



(51) International Patent Classification:

C10M 149/04 (2006.01) C10M 149/06 (2006.01)

(21) International Application Number:

PCT/EP2017/083038

(22) International Filing Date:

15 December 2017 (15.12.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

16205042.1 19 December 2016 (19.12.2016) EP

(71) Applicant: EVONIK OIL ADDITIVES GMBH
[DE/DE]; Kirschenallee, 64293 Darmstadt (DE).

(72) Inventors: YUKI, Tsuyoshi; 32-6 Takasagocho, Otsu
City, 520-0005 (JP). ARAI, Yasuo; 2-40-22 Kamiya,
Ushiku-shi, Ibaraki-ken, 300-1216 (JP). MATSUDA, To-
mohiro; 1343-16 Arakawahongo, Ami-machi, Inashi-
ki-gun, Ibaraki-ken, 300-1152 (JP). KISHIDA, Nobuhiro;
6-47-2-C, Kenkyugakuen, Tsukuba City, 305-0817 (JP).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to the applicant's entitlement to claim the priority of the
earlier application (Rule 4.17(iii))

Published:

- with international search report (Art. 21(3))

(54) Title: LUBRICATING OIL COMPOSITION COMPRISING DISPERSANT COMB POLYMERS

(57) Abstract: The present invention is directed to selected comb polymers comprising specified amounts of macromonomer and nitrogen-containing (meth)acrylates, their preparation, lubricant compositions comprising such comb polymers and their use as solubilizers in lubricant compositions, especially in engine oil (EO) compositions.



Lubricating oil composition comprising dispersant comb polymers

5 The present invention is directed to selected comb polymers comprising specified amounts of macromonomer and nitrogen-containing (meth)acrylates, their preparation, lubricant compositions comprising such comb polymers and their use as solubilizers in lubricant compositions, especially in engine oil (EO) compositions.

10 Automotive industries have strong interest in fuel economy. To enhance fuel economy, engine oils need to employ effective friction modifiers (FM). Molybdenum dithiocarbamate (MoDTC) is a commonly used FM and superior in friction reduction performance compared to other FM, especially in boundary lubrication regime.

15 The purpose of a lubricant is to reduce the amount of friction between two surfaces. In some cases, the base oil of a lubricant may not have enough lubricity to perform this function sufficiently. In this situation, friction modifiers are added to increase the oil's lubricity. Friction modifiers are used to modify a lubricant's coefficient of friction. They are designed to change the amount of energy needed to cause two surfaces to move past one another.

20 The vast majority of friction modifiers in use today are designed to reduce friction or increase lubricity for better fuel economy. One way to achieve this goal would be to reduce the viscosity of the engine oils in use. The challenge is lowering the viscosity while maintaining a sufficient lubricant film to reduce wear and friction.

25 Friction modifiers are most efficient under boundary conditions or where metal-to-metal contact occurs. Organic friction modifiers have long, soluble chains and a polar head. The polar head attaches to the metal surfaces. The soluble chains line up beside each other much like fibers in a carpet. The polar heads may be comprised of phosphoric or phosphonic acids, amines, amides or carboxylic acids. The soluble chains form dense mono layers or thick, reacted viscous layers.
30 These layers shear easily and create a relatively slippery surface.

Mechanical types of friction modifiers form layers of platelets that align with one another, providing a reduction in friction. The most common of these is molybdenum dithiocarbamate (MoDTC). These additives reduce friction by forming nano-sized single sheets dispersed in either a carbon or
35 pyrite matrix. These nano-sized sheets are oriented in layers and slide against one another, reducing the generated friction.

- 2 -

As fuel economy standards become more stringent, more will be required of engine oils. While the technology for friction modifiers continues to evolve, the most effective way to improve fuel economy or energy consumption is to lower the viscosity of the lubricant. However, you can only go so far before losing the hydrodynamic film and operating in either mixed-film lubrication or
5 boundary lubrication. It is in these two lubrication regimes that the use of friction modifiers becomes critical for reducing friction.

To design fuel economy engine oils, the reduction of friction at hydrodynamic lubrication and mixed and boundary lubrication is very important. MoDTC is well-known as friction modifier which reduces
10 friction at boundary lubrication, but the solubility of MoDTC in API Group III or Group III+ base oil is not so good. On the other hand, comb type viscosity index improvers can increase the viscosity index (VI) of a lubricating oil. Which means that it can reduce hydrodynamic friction at 40°C while keeping viscosity at high temperature. However, dosage of MoDTC was limited due to solubility. The use of dispersant comb helps to increase the solubility of MoDTC in Group III+ base oils and to
15 provide low friction coefficient and low KV₄₀.

Molybdenum dithiocarbamates are well-known additives for lubrication formulation. Molybdenum dialkyldithiocarbamates prepared from symmetrical dialkylamines and mixtures of symmetrical
20 dialkylamines are currently used as additives in lubricating oils (as well as mixtures thereof) for imparting antifriction properties (see US 7,763,744 B2). The drawback of molybdenum dialkyldithiocarbamates is that they do not have the desired solubility, especially at lower temperatures, so that the compound separates from the lubricating composition, resulting in the formation of a haze, cloud or precipitate in the lubricating composition, thus reducing its effectiveness.

25 Therefore, there is a desire for lubricating compositions which offer an improved solubility of molybdenum dialkyldithiocarbamate friction modifiers with in lubricating compositions.

It was now surprisingly found that novel polyalkyl(meth)acrylate based comb polymers are able to
30 increase the solubility of molybdenum in lubricating compositions.

The comb polymer technology in general and their use as viscosity index improver is already known (US 2008/0194443, US 2010/0190671 and WO 2014/170169), although an effect of these
35 compounds on the solubility of molybdenum in lubricating formulations has never been described.

Lubricant properties are typically improved by the addition of additives to lubricating oils.

- 3 -

US patents 5,565,130 and 5,597,871, for example, disclose using comb polymers comprising polybutadiene-derived macromonomers as viscosity index improvers. However, an effect of such comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein. WO 2007/003238 A1 describes oil-soluble comb polymers based on polyolefin-based

5 macromonomers, especially polybutadiene-based methacrylic esters, and C1-C10 alkyl methacrylates. The comb polymers can be used as an additive for lubricant oils, in order to improve the viscosity index and shear stability. However, an effect of such comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein.

10 WO 2009/007147 A1 discloses the use of comb polymers based on polyolefin-based macromonomers, especially polybutadiene-based methacrylic esters, and C1-C10 alkyl methacrylates for improving the fuel consumption of motor vehicles. However, an effect of such comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein.

15 WO 2010/102903 A1 discloses the use of dispersant comb polymers as antifatigue additives for transmission, motor and hydraulic oils. However, an effect of such dispersant comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein.

DE 10 2009 001 447 A1 describes the use of comb polymers for improving the load-bearing capacity of hydraulic oils having a high viscosity index. However, an effect of such comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein.

20 WO 2012/025901 A1 (Total) discloses the use of comb polymers in lubricants in combination with particular friction modifiers. However, an effect of such comb polymers on the solubility of molybdenum in lubricating formulations is not disclosed therein.

The prior art generally focused on non-dispersant comb polymers to reduce fuel consumption in terms of hydrodynamic lubrication. This present invention improves the friction for mixed and
25 boundary lubrication while keeping a long term storage stability, especially at low temperatures.

Detailed description of the invention

A first object of the present invention is directed to polyalkyl(meth)acrylate based comb polymers,
30 comprising the following monomers:

- (a) 10 to 20% by weight of esters of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene; and
- (b) 0.5% to 5% by weight, preferably 0.5 to 3% by weight, of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates,
35 aminoalkyl(meth)acrylamides and mixtures thereof.

A preferred first embodiment is directed to the polyalkyl(meth)acrylate based comb polymers, comprising the following monomers:

- 4 -

- 5 (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
- (b) 0% to 1% by weight of methyl methacrylate;
- (c) 60% to 75% by weight of n-butyl methacrylate;
- 10 (d) 10% to 20% by weight of C₁₀₋₃₀ alkyl (meth)acrylates, preferably C₁₀₋₁₅ alkyl methacrylates, more preferably C₁₂₋₁₄ alkyl methacrylates;
- (e) 0% to 1% by weight of styrene monomers; and
- (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.

