

**HYDROGENATED MULTIBLOCK LINEAR STYRENE-BUTADIENE
COPOLYMERS, PROCESS FOR THEIR PREPARATION AND THEIR USE AS
VISCOSITY INDEX-IMPROVER ADDITIVES**

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DESCRIPTION

The present invention relates to hydrogenated multiblock linear styrene-butadiene copolymers.

More particularly, the present invention relates to a hydrogenated multiblock linear styrene-butadiene copolymer having a specific multiblock architecture, i.e.,
10 having the specific general formula (I) or (II) below reported.

The above-mentioned hydrogenated multiblock linear styrene-butadiene copolymer can advantageously be used as a viscosity index improver (V.I.I.) additive of lubricating oil compositions such as, for example, lubricating oil compositions for passenger cars, both diesel and petrol, or for heavy duty diesel engine, and functional
15 fluids such as, for example, manual or automatic transmission fluids and hydraulic fluids.

The present invention also relates to processes for the preparation of said hydrogenated multiblock linear styrene-butadiene copolymer.

The present invention also relates to concentrated solutions comprising at least
20 one hydrogenated multiblock linear styrene-butadiene copolymer above reported in at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

The present invention also relates to a lubricating oil composition comprising at least one hydrogenated multiblock linear styrene-butadiene copolymer reported above,
25 either as such or in a concentrated solution, and at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

It is known that the viscosity of lubricating oils varies with temperature. Many lubricating oils have to be used over a wide temperature range, so it is important that the
30 lubricating oil is not too viscous at low temperatures and not too fluid at high temperatures. The change in viscosity of a lubricating oil with temperature is expressed

by the viscosity index value: the higher the viscosity index value, the lower the change in viscosity of the lubricating oil with temperature.

Polymer-based additives are also known to be used as viscosity index improvers (V.I.I.) of lubricating oils, in order to modulate the viscosity of said lubricating oils as the temperature changes, i.e. to increase the viscosity at high temperatures and to limit the increase in viscosity at low temperatures as much as possible.

For example, polymers usually used as viscosity index improvers (V.I.I.) of lubricating oils are: ethylene-propylene copolymers [also known in the industry as Olefin CoPolymers (OCP)], hydrogenated conjugated polydienes (for example, hydrogenated polyisoprene), hydrogenated styrene/butadiene copolymers, hydrogenated styrene/isoprene copolymers, polyalkyl methacrylates.

The synthesis and use in lubricants of hydrogenated linear polymers of conjugated dienes and conjugated styrene-diene copolymers in lubricating oil compositions are described, for example, in the following US patents: US 3,554,911 (hydrogenated random butadiene-styrene copolymers); US 3,668,125 (hydrogenated or saturated block copolymers having at least three blocks, for example, hydrogenated polystyrene-polybutadiene, hydrogenated polystyrene-polyisoprene); US 3,772,196 [di-block copolymer comprising a first block derived from an alkenyl arene (e.g., styrene) and a second block derived from essentially fully hydrogenated isoprene]; US 3,775,329 (hydrogenated “tapered” isoprene-styrene copolymer); US 3,835,053 (hydrogenated polyisoprene homopolymer); EP 585269 [hydrogenated butadiene-diene copolymer, e.g., hydrogenated butadiene-isoprene copolymer, possibly with a star structure] and EP 578725 (hydrogenated polybutadiene block copolymer comprising 1,4-butadiene monomer units and 1,2-butadiene monomer units).

US patent US 9,133,413 relates to polymers adapted for use as viscosity index improvers for lubricating oil compositions comprising:

- linear polymers characterized by the formula:



- star polymers characterized by the formula:



wherein D' represents a block derived from at least one diene selected from isoprene

and butadiene; PA represents a block derived from styrene; D'' represents a block derived from at least one diene selected from isoprene and butadiene; n is comprised between 10 and 20 and represents the average number of arms per star polymer; and X represents a polyalkenyl coupling agent core;

- 5 wherein at least one of the diene block D' and D'' is a copolymeric block derived from a mixture of diene monomers, wherein from about 72% by weight to about 85% by weight of the incorporated monomeric units are from isoprene and from about 15% by weight to about 28% by weight of the incorporated monomeric units are from butadiene, and wherein at least about 80% by weight of the butadiene is incorporated in a 1,4
10 configuration; and

- wherein D' has a number-average molecular weight from about 20000 to about 60000 daltons; PA has a number-average molecular weight from about 10000 to about 35000 daltons; and D'' has a number-average molecular weight from about 5000 to about 30000 daltons. The above-mentioned polymers are said to be adapted for use as viscosity
15 index improvers for lubricating oil compositions including lubricating oil compositions for passenger cars and heavy-duty diesel engines, as well as for marine diesel engines and functional fluids such as, for example, automatic transmission fluids.

US patent application US 2021/0171853 relates to viscosity modifier (VM) concentrate comprising:

- 20 - from about 60 parts to about 95 parts of a diluent oil; and
- from about 5 parts to about 40 parts of a linear triblock copolymer characterized by the formula:



- 25 wherein D' represents a block derived from a diene, PA represents a block derived from a monoalkenyl arene, D'' represents a block derived from a diene, and the linear triblock copolymer is present in an effective amount for modifying the kinematic lubricating viscosity at approximately 100°C (KV100) of the concentrate,

- wherein the concentrate comprises at least 50% by weight of the diluent oil and the
30 effective amount of the linear triblock copolymer is such that the concentrate comprises at least 6% by weight of the linear triblock copolymer, and

wherein the KV100 of the diluent oil is comprised between about 2 cSt and about 40 cSt, the KV100 of the concentrate is about 2000 cSt or less, and the concentrate has a beaker pour at about 80°C of at least 87% and/or a $\tan \delta$ of at least 1.8. The above-mentioned linear triblock copolymers are said to be suitable for use as viscosity
5 modifiers/viscosity index improvers for lubricating oil compositions including lubricating oil compositions for passenger cars and heavy-duty diesel engines, as well as for marine diesel engines and functional fluids such as, for example, manual/automatic transmission fluids.

For each of the above-mentioned classes of (co)polymers, an increase in the
10 weight-average molecular weight (M_w) corresponds to an increase in the thickening power (TP) and thus reduces the amount of (co)polymer required to achieve a certain increase in the viscosity index of the lubricating oil composition (thickening) at high-temperature. For a (co)polymer to be a good viscosity index improver (V.I.I.) additive, it must not only have a beneficial influence on the viscosity index of the fresh lubricating
15 oil, but it must also be stable and maintain its function even when the lubricating oil is in use in an engine and, for this reason, a good viscosity index improver (V.I.I.) additive must also have good mechanical shear stability [i.e. good values of the shear stability index – SSI]. It is known that, contrary to the thickening power (“TP”), the mechanical shear stability of a (co)polymer decreases as its weight average molecular weight (M_w)
20 increases and, therefore, the choice of a viscosity index improver (“V.I.I.”) additive is usually a compromise between the use of high amounts of mechanically shear stable (co)polymers with a low weight average molecular weight (M_w) [i.e. having a low value of the shear stability index (SSI)] but having a low thickening power (TP) and the use of small amounts of (co)polymers with a high weight average molecular weight (M_w)
25 and poor shear stability (i.e. having a high value of the shear stability index (SSI)] but having a high thickening power (TP)).

It is also desirable to have (co)polymers that not only effectively improve the viscosity index improver (V.I.I.) of the lubricating compositions and have good mechanical shear stability [i.e. good values of the shear stability index – SSI], but also
30 have dispersing characteristics of the carbonaceous particulate (“soot”), which is formed in the lubricating oil as a result of its operation in the engine. This carbonaceous

particulate ("soot"), which is formed as a result of oxidation processes in the lubricating oil, is insoluble in the lubricating oil itself because it contains carbon particles with polar functionalities. These carbonaceous particles with polar functionalities tend to aggregate to form larger particles (agglomerates), which can precipitate to form deposits mainly in the cooler parts of the engine where the lubricating oil sits for the longest time (for example, oil sump). Generally, in order to limit the formation of carbonaceous particulate deposits ("soot"), dispersing additives such as poly-isobutylene succinimides (PIBSIs) are used, which cover the surface of the carbonaceous particles, preventing their aggregation and precipitation.

Consequently, having (co)polymers that also have the function of dispersing the carbonaceous particulate ("soot"), as well as of viscosity index improver (V.I.I.) of the lubricating oil, would be very advantageous, both to enhance the dispersing capacity of the lubricating oil when necessary, and to reduce the amount of dispersing additives it contains. It is also desirable that such (co)polymers are cheap and easy to manufacture by an industrially implementable process.

