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(54) **METALWORKING FLUID**

(57) A first oil for metal working of the invention comprises an ester oil and a hydrocarbon oil with a kinematic viscosity of 1-20 mm²/s at 40°C. A second oil for metal working of the invention employs an ester oil as the base oil and has a moisture content of 200-20,000 ppm. The first and second oils for metal working have excellent

properties as water-insoluble oils for non-ferrous metal working and as oils for cutting and grinding in a minimum quantity lubrication system, and can therefore achieve improved working efficiency and extended tool life.

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Description**Technical Field**

5 [0001] The present invention relates to an oil for metal working.

Background Art

10 [0002] In cutting and grinding, it is common to employ cutting and grinding oils for the purpose of extending the life of working tools such as drills, mills, cutting tools, grinding wheels and the like, improving the surface roughness of working surfaces and raising productivity in mechanical working by increasing machining performance.

[0003] Cutting and grinding oils fall into two general categories, water-soluble cutting and grinding oils used by diluting surfactants and lubricant components with water, and water-insoluble cutting and grinding oils used directly as stock solutions composed mainly of mineral oils. Generally speaking, water-insoluble cutting and grinding oils exhibit superior lubricating performance while water-soluble cutting and grinding oils exhibit superior cooling performance.

15 [0004] Cutting and grinding oils that are effective for improving working efficiency have drawbacks from other viewpoints, typically their adverse effects on the environment. Whether water-insoluble or water-soluble, oils undergo gradual degradation with use and eventually become unusable. In the case of water-soluble oils, for example, solution stability is lost with growth of microorganisms, resulting in separation of the components, a significantly fouled environment and unsuitability for use. In the case of water-insoluble oils, progressive oxidation produces acidic components that corrode metal materials and produce significant changes in viscosity, also resulting in unsuitability for use. The oils also adhere to cutting chips and the like, becoming consumed and forming waste.

[0005] The degraded oils must therefore be disposed of and replaced with new oils. The oils that have been discharged as waste must be treated in some manner to avoid adversely affecting the environment. For example, chlorine-based compounds that can potentially generate harmful dioxins during thermal disposal are often used in cutting and grinding oils developed for the principal purpose of improving working efficiency, and such compounds must therefore be removed. Cutting and grinding oils containing no chlorine compounds have therefore been developed, but even such toxic substance-free cutting and grinding oils can adversely affect the environment with large-scale emission of waste products. Water-soluble oils can also contaminate environmental waters and therefore require costly high-level treatment.

30 [0006] As examples of cases where it is difficult to achieve both improved working efficiency and reduced environmental burden, there may be mentioned the field of producing non-ferrous metal parts as automobile parts or electronic appliance parts. More specifically, while it has been common in the prior art to use water-soluble oils for working of non-ferrous metal parts such as aluminum or aluminum alloy parts, the metals generally tend to dissolve in the waste liquid after the non-ferrous metals have been worked, thus vastly increasing the cost for waste liquid treatment. Moreover, using water-soluble oils results in decay or corrosion of parts unless the working fluid is at the optimum pH, and therefore strict and frequent management is essential during their use.

[0007] In order to solve these problems, the application of dry working or water-insoluble working oils has been investigated in the field of non-ferrous metal working.

40 [0008] Novel working methods are also being developed, such as minimum quantity lubrication system cutting/grinding methods. In such methods, a trace amount of oil at about 1/100,000-1/1,000,000 of the amount of oil used for conventional cutting and grinding is supplied to the working part together with a compressed gas (for example, compressed air) for cutting and grinding. In such systems, a cooling effect is achieved due to the compressed air, and the trace amount of oil used allows the amount of waste to be reduced, thereby resulting in improvement in the effect on the environment that is caused by large-scale emission of waste products. Such methods, therefore, are promising not only for non-ferrous metal working but also for ferrous metal working.

45 [0009] In the case of a minimum quantity lubrication system, higher performance is demanded than for cutting/grinding oils in that, preferably, it must be possible to obtain working pieces with satisfactory surfaces even when only trace amounts of oil are supplied, tool wear must be minimal, and cutting/grinding must be efficiently achieved. Moreover, oils with excellent biodegradability are preferred from the viewpoint of waste treatment and working environment.

Disclosure of the Invention**Problems to be Solved by the Invention**

50 [0010] However, dry working often leads to tool damage as a result of adhesion of the metal from the workpieces or increased working resistance in the case of non-ferrous metal (especially aluminum) tools, such that it has not been possible to achieve adequate working efficiency and tool life. Also, water-insoluble cutting oils are associated with increased risk of fire and corrosion or discoloration caused by additives, generally rendering them poor substitutes for

water-soluble cutting oils.

[0011] On the other hand, even when cutting and grinding is carried out utilizing a minimum quantity lubrication system, it is very difficult to achieve a satisfactory balance between all of the required performance aspects if a conventional cutting/grinding oil is used directly in the minimum quantity lubrication system. Furthermore, even using a minimum quantity lubrication system with a non-ferrous metal workpiece, it is not always a simple matter to avoid damage to tools by adhesion of the metal from the workpieces or increased working resistance of the non-ferrous metal.

[0012] It is an object of the present invention, which has been accomplished in light of the circumstances described above, to provide an oil for metal working with excellent properties as a water-insoluble oil for non-ferrous metal working and excellent properties as a cutting/grinding oil in a minimum quantity lubrication system, and which can achieve improved working efficiency and extended tool life.

Means for Solving the Problems

[0013] In order to achieve this object, the present invention provides an oil for metal working characterized by comprising an ester oil and a hydrocarbon oil with a kinematic viscosity of 1-20 mm²/s at 40°C (hereinafter referred to as "first oil for metal working").

[0014] By thus using an ester oil together with a hydrocarbon oil with a kinematic viscosity of 1-20 mm²/s at 40°C, it is possible to adequately control adhesion of the metal from the workpieces or increased working resistance for non-ferrous metal (especially aluminum) tools when using the aforementioned first oil for metal working as a water-insoluble oil for non-ferrous metal working, so that improved working efficiency and extended tool life can be achieved. The first oil for metal working having the composition described above can form a satisfactory oil mist when used as a cutting/grinding oil in a minimum quantity lubrication system, in order to achieve a high level of improved working efficiency and extended tool life.

[0015] The hydrocarbon oil in the first oil for metal working is preferably one or more types selected from among white oils and polyolefins or their hydrogenated forms.

[0016] The moisture content of the first oil for metal working is preferably 200-20,000 ppm.

[0017] The invention further provides an oil for metal working comprising an ester oil as the base oil, characterized by having a moisture content of 200-20,000 ppm (hereinafter referred to as "second oil for metal working").

[0018] If the moisture content of the oil for metal working comprising an ester oil as the base oil is 200-20,000 ppm, as the second oil for metal working which is to be used as a water-insoluble oil for non-ferrous metal working, it is possible to sufficiently prevent adhesion of the metal from the workpieces or working resistance increase for non-ferrous metal (especially aluminum) tools, in order to achieve improved working efficiency and extended tool life. The second oil for metal working having the composition described above can form a satisfactory oil mist when used as a cutting/grinding oil in a minimum quantity lubrication system, in order to achieve a high level of improved working efficiency and extended tool life. Moreover, since the second oil for metal working comprises an ester oil with higher biodegradability than mineral oils and water, which does not adversely affect the environment, it is also useful from the standpoint of alleviating the burden on the environment.

[0019] These effects of the second oil for metal working are based on knowledge of the present inventors that a moisture content within the aforementioned range allows sufficient control of phenomena such as water separation or ester oil hydrolysis, while effectively taking advantage of the excellent properties of water as an additive. This is an unexpected effect considering the technical knowledge of the prior art that the moisture content should be minimized when using an ester oil from the viewpoint of preventing hydrolysis of the ester oil.

[0020] The first and second oils for metal working preferably further comprise an oiliness agent and/or an extreme-pressure agent.

[0021] The first and second oils for metal working of the invention may be suitably used for non-ferrous metal working. In addition, the first and second oils for metal working may also be suitably used for cutting, grinding or rolling, as well as for minimum quantity lubrication system metal working.

[0022] Here, minimum quantity lubrication system metal working is metal working carried out while supplying to the cutting/grinding site a trace amount of oil at about 1/100,000-1/1,000,000 of the amount of oil used for conventional metal working, together with a compressed gas. More specifically, a minimum quantity lubrication system is a system wherein a trace amount of oil, usually at no more than 1 milliliter/min, is supplied toward the working site (for example, the cutting/grinding site) together with a compressed gas (for example, compressed air). Instead of compressed air, compressed gas such as nitrogen, argon, helium, carbon dioxide or water may be used alone or any of these may be used in admixture.

[0023] In the case of a minimum quantity lubrication system, it is of utmost importance to generate a satisfactory oil mist. If the oil mist condition is poor, the pipes may become clogged and prevent a sufficient amount of oil from reaching the working point, thereby reducing the working efficiency and shortening the tool life. On the other hand, if the oil forms a mist too readily, the discharged oil mist will fly out and contaminate the working environment. In this case as well, the

oil mist tends to fly out and result in loss of oil such that the amount of oil reaching the working point becomes insufficient, and the working efficiency is reduced and tool life is shortened.

[0024] Moreover, because the oil is supplied as an oil mist in a minimum quantity lubrication system, using an oil with poor stability can result in adhesion to the machine tool interior, workpiece, tool, mist collector interior, etc. producing a sticking phenomenon, and can thereby impair the handleability and lower working efficiency. Thus, the oil used in a minimum quantity lubrication system is preferably one which is resistant to sticking.

[0025] Although both the first and second oils for metal working of the invention may be suitably used for metal working in a minimum quantity lubrication system, the first oil for metal working of the invention is particularly preferred from the standpoint of mist properties and sticking resistance.

Effect of the Invention

[0026] According to the invention, there is provided an oil for metal working that exhibits excellent properties as a water-insoluble oil for non-ferrous metal working and excellent properties as a cutting/grinding oil for a minimum quantity lubrication system, and that therefore allows improved working efficiency and extended tool life to be achieved.

Brief Explanation of the Drawings

[0027] Fig. 1 is a schematic diagram showing an example of a machine tool suitable for use in a cutting/grinding method with a minimum quantity lubrication system.

Explanation of Symbols

[0028] 1: Bed, 2: table, 3: workpiece, 11: tool, 12: oil feeding tank, 13: working oil feeding section, 14: sliding surface oil feeding section, 15: bearing oil feeding section, 16: sliding surface, 17: bearing section, 18: compressed air injection port.

Best Mode for Carrying Out the Invention

[0029] Preferred embodiments of the invention will now be described in detail.

[0030] The first oil for metal working of the invention comprises (A) an ester oil and (B) a hydrocarbon oil with a kinematic viscosity of 1-20 mm²/s at 40°C (hereinafter referred to simply as "(B) hydrocarbon oil").

[0031] The (A) ester oil may be a natural substance (which generally includes any natural fat or oil such as an animal or vegetable oil) or a synthetic substance. According to the invention, a synthetic ester is preferred from the viewpoint of stability of the obtained lubricating oil and uniformity of the ester component. However, a natural ester is preferred from the standpoint of effects on the environment.

[0032] The alcohol in the (A) ester oil may be a monohydric alcohol or polyhydric alcohol, and the acid of the (A) ester oil may be a monobasic acid or polybasic acid.

[0033] As monohydric alcohols there may be used C1-24, preferably C1-12 and even more preferably C1-8 alcohols, which may be straight-chain or branched and may be saturated or unsaturated. As specific examples of C1-24 alcohols there may be mentioned methanol, ethanol, straight-chain or branched propanol, straight-chain or branched butanol, straight-chain or branched pentanol, straight-chain or branched hexanol, straight-chain or branched heptanol, straight-chain or branched octanol, straight-chain or branched nonanol, straight-chain or branched decanol, straight-chain or branched undecanol, straight-chain or branched dodecanol, straight-chain or branched tridecanol, straight-chain or branched tetradecanol, straight-chain or branched pentadecanol, straight-chain or branched hexadecanol, straight-chain or branched heptadecanol, straight-chain or branched octadecanol, straight-chain or branched nonadecanol, straight-chain or branched eicosanol, straight-chain or branched heneicosanol, straight-chain or branched tricosanol, straight-chain or branched tetracosanol, and mixtures thereof.

[0034] As polyhydric alcohols there may be used C2-10 and preferably C2-6 alcohols. As specific examples of C2-10 polyhydric alcohols there may be mentioned dihydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to pentadecamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to pentadecamer of propylene glycol), 1,3-propanediol, 1,2-propanediol, 1,3-butanediol, 1,4-butanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol and neopentyl glycol; polyhydric alcohols such as glycerin, polyglycerin (dimer to octamer of glycerin, such as diglycerin, triglycerin, tetraglycerin and the like), trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to octamer, pentaerythritol and its dimer to tetramer, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol; sugars such as xylose, arabinose, ribose, rhamnose, glucose, fructose, galactose, mannose, sorbose, cellobiose, maltose,

isomaltose, trehalose and sucrose; and mixtures thereof.

[0035] Preferred among these polyhydric alcohols are C2-6 polyhydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to decamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to decamer of propylene glycol), 1,3-propanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, neopentyl glycol, glycerin, diglycerin, triglycerin, trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to tetramer, pentaerythritol, dipentaerythritol, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol, and mixtures thereof. More preferred are ethylene glycol, propylene glycol, neopentyl glycol, glycerin, trimethylolethane, trimethylolpropane, pentaerythritol, sorbitan and mixtures thereof. Most preferred among these are neopentyl glycol, trimethylolethane, trimethylolpropane, pentaerythritol and mixtures thereof, since these can yield higher heat and oxidation stability.

[0036] The alcohol composing the ester oil may be a monohydric alcohol or a polyhydric alcohol as mentioned above, but it is preferably a polyhydric alcohol from the viewpoint of achieving superior lubricity, more easily obtaining a low pour point and improving the handleability in winter season and cold climates. Using a polyhydric alcohol ester oil will result in improved precision of the finishing surface of the workpiece and an even greater anti-abrasive effect for tool blades during cutting and grinding.

[0037] In most cases a C2-24 fatty acid will be used as the monobasic acid among acids for the ester oil, and such fatty acids may be straight-chain or branched and either saturated or unsaturated. As specific examples there may be mentioned saturated fatty acids such as acetic acid, propionic acid, straight-chain or branched butanoic acid, straight-chain or branched pentanoic acid, straight-chain or branched hexanoic acid, straight-chain or branched heptanoic acid, straight-chain or branched octanoic acid, straight-chain or branched nonanoic acid, straight-chain or branched decanoic acid, straight-chain or branched undecanoic acid, straight-chain or branched dodecanoic acid, straight-chain or branched tridecanoic acid, straight-chain or branched tetradecanoic acid, straight-chain or branched pentadecanoic acid, straight-chain or branched hexadecanoic acid, straight-chain or branched heptadecanoic acid, straight-chain or branched octadecanoic acid, straight-chain or branched hydroxyoctadecanoic acid, straight-chain or branched nonadecanoic acid, straight-chain or branched eicosanoic acid, straight-chain or branched heneicosanoic acid, straight-chain or branched docosanoic acid, straight-chain or branched tricosanoic acid and straight-chain or branched tetracosanoic acid; unsaturated fatty acids such as acrylic acid, straight-chain or branched butenoic acid, straight-chain or branched pentenoic acid, straight-chain or branched hexenoic acid, straight-chain or branched heptenoic acid, straight-chain or branched octenoic acid, straight-chain or branched nonenoic acid, straight-chain or branched decenoic acid, straight-chain or branched undecenoic acid, straight-chain or branched dodecenoic acid, straight-chain or branched tridecenoic acid, straight-chain or branched tetradecenoic acid, straight-chain or branched pentadecenoic acid, straight-chain or branched hexadecenoic acid, straight-chain or branched heptadecenoic acid, straight-chain or branched octadecenoic acid, straight-chain or branched hydroxyoctadecenoic acid, straight-chain or branched nonadecenoic acid, straight-chain or branched eicosenoic acid, straight-chain or branched heneicosenoic acid, straight-chain or branched docosenoic acid, straight-chain or branched tricosenoic acid and straight-chain or branched tetracosenoic acid; and mixtures thereof. Particularly preferred among these, from the standpoint of improving the lubricity and handleability, are C3-20 saturated fatty acids, C3-22 unsaturated fatty acids and mixtures thereof, among which C4-18 saturated fatty acids, C4-18 unsaturated fatty acids and mixtures thereof are more preferred and C4-18 unsaturated fatty acids are even more preferred, while from the viewpoint of preventing sticking, C4-18 saturated fatty acids are yet more preferred.

[0038] As polybasic acids there may be mentioned C2-16 dibasic acids, trimellitic acid and the like. Such C2-16 dibasic acids may be straight-chain or branched, and either saturated or unsaturated. As specific examples there may be mentioned ethanedioic acid, propanedioic acid, straight-chain or branched butanedioic acid, straight-chain or branched pentanedioic acid, straight-chain or branched hexanedioic acid, straight-chain or branched heptanedioic acid, straight-chain or branched octanedioic acid, straight-chain or branched nonanedioic acid, straight-chain or branched decanedioic acid, straight-chain or branched undecanedioic acid, straight-chain or branched dodecanedioic acid, straight-chain or branched tridecanedioic acid, straight-chain or branched tetradecanedioic acid, straight-chain or branched heptadecanedioic acid, straight-chain or branched hexadecanedioic acid, straight-chain or branched hexenedioic acid, straight-chain or branched heptenedioic acid, straight-chain or branched octenedioic acid, straight-chain or branched nonenedioic acid, straight-chain or branched decenedioic acid, straight-chain or branched undecenedioic acid, straight-chain or branched dodecenedioic acid, straight-chain or branched tridecenedioic acid, straight-chain or branched tetradecenedioic acid, straight-chain or branched heptadecenedioic acid, straight-chain or branched hexadecenedioic acid, and mixtures thereof.