A further preferred first embodiment is directed to the polyalkyl(meth)acrylate based comb polymers, comprising the following monomers:

- 15 (a) 14 to 16% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
- (b) 0% to 1% by weight of methyl methacrylate;
- (c) 65% to 70% by weight of n-butyl methacrylate;
- 20 (d) 14% to 17% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
- (e) 0% to 1% by weight of styrene monomers; and
- (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.

25

The content of each component (a), (b), (c), (d), (e) and (f) is based on the total composition of the polyalkyl(meth)acrylate based comb polymer.

In a particular embodiment, the proportions of components (a) to (f) add up to 100% by weight.

- 30 The weight-average molecular weight M_w of the polyalkyl(meth)acrylate based copolymers according to the present invention is preferably in the range of 200.000 to 500.000 g/mol, and more preferably in the range of 300.000 to 400.000 g/mol.

- 35 Preferably, the polyalkyl(meth)acrylate based comb polymers according to the present invention have a polydispersity index (PDI) M_w/M_n in the range of 1 to 6, more preferably in the range of 3 to 5.

M_w and M_n are determined by gel permeation chromatography (GPC) with RI detector in tetrahydrofuran at 40°C using a polymethyl methacrylate (PMMA) calibration.

- 5 -

A comb polymer in the context of this invention comprises a first polymer, which is also referred to as backbone or main chain, and a multitude of further polymers which are referred to as side chains and are bonded covalently to the backbone. In the present case, the backbone of the comb polymer is formed by the interlinked unsaturated groups of the mentioned (meth)acrylates. The ester groups of the (meth)acrylic esters, the phenyl radicals of the styrene monomers and the substituents of the further free-radically polymerizable comonomers form the side chains of the comb polymer.

The term "acrylate" refers to esters of acrylic acid; the term "methacrylate" refers to esters of methacrylic acid; and the term "(meth)acrylate" refers to both, esters of acrylic acid and esters methacrylic acid.

The hydroxylated hydrogenated polybutadiene for use in accordance with the invention has a number-average molar mass M_n of 4.000 to 6.000 g/mol, preferably 4.000 to 5.000 g/mol. Because of their high molar mass, the hydroxylated hydrogenated polybutadienes can also be referred to as macroalcohols in the context of this invention.

The number-average molar mass M_n is determined by size exclusion chromatography using commercially available polybutadiene standards. The determination is effected to DIN 55672-1 by gel permeation chromatography with THF as eluent.

Preferably, the hydroxylated hydrogenated polybutadiene has a hydrogenation level of at least 99%. An alternative measure of the hydrogenation level which can be determined on the copolymer of the invention is the iodine number. The iodine number refers to the number of grams of iodine which can be added onto 100 g of copolymer. Preferably, the copolymer of the invention has an iodine number of not more than 5 g of iodine per 100 g of copolymer. The iodine number is determined by the Wijs method according to DIN 53241-1:1995-05.

Preferred hydroxylated hydrogenated polybutadienes can be obtained according to GB 2270317.

Some hydroxylated hydrogenated polybutadienes are also commercially available. The commercially hydroxylated hydrogenated polybutadienes include, for example, Kraton Liquid® L-1203, a hydrogenated polybutadiene OH-functionalized to an extent of about 98% by weight (also called olefin copolymer OCP) having about 50% each of 1,2 repeat units and 1,4 repeat units, of $M_n = 4200$ g/mol, from Kraton Polymers GmbH (Eschborn, Germany). A further supplier of suitable alcohols based on hydrogenated polybutadiene is Cray Valley (Paris), a daughter company of Total (Paris), or the Sartomer Company (Exton, PA, USA).

- 6 -

Preference is given to monohydroxylated hydrogenated polybutadienes. More preferably, the hydroxylated hydrogenated polybutadiene is a hydroxyethyl- or hydroxypropyl-terminated hydrogenated polybutadiene. Particular preference is given to hydroxypropyl-terminated polybutadienes.

5

These monohydroxylated hydrogenated polybutadienes can be prepared by first converting butadiene monomers by anionic polymerization to polybutadiene. Subsequently, by reaction of the polybutadiene monomers with ethylene oxide or propylene oxide, a hydroxy-functionalized polybutadiene can be prepared. This hydroxylated polybutadiene can be hydrogenated in the presence of a suitable transition metal catalyst.

10

The esters of (meth)acrylic acid for use in accordance with the invention and a hydroxylated hydrogenated polybutadiene described are also referred to as macromonomers in the context of this invention because of their high molar mass.

15

The macromonomers for use in accordance with the invention can be prepared by transesterification of alkyl (meth)acrylates. Reaction of the alkyl (meth)acrylate with the hydroxylated hydrogenated polybutadiene forms the ester of the invention. Preference is given to using methyl (meth)acrylate or ethyl (meth)acrylate as reactant.

20

This transesterification is widely known. For example, it is possible for this purpose to use a heterogeneous catalyst system, such as lithium hydroxide/calcium oxide mixture (LiOH/CaO), pure lithium hydroxide (LiOH), lithium methoxide (LiOMe) or sodium methoxide (NaOMe) or a homogeneous catalyst system such as isopropyl titanate (Ti(OiPr)₄) or dioctyltin oxide (Sn(OCt)₂O).

25

The reaction is an equilibrium reaction. Therefore, the low molecular weight alcohol released is typically removed, for example by distillation.

In addition, the macromonomers can be obtained by a direct esterification proceeding, for example, from (meth)acrylic acid or (meth)acrylic anhydride, preferably under acidic catalysis by p-toluenesulfonic acid or methanesulfonic acid, or from free methacrylic acid by the DCC method (dicyclohexylcarbodiimide).

30

Furthermore, the present hydroxylated hydrogenated polybutadiene can be converted to an ester by reaction with an acid chloride such as (meth)acryloyl chloride.

35

Preferably, in the above-detailed preparations of the esters of the invention, polymerization inhibitors are used, for example the 4-hydroxy-2,2,6,6-tetramethylpiperidinoxyl radical and/or hydroquinone monomethyl ether.

- 7 -

Some of the macromonomers for use in accordance with the invention are also commercially available, for example Kraton Liquid® L-1253 which is produced from Kraton Liquid® L-1203 and is a hydrogenated polybutadiene methacrylate-functionalized to an extent of about 96% by weight, having about 50% each of 1,2 repeat units and 1,4 repeat units, from Kraton Polymers GmbH
5 (Eschborn, Germany). Kraton® L-1253 is likewise synthesized according to GB 2270317.

The C₁₀₋₃₀ alkyl (meth)acrylates for use in accordance with the invention are esters of (meth)acrylic acid and straight chain or branched alcohols having 10 to 30 carbon atoms. The term "C₁₀₋₃₀ alkyl methacrylates" encompasses individual (meth)acrylic esters with an alcohol of a particular length,
10 and likewise mixtures of (meth)acrylic esters with alcohols of different lengths.

Suitable C₁₀₋₃₀ alkyl (meth)acrylates include, for example, 2-butyloctyl (meth)acrylate, 2-hexyloctyl (meth)acrylate, decyl (meth)acrylate, 2-butyldecyl (meth)acrylate, 2-hexyldecyl (meth)acrylate, 2-octyldecyl (meth)acrylate, undecyl (meth)acrylate, 2-methylundecyl (meth)acrylate, dodecyl (meth)acrylate, 2-methyldodecyl (meth)acrylate, 2-hexyldodecyl (meth)acrylate, 2-octyldodecyl
15 (meth)acrylate, tridecyl (meth)acrylate, 2-methyltridecyl (meth)acrylate, tetradecyl (meth)acrylate, 2-decyltetradecyl (meth)acrylate, pentadecyl (meth)acrylate, hexadecyl (meth)acrylate, 2-methylhexadecyl (meth)acrylate, 2-dodecylhexadecyl (meth)acrylate, heptadecyl (meth)acrylate, 5-isopropylheptadecyl (meth)acrylate, 4-*tert*-butyloctadecyl (meth)acrylate, 5-ethyloctadecyl (meth)acrylate, 3-isopropyloctadecyl (meth)acrylate, octadecyl (meth)acrylate, 2-decyloctadecyl
20 (meth)acrylate, 2-tetradecyloctadecyl (meth)acrylate, nonadecyl (meth)acrylate, eicosyl (meth)acrylate, cetyleicosyl (meth)acrylate, stearyleicosyl (meth)acrylate, docosyl (meth)acrylate and/or eicosyltetratriacontyl (meth)acrylate. 2-decyl-tetradecyl (meth)acrylate, 2-decyloctadecyl (meth)acrylate, 2-dodecyl-1-hexadecyl (meth)acrylate, 1,2-octyl-1-dodecyl (meth)acrylate, 2-tetradecylocadecyl (meth)acrylate, 1,2-tetradecyl-octadecyl (meth)acrylate and 2-hexadecyl-eicosyl
25 (meth)acrylate.

