, each plug defining at least one passage for components in the direction of the longitudinal axis of the elongate mixing chamber, each passage having a discontinuous, non-uniform cross-section. In particular:

- Figure 1 represents in schematic form, apparatus comprising an elongate mixing vessel comprising a first inlet, a second inlet a static mixer and an outlet;
- Figure 2 represents in schematic form, apparatus comprising an elongate mixing vessel comprising a first inlet, a second inlet, a third inlet, a first static mixer, a second static mixer and an outlet;
- Figure 3 represents in schematic form, apparatus comprising an elongate mixing vessel comprising a first inlet, a second inlet, a third inlet, a first static mixer, a second static mixer, an outlet and downstream of the first static mixer, a fourth inlet and downstream thereof a third static mixer;
- Figure 4 represents in schematic form, apparatus comprising an elongate mixing vessel comprising a first inlet, a second inlet, a third inlet, a first static mixer, a second static mixer, an outlet and upstream of the third inlet, a fourth inlet and downstream thereof a third static mixer;
- Figure 5 represents in schematic form, apparatus comprising an elongate mixing vessel comprising a first inlet, a second inlet, a third inlet, a first static mixer, a second static mixer, an outlet and downstream of the second static mixer and upstream of the second inlet, a fourth inlet and downstream thereof a third static mixer;
- Figure 6 represents in schematic form, the apparatus of Figure 1 with an additional static mixer upstream of the second inlet.
- Figure 7 represents in schematic form, the apparatus of Figure 2 with an additional static mixer downstream of the first inlet and upstream of the third inlet.
- Figure 8 represents in schematic form, the apparatus of Figure 3 with an additional static mixer downstream of the first inlet and upstream of the third inlet.
- Figure 9 represents in elevated schematic form, a static mixer which may be used in the elongate mixing vessel.
- Figure 10 represents in schematic form a set of static mixers in the form of plugs which may be located in a cylindrical mixing vessel, each plug defining at least one passage for components in the direction of the longitudinal axis of the elongate mixing chamber, each passage having a discontinuous, non-uniform cross-section in which Figure 10a is an isometric view of the set of plugs, Figure 10b is a longitudinal, cross section of the set of plugs, Figure 10c is a transverse end view of the set of plugs and Figure 10d is a detailed longitudinal cross-section of one of the plugs.

Key to common features of the drawings are identified by common reference numerals as follows:

1. mixing vessel;
2. first static mixer;
3. first inlet;
4. second inlet;
5. outlet;
6. second static mixer;
7. third inlet;
8. mixture of the at least one base oil component and the at least one first additive component;
9. mixture of the at least one base oil component and the at least one first additive component and the at least one second additive component;
10. fourth inlet;
11. third static mixer;
12. further optional static mixer;
13. longitudinal axis of elongate mixing vessel;
14. circular orifice in plate of static mixer;
15. slot in plate of static mixer and
16. plate of static mixer.

[0145] Figure 1 - represents in schematic form, an apparatus which may be used in a method of preparing a lubricant composition according to the present invention, which method comprises introducing into an elongate mixing vessel comprising at one static mixer:

- at least one base oil component,
- at least one first additive component, and
- at least one second additive component;

in which method:

the at least one first additive component is introduced into the mixing vessel separately from the at least one second additive component and

the at least one second additive component is mixed in the elongate mixing vessel with a mixture of the at least one first additive component and the at least one base oil component using the at least one static mixer in which the elongate mixing vessel (1) comprises:

- at least one first static mixer (2),
- at least one first inlet (3) which is upstream of the at least one first static mixer (2),
- at least one second inlet (4) which is upstream of the at least one first static mixer (2), and
- at least one outlet (5) which is downstream of the at least one first static mixer;

and in which the method comprises the steps of:

a) introducing a mixture of the at least one base oil component and the at least one first additive component into the mixing vessel (1) through the at least one first inlet (3);

b) introducing the at least one second additive component into the mixing vessel (1) through the at least one second inlet (4) upstream of the at least one static mixer (2);

c) flowing the at least one second additive component and the mixture from step a, through the mixing vessel and past the at least one static mixer (2) to produce a mixture (9) of the at least one base oil component, the at least one first additive component and the at least one second additive component; and

d) removing the mixture (9) produced in step c from the mixing vessel (1) through the at least one outlet (5) downstream of the static mixer (2).