[0039] The acid of the (A) ester oil may be a monobasic acid or polybasic acid as mentioned above, but using a monobasic acid is preferred to obtain an ester for an improved viscosity index and improved sticking resistance.

[0040] The combination of the alcohol and acid in the (A) ester may be as desired and is not particularly restricted, but the following esters may be mentioned as examples of ester oils to be used for the invention.

[0041]

- (i) Esters of monohydric alcohols and monobasic acids
- (ii) Esters of polyhydric alcohols and monobasic acids
- (iii) Esters of monohydric alcohols and polybasic acids
- (iv) Esters of polyhydric alcohols and polybasic acids
- (v) Mixed esters of monohydric alcohol and polyhydric alcohol mixtures with polybasic acids
- (vi) Mixed esters of polyhydric alcohols with monobasic acid and polybasic acid mixtures
- (vii) Mixed esters of monohydric alcohol and polyhydric alcohol mixtures with monobasic acids and polybasic acids

[0042] Preferred among these are (ii) esters of polyhydric alcohols and monobasic acids, from the viewpoint of achieving superior lubricity, more easily obtaining a low pour point, improving the handleability in winter season and cold climates, and more easily obtaining a high viscosity index.

[0043] As naturally-derived esters to be used for the invention there may be mentioned natural fats and oils including vegetable oils such as palm oil, palm kernel oil, rapeseed oil, soybean oil, sunflower oil, and high-oleic rapeseed oil or high-oleic sunflower oil obtained by increasing the oleic acid content of the fatty acids in glycerides by cross-breeding or gene recombinant techniques, and animal oils such as lard.

[0044] Among these naturally-derived esters, there are preferred high-oleic natural fats and oils with increased oleic acid contents from the viewpoint of lubricant stability, and there are particularly preferred fatty acid and glycerin triesters (hereinafter referred to simply as "triesters") with 40-98 % by mass oleic acid in the fatty acid portion. By using such triesters it is possible to achieve a satisfactory high-level balance between lubricity and heat/oxidation stability. The oleic acid content of the fatty acid composing the triester is preferably not less than 50 % by mass, more preferably not less than 60 % by mass, even more preferably not less than 70 % by mass, and preferably not greater than 95 % by mass and more preferably not greater than 90 % by mass, from the standpoint of achieving a satisfactory high-level balance between lubricity and heat/oxidation stability.

[0045] The proportions of oleic acid, and of linoleic acid, etc. described hereunder in the fatty acid of the aforementioned triester (hereinafter referred to as "constituent fatty acid") are measured in a manner based on the Standard Fat and Oil Analysis Methods 2.4.2, "Fatty Acid Composition", established by the Japan Oil Chemists' Society.

[0046] There are no particular restrictions on fatty acids other than oleic acid for the constituent fatty acid of the triester so long as the lubricity and heat/oxidation stability are not impaired, but preferably they are C6-24 fatty acids. The C6-24 fatty acids may be saturated fatty acids, or they may be unsaturated fatty acids with 1-5 unsaturated bonds. The fatty acids may also be either straight-chain or branched. They may also contain 1-3 hydroxyl groups (-OH) in the molecule in addition to carboxyl groups (-COOH). As such fatty acids there may be mentioned, specifically, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, behenic acid, lignoceric acid, lauroleic acid, myristoleic acid, palmitoleic acid, gadoleic acid, erudic acid, ricinolic acid, linoleic acid, linolenic acid, oleostearic acid, licanic acid, arachidonic acid and clupanodoic acid. Linoleic acid is preferred among these fatty acids from the viewpoint of achieving both lubricity and heat/oxidation stability, and more preferably linoleic acid constitutes 1-60 % by mass (more preferably 2-50 % by mass, and even more preferably 4-40 % by mass) of the constituent fatty acids of the triester.

[0047] Also from the viewpoint of achieving both lubricity and heat/oxidation stability, C6-16 fatty acids preferably constitute 0.1-30 % by mass (more preferably 0.5-20 % by mass and even more preferably 1-10 % by mass) of the constituent fatty acids in the triester. If the proportion of C6-16 fatty acids is less than 0.1 % by mass the heat/oxidation stability will tend to be reduced, while if it is greater than 30 % by mass the lubricity will tend to be reduced.

[0048] The total degree of unsaturation of the triester is preferably not greater than 0.3, and more preferably not greater than 0.2. If the total degree of unsaturation of the triester is greater than 0.3, the heat/oxidation stability of the lubricating oil of the invention will tend to be impaired. The total degree of unsaturation according to the invention is the total degree of unsaturation measured by the "Testing method of polyether for polyurethane" (JIS K1557-1970), using the same apparatus and procedure, except that a triester was used instead of a polyether for polyurethane.

[0049] The triester of the invention may be a synthetically obtained oil or a natural oil such as a triester-containing vegetable oil, so long as the proportion of oleic acid of the constituent fatty acid satisfies the conditions specified above, but from the standpoint of human safety it is preferred to use a natural oil such as a vegetable oil. Preferred vegetable oils include rapeseed oil, sunflower oil, soybean oil, corn oil and canola oil, among which sunflower oil, rapeseed oil and soybean oil are particularly preferred.

[0050] Although most natural vegetable oils have a total degree of unsaturation exceeding 0.3, their total degree of unsaturation can be reduced by treatment such as hydrogenation in a refining step. In addition, vegetable oils with low total degrees of unsaturation can be easily produced by gene recombinant techniques. Examples of vegetable oils with a degree of unsaturation of not greater than 0.3 and an oleic acid content of 70 % by mass or greater include high-oleic-acid canola oil, and examples of vegetable oils having contents of 80 % by mass and greater include high-oleic-acid soybean oil, high-oleic-acid sunflower oil and high-oleic-acid rapeseed oil.

[0051] According to the invention, when a polyhydric alcohol is used as the alcohol component, the ester may be a

total ester wherein all of the hydroxyl groups of the polyhydric alcohol are esterified, or it may be a partial ester wherein a portion of the hydroxyl groups remain as hydroxyl groups without esterification. Also, when a polybasic acid is used as the acid component, the organic acid ester may be a total ester wherein all of the carboxyl groups of the polybasic acid are esterified, or it may be a partial ester wherein a portion of the carboxyl groups remain as carboxyl groups without esterification.

[0052] The iodine value of the (A) ester oil is preferably 0-80, more preferably 0-60, even more preferably 0-40, yet more preferably 0-20 and most preferably 0-10. The bromine value of the ester of the invention is preferably 0-50 g Br₂/100 g, more preferably 0-30 g Br₂/100 g, even more preferably 0-20 g Br₂/100 g and most preferably 0-10 g Br₂/100 g. If the iodine value or bromine value of the ester are within the aforementioned ranges, the obtained lubricating oil will tend to have higher sticking resistance. Here, the "iodine value" is the value measured by the indicator titration method defined by JIS K 0070 "Method of measuring acid value, saponification value, ester value, iodine value, hydroxyl value and unsaponifiable matter of chemical products". The bromine value is the value measured by JIS K 2605 "Chemical Products - Test method for bromine value - electrometric titration".

[0053] In order to impart more satisfactory lubricating performance to the oil for metal working of the invention, preferably the hydroxyl value of the (A) ester oil is 0.01-300 mgKOH/g and the saponification degree is 100-500 mgKOH/g. In order to obtain even further increased lubricity according to the invention, the upper limit for the hydroxyl value of the ester is more preferably 200 mgKOH/g and most preferably 150 mgKOH/g, while the lower limit is more preferably 0.1 mgKOH/g, even more preferably 0.5 mgKOH/g, yet more preferably 1 mgKOH/g, even yet more preferably 3 mgKOH/g and most preferably 5 mgKOH/g. The upper limit for the saponification degree of the (A) ester oil is more preferably 400 mgKOH/g, while the lower limit is more preferably 200 mgKOH/g. Here, the "hydroxyl value" is the value measured by the indicator titration method defined by JIS K 0070 "Method of measuring acid value, saponification value, ester value, iodine value, hydroxyl value and unsaponifiable matter of chemical products". The saponification value is the value measured by the indicator titration method of JIS K 2503 "Testing method of lubricating oil for aircraft".

[0054] There are no particular restrictions on the kinematic viscosity of the (A) ester oil, but the kinematic viscosity at 40°C is preferably not greater than 300 mm²/s, more preferably not greater than 200 mm²/s, even more preferably not greater than 100 mm²/s and most preferably not greater than 75 mm²/s. The kinematic viscosity of the ester is also preferably not less than 1 mm²/s, more preferably not less than 3 mm²/s and even more preferably not less than 5 mm²/s.

[0055] There are no particular restrictions on the pour point and viscosity index of the (A) ester oil, but the pour point is preferably no higher than -10°C and more preferably no higher than -20°C. The viscosity index is preferably between 100 and 200.

[0056] The (B) hydrocarbon oil in the first oil for metal working is not particularly restricted so long as it has a kinematic viscosity of 1-20 mm²/s at 40°C, and it may be a mineral oil or synthetic oil, or a mixture of two or more different types.

[0057] As examples of mineral oils there may be mentioned paraffin-based mineral oils or naphthene-based mineral oils which are lube-oil distillates obtained by atmospheric distillation and vacuum distillation of crude oil, with refinement by appropriate combinations of refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrotreating, sulfuric acid treating and clay treatment.

[0058] As synthetic oils there may be mentioned, specifically, polyolefins such as propylene oligomer, polybutene, polyisobutylene, C5-20 α -olefin oligomers and ethylene and C5-20 α -olefin co-oligomers, or their hydrogenated products; alkylbenzenes such as monoalkylbenzenes, dialkylbenzenes and polyalkylbenzenes; and alkylnaphthalenes such as monoalkylnaphthalenes, dialkylnaphthalenes and polyalkylnaphthalenes. These may be used alone or in combinations of two or more.

[0059] When the polyolefin is a copolymer of olefin monomers with different structures, there are no particular restrictions on the monomer ratio and monomer arrangement of the copolymer, and it may be a random copolymer, an alternating copolymer or a block copolymer. An olefin monomer may be an α -olefin, internal olefin, straight-chain olefin or branched olefin.

[0060] Among these, white oils and polyolefins or their hydrogenated forms are preferred from the viewpoint of oil mist properties and biodegradability.

[0061] White oil is also known as liquid paraffin, and it is highly refined by sulfuric acid treatment or hydrogenation treatment of mineral oil. More specifically, white oil is a substance that matches the specification of "liquid paraffin" of JIS K 2231, i.e. has an evaluation score of not greater than 1 in the corrosion test (100°C, 3 hrs), has a color (Saybolt) of +30 or greater, exhibits the same or a lighter color than standard color solution in the readily carbonizable substances test, and does not produce a residue of yellow crystals (nitronaphthalene) in a nitronaphthalene test.

[0062] Among polyolefins and their hydrogenated products, there are preferred C5-20 α -olefin oligomers and their hydrogenated products, among which hydrogenated 1-octene oligomers, hydrogenated 1-decene oligomers and hydrogenated 1-dodecene oligomers are particularly preferred.

[0063] The polyolefin used for the invention may be produced by a process known in the prior art. Specifically, a target polyolefin may be produced, for example, by heated reaction in the absence of a catalyst, or it may be produced by homopolymerization or copolymerization of the aforementioned olefins using a publicly known catalyst, for example, an

organic peroxide catalyst such as benzoyl peroxide; a Friedel-Crafts catalyst such as aluminum chloride, aluminum chloride-polyhydric alcohol, aluminum chloride-titanium tetrachloride, aluminum chloride-alkyl tin halide or boron fluoride; a Ziegler catalyst such as organic aluminum chloride-titanium tetrachloride or organic aluminum-titanium tetrachloride; a metallocene catalyst such as aluminoxane-zirconocene or ionic compound-zirconocene; or a Lewis acid complex catalyst such as aluminum chloride-base or boron fluoride-base.

[0064] The polyolefin obtained by this process usually has a double bond, but as mentioned above, the first oil for metal working preferably uses a polyolefin having the double bonded carbons hydrogenated, i.e. a hydrogenated polyolefin, as the base oil. Using a hydrogenated polyolefin will tend to improve the heat/oxidation stability of the oil for metal working. A hydrogenated polyolefin can be obtained, for example, by hydrogenating a polyolefin with hydrogen in the presence of a publicly known hydrogenation catalyst, for saturation of the double bonds in the polyolefin. Selection of the catalyst used for polymerization of the olefin will allow polymerization of the olefin and hydrogenation of the double bonds in the polymer to be accomplished in a single step without requiring two separate steps for polymerization of the olefin and hydrogenation of the polymer.

[0065] As mentioned above, the kinematic viscosity of the (B) hydrocarbon oil at 40°C is not greater than 20 mm²/s, preferably not greater than 15 mm²/s, more preferably not greater than 10 mm²/s and even more preferably not greater than 5 mm²/s. If the kinematic viscosity is greater than 20 mm²/s, the oil mist property will be reduced, resulting in an insufficient working efficiency and tool life with minimum quantity lubrication systems, as well as unsatisfactory biodegradability. Also as mentioned above, the kinematic viscosity of the (B) hydrocarbon oil at 40°C is not less than 1 mm²/s, preferably not less than 2 mm²/s and even more preferably not less than 3 mm²/s. If the kinematic viscosity is 1 mm²/s, the oil will form a mist too readily, causing more mist to fly out into the working environment and preventing a sufficient amount of oil from being supplied in the minimum quantity lubrication system, or it may become impossible to avoid adhesion of the metal from the workpieces or increased working resistance for non-ferrous metal working, resulting in insufficient working efficiency and tool life in either case.

[0066] The content of the (B) hydrocarbon oil in the first oil for metal working is preferably not greater than 70 % by mass, more preferably not greater than 60 % by mass and even more preferably not greater than 50 % by mass based on the total amount of the oil for metal working. If the content exceeds 70 % by mass the oil mist property will be reduced, and the working efficiency and tool life will tend to be poor when it is used for cutting and grinding in a minimum quantity lubrication system. The content of the (B) hydrocarbon oil is preferably not less than 1 % by mass, more preferably not less than 5 % by mass, even more preferably not less than 10 % by mass and most preferably not less than 20 % by mass based on the total amount of the oil for metal working. If the content is less than 1 % by mass, it may become impossible to avoid adhesion of the metal from the workpieces or increased working resistance for non-ferrous metal working, and the working efficiency and tool life will tend to be reduced.

[0067] The first oil for metal working of the invention may be composed entirely of the (A) ester oil and (B) hydrocarbon oil, but it may also contain other base oils as well. As other base oils there may be mentioned, specifically, polyglycols such as polyethylene glycol, polypropylene glycol, polyoxyethylenepolyoxypropylene glycol, polyethyleneglycol monoether, polypropyleneglycol monoether, polyoxyethylenepolyoxypropyleneglycol monoether, polyethyleneglycol diether, polypropyleneglycol diether and polyoxyethylenepolyoxypropyleneglycol diether; phenyl ethers such as monoalkyldiphenyl ethers, dialkyldiphenyl ether, monoalkyltriphenyl ethers, dialkyltriphenyl ethers, tetraphenyl ether, monoalkyl tetraphenyl ethers, dialkyltetraphenyl ethers and pentaphenyl ether; silicone oil; and fluoroethers such as perfluoroether. These may be used alone or in combinations of two or more.

[0068] The content of base oils other than components (A) and (B) in the first oil for metal working of the invention is preferably not greater than 65 % by mass, more preferably not greater than 50 % by mass, even more preferably not greater than 30 % by mass, yet more preferably not greater than 20 % by mass and most preferably not greater than 10 % by mass based on the total amount of the oil for metal working.

[0069] The moisture content of the first oil for metal working is not particularly restricted, but from the viewpoint of storage stability and rust inhibition, it is preferably not greater than 20,000 ppm, more preferably not greater than 10,000 ppm and even more preferably not greater than 5000 ppm. From the viewpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve an excellent working efficiency and tool life, the moisture content is preferably not less than 200 ppm, more preferably not less than 300 ppm, even more preferably not less than 400 ppm and yet more preferably not less than 500 ppm. The moisture content according to the invention is the moisture content as measured by Karl Fischer coulometric titration based on JIS K 2275.

[0070] When the moisture content is adjusted by addition of water to the first oil for metal working, the added water may be hard water or soft water, and any desired source such as city water, industrial water, ion-exchanged water, distilled water or alkali ion water may be used.

[0071] The second oil for metal working of the invention employs the (A) ester oil as the base oil and has a moisture content of 200-20,000 ppm. Specific examples and preferred modes of the (A) ester oil in the second oil for metal working are the same as for the (A) ester oil of the first oil for metal working, and their explanation will not be repeated.

[0072] The moisture content of the second oil for metal working of the invention is 200-20,000 ppm. Specifically, the

moisture content of the second oil for metal working must be not greater than 20,000 ppm, preferably not greater than 10,000 ppm and more preferably not greater than 5000 ppm from the standpoint of storage stability and rust inhibition. From the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve an excellent working efficiency and tool life, the moisture content is preferably not less than 200 ppm, more preferably not less than 300 ppm, even more preferably not less than 400 ppm and yet more preferably not less than 500 ppm. The moisture content according to the invention is the moisture content as measured by Karl Fischer coulometric titration based on JIS K 2275.

