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SOLUBLE CUTTING OIL COMPRISING THICKENED OIL AND METHOD OF APPLYING THE SAME

Elliott S. Francis, Allison Park, and Joseph H. Piatt, Plum Township, Allegheny County, Pa., assignors to Gulf Research & Development Company, Pittsburgh, Pa., a corporation of Delaware

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This invention relates to cutting liquids employed in metal working operations and more particularly to soluble cutting oils which are adapted to be directed as a thin, high speed jet into the angle between the work and the cutting edge of the tool.

The application of a cutting oil to a metal surface being worked has conventionally comprised flowing over the metal working tool, either by gravity or under low pressure, a large amount of the oil, the theory being that by floating the working surface with the cutting oil the heat evolved in the operation would be dissipated, the metal chips washed away and the cutting operation lubricated by the large quantity of oil used. However, in the cutting operation the chip which is formed overlies and shields the cutting edge so that an insufficient amount, if any, of the cutting oil flooding the work from overhead finds its way around the chip to the tool edge. Accordingly, with the conventional overhead stream, little or no cutting oil reaches the cutting edge and the tool is cooled solely by conduction through the chip and through the tool shank. The ineffective application of cutting liquids by the conventional method results in one of the major disadvantages of dry cutting, namely, the early breakdown of the cutting tool.

A newly developed method of applying cutting oils is an improvement over the conventional low pressure, overhead method of application. The new method is described in U. S. Patent 2,653,517 to R. J. S. Pigott. In the new method a thin, high speed jet of oil is directed between the work and the cutting surface of the tool. A velocity of the jet such as 225 to 260 feet per second is obtained by pumping the oil at pressures such as 300 to 600 pounds per square inch through a small nozzle. As a result, it is believed that at least a portion of the oil, possibly as a vapor which thereafter condenses, penetrates the very small clearance between the work and the relief surface of the tool without impinging upon the heel of the tool or otherwise dissipating its energy before reaching its destination. In this manner the cutting operation is more efficiently cooled and lubricated so that the life of the cutting tool is increased, "build-up" of metal particles on the cutting tool is reduced or eliminated, the surface of the finished work is improved and other important advantages are obtained.

While the newly developed technique of applying the cutting liquid to the work as a high speed jet results in increased tool life even with cutting liquids of conventional composition, the conventional cutting liquids have not proven to be entirely satisfactory for the new technique. A serious problem encountered in the use of conventional cutting oils in the high speed jet technique has been the formation of large amounts of smoke or vapor during the cutting operation. Conventional soluble cutting oils which reduce the smoking problem are not entirely satisfactory with respect to the increased tool life which should result from the use of the high speed jet technique. An object of the present invention is to increase further the advantages obtainable through the high speed jet method

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of applying cutting liquids by providing cutting liquids which are particularly adapted for the newly developed method of application.

In accordance with the present invention, we have produced a soluble cutting oil composition which is particularly adapted to be employed in an emulsion with water in metal working operations in which the cutting liquid is directed at a high velocity between the tool and the work as a thin, high speed jet and which comprises an oil-in-water emulsifying agent and a lubricating oil thickened to the consistency of a grease by the addition of a water-insoluble metal soap of a saturated fatty acid. Our invention also in general comprises an improvement in the method of working metal in which a thin, high speed jet of cutting liquid is directed at a high velocity between the tool and the work, the improvement comprising the use of a cutting liquid composed of water and a soluble cutting oil of the described composition.

The lubricating oil base in the compositions of our invention can be a distillate or residual mineral lubricating oil derived from a crude oil of paraffinic, naphthenic or mixed base. It can be a refined or unrefined lubricating oil and can comprise a single stock or any blend which produces a lubricating oil. Suitable oils exist over a wide range of viscosity, for example, from light lubricating oils having a viscosity as low as about 50 SUS at 100° F. to oils having a viscosity as high as about 250 SUS at 210° F. The base oil can also be entirely or in part an oil of non-mineral origin such as, for example, a lubricating oil obtained by Fischer-Tropsch synthesis, by olefin polymerization, etc.

