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(54) HYDRAULIC OIL FOR USE IN CONSTRUCTION MACHINERY

HYDRAULISCHES ÖL ZUR VERWENDUNG FÜR BAUMASCHINEN

HUILE HYDRAULIQUE POUR UNE UTILISATION DANS DES ENGINES DE CONSTRUCTION

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DescriptionTechnical Field of the Invention

5 **[0001]** This invention relates to a hydraulic oil for use in construction machinery, and more specifically relates to a hydraulic oil for use in the hydraulic apparatus of construction machinery, in order to actuate the hydraulic apparatus, including hydraulic actuators in construction machinery such as hydraulic motors and hydraulic cylinders.

Background of the Invention

10 **[0002]** Construction machinery uses hydraulic apparatus which includes hydraulic actuators such as hydraulic motors and hydraulic cylinders. In such construction machinery, a hydraulic oil pressurised by running a hydraulic pump by means of an engine is conveyed to hydraulic actuators such as hydraulic motors and hydraulic cylinders, or other hydraulic apparatus, thereby operating the hydraulic apparatus. In hydraulic apparatus which includes such hydraulic
15 actuators, a hydraulic circuit is formed, from the hydraulic pump run by means of an engine and via a path, disposed with hydraulic apparatus such as pilot valves, control valves, release valves, brakes and so on, that leads to a hydraulic actuator such as a hydraulic motor or hydraulic cylinder.

[0003] The hydraulic apparatus which includes such hydraulic actuators operates at high temperatures, of the order of 60 to 80°C for example, because of the heat transferred from the engine or power elements, or heat generated within
20 the hydraulic apparatus or pipes through pressurisation, friction, pipe resistance and so on, and this requires hydraulic oils capable of efficient operation within this temperature domain. From the standpoint of protecting the global environment, it is important to save energy and improve the efficiency of hydraulic oils within hydraulic equipment. Much research and development is being carried out as regards saving energy on the basis of how hydraulic oils are formulated. The idea has been to obtain hydraulic oils with lower viscosities, and to obtain lower friction by blending in an oiliness agent.
25 However, when a hydraulic oil as used in construction machinery is given a lower viscosity, internal leaks increase within the hydraulic pumps and control valves and so on, so that there is no contribution to energy savings.

[0004] Moreover, when friction is reduced by incorporating an oiliness agent, the friction coefficient in brakes in construction machinery which utilise wet discs is reduced, so that swing brake and parking brake functions are reduced and this is detrimental to the operating characteristics. In other words, in construction machinery which has a rotating part
30 such as a hydraulic shovel and a parking brake, brakes utilising wet discs are fitted to the rotating parts that use swing motors or the like and to travel motors. Brakes that use such wet discs are endowed with lubrication properties by means of the hydraulic oil, but if the friction coefficient of the hydraulic oil is reduced, the swing brake and parking brake functions are detrimentally affected and there is the possibility of a serious incident caused by a swinging movement that will not stop or by slipping off a slope.

35 **[0005]** Moreover, since construction machines are at low temperatures when they are parked overnight and are started at times of cold or in cold regions in a low temperature domain of the order, for example, of -30 to -20°C, they must have low viscosities at low temperatures. Hydraulic oils used in such hydraulic apparatus must therefore have viscosity characteristics suitable for a wide range of temperatures, from temperatures as low as -30 to -20°C to high temperatures of the order of 60 to 80°C.

40 **[0006]** Hitherto, Japanese Laid-open Patent H9-111277 (1997) has proposed, as a hydraulic oil for use in such hydraulic apparatus, a hydraulic oil which incorporates in a base oil an amine-based anti-oxidant, a phenolic anti-oxidant, a phosphate ester and a fatty acid amide or polyhydric alcohol ester, and it specifies that a poly(meth)acrylate can be added as a viscosity index improver. The hydraulic oil of Japanese Laid-open Patent H9-111277 (1997) has been proposed as a hydraulic oil which not only effectively stops the premature ageing of hydraulic oils and the generation of
45 sludge that are associated with higher pressures and so can be used over long periods, but which also eliminates the chatter phenomenon in cylinders and so exhibits stable operating characteristics.

[0007] However, the hydraulic oil of Japanese Laid-open Patent H9-111277 (1997) is focused on eliminating premature ageing and sludge generation and also the phenomenon of cylinder chatter, and does not take into consideration having a specified viscosity over a wide temperature range from low temperatures to high temperatures of the order of 60 to
50 80°C. Japanese Laid-open Patent H9-111277 (1997) also reduces the friction coefficient by means of an oiliness agent such as a fatty acid amide added in order to prevent the cylinder chatter phenomenon, and does not make adequate provision in respect of brake performance when using wet discs. Japanese Laid-open Patent H9-111277 (1997) mentions that a poly(meth)acrylate can be incorporated as a viscosity index improver, but does not specifically describe it.

55 **[0008]** Japanese Laid-open Patent 2007-91768 has proposed, as a hydraulic oil for use in door closers, a hydraulic oil which incorporates, in a hydrocarbon-based base oil comprised of a mineral oil or a hydrocarbon-based synthetic oil, a poly(meth)acrylate as a viscosity index improver and an overbased calcium sulphonate as a lubricity improver. Japanese Laid-open Patent 2007-91768 mentions that it is preferable to incorporate an oiliness agent such as a fatty acid, an aliphatic alcohol, a fatty acid ester or fatty oils, and these oiliness agents are included in the examples.

[0009] However, the door closers of Japanese Laid-open Patent 2007-91768 require the function of opening and closing doors smoothly by allowing passage of the hydraulic oil at a fixed rate via orifices disposed in the cylinder element. For this reason, the hydraulic oil used for the door closer must have a high viscosity index in order to maintain the opening or closing rate at a steady level irrespective of any change in temperature, hence the aforementioned composition. What is meant by a hydraulic oil having a high viscosity index is that it has certain kinematic viscosities at both low temperatures and high temperatures. In Japanese Laid-open Patent 2007-91768, a viscosity index for the hydraulic oil of not less than 250 is desirable, and not less than 270 is preferred.

[0010] In Japanese Laid-open Patent 2007-91768, in order to obtain a hydraulic oil having a high viscosity index of this order, a poly(meth)acrylate is incorporated as a viscosity index improver, but the weight average molecular weight of the poly(meth)acrylate incorporated herein is set at from 50,000 to 700,000, though from 100,000 to 500,000 and, especially, from 150,000 to 400,000 are preferred. In the examples, examples with a molecular weight of from 250,000 to 550,000 are used. However, when a poly(meth)acrylate of such high molecular weight is added, the viscosity index becomes too high and it is not possible fully to achieve low temperature performance and operational characteristics at high temperatures. Since an oiliness agent also has to be incorporated, there is a problem in that there is no adequate provision in respect of brake performance when using wet discs.

[0011] Japanese Laid-open Patent 2007-106878 describes; as a hydraulic oil for use in door closers, a hydraulic actuating oil with a kinematic viscosity at 40°C of from 22 to 95 mm²/s, a kinematic viscosity at 100°C of from 10 to 30 mm²/s, a pour point of -10°C or less, a CCS viscosity at -20°C of not more than 2500 mPa.s and a flash point of not less than 140°C, and which contains a base oil with a kinematic viscosity at 40°C of from 2 to 20 mm²/s and viscosity index of not less than 50 together with a poly(meth)acrylate. The weight average molecular weight of the poly(meth)acrylate is from 150,000 to 700,000, but preferably from 200,000 to 500,000 and so virtually the same remarks as about Japanese Laid-open Patent 2007-91768 may be made.

