

POLYMERIC FLOW IMPROVER ADDITIVES

The present invention relates to copolymers of n-alkyl (meth)-acrylates with maleic anhydride, a process for their preparation, hydrocarbon oil compositions containing them and their use as flow improver additives.

5 Hydrocarbon oils such as gas oils, diesel oils, fuel oils, lubricating oils and crude oils contain varying amounts of paraffins. The proportion of long chain n-paraffins, in particular, determines the cold-flow behaviour of the oils. On cooling, the n-paraffins separate out as plate-like crystals which
10 interact together to form a three-dimensional network in which still liquid oil becomes trapped, resulting in increased oil viscosity and decreased oil flowability. In gas oil and diesel oil applications, this phenomenon results in filter blockage, whereas in crude oil applications, it results in the gellation of the crude
15 oil and the formation of deposits in pipelines and storage tanks leading to considerable losses in production and capacity.

It is well known that these problems can be alleviated by the addition of so-called flow improvers to such oils. There are two kinds of flow improver: nucleation modifiers and growth modifiers.
20 Nucleation modifiers promote the formation of many small paraffin crystals whereas growth modifiers promote the formation of larger crystal clusters. In both cases however, the plate-like crystals described above are not formed. Nucleation modifiers find application in gas oils and diesel oils since the paraffin crystals
25 formed are sufficiently small enough to pass through a filter. Growth modifiers, by contrast, are used in filter-free applications, e.g. in crude oils.

US-A-4,663,491 discloses the use as crystallisation inhibitors in crude oil of copolymers of maleic anhydride and n-alkyl acrylates of the general formula



in which:

R₁ represents hydrogen or methyl and

R₂ represents an n-alkyl radical having at least 16, preferably
10 from 16 to 30, carbon atoms.

The copolymers are prepared by a process which comprises first mixing the total charge of n-alkyl acrylate with the total charge of maleic anhydride (the molar ratio acrylate: anhydride being in the range from 20:1 to 1:10, preferably from 8:1 to 1:5 and
15 especially from 4:1 to 1:1), and heating the mixture, in the presence of an organosoluble radical-forming catalyst, at a temperature in the range from 50 to 150°C, preferably from 80 to 120°C. It is clear from the examples of the patent that the most preferred temperatures are in the range from 85 to 95°C. At such
20 temperatures, the reaction is complete in about 4 hours.

No information is provided in the patent of the composition (e.g. the molar percentages of n-alkyl acrylate and maleic anhydride monomers) or of the structure of the copolymers obtained by the above process. However, the known higher reactivity of
25 n-alkyl acrylate monomers and their much greater tendency to homopolymerise than maleic anhydride monomers will, in view of the initial mixing of the total charge of n-alkyl acrylate with the total charge of maleic anhydride, result in the copolymer obtained containing proportionally more n-alkyl acrylate than maleic
30 anhydride and having a structure which is not highly uniform.

A.I. Akhmedov et al., Neftekhimiya 23, No. 5, 696-699, 1983, "Synthesis and study of additives based on decyl methacrylate-maleic anhydride copolymers" discloses the preparation of lubricating oil additives having both viscosity index improving and
35 detergent-dispersant properties, by copolymerisation of decyl

methacrylate with maleic anhydride and subsequent treatment with amines. Copolymerisation of decyl methacrylate with maleic anhydride was carried out in the presence of benzoyl peroxide as initiator in a toluene solution, the optimal conditions for which
5 consisted of heating a 50%w toluene solution of a mixture containing 90%w decyl methacrylate and 10%w maleic anhydride (corresponding to a molar ratio decyl methacrylate to maleic anhydride of 3.9:1) at 80°C for 3 hours in the presence of 0.5%w initiator. It was found that increasing the quantity of maleic
10 anhydride in the monomer mixture to 20%w or more had a detrimental effect on the solubility of the end product in mineral oils.

Akhmedov et al. state that the constants of copolymerisation (r) of the monomers being investigated were 1.75 for decyl methacrylate and 0 for maleic anhydride.