The C₁₀₋₁₅ alkyl methacrylates for use in accordance with the invention are esters of methacrylic acid and alcohols having 10 to 15 carbon atoms. The term "C₁₀₋₁₅ alkyl methacrylates" encompasses individual methacrylic esters with an alcohol of a particular length, and likewise
30 mixtures of methacrylic esters with alcohols of different lengths.

The suitable C₁₀₋₁₅ alkyl methacrylates include, for example, decyl methacrylate, undecyl methacrylate, 2-methylundecyl methacrylate, dodecyl methacrylate, 2-methyldodecyl methacrylate, tridecyl methacrylate, 2-methyltridecyl methacrylate, tetradecyl methacrylate and/or pentadecyl
35 methacrylate.

Particularly preferred C₁₀₋₁₅ alkyl methacrylates are methacrylic esters of a linear C₁₂₋₁₄ alcohol mixture (C₁₂₋₁₄ alkyl methacrylate).

- 8 -

The aminoalkyl (meth)acrylates are preferably selected from the group consisting of N,N-dimethylaminoethyl (meth)acrylate, N,N-dimethylaminopropyl (meth)acrylate, N,N-diethylaminopentyl (meth)acrylate and N,N-dibutylaminohexadecyl (meth)acrylate.

- 5 Preferred aminoalkyl(meth)acrylamides are N,N-dimethylaminopropyl (meth)acrylamide.

The copolymer for use in accordance with the invention can be characterized on the basis of its molar degree of branching ("f-branch"). The molar degree of branching refers to the percentage in mol% of macromonomers (component (A)) used, based on the total molar amount of all the
 10 monomers in the monomer composition. The molar amount of the macromonomers used is calculated on the basis of the number-average molar mass M_n of the macromonomers. The calculation of the molar degree of branching is described in detail in WO 2007/003238 A1, especially on pages 13 and 14, to which reference is made here explicitly.

- 15 The polyalkyl(meth)acrylate based comb polymers in accordance with the invention preferably have a molar degree of branching f_{branch} of 0.1 to 5 mol%, more preferably 0.3 to 2 mol% and most preferably 0.3 to 1.1 mol%.

The polyalkyl(meth)acrylate based comb polymers in accordance with the invention can be
 20 prepared by free-radical polymerization and by related methods of controlled free-radical polymerization, for example ATRP (= atom transfer radical polymerization) or RAFT (= reversible addition fragmentation chain transfer).

Standard free-radical polymerization is detailed, inter alia, in Ullmann's Encyclopedia of Industrial
 25 Chemistry, Sixth Edition. In general, a polymerization initiator and optionally a chain transfer agent are used for this purpose.

The usable initiators include azo initiators widely known in the technical field, such as AIBN and 1,1-azobiscyclohexanecarbonitrile, and also peroxy compounds such as methyl ethyl ketone
 30 peroxide, acetylacetone peroxide, dilauryl peroxide, tert-butyl per-2-ethylhexanoate, ketone peroxide, tert-butyl peroctoate, methyl isobutyl ketone peroxide, cyclohexanone peroxide, dibenzoyl peroxide, tert-butyl peroxybenzoate, tert-butyl peroxyisopropylcarbonate, 2,5-bis(2-ethylhexanoylperoxy)-2,5-dimethylhexane, tert-butyl peroxy-2-ethylhexanoate, tert-butyl peroxy-3,5,5-trimethylhexanoate, dicumyl peroxide, 1,1-bis(tert-butylperoxy)cyclohexane, 1,1-bis(tert-
 35 butylperoxy)-3,3,5-trimethylcyclohexane, cumyl hydroperoxide, tert-butyl hydroperoxide, bis(4-tert-butylcyclohexyl) peroxydicarbonate, mixtures of two or more of the aforementioned compounds with one another, and mixtures of the aforementioned compounds with unspecified compounds which can likewise form free radicals. Suitable chain transfer agents are especially oil-soluble

- 9 -

mercaptans, for example n-dodecyl mercaptan or 2-mercaptoethanol, or else chain transfer agents from the class of the terpenes, for example terpinolene.

The ATRP method is known in the art. It is assumed that this is a "living" free-radical
5 polymerization, but no restriction is intended by the description of the mechanism. In these processes, a transition metal compound is reacted with a compound having a transferable atom group. This involves transfer of the transferable atom group to the transition metal compound, as a result of which the metal is oxidized. This reaction forms a free radical which adds onto ethylenic groups. However, the transfer of the atom group to the transition metal compound is reversible, and
10 so the atom group is transferred back to the growing polymer chain, which results in formation of a controlled polymerization system. It is accordingly possible to control the formation of the polymer, the molecular weight and the molecular weight distribution.

This reaction regime is described, for example, by J.-S. Wang, et al., J. Am. Chem. Soc, vol. 117,
15 p. 5614-5615 (1995), by Matyjaszewski, Macromolecules, vol. 28, p. 7901-7910 (1995). In addition, patent applications WO 96/30421, WO 97/47661, WO 97/18247, WO 98/40415 and WO 99/10387 disclose variants of the above-elucidated ATRP. In addition, the polymers of the invention can also be obtained via RAFT methods, for example. This method is described in detail, for example, in WO 98/01478 and WO 2004/083169.

20

The polymerization can be conducted under standard pressure, reduced pressure or elevated pressure. The polymerization temperature is also uncritical. In general, however, it is in the range from -20 to 200°C, preferably 50 to 150°C and more preferably 80 to 130°C.

25 The polymerization can be conducted with or without solvent. The term "solvent" should be understood here in a broad sense. The solvent is selected according to the polarity of the monomers used, it being possible with preference to use 100N oil, comparatively light gas oil and/or aromatic hydrocarbons, for example toluene or xylene.

30 The polymers according to the present invention are characterized by their contribution to the solubility of (organic) molybdenum in lubricating oil compositions.

The present invention therefore also relates to the use of the above-described polyalkyl(meth)acrylate based comb polymers as solubilizer for (organic) molybdenum in lubricating
35 oil compositions.

They are especially used to increase the solubility (and therefore the concentration) of molybdenum in lubricating oil compositions.

- 10 -

The present invention further relates to a method of increasing the solubility of molybdenum in lubricating compositions, especially in engine oil compositions, by adding the above-described polyalkyl(meth)acrylate based comb polymers.

- 5 By using the polyalkyl(meth)acrylate based comb polymers according to the present invention, the solubility of molybdenum in lubricating oil compositions can be increased by up to 0.2% by weight, based on the total weight of the lubricating oil composition.

Accordingly, by using a polyalkyl(meth)acrylate based comb polymers according to the present invention, 0.5 to 5% by weight, preferably 0.5 to 2% by weight, more preferably 1 to 2% by weight,
 10 based on the total weight of the lubricating oil composition, of molybdenum dithiocarbamate can be dissolved which deliver 0.005 to 0.5% by weight, preferably 0.05 to 0.2% by weight, and more preferably 0.1 to 0.2% by weight of molybdenum to the lubricating oil composition.

A second object of the present invention is directed to an additive composition, comprising:

- 15 (A) a base oil, and
 (B) a polyalkyl(meth)acrylate based comb polymer, comprising the following monomers:
 (a) 10 to 20% by weight of esters of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene; and
 20 (b) 0.5% to 5% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof.