[0012] The prior art has included, as hydraulic oils for hydraulic apparatus, the use of other compositions which incorporate in a base oil, as well as other additives, a poly(meth)acrylate as a viscosity index improver, but the inclusion of a viscosity index improver is there intended to improve the viscosity index as far as practicable and so to reduce the difference between the kinematic viscosity at low temperature and the kinematic viscosity at high temperature. For this purpose, a poly(meth)acrylate of high molecular weight is added as the viscosity index improver, and so in these cases, too, problems similar to those in the three patent documents mentioned above exist.

[0013] The theme of the invention is to resolve the aforementioned problems of the prior art by offering a hydraulic oil which not only has a high kinematic viscosity in the high-temperature domain even though the incorporation of an oiliness agent is omitted, and can thereby effect satisfactory operation efficiently and has excellent braking characteristics, but which also has a low viscosity in the low-temperature domain and so has excellent low-temperature performance.

Summary of the Invention

[0014] This invention is a hydraulic oil for use in construction machinery, wherein the hydraulic oil comprises a poly(meth)acrylate of weight average molecular weight in the range of from 30,000 to 100,000 in a highly refined base oil, but does not incorporate an oiliness agent, and wherein the kinematic viscosity at 60°C is in the range of from 25 to 60 mm²/s, the kinematic viscosity at 80°C is in the range of from 15 to 34 mm²/s, the viscosity index is in the range of from 200 to 220, and the low temperature cranking viscosity at -25°C is in the range of from 1000 to 8000 mPa.s. The base oil belongs to API group I, group II or group III base oil categories.

Detailed Description of the Invention

[0015] The hydraulic oil of the present invention is a hydraulic oil for use in the hydraulic apparatus of construction machinery, and is the hydraulic oil meant to actuate the hydraulic apparatus, including hydraulic actuators such as hydraulic motors and hydraulic cylinders. What is meant by construction machinery in this invention is machinery used in the construction industry and which is fitted with hydraulic apparatus. As examples of such machinery, mention may be made of: digging machinery such as shovels; loading machinery such as wheel loaders; excavating and moving machinery such as bulldozers; moving machinery such as dump trucks, rough terrain haulers and forklifts, cranes such as rough-terrain cranes, and winches; foundation work machinery such as hydraulic breakers; boring and tunnelling machinery such as the Iron Mole; aggregate plant and recycling machinery such as self-propelled crushers; land grading and roadbed machinery such as motorised graders; and compacting machinery such as road rollers, paving machinery such as asphalt finishers; and road maintenance machinery such as snowploughs. As examples of hydraulic apparatus, mention may be made of hydraulic pumps such as piston pumps; hydraulic actuators such as hydraulic motors and hydraulic cylinders; hydraulic control valves such as pressure control valves and directional control valves; brakes such as wet-disc brakes; and other machinery utilising the oil pressure of an actuating oil.

[0016] In order to achieve energy savings and higher efficiencies, by inhibiting internal leaks in hydraulic pumps and

control valves, the kinematic viscosity during operation, that is the kinematic viscosities at 60°C and 80°C, for the hydraulic oil of this invention are set higher than hitherto. In order to increase the kinematic viscosity during operation, in this invention a poly(meth)acrylate is incorporated in the base oil, this being a highly refined base oil, as a viscosity index improver.

[0017] When the kinematic viscosity in the high-temperature domain is thus set at a high level, the start-up properties in the low-temperature domain deteriorate, and so in this invention the low-temperature cranking viscosity at -25°C is reduced by incorporating, as a viscosity index improver, a specified poly(meth)acrylate so that the viscosity index becomes from 200 to 220. The low-temperature working viscosity and other low-temperature performance levels can thus be brought down.

[0018] For the base oil used in this invention it is possible to use mineral oils and synthetic oils designated as highly refined base oil, and in particular it is possible to use, singly or as mixtures, base oils which belong to Group I, Group II and Group III of the API (American Petroleum Institute) base oil categories. The base oils used here should have an elemental sulphur content of less than 0.8% by mass and preferably less than 0.5% by mass. Further, the density should be in the range of from 0.8 to 0.9 g/cm³. The aromatic content should be not more than 5% by mass and preferably not more than 3% by mass.

[0019] Group I base oils include, for example, paraffinic mineral oils obtained by a suitable combination of refining processes such as solvent refining, hydrorefining, and dewaxing in respect of lubricating oil fractions obtained by atmospheric distillation of crude oil. The viscosity index should be in the range of from 80 to 120 and preferably in the range of from 95 to 110. The kinematic viscosity at 40°C should preferably be in the range of from 2 to 150 mm²/s and even more preferably in the range of from 8 to 100 mm²/s. Also, the total sulphur content should be less than 0.8% by mass and preferably less than 0.5% by mass. The total nitrogen content should be less than 50 ppm and preferably less than 25 ppm. In addition, oils with an aniline point in the range of from 80 to 150°C and preferably in the range of from 90 to 120°C should be used.

[0020] Group II base oils include, for example, paraffinic mineral oils obtained by a suitable combination of refining processes such as hydrorefining and dewaxing in respect of lubricating oil fractions obtained by atmospheric distillation of crude oil. Group II base oils refined by hydrorefining methods such as the Gulf Company method have a total sulphur content of less than 10 ppm and an aromatic content of not more than 5% and so are suitable for this invention. The viscosity of these base oils is not specially limited, but the viscosity index should be in the range of from 80 to 120 and preferably in the range of from 100 to 120. The kinematic viscosity at 40°C should preferably be in the range of from 2 to 150 mm²/s and even more preferably in the range of from 8 to 100 mm²/s. Also, the total sulphur content should be less than 300 ppm, preferably less than 200 ppm and even more preferably less than 10 ppm. The total nitrogen content should be less than 10 ppm and preferably less than 1 ppm. In addition, oils with an aniline point in the range of from 80 to 150°C and preferably in the range of from 100 to 135°C should be used.

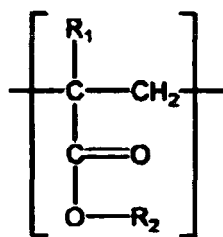
[0021] Among what are normally designated as Group III base oils and Group II+ base oils, suitable examples are paraffinic mineral oils manufactured by a high degree of hydrorefining in respect of lubricating oil fractions obtained by atmospheric distillation of crude oil, base oils refined by the Isodewax process which dewaxes and substitutes the wax produced by the dewaxing process with isoparaffins, and base oils refined by the Mobil wax isomerisation process. They include also those that may be designated as "synthetic oils" according to the rulings of the NAD (National Advertising Division) which is responsible for advertising adjudications in America.

[0022] The viscosity of these base oils is not specially limited, but the viscosity index should be in the range of from 95 to 145 and preferably in the range of from 100 to 140. The kinematic viscosity at 40°C should preferably be in the range of from 2 to 150 mm²/s and even more preferably in the range of from 8 to 100 mm²/s. Also, the total sulphur content should be in the range of from 0 to 100 ppm and preferably less than 10 ppm. The total nitrogen content should be less than 10 ppm and preferably less than 1 ppm. In addition, oils with an aniline point in the range of from 80 to 150°C and preferably in the range of from 110 to 135°C should be used. (The aforementioned Group II+ oils belong to Group II.)

[0023] Further, GTLs (gas to liquid) synthesised by the Fischer-Tropsch method of converting natural gas to liquid fuel have a very low sulphur content and aromatic content compared with mineral oil base oils refined from crude oil and have a very high paraffin constituent ratio, and so have excellent oxidative stability, and because they also have extremely small evaporation losses, they are suitable as base oils belonging to Group III. The viscosity characteristics of such GTL base oils are not specially limited, but normally the viscosity index should be in the range of from 130 to 180 and preferably in the range of from 140 to 175. Also, the kinematic viscosity at 40°C should be in the range of from 2 to 150 mm²/s and more preferably in the range of from 5 to 100 mm²/s. Normally the total sulphur content should also be less than 10 ppm and the total nitrogen content less than 1 ppm. A commercial example of such a GTL base oil is Shell XHVI (registered trademark).