15 According to Akhmedov et al., the product of the values of the constants of copolymerisation is thus equal to zero, which points to formation of a copolymer with alternating monomeric units. This conclusion is supported by the fact that maleic anhydride does not form a homopolymer under these reaction conditions.

20 Akhmedov et al. further state that the structure of the copolymers was confirmed spectrally, and the composition by the value of the acid number. Copolymers were obtained with molecular weight 7000 - 17000, maleic anhydride content 8 - 36%w, acid number 46 - 105 mg KOH/g and yield of 80 - 96%.

25 A perfectly alternating copolymer (100% alternation) of decyl methacrylate and maleic anhydride would contain 50 mol% of each monomer. A copolymer containing a lower molar percentage of maleic anhydride would inevitably have a lower degree of alternation (< 100%). The copolymers obtained contained 8 to 36%w maleic
30 anhydride which corresponds to 16.7 to 56.5 mol% maleic anhydride. Bearing in mind that maleic anhydride is said not to form a homopolymer under the reaction conditions used, an observed maleic anhydride content of greater than 50 mol% strongly suggests that this parameter was calculated on the basis of the crude, rather
35 than the pure, copolymer product, and this crude product would

naturally have contained some free (unreacted) maleic anhydride. Thus, the maleic anhydride contents quoted would appear to be higher than would actually have been the case. It is not possible, however, on the basis of the information available, to calculate
5 the actual content of maleic anhydride moieties and hence the possible degrees of alternation in the copolymers. Notwithstanding this, in view of the fact that decyl methacrylate is more reactive and has a much greater tendency to homopolymerise than maleic anhydride, that it was used in considerable excess in the process
10 (molar ratio decyl methacrylate to maleic anhydride 3.9:1), and that the total charge of decyl methacrylate was mixed with the total charge of maleic anhydride at the start of the process, the copolymers would be expected to contain low rather than high degrees of alternation.

15 EP-A-485 773 discloses petroleum middle distillates containing small amounts of (A) known flow-improvers based on ethylene and (B) copolymers consisting of 10 to 95 mol% of one or more alkyl acrylates or alkyl methacrylates with C_1 - to C_{26} -alkyl chains and of 5 to 90 mol% of one or more ethylenically unsaturated
20 dicarboxylic acids or their anhydrides, the copolymer having been extensively reacted with one or more primary or secondary amines to give the monoamide or amide/ammonium salt of the dicarboxylic acid.

The copolymers B contain from 10 to 95, preferably 40 to 95, and most preferably 60 to 90, mol% of the one or more alkyl
25 (meth)acrylates and from 5 to 90, preferably 5 to 60, and most preferably 10 to 40, mol% of the one or more ethylenically unsaturated dicarboxylic acids or anhydrides.

The alkyl groups of the alkyl (meth)acrylates are said to contain from 1 to 26, preferably 4 to 22, and most preferably 8 to
30 18, carbon atoms. The alkyl groups are preferably straight-chained and unbranched. However, up to 20%w of cyclic and/or branched alkyl components may be present.

Examples of particularly preferred alkyl (meth)acrylates are listed as n-octyl (meth)acrylate, n-decyl (meth)acrylate, n-dodecyl
35 (meth)acrylate, n-tetradecyl (meth)acrylate, n-hexadecyl

(meth)acrylate and n-octadecyl (meth)acrylate and mixtures of these.

5 Examples of ethylenically unsaturated dicarboxylic acids are said to be maleic acid, tetrahydrophthalic acid, citraconic acid and itaconic acid and their anhydrides as well as fumaric acid. Maleic anhydride is preferred.

10 The copolymers B are prepared by polymerising the one or more alkyl (meth)acrylates with the one or more ethylenically unsaturated dicarboxylic acids or anhydrides and reacting the copolymer obtained with a suitable amine. The first stage in the preparation may be carried out using discontinuous or continuous polymerisation processes such as mass, suspension, precipitation or solution polymerisation, initiated using the usual radical donors. Solution polymerisation is the preferred method.