[0073] When the moisture content is adjusted by addition of water to the second oil for metal working, the added water may be hard water or soft water, and any desired source such as city water, industrial water, ion-exchanged water, distilled water or alkali ion water may be used.

[0074] So long as the second oil for metal working of the invention has a moisture content in the range of 200-20,000 ppm, it may consist entirely of the (A) ester oil or it may further contain other base oils and additives described hereunder. When the second oil for metal working contains components other than the (A) ester oil, the content of the (A) ester oil is preferably not less than 30 % by mass, more preferably not less than 50 % by mass, even more preferably not less than 70 % by mass and most preferably not less than 80 % by mass based on the total amount of the oil for metal working. If the content is less than 30 % by mass, the oil mist property will be reduced, leading to adhesion of the metal from the workpieces or increased working resistance when used for cutting and grinding in a minimum quantity lubrication system, and tending to result in insufficient working efficiency and tool life, as well as reduced biodegradability.

[0075] When the second oil for metal working also contains a base oil other than the (A) ester oil, the additional base oil may be a mineral oil or synthetic oil, or it may be a mixture of two or more thereof.

[0076] As examples of mineral oils there may be mentioned paraffin-based mineral oils or naphthene-based mineral oils which are lube-oil distillates obtained by atmospheric distillation and vacuum distillation of crude oil, with refinement by appropriate combinations of refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrotreating, sulfuric acid treating and clay treatment.

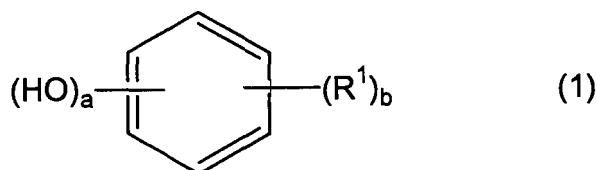
[0077] As synthetic oils there may be mentioned, specifically, polyolefins such as propylene oligomer, polybutene, polyisobutylene, C5-20 α -olefin oligomers and ethylene and C5-20 α -olefin co-oligomers, or their hydrogenated products; alkylbenzenes such as monoalkylbenzenes, dialkylbenzenes and polyalkylbenzenes; alkylnaphthalenes such as monoalkylnaphthalenes, dialkylnaphthalenes and polyalkylnaphthalenes, polyglycols such as polyethylene glycol, polypropylene glycol, polyoxyethylenepolyoxypropylene glycol, polyethyleneglycol monoether, polypropyleneglycol monoether, polyoxyethylenepolyoxypropyleneglycol monoether, polyethylene glycol diether, polypropylene glycol diether and polyoxyethylenepolyoxypropylene glycol diether; phenyl ethers such as monoalkyldiphenyl ethers, dialkyldiphenyl ethers, monoalkyltriphenyl ethers, dialkyltriphenyl ethers, tetraphenylether, monoalkyltetraphenyl ethers, dialkyltetraphenyl ethers and pentaphenyl ether; silicone oil; fluoroethers such as perfluoroether, and the like. These may be used alone or in combinations of two or more.

[0078] The content of the other base oils in the second oil for metal working is preferably not greater than 70 % by mass, more preferably not greater than 50 % by mass, even more preferably not greater than 30 % by mass, yet more preferably not greater than 20 % by mass and most preferably not greater than 10 % by mass based on the total amount of the oil for metal working.

[0079] The first and second oils for metal working according to the invention preferably also contain (C) an oiliness agent from the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life. As oiliness agents there may be mentioned (C-1) alcohol oiliness agents, (C-2) carboxylic acid oiliness agents, (C-3) unsaturated carboxylic acid sulfides, (C-4) compounds represented by general formula (1) below, (C-5) compounds represented by general formula (2) below, (C-6) polyoxyalkylene compounds, (C-7) ester oiliness agents, (C-8) polyhydric alcohol hydrocarbylethers and (C-9) amine oiliness agents.

[0080]

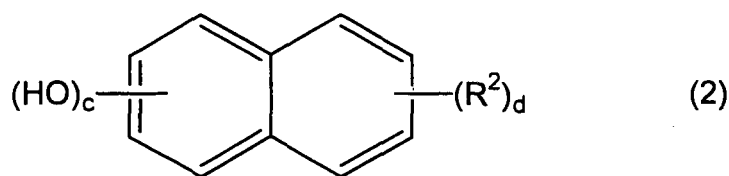
[Chemical Formula 1]



[wherein R^1 represents a C1-30 hydrocarbon group, a represents an integer of 1-6 and b represents an integer of 0-5.]

[0081]

[Chemical Formula 2]



[wherein R² represents a C1-30 hydrocarbon group, c represents an integer of 1-6 and d represents an integer of 0-5.]

15 **[0082]** The (C-1) alcohol oiliness agent may be a monohydric alcohol or a polyhydric alcohol. From the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, C1-40 monohydric alcohols are preferred, C1-25 alcohols are more preferred and C8-18 alcohols are most preferred. More specifically, there may be mentioned as examples the alcohols composing the aforementioned base oil esters. These alcohols may be straight-chain or branched and either saturated or unsaturated, but from the standpoint of preventing sticking, they are preferably saturated.

20 **[0083]** The (C-2) carboxylic acid oiliness agent may be a monobasic or polybasic acid. From the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, C1-40 monobasic carboxylic acids are preferred, C5-25 carboxylic acids are more preferred and C5-20 carboxylic acids are most preferred. More specifically, there may be mentioned as examples the carboxylic acids composing the esters for the aforementioned base oils. These carboxylic acids may be straight-chain or branched and either saturated or unsaturated, but from the standpoint of preventing sticking they are preferably saturated carboxylic acids.

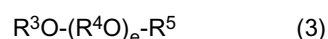
25 **[0084]** As examples of the (C-3) unsaturated carboxylic acid sulfides there may be mentioned sulfides of unsaturated carboxylic acids among the aforementioned (C-2) carboxylic acids. As specific examples there may be mentioned sulfides of oleic acid.

30 **[0085]** As examples of C1-30 hydrocarbon groups represented by R¹ in the (C-4) compounds represented by general formula (1) above, there may be mentioned C1-30 straight-chain or branched alkyl, C5-7 cycloalkyl, C6-30 alkylcycloalkyl, C2-30 straight-chain or branched alkenyl, C6-10 aryl, C7-30 alkylaryl and C7-30 arylalkyl. Among these, C1-30 straight-chain or branched alkyl groups are preferred, C1-20 straight-chain or branched alkyl groups are more preferred, C1-10 straight-chain or branched alkyl groups are even more preferred, and C1-4 straight-chain or branched alkyl groups are most preferred. As examples of C1-4 straight-chain or branched alkyl groups there may be mentioned methyl, ethyl, straight-chain or branched propyl and straight-chain or branched butyl.

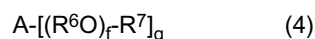
35 **[0086]** The hydroxyl may be substituted at any position, but in the case of two or more hydroxyl groups they are preferably substituted at adjacent carbon atoms. The symbol a is preferably an integer of 1-3 and more preferably 2. The symbol b is preferably an integer of 0-3 and more preferably 1 or 2. As an example of a compound represented by general formula (1) there may be mentioned p-tert-butylcatechol.

40 **[0087]** As examples of C1-30 hydrocarbon groups represented by R² in the (C-5) compounds represented by general formula (2) above, there may be mentioned the same examples of C1-30 hydrocarbon groups represented by R¹ in general formula (1), and the preferred examples are also the same. The hydroxyl may be substituted at any position, but in the case of two or more hydroxyl groups they are preferably substituted at adjacent carbon atoms. The symbol c is preferably an integer of 1-3 and more preferably 2. The symbol d is preferably an integer of 0-3 and more preferably 1 or 2. As examples of compounds represented by general formula (2) there may be mentioned 2,2-dihydroxynaphthalene and 2,3-dihydroxynaphthalene.

45 **[0088]** As examples of the (C-6) polyoxyalkylene compounds there may be mentioned compounds represented by the following general formulas (3) and (4).



[wherein R³ and R⁵ each independently represent hydrogen or a C1-30 hydrocarbon group, R⁴ represents C2-4 alkylene, and e represents an integer such that the number-average molecular weight is 100-3500.]



[wherein A represents the residue of a polyhydric alcohol having 3-10 hydroxyl groups of which all or a portion of the

hydrogens of the hydroxyl groups have been removed, R⁶ represents C2-4 alkylene, R⁷ represents hydrogen or a C1-30 hydrocarbon group, f represents an integer such that the number-average molecular weight is 100-3500, and g represents the same number as the number of hydrogens removed from the hydroxyl groups of A.]

[0089] In general formula (3), at least one of R³ and R⁵ is preferably hydrogen. As examples of C1-30 hydrocarbon groups represented by R³ and R⁵ there may be mentioned the same examples of C1-30 hydrocarbon groups represented by R¹ of general formula (1) above, and the preferred examples are also the same. As specific examples of C2-4 alkylene groups represented by R⁴ there may be mentioned ethylene, propylene (methylethylene) and butylene (ethylethylene). The symbol e is preferably a integer such that the number-average molecular weight is 300-2000, and more preferably an integer such that the number-average molecular weight is 500-1500.

[0090] As specific examples of polyhydric alcohols having 3-10 hydroxyl groups in A of general formula (4) above, there may be mentioned polyhydric alcohols such as glycerin, polyglycerin (dimer to tetramer of glycerin such as diglycerin, triglycerin and tetraglycerin), trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to tetramer, pentaerythritol, dipentaerythritol, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation products, adonitol, arabitol, xylitol, mannitol, iditol, talitol, dulcitol and allitol; and sugars such as xylose, arabinose, ribose, rhamnose, glucose, fructose, galactose, mannose, sorbose, cellobiose, mantose, isomantose, trehalose and sucrose. Preferred among these are glycerin, polyglycerin, trimethylolalkanes and their dimer to tetramer, pentaerythritol, dipentaerythritol, sorbitol and sorbitan.

[0091] As examples of C2-4 alkylene groups represented by R⁶ there may be mentioned the same examples of C2-4 alkylene groups represented by R⁴ in general formula (3) above. As examples of C1-30 hydrocarbon groups represented by R⁷ there may be mentioned the same examples of C1-30 hydrocarbon groups represented by R¹ in general formula (1) above, and the preferred examples are also the same. At least one of the g R⁷ groups is preferably hydrogen, and more preferably all of them are hydrogen. The symbol f is preferably an integer such that the number-average molecular weight is 300-2000, and more preferably an integer such that the number-average molecular weight is 500-1500.

[0092] The alcohols in the (C-7) ester oiliness agents may be monohydric alcohols or polyhydric alcohols, and the carboxylic acids may be monobasic acids or polybasic acids. The "ester" referred to here is distinct from the triester which is the essential component of the first and second oils for metal working. Throughout the following explanation, the former will be referred to as "ester oiliness agent" for convenience.

[0093] The alcohol composing the (C-7) ester oiliness agent may be a monohydric alcohol or polyhydric alcohol, and the acid composing the ester oiliness agent may be a monobasic acid or polybasic acid.

[0094] As monohydric alcohols there may be used C1-24, preferably C1-12 and even more preferably C1-8 alcohols, which may be straight-chain or branched and may be saturated or unsaturated. As specific examples of C1-24 alcohols there may be mentioned methanol, ethanol, straight-chain or branched propanol, straight-chain or branched butanol, straight-chain or branched pentanol, straight-chain or branched hexanol, straight-chain or branched heptanol, straight-chain or branched octanol, straight-chain or branched nonanol, straight-chain or branched decanol, straight-chain or branched undecanol, straight-chain or branched dodecanol, straight-chain or branched tridecanol, straight-chain or branched tetradecanol, straight-chain or branched pentadecanol, straight-chain or branched hexadecanol, straight-chain or branched heptadecanol, straight-chain or branched octadecanol, straight-chain or branched nonadecanol, straight-chain or branched eicosanol, straight-chain or branched heneicosanol, straight-chain or branched tricosanol, straight-chain or branched tetracosanol, and mixtures thereof.

[0095] As polyhydric alcohols there may be used C2-10 and preferably C2-6 alcohols. As specific examples of C2-10 polyhydric alcohols there may be mentioned dihydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to pentadecamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to pentadecamer of propylene glycol), 1,3-propanediol, 1,2-propanediol, 1,3-butanediol, 1,4-butanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol and neopentyl glycol; polyhydric alcohols such as glycerin, polyglycerin (dimer to octamer of glycerin, such as diglycerin, triglycerin, tetraglycerin and the like), trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to octamer, pentaerythritol and its dimer to tetramer, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol; sugars such as xylose, arabinose, ribose, rhamnose, glucose, fructose, galactose, mannose, sorbose, cellobiose, maltose, isomaltose, trehalose and sucrose; and mixtures thereof.

[0096] Preferred among these polyhydric alcohols are C2-6 polyhydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to decamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to decamer of propylene glycol), 1,3-propanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, neopentyl glycol, glycerin, diglycerin, triglycerin, trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to tetramer, pentaerythritol, dipentaerythritol, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol, and mixtures thereof. More preferred are ethylene glycol, propylene glycol, neopentyl glycol, glycerin, trimethylolethane, trimethylolpropane, pentaerythritol, sorbitan and mixtures thereof. Most preferred among these are neopentyl glycol,

trimethylolethane, trimethylolpropane, pentaerythritol and mixtures thereof, since these can yield higher heat and oxidation stability.

[0097] The alcohol composing the ester oiliness agent may be a monohydric alcohol or a polyhydric alcohol as mentioned above, but it is preferably a polyhydric alcohol from the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, more easily obtaining a low pour point and improving the handleability in winter season and cold climates. Using a polyhydric alcohol ester will result in improved precision of the finishing surface of the workpiece and an even greater anti-abrasive effect for tool blades during cutting and grinding.

[0098] In most cases a C2-24 fatty acid will be used as the monobasic acid among acids for the ester oiliness agent, and such fatty acids may be straight-chain or branched and either saturated or unsaturated. As specific examples there may be mentioned saturated fatty acids such as acetic acid, propionic acid, straight-chain or branched butanoic acid, straight-chain or branched pentanoic acid, straight-chain or branched hexanoic acid, straight-chain or branched heptanoic acid, straight-chain or branched octanoic acid, straight-chain or branched nonanoic acid, straight-chain or branched decanoic acid, straight-chain or branched undecanoic acid, straight-chain or branched dodecanoic acid, straight-chain or branched tridecanoic acid, straight-chain or branched tetradecanoic acid, straight-chain or branched pentadecanoic acid, straight-chain or branched hexadecanoic acid, straight-chain or branched heptadecanoic acid, straight-chain or branched octadecanoic acid, straight-chain or branched hydroxyoctadecanoic acid, straight-chain or branched nonadecanoic acid, straight-chain or branched eicosanoic acid, straight-chain or branched heneicosanoic acid, straight-chain or branched docosanoic acid, straight-chain or branched tricosanoic acid and straight-chain or branched tetracosanoic acid; unsaturated fatty acids such as acrylic acid, straight-chain or branched butenoic acid, straight-chain or branched pentenoic acid, straight-chain or branched hexenoic acid, straight-chain or branched heptenoic acid, straight-chain or branched octenoic acid, straight-chain or branched nonenoic acid, straight-chain or branched decenoic acid, straight-chain or branched undecenoic acid, straight-chain or branched dodecenoic acid, straight-chain or branched tridecenoic acid, straight-chain or branched tetradecenoic acid, straight-chain or branched pentadecenoic acid, straight-chain or branched hexadecenoic acid, straight-chain or branched heptadecenoic acid, straight-chain or branched octadecenoic acid, straight-chain or branched hydroxyoctadecenoic acid, straight-chain or branched nonadecenoic acid, straight-chain or branched eicosenoic acid, straight-chain or branched heneicosenoic acid, straight-chain or branched docosenoic acid, straight-chain or branched tricosenoic acid and straight-chain or branched tetracosenoic acid; and mixtures thereof. From the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, as well as handleability, C3-20 saturated fatty acids, C3-22 unsaturated fatty acids and their mixtures are preferred, C4-18 saturated fatty acids, C4-18 unsaturated fatty acids and their mixtures are more preferred and C4-18 unsaturated fatty acids are even more preferred, and from the viewpoint of sticking prevention, C4-18 saturated fatty acids are preferred.

[0099] As polybasic acids there may be mentioned C2-16 dibasic acids, trimellitic acid and the like. Such C2-16 dibasic acids may be straight-chain or branched, and either saturated or unsaturated. As specific examples there may be mentioned ethanedioic acid, propanedioic acid, straight-chain or branched butanedioic acid, straight-chain or branched pentanedioic acid, straight-chain or branched hexanedioic acid, straight-chain or branched heptanedioic acid, straight-chain or branched octanedioic acid, straight-chain or branched nonanedioic acid, straight-chain or branched decanedioic acid, straight-chain or branched undecanedioic acid, straight-chain or branched dodecanedioic acid, straight-chain or branched tridecanedioic acid, straight-chain or branched tetradecanedioic acid, straight-chain or branched heptadecanedioic acid, straight-chain or branched hexadecanedioic acid, straight-chain or branched hexenedioic acid, straight-chain or branched heptenedioic acid, straight-chain or branched octenedioic acid, straight-chain or branched nonenedioic acid, straight-chain or branched decenedioic acid, straight-chain or branched undecenedioic acid, straight-chain or branched dodecenedioic acid, straight-chain or branched tridecenedioic acid, straight-chain or branched tetradecenedioic acid, straight-chain or branched heptadecenedioic acid, straight-chain or branched hexadecenedioic acid, and mixtures thereof.