[0024] The proportion of the aforementioned base oil blended in the hydraulic oil of this invention is not specially limited, but preferably should be in the range of from 70 to 90% by mass and more preferably in the range of from 75 to 85% by mass.

[0025] The poly(meth)acrylate added to the aforementioned base oil is used as a viscosity index improver and comprises a polyacrylate or a polymethacrylate. Preferred poly(meth)acrylates are polymers having one kind or two or more kinds of the constituent units represented by the general formula (1) below, or polymers having these constituent units together with other constituent units.



(1)

[0026] In general formula 1, R_1 denotes hydrogen or a methyl group, a methyl group being preferred. R_2 denotes an alkyl group having from 1 to 30 carbons or a group represented by $-(R)_a-E$ where R is an alkylene group having from 1 to 30 carbons, E denotes either an amine residual group containing 1 to 2 nitrogen atoms and 0 to 2 oxygen atoms or a heterocyclic residual group, and a denotes an integer of 0 or 1.

[0027] As examples of the alkyl groups having from 1 to 30 carbons denoted by R_2 , mention may be made of methyl groups, ethyl groups, propyl groups, butyl groups, pentyl groups, hexyl groups, heptyl groups, octyl groups, nonyl groups, decyl groups, undecyl groups, dodecyl groups, tridecyl groups, tetradecyl groups, pentadecyl groups, hexadecyl groups, heptadecyl groups, octadecyl groups, eicosyl groups, docosyl groups, tetracosyl groups, hexacosyl groups and octacosyl groups (these alkyl groups may be straight chain or branched).

[0028] As examples of the alkylene groups having from 1 to 30 carbons denoted by R, mention may be made of methylene groups, ethylene groups, propylene groups, butylene groups, pentylene groups, hexylene groups, heptylene groups, octylene groups, nonylene groups, decylene groups, undecylene groups, dodecylene groups, tridecylene groups, tetradecylene groups, pentadecylene groups, hexadecylene groups, heptadecylene groups and octadecylene groups (these alkylene groups may be straight chain or branched).

[0029] Also, if E is an amine residue, as specific examples thereof mention may be made of dimethyl amino groups, diethyl amino groups, dipropyl amino groups, dibutyl amino groups, anilino groups, toluidino groups, xylydino groups, acetyl amino groups and benzoyl amino groups. If E is heterocyclic residue, as specific examples thereof mention may be made of morpholino groups, pyrrolyl groups, pyrrolino groups, pyridyl groups, methylpyridyl groups, pyrrolidinyl groups, piperidinyl groups, quinonyl groups, pyrrolidonyl groups, pyrrolidono groups, imidazolino groups and pyrazino groups.

[0030] The molecular weight of the poly(meth)acrylate (weight average molecular weight determined by GPC) should be in the range of from 30,000 to 100,000, but preferably in the range of from 30,000 to 70,000. It is possible to use commercial poly(meth)acrylates as they are. Also, the poly(meth)acrylates added as viscosity index improvers to the hydraulic oil herein may be incorporated singly or as a mixture of two or more polymers. Taking into consideration handling and solubility in lubricating oil base oils, poly(meth)acrylates for additives are manufactured and sold in the form of a dilution in a mineral oil, normally of the order of from 10 to 80% by mass.

[0031] In the hydraulic oil of this invention, the poly(meth)acrylate is incorporated in an amount such that the kinematic viscosity at 60°C is in the range of from 25 to 60 mm²/s and preferably in the range of from 28 to 50 mm²/s, the kinematic viscosity at 80°C is in the range of from 15 to 34 mm²/s and preferably in the range of from 17 to 30 mm²/s, the viscosity index is in the range of from 200 to 220 and preferably in the range of from 205 to 215, the viscosity at -25°C is in the range of from 1000 to 8000 mPa.s and preferably in the range of from 1000 to 5000 mPa.s, and for further preference in an amount such that the kinematic viscosity at 40°C is in the range of from 45 to 150 mm²/s and preferably in the range of from 50 to 100 mm²/s. The amount incorporated will vary according to the amount and viscosity and other characteristics of the base oil, the molecular weight of the poly(meth)acrylate and the amount of the diluting agent, but in general it is best if the amount of poly(meth)acrylate as additive, including diluent, is set at from 10 to 30% by mass, and preferably from 15 to 25% by mass, based on the total amount of the hydraulic oil. The diluent added to the hydraulic oil will be contained in the base oil, and the proportion of pure poly(meth)acrylate incorporated should be in the range of from 1 to 24% by mass, and preferably in the range of from 1.5 to 20% by mass, on the basis of the total amount of the hydraulic oil.

[0032] The hydraulic oil of this invention is a hydraulic oil which does not substantially include an oiliness agent. Oiliness agents are oily organic compounds which have been added to hydraulic oils in the prior art as a means of

reducing the friction coefficient. They are friction coefficient reducing compounds such as fatty acids, fatty acid esters, polyhydric alcohol esters, amines, amides, and amides of polyamines. By not incorporating these oiliness agents in the hydraulic oil it is possible to increase the damping characteristics of brakes. However, minute amounts of oily organic compounds contained ab initio in the base oil which forms the hydraulic oil, the poly(meth)acrylate and the other additives

are allowed.

[0033] In the hydraulic oil of this invention, it is possible to incorporate other additives as appropriate and where necessary apart from the aforementioned base oil and polymethacrylate. Mention may be made of anti-oxidants, metal deactivators, extreme pressure agents, defoaming agents, viscosity index improvers, pour point depressants, detergent dispersants, rust preventatives, demulsifiers and other known additives used as lubricating oil additives. The amount of these additives in the blend should be not more than 10% by mass on the basis of the total amount of the hydraulic oil, and preferably not more than 5% by mass.

[0034] For the anti-oxidants used in this invention, those used in lubricating oils are preferred for practical use, and mention may be made of phenolic anti-oxidants, aromatic amine-based anti-oxidants, sulphur-based anti-oxidants and phosphorus-based anti-oxidants. These anti-oxidants may be used singly or as mixtures within the range of from 0.01 to 5% by mass based on the total amount of the hydraulic oil.

[0035] As examples of the aforementioned aromatic amine-based anti-oxidants, mention may be made of dialkyl-diphenylamines such as p,p'-dioctyl-diphenylamine (Nonflex OD-3, made by Seiko Chemical Ltd), p,p'-di- α -methylbenzyl-diphenylamine and N-p-butylphenyl-N-p'-octylphenylamine, monoalkyldiphenylamines such as mono-t-butyl-diphenylamine and mono-octyldiphenylamine, bis(dialkylphenyl)amines such as di(2,4-diethylphenyl)amine and di(2-ethyl-4-nonylphenyl)amine, alkylphenyl-1-naphthylamines such as octyl-phenyl-1-naphthylamine and N-t-dodecylphenyl-1-naphthylamine; 1-naphthylamine, aryl-naphthylamines such as phenyl-1-naphthylamine, phenyl-2-naphthylamine, N-hexylphenyl-2-naphthylamine and N-octylphenyl-2-naphthylamine, phenylenediamines such as N,N'-diisopropyl-p-phenylenediamine and N,N'-diphenyl-p-phenylenediamine, and phenothiazines such as Phenothiazine (made by Hodogaya Chemical Ltd.) and 3,7-dioctylphenothiazine.