The Applicant was therefore faced with the problem of finding viscosity index improver (V.I.I.) copolymers of lubricating oils that, in addition to presenting good values of the shear stability index (SSI) and of the thickening power (TP), are also useful as dispersing agents of carbonaceous particulates ("soot") and, when used in concentrated solutions in lubricating base oil, are able to provide clear and homogeneous solutions, even at low temperatures, without the formation of gelatinous compounds.

The Applicant has now found a hydrogenated multiblock linear styrene-butadiene copolymer having a specific multiblock architecture, i.e. having the specific general formula (I) or (II) below reported, as viscosity index improver (V.I.I.) of lubricating oils that, in addition to presenting good values of the shear stability index (SSI) and of the thickening power (TP), is also useful as a dispersing agent of carbonaceous particulates ("soot") and, when used in concentrated solutions in lubricating base oil, is able to provide clear and homogeneous solutions, even at low temperatures, without formation of gelatinous compounds. The above-mentioned hydrogenated multiblock linear styrene-butadiene copolymer can advantageously be used as a viscosity index improver (V.I.I.) additive of lubricating oil compositions such as, for example, lubricating oil

compositions for passenger cars, both diesel and petrol, or for heavy duty diesel engine, and functional fluids such as, for example, manual or automatic transmission fluids and hydraulic fluids. In addition, the above-mentioned hydrogenated multiblock linear styrene-butadiene copolymer can advantageously be used as a dispersing agent of carbonaceous particulate (“soot”) in lubricating oil compositions such as, for example, lubricating oil compositions for passenger cars, both diesel and petrol, or for heavy duty diesel engines. The above-mentioned hydrogenated multiblock linear styrene-butadiene copolymer is therefore particularly useful in the engine sector where proper lubrication is increasingly important both to prolong engine life, especially in diesel engines, but also in the latest direct injection petrol engines, and to reduce fuel consumption: said proper lubrication thus has a direct benefit on sustainability and reduced engine emissions.

Therefore, the subject matter of the present invention is a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II):



wherein:

- $(EB)_1$, $(EB)_2$ and $(EB)_3$, represent the hydrogenated polymeric blocks deriving from 1,3-butadiene;
- S_1 and S_2 represent the polymeric blocks deriving from styrene;

wherein:

- in general formula (I) the polymeric blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene are present in an amount comprised between 56% by weight and 74% by weight, preferably between 64% by weight and 70% by weight, with respect to the total weight of the copolymer, said amount being defined as the sum of $[(EB)_1 + (EB)_2]$, the polymeric blocks $(EB)_3$ deriving from 1,3-butadiene are present in an amount comprised between 1% by weight and 4% by weight, preferably between 1% by weight and 2% by weight, with respect to the total weight of the copolymer, and the polymeric blocks S_1 and S_2 deriving from styrene are present in an amount comprised between 25 % by weight and 40% by weight, preferably between 29% by weight and 34% by weight, with respect to the total weight of the

copolymer, said amount being defined as the sum of $S_1 + S_2$;

- in general formula (II) the polymeric blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene are present in an amount comprised between 60% by weight and 75% by weight, preferably between 66% by weight and 71% by weight, with respect to the total weight of the copolymer, said amount being defined as the sum of $[(EB)_1 + (EB)_2]$, and the polymeric block S_1 deriving from styrene is present in an amount comprised between 25% in weight and 40% by weight, preferably between 29% by weight and 34% by weight, with respect to the total weight of the copolymer;
- in said polymeric blocks $(EB)_1$, $(EB)_2$ and $(EB)_3$ deriving from 1,3-butadiene the polybutadiene has a content of units having configuration 1,2 comprised between 45% by weight and 70% by weight, preferably between 50% by weight and 65% by weight, with respect to the total weight of the butadiene units and a content of units having configuration 1,4 comprised between 30% by weight and 55% by weight, preferably between 35% by weight and 50% by weight, with respect to the total weight of butadiene units.

For the purpose of the present description and of the following claims, the definitions of the numerical ranges always include the extreme values unless otherwise specified.

For the purpose of the present description and of the following claims, the term “comprising” also includes the terms “which essentially consists of” or “which consists of”.

For the purpose of the present description and of the following claims, both the amount of the polymeric block(s) derived from 1,3-butadiene $[(EB)_1 + (EB)_2]$ and the amount of the polymeric block(s) derived from styrene (S_1 or $S_1 + S_2$), said amounts being expressed as % by weight with respect to the total weight of the copolymer, were determined as reported below under the “¹H-NMR Spectra” paragraph on the non-hydrogenated multiblock linear styrene-butadiene copolymer (“parent polymer”).

For the purpose of the present description and the of following claims, the amount of the polymer block derived from 1,3-butadiene $(EB)_3$, said amount being expressed as a % by weight with respect to the total weight of the copolymer, was determined theoretically with respect to the amount of 1,3-butadiene fed during polymerization in

step (c) below reported.

For the purpose of the present description and of the following claims, the content of 1,2-configuration units and the content of 1,4-configuration units in the polymeric blocks derived from 1,3-butadiene, said content being expressed as a % by weight with respect to the total weight of the butadiene units, were determined as reported below under the “¹H-NMR Spectra” paragraph on the non-hydrogenated, multiblock linear styrene-butadiene copolymer (“parent polymer”).

In accordance with a preferred embodiment of the present invention, said hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) has the following characteristics:

- a weight average molecular weight (M_w) of each of the polymer blocks (EB)₁ and (EB)₂ deriving from 1,3-butadiene comprised between 29000 Da and 60000 Da, preferably between 30000 Da and 48000 Da, said average molecular weight (M_w) being equal or different for each of the two polymer blocks (EB)₁ and (EB)₂ deriving from 1,3-butadiene, preferably equal;
- a weight average molecular weight (M_w) of the polymer block (EB)₃ deriving from 1,3-butadiene comprised between 900 Da and 6000 Da, preferably between 1000 Da and 2800 Da;
- a weight average molecular weight (M_w) of the polymeric block(s) (S₁ or S₁ + S₂) deriving from styrene comprised between 25000 Da and 55000 Da, preferably between 26000 Da and 48000 Da;
- the three polymer blocks (EB)₁, (EB)₂ and (EB)₃ deriving from 1,3-butadiene have a degree of hydrogenation greater than or equal to 98%, preferably greater than or equal to 99%, more preferably equal to 100%;
- a weight average molecular weight (M_w) of the hydrogenated multiblock linear styrene-butadiene copolymer comprised between 90000 Daltons and 181000 Daltons, preferably between 113000 Daltons and 147000 Daltons;
- a polydispersion index (PDI) corresponding to the M_w/M_n ratio, comprised between 0.98 and 1.2, preferably between 1.0 and 1.1.

For the purpose of the present description and of the following claims, the weight average molecular weight (M_w) both of each of the polymeric block(s) derived from 1,3-

butadiene (EB)₁ and (EB)₂ and the weight average molecular weight (M_w) of the polymeric block(s) derived from styrene (S_1 or $S_1 + S_2$) were determined as reported below under the “Determination of the molecular weight” paragraph on the non-hydrogenated multiblock linear styrene-butadiene copolymer (“parent polymer”) during polymerization.

For the purpose of the present description and of the following claims, the weight-average molecular weight (M_w) of the polymer block derived from 1,3-butadiene (EB)₃ was determined theoretically with respect to the amount of 1,3-butadiene and lithium-based initiator fed during polymerization.

In accordance with a preferred embodiment of the present invention, said hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) has the following characteristics:

- a shear stability index (SSI) comprised between 3% and 20%, preferably between 5% and 15%, measured according to CEC-L-14-A-93 standard (30 cycles of shearing) in Group I base oil;
- a thickening power (TP) comprised between 2.5 mm²/s and 5 mm²/s, preferably between 2.8 mm²/s and 4.5 mm²/s, measured according to ASTM D445-21e2 standard in Group I base oil;
- a cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”), at -25°C, comprised between 5000 cP and 6800 cP, preferably between 5500 cP and 6500 cP, measured according to ASTM D5293-20 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD);
- a cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”), at -20°C, comprised between 2500 cP and 3400 cP, preferably between 2700 cP and 3100 cP, measured according to ASTM D5293-20 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD);
- a pour point lower than -25°C, preferably comprised between -27°C and -45°C, measured according to ASTM D5950-14 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD);

- a gelation index comprised between 3 and 10, preferably between 5 and 8, measured according to ASTM D5133-05 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) ("Pour Point Depressant" - PPD).

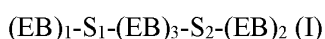
As mentioned above, said hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) is also useful as a dispersing agent of carbonaceous particulate ("soot") in lubricating oil compositions.

In accordance with a preferred embodiment of the present invention, the hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) has a dispersing capacity of carbonaceous particulate ("soot") in lubricating oil compositions, measured as a lacunarity value, comprised between 0 and 1, preferably between 0.05 and 0.80.