[0146] Figure 2 represents in schematic form, an apparatus which may be used in a method of preparing a lubricant composition according to the present invention, which method comprises introducing into an elongate mixing vessel comprising at least one static mixer:

- at least one base oil component,
- at least one first additive component, and
- at least one second additive component;

in which method:

the at least one first additive component is introduced into the mixing vessel separately from the at least one second additive component; and

the at least one second additive component is mixed in the elongate mixing vessel with a mixture of the at least one first additive component and the at least one base oil component using the at least one static mixer in which the mixing vessel is an elongate mixing vessel (1) comprising:

- at least one first static mixer (2),
- at least one first inlet (3) which is upstream of the at least one first static mixer (2),
- at least one second inlet (4) which is upstream of the at least one first static mixer (2),
- at least one third inlet (7) which is upstream of the at least one first static mixer (2) and is upstream of the at least one second inlet (4),
- at least one outlet (5) which is downstream of the at least one first static mixer (2),
at least one second static mixer (6) which is upstream of the at least one first static mixer (2), is upstream of the at least one second inlet (4), is downstream of the at least one first inlet (3) and is downstream of the at least one third inlet (7);

which method comprises the steps of:

a) introducing at least one base oil component into the mixing vessel (1) through the at least one first inlet (3), introducing the at least one first additive component into the mixing vessel (1) through the at least one third inlet (7), and mixing together the at least one base oil component and the at least one first additive component in the mixing vessel by flowing them through the mixing vessel and past the at least one second static mixer (6) to produce a mixture (8) of the at least one base oil component and the at least one first additive component;

b) introducing the at least one second additive component into the mixing vessel (1) through the at least one second inlet (4) upstream of the at least one static mixer (2);

c) flowing the at least one second additive component and the mixture (8) from step a, through the mixing vessel and past the at least one first static mixer (2) to produce a mixture (9) of the at least one base oil component, the at least one first additive component and the at least one second additive component; and

d) removing the mixture (9) produced in step c from the mixing vessel (1) through the at least one outlet (5) downstream of the static mixer (2).

Figures 3, 4 and 5 represent in schematic form apparatus as in Figure 2 except that the mixing vessel (1) additionally comprises at least one fourth inlet (10) (for additional additives) and downstream thereof at least one third static mixer (11). This combination of at least one fourth inlet (10) and at least one third static mixer (11) may be located downstream of the at least one first static mixer (2) as shown schematically in Figure 3. This combination of at least one fourth inlet (10) and at least one third static mixer (11) may be located upstream of the at least one first inlet (3) as shown schematically in Figure 4. This combination of at least one fourth inlet (10) and at least one third static mixer (11) may be located downstream of the at least one second static mixer (6) and upstream of the second inlet (4) as shown schematically in Figure 5. In use in the method of the present invention the additional additive is introduced into the mixing vessel (1) through the at least one further inlet (10).

Figure 6 represents in schematic form apparatus as in Figure 1 with an additional static mixer (12) upstream of the at least one second inlet (4). In use in the method of the present invention this further static mixer introduces turbulent flow into the mixture of at least one base oil component and at least one first additive component prior to mixing with the at least one second additive in the first static mixer (2).

Figures 7 and 8 represent in schematic form apparatus as in Figures 2 and 3 with an additional static mixer (12) downstream of the at least one first inlet and upstream of the at least one third inlet (7). In use in the method of the present invention this further static mixer introduces turbulent flow into the at least one base oil component prior to mixing with the at least one second static mixer (6).

In Figures 1 to 8 the elongate mixing vessel has a longitudinal axis (13). The additive components may be introduced into the mixing vessel in a direction which has a component which is perpendicular to the direction of the longitudinal axis (13). The additive components may be introduced into the mixing vessel in a direction which is perpendicular to the direction of the longitudinal axis (13). The first inlet is used to introduce the at least one base oil component (optionally as a mixture with at least one first additive component) into the mixing vessel in the direction of the longitudinal axis (13) of the elongate mixing vessel (1).

Figure 9 shows in elevated schematic form, a static mixer which may be used in an elongate mixing vessel, for example as shown schematically in Figures 1 to 8. The static mixer (2) comprises a plate (16) which comprises four circular orifices (14) and four slots (15), the slots interconnecting with the orifices. This plate may be located in an elongate mixing vessel transverse to the longitudinal axis of the elongate mixing vessel. In use, the orifices and slots provides shearing boundary surfaces to induce turbulent flow of components and/or mixtures flowing through the mixing vessel to thereby mix them.