[0036] Phenolic anti-oxidants include 2-t-butylphenol, 2-t-butyl-4-methylphenol, 2-t-butyl-5-methylphenol, 2,4-di-t-butylphenol, 2,4-dimethyl-6-t-butylphenol, 2-t-butyl-4-methoxyphenol, 3-t-butyl-4-methoxyphenol, 2,5-di-t-butylhydroquinone (Antage DBH, made by Kawaguchi Chemical Industry Co. Ltd.), 2,6-di-t-butylphenol, 2,6-di-t-butyl-4-alkylphenols such as 2,6-di-t-butyl-4-methylphenol and 2,6-di-t-butyl-4-ethylphenol, and 2,6-di-t-butyl-4-alkoxyphenols such as 2,6-di-t-butyl-4-methoxyphenol and 2,6-di-t-butyl-4-ethoxyphenol.

[0037] Also, there are 3,5-di-t-butyl-4-hydroxybenzylmercapto-octylacetate, alkyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionates such as n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate (Yoshinox SS, made by Yoshitomi Fine Chemicals Ltd.), n-dodecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate and 2'-ethylhexyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate, benzenepropanoic acid 3,5-bis(1,1-dimethyl-ethyl)-4-hydroxy-C7-C9 side-chain alkyl esters (Irganox L135, made by Ciba Specialty Chemicals Ltd.), 2,6-di-t-butyl- α -dimethylamino-p-cresol, and 2,2'-methylenebis(4-alkyl-6-t-butylphenol)s such as 2,2'-methylenebis(4-methyl-6-t-butylphenol) (Antage W-400, made by Kawaguchi Chemical Industry Ltd.) and 2,2'-methylenebis(4-ethyl-6-t-butylphenol) (Antage W-500, made by Kawaguchi Chemical Industry Ltd).

[0038] Furthermore, there are bisphenols such as 4,4'-butylidenebis(3-methyl-6-t-butylphenol) (Antage W-300, made by Kawaguchi Chemical Industry Ltd.), 4,4'-methylenebis(2,6-di-t-butylphenol) (Ionox 220AH, made by Shell Japan Ltd.), 4,4'-bis(2,6-di-t-butylphenol), 2,2-(di-p-hydroxyphenyl)propane (Bisphenol A, made by Shell Japan Ltd.), 2,2-bis(3,5-di-t-butyl-4-hydroxyphenyl)propane, 4,4'-cyclohexylidenebis(2,6-t-butylphenol), hexamethylene glycol bis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate] (Irganox L109, made by Ciba Specialty Chemicals Ltd.), triethylene glycol bis[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionate] (Tominox 917, made by Yoshitomi Fine Chemicals Ltd.), 2,2'-thio-[diethyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate] (Irganox L115, made by Ciba Specialty Chemicals Ltd.), 3,9-bis(1,1-dimethyl-2-[3-(3-t-butyl-4-hydroxy-5-methylphenyl) propionyloxy]ethyl)2,4,8,10-tetraoxaspiro[5,5]undecane (Sumilizer GA80, made by Sumitomo Chemicals), 4,4'-thiobis(3-methyl-6-t-butylphenol) (Antage RC, made by Kawaguchi Chemical Industry Ltd.) and 2,2'-thiobis(4,6-di-t-butyl-resorcinol). Mention may also be made of tetrakis[methylene-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate]methane (Irganox L101, made by Ciba Specialty Chemicals Ltd.), 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane (Yoshinox 930, made by Yoshitomi Fine Chemicals Ltd.), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl)benzene (Ionox 330, made by Shell Japan Ltd.), bis-[3,3'-bis(4'-hydroxy-3'-t-butylphenyl) butyric acid] glycol ester, and polyphenols such as 2-(3',5'-di-t-butyl-4-hydroxyphenyl) methyl-4-(2'',4''-dit-butyl-3''-hydroxyphenyl)methyl-6-t-butylphenol and 2,6-bis(2'-hydroxy-3'-t-butyl-5'-methyl-benzyl)-4-methylphenol, and phenol-aldehyde condensates such as condensates of p-t-butylphenol and formaldehyde and condensates of p-t-butylphenol and acetaldehyde.

[0039] As examples of sulphur-based anti-oxidants, mention may be made of dialkyl sulphides such as didodecyl sulphide and dioctadecyl sulphide, thiodipropionate esters such as didodecyl thiodipropionate, dioctadecyl thiodipropionate, dimyristyl thiodipropionate and dodecyloctadecyl thiodipropionate, and 2-mercaptobenzoimidazole.

[0040] As examples of phosphorus-based anti-oxidants mention may be made of triarylphosphites such as triphenyl-

phosphite and tricresylphosphite, and trialkylphosphites such as trioctadecylphosphite and tridecylphosphite, and trido-decyltrithiophosphite.

[0041] Metal deactivators that can be blended with the hydraulic oil of this invention include benzotriazole and benzotriazole derivatives which are 4-alkyl-benzotriazoles such as 4-methyl-benzotriazole and 4-ethyl-benzotriazole, 5-alkyl-benzotriazoles such as 5-methyl-benzotriazole and 5-ethyl-benzotriazole, 1-alkyl-benzotriazoles such as 1-dioc-tylaminomethyl-2,3-benzotriazole and 1-alkyl-tolutriazoles such as 1-diocylaminomethyl-2,3-tolutriazole, and benzoim-idazole and benzoimidazole derivatives which are 2-(alkyldithio)-benzoimidazoles such as 2-(octyldithio)-benzoimida-zole, 2-(decyldithio)-benzoimidazole and 2-(dodecyldithio)-benzoimidazole and 2-(alkyldithio)toluimidazoles such as 2-(octyldithio)-toluimidazole, 2-(decyldithio)-toluimidazole and 2-(dodecyldithio)toluimidazole.

[0042] Also, mention may be made of indazole, indazole derivatives which are toluindazoles such as 4-alkyl-indazoles and 5-alkyl-indazoles, benzothiazole, and benzothiazole derivatives which are 2-mercaptobenzothiazole derivatives (Thiolite B-3100, made by Chiyoda Chemical Industries Ltd.), 2-(alkyldithio)benzothiazoles such as 2-(hexyldithio) benzothiazole and 2-(octyldithio)benzothiazole, 2-(alkyldithio)toluthiazoles such as 2-(hexyldithio)toluthiazole and 2-(oc-tyldithio)toluthiazole, 2-(N,N-dialkyldithiocarbamyl)-benzothiazoles such as 2-(N,N-diethyldithiocarbamyl)-benzothia-zole, 2-(N,N-dibutyldithiocarbamyl)-benzothiazole and 2-(N,N-dihexyldithiocarbamyl)-benzothiazole, and 2-(N,N-di-alkyldithiocarbamyl)-toluthiazoles such as 2-(N,N-diethyldithiocarbamyl)-toluthiazole, 2-(N,N-dibutyldithiocarbamyl)-to-luthiazole and 2-(N,N-dihexyldithiocarbamyl)-toluthiazole. Further, mention may be made of benzooxazole derivates which are 2-(alkyldithio)benzooxazoles such as 2-(octyldithio)benzooxazole, 2-(decyldithio)benzooxazole and 2-(do-decyl)benzooxazole or which are 2-(alkyldithio)toluoxazoles such as 2-(octyldithio)toluoxazole, 2-(decyldithio)toluoxa-zole and 2-(dodecyl)toluoxazole, thiadiazole derivatives which are 2,5-bis(alkyldithio)-1,3,4-thiadiazoles such as 2,5-bis (heptyldithio)-1,3,4-thiadiazole, 2,5-bis(nonyldithio)-1,3,4-thiadiazole, 2,5-bis(dodecyldithio)-1,3,4-thiadiazole and 2,5-bis(octadecyldithio)-1,3,4-thiadiazole, 2,5-bis(N,N-dialkyldithiocarbamyl)-1,3,4-thiadiazoles such as 2,5-bis(N,N-diethyl-dithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dibutyldithiocarbamyl)-1,3,4-thiadiazole and 2,5-bis(N,N-dioclyldithiocar-bamyl)-1,3,4-thiadiazole and 2-N,N-dialkyldithiocarbamyl-5-mercapto-1,3,4-thiadiazoles such as 2-N,N-dibutyldithiocar-bamyl-5-mercapto-1,3,4-thiadiazole and 2-N,N-dioclyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole, and triazole deri-vates which are, for example, 1-alkyl-2,4-triazoles such as 1-di-octylaminomethyl-2,4-triazole.