Said dispersion capacity was measured according to the method described and claimed in international patent application WO 2021/205360: further details are reported below under the paragraph "Determination of the dispersion capacity of carbonaceous particulate matter ("soot") (lacunarity)".

As reported above, the present invention also relates to processes for the preparation of the above-mentioned hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II).

A further object of the present invention is therefore a first batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I):



wherein (EB)₁, (EB)₂, (EB)₃, S₁ and S₂ have the same meanings reported above, comprising the following steps:

- (a) subjecting 1,3-butadiene to living polymerization by an anionic route in the presence of at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier and continuing said polymerization until substantially complete conversion of 1,3-butadiene obtaining a block (EB)₁;
- (b) adding styrene to the polymerization mixture obtained in step (a) and continuing said living polymerization until substantially complete conversion of styrene obtaining the blocks (EB)₁-S₁ and S₂-(EB)₂;

- (c) adding 1,3-butadiene to the polymerization mixture obtained in step (b) in an amount equal to 2% by weight, preferably equal to 1% by weight, more preferably equal to 0.5% by weight, with respect to the total weight of the butadiene-styrene copolymer obtained in step (b), continuing said living polymerization until
5 substantially complete conversion of 1,3-butadiene and, subsequently adding at least one coupling agent to the polymerization mixture obtained, obtaining a multiblock linear styrene-butadiene copolymer $(EB)_1-S_1-(EB)_3-S_2-(EB)_2$ wherein the blocks $(EB)_1$ and $(EB)_2$ are the same and the blocks S_1 and S_2 are the same;
- (d) subjecting the multiblock linear styrene-butadiene copolymer obtained in step (c)
10 to hydrogenation, obtaining a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I).

For the purpose of the present description and of the following claims, the phrase “substantially complete conversion” means that polymerization is continued until at least 98%, preferably at least 99%, more preferably 100%, of the filled monomer, i.e.
15 1,3-butadiene in step (a) and step (c), and styrene in step (b), has been polymerized.

In accordance with a preferred embodiment of the present invention, said at least one hydrocarbon solvent can be selected, for example, from aliphatic, cycloaliphatic or aromatic hydrocarbon solvents such as, for example, propane, *n*-butane, *iso*-butane, *n*-pentane, *iso*-pentane, *n*-hexane, *n*-heptane, *n*-octane, cyclohexane, cyclopentane,
20 propene, 1-butene, *iso*-butene, *trans*-2-butene, *cis*-2-butene, 1-pentene, 2-pentene, 1-hexene, 2-hexene, benzene, toluene, xylene, ethylbenzene, or mixtures thereof. Said solvents can advantageously be used in anhydrous form. Cyclohexane, *n*-hexane, or mixtures thereof, in anhydrous form, are preferred.

Generally, the amount of hydrocarbon solvent used in such copolymerization by
25 the anionic route is such as to allow the full solubility of the monomers (i.e. 1,3-butadiene and styrene), of any additives that can be present, of the compounds obtained in steps (a)-(d) above-mentioned, the complete stirring of the reaction mixture, also during said copolymerization, and the diffusion of the reaction heat. Preferably, said hydrocarbon solvent is used in amounts such as to have a monomer concentration (i.e.
30 1,3-butadiene and styrene) in the hydrocarbon solvent comprised between 4% by weight and 20% by weight, more preferably between 6% by weight and 15% by weight, with

respect to the total weight of the hydrocarbon solvent.

In accordance with a preferred embodiment of the present invention, said at least one lithium-based initiator can be selected, for example, from compounds having general formula (III):



wherein R_1 represents a C_1 - C_{20} , preferably C_2 - C_{12} alkyl group, linear or branched, a C_3 - C_{30} , preferably C_4 - C_{10} cycloalkyl group, a C_6 - C_{30} , preferably C_6 - C_{12} aryl group, and n is an integer comprised between 1 and 4.

10 In accordance with a particularly preferred embodiment of the present invention, said at least one lithium-based initiator can be selected, for example, from: lithium methyl, lithium *n*-butyl, lithium *sec*-butyl, lithium *t*-butyl, lithium *n*-propyl, lithium *iso*-butyl, lithium amyl, lithium cyclohexyl, lithium phenyl, lithium 1-methyl styryl, lithium *p*-tolyl, lithium naphthyl, L,L-diphenyl-5-lithium-3-methyl-pentyl, or mixtures thereof. Lithium *n*-butyl is preferred.

15 The amount of lithium-based initiator that can be used in the process of the present invention depends on various factors such as, for example, the monomers being copolymerized and the molecular weight of the copolymer to be obtained. Generally, said lithium-based initiator can be used in amounts comprised between 0.01 phm and 0.25 phm (phm = parts per hundred parts by weight of monomer(s)). Preferably, said
20 lithium-based initiator can be used in amounts comprised between 0.01 phm and 0.15 phm, more preferably between 0.012 phm and 0.01 phm.

In accordance with a preferred embodiment of the present invention, said at least one polar modifier can be selected, for example, from: non-cyclic ethers such as, for example, ethyl ether, or mixtures thereof; tertiary amines such as, for example, tri-
25 butylamine; cyclic ethers such as, for example, tetrahydrofuran (THF); chelating ethers such as, for example, ethylene glycol dimethyl ether (dimethylglime), dioxane, 2-methoxy ethyl tetrahydrofuran (THFA-ethyl), 2-methoxy ethyl tetrahydropyran, or mixtures thereof; chelating amines such as, for example, *N,N,N',N'*-tetramethylethylenediamine (TMEDA); or mixtures thereof. Tetrahydrofuran (THF), 2-
30 methoxy-ethyl-tetrahydrofuran (THFA-ethyl), or mixtures thereof, are preferred.

The amount of polar modifier that can be used in said first process of the present

invention depends on various factors such as, for example, the amount of lithium-based initiator used, the type of polar modifier used. By way of example, in the case of the above-mentioned first process object of the present invention, tetrahydrofuran (THF) can be used in an amount comprised between 100 moles and 250 moles, preferably
5 between 140 moles and 190 moles, per mole of lithium-based initiator.

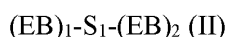
In accordance with a preferred embodiment of the present invention, said at least one coupling agent can be selected, for example, from dimethyl dichlorosilane, diphenyl dichlorosilane, methyl phenyl dichlorosilane, or mixtures thereof. Diphenyl dichlorosilane is preferred. Preferably, said coupling agent and said lithium-based
10 initiator can be used in a molar ratio comprised between 0.4 and 0.6, more preferably between 0.45 and 0.55.

In accordance with a preferred embodiment of the present invention, in said first process:

- said step (a) can be carried out at a temperature comprised between 20°C and
15 100°C, preferably between 25°C and 85°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or
- said step (b) can be carried out at a temperature comprised between 40°C and 110°C, preferably between 50°C and 95°C; and/or for a time comprised between 1 minute and 9 minutes, preferably between 3 minutes and 7 minutes; and/or
- 20 - said step (c) can be carried out at a temperature comprised between 45°C and 115°C, preferably between 55°C and 100°C; and/or for a time comprised between 3 minutes and 30 minutes, preferably between 4 minutes and 25 minutes.

The above-mentioned hydrogenation step (d) can be carried out according to procedures known in the art. Preferably, it can be carried out in the presence of a
25 titanium/magnesium-based catalytic composition (for example, bis-cyclopentadienyl-titanium-dichloride/butyl-ethyl-magnesium) as described, for example, in European patents EP 0816382 and EP 0914867.

A further object of the present invention is a second batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having
30 general formula (II):



wherein (EB)₁, (EB)₂ and S₁ have the same meanings reported above, comprising the following steps:

- (a') subjecting 1,3-butadiene to living polymerization by an anionic route in the presence of at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier and continuing said polymerization until substantially complete conversion of 1,3-butadiene obtaining a block (EB)₁;
- (b') adding styrene to the polymerization mixture obtained in step (a') and continuing said living polymerization until substantially complete conversion of styrene obtaining a block (EB)₁-S₁;
- (c') adding 1,3-butadiene to the polymerization mixture obtained in step (b') and continuing said living polymerization until substantially complete conversion of 1,3-butadiene obtaining a linear multiblock styrene-butadiene copolymer (EB)₁-S₁-(EB)₂ wherein the blocks (EB)₁ and (EB)₂ are the same or different from each other;
- (d') adding at least one termination agent to the polymerization mixture obtained in step (c');;
- (e') subjecting the multiblock linear styrene-butadiene copolymer obtained in step (d') to hydrogenation obtaining the hydrogenated multiblock linear styrene-butadiene copolymer having general formula (II).

Said at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier can be selected from those reported above.