A preferred second object is directed to an additive composition, comprising:

- 25 (A) a base oil; and
 (B) a polyalkyl(meth)acrylate based comb polymer, comprising the following monomers:
 (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 30 (b) 0% to 1% by weight of methyl methacrylate;
 (c) 60% to 75% by weight of n-butyl methacrylate;
 (d) 10% to 20% by weight of C₁₀₋₃₀ alkyl (meth)acrylates, preferably C₁₀₋₁₅ alkyl methacrylates, more preferably C₁₂₋₁₄ alkyl methacrylates;
 (e) 0% to 1% by weight of styrene monomers; and
 35 (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.

- 11 -

A further preferred second object is directed to an additive composition, comprising:

- (A) a base oil; and
- (B) a polyalkyl(meth)acrylate based comb polymer, comprising the following
5 monomers:
 - (a) 14 to 16% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 65% to 70% by weight of n-butyl methacrylate;
 - 10 (d) 14% to 17% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from
15 the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.

20 The content of each component (A) and (B) is based on the total weight of the additive composition.

In a particular embodiment, the proportions of components (A) and (B) add up to 100% by weight.

The content of each component (a), (b), (c), (d), (e) and (f) is based on the total composition of the polyalkyl(meth)acrylate based comb polymer.

25 In a particular embodiment, the proportions of components (a), (b), (c), (d), (e) and (f) add up to 100% by weight.

30 The base oil to be used in the additive composition and in the lubricating oil composition comprises an oil of lubricating viscosity. Such oils include natural and synthetic oils, oil derived from hydrocracking, hydrogenation, and hydro-finishing, unrefined, refined, re-refined oils or mixtures thereof.

The base oil may also be defined as specified by the American Petroleum Institute (API) (see April 2008 version of "Appendix E-API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils", section 1.3 Sub-heading 1.3. "Base Stock Categories").

35

The API currently defines five groups of lubricant base stocks (API 1509, Annex E - API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils, September 2011). Groups I, II and III are mineral oils which are classified by the amount of saturates and

- 12 -

sulphur they contain and by their viscosity indices; Group IV are polyalphaolefins; and Group V are all others, including e.g. ester oils. The table below illustrates these API classifications.

Group	Saturates	Sulphur content	Viscosity Index (VI)
I	< 90%	> 0.03%	80-120
II	at least 90%	not more than 0.03%	80-120
III	at least 90%	not more than 0.03%	at least 120
IV	All polyalphaolefins (PAOs)		
V	All others not included in Groups I, II, III or IV (e.g. ester oils)		

- 5 The kinematic viscosity at 100°C (KV₁₀₀) of appropriate apolar base oils used to prepare an additive composition or lubricating composition in accordance with the present invention is preferably in the range of 1 mm²/s to 10 mm²/s, more preferably in the range of 2 mm²/s to 8 mm²/s, according to ASTM D445.
- 10 Further base oils which can be used in accordance with the present invention are Group II-III Fischer-Tropsch derived base oils.
- Fischer-Tropsch derived base oils are known in the art. By the term "Fischer-Tropsch derived" is meant that a base oil is, or is derived from, a synthesis product of a Fischer-Tropsch process. A Fischer-Tropsch derived base oil may also be referred to as a GTL (Gas-To-Liquids) base oil.
- 15 Suitable Fischer-Tropsch derived base oils that may be conveniently used as the base oil in the lubricating composition of the present invention are those as for example disclosed in EP 0 776 959, EP 0 668 342, WO 97/21788, WO 00/15736, WO 00/14188, WO 00/14187, WO 00/14183, WO 00/14179, WO 00/08115, WO 99/41332, EP 1 029 029, WO 01/18156, WO 01/57166 and WO 2013/189951.
- 20 Especially for engine oil formulations are used base oils of API Group III and mixtures of different Group III oils.
- The additive composition of the present invention comprises preferably 60% to 80% by weight, more preferably 70% to 75% by weight, of base oil (component (A)), based on the total weight of the additive composition.
- 25 The concentration of the polyalkyl(meth)acrylate based comb polymer (component (B)) in the additive composition is preferably in the range from 20% to 40% by weight, more preferably in the range of 25% to 30% by weight, based on the total weight of the additive composition.
- 30 In a particular embodiment, the proportions of components (A) and (B) add up to 100% by weight.

- 13 -

A third object of the present invention is directed to a lubricating oil composition, comprising:

- (A) 85 to 99% by weight of a base oil;
- (B) 0.5 to 10% by weight of a polyalkyl(meth)acrylate based comb polymer, comprising the following monomers:
 - 5 (a) 10 to 20% by weight of esters of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene; and
 - (b) 0.5% to 5% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-
10 dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide;
- (C) 0.5 to 5% by weight of molybdenum-containing friction modifier delivering 0.05 to 0.5% by weight of molybdenum; and
- (D) optionally one or more further additives.

15

A preferred third object of the present invention is directed to a lubricating oil composition, comprising:

- (A) 85 to 99% by weight of a base oil;
- (B) 0.5 to 10% by weight of a polyalkyl(meth)acrylate based comb polymer, comprising the following monomers:
 - 20 (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 60% to 75% by weight of n-butyl methacrylate;
 - 25 (d) 10% to 20% by weight of C₁₀₋₃₀ alkyl (meth)acrylates, preferably C₁₀₋₁₅ alkyl methacrylates, more preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-
30 dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide;
- (C) 0.5 to 5% by weight of molybdenum-containing friction modifier delivering 0.05 to 0.5% by weight of molybdenum; and
- 35 (D) optionally one or more further additives.

A further preferred third object of the present invention is directed to a lubricating oil composition, comprising:

- (A) 85 to 99% by weight of a base oil;

- 14 -

- (B) 0.5 to 10% by weight of a polyalkyl(meth)acrylate based comb polymer, comprising the following monomers:
- (a) 14 to 16% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 65% to 70% by weight of n-butyl methacrylate;
 - (d) 14% to 17% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof, preferably N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide;
- (C) 0.5 to 5% by weight of molybdenum-containing friction modifier delivering 0.05 to 0.5% by weight of molybdenum; and
- (D) optionally one or more further additives.

The content of each component (A), (B), (C) and (D) is based on the total weight of the lubricating oil composition.

In a particular embodiment, the proportions of components (A) to (D) add up to 100% by weight.

The content of each component (a), (b), (c), (d), (e) and (f) is based on the total composition of the polyalkyl(meth)acrylate based comb polymer.

In a particular embodiment, the proportions of components (a), (b), (c), (d), (e) and (f) add up to 100% by weight.

The lubricating oil composition of the present invention comprises preferably 88 to 94.5% by weight of a base oil (component (A)), based on the total weight of the lubricating oil composition.

The concentration of the polyalkyl(meth)acrylate based comb polymer (component (B)) in the lubricating oil composition is preferably in the range of 5 to 10% by weight, based on the total weight of the lubricating oil composition.

The concentration of the molybdenum-containing friction modifier is preferably 0.5 to 2% by weight and more preferably 1 to 2% by weight. Accordingly, the amount of molybdenum which is delivered is preferably in the range of 0.05 to 0.2% by weight and more preferably in the range of 0.1 to 0.2% by weight, based on the total weight of the lubricating oil composition.

- 15 -

Further preferred contents of components (A), (B), (C) and (D) in the lubricating oil compositions according to the present invention are as detailed in the following table:

Lubricating Oil Composition	Component (A) [% by weight]	Component (B) [% by weight]	Component (C) [% by weight]
(1a)	88 to 99	0.5 to 10	0.5 to 2
(2a)	88 to 98.5	0.5 to 10	1 to 2
(3a)	85 to 94.5	5 to 10	0.5 to 5
(4a)	88 to 94.5	5 to 10	0.5 to 2
(5a)	88 to 94	5 to 10	1 to 2

Lubricating Oil Composition	Component (A) [% by weight]	Component (B) [% by weight]	Component (C) [% by weight]	Component (D) [% by weight]
(1b)	70 to 99	0.5 to 10	0.5 to 5	0 to 15
(2b)	73 to 99	0.5 to 10	0.5 to 2	0 to 15
(3b)	73 to 98.5	0.5 to 10	1 to 2	0 to 15
(4b)	70 to 94.5	5 to 10	0.5 to 5	0 to 15
(5b)	73 to 94.5	5 to 10	0.5 to 2	0 to 15
(6b)	73 to 94	5 to 10	1 to 2	0 to 15

5

In a particular embodiment, the proportions of components (A), (B), (C) and (D) add up to 100% by weight.