[0043] These metal deactivators may be used singly or as mixtures within the range of from 0.01 to 0.5% by mass based on the total amount of the hydraulic oil.

[0044] It is possible to add phosphorus compounds as extreme pressure agents to the hydraulic oil of this invention. By doing this it is possible to impart further wear resistance and extreme pressure properties. As examples of phosphorus compounds suitable for this invention, mention may be made of phosphate esters, acidic phosphate esters, amine salts of acidic phosphate esters, chlorinated phosphate esters, phosphite esters, phosphorothionates, zinc dithiophosphates, phosphorus-containing carboxylic acids and phosphorus-containing carboxylic acid esters. These phosphorus com-pounds may be used singly or as mixtures within the range of from 0.01 to 2% by mass based on the total amount of the hydraulic oil.

[0045] As examples of the aforementioned phosphate esters, mention may be made of tributyl phosphate, tripentyl phosphate, trihexyl phosphate, triheptyl phosphate, trioctyl phosphate, trinonyl phosphate, tridecyl phosphate, triundecyl phosphate, tridodecyl phosphate, tritridecyl phosphate, tritetradecyl phosphate, tripentadecyl phosphate, trihexadecyl phosphate, triheptadecyl phosphate, trioctadecyl phosphate, trioleyl phosphate, triphenyl phosphate, tris(isopropylphe-nyl)phosphate, triallyl phosphate, tricresyl phosphate, trixylenyl phosphate, cresyldiphenyl phosphate and xylenyldiphe-nyl phosphate.

[0046] As specific examples of the aforementioned acidic phosphate esters, mention may be made of monobutyl acid phosphate, monopentyl acid phosphate, monohexyl acid phosphate, monoheptyl acid phosphate, monononyl acid phos-phate, monodecyl acid phosphate, monoundecyl acid phosphate, monododecyl acid phosphate, monotridecyl acid phos-phate, monotetradecyl acid phosphate, monopentadecyl acid phosphate, monohexadecyl acid phosphate, monohepta-decyl acid phosphate, monooctadecyl acid phosphate, monooleyl acid phosphate, dibutyl acid phosphate, dipentyl acid phosphate, dihexyl acid phosphate, diheptyl acid phosphate, dioctyl acid phosphate, dinonyl acid phosphate, didecyl acid phosphate, diundecyl acid phosphate, didodecyl acid phosphate, ditridecyl acid phosphate, ditetradecyl acid phos-phate, dipentadecyl acid phosphate, dihexadecyl acid phosphate, diheptadecyl acid phosphate, dioctadecyl acid phos-phate and dioleyl acid phosphate.

[0047] As examples of the aforementioned amine salts of acidic phosphate esters, mention may be made of the methylamine, ethylamine, propylamine, butylamine, pentylamine, hexylamine, heptylamine, octylamine, dimethylamine, diethylamine, dipropylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine, dioctylamine, trimethylamine, triethylamine, tripropylamine, tributylamine, tripentylamine, trihexylamine, triheptylamine and trioctylamine salts of the previously mentioned acid phosphate esters.

[0048] As examples of the aforementioned phosphite esters, mention may be made of dibutyl phosphite, dipentyl phosphite, dihexyl phosphite, diheptyl phosphite, dioctyl phosphite, dinonyl phosphite, didecyl phosphite, diundecyl phosphite, didodecyl phosphite, dioleyl phosphite, diphenyl phosphite, dicresyl phosphite, tributyl phosphite, tripentyl

phosphite, trihexyl phosphite, triheptyl phosphite, trioctyl phosphite, trinonyl phosphite, tridecyl phosphite, triundecyl phosphite, tridodecyl phosphite, trioleyl phosphite, triphenyl phosphite and tricresyl phosphite.

[0049] As examples of the aforementioned phosphorothionates, mention may be made specifically of tributyl phosphorothionate, tripentyl phosphorothionate, trihexyl phosphorothionate, triheptyl phosphorothionate, trioctyl phosphorothionate, trinonyl phosphorothionate, tridecyl phosphorothionate, triundecyl phosphorothionate, tridodecyl phosphorothionate, tritridecyl phosphorothionate, tritetradecyl phosphorothionate, tripentadecyl phosphorothionate, trihexadecyl phosphorothionate, triheptadecyl phosphorothionate, trioctadecyl phosphorothionate, trioleyl phosphorothionate, triphenyl phosphorothionate, tricresyl phosphorothionate, trixylenyl phosphorothionate, cresyldiphenyl phosphorothionate, xylenyldiphenyl phosphorothionate, tris(n-propylphenyl) phosphorothionate, tris(isopropylphenyl) phosphorothionate, tris(n-butylphenyl) phosphorothionate, tris(isobutylphenyl) phosphorothionate, tris(s-butylphenyl) phosphorothionate and tris(t-butylphenyl) phosphorothionate. Mixtures of these may also be used.

[0050] As examples of the aforementioned zinc dithiophosphates, mention may be made in general of zinc dialkyl dithiophosphates, zinc diaryl dithiophosphates and zinc arylalkyl dithiophosphates. For example, zinc dialkyl dithiophosphates where the alkyl groups of the zinc dialkyl dithiophosphates have primary or secondary alkyl groups of from 3 to 22 carbons or alkylaryl groups substituted with alkyl groups of from 3 to 18 carbons may be used.

[0051] As specific examples of zinc dialkyl dithiophosphates, mention may be made of zinc dipropyl dithiophosphate, zinc dibutyl dithiophosphate, zinc dipentyl dithiophosphate, zinc dihexyl dithiophosphate, zinc diisopentyl dithiophosphate, zinc diethylhexyl dithiophosphate, zinc dioctyl dithiophosphate, zinc dinonyl dithiophosphate, zinc didecyl dithiophosphate, zinc didoecyl dithiophosphate, zinc dipropylphenyl dithiophosphate, zinc dipentylphenyl dithiophosphate, zinc dipropylmethylphenyl dithiophosphate, zinc dinonylphenyl dithiophosphate, and zinc didodecylphenyl dithiophosphate.

[0052] Phosphorus-containing carboxylic compounds such as phosphorus-containing carboxylic acids and their acid esters should include both a carboxyl group and a phosphorus atom in the same molecule. Their structure is not specially limited but normally, from the standpoint of extreme pressure properties and thermal and oxidative stability, phosphorylated carboxylic acids or phosphorylated carboxylic acid esters are preferred.

[0053] The amount of phosphorus-containing carboxylic acid compounds in the hydraulic oil of this invention is not specially restricted, but is preferably in the range of from 0.001 to 1% by mass based on the total amount of the hydraulic oil, and more preferably in the range of from 0.002 to 0.5% by mass. If the amount of phosphorus-containing carboxylic acid compound is less than the aforementioned lower limit, there will be a tendency for the lubricating properties not to be obtained. On the other hand, if it exceeds the aforementioned upper limit, there will be a tendency for the improvement in lubricating properties corresponding to the amount contained not to be obtained, and furthermore there will be a risk that thermal and oxidative stability or hydrolytic stability will decrease, which is not desirable.