15 At page 5, lines 22 to 46 of EP-A-485 773, it is stated that solution polymerisation is carried out in solvents in which the monomers and the copolymers formed are soluble. All solvents are suitable for this which meet this criterion and do not react with the monomers. Examples are toluene, xylene, ethylbenzene, cumene,
20 high boiling point mixtures of aromatics such as "SOLVESSO" (trade mark) 100, 150 and 200, aliphatic and cycloaliphatic hydrocarbons such as n-hexane, cyclohexane, methylcyclohexane, n-octane, iso-octane, paraffin oils, "SHELLSOL" (trade mark) TD, T and K, tetrahydrofuran and dioxan. Tetrahydrofuran and dioxan are
25 particularly suitable for producing low molecular weight copolymers. When carrying out solution polymerisation it is good practice to start with part of the monomer mixture (e.g. ca 5 to 20%) in the reactor and add to it the rest of the monomer mixture with the initiator and, if used, coinitiator, regulator and
30 solvent. The monomers can also be added individually at different speeds. This is recommended in the case of monomers with very different reactivities, as is the case with (meth)acrylates and unsaturated dicarboxylic acids or their anhydrides and if a particularly uniform distribution of the less reactive monomer in
35 the polymer is wanted. In this case the less reactive monomer is

added more rapidly and the more reactive monomer more slowly. It is also possible to start with the whole amount of a monomer, preferably the less-reactive anhydride, and add only the (meth)acrylate. Finally, it is also possible to start with all the monomer and the solvent and add only the initiator and, if used, 5 coiniciator and regulator (batch procedure). When carrying out this procedure on a large scale problems can arise, however, with removing the heat so that this procedure should be used only in the case of low concentrations of the monomers to be polymerised. The 10 concentrations of the monomers to be polymerised are between 10 and 80%w, preferably 30 and 70 %w. The solid copolymer can be obtained without problems by evaporating the solvent. It is, however, good practice to choose for the polymerisation a solvent in which the reaction with the amines can take place and which is miscible with 15 the middle distillate, so that the polymer solution can be added directly to the middle distillate.

In the above passage, it is stated that by adding the alkyl (meth)acrylate and ethylenically unsaturated dicarboxylic acid/anhydride monomers at different speeds during the reaction, a 20 polymer containing a particularly uniform distribution of the less reactive monomer can be obtained, the implication being that the procedure leads to polymers containing comparable amounts of the different monomers. There is no teaching in this document concerning desirability or otherwise of particular degrees of 25 alternation in polymer structure and, in particular, there is no suggestion that any polymer formed by solution polymerisation would, or desirably should, have a highly alternating structure.

Examples 1 to 6 in EP-A-485 773 relate to the preparation of polymers of alkyl (meth)acrylates with maleic anhydride, whilst 30 Examples 7 to 18 which follow relate to the reaction of those polymers with amines to form the copolymers B.

In each of Examples 1 to 5, a batch solution polymerisation process was used. The polymers obtained in Examples 1 to 5 contained molar ratios acrylate to maleic anhydride in the range 35 from 80:20 to 40:60. No information is given on the structure of

the polymers. Assuming, however, polymers containing alternating monomeric units had been formed, the maximum degree of alternation in the polymers would vary between 40% (based on 80:20 molar ratio) and 80 % (based on 40:60 molar ratio).

5 It has now surprisingly been found possible to prepare copolymers of n-alkyl (meth)acrylates and maleic anhydride which have a structure consisting substantially of alternating (meth)acrylate and maleic anhydride monomeric units, resulting in advantageous flow improver activity in a wide range of hydrocarbon
10 oils.

Therefore, in accordance with the present invention, there is provided a copolymer of at least one n-(C₈-C₃₀-alkyl) (meth)acrylate with maleic anhydride, which contains alternating (meth)acrylate and maleic anhydride monomeric units, characterised
15 in that the copolymer has a degree of alternation of at least 85%.

Preferred copolymers are those prepared from one or more n-(C₁₀-C₃₀-alkyl) (meth)acrylates, most preferably one or more n-(C₁₂-C₂₄-alkyl) (meth)acrylates. Acrylates are most preferred.