As additives which may deliver molybdenum can be used commercially available molybdenum-containing friction modifiers, preferably molybdenum dithiocarbamates (MoDTCs).

Commercially available molybdenum dithiocarbamates are, for example, the MOLIVAN® series from R.T. Vanderbilt Company, Inc., New York. As an especially preferred example Molivan®3000 can be used which contains 10% of molybdenum.

The molybdenum-containing friction modifier may be present in a range of 0.5 to 5% by weight, preferably 0.5 to 2% by weight, more preferably 1 to 2% by weight, based on the total weight of the lubricating oil composition, and delivers 0.005 to 0.5% by weight, preferably 0.05 to 0.2% by weight, and more preferably 0.1 to 0.2% by weight of molybdenum.

The lubricating oil compositions according to the present invention are characterized by their low friction coefficient. They are especially characterized by a friction coefficient below 0.1, preferably between 0.05 and 0.1 (measured after 30 minutes).

20

The lubricating oil compositions according to the present invention are further characterized by their low KV₄₀ values. The KV₄₀ is preferably below 25 mm²/s, more preferably between 18 and 22 mm²/s, even more preferred around 20 mm²/s, i.e. 20±1 mm²/s (when formulated to a given KV₈₀ of 7 mm²/s).

Preferred lubricating oil compositions are characterized by a friction coefficient between 0.05 and 0.1 (measured after 30 minutes) and a KV₄₀ of below 25 mm²/s, preferably between 18 and 22 mm²/s and more preferably of 20±1 mm²/s.

10

The lubricating oil composition according to the invention may also contain, as component (D), further additives selected from the group consisting of conventional VI improvers, dispersants, defoamers, detergents, antioxidants, pour point depressants, antiwear additives, extreme pressure additives, anticorrosion additives, dyes and mixtures thereof.

15

Conventional VI improvers include hydrogenated styrene-diene copolymers (HSDs, US4116 917, US3772196 and US4788316), especially based on butadiene and isoprene, and also olefin copolymers (OCPs, K. Marsden: "Literature Review of OCP Viscosity Modifiers", Lubrication Science 1 (1988), 265), especially of the poly(ethylene-co-propylene) type, which may often also be present in N/O-functional form with dispersing action, or PAMAs, which are usually present in N-functional form with advantageous additive properties (*boosters*) as dispersants, wear protection additives and/or friction modifiers (DE 1 520 696 to Röhm and Haas, WO 2006/007934 to RohMax Additives).

Compilations of VI improvers and pour point improvers for lubricant oils, especially motor oils, are detailed, for example, in T. Mang, W. Dresel (eds.): "Lubricants and Lubrication", Wiley-VCH, Weinheim 2001; R. M. Mortier, S. T. Orszulik (eds.): "Chemistry and Technology of Lubricants", Blackie Academic & Professional, London 1992; or J. Bartz: "Additive für Schmierstoffe", Expert-Verlag, Renningen-Malmsheim 1994.

30

Appropriate dispersants include poly(isobutylene) derivatives, for example poly(isobutylene)succinimides (PIBSIs), including borated PIBSIs; and ethylene-propylene oligomers having N/O functionalities.

Dispersants (including borated dispersants) are preferably used in an amount of 0 to 5% by weight, based on the total amount of the lubricating oil composition.

35

Suitable defoamers are silicone oils, fluorosilicone oils, fluoroalkyl ethers, etc..

The defoaming agent is preferably used in an amount of 0.005 to 0.1% by weight, based on the total amount of the lubricating oil composition.

- 17 -

The preferred detergents include metal-containing compounds, for example phenoxides; salicylates; thiophosphonates, especially thiopyrophosphonates, thiophosphonates and phosphonates; sulfonates and carbonates. As metal, these compounds may contain especially calcium, magnesium and barium. These compounds may preferably be used in neutral or overbased form.

Detergents are preferably used in an amount of 0.2 to 1% by weight, based on the total amount of the lubricating oil composition.

The suitable antioxidants include, for example, phenol-based antioxidants and amine-based antioxidants.

Phenol-based antioxidants include, for example, octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate; 4,4'-methylenebis(2,6-di-tert-butylphenol); 4,4'-bis(2,6-di-tert-butylphenol); 4,4'-bis(2-methyl-6-tert-butylphenol); 2,2'-methylenebis(4-ethyl-6-tert-butylphenol); 2,2'-methylenebis(4-methyl-6-tert-butylphenol); 4,4'-butylidenebis(3-methyl-6-tert-butylphenol); 4,4'-isopropylidenebis(2,6-di-tert-butylphenol); 2,2'-methylenebis(4-methyl-6-nonylphenol); 2,2'-isobutylidenebis(4,6-dimethylphenol); 2,2'-methylenebis(4-methyl-6-cyclohexylphenol); 2,6-di-tert-butyl-4-methylphenol; 2,6-di-tert-butyl-4-ethylphenol; 2,4-dimethyl-6-tert-butylphenol; 2,6-di-tert-amyl-p-cresol; 2,6-di-tert-butyl-4-(N,N'-dimethylaminomethylphenol); 4,4'-thiobis(2-methyl-6-tert-butylphenol); 4,4'-thiobis(3-methyl-6-tert-butylphenol); 2,2'-thiobis(4-methyl-6-tert-butylphenol); bis(3-methyl-4-hydroxy-5-tert-butylbenzyl) sulfide; bis(3,5-di-tert-butyl-4-hydroxybenzyl) sulfide; n-octyl-3-(4-hydroxy-3,5-di-tert-butylphenyl)propionate; n-octadecyl-3-(4-hydroxy-3,5-di-tert-butylphenyl)propionate; 2,2'-thio[diethyl-bis-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], etc. Of those, especially preferred are bis-phenol-based antioxidants and ester group containing phenol-based antioxidants.

The amine-based antioxidants include, for example, monoalkyldiphenylamines such as mono-octyldiphenylamine, monononyldiphenylamine, etc.; dialkyldiphenylamines such as 4,4'-dibutyldiphenylamine, 4,4'-dipentyldiphenylamine, 4,4'-dihexyldiphenylamine, 4,4'-diheptyldiphenylamine, 4,4'-dioctyldiphenylamine, 4,4'-dinonyldiphenylamine, etc.; polyalkyldiphenylamines such as tetrabutyldiphenylamine, tetrahexyldiphenylamine, tetraoctyldiphenylamine, tetranonyldiphenylamine, etc.; naphthylamines, concretely alpha-naphthylamine, phenyl-alpha-naphthylamine and further alkyl-substituted phenyl-alpha-naphthylamines such as butylphenyl-alpha-naphthylamine, pentylphenyl-alpha-naphthylamine, hexylphenyl-alpha-naphthylamine, heptylphenyl-alpha-naphthylamine, octylphenyl-alpha-naphthylamine, nonylphenyl-alpha-naphthylamine, etc. Of those, diphenylamines are preferred to naphthylamines, from the viewpoint of the antioxidation effect thereof.

Suitable antioxidants may further be selected from the group consisting of compounds containing sulfur and phosphorus, for example metal dithiophosphates, for example zinc dithiophosphates (ZnDTPs), "OOS triesters" = reaction products of dithiophosphoric acid with activated double bonds from olefins, cyclopentadiene, norbornadiene, α -pinene, polybutene, acrylic esters, maleic esters

- 18 -

(ashless on combustion); organosulfur compounds, for example dialkyl sulfides, diaryl sulfides, polysulfides, modified thiols, thiophene derivatives, xanthates, thioglycols, thioaldehydes, sulfur-containing carboxylic acids; heterocyclic sulfur/nitrogen compounds, especially dialkyldimercaptothiadiazoles, 2-mercaptobenzimidazoles; zinc bis(dialkyldithiocarbamate) and methylene bis(dialkyldithiocarbamate); organophosphorus compounds, for example triaryl and trialkyl phosphites; organocopper compounds and overbased calcium- and magnesium-based phenoxides and salicylates.