[0100] The combination of the alcohol and acid in the (C-7) ester oiliness agent may be as desired and is not particularly restricted, but the following esters may be mentioned as examples of ester oiliness agents to be used for the invention.

(C-7-1) Esters of monohydric alcohols and monobasic acids

(C-7-2) Esters of polyhydric alcohols and monobasic acids

(C-7-3) Esters of monohydric alcohols and polybasic acids

(C-7-4) Esters of polyhydric alcohols and polybasic acids

(C-7-5) Mixed esters of monohydric alcohol and polyhydric alcohol mixtures with polybasic acids

(C-7-6) Mixed esters of polyhydric alcohols with monobasic acid and polybasic acid mixtures

(C-7-7) Mixed esters of monohydric alcohol and polyhydric alcohol mixtures with monobasic acids and polybasic acids

[0101] When a polyhydric alcohol is used as the alcohol component, the ester may be a total ester wherein all of the

hydroxyl groups of the polyhydric alcohol are esterified, or it may be a partial ester wherein a portion of the hydroxyl groups remain as hydroxyl groups without esterification. Also, when a polybasic acid is used as the carboxylic acid component, the ester may be a total ester wherein all of the carboxyl groups of the polybasic acid are esterified, or it may be a partial ester wherein a portion of the carboxyl groups remain as carboxyl groups without esterification.

[0102] There are no particular restrictions on the total number of carbon atoms of the ester oiliness agent, but from the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, the total number of carbon atoms of the ester is preferably 7 or more, more preferably 9 or more and most preferably 11 or more. From the standpoint of minimizing staining and corrosion and of compatibility with organic materials, the ester preferably has a total number of carbon atoms of not greater than 60, more preferably not greater than 45, even more preferably not greater than 26, yet more preferably not greater than 24 and most preferably not greater than 22.

[0103] As polyhydric alcohols of the (C-8) polyhydric alcohol hydrocarbylethers there are usually used those with 2-10 and preferably 2-6 hydroxyl groups. As specific examples of C2-10 polyhydric alcohols there may be mentioned dihydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to pentadecamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to pentadecamer of propylene glycol), 1,3-propanediol, 1,2-propanediol, 1,3-butanediol, 1,4-butanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol and neopentyl glycol; polyhydric alcohols such as glycerin, polyglycerin (dimer to octamer of glycerin, such as diglycerin, triglycerin, tetraglycerin and the like), trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to octamer, pentaerythritol and its dimer to tetramer, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol; sugars such as xylose, arabinose, ribose, rhamnose, glucose, fructose, galactose, mannose, sorbose, cellobiose, maltose, isomaltose, trehalose and sucrose; and mixtures thereof.

[0104] Preferred among these polyhydric alcohols are C2-6 polyhydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to decamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to decamer of propylene glycol), 1,3-propanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, neopentyl glycol, glycerin, diglycerin, triglycerin, trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and their dimer to tetramer, pentaerythritol, dipentaerythritol, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensation product, adonitol, arabitol, xylitol and mannitol, and mixtures thereof. More preferred are ethylene glycol, propylene glycol, neopentyl glycol, glycerin, trimethylolethane, trimethylolpropane, pentaerythritol, sorbitan and mixtures thereof. Glycerin is most preferred among these from the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life.

[0105] As (C-8) polyhydric alcohol hydrocarbylethers there may be used ones obtained by hydrocarbyletherification of all or a portion of the hydroxyl groups of the aforementioned polyhydric alcohols. From the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, preferably a portion of the hydroxyl groups of the polyhydric alcohol are hydrocarbyletherified (partial etherification). Here, a hydrocarbyl group is a C1-24 hydrocarbon group such as C1-24 alkyl, C2-24 alkenyl, C5-7 cycloalkyl, C6-11 alkylcycloalkyl, C6-10 aryl, C7-18 alkylaryl, C7-18 arylalkyl, or the like.

[0106] As C1-24 alkyl groups there may be mentioned methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, straight-chain or branched pentyl, straight-chain or branched hexyl, straight-chain or branched heptyl, straight-chain or branched octyl, straight-chain or branched nonyl, straight-chain or branched decyl, straight-chain or branched undecyl, straight-chain or branched dodecyl, straight-chain or branched tridecyl, straight-chain or branched tetradecyl, straight-chain or branched pentadecyl, straight-chain or branched hexadecyl, straight-chain or branched heptadecyl, straight-chain or branched octadecyl, straight-chain or branched nonadecyl, straight-chain or branched eicosyl, straight-chain or branched heneicosyl, straight-chain or branched docosyl, straight-chain or branched tricosyl and straight-chain or branched tetracosyl.

[0107] As C2-24 alkenyl groups there may be mentioned vinyl, straight-chain or branched propenyl, straight-chain or branched butenyl, straight-chain or branched pentenyl, straight-chain or branched hexenyl, straight-chain or branched heptenyl, straight-chain or branched octenyl, straight-chain or branched nonenyl, straight-chain or branched decenyl, straight-chain or branched undecenyl, straight-chain or branched dodecenyl, straight-chain or branched tridecenyl, straight-chain or branched tetradecenyl, straight-chain or branched pentadecenyl, straight-chain or branched hexadecenyl, straight-chain or branched heptadecenyl, straight-chain or branched octadecenyl, straight-chain or branched nonadecenyl, straight-chain or branched eicosenyl, straight-chain or branched heneicosenyl, straight-chain or branched docosenyl, straight-chain or branched tricosenyl and straight-chain or branched tetracosenyl.

[0108] As C5-7 cycloalkyl groups there may be mentioned cyclopentyl, cyclohexyl and cycloheptyl. As C6-11 alkylcycloalkyl groups there may be mentioned methylcyclopentyl, dimethylcyclopentyl (including all structural isomers), methylethylcyclopentyl (including all structural isomers), diethylcyclopentyl (including all structural isomers), methylcyclohexyl, dimethylcyclohexyl (including all structural isomers), methylethylcyclohexyl (including all structural isomers), diethylcyclo-

clohexyl (including all structural isomers), methylcycloheptyl, dimethylcycloheptyl (including all structural isomers), methylethylcycloheptyl (including all structural isomers) and diethylcycloheptyl (including all structural isomers).

[0109] As C6-10 aryl groups there may be mentioned phenyl and naphthyl. As C7-18 alkylaryl groups there may be mentioned tolyl (including all structural isomers), xylyl (including all structural isomers), ethylphenyl (including all structural isomers), straight-chain or branched propylphenyl (including all structural isomers), straight-chain or branched butylphenyl (including all structural isomers), straight-chain or branched pentylphenyl (including all structural isomers), straight-chain or branched hexylphenyl (including all structural isomers), straight-chain or branched heptylphenyl (including all structural isomers), straight-chain or branched octylphenyl (including all structural isomers), straight-chain or branched nonylphenyl (including all structural isomers), straight-chain or branched decylphenyl (including all structural isomers), straight-chain or branched undecylphenyl (including all structural isomers) and straight-chain or branched dodecylphenyl (including all structural isomers).

[0110] As C7-12 arylalkyl groups there may be mentioned benzyl, phenylethyl, phenylpropyl (including propyl isomers), phenylbutyl (including butyl isomers), phenylpentyl (including pentyl isomers) and phenylhexyl (including hexyl isomers).

[0111] From the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, C2-18 straight-chain or branched alkyl and C2-18 straight-chain or branched alkenyl groups are preferred, and C3-12 straight-chain or branched alkyl and oleyl (a residue obtained by removing the hydroxyl group from oleyl alcohol) are more preferred.

[0112] A monoamine is preferred for use as the (C-9) amine oiliness agent. The number of carbon atoms of the monoamine is preferably 6-24 and more preferably 12-24. Here, the number of carbon atoms is the number of carbon atoms of the monoamine, and when the monoamine has two or more hydrocarbon groups it is the total number of carbon atoms.

[0113] Monoamines to be used for the invention include primary monoamines, secondary monoamines and tertiary monoamines, although primary monoamines are preferred from the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and extended tool life.

[0114] As hydrocarbon groups bonded to the nitrogen atom of the monoamine there may be used alkyl, alkenyl, cycloalkyl, alkylcycloalkyl, aryl, alkylaryl, arylalkyl and the like, although alkyl and alkenyl groups are preferred from the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life. The alkyl and alkenyl groups may be straight-chain or branched, but are preferably straight-chain from the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life.

[0115] As specific examples of preferred monoamines to be used for the invention there may be mentioned hexylamine (including all isomers), heptylamine (including all isomers), octylamine (including all isomers), nonylamine (including all isomers), decylamine (including all isomers), undecylamine (including all isomers), dodecylamine (including all isomers), tridecylamine (including all isomers), tetradecylamine (including all isomers), pentadecylamine (including all isomers), hexadecylamine (including all isomers), heptadecylamine (including all isomers), octadecylamine (including all isomers), nonadecylamine (including all isomers), eicosylamine (including all isomers), heneicosylamine (including all isomers), docosylamine (including all isomers), tricosylamine (including all isomers), tetracosylamine (including all isomers), octadecenylamine (including all isomers) (including oleylamine and the like), and mixtures of two or more thereof. From the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, C 12-24 primary monoamines are preferred, C14-20 primary monoamines are more preferred and C16-18 primary monoamines are even more preferred.

[0116] According to the invention, one selected from among the aforementioned oiliness agents (C-1) to (C-9) may be used, or a mixture of two or more thereof may be used. From the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, it is preferably one or a mixture of two or more selected from among (C-2) carboxylic acid oiliness agents and (C-9) amine oiliness agents.

[0117] The content of the (C) oiliness agent is not particularly restricted, but from the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, it is preferably not less than 0.01 % by mass, more preferably not less than 0.05 % by mass and even more preferably not less than 0.1 % by mass based on the total oil for metal working. From the standpoint of stability, the oiliness agent content is preferably not greater than 15 % by mass, more preferably not greater than 10 % by mass and even more preferably not greater than 5 % by mass based on the total oil for metal working.

[0118] The first and second oils for metal working according to the invention preferably also contain (D) an extreme-pressure agent, from the viewpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life. Particularly when the (D) extreme-pressure agent is used together with the (C) oiliness agent described above, the components work synergistically to prevent adhesion of the metal from the workpieces and increased working resistance and achieve an even more excellent working efficiency and tool life. As described hereunder, the first and second oils for metal working may be used as lubricating oils for sections other than machine tool working sections, in which case they preferably contain the (C) oiliness agent.

[0119] As the (D) extreme-pressure agents there may be mentioned the (D-1) sulfur compounds and (D-2) phosphorus compounds described below.

[0120] There are no particular restrictions on (D-1) sulfur compounds so long as the properties as an oil for metal working are not impaired, but preferred for use are dihydrocarbyl polysulfide, sulfurized esters, sulfurized mineral oils, zinc dithiophosphate compounds, zinc dithiocarbamate compounds, molybdenum dithiophosphate compounds and molybdenum thiocarbamate.

[0121] Dihydrocarbyl polysulfides are sulfur-based compounds generally known as polysulfides or sulfurized olefins, and specifically refer to compounds represented by the following general formula (5):



wherein R^8 and R^9 are the same or different and each represents C3-20 straight-chain or branched alkyl, C6-20 aryl, C6-20 alkylaryl or C6-20 arylalkyl, and h represents an integer of 2-6 and preferably 2-5.]

[0122] As specific examples of R^8 and R^9 in general formula (5) above there may be mentioned straight-chain or branched alkyl groups such as n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, straight-chain or branched pentyl, straight-chain or branched hexyl, straight-chain or branched heptyl, straight-chain or branched octyl, straight-chain or branched nonyl, straight-chain or branched decyl, straight-chain or branched undecyl, straight-chain or branched dodecyl, straight-chain or branched tridecyl, straight-chain or branched tetradecyl, straight-chain or branched pentadecyl, straight-chain or branched hexadecyl, straight-chain or branched heptadecyl, straight-chain or branched octadecyl, straight-chain or branched nonadecyl and straight-chain or branched eicosyl; aryl groups such as phenyl and naphthyl; alkylaryl groups such as tolyl (including all structural isomers), ethylphenyl (including all structural isomers), straight-chain or branched propylphenyl (including all structural isomers), straight-chain or branched butylphenyl (including all structural isomers), straight-chain or branched pentylphenyl (including all structural isomers), straight-chain or branched hexylphenyl (including all structural isomers), straight-chain or branched heptylphenyl (including all structural isomers), straight-chain or branched octylphenyl (including all structural isomers), straight-chain or branched nonylphenyl (including all structural isomers), straight-chain or branched decylphenyl (including all structural isomers), straight-chain or branched undecylphenyl (including all structural isomers), straight-chain or branched dodecylphenyl (including all structural isomers), xylyl (including all structural isomers), ethylmethylphenyl (including all structural isomers), diethylphenyl (including all structural isomers), di(straight-chain or branched)propylphenyl (including all structural isomers), di(straight-chain or branched)butylphenyl (including all structural isomers), methylnaphthyl (including all structural isomers), ethylnaphthyl (including all structural isomers), straight-chain or branched propylnaphthyl (including all structural isomers), straight-chain or branched butylnaphthyl (including all structural isomers), dimethylnaphthyl (including all structural isomers), ethylmethylnaphthyl (including all structural isomers), diethylnaphthyl (including all structural isomers), di(straight-chain or branched)propylnaphthyl (including all structural isomers) and di(straight-chain or branched)butylnaphthyl (including all structural isomers); and arylalkyl groups such as benzyl, phenylethyl (including all isomers) and phenylpropyl (including all isomers). Among these there are preferred compounds wherein R^8 and R^9 of general formula (5) are C3-18 alkyl groups derived from propylene, 1-butene or isobutylene, or C6-8 aryl and alkylaryl groups, and as examples of such groups there may be mentioned alkyl groups such as isopropyl, propylene dimer-derived branched hexyl (including all branched isomers), propylene trimer-derived branched nonyl (including all branched isomers), propylene tetramer-derived branched dodecyl (including all branched isomers), propylene pentamer-derived branched pentadecyl (including all branched isomers), propylene hexamer-derived branched octadecyl (including all branched isomers), sec-butyl, tert-butyl, 1-butene dimer-derived branched octyl (including all branched isomers), isobutylene dimer-derived branched octyl (including all branched isomers), 1-butene trimer-derived branched dodecyl (including all branched isomers), isobutylene trimer-derived branched dodecyl (including all branched isomers), 1-butene tetramer-derived branched hexadecyl (including all branched isomers) and isobutylene tetramer-derived branched hexadecyl (including all branched isomers); alkylaryl groups such as phenyl, tolyl (including all structural isomers), ethylphenyl (including all structural isomers) and xylyl (including all structural isomers); and arylalkyl groups such as benzyl and phenylethyl (including all isomers).

[0123] From the standpoint of preventing adhesion of the metal from the workpieces and increased working resistance to achieve superior working efficiency and tool life, R^8 and R^9 in general formula (5) above are each preferably ethylene- or propylene-derived C3-18 branched alkyl groups and most preferably ethylene- or propylene-derived C6-15 branched alkyl groups.

[0124] As specific examples of sulfurized esters there may be mentioned esters obtained by using desired methods for sulfurization of animal and vegetable oils such as beef tallow, lard, fish oil, rapeseed oil and soybean oil; unsaturated fatty acid esters obtained by reacting unsaturated fatty acids (including oleic acid, linoleic acid and fatty acids extracted from the aforementioned animal and vegetable oils) with various alcohols; and mixtures thereof.

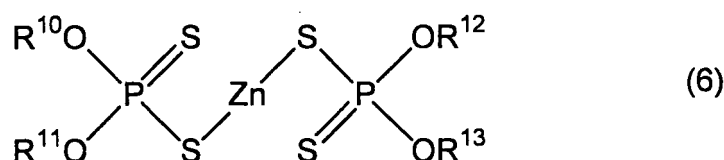
[0125] Sulfurized mineral oils are obtained by dissolving elemental sulfur in mineral oils. The mineral oils used for sulfurized mineral oils according to the invention are not particularly restricted, and specifically there may be mentioned paraffin-based mineral oils or naphthene-based mineral oils which are lube-oil distillates obtained by atmospheric dis-

tillation and vacuum distillation of crude oil, with refinement by appropriate combinations of refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrotreating, sulfuric acid treating and clay treatment. The elemental sulfur may be used in any of various forms such as bulk, powder or molten liquid forms, but using elemental sulfur in powder or molten liquid form is preferred as it allows efficient dissolution in the base oil. Molten liquid elemental sulfur permits mixture of liquids and is therefore advantageous by notably shortening the time required for dissolution, but it must be handled at above the melting point of elemental sulfur and therefore necessitates special heating equipment and the like, such that it is not always easy to manage given the risk associated with handling in high-temperature environments. In contrast, elemental sulfur powder is inexpensive and easy to manage while its dissolution time is sufficiently short, and it is therefore particularly preferred. There are no particular restrictions on the sulfur content of the sulfurized mineral oil for the invention, but normally it is preferably 0.05-1.0 % by mass and more preferably 0.1-0.5 % by mass based on the total sulfurized mineral oil weight.

[0126] Zinc dithiophosphate compounds, zinc dithiocarbamate compounds, molybdenum dithiophosphate compounds and molybdenum dithiocarbamate compounds are compounds represented by the following general formulas (6) to (9).