Figure 10 represents in schematic form a set of static mixers in the form of plugs (17) which may be located in a cylindrical mixing vessel (not shown). Each plug (17) may be a first second or third static mixer depending upon the location of inlets to the mixing vessel in which it is located. Each plug (17) defines at least one passage (18) for components in the direction of the longitudinal axis (13) of the elongate mixing chamber, each passage having a discontinuous, non-uniform cross-section. The plugs (20)(20') at each end of the set have passages with cross-sections which increase or decrease along the longitudinal axis. The other plugs (21)(21') have passages with cross-sections which increase along the longitudinal axis towards the centre of the plug (22) and decrease towards the ends of each plug (23). The plugs are spaced longitudinally apart by four retaining rods (19). Figure 10a is an isometric view of the set of plugs, Figure 10b is a longitudinal, cross section of the set of plugs, Figure 10c is a transverse end view of the set of plugs and Figure 10d is a detailed longitudinal cross-section of one of the plugs.
Example 1

[0153] A lubricating composition for lubricating the crankcase of an automotive internal combustion engine comprising base oil, a first additive component comprising pour point depressant and a second additive component comprising dispersant viscosity modifier was prepared using apparatus as shown schematically in Figure 6 but with a set of nine static mixers in the form of plugs each plug defining a passage having a discontinuous, non-uniform cross-section as shown in Figure 10. The set of plugs was 298 mm long corresponding to the length of the elongate mixing vessel, with the two end plugs (20)(20') having a length of 7 mm and the seven other plugs (21)(21') a length of 14 mm. The plugs (20)(20') and (21)(21') had a diameter of 10mm to fit within a cylindrical elongate mixing vessel (not shown). The passages (18) varied in cross-section diameter from 2 mm to 6mm giving a conical angle (24) of 32°. For end plug (20)(20') adjacent the first inlet (3) the cross section varied from 6mm down to 2 mm in the direction of flow of components through the vessel. For each of the seven other plugs (21)(21') which were not at the ends, the cross-section of the passage varied linearly from 2 mm up to 6 mm at the middle of the plug and then back down to 2 mm in the direction of flow of components through the mixing vessel. The plugs were spaced apart along the mixing vessel typically by 21 mm with the first end plug (20) counting in the general direction of component flow through the vessel being 18 mm from the first inlet end of the elongate mixing chamber.

[0154] In the method a mixture of a base oil and a first additive component comprising pour point depressant was introduced into the elongate mixing vessel through first inlet (3) at a flow rate of 28 litres per minute using a pump operating at a temperature of less than 75°C in the direction (shown as X in Figure 10a) of the longitudinal axis (13) of the elongate mixing vessel at the end, upstream of the first (counting in the general direction of flow of components) end plug (20) along the mixing vessel. The composition of this mixture is given in Table 2.

![Table 2](image)

<table>
<thead>
<tr>
<th>Composition of mixture of base oil and first additive component</th>
<th>Amount corresponding to % by weight in final lubricant composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobil Jurong 500 SN Base oil</td>
<td>66.7*</td>
</tr>
<tr>
<td>Detergent Inhibitor pack</td>
<td>5.2</td>
</tr>
<tr>
<td>Antioxidant Irganox-L-67</td>
<td>0.15</td>
</tr>
<tr>
<td>Antiwear additive LZ 1396</td>
<td>0.25</td>
</tr>
<tr>
<td>Pour point depressant Kusa kp -30</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* may be used in part in second additive component mixture

[0155] A second additive component comprising dispersant viscosity modifier was introduced into the elongate mixing vessel through second inlet (4) in a direction which was perpendicular to the longitudinal axis (13) of the elongate mixing vessel using a pump (not shown) operating at a temperature of less than 55°C at a location between the second and third plugs (counting in the direction of general fluid component flow along the mixing vessel) and downstream of the first end plug (20) shown as location Z in Figure 10. This component was introduced at a flow rate of 12 litres per minute. The second additive component could be introduced into the mixing vessel at a location between the first end plug (20) and the first middle plug (21') plug (counting in the direction of general fluid component flow along the mixing vessel) shown as location Y in Figure 10.

![Table 3](image)

<table>
<thead>
<tr>
<th>Composition of second additive component comprising dispersant viscosity modifier</th>
<th>Amount corresponding to % by weight in final lubricant composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobil Jurong 150 SN Base oil</td>
<td>10</td>
</tr>
<tr>
<td>Yubase 6 base oil</td>
<td>10</td>
</tr>
<tr>
<td>Polymer concentrate 7% LZ 7067C</td>
<td>5.5</td>
</tr>
<tr>
<td>Dye OS Red Dye</td>
<td>0.01925</td>
</tr>
<tr>
<td>Hitech 5777 dispersant viscosity modifier</td>
<td>2.1</td>
</tr>
</tbody>
</table>