In addition to a base oil, the compositions of our invention contain one or more of certain water-insoluble soaps which are gelling or thickening agents and have the property of forming with mineral oils, gels or mixtures thicker or more viscous than the original oil. Soaps which can be used include the fatty acid soaps of metals such as calcium, aluminum, lead, magnesium, barium, strontium, lithium, etc. Soaps of metals such as zinc are unsuitable because of their inability to form thickened mixtures with oils. Soaps of metals such as sodium and potassium are unsuitable because of their water solubility. It is important that the soaps be water-insoluble or of low water solubility so that when the soluble oils of the invention are employed in water emulsions the thickening effect of the soap on the oil base will not be lost.

The thickening agents of our compositions are derived from fatty acids having from about 10 to 24 carbon atoms and predominantly from saturated fatty acids. Preferably, the fatty acids are obtained from animal or vegetable fats or oils which yield a high percentage of saturated acids. Such oils and fats include beef and mutton tallow, lard, coconut oil, palm oil, hydrogenated vegetable, animal or fish oils and the like. Soaps prepared from stocks yielding predominantly unsaturated fatty acids are generally unsuitable because the unsaturated fatty acid soaps are principally soft soaps which do not perform satisfactorily as thickening agents. The thickening agent in our compositions can be a water-insoluble soap of a single saturated fatty acid, or, as is preferred, a mixture of the soaps such as mixtures derived from natural fats and oils which predominate in saturated fatty acids. Also, the oil can, if desired, be thickened by the addition of a grease or other mixture which contains a soap of the indicated type.

The particular amount of soap required to thicken properly the base oil will of course be different with different oils, a light oil requiring a greater amount of thickening agent than a heavy oil. A sufficient amount of the water-insoluble metal soap is used to produce a mixture of soap and oil having the consistency at room temperature of a semi-fluid grease, the viscosity of the thickened oil being substantially higher than that of the base oil and in any case, if measurable in Saybolt Universal seconds, greater than about 200 SUS at 210° F. Usually, however, the thickened oils are not Newtonian liquids and consequently there is no true physical constant of viscosity. The apparent viscosity will vary with the rate of shear. The most satisfactory method of defining the consistency of such thickened oils is with data obtained by ASTM test D1092–51 which is a standard procedure for measuring, in poises, the apparent viscosity of lubricating grease at room temperature.

In the compositions of the invention sufficient thickening agent is added to thicken the base oil to a consistency corresponding to an apparent viscosity of at least 5.0 poises as measured at 77° F. and at a shear rate of 200 reciprocal seconds by ASTM D1092–51. As for the maximum limit to which the oil should be thickened, it would generally be undesirable to produce a thickened oil having an apparent viscosity greater than about 20 poises at 77° F. and 200 reciprocal seconds. (Equivalent to about 10,000 SUS at these conditions.) The amount of water-insoluble soap required to thicken the oil to the proper consistency or apparent viscosity is usually more than about 4 percent by weight of the mixture of oil and soap. As much as about 40 percent by weight soap may be required for some light oils. With very heavy oils amounts somewhat less than 4 percent by weight of soap may suffice.

The soluble oil of the compositions of our invention is prepared by mixing with the base oil thickened by a water-insoluble soap, as described above, an emulsifying agent of the oil-in-water type such, for example, as oil-soluble sulfonates, and particularly sodium mahogany sulfonates, obtained in the sulfuric acid treatment of petroleum oils. Either the purified sulfonates or any of the commercial mahogany sulfonates of varying purity can be used. Numerous other conventional oil-in-water emulsifying agents can be used including sulfonated fattty material such as sperm oil, olive oil, cottonseed oil, etc., the stearates and oleates of alkylol amines such as mono-, di-, or triethanolamine and various non-ionic complex esters such as polyoxyethylene sorbitan fatty acid esters.

The relative amounts of thickened lubricating oil and emulsifying agent in the soluble oil composition will depend upon the ease with which the thickened oil is made emulsifiable and upon the efficiency of the particular emulsifying agent. Usually the emulsifying agent will comprise from about 15 to 40 percent by weight of the soluble oil composition including the emulsifying agent, the base oil, and the metal soap thickening agent. However, with easily emulsifiable thickened oils as little as 5 percent by weight of the emulsifying agent may suffice, while with difficultly emulsifiable thickened oils it may be necessary that the soluble oil composition comprise as much as 50 weight percent emulsifying agent.