[0054] In order to impart defoaming characteristics to the hydraulic oil of this invention, defoaming agents may also be added. As examples of defoaming agents suitable for this invention, mention may be made of organosilicates such as dimethylpolysiloxane, diethylsilicate and fluorosilicone, and non-silicone type defoaming agents such as polyalkylacrylates. As regards the amount thereof to be added, they may be used singly or as mixtures within the range of from 0.0001 to 0.1% by mass based on the total amount of the hydraulic oil.

[0055] As examples of demulsifiers suitable for this invention, mention may be made of those in the known art normally used as additives for lubricating oils. As regards the amount thereof to be added, they may be used in the range of from 0.0005 to 0.5% by mass based on the total amount of the hydraulic oil.

[0056] The hydraulic oil of this invention is obtained by blending each of the aforementioned components so that the kinematic viscosity at 60°C is in the range of from 25 to 60 mm²/s but preferably in the range of from 28 to 50 mm²/s, the kinematic viscosity at 80°C is in the range of from 15 to 34 mm²/s but preferably in the range of from 17 to 30 mm²/s, the viscosity index is in the range of from 200 to 220 but preferably in the range of from 205 to 215, and the low temperature cranking viscosity at -25°C is in the range of from 1000 to 8000 mPa.s but preferably in the range of from 1000 to 5000 mPa.s. Further, the aforementioned components should be blended in the hydraulic oil of this invention so that the kinematic viscosity at 40°C is in the range of from 45 to 150 mm²/s but preferably in the range of from 50 to 100 mm²/s.

[0057] The amount of each component to be incorporated will vary according to the amount and the viscosity and other properties of the base oil, the molecular weight of the poly(meth)acrylate, the amount of diluent and so on, but it is possible to decide this experimentally by preparing samples with varying proportions of each component within the ranges of the blend proportions mentioned above, measuring the various aforementioned properties, and selecting the optimum blend proportions and properties from pass-grade products where the various properties fall within the aforementioned ranges.

[0058] The hydraulic oil of this invention will be used as a hydraulic oil for hydraulic apparatus used in construction work, by introducing it into hydraulic systems which include hydraulic actuators such as hydraulic motors and hydraulic cylinders, mainly in construction machinery such as hydraulic shovels, wheel loaders, bulldozers, dump trucks, rough terrain haulers, rough-terrain cranes, hydraulic breakers, the Iron Mole, self-propelled crushers, motorised graders, road rollers, asphalt finishers and snowploughs. The hydraulic oil of this invention is used in such manner that, within hydraulic

systems in which it has been introduced, hydraulic oil pressurised by running a hydraulic pump by means of an engine is conveyed to hydraulic actuators such as hydraulic motors and hydraulic cylinders or other hydraulic apparatus, and so effects operation of the machinery.

[0059] During operation of such hydraulic systems, hydraulic apparatus which includes hydraulic actuators operates at high temperatures of the order, for example, of from 60 to 80°C because of heat transmitted from engines or power elements and heat generated by pressure and friction in the hydraulic apparatus or piping, but the kinematic viscosity of the hydraulic oil of this invention in such a temperature domain has, as mentioned above, been established at a higher domain than hydraulic oils of the prior art, so that it is possible to inhibit internal leaks within hydraulic pumps and control valves, and thereby to attain energy savings and higher efficiencies in hydraulic equipment, and to operate efficiently.

[0060] Because no oiliness agents such as fatty acids, fatty acid esters, polyhydric alcohols esters, amines, amides or amides of polyamines are incorporated in the hydraulic oil of this invention, it is possible to reduce the friction coefficient of the hydraulic oil and to sustain swinging brake control at a high level.

[0061] Further, in the hydraulic oil of this invention the viscosity index is in the range of from 200 to 220 and the low-temperature cranking viscosity at -25°C is in the range of from 1000 to 8000 mPa.s. Because it has a low viscosity at low temperatures, even in cases where low temperatures are reached during stoppages overnight and so on in cold periods or in cold regions, and machinery is operated in a low-temperature domain of the order of, for example, -30°C to -20°C, low temperature performance is excellent in that the response of the hydraulic actuators is good, handling is excellent, and so on.

[0062] In other words, in this invention, by incorporating a poly(meth)acrylate of weight average molecular weight in the range of from 30,000 to 100,000 in a highly refined base oil, it is possible to make the viscosity index of the composition in the range of from 200 to 220, and by this means the kinematic viscosity at 60°C becomes from 25 to 60 mm²/s, the kinematic viscosity at 80°C becomes from 15 to 34 mm²/s and the low-temperature cranking viscosity at -25°C becomes from 1000 to 8000 mPa.s even for compositions of high kinematic viscosity, so that it is possible to reduce the low-temperature starting viscosity. Even though no oiliness agent is incorporated, it is possible to run efficiently at high temperatures and to maintain low-temperature performance.

[0063] The hydraulic oil of this invention is a blend of specified components such that it has specified properties, and so, even though the incorporation of an oiliness agent is minimised or omitted, it has a high kinematic viscosity in the high-temperature domain and can effect operation with good efficiency, and further it has excellent braking properties as well as low viscosity in the low-temperature domain, so that a hydraulic oil with excellent low-temperature performance is obtained.

Examples

[0064] The invention is described in specific detail below by means of examples and comparative examples, but the invention is not limited to these examples. In each of the examples below, except in the case of efficiency and low-temperature working properties, % means % by weight.

[0065] The following materials were used in preparation of the compositions of the examples and comparative examples.

1. Base Oils

[0066] Base oil 1: A paraffinic mineral oil obtained by a suitable combination of refining processes such as hydrocracking and dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group I according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinematic viscosity at 40°C, 16.3 mm²/s; kinematic viscosity at 60°C, 8.85 mm²/s; kinematic viscosity at 80°C, 5.4 mm²/s; kinematic viscosity at 100°C, 3.72 mm²/s; viscosity index, 116; density at 15°C, 0.851 g/cm³; sulphur content (as converted to elemental sulphur), 0.3%; nitrogen content (as converted to elemental nitrogen), less than 5 ppm; ring-analysis paraffin content according to the method of ASTM D3238, 70%; naphthene content ditto, 28%; aromatic content ditto, 2%.

[0067] Base oil 2: A paraffinic mineral oil obtained by a suitable combination of refining processes such as hydrocracking and dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group I according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinematic viscosity at 40°C, 17.7 mm²/s; kinematic viscosity at 60°C, 9.50 mm²/s; kinematic viscosity at 80°C, 5.83 mm²/s; kinematic viscosity at 100°C, 3.94 mm²/s; viscosity index, 118; density at 15°C, 0.856 g/cm³; sulphur content (as converted to elemental sulphur), 0.4%; nitrogen content (as converted to elemental nitrogen), less than 5 ppm; ring-analysis paraffin content according to the method of ASTM D3238, 69%; naphthene content ditto, 29%; aromatic content ditto, 2%.

[0068] Base oil 3: A paraffinic mineral oil obtained by a combination of refining processes such as hydrocracking and dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group I according to the API (American Petroleum Institute) base oil classification.

(Characteristics: kinematic viscosity at 40°C, 16.2 mm²/s; kinematic viscosity at 60°C, 8.77 mm²/s; kinematic viscosity at 80°C, 5.43 mm²/s; kinematic viscosity at 100°C, 3.69 mm²/s; viscosity index, 115; density at 15°C, 0.850 g/cm³; sulphur content (as converted to elemental sulphur), 0.3%; nitrogen content (as converted to elemental nitrogen), less than 5 ppm; ring-analysis paraffin content according to the method of ASTM D3238, 70%; naphthene content ditto, 28%; aromatic content ditto, 2%.

2. Viscosity Index Improver

[0069] Polymethacrylate of weight average molecular weight 60,000.