[0156] The method was performed at a temperature of 30°C without any temperature control. The pressure drop
across the mixing vessel was 2.39 bar

[0157] In the method, the mixture (8) comprising the base oil components and the first additive component (pour point depressant) was passed through the mixing vessel (1) and past the first (counting in the direction of general fluid component flow) end plug (20) and the first (counting in the direction of general fluid component flow) middle plug (21') which provides the at least one further static mixer (12) shown in Figure 6. These and the change in geometry between the inlet and the vessel introduced turbulent flow into the mixture (8) of base oil components and first additive component prior to mixing with the second additive component comprising dispersant viscosity modifier in the at least one first static mixer (2) in the form of one or more of the middle plugs (21) and the other end plug (20').

[0158] The flow rate of the mixture (8) of base oil components and the first additive component introduced into the mixing vessel through the first inlet (3) was 28 litres per minute. The flow rate of the second additive component mixture introduced into the mixing vessel (1) through the second inlet (4) was 12 litres per minute. Therefore, the rate of removal of the mixture from the mixing vessel through outlet (5) was 40 litres per minute.

[0159] The formulated crankcase lubricant composition product removed through outlet (5) was clear and bright.

[0160] The presence of dye in the composition comprising the dispersant viscosity modifier provided a visual indicator of the mixing which was seen to be uniform. The pressure drop across the mixing vessel became constant as the method progressed. The method produced product at 40 litres per minute using small inventories (the volume of the mixing vessel was estimated to be merely 500 ml). This demonstrates for example that the method of the present invention may permit production of lubricating compositions using apparatus which has a very small size.

[0161] This example demonstrates the method of the present invention using a first additive component which comprises a pour point depressant and a second additive component which comprises a dispersant viscosity modifier (DVM) to prepare a lubricant composition suitable for lubricating the crankcase of an internal combustion engine.

Example 2

[0162] Example 1 was repeated except that the flow rate of the mixture (8) of the base oil components and the first additive component comprising pour point depressant was 22.4 litres per minute. The second additive component comprising dispersant viscosity modifier was introduced into the mixing vessel (1) through the second inlet (4) at 9.6 litres per minute. Therefore, the rate of removal of the mixture from the mixing vessel through outlet (5) was 32 litres per minute and the ratio of the flow rates through the first and second inlets was the same as in Example 1. The pressure drop across the mixing vessel was 2.21 bar and the temperature was the same as in Example 1. This example demonstrated the same results as Example 1.

Example 3

[0163] Example 1 was repeated except that the flow rate of the mixture (8) of the base oil components and the first additive component comprising pour point depressant was 7.2 litres per minute, the flow rate of the second additive component mixture comprising dispersant viscosity modifier was 7.2 litres per minute, the rate of removal of the mixture from the mixing vessel through outlet (5) was 24 litres per minute and the pressure drop across the mixing vessel was 2.02 bar.

[0164] This example demonstrated the same results as Example 1.

Example 4

[0165] Apparatus as described for Examples 1 to 3 was used except that the second inlet was positioned with respect to the static mixers as shown in Figure 6, upstream of the first static mixer, but between the first end plug (20) and the first middle plug (21') shown at location Y in Figure 10a.

[0166] The flow rate of the mixture (8) of the base oil components and the first additive component comprising pour point depressant was 19.6 litres per minute, the flow rate of the second additive component mixture comprising dispersant viscosity modifier was 8.4 litres per minute, the rate of removal of the mixture from the mixing vessel through outlet (5) was 28 litres per minute and the pressure drop across the mixing vessel was 2.13 bar.

[0167] This example demonstrated the same results as Example 1.

Example 5

[0168] Apparatus as used in Examples 1 to 3 and shown in Figure 10 and represented by configuration as shown in Figure 6 with additional static mixers downstream of static mixer (2) was used to prepare a trunk piston oil lubricant composition.

[0169] Referring to Figures 6 and 10, a mixture of at least one base oil component (BO-I) and least one first additive
component comprising at least one additive other than an anti-foam additive (that is, a pour point depressant) was into the mixing vessel through first inlet (3) in the direction (shown as X in Figure 10a) of the longitudinal axis (13) of the elongate mixing vessel at the end, upstream of the first (counting in the general direction of flow of components) end plug (20) along the mixing vessel.

**0170** The first end plug (20) representing a further static mixer (12), introduced turbulent flow into the mixture of BO-I and pour point depressant prior to mixing with a second additive component. The flow rate of base oil (BO-I) and first additive component (pour point depressant) was 35 litres per minute.