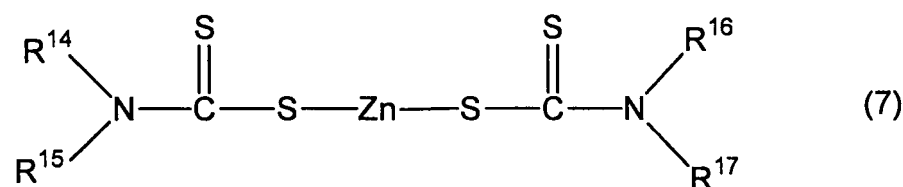
[0127]

[Chemical Formula 3]



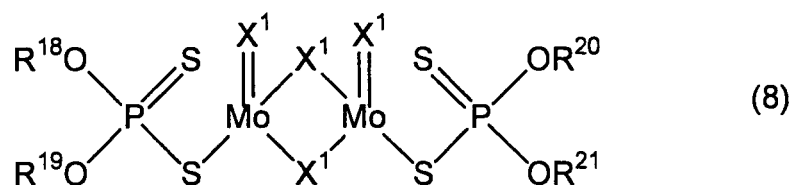
[0128]

[Chemical Formula 4]



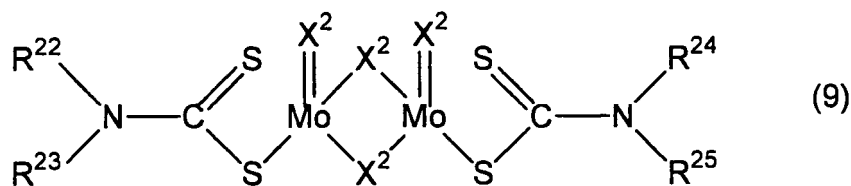
[0129]

[Chemical Formula 5]



[0130]

[Chemical Formula 6]



10 [wherein R¹⁰, R¹¹, R¹², R¹³, R¹⁴, R¹⁵, R¹⁶, R¹⁷, R¹⁸, R¹⁹, R²⁰, R²¹, R²², R²³, R²⁴ and R²⁵ may be the same or different, and each represents a C1 or greater hydrocarbon group, and X¹ and X² each represents oxygen or sulfur].

[0131] As specific examples of hydrocarbon groups represented by R¹⁰, R¹¹, R¹², R¹³, R¹⁴, R¹⁵, R¹⁶, R¹⁷, R¹⁸, R¹⁹, R²⁰, R²¹, R²², R²³, R²⁴ and R²⁵ there may be mentioned alkyl groups such as methyl, ethyl, propyl (including all branched isomers), butyl (including all branched isomers), pentyl (including all branched isomers), hexyl (including all branched isomers), heptyl (including all branched isomers), octyl (including all branched isomers), nonyl (including all branched isomers), decyl (including all branched isomers), undecyl (including all branched isomers), dodecyl (including all branched isomers), tridecyl (including all branched isomers), tetradecyl (including all branched isomers), pentadecyl (including all branched isomers), hexadecyl (including all branched isomers), heptadecyl (including all branched isomers), octadecyl (including all branched isomers), nonadecyl (including all branched isomers), eicosyl (including all branched isomers), heneicosyl (including all branched isomers), docosyl (including all branched isomers), tricosyl (including all branched isomers) and tetracosyl (including all branched isomers); cycloalkyl groups such as cyclopentyl, cyclohexyl and cycloheptyl; alkylcycloalkyl groups such as methylcyclopentyl (including all substituted isomers), ethylcyclopentyl (including all substituted isomers), dimethylcyclopentyl (including all substituted isomers), propylcyclopentyl (including all branched isomers and substituted isomers), methylethylcyclopentyl (including all substituted isomers), trimethylcyclopentyl (including all substituted isomers), butylcyclopentyl (including all branched isomers and substituted isomers), methylpropylcyclopentyl (including all branched isomers and substituted isomers), diethylcyclopentyl (including all substituted isomers), dimethylethylcyclopentyl (including all substituted isomers), methylcyclohexyl (including all substituted isomers), ethylcyclohexyl (including all substituted isomers), dimethylcyclohexyl (including all substituted isomers), propylcyclohexyl (including all branched isomers and substituted isomers), methylethylcyclohexyl (including all substituted isomers), trimethylcyclohexyl (including all substituted isomers), butylcyclohexyl (including all branched isomers and substituted isomers), methylpropylcyclohexyl (including all branched isomers and substituted isomers), diethylcyclohexyl (including all substituted isomers), dimethylethylcyclohexyl (including all substituted isomers), methylcycloheptyl (including all substituted isomers), ethylcycloheptyl (including all substituted isomers), dimethylcycloheptyl (including all substituted isomers), propylcycloheptyl (including all branched isomers and substituted isomers), methylethylcycloheptyl (including all substituted isomers), trimethylcycloheptyl (including all substituted isomers), butylcycloheptyl (including all branched isomers and substituted isomers), methylpropylcycloheptyl (including all branched isomers and substituted isomers), diethylcycloheptyl (including all substituted isomers) and dimethylethylcycloheptyl (including all substituted isomers); aryl groups such as phenyl and naphthyl; alkylaryl groups such as tolyl (including all substituted isomers), xylyl (including all substituted isomers), ethylphenyl (including all substituted isomers), propylphenyl (including all branched isomers and substituted isomers), methylethylphenyl (including all substituted isomers), trimethylphenyl (including all substituted isomers), butylphenyl (including all branched isomers and substituted isomers), methylpropylphenyl (including all branched isomers and substituted isomers), diethylphenyl (including all substituted isomers), dimethylethylphenyl (including all substituted isomers), pentylphenyl (including all branched isomers and substituted isomers), hexylphenyl (including all branched isomers and substituted isomers), heptylphenyl (including all branched isomers and substituted isomers), octylphenyl (including all branched isomers and substituted isomers), nonylphenyl (including all branched isomers and substituted isomers), decylphenyl (including all branched isomers and substituted isomers), undecylphenyl (including all branched isomers and substituted isomers), dodecylphenyl (including all branched isomers and substituted isomers), tridecylphenyl (including all branched isomers and substituted isomers), tetradecylphenyl (including all branched isomers and substituted isomers), pentadecylphenyl (including all branched isomers and substituted isomers), hexadecylphenyl (including all branched isomers and substituted isomers), heptadecylphenyl (including all branched isomers and substituted isomers) and octadecylphenyl (including all branched isomers and substituted isomers); and arylalkyl groups such as benzyl, phenethyl, phenylpropyl (including all branched isomers) and phenylbutyl (including all branched isomers).

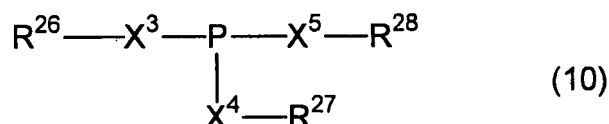
[0132] According to the invention, using at least one of the aforementioned sulfur compounds selected from the group consisting of dihydrocarbyl polysulfides and sulfurized esters is preferred in order to achieve an even higher level of improvement in working efficiency and tool life by preventing adhesion of the metal from the workpieces and preventing increase in working resistance.

[0133] As specific examples of (D-1) phosphorus compounds there may be mentioned phosphoric acid esters, acidic

phosphoric acid esters, acidic phosphoric acid ester amine salts, chlorinated phosphoric acid esters, phosphorous acid esters and phosphorothionates, and metal salts of the phosphorus compounds represented by the following general formulas (10) and (11). These phosphorus compounds may be esters of phosphoric acid, phosphorous acid or thio-phosphoric acid with alkanols or polyether alcohols, or they may be derivatives thereof.

[0134]

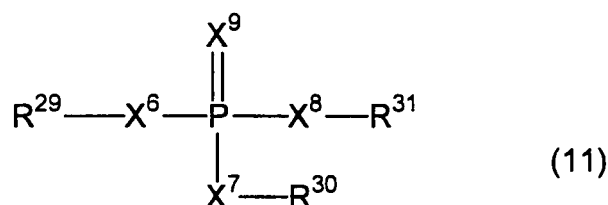
[Chemical Formula 7]



[wherein X^3 , X^4 and X^5 may be the same or different and each represents oxygen or sulfur, with at least two from among X^3 , X^4 and X^5 being oxygen, and R^{26} , R^{27} and R^{28} may be the same or different and each represents hydrogen or a C1-30 hydrocarbon group.]

[0135]

[Chemical Formula 8]



[X^6 , X^7 , X^8 and X^9 may be the same or different and each represents oxygen or sulfur, with at least three from among X^6 , X^7 , X^8 and X^9 being oxygen, and R^{29} , R^{30} and R^{31} may be the same or different and each represents hydrogen or a C1-30 hydrocarbon group.]

[0136] More specifically, as phosphoric acid esters there may be mentioned tributyl phosphate, triphenyl 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, tricresyl phosphate, trixylenyl phosphate, cresyldiphenyl phosphate and xylenyldiphenyl phosphate;

as acidic phosphoric acid esters there may be mentioned monobutyl acid phosphate, monopentyl acid phosphate, monohexyl acid phosphate, monoheptyl acid phosphate, monooctyl acid phosphate, monononyl acid phosphate, monodecyl acid phosphate, monoundecyl acid phosphate, monododecyl acid phosphate, monotridecyl acid phosphate, monotetradecyl acid phosphate, monopentadecyl acid phosphate, monohexadecyl acid phosphate, monoheptadecyl 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 phosphate, dipentadecyl acid phosphate, dihexadecyl acid phosphate, diheptadecyl acid phosphate, dioctadecyl acid phosphate and dioleyl acid phosphate;

as acidic phosphoric acid ester amine salts there may be mentioned salts of amines such as methylamines, ethylamines, propylamines, butylamines, pentylamines, hexylamines, heptylamines, octylamines, dimethylamines, diethylamines, dipropylamines, dibutylamines, dipentylamines, dihexylamines, diheptylamines, dioctylamines, trimethylamines, triethylamines, tripropylamines, tributylamines, tripentylamines, trihexylamines, triheptylamines and trioctylamines of the aforementioned acidic phosphoric acid esters;

as chlorinated phosphoric acid esters there may be mentioned tris-dichloropropyl phosphate, tris-chloroethyl phosphate, tris-chlorophenyl phosphate and polyoxyalkylene-bis[di(chloroalkyl)] phosphate;

as phosphorous acid esters there may be mentioned 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, triphenyl phosphite, trihexyl phosphite, triheptyl phosphite, trioctyl phosphite, trinonyl phosphite, tridecyl phosphite, triundecyl phosphite, tridodecyl phosphite, trioleyl

phosphite, triphenyl phosphite and tricresyl phosphite;

and as phosphorothionates there may be mentioned tributyl phosphorothionate, tripentyl phosphorothionate, trihexyl phosphorothionate, triheptyl phosphorothionate, trioctyl phosphorothionate, trinonyl phosphorothionate, tridecyl phosphorothionate, triundecyl phosphorothionate, tridodecyl phosphorothionate, tritridecyl phosphorothionate, tritetrade-
 5 phosphorothionate, tripentadecyl phosphorothionate, trihexadecyl phosphorothionate, triheptadecyl phosphorothionate, trioctadecyl phosphorothionate, trioleyl phosphorothionate, triphenyl phosphorothionate, tricresyl phosphorothionate, trixylenyl phosphorothionate, cresyldiphenyl phosphorothionate, xylenyldiphenyl phosphorothionate, tris(n-propylphe-
 10 nyl) phosphorothionate, tris(isopropylphenyl) phosphorothionate, tris(n-butylphenyl) phosphorothionate, tris(isobutylphenyl) phosphorothionate, tris(s-butylphenyl) phosphorothionate and tris(t-butylphenyl) phosphorothionate.

[0137] For metal salts of the phosphorus compounds represented by general formulas (10) and (11) above, alkyl, cycloalkyl, alkenyl, alkylcycloalkyl, aryl, alkylaryl and arylalkyl groups may be mentioned as specific examples of C1-30 hydrocarbon groups represented by R^{26} - R^{31} in the formulas.

[0138] As examples of the aforementioned alkyl groups there may be mentioned alkyl groups such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl and octadecyl (where the alkyl groups may be straight-chain or branched).

[0139] As the aforementioned cycloalkyl groups there may be mentioned C5-7 cycloalkyl groups such as cyclopentyl, cyclohexyl and cycloheptyl. As examples of the aforementioned alkylcycloalkyl groups there may be mentioned C6-11 alkylcycloalkyl groups such as methylcyclopentyl, dimethylcyclopentyl, methylethylcyclopentyl, diethylcyclopentyl, methylcyclohexyl, dimethylcyclohexyl, methylethylcyclohexyl, diethylcyclohexyl, methylcycloheptyl, dimethylcycloheptyl, methylethylcycloheptyl and diethylcycloheptyl (with any positions of substitution of the alkyl groups on the cycloalkyl groups).

[0140] As examples of the aforementioned alkenyl groups there may be mentioned alkenyl groups such as butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl and octadecenyl (where the alkenyl groups may be straight-chain or branched, and the
 25 double bonds may be at any positions).

[0141] As examples of the aforementioned aryl groups there may be mentioned aryl groups such as phenyl and naphthyl. As examples of the aforementioned alkylaryl groups there may be mentioned C7-18 alkylaryl groups such as tolyl, xylyl, ethylphenyl, propylphenyl, butylphenyl, pentylphenyl, hexylphenyl, heptylphenyl, octylphenyl, nonylphenyl, decylphenyl, undecylphenyl and dodecylphenyl (where the alkyl groups may be straight-chain or branched and substituted
 30 at any positions on the aryl groups).

[0142] As examples of the aforementioned arylalkyl groups there may be mentioned C7-12 arylalkyl groups such as benzyl, phenylethyl, phenylpropyl, phenylbutyl, phenylpentyl and phenylhexyl (where the alkyl groups may be straight-chain or branched).

[0143] The C1-30 hydrocarbon groups represented by R^{26} - R^{31} are preferably C1-30 alkyl groups or C6-24 aryl groups, and are more preferably C3-18 alkyl groups and even more preferably C4-12 alkyl groups.

[0144] Here, R^{26} , R^{27} and R^{28} may be the same or different and each represents hydrogen or one of the aforementioned hydrocarbon groups, where preferably 1-3 from among R^{26} , R^{27} and R^{28} are the aforementioned hydrocarbon groups, more preferably 1-2 are the aforementioned hydrocarbon groups and even more preferably two are the aforementioned hydrocarbon groups.]

[0145] Also, R^{29} , R^{30} and R^{31} may be the same or different and each represents hydrogen or one of the aforementioned hydrocarbon groups, where preferably 1-3 from among R^{29} , R^{30} and R^{31} are the aforementioned hydrocarbon groups, more preferably 1-2 are the aforementioned hydrocarbon groups and even more preferably two are the aforementioned hydrocarbon groups.]

[0146] In the phosphorus compounds represented by general formula (10), at least two of X^3 - X^5 must be oxygen, but preferably all of X^3 - X^5 are oxygen.

[0147] Also, in the phosphorus compounds represented by general formula (11), at least three of X^6 - X^9 must be oxygen, but preferably all of X^6 - X^9 are oxygen.

[0148] As examples of phosphorus compounds represented by general formula (10) there may be mentioned phosphorous acid and monothiophosphorous acid; phosphorous acid monoesters and monothiophosphorous acid monoesters having one of the aforementioned C1-30 hydrocarbon groups; phosphorous acid diesters and monothiophosphorous acid diesters having two of the aforementioned C1-30 hydrocarbon groups; phosphorous acid triesters and monothiophosphorous acid triesters having three of the aforementioned C1-30 hydrocarbon groups; and mixtures thereof. Among these, phosphorous acid monoesters and phosphorous acid diesters are preferred, and phosphorous acid diesters are especially preferred.

[0149] As examples of phosphorus compounds represented by general formula (11) there may be mentioned phosphoric acid and monothiophosphoric acid; phosphoric acid monoesters and monothiophosphoric acid monoesters having one of the aforementioned C1-30 hydrocarbon groups; phosphoric acid diesters and monothiophosphoric acid diesters having two of the aforementioned C1-30 hydrocarbon groups; phosphoric acid triesters and monothiophosphoric acid

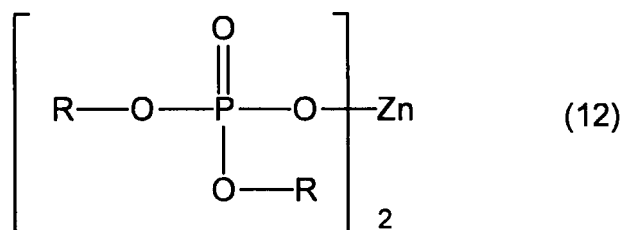
triesters having three of the aforementioned C1-30 hydrocarbon groups; and mixtures thereof. Among these, phosphoric acid monoesters and phosphoric acid diesters are preferred, and phosphoric acid diesters are especially preferred.

[0150] As metal salts of the phosphorus compounds represented by general formula (10) and (11) there may be mentioned salts of the aforementioned phosphorus compounds wherein all or a portion of the acidic hydrogens are neutralized with a metal base. As such metal bases there may be mentioned metal oxides, metal hydroxides, metal carbonates and metal chlorides, and as the metals thereof there may be mentioned specifically alkali metals such as lithium, sodium, potassium and cesium, alkaline earth metals such as calcium, magnesium and barium, and heavy metals such as zinc, copper, iron, lead, nickel, silver and manganese. Preferred among these are alkaline earth metals such as calcium and magnesium, and zinc.

[0151] These phosphorus compound metal salts will differ in structure depending on the valence of the metal and the number of OH groups or SH groups in the phosphorus compound, and therefore no limitations are placed on the structure; however, when 1 mole of zinc oxide is reacted with two moles of a phosphoric acid diester (with one OH group), for example, a compound having the structure represented by formula (12) below may be obtained as the major component, although polymerized molecules may also be present.