Antioxidants are used in an amount of 0 to 15% by weight, preferably 0.1 to 10% by weight, more preferably 0.5 to 5% by weight, based on the total amount of the lubricating oil composition.

The pour-point depressants include ethylene-vinyl acetate copolymers, chlorinated paraffin-naphthalene condensates, chlorinated paraffin-phenol condensates, polymethacrylates, polyalkylstyrenes, etc. Preferred are polymethacrylates having a mass-average molecular weight of from 5.000 to 200.000 g/mol.

The amount of the pour point depressant is preferably from 0.1 to 5% by weight, based on the total amount of the lubricating oil composition.

The preferred antiwear and extreme pressure additives include sulfur-containing compounds such as zinc dithiophosphate, zinc di-C₃₋₁₂-alkyldithiophosphates (ZnDTPs), zinc phosphate, zinc dithiocarbamate, molybdenum dithiocarbamate, molybdenum dithiophosphate, disulfides, sulfurized olefins, sulfurized oils and fats, sulfurized esters, thiocarbonates, thiocarbamates, polysulfides, etc.; phosphorus-containing compounds such as phosphites, phosphates, for example trialkyl phosphates, triaryl phosphates, e.g. tricresyl phosphate, amine-neutralized mono- and dialkyl phosphates, ethoxylated mono- and dialkyl phosphates, phosphonates, phosphines, amine salts or metal salts of those compounds, etc.; sulfur and phosphorus-containing anti-wear agents such as thiophosphites, thiophosphates, thiophosphonates, amine salts or metal salts of those compounds, etc.

The antiwear agent may be present in an amount of 0 to 3% by weight, preferably 0.1 to 1.5% by weight, more preferably 0.5 to 0.9% by weight, based on the total amount of the lubricating oil composition.

Some of the compounds listed above may fulfil multiple functions. ZnDTP, for example, is primarily an antiwear additive and extreme pressure additive, but also has the character of an antioxidant and corrosion inhibitor (here: metal passivator/deactivator).

The above-detailed additives are described in detail, inter alia, in T. Mang, W. Dresel (eds.): "Lubricants and Lubrication", Wiley-VCH, Weinheim 2001; R. M. Mortier, S. T. Orszulik (eds.): "Chemistry and Technology of Lubricants".

- 19 -

Preferably, the total concentration of the one or more additives (D) is 0 to 15% by weight, more preferably 0.05% to 15% by weight, more preferably 3% to 10% by weight, based on the total weight of the lubricating oil composition.

5 The invention has been illustrated by the following non-limiting examples.

Experimental Part

Abbreviations

10

AMA C₁₂₋₁₄ alkyl methacrylate

BMA n-butyl methacrylate

DMAEMA N,N-dimethylaminoethyl methacrylate

DMAPMAM N,N-dimethylaminopropyl methacrylamide

15

Hydroseal

G232H base oil from Total with a KV₁₀₀ of 1 cSt

LMA lauryl methacrylate, 73% C12, 27% C14, all linear

KV₄₀ kinematic viscosity @40°C, measured according to ASTM D7042

KV₈₀ kinematic viscosity @80°C, measured according to ASTM D7042

20

KV₁₀₀ kinematic viscosity @100°C, measured according to ASTM D7042

M_n number-average molecular weight

M_w weight-average molecular weight

MMA methyl methacrylate

Molyvan®3000 Molybdenum content is 10.1% by weight

25

NB3020 Nexbase® 3020, Group III base oil from Neste with a KV₁₀₀ of 2.2 cSt

NB3043 Nexbase® 3043, Group III base oil from Neste with a KV₁₀₀ of 4.3 cSt

PDI Polydispersity index

Shell Risella

X420 Group III base oil from Shell, KV₁₀₀ = 4.1 cSt, KV₄₀ = 18.2 cSt, VI = 131,
density = 0.808 g/cm³

30

tBPO tert-butyl peroctoate

VI viscosity index, measured according to ASTM D2270

Test methods

35

The comb polymers according to the present invention and the comparative examples were characterized with respect to their molecular weight and PDI.

- 20 -

The weight average and number average molecular weights were determined by GPC with RI detector in tetrahydrofuran at 40°C using a polymethyl methacrylate calibration. A combination of PSS-SDV Linear XL 10 μ * 2 and PSS-SDV 100A columns was used. Flow rate is 1 mL/min. Injection volume is 100 μ L.

5

The lubricating oil compositions including the comb polymers according to the present invention and comparative examples were characterized with respect to kinematic viscosity at 40°C (KV₄₀), 80°C (KV₈₀) and 100°C (KV₁₀₀) to ASTM D445, the viscosity index (VI) to ASTM D 2270, low temperature storage test was performed at -20°C for 1 week and the appearance was observed by visual. The friction coefficient was measured according to ASTM D6425 (load: 400 N, Oscillation = 3 mm*50Hz, Temperature is 80°C, Cylinder on disc, Steel cylinder = ϕ 15 * 22 mm, Steel disc = ϕ 24*7.9 mm, Sample volume = 100 μ L) and values are reported after 30 and 60 minutes.

10

Synthesis of a hydroxylated hydrogenated polybutadiene

15

The macroalcohol prepared was a hydroxypropyl-terminated hydrogenated polybutadiene having a mean molar mass $M_n = 4750$ g/mol.

20

The macroalcohol was synthesized by an anionic polymerization of 1,3-butadiene with butyllithium at 20-45°C. On attainment of the desired degree of polymerization, the reaction was stopped by adding propylene oxide and lithium was removed by precipitation with methanol. Subsequently, the polymer was hydrogenated under a hydrogen atmosphere in the presence of a noble metal catalyst at up to 140°C and pressure 200 bar. After the hydrogenation had ended, the noble metal catalyst was removed and organic solvent was drawn off under reduced pressure. Finally, the base oil NB3020 was used for dilution to a polymer content of 70% by weight.

25

The vinyl content of the macroalcohol was 61%, the hydrogenation level > 99% and the OH-functionality > 98%. These values were determined by ¹H-NMR (nuclear resonance spectroscopy).

30

Synthesis of macromonomer (MM)

35

In a 2 L stirred apparatus equipped with saber stirrer, air inlet tube, thermocouple with controller, heating mantle, column having a random packing of 3 mm wire spirals, vapor divider, top thermometer, reflux condenser and substrate cooler, 1000 g of the above-described macroalcohol are dissolved in 450 g of methyl methacrylate (MMA) by stirring at 60°C. Added to the solution are 20 ppm of 2,2,6,6-tetramethylpiperidin-1-oxyl radical and 200 ppm of hydroquinone monomethyl ether. After heating to MMA reflux (bottom temperature about 110°C) while passing air through for stabilization, about 20 g of MMA are distilled off for azeotropic drying. After cooling to 95°C, 0.30 g

- 21 -

of LiOCH_3 is added and the mixture is heated back to reflux. After the reaction time of about 1 hour, the top temperature has fallen to $\sim 64^\circ\text{C}$ because of methanol formation. The methanol/MMA azeotrope formed is distilled off constantly until a constant top temperature of about 100°C is established again. At this temperature, the mixture is left to react for a further hour. For further workup, the bulk of MMA is drawn off under reduced pressure. Insoluble catalyst residues are removed by pressure filtration (Seitz T1000 depth filter). The content of NB3020 "entrained" into the copolymer syntheses described further down was taken into account accordingly.

Preparation of Polymer A-C

10

In a beaker, the reaction mixture was made up according to Table 1. A 2 liter 4-neck round-bottom flask with saber stirrer, nitrogen blanketing, thermometer, heater, and reflux condenser was initially charged with 199.7 g of the reaction mixture and heated to 95°C while stirring. During the heating phase, nitrogen was passed through the reaction flask for inertization. On attainment of 95°C , 0.20 g of tBPO was introduced into the reaction flask; at the same time, the feed consisting of the rest of the reaction mixture and 0.20 g of tBPO was started. The feed time was 3 hours; the reaction temperature was kept constant at 95°C . After the end of feed, it was held for 45 minutes. Then 101.1 g of NB3043 was fed over 180 minutes. 0.4 g of tBPO was charged into dilution feed oil of NB3043 in 75 minutes. In the end of feed, the batch was kept at 95°C for 2 hours, and then 0.40 g of tBPO and 165.3 g of NB3043 were charged into the reaction flask. Next day, 133.1 g of NB3043 was charged into the reaction flask and held the batch for 1 hour. 800 g of a high-viscosity solution was obtained.