In accordance with a preferred embodiment of the present invention, said at least one terminating agent can be selected, for example, from trimethyl chlorosilane, butanol, octanol, or mixtures thereof. Trimethyl dichlorosilane is preferred. Preferably, said terminating agent and said lithium-based initiator can be used in a molar ratio comprised between 0.8 and 1.3, more preferably between 0.9 and 1.2.

In accordance with a preferred embodiment of the present invention, in said second process:

- said step (a') can be carried out at a temperature comprised between 20°C and 60°C, preferably between 25°C and 55°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or

- said step (b') can be carried out at a temperature comprised between 30°C and 75°C, preferably between 35°C and 70°C; and/or for a time comprised between 1 minute and 9 minutes, preferably between 3 minutes and 7 minutes; and/or
- said step (c') can be carried out at a temperature comprised between 45°C and 115°C, preferably between 45°C and 100°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or
- said step (d') can be carried out at a temperature comprised between 45°C and 115°C, preferably between 55°C and 110°C; and/or for a time comprised between 1 minute and 10 minutes, preferably between 3 minutes and 8 minutes.

10 The above-mentioned hydrogenation step (e') can be carried out as described above according to procedures known in the art. Preferably, it can be carried out in the presence of a titanium/magnesium-based catalytic composition (for example, bis-cyclopentadienyl-titanium-dichloride/butyl-ethyl-magnesium) as described, for example, in European patents EP 0816382 and EP 0914867.

15 As reported above, the present invention also relates to concentrated solutions comprising at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) in at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

20 Consequently, the present invention also relates to a concentrated solution comprising:

- from 3% by weight to 30% by weight, preferably from 5% by weight to 25% by weight, more preferably from 8% by weight to 15% by weight, with respect to the total weight of said concentrated solution, of at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II);
- from 70% by weight to 97% by weight, preferably from 75% by weight to 95% by weight, more preferably from 85% by weight to 92% by weight, with respect to the total weight of said concentrated solution of at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

30 It should be noted that said concentrated solution presents itself as a clear,

homogeneous solution even when cold, at least down to -5°C , without the formation of gelatinous compounds.

Lubricating base oils of mineral origin are derived from well-known petroleum refining processes such as distillation, deparaffining, deasphalting, dearomatization,
5 hydrogenation.

Lubricating base oils of synthetic origin can preferably be selected from: hydrocarbon oils such as, for example, polymerized and hydrogenated terminal or internal olefins; alkylbenzenes; polyphenyls; alkylated diphenylethers; polyalkylene glycols and their derivatives, in which the terminal hydroxyl groups have been modified,
10 for example, by esterification or etherification.

Alternatively, lubricating base oils of synthetic origin can be selected, for example, from: synthetic or animal or vegetable derived carboxylic acid esters with a variety of alcohols or polyols; or from carbonic acid esters with a variety of alcohols and polyols.

15 Lubricating base oils of vegetable origin can be selected, for example, from: soybean oil, palm oil, castor oil, or mixtures thereof.

Lubricating base oils of animal origin can be selected, for example, from: tallow oil, lard oil, whale oil, or mixtures thereof.

Another method for the classification of the base oils is the one defined by the
20 American Petroleum Institute (API) in the publication "Engine Oil Licensing and Certification System" (API EOLCS, 1507 - Industry Services Department, Fourteenth Edition, December 1996, Addendum 1, December 1998).

According to the above-mentioned classification method (API), lubricating base oils are divided into five groups according to their chemical-physical and compositional
25 characteristics.

In accordance with the above-mentioned classification mode (API), the lubricating base oils that can be used according to the present invention are those belonging to all Groups I, II, III, IV and V, more preferably Groups I, II and III.

As reported above, the present invention also relates to a lubricating oil
30 composition comprising at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II), either as such or in a concentrated solution,

and at least one lubricating base oil, said lubricating base oil being selected from among lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

Consequently, the present invention also relates to a lubricating oil composition comprising at least one lubricating base oil, said lubricating base oil being selected from
5 lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof, and at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II), as such, said hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) being present in said lubricating oil composition in an amount comprised between 0.1% by weight and 5% by weight,
10 preferably between 0.2% by weight and 2% by weight, with respect to the total weight of said lubricating oil composition.

The present invention also relates to a lubricating oil composition comprising at least one lubricating base oil, said lubricating base oil being selected from among lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof,
15 and at least one concentrated solution of at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II), said concentrated solution being present in said lubricating composition in an amount comprised between 0.5% by weight and 50% by weight, preferably between 3.5% by weight and 30% by weight, more preferably between 5% by weight and 15% by weight, with respect to the
20 total weight of said lubricating composition.

The above-mentioned lubricating oil compositions can comprise, in addition to said at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II), other additives capable of improving the viscosity index, detergent additives, dispersing additives, antioxidant additives, friction modifying
25 additives, wear and extreme pressure additives (EP additives), corrosion inhibitors, pour point depressant additives, foam inhibitors, emulsifiers, or mixtures thereof, and the like.

In order to better understand the present invention and to put it into practice, some illustrative and non-limiting examples thereof are reported below.

The analysis and the characterization methodologies reported below were used.

30 ¹H-NMR Spectra

The quantitative determination of the microstructure of 1,3-butadiene in terms of

the content of units having configuration 1,2 and of the polymer composition in terms of the content of total 1,3-butadiene in the hydrogenated linear multiblock styrene-butadiene copolymers object of the present invention was determined according to ISO 21561-1:2015 standard by means of ^1H -NMR spectrometry performed on non-hydrogenated linear multiblock styrene-butadiene copolymers (“parent polymers”).

The ^1H -NMR spectra were recorded at room temperature (25°C) and at 50°C by means of a nuclear magnetic resonance spectrometer mod. Bruker Avance 300, equipped with 5 mm probes and variable temperature.

For this purpose, polymer solutions of the non-hydrogenated multiblock linear styrene-butadiene copolymers (“parent polymers”) obtained as reported in the following examples were used, with concentrations of 3% w/v (g/mL) prepared using deuterated chloroform (CDCl_3) (Merck - purity > 99.8%) added with 0.03% wt. tetramethylsilane (TMS) (Merck) (internal standard).

Determination of the molecular weight

The determination of the weight-average molecular weight (M_w), number-average molecular weight (M_n) and polydispersion index (PDI) (M_w/M_n) of the hydrogenated linear multiblock styrene-butadiene copolymers obtained as reported in the following examples was carried out by GPC (“Gel Permeation Chromatography”), using the Agilent Technologies 1200 series integrated instrument using fixed wavelength UV detection (254 nm), operating under the following conditions:

- six GPC PL columns from Agilent Technologies with dimensions 300 x 7.5 mm, specifically as follows:

TYPE	Particle size	Porosity (Å)
PLGEL	5 μm	10^5
PLGEL	5 μm	10^5
PLGEL	5 μm	10^4
PLGEL	5 μm	10^3
PLGEL	10 μm	10^6
PLGEL	5 μm	500

- Mettler Toledo analytical balance;
- laboratory glassware;
- shaker;

- columns injection temperature: 25°C;
- columns temperature and detector: 25°C;
- solvent/eluent: tetrahydrofuran (THF) (99+% for HPLC - Merck);
- flow: 1 mL/min;
- 5 - calculation of the molecular mass by universal calibration curve.

The above-mentioned operating conditions have been constantly monitored through a personal computer provided with Agilent GPC/SEC software from Agilent Technologies.

The calibration was carried out as follows.

- 10 Four tetrahydrofuran (THF) solutions (99+% for HPLC - Merck) were prepared, each containing three polystyrene (PS) standards with different nominal peak molecular weights (M_p) and equal concentrations: the molecular weights were selected in such a way that the eluted chromatographic peaks were well separated. The range of the different nominal peak molecular weights (M_p) of the above -mentioned standards used
- 15 for the calibration curve was comprised between about 3 kDa and 10 kDa.

The different solutions were prepared, under stirring, at room temperature (25°C).

- The calibration curve was calculated using a personal computer equipped with the aforementioned Agilent GPC/SEC software from Agilent Technologies, using a 3rd-order polynomial function: through this polynomial, it was possible to obtain the above-
- 20 mentioned molecular weight information.

Determination of the degree of hydrogenation (GI)

- The determination of the degree of hydrogenation (GI) of the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples was carried out by Fourier-Transform Infrared Spectroscopy (FTIR), using
- 25 the NICOLET iS50 spectrophotometer instrument from THERMO FISHER and operating under the following conditions:

- transmission measurement;
- spectral range: 1050-650 cm^{-1} ;
- number of scans: 25;
- 30 - resolution: 4 cm^{-1} ;
- gain: 1;

- speed of movement of the mirror in the interferometer: 0.6329 cm/s;
- opening: 65.

The main instrumental characteristics were:

- OMNIC software version 9.12;
- 5 - spectral range: 4000-400 cm^{-1} ;
- single beam;
- detector: TGS (triglycin sulphate deuterate).