[0152]

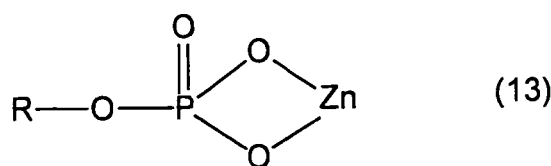
[Chemical Formula 9]



[0153] Also, when 1 mole of zinc oxide is reacted with 1 mole of a phosphoric acid monoester (with two OH groups), for example, a compound having the structure represented by formula (13) below may be obtained as the major component, although polymerized molecules may also be present.

[0154]

[Chemical Formula 10]



[0155] Two or more of these may also be used in admixture.

[0156] According to the invention, phosphoric acid esters, acidic phosphoric acid esters and acidic phosphoric acid ester amine salts are preferred among the aforementioned phosphorus compounds from the standpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve superior working efficiency and tool life.

[0157] As described hereunder, the oil for metal working of the invention may be applied for purposes other than metal working, and when the oil for metal working of the invention is used as an oil for machine tool sliding surfaces, it preferably comprises an acidic phosphoric acid ester or an acidic phosphoric acid ester amine salt. Also, when the oil for metal working of the invention is used as a hydraulic oil, a phosphoric acid ester is preferred. When it is used for both a sliding surface oil and a hydraulic oil, it is preferred to employ a combination of a phosphoric acid ester with at least one selected from among acidic phosphoric acid esters and acidic phosphoric acid ester amine salts.

[0158] The oil for metal working of the invention may contain either the (D-1) sulfur compound or (D-2) phosphorus compound, or it may contain both. From the standpoint of preventing adhesion of the metal from the workpieces and

increase in working resistance to achieve superior working efficiency and tool life, it preferably contains a (D-2) phosphorus compound or both a (D-1) sulfur compound and (D-2) phosphorus compound, and more preferably it contains both a (D-1) sulfur compound and (D-2) phosphorus compound.

[0159] The content of the (D) extreme-pressure agent may be as desired, but from the standpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve superior working efficiency and tool life, it is preferably not less than 0.005 % by mass, more preferably not less than 0.01 % by mass and even more preferably not less than 0.05 % by mass based on the total amount of the oil for metal working. From the viewpoint of preventing abnormal abrasion, the extreme pressure agent content is preferably not greater than 15 % by mass, more preferably not greater than 10 % by mass and even more preferably not greater than 7 % by mass, based on the total weight of the oil for metal working.

[0160] According to the invention, either a (C) oiliness agent or (D) extreme-pressure agent may be used, but from the standpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve even better improvement in working efficiency and tool life, preferably a (C) oiliness agent and (D) extreme-pressure agent are used in combination.

[0161] The first and second oils for metal working according to the invention preferably also contain (E) an organic acid salt, from the viewpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve superior working efficiency and tool life. As organic acid salts there are preferably used sulfonates, phenates and salicylates, as well as mixtures thereof. As cationic components of these organic acid salts there may be mentioned alkali metals such as sodium and potassium; alkaline earth metals such as magnesium, calcium and barium; amines including ammonia, C1-3 alkyl group-containing alkylamines (monomethylamine, dimethylamine, trimethylamine, monoethylamine, diethylamine, triethylamine, monopropylamine, dipropylamine, tripropylamine, etc.), C1-3 alkanol group-containing alkanolamines (monomethanolamine, dimethanolamine, trimethanolamine, monoethanolamine, diethanolamine, triethanolamine, monopropanolamine, dipropanolamine, tripropanolamine, etc.), and zinc, among which alkali metals and alkaline earth metals are preferred, and calcium is particularly preferred. Using an alkali metal or alkaline earth metal as the cationic component of the organic acid salt will tend to produce even higher lubricity.

[0162] The sulfonate used may be one produced by any desired process. For example, there may be used an alkali metal salt, alkaline earth metal salt or amine salt of an alkylaromaticsulfonic acid obtained by sulfonation of an alkylaromatic compound with a molecular weight of 100-1500 and preferably 200-700, or a mixture thereof. As the alkylaromaticsulfonic acid referred to here, there may be mentioned synthetic sulfonic acids including sulfonated alkylaromatic compounds of lube-oil distillates of common mineral oils, petroleum sulfonic acids such as "mahogany acid" yielded as a by-product of white oil production, sulfonated products of alkylbenzenes with straight-chain or branched alkyl groups, which are by-products in production plants for alkylbenzenes used as starting materials for detergents and are obtained by alkylation of benzene with polyolefins, or sulfonated alkylnaphthalenes such as dinonylnaphthalene. There may also be mentioned neutral sulfonates obtained by reacting an alkylaromaticsulfonic acid with an alkali metal base (alkali metal oxide, hydroxide or the like), an alkaline earth metal base (alkaline earth metal oxide, hydroxide or the like) or one of the aforementioned amines (ammonia, alkylamine, alkanolamine, etc.); basic sulfonates obtained by heating a neutral sulfonate with an excess of an alkali metal salt, alkaline earth metal salt or amine in the presence of water; "carbonated overbased sulfonates" obtained by reacting a neutral sulfonate with an alkali metal salt, alkaline earth metal salt or amine in the presence of carbon dioxide gas; "borated overbased sulfonates" produced by reacting a neutral sulfonate with an alkali metal salt, alkaline earth metal salt or amine and a boric acid compound such as boric acid or boric anhydride, or by reacting a carbonated overbased sulfonate with a boric acid compound such as boric acid or boric anhydride; and mixtures of these compounds.

[0163] As phenates there may be mentioned, specifically, neutral phenates obtained by reacting an alkylphenol having one or two C4-20 alkyl groups with an alkali metal base (alkali metal oxide, hydroxide or the like), an alkaline earth metal base (alkaline earth metal oxide, hydroxide or the like) or one of the aforementioned amines (ammonia, alkylamine, alkanolamine, etc.) in the presence or in the absence of elemental sulfur; basic phenates obtained by heating a neutral phenate with an excess of an alkali metal salt, alkaline earth metal salt or amine in the presence of water; "carbonated overbased phenates" obtained by reacting a neutral phenate with an alkali metal salt, alkaline earth metal salt or amine in the presence of carbon dioxide gas; "borated overbased phenates" produced by reacting a neutral phenate with an alkali metal salt, alkaline earth metal salt or amine and a boric acid compound such as boric acid or boric anhydride, or by reacting a carbonated overbased phenate with a boric acid compound such as boric acid or boric anhydride; and mixtures of these compounds.

[0164] As salicylates there may be mentioned, specifically, neutral salicylates obtained by reacting an alkylsalicylic acid having one or two C4-20 alkyl groups with an alkali metal base (alkali metal oxide, hydroxide or the like), an alkaline earth metal base (alkaline earth metal oxide, hydroxide or the like) or one of the aforementioned amines (ammonia, alkylamine, alkanolamine, etc.) in the presence or in the absence of elemental sulfur; basic salicylates obtained by heating a neutral salicylate with an excess of an alkali metal salt, alkaline earth metal salt or amine in the presence of water; "carbonated overbased salicylates" obtained by reacting a neutral salicylate with an alkali metal salt, alkaline

earth metal salt or amine in the presence of carbon dioxide gas; "borated overbased salicylates" produced by reacting a neutral salicylate with an alkali metal salt, alkaline earth metal salt or amine and a boric acid compound such as boric acid or boric anhydride, or by reacting a carbonated overbased salicylate with a boric acid compound such as boric acid or boric anhydride; and mixtures of these compounds.

[0165] The total base value of the (E) organic acid salt is preferably 50-500 mgKOH/g and more preferably 100-450 mgKOH/g. If the total base value of the organic acid salt is less than 100 mgKOH/g the lubricity-enhancing effect of the organic acid salt addition will tend to be unsatisfactory, while organic acid salts with a the total base value of greater than 500 mgKOH/g are also not preferred because they are generally very difficult to produce and obtain. The base value referred to here is the base value [mgKOH/g] determined by the perchlorate method, with measurement according to JIS K 2501 "Petroleum Products and Lubricants - Determination of Neutralization Number", Section 7.

[0166] The content of the (E) organic acid salt is preferably 0.1-30 % by mass, more preferably 0.5-25 % by mass and even more preferably 1-20 % by mass based on the total weight of the oil for metal working. If the content of the (E) organic acid salt is below this lower limit, the improving effect of the addition on the working efficiency and tool life by preventing adhesion of the metal from the workpieces and increase in working resistance will tend to be unsatisfactory, while if it is above the aforementioned upper limit the stability of the oil for metal working will be reduced and deposits will tend to form.

[0167] According to the invention, the an (E) organic acid salt may be used alone, or an organic acid salt may be used in combination with other additives. From the standpoint of preventing adhesion of the metal from the workpieces and increase in working resistance to achieve superior working efficiency and tool life, it is preferred to use a combination of an organic acid salt with the aforementioned extreme-pressure agent, and it is particularly preferred to use a combination of three components, a sulfur compound, a phosphorus compound and an organic acid salt.

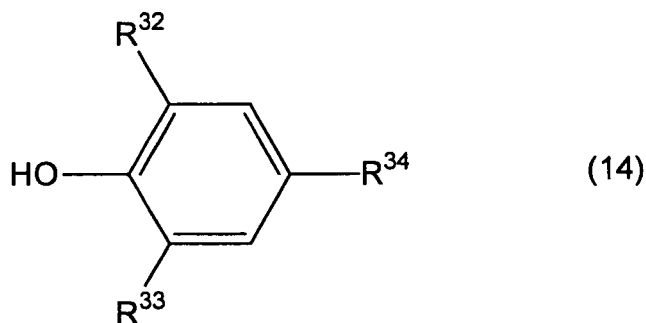
[0168] The first and second oils for metal working according to the invention also preferably contain (F) an antioxidant. Addition of (F) an antioxidant can prevent sticking caused by degradation of the constituent components, while further enhancing the heat and oxidation stability.

[0169] As (F) antioxidants to be used there may be mentioned phenol-based antioxidants, amine-based antioxidants, zinc dithiophosphate-based antioxidants, and antioxidants used as food additives.

[0170] As phenol-based antioxidants there may be used any phenol-based compounds that are employed as antioxidants for lubricating oils, with no particular restrictions, and as preferred examples there may be mentioned one or more alkylphenol compounds selected from among compounds represented by the following general formulas (14) and (15).

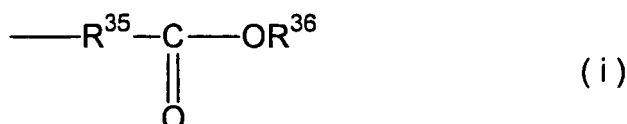
[0171]

[Chemical Formula 11]



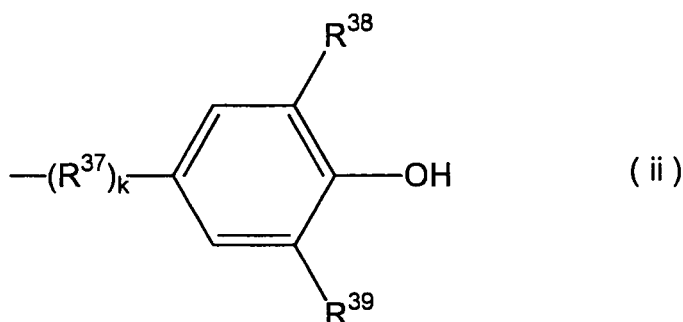
[wherein R^{32} represents C1-4 alkyl, R^{33} represents hydrogen or C1-4 alkyl, and R^{34} represents hydrogen, C1-4 alkyl or a group represented by the following general formula (i) or (ii):

[Chemical Formula 12]



(wherein R³⁵ represents C1-6 alkylene and R³⁶ represents C1-24 alkyl or alkenyl),

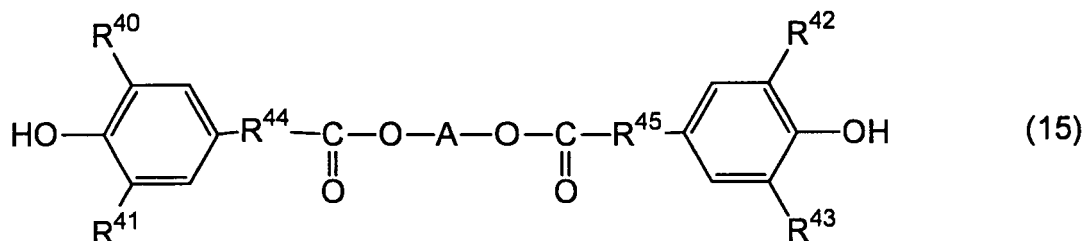
[Chemical Formula 13]



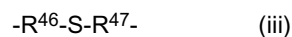
(wherein R³⁷ represents C1-6 alkylene, R³⁸ represents C1-4 alkyl, R³⁹ represents hydrogen or C1-4 alkyl, and k represents 0 or 1).]

[0172]

[Chemical Formula 14]



[wherein R⁴⁰ and R⁴² may be the same or different and each represents C1-4 alkyl, R⁴¹ and R⁴³ may be the same or different and each represents hydrogen or C1-4 alkyl, R⁴⁴ and R⁴⁵ may be the same or different and each represents C1-6 alkylene, and A is C 1-18 alkylene or a group represented by the following general formula (iii):

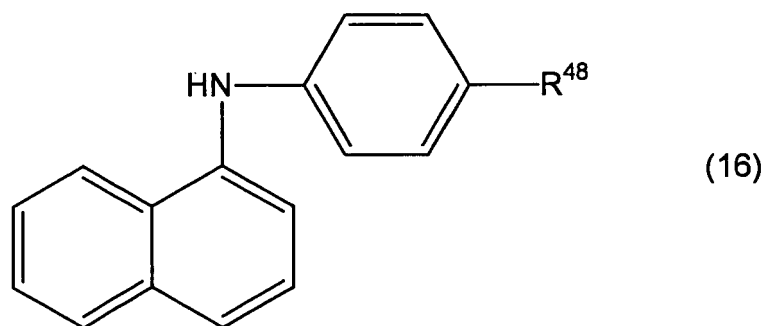


(wherein R⁴⁶ and R⁴⁷ may be the same or different and each represents C1-6 alkylene).]

[0173] As amine-based antioxidants for the invention there may be used any amine-based compounds that are employed as antioxidants for lubricating oils, with no particular restrictions, and as preferred examples there may be mentioned one or more aromatic amines selected from among phenyl- α -naphthylamine or N-p-alkylphenyl- α -naphthylamines represented by the following general formula (16), and p,p'-dialkyldiphenylamines represented by the following general formula (17).

[0174]

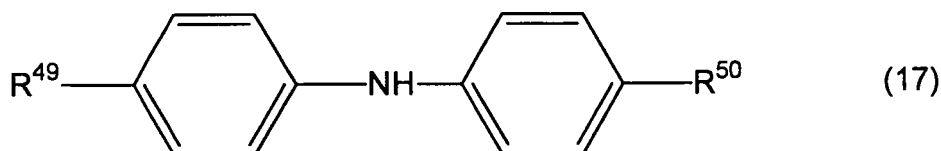
[Chemical Formula 15]



[wherein R^{48} represents hydrogen or alkyl]

[0175]

[Chemical Formula 16]



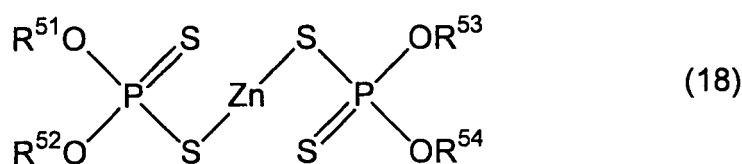
[wherein R^{49} and R^{50} may be the same or different and each represents alkyl.]

[0176] As specific examples of amine-based antioxidants there may be mentioned 4-butyl-4'-octyldiphenylamine, phenyl- α -naphthylamine, octylphenyl- α -naphthylamine, dodecylphenyl- α -naphthylamine, and mixtures thereof.

[0177] As zinc dithiophosphate-based antioxidants to be used for the invention there may be mentioned, specifically, zinc dithiophosphates represented by the following general formula (18).

[0178]

[Chemical Formula 17]



[wherein R^{51} , R^{52} , R^{53} and R^{54} may be the same or different and each represents a hydrocarbon group.]

[0179] Antioxidants employed as food additives may also be used, and although these partially overlap with the aforementioned phenol-based antioxidants, there may be mentioned as examples 2,6-di-tert-butyl-p-cresol (DBPC), 4,4'-methylenebis(2,6-di-tert-butylphenol), 4,4'-bis(2,6-di-tert-butylphenol), 4,4'-thiobis(6-tert-butyl-o-cresol), ascorbic acid (vitamin C), ascorbic acid fatty acid esters, tocopherol (vitamin E), 3,5-di-tert-butyl-4-hydroxyanisole, 2-tert-butyl-4-hydroxyanisole, 3-tert-butyl-4-hydroxyanisole, 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline (ethoxyquin), 2-(1,1-dimethyl)-1,4-benzenediol (TBHQ) and 2,4,5-trihydroxybutyrophenone (THBP).

[0180] Preferred among these antioxidants are phenol-based antioxidants, amine-based antioxidants and antioxidants that are employed as food additives. The use of food additive antioxidants is especially preferred when biodegradability is a primary concern, and of these, ascorbic acid (vitamin C), ascorbic acid fatty acid esters, tocopherol (vitamin E), 2,6-di-tert-butyl-p-cresol (DBPC), 3,5-di-tert-butyl-4-hydroxyanisole, 2-tert-butyl-4-hydroxyanisole, 3-tert-butyl-4-hydroxyanisole, 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline (ethoxyquin), 2-(1,1-dimethyl)-1,4-benzenediol (TBHQ) and 2,4,5-trihydroxybutyrophenone (THBP) are preferred, among which ascorbic acid (vitamin C), ascorbic acid fatty acid esters, tocopherol (vitamin E), 2,6-di-tert-butyl-p-cresol (DBPC) and 3,5-di-tert-butyl-4-hydroxyanisole are especially

preferred.