[0070] The weight average molecular weight is the polystyrene-converted weight average molecular weight measured by means of a differential refractometer detector and a low-angle light scattering detector with tetrahydrofuran as the solvent, temperature 23°C, flow rate 1 mL/min, specimen concentration 1% by mass and specimen input 75 µL, using two GMHHR-M (7.8 mm ID x 30cm) columns made by Toso Ltd. in series in a 150-CALC/GPC apparatus made by Waters Ltd.

[0071] The polymer concentration measured by means of rubber membrane dialysis of the viscosity index improver was 63% by mass. In rubber membrane dialysis, 2 to 3 g of viscosity index improver specimen is first weighed accurately inside a sanitary (rubber) sack, then with the mouth tied up and using 100 ml of petroleum ether in a Soxhlet extractor, it is refluxed for 8 hours at 80°C. After refluxing, the dialysis residue within the rubber membrane is recovered, heated in a water bath to remove the solvent, and then weighed. The proportion of dialysis residue relative to the original specimen was taken as the polymer concentration.

3. Oiliness Agent

[0072] Triethylene tetramide isostearate.

4. Other Additives

[0073] The additives were a mixture of ZnDTP, rust preventative, metal deactivator, defoaming agent and diluting mineral oil.

Example 1, Reference Example 1, Comparative Examples 1 to 4:

[0074] Using the aforementioned materials, the lubricating oil compositions of Example 1 and Comparative Examples 1 and 2 were prepared in accordance with the formulations shown in Tables 1 and 2. The Reference Example was a commercial diesel engine oil, JASO DH-1 SAE 10W (characteristics: kinematic viscosity at 40°C, 36.2 mm²/s; kinematic viscosity at 100°C, 6.04 mm²/s; viscosity index, 112), Comparative Example 3 was a commercial anti-wear hydraulic oil, ISOVG46 (characteristics: kinematic viscosity at 40°C, 48.4 mm²/s; kinematic viscosity at 100°C, 6.99 mm²/s; viscosity index, 100) and Comparative Example 4 was a commercial anti-wear hydraulic oil, ISOVG100 (characteristics: kinematic viscosity at 40°C, 103.3 mm²/s; kinematic viscosity at 100°C, 11.5 mm²/s; viscosity index, 98).

Tests:

[0075] The viscosity characteristics of the lubricating oil compositions of Example 1, Comparative Examples 1 to 4 and the Reference Example were measured, and in order to assess their performance, measurements were made as follows for efficiency tests, low-temperature working characteristic tests and friction coefficients.

Viscosity Characteristics:

[0076] The 60°C kinetic viscosity, the 80°C kinematic viscosity and the viscosity index were measured by using the kinematic viscosity test method and viscosity index calculation method for crude oil and petroleum products as given in JIS K2283. The low-temperature cranking viscosity at -25°C was measured by means of the cold cranking simulator described in JIS K2010 Appendix A.

Efficiency Tests:

[0077] Using a hydraulic shovel of rated output 110 kW and gasket size 0.8 m³, and selecting maximum output as the operating mode, excavation and loading operations were carried out at normal full throttle, and cycle times were measured. What was meant by excavation and loading work was excavation carried out by operating the arm, bucket and boom

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from specified positions, and then swinging 90 degrees with the boom raised, operating the arm and bucket so as to discharge earth, and then finally returning the arm, bucket, boom and swing to their original positions. The time from start of excavation to returning to the original positions was measured with a stop watch, and the average value of four tests was taken as the cycle time. The efficiency was evaluated by comparison with a standard oil.

Test of Low-temperature Working Characteristics:

[0078] Using the hydraulic shovel of rated output 110 kW and gasket size 0.8 m³, an evaluation of the handling characteristics after running a heater in a low-temperature environment was carried out by evaluating the working speeds of the various actuators. The engine was started up at an outside air temperature of -30°C and it was conformed that the hydraulic oil and pilot circuit oil temperature was -20°C. Next, after running a heater so that the hydraulic oil temperature reached 10°C, the arm, bucket and boom were each operated individually. The time for each cylinder to reach stroke end after application of the lever was measured by means of a stopwatch. The handling characteristics in a low-temperature environment were assessed on the basis of total time for operation of the arm, bucket and boom and the feel when handling the various operating levers. The low-temperature handling characteristics were evaluated in comparison with a standard oil. If the handling feel of the levers was worse than when using the standard oil, a failure was assessed.

Friction Coefficient:

[0079] The friction coefficient at an oil temperature of 140°C was measured by the Microclutch test method specified in the friction characteristics tests for hydraulic oils used in construction machinery established by the Japan Construction Machinery Association (JCMAS PO47). A friction coefficient of at least 0.090 was regarded as a pass.

Test Results:

[0080] The results of the various tests are shown in Table 1 and Table 2.

Table 1

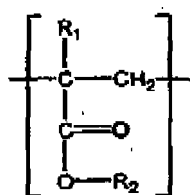
			Example 1	Example 2	Reference Example
Composition	Base oil 1		79.0		Commercial oil
	Base oil 2			73.0	
	Viscosity index improver		20.0	26.0	
	Other additives		1.0	1.0	
Viscosity characteristics	60°C kinematic viscosity mm ² /s		31.2	48.7	17.1
	80°C kinematic viscosity mm ² /s		19.2	28.2	9.0
	Viscosity index		211	207	112
	-25°C cranking Viscosity mPa.s		3100	4900	5440
Test results	Efficiency		14.5 sec 2.0% improvement	14.2 sec 4.1% improvement	14.8 sec
	Low-temperature handling	Work machine speed	15.9 sec 24.6% improvement	19.9 sec 5.7% improvement	21.1 sec
		Handling feel	Good	Good	Good
	Friction coefficient		0.097 Pass	0.099 Pass	-

Claims

- Hydraulic oil for use in construction machinery, wherein the hydraulic oil comprises a poly(meth) acrylate of weight average molecular weight in the range of from 30,000 to 300,000 in a base oil but does not incorporate an oiliness agent, and wherein the kinematic viscosity at 60°C is in the range of from 15 to 34 mm²/s, the viscosity index is in the range of from 200 to 220, and the low temperature cranking viscosity at -25°C is in the range of from 1000 to

8000 mPa.s, wherein the base oil is selected from singly or as mixtures, base oils which belong to Group I, Group II and Group III of the API (American Petroleum Institute) base oil categories.

2. Hydraulic oil according to Claim 1 wherein the poly(meth)acrylate has a weight average molecular weight in the range of from 30,000 to 70,000.
3. Hydraulic oil according to Claim 1 or 2 wherein the kinematic viscosity at 60°C is in the range of from 28 to 50 mm²/s.
4. Hydraulic oil according to Claims 1 to 3 wherein the kinematic viscosity at 80°C is in the range of from 17 to 30 mm²/s.
5. Hydraulic oil according to Claims 1 to 4 wherein the viscosity index is in the range of from 205 to 215.
6. Hydraulic oil according to Claims 1 to 5 wherein the low temperature cranking viscosity at -25°C is in the range of from 1000 to 5000 mPa.s.
7. Hydraulic oil according to Claims 1 to 6 wherein the kinematic viscosity at 40°C is in the range of from 45 to 150 mm²/s.
8. Hydraulic oil according to Claims 1 to 7 wherein the amount of poly(meth)acrylate, including diluent, is in the range of from 15 to 25% by mass, based on the total amount of the hydraulic oil.
9. Hydraulic oil according to Claims 1 to 7 wherein the amount of pure poly(meth)acrylate is in the range of from 1 to 24% by mass, based on the total amount of the hydraulic oil.
10. Hydraulic oil according to any of Claims 1 to 9 wherein the poly(meth)acrylate is selected from polymer having one kind or two or more kinds of the constituent units represented by general formula (1) below or polymers having those constituent units together with other constituent units



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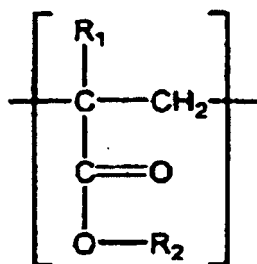
wherein R₁ denotes hydrogen or a methyl group, R₂ denote an alkyl group having from 1 to 30 carbons or a group represented by -(R)_a-E where R is an alkylene group having from 1 to 30 carbons, E denotes either an amine residual group containing 1 to 2 nitrogen atoms and 0 to 2 oxygen atoms or a heterocyclic residual group, and a denotes an integer of 0 or 1.