Non-hydrogenated multiblock linear styrene-butadiene copolymers (“parent polymers”) with the same composition as the hydrogenated multiblock linear styrene-butadiene copolymers to be analysed were used to calculate the calibration line.

For the above-mentioned non-hydrogenated multiblock linear styrene-butadiene copolymers (“parent polymers”), it was necessary to determine the absorbances for the functional groups under investigation. In detail, the following conditions were implemented:

- 15 - approximately 0.8 g of sample was weighed in a 20 ml screw-capped vial, then approximately 10 ml of cyclohexane (Merck) (~10% w/w) was added and everything was placed in a shaker until complete solubilization;
- a thin layer of the polymer solution obtained was spread, with a glass rod, onto a rectangular window of potassium bromide (40x20 mm with a thickness of 5 mm)
- 20 - and the solvent was evaporated by a flow of nitrogen;
- a background was performed, to be subtracted from the IR spectra of the sample, by taking 25 scans in the spectral range between 1050 cm^{-1} e 650 cm^{-1} , leaving the sample compartment empty;
- 25 scans of the sample were carried out in the same spectral range by inserting,
- 25 - along the optical path of the IR beam, the window on which the polymer solution was spread (for a correct evaluation of the spectrum, the transmittance at 1050 cm^{-1} must be greater than 80%, while the most intense spectral band must be between 20% and 40%; if the above conditions are not met, the value obtained must be disregarded and the sample analysis repeated);
- 30 - the absorbance maximum was measured at approximately 968 cm^{-1} (At), 910 cm^{-1} (Av) and at 700 cm^{-1} (As);

- for the “parent polymer”, the ratio $(A_t + A_v)/A_s$ was measured and plotted; for the fully hydrogenated polymer, the ratio $(A_t + A_v)/A_s$ will be equal to 0; the equation of the straight line $y=aX + b$ of linear type interpolating the two points was calculated (reported in Figure 1).

5 The degree of hydrogenation was calculated using the following expression:

$$GI = a * \frac{A_v + A_t}{A_s} + b$$

wherein:

- A_v = vinyl absorbance (910 cm^{-1});
- A_t = trans absorbance (968 cm^{-1});
- 10 - A_s = styrene absorbance (700 cm^{-1});
- a = angular coefficient of the line;
- b = Intercept of the line on the y-axis.

Determination of the thickening power (TP)

For this purpose, the hydrogenated multiblock styrene-butadiene copolymers
15 obtained as reported in the following examples were dissolved in an amount equal to 1% by weight in the reference base oil SN 150 Group I (Eni S.p.A.).

The thickening power (TP) was calculated according to the following formula in which the kinematic viscosity (KV) at 100°C was determined according to ASTM D445-21e2 standard:

20
$$TP = KV_{100^\circ\text{C}}(\text{oil} + \text{polymer } 1\%\text{weight}) - KV_{100^\circ\text{C}}(\text{oil}).$$

Determination of the shear stability index (SSI)

For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples, were dissolved in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and, to
25 the solution obtained, an amount equal to 0.2% by weight was added to the total weight of said solution of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD).

The shear stability index (SSI) was determined according to CEC-L-14-A-93 standard (30 cycles of shearing).

Determination of shear stability of finished lubricating compositions (KV loss at
30 100°C)

On the finished lubricant compositions, the percentage of kinematic viscosity

(KV) loss at 100°C was determined according to CEC-L-14-A-93 standard (30 “cycles of shearing”).

Determination of the cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”)

5 For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples, were dissolved in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and, to the solution obtained, an amount equal to 0.2% by weight was added to the total weight of said solution of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD).

10 The cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”) was measured according to ASTM D5293-20 standard.

Determination of the gelation index

For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples, were dissolved in an amount
15 equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and, to the solution obtained, an amount equal to 0.2% by weight was added to the total weight of said solution of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD).

The gelation index was measured by means of Brookfield scanning equipment according to ASTM D5133-05 standard.

20 Determination of the pour point

For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples, were dissolved in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and, to the solution obtained, an amount equal to 0.2% by weight was added to the total weight
25 of said solution of the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD).

The pour point was measured according to ASTM D5950-14 standard.

Determination of the dispersing capacity of the carbonaceous particulate (“soot”) (lacunarity)

This dispersing capacity was measured according to the method described and
30 claimed in international patent application WO 2021/205360.

Said method comprises the following steps:

- preparation of a dispersion of Carbon Black Corax N550 (synthetic “soot”) using a solution in a reference base oil SN 150 Group I (Eni S.p.A.) in which a hydrogenated multiblock linear styrene-butadiene copolymer obtained as reported in the following examples was dissolved in an amount equal to 1.2% by weight;
- 5 - analysis of the obtained dispersion by means of optical microscopy with image acquisition;
- evaluation of the dispersing capacity of the solution containing the hydrogenated multiblock linear styrene-butadiene copolymer by means of image analysis software and determination of the “lacunarity” (i.e. a parameter measuring the
10 ethereogeneity of the image): the higher the “lacunarity”, the worse the dispersing capacity of the hydrogenated multiblock linear styrene-butadiene copolymer.

More details on this method can be found in the following Example 8.

Determination of kinematic viscosity

- The kinematic viscosity of lubricating oil compositions containing hydrogenated
15 multiblock linear styrene-butadiene copolymers obtained as reported in the following examples was measured according to ASTM D445-21e2 standard.

Determination of the viscosity index

- The viscosity index of lubricating oil compositions containing hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following
20 examples was measured according to ASTM D2270-10(2016) standard.

Determination of viscosity at high temperature and high shear rate (HTHS)

- The viscosity at high temperature and high shear rate (HTHS) of lubricating oil compositions containing the hydrogenated multiblock linear styrene-butadiene copolymers obtained as reported in the following examples was measured according to
25 CEC-L-36-A-90 standard.

EXAMPLES 1-2 (invention) - EXAMPLE 3 (comparative)

Preparation of hydrogenated multiblock linear styrene-butadiene copolymers

Three hydrogenated multiblock linear styrene-butadiene copolymers were prepared as described below.

- 30 The suspension polymerization batch reaction was carried out in a 20 L batch reactor (of which 15 L were useful), equipped with impeller blades, anchor bottom

scraper, bottom discharge and cooling jacket.

Said reactor was fed with anhydrous cyclohexane (Cepco) and, after the temperature had been raised to 27°C, tetrahydrofuran (THF) (VWR International) was added and, subsequently, the following reactions were carried out:

5 Reaction 1 [step (a)]:

- addition of anhydrous 1,3-butadiene (Versalis S.p.A.);
- addition of lithium *n*-butyl (15% solution in hexane) (Merck) (NBL);
- waiting reaction time.

Reaction 2 [step (b)]:

- 10 - addition of anhydrous styrene (Versalis S.p.A.);
- waiting reaction time.

Reaction 3 [step (c)]:

- addition of anhydrous 1,3-butadiene (Versalis S.p.A.);
 - waiting reaction time (polymerization);
- 15 - addition of diphenyl dichlorosilane (Ametech)(DFCISi);
- waiting reaction time (coupling).

Hydrogenation reaction [(step (d))]:

- addition of butyl ethyl magnesium chloride (Nouryon);
 - addition of bis-cyclopentadienyl-titanium-dichloride (Nouryon);
- 20 - waiting reaction time.

Table 1 reports the operating conditions used: feeding the compounds to the reactor, temperature and reaction duration.

The obtained solution of the hydrogenated multiblock linear styrene-butadiene copolymer was discharged from the bottom of the reactor and sent to a storage container.

- 25 Subsequently, said solution was continuously sent to “strippers” filled with water at 90°C, to which water vapour was also sent, so that the unreacted monomers (1,3-butadiene and styrene) and solvent were stripped.

The water leaving the strippers was collected and sent for water treatment.

- 30 The hydrogenated multiblock linear styrene-butadiene copolymers obtained were subjected to the above characterizations and the results obtained are reported in Table 2.

Table 1

	Compounds	Example 1 (invention)	Example 2 (invention)	Example 3 (comparative)
	Cyclohexane (g)	9000	9000	9000
	THF (ml)	91.11	91.11	91.11
Reaction 1 [step (a)]	NBL (moles)	0.0098	0.0070	0.0085
	1,3-butadiene (g)	634	634	760
Reaction 2 [step (b)]	styrene (g)	256	256	130
Reaction 3 (polymerization) [step (c)]	1,3-butadiene (g)	10	10	10
Reaction 3 (coupling) [step (c)]	DFCISi (moles)	0.0047	0.0033	0.0040
Operating conditions	Start T Reaction 1 [step (a)] (°C)	27	27	27
	End T Reaction 1 [step (a)] (°C)	62	62	62
	Duration Reaction 1 [step (a)] (min)	25	25	25
	End T Reaction 2 [step (b)] (°C)	64	64	64
	Duration Reaction 2 [step (b)] (min)	5	5	5
	End T Reaction 3 (polymerization) [step (c)] (°C)	66	66	66
	Duration Reaction 3 (polymerization) [step (c)] (min)	5	5	5
	End T Reaction 3 (coupling) [step (c)] (°C)	66	66	66
	Duration Reaction 3 (coupling) [step (c)] (min)	15	15	15

Hydrogenation [step (d)]	titanium (calculated as Ti metal)	ppm ⁽¹⁾	350	350	350
	Mg/Ti molar ratio	-	3.5	3.5	3.5

⁽¹⁾: ppm referring to the sum of the added monomers (1,3-butadiene and styrene).