[0181] There are no particular restrictions on the content of the (F) antioxidant, but for maintenance of satisfactory heat and oxidation stability the content is preferably 0.01 % by mass or greater, more preferably 0.05 % by mass or greater and most preferably 0.1 % by mass or greater based on the total weight of the oil for metal working. Since no corresponding effect can be expected with larger amounts of addition, the content is preferably not greater than 10 % by mass, more preferably not greater than 5 % by mass and most preferably not greater than 3 % by mass.

[0182] The first and second oils for metal working of the invention may contain various additives known in the prior art in addition to those mentioned above. As examples of such additives there may be mentioned extreme pressure agents (including chlorine-based extreme pressure agents) other than the aforementioned phosphorus compounds and sulfur compounds; moistening agents such as diethyleneglycol monoalkylethers; film-forming agents such as acryl polymers, paraffin wax, microwax, slack wax and polyolefin wax; water displacement agents such as fatty acid amine salts; solid lubricants such as graphite, fluorinated graphite, molybdenum disulfide, boron nitride and polyethylene powder; corrosion inhibitors such as amines, alkanolamines, amides, carboxylic acids, carboxylic acid salts, sulfonic acid salts, phosphoric acid, phosphoric acid salts and polyhydric alcohol partial esters; metal deactivating agents such as benzotriazole and thiadiazole; defoaming agents such as methylsilicone, fluorosilicone and polyacrylate; and non-ash powders such as alkenylsuccinic imides, benzylamines and polyalkenylamineaminoamides. The contents of such publicly known additives when used in combination are not particularly restricted, but they are generally added in amounts so that the total content of the publicly known additives is 0.1-10 % by mass based on the total weight of the oil for metal working.

[0183] The first and second oils for metal working of the invention may also contain chlorine-based additives such as the aforementioned chlorine-based extreme-pressure agents, but they preferably contain no chlorine-based additives from the viewpoint of improving stability and reducing the environmental burden. The chlorine concentration is preferably not greater than 1000 ppm by weight, more preferably not greater than 500 ppm by weight, even more preferably not greater than 200 ppm by weight and most preferably not greater than 100 ppm by weight, based on the total weight of the oil for metal working.

[0184] No particular restrictions are placed on the kinematic viscosity of the first and second oils for metal working of the invention, but from the viewpoint of facilitating supply to working sites, the kinematic viscosity at 40°C is preferably not greater than 200 mm²/s, more preferably 100 mm²/s, even more preferably 75 mm²/s and most preferably 50 mm²/s. The lower limit is preferably 1 mm²/s, even more preferably 3 mm²/s and most preferably 5 mm²/s.

[0185] The first and second oils for metal working of the invention having the composition described above exhibit excellent machining performance including working efficiency and tool life and excellent handleability, and may therefore be suitably used for a wide range of purposes in the field of metal working. Here, metal working refers to metal working in general, without being restricted to cutting and grinding.

[0186] The first and second oils for metal working of the invention may be applied for metal working with ordinary oil supply systems, but they are preferably used as oils for metal working in minimum quantity lubrication (MQL) system in order to exhibit a more notable effect. As such types of metal working there may be mentioned, specifically, cutting, grinding, rolling, forging, pressing, punching and rolling. Among these, the first and second oils for metal working are highly useful for use in cutting, grinding and rolling.

[0187] There are no particular restrictions on the materials for workpieces to which the first and second oils for metal working of the invention may be applied, but the oils for metal working of the invention are suitable as non-ferrous metal working oils, and exhibit especially superior performance as aluminum or aluminum alloy working oils.

[0188] The first and second oils for metal working of the invention can be used as lubricating oils for sections other than working sites of machine tools, such as a sliding surface oils, bearing section oils, hydraulic equipment oils or the like, and are therefore highly useful from the standpoint of allowing savings in space and energy for machine tools.

[0189] A sliding surface oil according to the invention is a lubricating oil used in guiding mechanisms for sliding movement between two surfaces in contact, such as those of structural members of machine tools used for cutting and grinding. For example, in a machine tool which sets a workpiece on a table capable of moving a bed and moves the table to transport the workpiece toward a cutting/grinding tool, the sliding surface between the table and the bed is lubricated with a sliding surface oil. Or in a machine tool which fixes a cutting/grinding tool on a platform capable of moving over a bed and moves the platform to transport the tool toward a workpiece, the sliding surface between the platform and bed is also lubricated with a sliding surface oil.

[0190] Such sliding surface oils must have satisfactory friction properties, including a small friction coefficient on the sliding surface and high anti-stick-slip properties. When stick-slip occurs on the sliding surface such as the working table of a machine tool, the frictional vibration is transferred to the workpiece thereby lowering the working precision, or in some cases the vibration may shorten the tool life. When the first and second oils for metal working of the invention are used as sliding surface oils these phenomena can be satisfactorily prevented, but a phosphorus compound is preferably further added from the standpoint of friction properties.

[0191] Lubrication methods such as oil bearing lubrication and mist bearing lubrication are employed for lubrication of bearing sections, and a first or second oil composition for metal working according to the invention can be used for

either type of method.

[0192] Oil bearing lubrication is a lubricating system whereby a lubricating oil is supplied directly as a liquid to the bearing section for smooth sliding of the section, and the bearing section is also cooled by the lubricating oil. Because such a lubricating oil for bearing lubrication is used at high-temperature sections it must be resistant to thermal degradation, i.e. it must have excellent heat resistance, and the first and second oils for metal working can also be suitably used for such oil bearing lubrication.

[0193] Mist bearing lubrication is a lubricating system wherein the lubricating oil is atomized with a mist generator and the atomized oil is supplied to the bearing sections with a gas such as air to achieve smooth sliding of the sections, and since a cooling effect is provided by the air at the high-temperature sections such as bearing sections, this type of lubricating system is becoming more commonly used in recent years for machine tools. Because such a lubricating oil for mist lubrication is used at high-temperature sections it must also be resistant to thermal degradation, i.e. it must have excellent heat resistance, and the first and second oils for metal working can also be suitably used for such mist bearing lubrication.

[0194] Hydraulic equipment accomplishes operation and control of machines by oil pressure, and hydraulic oil with a lubricating, sealing and cooling effect is used in hydraulic control sections that govern machine operation. Hydraulic oil is used by compressing lubricating oil at high pressure with a pump to produce oil pressure and move equipment, and therefore the lubricating oil must have high lubricity and high oxidation stability and thermal stability; the first and second oils for metal working can also be used as hydraulic oils. When the first and second oils for metal working are used as hydraulic oils, they preferably also contain phosphorus compounds for further improved lubricity.

[0195] An example of a cutting and grinding method using first and second oils for metal working according to the invention will now be explained.

[0196] Fig. 1 is a schematic diagram showing an example of a machine tool suitable for use in a cutting/grinding method with a minimum quantity lubrication system. The machine tool shown in Fig. 1 comprises a table 2 which is movable in the direction of the arrow on a bed 1, and a tool 11 which is supported on support means 10 and is rotatable in the direction of the arrow. An oil according to the invention is housed in an oil feeding tank 12, and during cutting/grinding of a workpiece 3 placed on the table 2, compressed air fed from a compressed air injection port 18 is supplied, together with the oil of the invention in mist form, from the working oil feeding section 13 toward the working site. The oil of the invention housed in the oil feeding tank 12 is supplied from the sliding surface oil feeding section 14 to the sliding surface 16 between the bed 1 and the table 2, while also being supplied from the bearing oil feeding section 15 to the bearing section between the support means 10 and tool 11, for lubrication of the sliding surface 16 and the bearing section 17.

[0197] Thus, by using oils containing the same ester for lubrication of cutting/grinding sites, machine tool sliding surfaces and bearing sections in a cutting and grinding process with a minimum quantity lubrication system according to the invention, it is possible to achieve improved workability and improved operating efficiency for cutting and grinding in the minimum quantity lubrication system.

[0198] Moreover, for cutting and grinding in a minimum quantity lubrication system according to the invention, as shown in Fig. 1, it is preferred to use the same oil as the cutting/grinding oil, the sliding surface oil and the bearing oil in order to eliminate the need for separate oil supply tanks for supply of different oils, thereby allowing savings in space and energy for machine tools.

[0199] Also, while not shown in Fig. 1, the oil of the invention housed in the oil feeding tank 12 may also be supplied to hydraulic equipment in the machine tool for use of the oil of the invention as a hydraulic oil.

Examples

[0200] The present invention will now be explained in further detail by examples and comparative examples, with the understanding that the invention is in no way limited by the examples.

[Examples 1-21, Comparative Examples 1-2]

[0201] For Examples 1-21 and Comparative Examples 1-2, oils for metal working were prepared having the compositions listed in Tables 1-6, using the base oils and additives listed below. Tables 1-6 also show the kinematic viscosity at 40°C and the moisture content of each obtained oil for metal working. The fatty acid composition and total degree of unsaturation of the base oils A4 are listed in Table 7.

(Base oils)

A1: Trimethylolpropane and oleic acid triester (kinematic viscosity at 40°C: 46 mm²/s)

A2: Neopentyl glycol and oleic acid diester (kinematic viscosity at 40°C: 24 mm²/s)

A3: Isodecyl alcohol and adipic acid diester (kinematic viscosity at 40°C: 14 mm²/s)

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A4: High-oleic rapeseed oil (kinematic viscosity at 40°C: 39 mm²/s)
B1: Hydrogenated 1-decene dimer (kinematic viscosity at 40°C: 4.5 mm²/s)
B2: Hydrogenated 1-decene trimer (kinematic viscosity at 40°C: 19 mm²/s)
B3: White oil (kinematic viscosity at 40°C: 5 mm²/s)

(Additives)

C1: Oleyl alcohol
C2: Oleylamine
C3: Oleic acid
C4: Glycerin monooleate
D1: Tricresyl phosphate
D2: Sulfurized ester

[0202] The oils for metal working of Examples 1-21 and Comparative Examples 1-2 were subjected to the following evaluation tests.

[Tapping test]

[0203] A tapping test was conducted with a minimum quantity lubrication system (MQL) or an ordinary oil supply system.

[0204] For testing with the MQL, each oil for metal working and standard oil for comparison (DIDA: diisodecyl adipate) was used alternately in a tapping test under the conditions listed below, and the tapping energy for each was measured. (Tapping conditions)

Tool: Nut tap M8 (P=1.25 mm)
Lower hole diameter: $\phi 7.2$ mm
Workpiece: AC8A (t=10 mm)
Cutting speed: 9.0 m/min

(Oil supply system)

Oil for metal working: Spraying under conditions of 25 ml/h oil composition, with 0.2 MPa compressed air
DIDA: Direct spraying of the working site under conditions of 4.3 ml/min without using compressed air.

[0205] For testing with the ordinary oil supply system, each oil for metal working and standard oil for comparison (DIDA: diisodecyl adipate) was used alternately in a tapping test under the conditions listed below, and the tapping energy for each was measured. (Tapping conditions)

Tool: Nut tap M8 (P=1.25 mm)
Lower hole diameter: $\phi 7.2$ mm
Workpiece: AC8A (t=10 mm)
Cutting speed: 9.0 m/min

(Oil supply system)

Oil for metal working and DIDA: Direct spraying of the working site under conditions of 4.3 ml/min without using compressed air.

[0206] Next, the measured values of the tapping energy for both the MQL and ordinary oil supply systems were used to calculate the tapping energy efficiency (%) by the formula shown below. The results are shown in Tables 1-6. In the tables, a higher value for the tapping energy efficiency indicates higher lubricity.

$$\text{Tapping energy efficiency (\%)} = \frac{\text{(tapping energy using DIDA)}}{\text{(tapping energy using oil composition)}}$$

[Wear resistance evaluation test]

[0207] Each oil for metal working was subjected to wear testing by a highspeed four-ball test for 30 minutes with a rotation rate of 1800 rpm and a load of 392 N, and the wear scar diameter was measured for evaluation of the anti-wear property of each oil. The results are shown in Tables 1-6.

[Oil mist property evaluation test]

[0208] Each oil for metal working was supplied to a minimum quantity lubrication system and the oil mist property was evaluated. Specifically, each oil for metal working was ejected through an MQL supply port under conditions of 0.2 MPa compressed air, 25 ml/h oil composition to produce an oil mist, and the amount of oil mist collected on a glass dish placed at a position corresponding to the working point was measured. The results are shown in Tables 1-6.

[0209]

[Table 1]

		Example 1	Example 2	Example 3	Example 4
Composition [% by mass]	A1	70	70	70	-
	A2	-	-	-	70
	A3	-	-	-	-
	A4	-	-	-	-
	B1	30	-	-	30
	B2	-	30	-	-
	B3	-	-	30	-
	C1	-	-	-	-
	C2	-	-	-	-
	C3	-	-	-	-
	C4	-	-	-	-
	D1	-	-	-	-
	D2	-	-	-	-
Kinematic viscosity at 40°C [mm ² /s]		20	36	20	14
Moisture content [ppm]		250	250	250	250
Working property (tapping energy efficiency [%])	MQL	110	105	107	118
	Normal oil feeding oil	123	121	120	120
Anti-wear property (Wear scar diameter [μm])		0.70	0.67	0.71	0.70
Mist property (collected mist [mg/h])		18.0	15.5	16.5	22.5

[0210]

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[Table 2]

		Example 5	Example 6	Example 7	Example 8
5 10 15 20	Composition [% by mass]	A1	-	-	-
		A2	70	-	-
		A3	-	70	70
		A4	-	-	70
		B1	-	30	30
		B2	-	-	-
		B3	30	-	30
		C1	-	-	-
		C2	-	-	-
		C3	-	-	-
		C4	-	-	-
		D1	-	-	-
		D2	-	-	-
		Kinematic viscosity at 40°C [mm ² /s]	14	10	10
		Moisture content [ppm]	250	250	250
25	Working property (tapping energy efficiency [%])	MQL	115	115	114
		Normal oil feeding	119	118	118
30	Anti-wear property (Wear scar diameter [μm])		0.71	0.72	0.70
	Mist property (collected mist [mg/h])		19.2	18.0	16.3
				16.3	17.5

[0211]

[Table 3]

		Example 9	Example 10	Example 11	Example 12
35 40 45 50 55	Composition [% by mass]	A1	-	70	70
		A2	-	-	-
		A3	-	-	-
		A4	70	-	-
		B1	-	30	30
		B2	-	-	-
		B3	30	-	-
		C1	-	5	-
		C2	-	-	5
		C3	-	-	-
		C4	-	-	-
		D1	-	-	-
		D2	-	-	-
		Kinematic viscosity at 40°C [mm ² /s]	28	20	20
		Moisture content [ppm]	250	250	250

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(continued)

		Example 9	Example 10	Example 11	Example 12
Working property (tapping energy efficiency [%])	MQL	117	120	118	122
	Normal oil feeding feeding	120	128	126	129
Anti-wear property (Wear scar diameter [μm])		0.71	0.65	0.67	0.62
Mist property (collected mist [mg/h])		15.3	17.5	17.8	18.5

[0212]

[Table 4]

		Example 13	Example 14	Example 15	Example 16
Composition [% by mass]	A1	70	70	70	70
	A2	-	-	-	-
	A3	-	-	-	-
	A4	-	-	-	-
	B1	30	30	30	30
	B2	-	-	-	-
	B3	-	-	-	-
	C1	-	-	-	-
	C2	-	-	-	-
	C3	-	-	-	-
	C4	5	-	-	-
	D1	-	5	-	5
	D2	-		10	10
Kinematic viscosity at 40°C [mm²/s]		20	20	21	21
Moisture content [ppm]		250	250	250	250
Working property (tapping energy efficiency [%])	MQL	121	115	115	118
	Normal oil feeding	131	127	126	130
Anti-wear property (Wear scar diameter [μm])		0.64	0.54	0.56	0.52
Mist property (collected mist [mg/h])		18.2	18.1	18.4	18.0

[0213]

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[Table 5]

		Example 17	Example 18	Example 19	Example 20
Composition [% by mass]	A1	70	70	70	70
	A2	-	-	-	-
	A3	-	-	-	-
	A4	-	-	-	-
	B1	30	30	30	30
	B2	-	-	-	-
	B3	-	-	-	-
	C1	-	-	-	-
	C2	-	-	-	-
	C3	-	-	-	-
	C4	5	5	5	-
	D1	5	-	5	-
	D2	-	10	10	-
	Kinematic viscosity at 40°C [mm ² /s]		21	22	23
Moisture content [ppm]		250	250	250	1000
Working property (tapping energy efficiency [%])	MQL	128	125	129	124
	Normal oil feeding	135	133	138	130
Anti-wear property (Wear scar diameter [μm])		0.52	0.52	0.50	0.68
Mist property (collected mist [mg/h])		18.5	18.1	17.8	17.2

[0214]

[Table 6]

		Example 21	Comp. Ex.1	Comp. Ex.2
Composition [% by mass]	A1	100	-	-
	A2	-	-	-
	A3	-	-	-
	A4	-	-	-
	B1	-	100	-
	B2	-	-	100
	B3	-	-	-
	C1	-	-	-
	C2	-	-	-
	C3	-	-	-
	C4	-	-	-
	D2	-	-	-
	D2	-	-	-
Kinematic viscosity at 40°C [mm ² /s]		46	4.5	19
Moisture content [ppm]		250	25	25

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(continued)

		Example 21	Comp. Ex. 1	Comp. Ex. 2
Working property (tapping energy efficiency [%])	MQL	85	75	80
	Normal oil feeding	109	95	92
Anti-wear property (Wear scar diameter [μm])		0.71	0.89	0.85
Mist property (collected mist [mg/h])		9.2	9.5	10

[0215]

[Table 7]

		Base oil A4 (High-oleic rapeseed oil)
Fatty acid composition [% by mass]	Oleic acid	64
	Linoleic acid	20
	Palmitic acid	5
	Stearic acid	2
	Other fatty acids	9
C6-16 fatty acid content [% by mass]		9
Total degree of unsaturation		0.26

[Examples 22-36, Comparative Examples 3-8]

[0216] For Examples 22-36 and Comparative Examples 3-8, oils for metal working were prepared using the base oils and additives listed below, with adjustment of the moisture content, to yield the compositions and moisture contents listed in Tables 8-13. Tables 8-13 show the compositions of the oils for metal working with 100 % by mass as the total of the base oil and additive contents and moisture contents. Tables 8-13 also show the kinematic viscosity at 40°C for each obtained oil for metal working. The base oil A4 fatty acid compositions and total degrees of unsaturation are as shown in Table 7 above.