The degree of alternation in the copolymers can be readily
20 determined by quantitative C¹³ Nuclear Magnetic Resonance Spectroscopy (NMR). Thus, a sample of pure copolymer is dissolved in deuterated chloroform containing 0.15 M 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) and is subsequently analysed by NMR. From the NMR spectrum obtained, the ratio a/b of the integrals in the
25 carbonyl (CO) region at 172-174 ppm (a) and in the ester (OCH₂) region at about 65 ppm (b) is calculated. In the case of a homopoly(meth)acrylate, there is one carbonyl carbon for every OCH₂ carbon, so that the ratio a/b is 1. By comparison, in the case of a perfectly alternating copolymer of n-alkyl (meth)acrylate with
30 maleic anhydride, there are three carbonyl carbons for every OCH₂ carbon, so that the ratio a/b is 3. In the case where a copolymer of n-alkyl (meth)acrylate with maleic anhydride contains y perfectly alternating segments and 1-y acrylate segments (y x 100% represents the degree of alternation as a percentage), then there
35 are 3y + (1-y), i.e. 2y + 1, carbonyl carbons for every y + (1-y),

i.e. 1, OCH₂ carbon, so that the ratio a/b is 2y + 1 (or y is (a/b-1)/2).

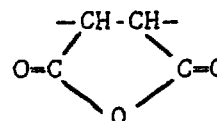
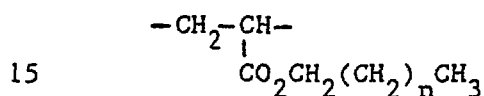
The latter expression is based on the understanding that maleic anhydride has an extremely low tendency to homopolymerise.

5 This was confirmed in control experiments carried out under the same polymerisation conditions as used in the preparation of the copolymers according to the present invention, in which no oligomers or polymers of maleic anhydride were formed.

The above explanation of the calculation of the degree of
10 alternation may be more readily understood by reference to the following structural representations:

(A)

(M)



"A" represents an acrylate monomeric unit in which "n" is an integer in the range from 6 to 28, and "M" represents a maleic
20 anhydride monomeric unit.

For: AAAAAAAAA C=O/OCH₂ = 1
AMAMAMAM C=O/OCH₂ = 3
(AM)_y(A)_(1-y), C=O/OCH₂ = $\frac{3y + (1-y)}{y + (1-y)} = 2y + 1$

25 The degree of alternation in the copolymers of the present invention is preferably at least 86%, more preferably at least 88%, and especially at least 90%.

The present invention also provides a process for the preparation of a copolymer according to the invention which
30 comprises reacting at least one n-(C₈-C₃₀-alkyl) (meth)acrylate with maleic anhydride in the presence of a radical-forming initiator, characterised in that a predetermined molar amount of the (meth)acrylate is dosed to a predetermined molar amount of the maleic anhydride at a dosage rate of 20 to 100 mol% (meth)acrylate

per hour, and that the ratio of the predetermined molar amount of (meth)acrylate to the predetermined molar amount of maleic anhydride is in the range from 1:1 to 1:5.

The n-(C₈-C₃₀-alkyl) (meth)acrylates used in the process of the present invention are known compounds or can be prepared by processes analogous to known processes. Thus, the (meth)acrylates may conveniently be prepared by an esterification process in which (meth)acrylic acid is heated together with one or more C₈-C₃₀ n-alkanols in an azeotropic solvent such as toluene, in the presence of an esterification catalyst, e.g. p-toluenesulphonic acid, and a polymerisation inhibitor, e.g. copper (II) acetate, with removal of water. The esterification reaction is typically carried out at a temperature in the range from 70 to 90°C under 20 kPa vacuum.

Preferred (meth)acrylates are those prepared from C₁₂-C₂₄ n-alkanols, e.g. 1-dodecanol, or a mixture of C₁₂-C₁₅ n-alkanols which is available from member companies of the Royal Dutch/Shell Group under the trade mark "DOBANOL 25", or a mixture of C₁₆-C₂₄ n-alkanols which is available from Sidobre Sinnova (France) as "Behenyl Alcohol X5".