Table 2

Characteristic	Example 1 (invention)	Example 2 (invention)	Example 3 (comparative)
	Multiblock linear (EB) ₁ -S ₁ -(EB) ₃ -S ₂ -(EB) ₂ (I)	Multiblock linear (EB) ₁ -S ₁ -(EB) ₃ -S ₂ -(EB) ₂ (I)	Multiblock linear (EB) ₁ -S ₁ -(EB) ₃ -S ₂ -(EB) ₂ (I)
M _w ⁽¹⁾ (x ¹⁰³ - Daltons)	92.0	129.0	106.0
M _w S ⁽²⁾ (x ¹⁰³ - Daltons)	28.1	38.3	17.0
bonded styrene (% by weight)	30.5	29.9	16.0
PDI (M _w /M _n)	1.06	1.07	1.09
M _w EB ₁ ⁽³⁾ (x ¹⁰³ - Daltons)	31.5	44.5	43.9
M _w EB ₂ ⁽³⁾ (x ¹⁰³ - Daltons)	31.5	44.5	43.9
M _w EB ₃ ⁽³⁾ (Daltons)	1020	1428	1176
I ₂ ⁽⁴⁾ (% by weight)	59.8	59.1	58.8
Degree of hydrogenation (% by weight)	99	99	99

- 5 ⁽¹⁾: M_w hydrogenated multiblock linear styrene-butadiene copolymer [M_w determined on non-hydrogenated multiblock linear styrene-butadiene copolymer (“parent polymer”)];
- ⁽²⁾: M_w of the total bound styrene (S₁ + S₂) on the hydrogenated multiblock linear styrene-butadiene copolymer [M_w determined on the non-hydrogenated
- 10 multiblock linear styrene-butadiene copolymer (“parent polymer”)];
- ⁽³⁾: M_w of the EB₁, EB₂ and EB₃ blocks of the hydrogenated multiblock linear styrene-butadiene copolymer [M_w determined on the non-hydrogenated multiblock linear styrene-butadiene copolymer (“parent polymer”)];
- ⁽⁴⁾: % by weight of the total weight of butadiene units in the hydrogenated multiblock
- 15 linear styrene-butadiene copolymer (% by weight determined on the non-hydrogenated multiblock linear styrene-butadiene copolymer (“parent polymer”)).

EXAMPLES 4-5 (invention) - EXAMPLE 6 (comparative)Evaluation as viscosity index improver (V.I.I.) additives of lubricating oils of hydrogenated multiblock linear styrene-butadiene copolymers

For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained in Examples 1-2 (invention) and Example 3 (comparative) were dissolved in amounts of 1% by weight and 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.).

The solutions obtained by dissolving the hydrogenated multiblock linear styrene-butadiene copolymers obtained in Examples 1-2 (invention) and in Example 3 (comparative) in an amount equal to 1% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) were subjected to characterisation to determine the thickening power ("TP") operating as described above: the results obtained are reported in Table 3.

The solutions obtained by dissolving the hydrogenated multiblock linear styrene-butadiene copolymers obtained in Examples 1-2 (the invention) and Example 3 (comparative) in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and adding to the solution obtained an amount equal to 0.2% by weight with respect to the total weight of said solution of the additive MX 4333 (Eni S.p.A.) (Pour Point Depressant - PPD), were subjected to characterisation to determine shear stability index (SSI), cold viscosity ("Cold Cranking Simulator viscosity" - "CCS viscosity"), pour point and gelation index (Gelation Index) operating as described above: the obtained results are reported in Table 3.

EXAMPLE 7 (comparative)Evaluation as a viscosity index improver (V.I.I.) additive of lubricating oil of a commercial olefin copolymer (OCP) lubricating oils

For this purpose, commercial olefin copolymer (OCP) MX 4006 (Eni S.p.A.) was dissolved in amounts of 1% by weight and 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.).

The solutions obtained by dissolving the commercial olefin copolymer (OCP) MX 4006 (Eni S.p.A.) in an amount equal to 1% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) were subjected to characterization to determine the thickening power (TP) operating as described above: the results obtained are reported in Table 3.

The solutions obtained by dissolving the commercial olefin copolymer (“Olefin Copolymer” OCP) MX 4006 (Eni S.p.A.) in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and adding to the solution obtained an amount equal to 0.2% by weight of the total weight of said solution of the additive MX 4333 (Eni S.p.A.) (Pour Point Depressant -PPD), were subjected to characterisation to determine shear stability index (SSI), cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”), pour point and gelation index (Gelation Index) operating as described above: the obtained results are reported in Table 3.

Table 3

Characteristic	Example 4 (invention) (copolymer Example 1)	Example 5 (invention) (copolymer Example 2)	Example 6 (comparative) (copolymer Example 3)	Example 7 (comparative) (OCP copolymer) MX 4006)
Thickening power (TP) (mm ² /s)	2.9	4.2	3.9	4.8
Shear stability index (SSI) (%)	6	13	18	23
Cold viscosity (-20°C) (“Cold Cranking Simulator Viscosity” - CCS) (cP)	2872	2881	2989	3450
Cold viscosity (-25°C) (“Cold Cranking Simulator Viscosity” - CCS) (cP)	5899	5938	6202	6860
Pour point (°C)	-39	-36	-33	-30
Gelation Index	6.7	5.8	6.1	11.0

10

EXAMPLES 8-9 (invention) - EXAMPLES 10-11 (comparatives)

Evaluation of the dispersing capacity of hydrogenated multiblock linear styrene-butadiene copolymers in comparison with commercial olefin copolymer (OCP)

For this purpose, the hydrogenated multiblock linear styrene-butadiene copolymers obtained in Examples 1-2 (invention) and Example 3 (comparative) and the commercial olefin copolymer (“Olefin Copolymer” - OCP) MX 4006 (Eni S.p.A.) were dissolved in an amount equal to 1.2% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) and, to the solution obtained, an amount equal to 0.2% by weight with respect to the total weight of said solution of the additive MX 4333 (Eni S.p.A.) was

15

added.

Then mixtures were prepared containing the above-mentioned solutions and 4.5% of Corax N550 carbonaceous particulate, expressed as a weight percentage of the total weight of the mixture. The obtained mixture was mixed with a stirrer (manufacturer
5 IKA, model VORTEX3) operating at 1500 rpm for 10 minutes. Subsequently, the mixture was homogenized using an IKA Ultra-Turrax homogenizer, model T25 digital, with an S25N-8G head, operating at a speed of 20000 rpm for 15 minutes at a temperature of 75°C. At the end of this operation, a homogeneous paste was obtained. The homogeneous paste obtained was left to equilibrate for a time of 28 hours in an
10 orbital thermo-agitator (manufacturer Torrey Pines Scientific, model ECHOTHERM SC20) operating at a speed of 300 rpm and a temperature of 75°C. At the end of this operation, a final dispersion was obtained, ready to be analysed by light microscopy.

The analysis was carried out using an optical microscope equipped with a 10X objective (manufacturer Nikon, model Diaphot 300, equipped with the CCD Nikon
15 Digital Sight DS-5M-U1, light source: 50 W halogen bulb), maintaining the sample at a temperature of 100°C, with the aid of a temperature-controlled heating table (manufacturer LINKAM, model PE94 Inverted Peltier Systems). Specimens for analysis were prepared by depositing 4 µL between two circular microscope slides with a thickness of 0.15 mm and a diameter of 35 mm. Optical micrographs were then obtained,
20 the images of which were acquired and the degree of dispersion determined. An image descriptor, which is the lacunarity (λ), was used to calculate the degree of dispersion.

Lacunarity is a measure of how a spatial pattern fills space, where a pattern with more and/or larger gaps (voids) has a greater lacunarity. The calculation of the lacunarity was carried out using an algorithm that can be implemented by a programme (software).
25 The programme used was the open-source software FracLac (version 2.5), which can be used as a plug-in for ImageJ (version 1.5.3).