In preparing stable emulsions of oil in water with emulsifying agents of the type indicated, it is often desirable to adjust the pH of the mixture by the addition of acid or basic substances. Therefore, the soluble oil compositions of our invention can contain minor amounts of materials such as oleic acid or caustic added for the purpose of adjusting the pH of the mixture and affording the maximum stability of the emulsion. Our compositions may also contain a minor amount of a suitable coupling agent such as diethylene glycol to improve the emulsion stability.

In addition to the thickened oil, the emulsifying agent, any acid or basic material necessary for pH adjustment, and any desired coupling agent, the soluble oils of our invention may include various agents such as rust inhibitors, extreme pressure agents, antiseptics, etc.

In preparing the soluble oils of our invention, it is preferred first to thicken the lubricating oil base by mixing the oil and preformed soap-type thickening agent in desired quantities and stirring the ingredients while warming to a temperature of, for example, from about 100 to 120° F. until there is obtained a homogeneous mixture of grease consistency having the desired thickness or viscosity. Alternatively, the soap can be formed in situ in the lubricating oil. In the latter case, stoichiometrical proportions of a metal hydroxide and a fatty material of the types described are added separately to the oil to form the desired soap within the oil. The rate of reaction can be increased if desired by stirring the ingredients at a suitable saponification temperature, for example, 250 to 350° F. and at superatmospheric pressure such as 50 to 100 pounds per square inch gauge over a period of an hour or more. Following the addition of soap to thicken the oil to the desired degree, the selected emulsifying agent is added to the thickened oil, again with stirring while warming until a clear mixture is obtained. Finally, the maximum emulsifiability of the composition can be obtained by adjusting the pH as by the addition of minor amounts of acid or base until the mixture is easily emulsifiable.

While the sequence of steps in preparation described above is preferred, it is also possible to prepare compositions of the invention when the ingredients are incorporated in the mixture in a different sequence. For example, in forming certain compositions of the invention the water-insoluble thickening agent and the oil-in-water emulsifying agent can be added simultaneously to the lubricating oil, although in general it is preferred to thicken the oil before the addition of the emulsifying agent in order to insure obtaining the proper viscosity.

The cutting liquid compositions or emulsions of our invention can vary considerably in the ratio of the amount of water to the amount of soluble oil depending upon a number of factors such as the emulsifiability of the particular soluble oil composition, the proportion of oil required to lubricate properly the cutting operation, the smoking problem at high oil concentrations, etc. For most cutting operations the cutting composition should contain at least about 5 percent of the soluble oil and usually at compositions above about 20 percent by volume of soluble oil the smoking problem begins to be serious. Therefore, from about 5 to 20 percent by volume of the soluble oil is the preferred range of composition in the emulsion. However, in certain operations and with certain soluble oil compositions as little as from 1 to 2 percent emulsions may be employed and in other operations as much as 50 percent by volume emulsions may be employed.

The following example will illustrate the preparation of a typical composition of our invention.

EXAMPLE

The base oil for a composition in accordance with our invention was a refined Coastal lubricating oil blend having the following inspection data:

Gravity, ° API	22.3
Viscosity, SUV, sec. at:	
77° F. (calculated)	1100
100° F.	465
210° F.	53.8
Flash, OC, ° F.	375
Fire, OC, ° F.	415
Pour, ° F.	—15
Color, ASTM union	5

The mineral lubricating oil was thickened by admixture with calcium soap of tallow to form a composition comprising 94.7 weight percent of the lubricating oil, 4.5 weight percent of the soap, 0.4 weight percent of glycerine and 0.4 weight percent of water. The resulting thickened oil was a semi-fluid or semi-solid material having an API gravity of 21.4°, a specific gravity (60/60° F.) of 0.925, a pour point of +40° F., a neutralization number of 0.3 and an ash content of 0.4 weight percent.