Examples of radical-forming initiators include benzoyl peroxide, di-tert-butyl peroxide, acetyl peroxide, acetyl benzoyl peroxide and α,α' -azoisobutyronitrile. Further examples of radical-forming initiators are mentioned in EP-A-485 773.

The radical-forming initiator is conveniently used in an amount from 1 to 10 mol%, preferably from 1 to 5 mol%, and most preferably from 1.5 to 3 mol%, based on (meth)acrylate. The radical-forming initiator may be added as a single portion, or, alternatively, may be divided into two or more portions which are added at different stages during the course of the reaction. The initiator is conveniently added in two portions, the first portion containing 65 to 75%, and the second portion containing 25 to 35%, of the total intake of initiator.

The process of the invention is conveniently carried out in the presence of a solvent. Suitable solvents include hydrocarbons

such as toluene, xylene, ethylbenzene, hexane, octane, cyclohexane and those sold by member companies of the Royal Dutch/Shell group under the trade mark "SHELLSOL"; and ethers, particularly tetrahydrofuran and dioxan. The reaction is carried out at a temperature preferably in the range from 60 to 90°C, more preferably from 70 to 80°C.

In the process of the invention, a predetermined molar amount of at least one n-(C₈-C₃₀-alkyl) (meth)acrylate is dosed to a predetermined molar amount of maleic anhydride at a dosage rate of 20 to 100 mol%, preferably 40 to 80 mol%, and especially 60 mol%, (meth)acrylate per hour.

The ratio of the predetermined molar amount of (meth)acrylate to the predetermined molar amount of maleic anhydride is in the range from 1:1 to 1:5, preferably from 1:1 to 1:3, more preferably from 1:1 to 1:1.5, and is especially 1:1.

The number average molecular weights (M_n) of the copolymers of the present invention obtained by the above process may vary within wide limits. For example, the copolymers may have number average molecular weights up to 100,000, e.g. in the range from 500 to 100,000, preferably from 1,000 to 50,000, more preferably from 1,000 to 35,000, still more preferably from 1,000 to 20,000, and advantageously from 4,500 to 10,000. Such number average molecular weights may conveniently be determined by gel permeation chromatography (GPC) against polystyrene standards.

The copolymers of the present invention are useful as additives in hydrocarbon oils such as gas oils, diesel oils, fuel oils, lubricating oils and crude oils. Particularly advantageous results are obtained when the copolymers are used in gas oils and crude oils. Thus, the present invention further provides a hydrocarbon oil composition comprising a major amount of a hydrocarbon oil and a minor amount of a copolymer according to the invention. The copolymer is used in an amount of 0.1 to 10,000 mg per kg hydrocarbon oil. Preferably 1 to 5,000, more preferably 10 to 3,000, and in particular 20 to 2,000, mg copolymer per kg hydrocarbon oil are used.

The hydrocarbon oil compositions may, depending on their end-use, contain various other additives such as dispersants, detergents, corrosion inhibitors and viscosity-index improvers.

The present invention still further provides the use of a
5 copolymer of the invention as a flow improver additive.

The present invention will be further understood from the following illustrative examples.

Example 1

10 Preparation of a highly alternating copolymer of C₁₂-C₁₅-alkyl acrylate and maleic anhydride

9.8 g (0.1 mol) maleic anhydride (MALA) and 50 g toluene were introduced into a double walled glass reactor equipped with an overhead stirrer, an argon inlet, a condenser and an inlet
15 connection for a perfusion pump. The reactor was purged with argon and a slight flow of argon was maintained throughout the entire reaction. The mixture in the reactor was heated, with stirring, to a temperature of about 80°C by circulating silicon oil from a thermostatted bath. When all the maleic anhydride had melted and
20 dissolved, a portion of α,α' -azoisobutyronitrile (AIBN) in toluene was introduced into the reactor using a syringe. This portion consisted of 75% of the total AIBN intake of 0.24 g (1.5 mol% based on acrylate intake) in 5.4 g toluene.