**0171** A mixture comprising a base oil (BO), detergent inhibitor package (DI) and anti-foam second additive component was introduced into the mixing vessel through the second inlet (4) upstream of the first static mixer (2) in a direction perpendicular to the longitudinal axis (13) of the elongate mixing vessel (1) as shown in Figure 7, at allocation between the first middle plug (21') (second static mixer (6)) and the next middle plug (21) (first static mixer (2), shown as location Z in Figure 10a. The mixture comprising a base oil (BO), detergent inhibitor package (DI) and anti-foam and was introduced at a feed rate of 15 litres per minute.

**0172** In the method, turbulent flow was introduced into the mixture (8) of base oil component (BO-I) and pour point depressant by the first end plug (20) (being a further static mixer (12)). The mixture (8) and the second additive component (introduced through second inlet (4) at location Z) was passed through the mixing vessel (1) and past the at least one first static mixer (2) (middle plugs (21) and the second end lug (20')) to produce a mixture (9) of the base oil component, the first additive component and the second additive component before being removed from the mixing vessel (1) through the outlet (5) downstream of the at least one first static mixer (2).

**0173** The rate of removal of the mixture from the mixing vessel through outlet (5) was 50 litres per minute. The mixing vessel was operated at 30 °C without temperature control. The pressure drop across the mixing vessel between first inlet (3) and the outlet (5) was 2.16 bar.

**0174** No compatibility problems were observed with the components. This example demonstrates the preparation of a lubricating composition comprising at least one base oil component, at least one first additive component comprising an anti-foam additive.

**0175** This example demonstrates the preparation of a lubricating composition comprising at least one base oil component, at least one first additive component comprising an anti-foam additive, and at least one second additive component comprising at least one anti-foam additive.

**Example 6**

**0176** Example 5 was repeated except that the flow rate of the mixture (8) of the base oil component (BO-I) and the first additive component comprising at least one additive other than an anti-foam additive (that is, a pour point depressant), through the mixing vessel was 22.4 litres per minute. The flow rate of the second additive component mixture (base oil (BO), DI pack and anti-foam) introduced into the mixing vessel (1) through the second inlet (4) was 9.6 litres per minute. The rate of removal of the mixture from the mixing vessel through outlet (5) was 32 litres per minute. The mixing vessel was operated at 30 °C without temperature control. The pressure drop across the mixing vessel between first inlet (3) and the outlet (5) was 2.13 bar.

**0177** This example demonstrates the same results as Example 5.

**Example 7**

**0178** Example 5 was repeated but using apparatus as shown in Figure 10 and represented by configuration as shown in Figure 1 where static mixer (2) is shown in Figure 1a as plug 20, inlet 3 is in direction X and inlet 4 is at location Y’, perpendicular to the longitudinal axis 13 of the mixing vessel. Additional static mixing plugs 21’ and 21 being located downstream of the first static mixer (20, 2).

**0179** The flow rate of flow rate of a mixture (8) of the base oil component and the first additive component comprising at least one additive other than an anti-foam additive (that is, a pour point depressant), introduced into the mixing vessel in direction (shown as X in Figure 10a) of the longitudinal axis (13) of the elongate mixing vessel through the first inlet (3) was 29.4 litres per minute. The flow rate of the second additive component mixture (base oil (BO), DI pack and anti-foam) introduced into the mixing vessel (1) through the second inlet (4) was 12.6 litres per minute perpendicular to the longitudinal axis (13) upstream of the first static mixer (2,20). The rate of removal of the mixture from the mixing vessel through outlet (5) was 42 litres per minute. The mixing vessel was operated at 30 °C without temperature control. The pressure drop across the mixing vessel between first inlet (3) and the outlet (5) was 2.13 bar.

**0180** This example demonstrated the same results as Example 5.

**Example 8**

**0181** A further lubricating composition was prepared using the apparatus and configuration as in Examples 1 to 3.
The base oil/first additive component and the second additive component compositions are given in Tables 4 and 5 below.

No issues of compatibility were observed.

| Table 4 |
|---|---|
| Mixture of base oil component and first additive component comprising pour point depressant | Amount corresponding to % by weight in final lubricant composition |
| Mobil Jurong 150 SN Base oil | 10 |
| Yubase 6 base oil | 10 |
| Detergent Inhibitor pack | 5.2 |
| Anti-oxidant Irganox-L-67 | 0.15 |
| Anti-wear LZ 1396 | 0.25 |
| Pour Point depressant Kusa kp -30 | 0.1 |

| Table 5 |
|---|---|
| Second additive component comprising dispersant viscosity modifier | Amount corresponding to % by weight in final lubricant composition |
| Mobil Jurong 500 SN Base oil | 66.7 |
| Polymer concentrate 7% LZ 7067C | 5.5 |
| Dye OS red | 0.01925 |
| Dispersant viscosity modifier HiTec 5777 | 2.1 |

In the examples, further additive components may be introduced into the elongate mixing vessel (1) in a direction transverse to the longitudinal axis (13). Depending upon the solubility of each additive component each may be introduced further downstream of the elongate mixing vessel - at locations shown as W in Figure 10a upstream of further middle plugs (21) and the second end plug (20'). The more soluble the additive component, the further downstream it may be introduced.