Table 4 shows the results obtained from which it can be inferred that the hydrogenated linear multiblock styrene-butadiene copolymers obtained in Examples 1-
2 (invention) covered by the present invention, have a superior dispersing capacity (low
30 lacunarity values) both with respect to the hydrogenated linear multiblock styrene-butadiene copolymer obtained in Example 3 (comparative) which has a lower styrene

content, and with respect to the commercial olefin copolymer (“Olefin Copolymer” OCP) MX 4006 (Eni S.p.A.).

Table 4

Characteristic	Example 8 (invention) (copolymer Example 1)	Example 9 (invention) (copolymer Example 2)	Example 10 (comparative) (copolymer Example 3)	Example 11 (comparative) (copolymer OCP MX 4006)
Dispersing capacity (“lacunarity”)	0.70	0.30	1.25	1.50

5 EXAMPLE 12

Concentrated solution of a hydrogenated multiblock linear styrene-butadiene copolymer

 A concentrated solution was prepared by dissolving the hydrogenated multiblock linear styrene-butadiene copolymer obtained in Example 2 (invention) in an amount equal to 10% by weight in the reference base oil SN 150 Group I (Eni S.p.A.) operating
10 at a temperature of 130°C, for 120 minutes, in an apparatus equipped with a mechanical paddle stirrer and in an inert nitrogen atmosphere to avoid colouration of the solution. The obtained solution appears as a clear liquid, which remains so up to a temperature of -5°C, showing no gelation phenomena during cooling. The kinematic viscosity at 100°C of the concentrated solution, measured according to the ASTM D445-21e2 standard,
15 was 950 mm²/s.

EXAMPLE 13

Lubricating oil composition containing a concentrated solution of a hydrogenated multiblock linear styrene-butadiene copolymer

 The composition of lubricating oil for heavy duty diesel engines (the amounts of
20 the various components are reported in Table 5) was prepared by mixing the concentrated solution of the hydrogenated multiblock linear styrene-butadiene copolymer obtained in Example 12 (invention), with a mixture of commercial base oils belonging to Group II (API classification) consisting of Chevron 220 R and Chevron 100R base oils to which the following was added:
25 - the MX 5217 package (Eni S.p.A.) comprising calcium and magnesium sulphonate detergents, a dispersant, antioxidant additives, anti-wear additives, and the additive MX 4333 (Eni S.p.A.) (“Pour Point Depressant” - PPD);

Table 5

Components	(% by weight)
Chevron 220R	50.9
Chevron 100R	23.8
Concentrated hydrogenated multiblock styrene-butadiene copolymer solution of Example 12 (invention)	11.5
MX 5217	13.6
MX 4333 (Pour Point Depressant - PPD)	0.2

The obtained lubricating oil composition was characterized to determine the kinematic viscosity at 100°C and 40°C, the viscosity index, the cold viscosity (“Cold Cranking Simulator viscosity” - “CCS viscosity”), high temperature and high shear rate (HTHS) viscosity, pour point, gelation index, mechanical stability as measured by kinematic viscosity loss (KV) at 100°C, and dispersing capacity, operating as described above: the results obtained are reported in Table 6.

Table 6

PARAMETER	LUBRICATING OIL COMPOSITION
Kinematic viscosity @ 100°C (mm ² /s)	14.20
Kinematic viscosity @ 40°C (mm ² /s)	94.30
Viscosity index	155
CCS viscosity @ -25°C (cP)	6485
HTHS viscosity (150°C, 10 ⁶ s ⁻¹) (cP)	3.60
Pour point (°C)	-39
Gelation Index	5.10
Mechanical stability (KV loss at 100°C (%))	3.80
Dispersing capacity (lacunarity)	0.05

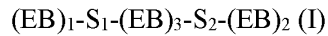
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From the data reported in Table 6, it can be inferred that the hydrogenated

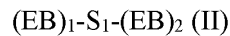
multiblock linear styrene-butadiene copolymer object of the present invention (concentrated solution obtained in Example 12), is capable of providing a lubricating oil composition having excellent mechanical stability as evidenced by low kinematic viscosity loss (KV) at 100°C and good hot thickening (kinematic viscosity at 100°C) with little influence on cold viscosity (CCS at -25°C). Furthermore, the low gelation index of the lubricating oil composition, together with the low pour point, make this copolymer very suitable for the preparation of lubricating oil compositions that can be used in very cold climates. Finally, this copolymer is able to provide an excellent dispersing capacity (“lacunarity”) of the carbonaceous particulate (“soot”) in the lubricating oil composition, as demonstrated by the lacunarity value close to 0.

CLAIMS

1. Hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II):



5



wherein:

- $(EB)_1$, $(EB)_2$ and $(EB)_3$, represent the hydrogenated polymeric blocks deriving from 1,3-butadiene;
- S_1 and S_2 represent the polymeric blocks deriving from styrene;

10 wherein:

- in general formula (I) the polymeric blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene are present in an amount comprised between 56% by weight and 74% by weight, preferably between 64% by weight and 70% by weight, with respect to the total weight of the copolymer, said amount being defined as the sum of $[(EB)_1 + (EB)_2]$, the polymeric blocks $(EB)_3$ deriving from 1,3-butadiene are present in an amount comprised between 1% by weight and 4% by weight, preferably between 1% by weight and 2% by weight, with respect to the total weight of the copolymer, and the polymeric blocks S_1 and S_2 deriving from styrene are present in an amount comprised between 25% by weight and 40% by weight, preferably between 29% by weight and 34% by weight, with respect to the total weight of the copolymer, said amount being defined as the sum of $S_1 + S_2$;
- in general formula (II) the polymeric blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene are present in an amount comprised between 60% by weight and 75% by weight, preferably between 66% by weight and 71% by weight, with respect to the total weight of the copolymer, said amount being defined as the sum of $[(EB)_1 + (EB)_2]$, and the polymeric block S_1 deriving from styrene is present in an amount comprised between 25% in weight and 40% by weight, preferably between 29% by weight and 34% by weight, with respect to the total weight of the copolymer;
- in said polymeric blocks $(EB)_1$, $(EB)_2$ and $(EB)_3$ deriving from 1,3-butadiene the polybutadiene has a content of units having configuration 1,2 comprised between 45% by weight and 70% by weight, preferably between 50% by weight and 65%

by weight, with respect to the total weight of the butadiene units and a content of units having configuration 1,4 comprised between 30% by weight and 55% by weight, preferably between 35% by weight and 50 % by weight, with respect to the total weight of butadiene units.

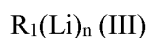
- 5 2. Hydrogenated multiblock linear styrene-butadiene copolymer according to claim 1, having the following features:
- a weight average molecular weight (M_w) of each of the polymer blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene comprised between 29000 Da and 60000 Da, preferably between 30000 Da and 48000 Da, said average molecular weight
10 weight (M_w) being equal or different for each of the two polymer blocks $(EB)_1$ and $(EB)_2$ deriving from 1,3-butadiene, preferably equal;
 - a weight average molecular weight (M_w) of the polymer block $(EB)_3$ deriving from 1,3-butadiene comprised between 900 Da and 6000 Da, preferably between 1000 Da and 2800 Da;
 - 15 - a weight average molecular weight (M_w) of the polymeric block(s) (S_1 or $S_1 + S_2$) deriving from styrene comprised between 25000 Da and 55000 Da, preferably between 26000 Da and 48000 Da;
 - the three polymer blocks $(EB)_1$, $(EB)_2$ and $(EB)_3$ deriving from 1,3-butadiene have a degree of hydrogenation greater than or equal to 98%, preferably greater than or
20 equal to 99%, more preferably equal to 100%;
 - a weight average molecular weight (M_w) of the hydrogenated multiblock linear styrene-butadiene copolymer comprised between 90,000 Daltons and 181,000 Daltons, preferably between 113,000 Daltons and 147,000 Daltons;
 - a polydispersion index (PDI) corresponding to the M_w/M_n ratio, comprised
25 between 0.98 and 1.2, preferably between 1.0 and 1.1.
3. Hydrogenated multiblock linear styrene-butadiene copolymer according to claim 1 or 2, having the following features:
- a shear stability index (SSI) comprised between 3% and 20%, preferably between 5% and 15%, measured according to CEC-L-14-A-93 standard (30 “cycles of
30 shearing”) in Group I base oil;
 - a thickening power (TP) comprised between 2.5 mm²/s and 5 mm²/s, preferably

between 2.8 mm²/s and 4.5 mm²/s, measured according to ASTM D445-21e2 standard in Group I base oil;