100 ml of a solution of 26.1 g (0.1 mol) C₁₂-C₁₅-alkyl
25 acrylate (being the reaction product of acrylic acid and a mixture of C₁₂-C₁₅ n-alkanols available from member companies of the Royal Dutch/Shell Group under the trade mark "DOBANOL 25") in toluene was subsequently dosed to the reaction mixture over a period of 100 minutes (molar ratio acrylate:MALA of 1:1; dosage rate of 60 mol%
30 acrylate per hour). On completion of the acrylate addition, the remaining portion of AIBN solution (25%) was immediately introduced into the reactor and the reaction was left to continue for a further 4 hours. On cooling to below 60°C, the crude reaction product containing the highly alternating copolymer of
35 C₁₂-C₁₅-alkyl acrylate and maleic anhydride was collected and

analysed by gel permeation chromatography (GPC) against polystyrene standards. The copolymer was found to have a number average molecular weight (M_n) of 7,700. Purification of the crude product by dialysis followed by analysis by Nuclear Magnetic Resonance (NMR) revealed the degree of alternation in the copolymer to be 90%.

Example 2

Example 1 was repeated with the following exceptions: 9.8 g maleic anhydride in 20 g toluene was used and the C_{12} - C_{15} -alkyl acrylate was replaced by C_{12} -alkyl acrylate (molar ratio acrylate: MALA of 1:1). The copolymer of C_{12} -alkyl acrylate and maleic anhydride obtained had M_n 4,900 (determined by GPC on the crude product) and a degree of alternation of 100% (calculated on the purified product).

Example 3

Example 1 was repeated with the following exceptions: 9.8 g maleic anhydride in 20 g toluene was used and the C_{12} - C_{15} -alkyl acrylate was replaced by C_{16} - C_{24} -alkyl acrylate (being the reaction production of acrylic acid and a mixture of C_{16} - C_{24} alcohols commercially available from Sidobre Sinnova (France) as "Behenyl Alcohol X5"). The molar ratio acrylate:MALA was 1:1. The copolymer of C_{16} - C_{24} -alkyl acrylate and maleic anhydride obtained had M_n 9,000 (determined by GPC on the crude product) and a degree of alternation of 100% (calculated on the purified product).

Comparative Example A

A copolymer of C_{12} - C_{15} -alkyl acrylate and maleic anhydride was prepared in accordance with the teaching of US Patent No. 4,663,491. Thus, 9.8 g (0.1 mol) maleic anhydride (MALA), 104.4 g (0.4 mol) of the C_{12} - C_{15} -alkyl acrylate described in Example 1 above (molar ratio acrylate:MALA of 4:1) and 114 g toluene were introduced into a reaction flask and the contents heated, with stirring, to 85°C in an inert argon atmosphere. A solution of

0.3 g α,α' -azoisobutyronitrile (AIBN) in 6 ml toluene was divided into 6 portions and the individual portions were added to the reaction mixture at half hourly intervals. The total reaction time was 4 hours. Once cooled, the crude reaction product containing a copolymer of C_{12} - C_{15} -alkyl acrylate and maleic anhydride was collected and analysed by gel permeation chromatography (GPC) against polystyrene standards. The copolymer was found to have a number average molecular weight (M_n) of 23,700. Purification of the crude product by dialysis followed by analysis by Nuclear Magnetic Resonance (NMR) revealed the degree of alternation in the copolymer to be 34%.

Comparative Example B

The procedure described in Comparative Example A was repeated except that the molar ratio acrylate:MALA was 1:1 and only 36 g toluene were used. The copolymer of C_{12} - C_{15} -alkyl acrylate and maleic anhydride obtained had M_n 9,450 (determined by GPC on the crude product) and a degree of alternation of 78% (calculated on the purified product).