15

20

Preparation of Polymers D and E

25

Polymers D and E were prepared according to Examples 1 and 2 of WO 2010/102903, respectively (see pages 61 and 62, herein incorporated by reference).

Table 1

	Polymer A	Polymer B	Polymer C	Polymer D	Polymer E
70% Macromonomer solution in oil [g]	42.8	42.8	42.8	90.0	94.3
LMA [g]	30.7	32.6	30.0	--	--
AMA [g]				0.3	0.3
BMA [g]	136.8	132.4	139.0	12.6	12.6
Styrene [g]	0.4	0.4	0.4	68.7	65.7
MMA [g]	0.4	0.4	0.4	0.3	0.3

- 22 -

	Polymer A	Polymer B	Polymer C	Polymer D	Polymer E
DMAEMA [g]	1.5	-	-	5.1	--
DMAPMAm [g]	-	4.0	-	--	5.1
NB3043 [g]	100.6	100.6	100.6	--	--
Hydrosel G232H [g]	86.2	86.2	86.2	--	--

The net compositions of the resulting comb polymers as well as their characteristic weight-average molecular weights M_w and their polydispersity indices (PDI) are given in the following Table 2. If not otherwise specified, [%] means % by weight.

5

Table 2: Net compositions of the comb polymers prepared according to the present invention

	Example 1	Example 2	Example 3 (CE)*	Example 4 (CE)*	Example 5 (CE)*
Polymer	Polymer A	Polymer B	Polymer C	Polymer D	Polymer E
Macromonomer [%]	15.0	15.0	15.0	42.0	44.0
LMA [%]	15.3	16.3	15.0	0.2	0.2
MMA [%]	0.2	0.2	0.2	0.2	0.2
BMA [%]	68.5	66.3	69.6	8.4	8.4
Styrene [%]	0.2	0.2	0.2	45.8	43.8
DMAPMA [%]	--	2.0	--	--	3.4
DMAEMA [%]	0.8	--	--	3.4	--
Total [%]	100	100	100	100	100
M_w [g/mol]	331.444	323.478	347.668	225.255	239.988
M_n [g/mol]	84.735	73.791	86.096	55.663	48.418
PDI	3.91	4.38	4.04	4.05	4.96

*) CE = comparative example

- 10 Examples 1 and 2 are in accordance with the present invention and comprise N-dispersant monomers within the defined ranges. Example 3 is a comparative example as it does not comprise any N-dispersant monomers. Examples 4 and 5 comprise N-dispersant monomers (DMAPMAm and DMAEMA) but higher amounts of macromonomer and lower amounts of butyl methacrylate than defined in the present invention.

15

- 23 -

To demonstrate the effect of the polyalkyl(methacrylate) based comb polymers according to the present invention on the solubility of molybdenum in lubricating oil compositions different formulation examples **A** were prepared and the corresponding viscosity data (KV₄₀, KV₈₀, KV₁₀₀, VI), stability (storage test) and friction coefficients were determined. The results are summarized in

5 Table 3.

Table 3: Lubricating oil compositions **A**

	A1	A2	A3	A4	A5	A6 (CE)*	A7 (CE)*	A8 (CE)*	A9 (CE)*
Polymer A [%]	7.9	--	--	--	--	--	--	--	--
Polymer B [%]	--	8.4	7.9	7.9	7.8	--	--	--	--
Polymer C [%]	--	--	--	--	--	--	8.0	8.0	7.9
Polymer D [%]	--	--	--	--	--	--	--	--	--
Polymer E [%]	--	--	--	--	--	--	--	--	--
Base Oil (Shell Risella X420) [%]	91.1	91.1	91.1	90.6	90.2	99.0	91.8	91.5	91.1
Molyvan®3000 (MoDTC) [%]	1.0	0.50	1.0	1.50	2.0	1.0	0.25	0.50	1.0
Mo content [%]	0.10	0.050	0.10	0.15	0.20	0.10	0.025	0.05	0.10
Total [%]	100	100	100	100	100	100	100	100	100
KV ₁₀₀ [mm ² /s]	4.89	4.88	4.86	4.88	4.92	**) Precipitation was observed	5.05	5.08	**) Precipitation was observed
KV ₈₀ [mm ² /s]	6.91	6.93	6.91	6.95	7.01		6.92	6.96	
KV ₄₀ [mm ² /s]	20.04	20.10	20.14	20.23	20.42		19.68	19.77	
VI	181	179	177	177	178		202	203	
Low temperature storage test (-20°C, 1 week)	No precipitation	No precipitation	No precipitation	No precipitation	No precipitation	Precipitation was observed	No precipitation	No precipitation	Precipitation was observed

	A1	A2	A3	A4	A5	A6 (CE) ^{*)}	A7 (CE) ^{*)}	A8 (CE) ^{*)}	A9 (CE) ^{*)}
SRV test @80°C Friction coefficient @30 min	0.067	0.157	0.072	0.073	0.067	--	--	0.155	--
SRV test @80°C Friction coefficient @60 min	0.149	0.139	0.141	0.066	0.060	--	--	0.159	--

*) CE = comparative example

**) Not applicable due to precipitation of MoDTC

Table 3 continued

	A10 (CE) ^{*)}	A11 (CE) ^{*)}	A12 (CE) ^{*)}	A13 (CE) ^{*)}
Polymer A [%]	--	--	--	--
Polymer B [%]	--	--	--	--
Polymer C [%]	--	--	--	--
Polymer D [%]	4.2	4.2	--	--
Polymer E [%]	--	--	4.0	3.9
Base Oil (Shell Risella X420) [%]	94.8	93.8	95.0	94.1
Molyvan®3000 (MoDTC)	1.0	2.0	1.0	2.0

	A10 (CE)*	A11 (CE)*	A12 (CE)*	A13 (CE)*
[%]				
Mo content [%]	0.10	0.20	0.10	0.20
Total [%]	100	100	100	100
KV ₁₀₀ [mm ² /s]	4.72	4.78	4.71	4.76
KV ₈₀ [mm ² /s]	6.98	7.03	6.93	7.0
KV ₄₀ [mm ² /s]	20.78	21.15	20.81	21.15
VI	154	155	153	153
Low temperature storage test (-20°C, 1 week)	No precipitation, but appearance was hazy	Precipitation was observed	No precipitation, but appearance was hazy	Precipitation was observed
SRV test @80°C Friction coefficient @30 min	0.051	--	0.053	--
SRV test @80°C Friction coefficient @60 min	0.139	--	0.149	--

*) CE = comparative example

**) Not applicable due to precipitation of MoDTC

- 27 -

Formulations A1 to A5 are according to the present invention as they contain a polyalkyl(meth)acrylate based comb polymer comprising a macromonomer and nitrogen-containing (meth)acrylates. Formulation A6 does not contain any polyalkyl(meth)acrylate based comb polymer; formulations A7 to A9 contain a polyalkyl(meth)acrylate based comb polymer, but no nitrogen-containing monomer. Formulations A10 to A13 contain a polyalkyl(meth)acrylate based comb polymer, but different amounts of macromonomer and butyl methacrylate than the claimed ranges.

As the test temperature of SRV is 80°C the KV_{80} of all formulations was adjusted to about 7 mm²/s in order to minimize the influence of viscosity on the corresponding friction coefficients.

10

Table 3 clearly shows that in formulations comprising a comb polymer in accordance with the present invention (Formulations A1 to A5) up to 2% of molybdenum dithiocarbamate (Molyvan®3000) can be dissolved (delivering up to 0.2% by weight of molybdenum); the storage tests did not reveal any haziness or precipitation. Molyvan®3000 comprises 10% by weight of molybdenum.

15

Formulation A6 which does not contain a comb polymer was not able to dissolve even 1% of molybdenum dithiocarbamate (Molyvan®3000); precipitation was observed.