- a cold viscosity ("Cold Cranking Simulator viscosity" - "CCS viscosity"), at -25°C, comprised between 5000 cP and 6800 cP, preferably between 5500 cP and 6500 cP, measured according to ASTM D5293-20 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) ("Pour Point Depressant" - PPD);
 - a cold viscosity ("Cold Cranking Simulator viscosity" - "CCS viscosity"), at -20°C, comprised between 2500 cP and 3400 cP, preferably between 2700 cP and 3100 cP, measured according to ASTM D5293-20 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) ("Pour Point Depressant" - PPD);
 - a pour point lower than -25°C, preferably comprised between -27°C and -45°C, measured according to ASTM D5950-14 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) ("Pour Point Depressant" - PPD);
 - a gelation index comprised between 3 and 10, preferably between 5 and 8, measured according to ASTM D5133-05 standard in Group I base oil in the presence of the additive MX 4333 (Eni S.p.A.) ("Pour Point Depressant" - PPD).
4. Hydrogenated multiblock linear styrene-butadiene copolymer according to any one of claims 1 to 3, having a dispersing capacity of carbonaceous particulate ("soot") in lubricating oil compositions, measured as a lacunarity value, comprised between 0 and 1, preferably between 0.05 and 0.80.
5. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) according to claim 1, comprising the following steps:
- (a) subjecting 1,3-butadiene to living polymerization by an anionic route in the presence of at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier and continuing said polymerization until substantially complete conversion of 1,3-butadiene obtaining a block (EB)₁;
 - (b) adding styrene to the polymerization mixture obtained in step (a) and continuing said living polymerization until substantially complete conversion of styrene

obtaining the blocks (EB)₁-S₁ and S₂-(EB)₂;

- (c) adding to the polymerization mixture obtained in step (b) 1,3-butadiene in an amount equal to 2% by weight, preferably equal to 1% by weight, more preferably equal to 0.5% by weight, with respect to the total weight of the butadiene-styrene copolymer obtained in step (b), continuing said living polymerization until substantially complete conversion of 1,3-butadiene and, subsequently adding at least one coupling agent to the polymerization mixture obtained, obtaining a multiblock linear styrene-butadiene copolymer (EB)₁-S₁-(EB)₃-S₂-(EB)₂ wherein the blocks (EB)₁ and (EB)₂ are the same and the blocks S₁ and S₂ are the same;
- (d) subjecting the multiblock linear styrene-butadiene copolymer obtained in step (c) to hydrogenation, obtaining a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I).
6. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) according to claim 5, wherein:
- said at least one hydrocarbon solvent is selected from aliphatic, cycloaliphatic or aromatic hydrocarbon solvents such as propane, *n*-butane, *iso*-butane, *n*-pentane, *iso*-pentane, *n*-hexane, *n*-heptane, *n*-octane, cyclohexane, cyclopentane, propene, 1-butene, *iso*-butene, *trans*-2-butene, *cis*-2-butene, 1-pentene, 2-pentene, 1-hexene, 2-hexene, benzene, toluene, xylene, ethylbenzene, or mixtures thereof; it is preferably selected from cyclohexane, *n*-hexane, or mixtures thereof, in anhydrous form; and/or
 - said at least one lithium-based initiator is selected from compounds having general formula (III):



- wherein R₁ represents a C₁-C₂₀, preferably C₂-C₁₂ alkyl group, linear or branched, a C₃-C₃₀, preferably C₄-C₁₀ cycloalkyl group, a C₆-C₃₀, preferably C₆-C₁₂ aryl group, and n is an integer comprised between 1 and 4; preferably it is selected from: lithium methyl, lithium *n*-butyl, lithium *sec*-butyl, lithium *t*-butyl, lithium *n*-propyl, lithium *iso*-butyl, lithium amyl, lithium cyclohexyl, lithium phenyl, lithium 1-methyl styryl, lithium *p*-tolyl, lithium naphthyl, L,L-diphenyl-5-lithium-3-methyl-pentyl, or mixtures thereof; even more preferably it is lithium *n*-butyl;

and/or

- said at least one polar modifier is selected from: non-cyclic ethers such as ethyl ether, or mixtures thereof; tertiary amines such as tri-butyl amine; cyclic ethers such as tetrahydrofuran (THF); chelating ethers such as ethylene glycol dimethyl ether (dimethylglyme), dioxane, 2-methoxy-ethyl-tetrahydrofuran (THFA-ethyl),
5 2-methoxy ethyl-tetrahydropyran, or mixtures thereof; chelating amines such as *N,N,N',N'*-tetramethylethylenediamine (TMEDA); or mixtures thereof; preferably it is selected from tetrahydrofuran (THF), 2-methoxy-ethyl-tetrahydrofuran (THFA-ethyl), or mixtures thereof; and/or
 - 10 - said at least one coupling agent is selected from dimethyl dichlorosilane, diphenyl dichlorosilane, methyl phenyl dichlorosilane, or mixtures thereof, preferably it is diphenyl dichlorosilane.
7. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) according to claim 5 or 6, wherein:
- 15 - said step (a) is carried out at a temperature comprised between 20°C and 100°C, preferably between 25°C and 85°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or
 - said step (b) is carried out at a temperature comprised between 40°C and 110°C, preferably between 50°C and 95°C; and/or for a time comprised between 1 minute
20 and 9 minutes, preferably between 3 minutes and 7 minutes; and/or
 - said step (c) is carried out at a temperature comprised between 45°C and 115°C, preferably between 55°C and 100°C; and/or for a time comprised between 3 minutes and 30 minutes, preferably between 5 minutes and 20 minutes.
8. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (II) according to claim 1, comprising the
25 following steps:
- (a') subjecting 1,3-butadiene to living polymerization by an anionic route in the presence of at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier and continuing said polymerization until
30 substantially complete conversion of 1,3-butadiene obtaining a block (EB)₁;
 - (b') adding styrene to the polymerization mixture obtained in step (a') and continuing

said living polymerization until substantially complete conversion of styrene obtaining a block $(EB)_1-S_1$;

- (c') adding 1,3-butadiene to the polymerization mixture obtained in step (b') and continuing said living polymerization until substantially complete conversion of 1,3-butadiene obtaining a linear multiblock styrene-butadiene copolymer $(EB)_1-S_1-(EB)_2$ wherein the blocks $(EB)_1$ and $(EB)_2$ are the same or different from each other;
- (d') adding at least one termination agent to the polymerization mixture obtained in step (c');
- (e') subjecting the multiblock linear styrene-butadiene copolymer obtained in step (d') to hydrogenation obtaining the hydrogenated multiblock linear styrene-butadiene copolymer having general formula (II).
9. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (II) according to claim 8, wherein:
- said at least one hydrocarbon solvent, at least one lithium-based initiator and at least one polar modifier are selected from those according to in claim 6; and/or
 - said at least one termination agent is selected from trimethyl chlorosilane, butanol, octanol, or mixtures thereof; preferably it is trimethyl dichlorosilane.
10. Batch process for the preparation of a hydrogenated multiblock linear styrene-butadiene copolymer having general formula (II) according to claim 8 or 9, wherein:
- said step (a') is carried out at a temperature comprised between 20°C and 60°C, preferably between 25°C and 55°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or
 - said step (b') is carried out at a temperature comprised between 30°C and 75°C, preferably between 35°C and 70°C; and/or for a time comprised between 1 minute and 9 minutes, preferably between 3 minutes and 7 minutes; and/or
 - said step (c') is carried out at a temperature comprised between 45°C and 115°C, preferably between 45°C and 100°C; and/or for a time comprised between 10 minutes and 1 hour, preferably between 20 minutes and 40 minutes; and/or
 - said step (d') is carried out at a temperature comprised between 45°C and 115°C, preferably between 55°C and 110°C; and/or for a time comprised between 1

minute and 10 minutes, preferably between 3 minutes and 8 minutes.

11. Concentrated solution comprising:

- from 3% by weight to 30% by weight, preferably from 5% by weight to 25% by weight, more preferably from 8% by weight to 15% by weight, with respect to the total weight of said concentrated solution, of at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) according to any one of claims 1 to 10;
- from 70% by weight to 97% by weight, preferably from 75% by weight to 95% by weight, more preferably from 85% by weight to 92% by weight, with respect to the total weight of said concentrated solution of at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof.

12. Composition of lubricant oil comprising at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof, and at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) according to any one of claims 1 to 10, as such, said hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) being present in said lubricating composition in an amount comprised between 0.1% by weight and 5% by weight, preferably between 0.2% by weight and 2% by weight, relative to the total weight of said lubricating oil composition.

13. Composition of lubricating oil comprising at least one lubricating base oil, said lubricating base oil being selected from lubricating base oils of mineral, synthetic, animal, vegetable origin, or mixtures thereof, and at least one concentrated solution of at least one hydrogenated multiblock linear styrene-butadiene copolymer having general formula (I) or (II) according to any one of claims 1 to 10, said concentrated solution being present in said lubricating composition in an amount comprised between 0.5% by weight and 50% by weight, preferably comprised between 3.5% by weight and 30% by weight more preferably between 5% by weight and 15% by weight, with respect to the total weight of said lubricating composition.