Comparative Example C

In a manner analogous to the procedure of Example 2 in US Patent No. 4,663,491, 65.25 g (0.25 mol) C_{12} - C_{15} -alkyl acrylate as described in Example 1 above and 24.5 g (0.25 mol) maleic anhydride (MALA) (molar ratio acrylate:MALA of 1:1) were placed in a reaction flask and heated to 85°C in a nitrogen atmosphere. At that temperature, 0.15 g of α,α' -azoisobutyronitrile (AIBN) in 3 ml toluene was added and a temperature increase was observed. After cooling to 95°C, further amounts of AIBN were added in five metered portions until a total of 0.75 g AIBN dissolved in 15 ml toluene had been consumed. The total reaction time was 4 hours. Once cooled, the crude reaction product containing a copolymer of C_{12} - C_{15} -alkyl acrylate and maleic anhydride was collected and analysed by gel permeation chromatography against polystyrene standards. The copolymer was found to have a number average

molecular weight (M_n) of 12,500. Purification of the crude product by dialysis followed by analysis by Nuclear Magnetic Resonance (NMR) revealed the degree of alternation in the copolymer to be 80%.

5 Example 4

Solutions of the copolymers of Examples 1 to 3 and of Comparative Examples A to C in toluene (50% by weight) were incorporated into seven gas oils (a,b,c,d,e,f and g) preheated to 50°C and the pour points (PP) and/or cold filter plugging points (CFPP) of the resulting compositions were determined according to standard test methods ASTM D97-66 and IP 309/83 respectively. The PP and CFPP values obtained are shown in Table I below. In this table, the amount of copolymer solution added to the gas oil is expressed as mg polymer solution per kg gas oil ("Solution mg/kg").

15 Gas oil a was a French industrial gas oil having density at 15°C of 870 kg/m³, viscosity at 40°C of 3.65 mm²/s, sulphur content of 0.3%w and a boiling point range: 10% = 184°C, 50% = 272°C and 90% = 368°C.

20 Gas oil b was a French industrial gas oil having density at 15°C of 843 kg/m³, viscosity at 40°C of 3.54 mm²/s and sulphur content of < 0.3%w.

Gas oil c was a French industrial gas oil having density at 15°C of 853 kg/m³, viscosity at 40°C of 3.82 mm²/s and sulphur content of < 0.3%w.

25 Gas oil d was a French automotive gas oil having density at 15°C of 841 kg/m³, viscosity at 40°C of 3.46 mm²/s and sulphur content of < 0.5%w.

30 Gas oil e was a Danish automotive gas oil having density at 15°C of 842 kg/m³, viscosity at 40°C of 2.92 mm²/s, sulphur content of 0.002%w and a boiling point range: 10% = 180°C, 50% = 249°C and 90% = 319°C.

Gas oil f was a German automotive gas oil having density at 15°C of 836 kg/m³, viscosity at 40°C of 3.17 mm²/s, sulphur content

of 0.11%w and a boiling point range: 10% = 204°C, 50% = 259°C and 90% = 324°C.

Gas oil g was a Swedish automotive gas oil having density at 15°C of 801 kg/m³, viscosity at 40°C of 2.64 mm²/s, sulphur content of 0.0005%w and a boiling point range: 10% = 206°C, 50% = 226°C and 90% = 266°C.

Gas oils a to f had aromatic contents in the region of 20 to 30%w whilst gas oil g had an aromatic content of less than 5%w.

10

TABLE I

Test No.	Gas Oil	Copolymer of Ex. No.	Solution mg/kg	PP (°C)	CFPP (°C)
1	a	-	-	-9 *	-9 *
2	a	1	40	-15	-
3	a	1	600	-21	-17
4	a	1	1000	-24	-18
5	a	1	2000	-27	-21
6	a	2	40	-9	-13
7	a	2	600	-12	-
8	a	2	2000	-24	-
9	b	-	-	-	-10 *
10	b	1	300	-	-20
11	b	Comp. A	300	-	-11
12	b	Comp. B	300	-	-9
13	b	Comp. C	300	-	-17
14	c	-	-	-	-17 *
15	c	1	300	-	-20
16	c	Comp. A	300	-	-15
17	c	Comp. B	300	-	-20
18	c	Comp. C	300	-	-17
19	d	-	-	-	-4 *
20	d	1	300	-	-9
21	d	Comp. A	300	-	-7

TABLE I (continued)