(Ester oils)

A5: Mixed ester of trimethylolpropane and oleic acid triester and neopentylglycol and oleic acid diester (kinematic viscosity at 40°C: 32 mm²/s)

A3: Isodecyl alcohol and adipic acid diester (kinematic viscosity at 40°C: 14 mm²/s)

A4: High-oleic rapeseed oil (kinematic viscosity at 40°C: 39 mm²/s)

(Additives)

C1: Oleyl alcohol

C2: Oleylamine

C3: Oleic acid

C4: Glycerin monooleate

D1: Tricresyl phosphate

D2: Sulfurized ester

[0217] The oils for metal working of Examples 22-36 and Comparative Examples 3-8 were subjected to the following evaluation tests.

[Tapping test]

[0218] A tapping test was conducted with a minimum quantity lubrication system (MQL) or an ordinary oil supply system.

[0219] For testing with the MQL, each oil for metal working and standard oil for comparison (DIDA: diisodecyl adipate, moisture content: 50 ppm) was used alternately in a tapping test under the conditions listed below, and the tapping

energy for each was measured.

[0220] (Tapping conditions)

Tool: Nut tap M8 (P=1.25 mm)

Lower hole diameter: $\phi 7.2$ mm

Workpiece: AC8A (t=10 mm)

Cutting speed: 9.0 m/min

(Oil supply system)

Oil for metal working: Spraying under conditions of 25 ml/h oil composition, with 0.2 MPa compressed air.

DIDA: Direct spraying of the working site under conditions of 4.3 ml/min without using compressed air.

[0221] For testing with the ordinary oil supply system, each oil for metal working and standard oil for comparison (DIDA: diisodecyl adipate, moisture content: 50 ppm) was used alternately in a tapping test under the conditions listed below, and the tapping energy for each was measured.

(Tapping conditions)

Tool: Nut tap M8 (P=1.25 mm)

Lower hole diameter: $\phi 7.2$ mm

Workpiece: AC8A (t=10 mm)

Cutting speed: 9.0 m/min

(Oil supply system)

Oil for metal working and DIDA: Direct spraying of the working site under conditions of 4.3 ml/min without using compressed air.

[0222] Next, the measured values of the tapping energy for both the MQL and ordinary oil supply systems were used to calculate the tapping energy efficiency (%) by the formula shown below. The results are shown in Tables 8-13. In the tables, a higher value for the tapping energy efficiency indicates higher lubricity.

$$\text{Tapping energy efficiency (\%)} = \left(\frac{\text{tapping energy using DIDA}}{\text{tapping energy using oil composition}} \right)$$

[Anti-wear property evaluation test]

[0223] Each oil for metal working was subjected to wear testing by a highspeed four-ball test for 30 minutes with a rotation rate of 1800 rpm and a load of 392 N, and the wear scar diameter was measured for evaluation of the anti-wear property of each oil. The results are shown in Tables 8-13.

[Storage stability test]

[0224] Each oil for metal working was allowed to stand at room temperature for 2 weeks, and the presence or absence of water separation was visually observed. The results are shown in Tables 8-13.

[0225]

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[Table 8]

		Example 22	Example 23	Example 24	Example 25
Composition [% by mass]	A5	99.965	99.900	99.700	-
	A3	-	-	-	99.700
	A4	-	-	-	-
	C1	-	-	-	-
	C2	-	-	-	-
	C3	-	-	-	-
	C4	-	-	-	-
	D1	-	-	-	-
	D2	-	-	-	-
Moisture content [ppm]		350	1000	3000	3000
Kinematic viscosity at 40°C [mm ² /s]		32	32	32	14
Working property (tapping energy efficiency [%])	MQL	93	95	97	100
	Normal oil Normal oil feeding	115	121	124	122
Anti-wear property (Wear scar diameter [μm])		0.70	0.70	0.69	0.70
Storage stability (presence of water separation)		-	-	-	-

[0226]

[Table 9]

		Example 26	Example 27	Example 28	Example 29
Composition [% by mass]	A5	-	94.700	94.700	94.700
	A3	-	-	-	-
	A4	99.700	-	-	-
	C1	-	5.000	-	-
	C2	-	-	5.000	-
	C3	-	-	-	5.000
	C4	-	-	-	-
	D1	-	-	-	-
	D2	-	-	-	-
Moisture content [ppm]		3000	3000	3000	3000
Kinematic viscosity at 40°C [mm ² /s]		39	32	32	32
Working property (tapping energy efficiency [%])	MQL	96	109	108	109
	Normal oil feeding	124	129	129	130
Anti-wear property (Wear scar diameter [μm])		0.72	0.67	0.68	0.67
Storage stability (presence of water separation)		-	-	-	-

[0227]

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[Table 10]

		Example 30	Example 31	Example 32	Example 33
Composition [% by mass]	A5	94.700	94.700	89.700	84.700
	A3	-	-	-	-
	A4	-	-	-	-
	C1	-	-	-	-
	C2	-	-	-	-
	C3	-	-	-	-
	C4	5.000	-	-	-
	D1	-	5.000	-	5.000
	D2	-	-	10.000	10.000
Moisture content [ppm]		3000	3000	3000	3000
Kinematic viscosity at 40°C [mm ² /s]		32	32	33	34
Working property (tapping energy efficiency [%])	MQL	112	110	108	113
	Normal oil Normal oil feeding	131	127	127	129
Anti-wear property (Wear scar diameter [μm])		0.68	0.54	0.56	0.52
Storage stability (presence of water separation)		-	-	-	-

[0228]

[Table 11]

		Example 34	Example 35	Example 36
Composition [% by mass]	A5	89.700	84.700	81.700
	A3	-	-	-
	A4	-	-	-
	C1	-	-	-
	C2	-	-	-
	C3	-	-	-
	C4	5.000	5.000	5.000
	D1	5.000	-	3.000
	D2	-	10	10
Moisture content [ppm]		3000	3000	3000
Kinematic viscosity at 40°C [mm ² /s]		33	34	35
Working property (tapping energy efficiency [%])	MQL	116	113	119
	Normal oil feeding	135	133	138
Anti-wear property (Wear scar diameter [μm])		0.52	0.54	0.51
Storage stability (presence of water separation)		-	-	-

[0229]

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[Table 12]

		Comp. Ex.3	Comp. Ex.4	Comp. Ex.5
Composition [% by mass]	A5	99.995	-	-
	A3	-	99.995	-
	A4	-	-	99.995
	C1	-	-	-
	C2	-	-	-
	C3	-	-	-
	C4	-	-	-
	D1	-	-	-
	D2	-	-	-
Moisture content [ppm]		50	50	50
Kinematic viscosity at 40°C [mm²/s]		32	14	39
Working property (tapping energy efficiency [%])	MQL	80	82	78
	Normal oil feeding	100	100	103
Anti-wear property (Wear scar diameter [μm])		0.71	0.73	0.73
Storage stability (presence of water separation)		-	-	-

[0230]

[Table 13]

		Comp. Ex.6	Comp. Ex.7	Comp. Ex.8
Composition [% by mass]	A5	97.000	-	-
	A3	-	97.000	-
	A4	-	-	97.000
	C1	-	-	-
	C2	-	-	-
	C3	-	-	-
	C4	-	-	-
	D1	-	-	-
	D2	-	-	-
Moisture content [ppm]		30,000	30,000	30,000
Kinematic viscosity at 40°C [mm²/s]		32	14	39
Working property (tapping energy efficiency [%])	MQL	98	99	98
	Normal oil feeding	129	125	127
Anti-wear property (Wear scar diameter [μm])		0.71	0.70	0.71
Storage stability (presence of water separation)		+	+	+

Claims

1. An oil for metal working **characterized by** comprising an ester oil and a hydrocarbon oil with a kinematic viscosity of 1-20 mm²/s at 40°C.

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2. The oil for metal working according to claim 1, **characterized in that** said hydrocarbon oil is at least one selected from among white oils and polyolefins or their hydrogenated forms.
3. The oil for metal working according to claim 1 or 2, **characterized in that** the moisture content is 200-20,000 ppm.
4. An oil for metal working **characterized by** comprising an ester oil as the base oil and having a moisture content of 200-20,000 ppm.
5. The oil for metal working according to any one of claims 1 to 4, **characterized by** further comprising an oiliness agent and/or an extreme-pressure agent.
6. The oil for metal working according to any one of claims 1 to 5, **characterized by** being used for non-ferrous metal working.
7. The oil for metal working according to any one of claims 1 to 6, **characterized by** being used for cutting, grinding or rolling.
8. The oil for metal working according to any one of claims 1 to 7, **characterized by** being used for metal working in a minimum quantity lubrication system.

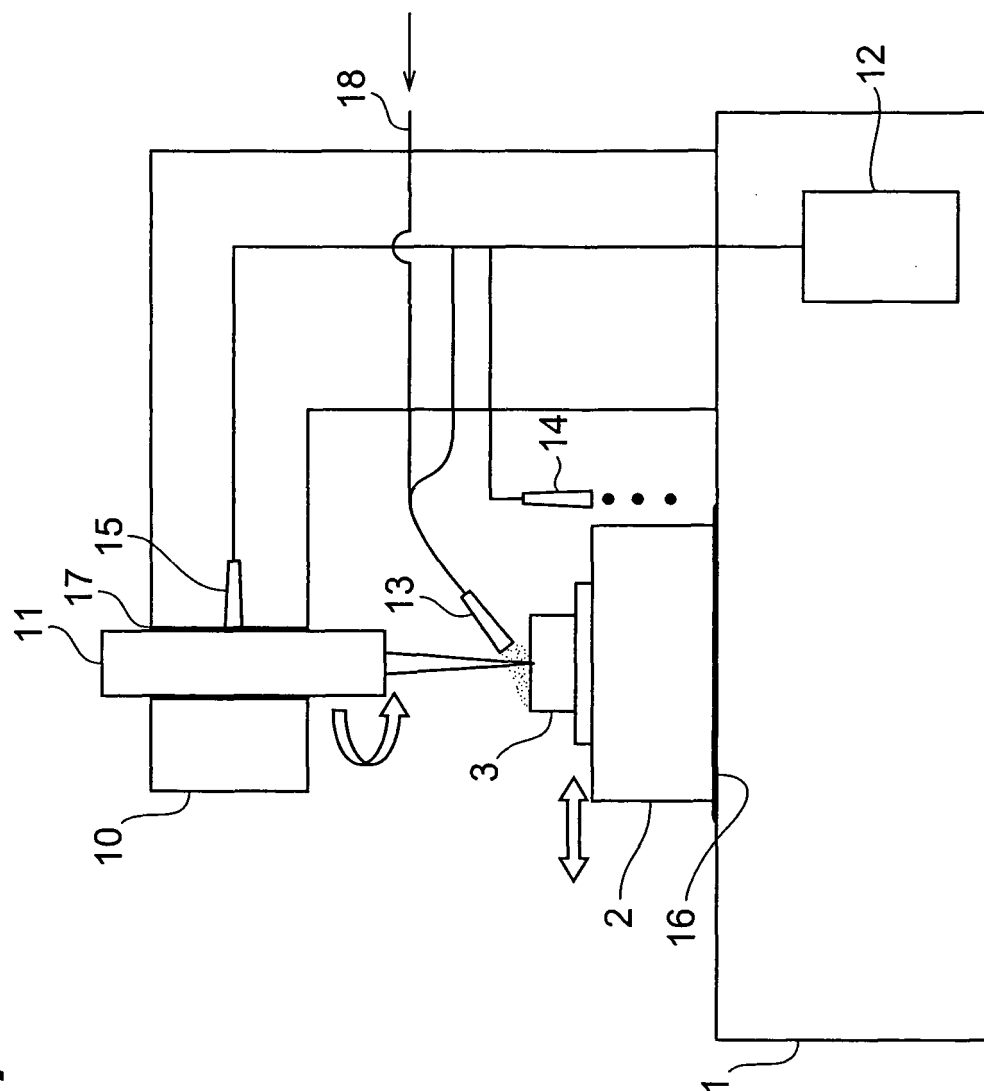


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005878

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁷ C10M101/04, 101/00, 105/00, 105/32, 111/02, 111/04// (C10M101/00, 101:02, 101:04) (C10M105/00, 105:02, 105:32) (C10M111/02, 101:02, 101:04, 105:02, 105:32) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl. ⁷ C10M101/00-101/04, 105/00-105/06, 105/32-105/48, 107/02-107/18, 111/02-111/04, C10N30:00, 30:06, 40:20-40:24, 50:04 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005 Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 8-53685 A (Idemitsu Kosan Co., Ltd.), 27 February, 1996 (27.02.96), (Family: none)	1-2, 5-8 3-4
X Y	JP 8-176581 A (Kobe Steel, Ltd. et al.), 09 July, 1996 (09.07.96), & KR 391164 B1 & US 5761941 A	1-2, 5-8 3-4
X Y	JP 9-316478 A (Nippon Oil Co., Ltd.), 09 December, 1997 (09.12.97), (Family: none)	1-2, 5-8 3-4
X Y	WO 95/32267 A1 (Idemitsu Kosan Co., Ltd.), 30 November, 1995 (30.11.95), & CN 1149312 A & EP 763590 A1 & KR 97702912 A & US 5726130 A	1-2, 5-8 3-4
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 17 June, 2005 (17.06.05)		Date of mailing of the international search report 05 July, 2005 (05.07.05)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

EP 1 741 771 A1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005878

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002-146378 A (Yushiro Chemical Industry Co., Ltd. et al.), 22 May, 2002 (22.05.02), (Family: none)	1-2,5-8 3-4
X Y	JP 2002-38181 A (Idemitsu Kosan Co., Ltd.), 06 February, 2002 (06.02.02), (Family: none)	1-2,5-8 3-4
X Y	JP 10-279977 A (Sugimura Kagaku Kogyo Kabushiki Kaisha), 20 October, 1998 (20.10.98), (Family: none)	1-2,5-8 3-4
X Y	WO 01/30945 A1 (Nippon Mitsubishi Oil Corp.), 03 May, 2001 (03.05.01), & CN 1337990 A & JP 2001-192685 A & JP 2001-192686 A & JP 2001-192690 A & JP 2001-192691 A & KR 2001111486 A & US 2002/0035043 A1	1-2,5-8 3-4
X Y	WO 02/081605 A1 (Nippon Mitsubishi Oil Corp.), 17 October, 2002 (17.10.02), & AU 2002244970 A & KR 2004010618 A & US 2004/0116309 A1	1-2,5-8 3-4
X Y	WO 02/083823 A1 (Nippon Mitsubishi Oil Corp.), 24 October, 2002 (24.10.02), & AU 2002246365 A & KR 2004058109 A & US 2004/0116308 A1	1-2,5-8 3-4
X Y	WO 02/087821 A1 (Nippon Mitsubishi Oil Corp.), 07 November, 2002 (07.11.02), & AU 2002251548 A	1-2,5-8 3-4
Y	JP 8-506614 A (FMC CORP. (UK) LTD.) 16 July, 1996 (16.07.96), & AU 9465795 A & DE 69429341 T2 & EP 696311 A1 & ES 2170097 T3 & US 6358895 B1 & WO 94/25550 A1	3-4
Y	JP 1-108300 A (Idemitsu Kosan Co., Ltd.), 25 April, 1989 (25.04.89), (Family: none)	3-4

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005878

Continuation of A. CLASSIFICATION OF SUBJECT MATTER

(International Patent Classification (IPC))

Int.Cl⁷ (C10M111/04, 101:02, 101:04, 105:02, 105:32, 107:02)
C10N30:00, 30:06, 40:20, 50:04

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

Continuation of Box No.III of continuation of first sheet(2)

A metalworking fluid containing an ester oil as the technical feature common to the invention of claims 1-3 and the invention of claim 4 is publicly known as described in document A shown below. Consequently, the metalworking fluid containing an ester oil cannot be a special technical feature within the meaning of PCT Rule 13.2, since it makes no contribution over the prior art. Therefore, there is no technical relationship involving a same or corresponding special technical feature between the above-mentioned two groups of inventions.

Further, the invention of claims 5-8 involves the above-mentioned two groups of inventions.

This international application is therefore considered to contain two groups of inventions which are not so linked as to form a single general inventive concept.

Document A: WO 01/30945 A1 (Nippon Mitsubishi Oil Corp.), 03 May, 2001
(03.05.01)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005878

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.