This example demonstrated the same results as Example 5.

Example 9

Example 5 was repeated but with the additive components other than anti-foam introduced separately. Thus, referring to the locations of inlets shown in Figure 10a, a mixture of base oil (BO) and DI pack was introduced at location X through inlet (3) at a flow rate of 14.71/min, a mixture of base oil (BO-I) and pour point depressant was introduced at location Y at a flow rate of 14.71/min and a mixture of base oil (BO) and anti-foam was introduced at a flow rate of 12.6 l/min at location Z.

No additive incompatibilities were observed.

Example 10

Example 9 was repeated with flow rates of 17.5 l/min, 17.5 l/min and 15 l/min at locations X, Y and Z respectively. The same results as in Example 9 were observed.

Claims

1. A method of preparing a lubricant composition comprising at least one base oil component, at least one first additive component and at least one second additive component which method comprises:

   introducing into an elongate mixing vessel comprising at least one static mixer, at least one base oil component, at least one first additive component and at least one second additive component; the at least one first additive component comprising:

   - a pour point depressant composition comprising:
     - Mobil Jurong 150 SN Base oil
     - Yubase 6 base oil
     - Detergent Inhibitor pack
     - Anti-oxidant Irganox-L-67
     - Anti-wear LZ 1396
     - Pour Point depressant Kusa kp -30
   - a viscosity modifier composition comprising:
     - Polymer concentrate 7% LZ 7067C
     - Dye OS red
     - Dispersant viscosity modifier HiTec 5777

2. The method of claim 1 wherein the viscosity modifier composition is comprised of:

   - a polymer concentrate 7% LZ 7067C
   - a dye OS red
   - a dispersant viscosity modifier HiTec 5777
component being introduced into the mixing vessel separately from the at least one second additive component; and
mixing the at least one second additive component with a mixture of the at least one first additive component
and the at least one base oil component in the elongate mixing vessel using the at least one static mixer.

2. A method as claimed in claim 1 in which the mixing vessel is an elongate mixing vessel comprising at least one first
static mixer, at least one first inlet which is upstream of the at least one first static mixer, at least one second inlet
which is upstream of the at least one first static mixer and at least one outlet which is downstream of the at least
one static mixer and in which the method comprises the steps of:
a) introducing a mixture of the at least one base oil component and the at least one first additive component
into the mixing vessel through the at least one first inlet;
b) introducing the at least one second additive component into the mixing vessel through the at least one second
inlet upstream of the at least one first static mixer;
c) flowing the at least one second additive component and the mixture of step a, through the mixing vessel and
past the at least one first static mixer to mix the at least one second additive component with the mixture of step
a to produce a mixture of the at least one base oil component, the at least one first additive component and the
at least one second additive component; and
d) removing the mixture produced in step c from the mixing vessel through the at least one outlet downstream
of the first static mixer.

3. A method as claimed in claim 1 in which the mixing vessel is an elongate mixing vessel comprising at least one first
static mixer, at least one first inlet which is upstream of the at least one first static mixer, at least one second inlet
which is upstream of the at least one first static mixer and is upstream of the at least one second inlet and at least one outlet which is downstream of the at least one static mixer;
and in which the method comprises the steps of:
a') introducing the at least one base oil component into the mixing vessel through the at least one first inlet,
introducing the at least one first additive component into the mixing vessel through the at least one third inlet
and mixing together the at least one base oil component and the at least one first additive component in the
mixing vessel to produce a mixture of the at least one base oil component and the at least one first additive
component;
b') introducing the at least one second additive component into the mixing vessel through the at least one second
inlet upstream of the at least one first static mixer;
c') flowing the at least one second additive component and the mixture from step a', through the mixing vessel
and past the at least one first static mixer to mix the at least one second additive component with the mixture
from step a to produce a mixture of the at least one base oil component, the at least one first additive component
and the at least one second additive component; and
d') removing the mixture produced in step c' from the mixing vessel through the at least one outlet downstream
of the first static mixer.