	Test No.	Gas Oil	Copolymer of Ex. No.	Solution mg/kg	PP (°C)	CFPP (°C)
5	22	d	Comp. B	300	-	-9
	23	3	Comp. C	300	-	-7
	24	e	-	-	-	-34 *
	25	e	2	40	-	-42
	26	e	2	300	-	-45
10	27	f	-	-	-	-10 *
	28	f	1	300	-	-19
	29	f	1	500	-	-20
	30	f	3	300	-	-12
	31	f	Comp. A	300	-	-13
15	32	f	Comp. B	300	-	-14
	33	f	Comp. C	300	-	-14
	34	f	Comp. C	2000	-	-19
	35	g	-	-	-	-37 *
	36	g	1	300	-	-45
	37	g	Comp. C	300	-	-42

20 * PP or CFPP measurement of gas oil preheated to 50°C.

Example 5

25 A 50% by weight solution of the copolymer of Example 3 in toluene was incorporated into two crude oils (a' and b') preheated to 50°C and the pour points (PP) of the resulting compositions were determined according to standard test method ASTM D97-66. Table II below shows the results obtained. In this table, the amount of copolymer solution added to the crude oil is expressed as mg polymer solution per kg crude oil ("Solution mg/kg").

30 Crude oil a' which was from New Zealand had density at 15°C of 833 kg/m³, viscosity at 40°C of 3.0 mm²/s, sulphur content of 0.08%w and cloud point of 50°C. Crude oil a' showed no minimum or maximum pour point behaviour.

Crude oil b' which was from New Zealand had density at 15°C of 831 kg/m³, viscosity at 40°C of 2.9 mm²/s, sulphur content of 0.077%w and cloud point of 49°C. The content of asphaltenes in crude oil b' was low; the wax content was 14.6%w. Crude oil b' showed no minimum or maximum pour point behaviour.

TABLE II

Test No.	Crude Oil	Copolymer of Ex. No.	Solution mg/kg	PP (°C)
38	a'	-	-	33*
39	a'	3	500	30
40	a'	3	1000	27
41	a'	3	2000	27
42	a'	3	3000	21
43	a'	3	4000	18
44	b'	-	-	33 *
45	b'	3	40	30
46	b'	3	400	27
47	b'	3	1000	27
48	b'	3	2000	21
49	b'	3	4000	12

* PP measurement of crude oil preheated to 50°C.



C L A I M S

1. A copolymer of at least one n-(C₈-C₃₀-alkyl) (meth)acrylate with maleic anhydride, which contains alternating (meth)acrylate and maleic anhydride monomeric units, characterised in that the copolymer has a degree of alternation of at least 85%.
- 5 2. A copolymer according to claim 1, wherein the at least one (meth)acrylate is selected from n-(C₁₀-C₃₀-alkyl) (meth)acrylates and mixtures thereof.
3. A copolymer according to claim 2, wherein the at least one (meth)acrylate is selected from n-(C₁₂-C₂₄-alkyl) (meth)acrylates and mixtures thereof.
- 10 4. A copolymer according to claim 3, wherein the at least one (meth)acrylate is selected from n-(C₁₂-alkyl) acrylate or mixtures of n-(C₁₂-C₂₄-alkyl) acrylates.
5. A copolymer according to any one of the preceding claims, wherein the degree of alternation is at least 86%.
- 15 6. A copolymer according to claim 5, wherein the degree of alternation is at least 88%.
7. A copolymer according to claim 6, wherein the degree of alternation is at least 90%.
- 20 8. A process for the preparation of a copolymer as defined in any one of the preceding claims which comprises reacting at least one n-(C₈-C₃₀-alkyl) (meth)acrylate with maleic anhydride in the presence of a radical-forming initiator, characterised in that a predetermined molar amount of the (meth)acrylate is dosed to a predetermined molar amount of the maleic anhydride at a dosage rate of 20 to 100 mol% (meth)acrylate per hour, and that the ratio of the predetermined molar amount of (meth)acrylate to the predetermined molar amount of maleic anhydride is in the range from 1:1 to 1:5.
- 25



9. A hydrocarbon oil composition comprising a major amount of a hydrocarbon oil and a minor amount of a copolymer as defined in any one of claims 1 to 7.
10. Use of a copolymer as defined in any one of claims 1 to 7 as a flow improver additive.
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