Patentansprüche

1. Hydraulisches Öl zur Verwendung in Baumaschinen, wobei das hydraulische Öl ein Poly(meth)acrylat mit gewichtsgemitteltem Molekulargewicht in dem Bereich von 30.000 bis 100.000 in einem Basisöl umfasst, aber kein Öligkeitsmittel enthält, und wobei die kinematische Viskosität bei 60°C in dem Bereich von 25 bis 60 mm²/s liegt, die kinematische Viskosität bei 80°C in dem Bereich von 15 bis 34 mm²/s liegt, der Viskositätsindex in dem Bereich von 200 bis 220 liegt, und die Tieftemperatur Cranking Viskosität bei -25°C in dem Bereich von 1.000 bis 8.000 mPa.s liegt, wobei das Basisöl ausgewählt ist aus einzelnen oder aus gemischten Basisölen, die zur Gruppe I, Gruppe II und Gruppe III der API (American Petroleum Institut) Basisölkategorien gehören.
2. Hydraulisches Öl nach Anspruch 1, wobei das Poly(meth)acrylat ein gewichtsgemitteltes Molekulargewicht in dem Bereich von 30.000 bis 700.000 aufweist.
3. Hydraulisches Öl nach Anspruch 1 oder 2, wobei die kinematische Viskosität bei 60°C in dem Bereich von 28 bis

50 mm²/s liegt.

4. Hydraulisches Öl nach einem der Ansprüche 1 bis 3, wobei die kinematische Viskosität bei 80°C in dem Bereich von 17 bis 30 mm²/s liegt.
5. Hydraulisches Öl nach einem der Ansprüche 1 bis 4, wobei der Viskositätsindex in dem Bereich von 205 bis 215 liegt.
6. Hydraulisches Öl nach einem der Ansprüche 1 bis 5, wobei die Tieftemperatur Cranking Viskosität bei -25°C in dem Bereich von 1.000 bis 5.000 mPa.s liegt.
7. Hydraulisches Öl nach einem der Ansprüche 1 bis 6, wobei die kinematische Viskosität bei 40°C in dem Bereich von 45 bis 150 mm²/s liegt.
8. Hydraulisches Öl nach einem der Ansprüche 1 bis 7, wobei die Menge an Poly(meth)acrylat, eingeschlossen Verdünner, in dem Bereich von 15 bis 25 Masse-% liegt, basierend auf der gesamten Menge des hydraulischen Öls.
9. Hydraulisches Öl nach einem der Ansprüche 1 bis 7, wobei die Menge an purem Poly(meth)acrylat in dem Bereich von 1 bis 24 Masse-% liegt, basierend auf der gesamten Menge des hydraulischen Öls.
10. Hydraulische Ölzusammensetzung nach einem der Ansprüche 1 bis 9, wobei das Poly(meth)acrylat ausgewählt ist aus Polymer, das eine Art oder zwei oder mehreren Arten der Aufbaueinheiten dargestellt durch die allgemeine Formel (1) unten aufweist, oder Polymeren, die diese Aufbaueinheiten zusammen mit anderen Aufbaueinheiten aufweisen



(1)

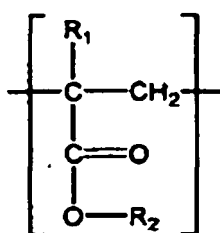
wobei R₁ Wasserstoff oder eine Methylgruppe kennzeichnet, R₂ eine Alkylgruppe mit von 1 bis 30 Kohlenstoffatomen oder eine Gruppe dargestellt durch - (R)_a-E, wobei R eine Alkylengruppe mit 1 bis 30 Kohlenstoffatomen ist, kennzeichnet, E entweder eine Amin-Restgruppe beinhaltend 1 bis 2 Stickstoffatome und 0 bis 2 Sauerstoffatome, oder eine heterozyklische Restgruppe kennzeichnet, und a eine ganze Zahl von 0 oder 1 kennzeichnet.

Revendications

1. Huile hydraulique pour usage dans des machines de construction, dans laquelle l'huile hydraulique comprend un poly(méth)acrylate ayant un poids moléculaire moyen en poids dans la plage de 30 000 à 100 000 dans une huile de base, mais ne comprend pas d'agent lubrifiant, et dans laquelle la viscosité cinématique à 60 °C se situe dans la plage de 25 à 60 mm²/s, la viscosité cinématique à 80 °C se situe dans la plage de 15 à 34 mm²/s, l'indice de viscosité se situe dans la plage de 200 à 220 et la viscosité de démarrage à basse température de -25 °C se situe dans la plage de 1000 à 8000 mPa.s, dans laquelle l'huile de base est choisie parmi les huiles de base individuelles ou mixtes, qui appartiennent au groupe I, au groupe II et au groupe III des catégories d'huile de base selon la référence API (American Petroleum Institute).
2. Huile hydraulique selon la revendication 1, dans laquelle le poly(méth)acrylate présente un poids moléculaire moyen en poids dans la plage de 30 000 à 70 000.
3. Huile hydraulique selon la revendication 1 ou 2, dans laquelle la viscosité cinématique à 60 °C se situe dans la

plage de 28 à 50 mm²/s.

4. Huile hydraulique selon l'une quelconque des revendications 1 à 3, dans laquelle la viscosité cinématique à 80 °C se situe dans la plage de 17 à 30 mm²/s.
5. Huile hydraulique selon l'une quelconque des revendications 1 à 4, dans laquelle l'indice de viscosité se situe dans la plage de 205 à 215.
6. Huile hydraulique selon l'une quelconque des revendications 1 à 5, dans laquelle la viscosité de démarrage à basse température de -25 °C se situe dans la plage de 1000 à 5000 mPa.s.
7. Huile hydraulique selon l'une quelconque des revendications 1 à 6, dans laquelle la viscosité cinématique à 40 °C se situe dans la plage de 45 à 150 mm²/s.
8. Huile hydraulique selon l'une quelconque des revendications 1 à 7, dans laquelle la quantité de poly(méth)acrylate, y compris le diluant, se situe dans la plage de 15 à 25 % en masse sur la base de la quantité totale d'huile hydraulique.
9. Huile hydraulique selon l'une quelconque des revendications 1 à 7, dans laquelle la quantité de poly(méth)acrylate pur se situe dans la plage de 1 à 24 % en masse sur la base de la quantité totale d'huile hydraulique.
10. Composition d'huile hydraulique selon l'une quelconque des revendications 1 à 9, dans laquelle le poly(méth)acrylate est choisi parmi des polymères présentant un type ou deux types ou plus des unités constitutives représentées par la formule générale (1) mentionnée ci-dessous, ou par des polymères présentant ces unités constitutives conjointement avec d'autres unités constitutives :



(1)

dans laquelle R₁ représente de l'hydrogène ou un groupement méthyle, R₂ représente un groupement alkyle ayant 1 à 30 atomes de carbone ou un groupement représenté par -(R)_a-E où R est un groupement alkylène ayant 1 à 30 atomes de carbone, E représente un groupement résiduel d'amine contenant 1 à 2 atomes d'azote et 0 à 2 atomes d'oxygène ou un groupement résiduel hétérocyclique, et a représente un nombre entier valant 0 ou 1.

REFERENCES CITED IN THE DESCRIPTION

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