4. A method as claimed in claim 3 in which the elongate mixing vessel further comprises at least one second static
mixer which is upstream of the at least one first static mixer, is upstream of the at least one second inlet, is downstream
of the at least one first inlet and is downstream of the at least one third inlet and in which in step a', the method
comprises mixing together the at least one base oil component and the at least one first additive component in the
mixing vessel by flowing them through the mixing vessel and past the at least one second static mixer to produce
a mixture of the at least one base oil component and the at least one first additive component.

5. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at
least one dispersant viscosity modifier and the at least one second additive component comprises at least one pour
point depressant.

6. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at
least one pour point depressant and the at least one second additive component comprises at least one dispersant
viscosity modifier.

7. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at
least one dispersant and the at least one second additive component comprises at least one metal-containing detergent.

8. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at least one metal-containing detergent and the at least one second additive component comprises at least one dispersant.

9. A method as claimed in claim 7 or claim 8 in which the dispersant is a dispersant viscosity modifier.

10. A method as claimed in claim 7, claim 8 or claim 9 in which the at least one base oil and the at least one first additive component and the at least one second additive component are mixed in the absence of any zinc dihydrocarbyl dithiophosphate.

11. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at least one detergent and the at least one second additive component comprises at least one detergent booster.

12. A method as claimed in any one of claims 1 to 4 in which the at least one first additive component comprises at least one detergent booster and the at least one second additive component comprises at least one detergent.

13. A method as claimed in any one of claims 1 to 4 in which the at least one second additive component comprises at least one anti-foam additive and the at least one first additive component is at least one lubricant additive which is other than an anti-foam additive.

14. A method as claimed in any one of claims 1 to 4 in which the at least one second additive component comprises at least one friction modifier additive and the at least one first additive component is at least one lubricant additive which is other than a friction modifier additive.

15. A method as claimed in any one of claims 1 to 14 in which the elongate mixing vessel further comprises:

- at least one fourth inlet downstream of the at least one first static mixer and
- at least one third static mixer which is downstream of the at least one first static mixer and which is downstream of the at least one fourth inlet

and in which the method further comprises:

- introducing at least one third additive component into the mixing vessel through the at least one fourth inlet; and
- mixing the at least one third additive component in the mixing vessel with the at least one base oil component, the at least one first additive component and the at least one second additive component in the mixing vessel by flowing them through the mixing vessel and past the at least one third static mixer to produce a mixture of the at least one base oil component and the at least one first additive component, the at least one second additive component and the at least one third additive component.

16. A method as claimed in claim 15 in which the at least one third additive component is mixed in the mixing vessel with the at least one base oil component, the at least one first additive component and the at least one second additive component in the mixing vessel by flowing them through the mixing vessel and past the at least one third static mixer at a temperature which is different to the temperature at which the components are flowed past the at least one first static mixer and which is different to the temperature at which the components are flowed past the at least one second static mixer, if present.

17. A method as claimed in claim 15 or claim 16 in which the at least one third additive component which is introduced into the mixing vessel through the at least one fourth inlet comprises at least one zinc dihydrocarbyl dithiophosphate.

18. A method as claimed in any one of the preceding claims in which the elongate mixing vessel has a volume of less than about 1 litre.

19. A method as claimed in any one of the preceding claims in which the total residence time of all the components in the elongate mixing vessel is less than about 1 minute.
## DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>* paragraphs [0038], [0039]; claims; figures 1,5; examples *</td>
<td>5-19</td>
<td>B01F5/06</td>
</tr>
<tr>
<td></td>
<td>-----</td>
<td></td>
<td>B01F3/08</td>
</tr>
<tr>
<td></td>
<td>Y US 3 779 518 A (KOEPKE G ET AL) 18 December 1973 (1973-12-18)</td>
<td>1-19</td>
<td>ADD. C10N70/00</td>
</tr>
<tr>
<td></td>
<td>* column 2, lines 53-57; figures *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y CN 102 311 852 A (OIL RES INST OF THE AIR FORCE PLA) 11 January 2012 (2012-01-11)</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* abstract *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y GB 1 446 998 A (SAUTER AG) 18 August 1976 (1976-08-18)</td>
<td>1-4,15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 1, line 80 - page 2, line 92; figures *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y GB 2 645 463 A (STEARNES REID F) 14 July 1953 (1953-07-14)</td>
<td>1-4,15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* claims; figure 3 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y GB 1 407 281 A (BASF AG) 24 September 1975 (1975-09-24)</td>
<td>1-3,18, 19</td>
<td>C10M</td>
</tr>
<tr>
<td></td>
<td>* figures; examples *</td>
<td></td>
<td>B01F</td>
</tr>
<tr>
<td></td>
<td>Y US 3 417 967 A (HAROLD RICHENS RAYMOND ET AL) 24 December 1968 (1968-12-24)</td>
<td>1-4,15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* column 3, lines 11-13,27-28; figures *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y US 4 332 483 A (HOPE HENRY F ET AL) 1 June 1982 (1982-06-01)</td>
<td>1-4,15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* abstract *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0106]; claims 1,8 *</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The present search report has been drawn up for all claims.