20

When using a comb polymer without N-dispersant monomer, in corresponding formulations could be dissolved up to 0.5% of molybdenum dithiocarbamate (Molyvan®3000). When adding 1% of molybdenum dithiocarbamate (Molyvan®3000) precipitation was observed (Formulations A7 to A9).

25

When using comb polymers comprising N-dispersant monomers but different amounts of macromonomer and butyl methacrylate than the claimed ranges, in corresponding formulations can be dissolved 1% of molybdenum dithiocarbamate (Molyvan®3000) but there appears already haziness (Formulations A10 and A12). By adding 2% of molybdenum dithiocarbamate (Molyvan®3000) precipitation was observed (Formulations A11 and A13).

30

Additionally, only the compositions comprising a comb polymer in accordance with the present invention show significant long-term friction reduction (SRV test after 60 minutes): the friction coefficient can be reduced especially when 0.15 and 0.2% of molybdenum are added from 0.139 (Formulation A2 comprising 0.05% of molybdenum) to 0.066 (Formulation A4 comprising 0.15% of molybdenum) and 0.060 (Formulation A5 comprising 0.2% of molybdenum).

- 28 -

Claims

1. A polyalkyl(meth)acrylate based comb polymer, consisting of the following monomers:
- (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 60% to 75% by weight of n-butyl methacrylate;
 - (d) 10% to 20% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof.
2. The polyalkyl(meth)acrylate based comb polymer according to claim 1, consisting of the following monomers:
- (a) 14 to 16% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 65% to 70% by weight of n-butyl methacrylate;
 - (d) 14% to 17% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.
3. The polyalkyl(meth)acrylate based copolymer according to claim 1 or 2, characterized in that they have a weight-average molecular weight M_w in the range of 200.000 to 500.000 g/mol, preferably in the range of 300.000 to 400.000 g/mol.
4. The polyalkyl(meth)acrylate based copolymer according to claim 1 to 3, characterized in that the hydroxylated hydrogenated polybutadiene of component (a) has a number-average molecular weight M_n in the range of 4.000 to 6.000 g/mol, preferably of 4.000 to 5.000 g/mol.
5. The polyalkyl(meth)acrylate based copolymer according to claim 1 to 4, characterized in that the nitrogen-containing (meth)acrylates are selected from the group consisting of N,N-dimethylaminoethyl methacrylate, N,N-dimethylaminopropylmethacrylamide and mixtures thereof.

- 29 -

6. Additive composition, comprising:
- (A) 60 to 80% by weight of a base oil; and
 - (B) 20 to 40% by weight of a polyalkyl(meth)acrylate based copolymer, consisting of the following monomers:
 - (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 60% to 75% by weight of n-butyl methacrylate;
 - (d) 10% to 20% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof.
7. The additive composition according to claim 6, wherein the polyalkyl(meth)acrylate based copolymer consists of the following monomers:
- (a) 14 to 16% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
 - (b) 0% to 1% by weight of methyl methacrylate;
 - (c) 65% to 70% by weight of n-butyl methacrylate;
 - (d) 14% to 17% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
 - (e) 0% to 1% by weight of styrene monomers; and
 - (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of N,N-dimethylaminoethyl methacrylate and N,N-dimethylaminopropyl methacrylamide.
8. The additive composition according to claim 6 or 7, wherein the base oil is selected from the group consisting of API Group I, II, III, IV, V oils and mixtures thereof.
9. The additive composition according to claim 6, 7 or 8, wherein component (A) is present in an amount of 70 to 75% by weight and component (B) is present in an amount of 25 to 30% by weight.
10. A lubricating oil composition, comprising:
- (A) 85 to 99% by weight of a base oil;
 - (B) 0.5 to 10% by weight of a polyalkyl(meth)acrylate based comb polymer, consisting of the following monomers:

- 30 -

- 5 (a) 10 to 20% by weight of an ester of (meth)acrylic acid and a hydroxylated hydrogenated polybutadiene;
- (b) 0% to 1% by weight of methyl methacrylate;
- (c) 60% to 75% by weight of n-butyl methacrylate;
- 10 (d) 10% to 20% by weight of C₁₀₋₁₅ alkyl methacrylates, preferably C₁₂₋₁₄ alkyl methacrylates;
- (e) 0% to 1% by weight of styrene monomers; and
- (f) 0.5 to 3% by weight of a nitrogen-containing (meth)acrylate selected from the group consisting of aminoalkyl (meth)acrylates, aminoalkyl(meth)acrylamides and mixtures thereof;
- 15 (C) 0.5 to 5% by weight of molybdenum-containing friction modifier delivering 0.005 to 0.5% by weight of molybdenum; and
- (D) optionally, one or more further additives.
11. The lubricating oil composition according to claim 10, characterized in that component (A) is present in an amount of 88 to 98.5% by weight, component (B) is present in an amount of 0.5 to 10% by weight and component (C) is present in an amount of 1 to 2% by weight, delivering 0.1 to 0.2% by weight of molybdenum, based on the total weight of the lubricating oil composition.
12. The lubricating oil composition according to claim 10 or 11, characterized in that the base oil is selected from the group consisting of API Group III oils and mixtures thereof.
13. The lubricating oil composition according to claim 10, 11 or 12, characterized by a friction coefficient below 0.1; preferably between 0.05 and 0.1.
14. Use of a polyalkyl(meth)acrylate based comb polymer according to claims 1 to 5 as a solubilizer for molybdenum, especially derived from molybdenum dithiocarbamate (MoDTC) in lubricating oil compositions.
15. Use according to claim 14, characterized in that 0.005 to 0.5% by weight, preferably 0.05 to 0.2% by weight, and more preferably 0.1 to 0.2% by weight of molybdenum can be dissolved.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/083038

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10M149/04 C10M149/06
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M C10N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2015 183123 A (SANYO CHEMICAL IND LTD) 22 October 2015 (2015-10-22) paragraph [0078]; examples 2,12; tables 2,3	1-15
A	----- JP 2014 224246 A (SANYO CHEMICAL IND LTD) 4 December 2014 (2014-12-04) paragraph [0062]; examples 1-4,9-12; tables	1-15
A	----- US 2016/097017 A1 (EISENBERG BORIS [DE] ET AL) 7 April 2016 (2016-04-07) cited in the application paragraph [0107]; claims; examples	1-15
	----- -/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

9 February 2018

Date of mailing of the international search report

05/03/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kazemi, Pirjo

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/083038

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/306533 A1 (EISENBERG BORIS [DE] ET AL) 15 December 2011 (2011-12-15) cited in the application claims; examples; tables -----	1-15
A	EP 3 093 334 A1 (SANYO CHEMICAL IND LTD [JP]) 16 November 2016 (2016-11-16) examples -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/083038

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2015183123 A	22-10-2015	NONE	
JP 2014224246 A	04-12-2014	JP 5878199 B2 JP 2014224246 A	08-03-2016 04-12-2014
US 2016097017 A1	07-04-2016	CA 2909115 A1 CN 105246928 A EP 2986653 A1 JP 6218924 B2 JP 2016515658 A KR 20150143721 A RU 2015149262 A SG 11201508650R A US 2016097017 A1 WO 2014170169 A1	23-10-2014 13-01-2016 24-02-2016 25-10-2017 30-05-2016 23-12-2015 24-05-2017 27-11-2015 07-04-2016 23-10-2014
US 2011306533 A1	15-12-2011	CA 2755057 A1 CN 102348789 A DE 102009001446 A1 EP 2406360 A1 JP 5705137 B2 JP 2012520359 A KR 20110133474 A RU 2011140693 A SG 173835 A1 US 2011306533 A1 WO 2010102903 A1	16-09-2010 08-02-2012 23-09-2010 18-01-2012 22-04-2015 06-09-2012 12-12-2011 20-04-2013 29-09-2011 15-12-2011 16-09-2010
EP 3093334 A1	16-11-2016	CN 106062155 A EP 3093334 A1 JP 6060311 B2 JP WO2015129732 A1 KR 20160125374 A US 2017009177 A1 WO 2015129732 A1	26-10-2016 16-11-2016 11-01-2017 30-03-2017 31-10-2016 12-01-2017 03-09-2015