**Place of search:** Munich  
**Date of completion of the search:** 26 April 2013  
**Examiner:** Kazemi, Pirjo
## DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
</tr>
</thead>
</table>

**TECHNICAL FIELDS SEARCHED (IPC)**

The present search report has been drawn up for all claims

<table>
<thead>
<tr>
<th>Place of search</th>
<th>Date of completion of the search</th>
<th>Examiner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munich</td>
<td>26 April 2013</td>
<td>Kazemi, Pirjo</td>
</tr>
</tbody>
</table>

**CATEGORY OF CITED DOCUMENTS**

- T: theory or principle underlying the invention
- E: earlier patent document, but published on, or after the filing date
- D: document cited in the application
- L: document cited for other reasons
- A: member of the same patent family, corresponding document

**P: intermediate document**
This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office ED3 file on. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 2003225166 A1</td>
<td>04-12-2003</td>
<td>CA 2430203 A1</td>
<td>03-12-2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 1482211 A</td>
<td>17-03-2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2004027223 A</td>
<td>29-01-2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MX PA03004799 A</td>
<td>29-10-2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RU 2323960 C2</td>
<td>10-05-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2003225166 A1</td>
<td>04-12-2003</td>
</tr>
<tr>
<td>US 3779518 A</td>
<td>18-12-1973</td>
<td>BE 779230 A2</td>
<td>11-08-1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH 537207 A</td>
<td>31-05-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 2106526 A1</td>
<td>31-08-1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2125404 A1</td>
<td>29-09-1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1354841 A</td>
<td>05-06-1974</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IT 948476 B</td>
<td>30-05-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP S5634854 B1</td>
<td>13-08-1981</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 3779518 A</td>
<td>18-12-1973</td>
</tr>
<tr>
<td>CN 102311852 A</td>
<td>11-01-2012</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>GB 1446998 A</td>
<td>18-08-1976</td>
<td>AT 358538 B</td>
<td>10-09-1980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH 564966 A5</td>
<td>15-08-1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 2430487 A1</td>
<td>28-08-1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2261803 A1</td>
<td>19-09-1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1446998 A</td>
<td>18-08-1976</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NL 7502248 A</td>
<td>27-08-1975</td>
</tr>
<tr>
<td>US 2645463 A</td>
<td>14-07-1953</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>GB 1407281 A</td>
<td>24-09-1975</td>
<td>BE 790131 A1</td>
<td>16-04-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH 543299 A</td>
<td>31-10-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 2151206 A1</td>
<td>19-04-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2156375 A1</td>
<td>25-05-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1407281 A</td>
<td>24-09-1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IT 972367 B</td>
<td>20-05-1974</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP S4847657 A</td>
<td>06-07-1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NL 7213985 A</td>
<td>17-04-1973</td>
</tr>
<tr>
<td>US 3417967 A</td>
<td>24-12-1968</td>
<td>BE 701614 A</td>
<td>02-01-1968</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 1557038 A1</td>
<td>10-02-1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1173302 A</td>
<td>10-12-1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE 330371 B</td>
<td>16-11-1970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 3417967 A</td>
<td>24-12-1968</td>
</tr>
<tr>
<td>US 4332483 A</td>
<td>01-06-1982</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82
This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-04-2013

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CN 1626632 A</td>
<td>15-06-2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2005146285 A</td>
<td>09-06-2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SG 112065 A1</td>
<td>29-06-2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2005153848 A1</td>
<td>14-07-2005</td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82
REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader’s convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

• US 3953002 A [0006] [0007] [0056]
• WO 2008124191 A [0074]
• WO 2007068799 A [0075]
• WO 9921902 A [0082]
• WO 2003099890 A [0082]
• WO 2006099250 A [0082]
• WO 200611663 A [0082]
• WO 2011062914 A [0082]
• US 7622431 B [0094]
• EP 1533362 A1 [0117]
• WO 9321288 A [0118]
• US 20050198894 A [0124]
• US 20060090393 A [0131]