The apparent viscosity data for the thickened oil, determined by ASTM D 1092–51, are as follows:

Shear Rate, Reciprocal seconds	Apparent Viscosity at 77° F.	
	Poises	Approximate Equivalent, SUS
200	6.8	3,437
330	6.1	3,085
500	6.0	3,035
800	5.6	2,832

The thickened oil was mixed in a ratio of 75 parts by weight with 25 parts by weight of a commercial emulsifying agent of which the principal active ingredient was sodium mahogany sulfonate. This mixture was stirred at a temperature of about 120° F. for about 30 minutes until a clear mixture of soluble cutting oil was obtained. The soluble oil had the following inspection data:

Gravity, ° API	18.8
Viscosity, SUV, secs. at:	
100° F	1477
130° F	520
210° F	86.7
Viscosity index	45
Neutralization value—total acid number	0.46
Saponification number	1.5
Sulfur, percent	0.94
Ash as oxide, percent	2.08
Sulfate, percent	2.73
Ash Analysis:	
Sodium, percent	0.70
Calcium, percent	0.40

We have employed the soluble cutting oil of our invention, described in the above example, in cutting operations in which the soluble cutting oil in an emulsion with water is applied as a thin, high speed jet between the work and the cutting edge of the tool and the results of these operations demonstrate the superiority of our cutting oil compositions over conventional soluble cutting oils.

We have employed a conventional soluble cutting oil in a water emulsion under conditions substantially the same as those in which the cutting liquid of our invention was employed. The conventional soluble cutting oil comprised 85 parts by weight of a light refined lubricating oil, 14.88 parts by weight of the same commercial sodium mahogany sulfonate mixture employed in the compositions of our invention and 0.12 parts by weight of a rust inhibiting agent (Alkylamine Isoamyl Octyl Orthophosphate). The lubricating oil of the conventional soluble oil had the following inspection data:

Gravity, °API	24.4
Viscosity, SUV, secs. at:	
100° F	104
130° F	63.6
210° F	38.3
Viscosity index	21
Color	—2
Pour point, °F	—65
Flash point, °F	310
Fire Point, °F	350
Carbon residue, percent	0.01
Neutralization No.	0.08
Ash as oxide, percent	less than 0.01
Sulfur, percent	0.15

The soluble cutting oil of our invention described in the example above and the conventional soluble cutting oil were similarly employed as 5 weight percent emulsions in water in the high speed jet method of applying a cutting liquid. The cutting compositions were used in lathe tests on AISI 4140 mill annealed steel using a high speed steel tool (shape: 10°–12°–8°–10°–6°–6°–3/64″ R). In these tests the cutting compositions were directed in the form of a thin jet at a velocity of about 246 feet per second and 0.125 gallon per minute into the angle between the work and the tool. The thin jet was obtained by passing the cutting composition through a small orifice (0.0183 inch) in a nozzle which was mounted on the carriage of the lathe. The cutting compositions were supplied to the nozzle at a temperature of about 90 to 100° F. under a pressure of 400 pounds per square inch. The depth of cut was 0.088 inch and the feed was 0.011 inch per revolution. The results of the lathe tests in terms of actual tool life and adjusted tool life (derived in the manner hereinafter described) are given in the table below.

Results of tool life tests of soluble cutting oils (in 5 vol. percent emulsions with water)

Tool Life, minutes	Cutting Composition of the Invention	Conventional Cutting Composition
At 100 SFM:[1]		
Test No. 1	292	109
Test No. 2	129	99
Adjusted Tool Life Average	148.1	138
At 140 SFM:[1]		
Test No. 3	45	18
Test No. 4	28	14
Test No. 5	35	----------
Adjusted Tool Life Average	30.2	22

[1] SFM=surface feet per minute.

In lathe tests such as those described above, a problem arises in interpreting the tool life results due to unavoidable differences in the machineability of the various steel specimens. Consequently, it is desirable to adjust the test results for the differences in the steel specimens where possible. A method of adjusing the results is by the calculation of "adjusted tool life values" such as those presented in the table above. These are obtained as follows: For a particular steel a large number of determinations of the "dry tool life" of different specimens of the steel are taken and an average value is calculated. For the AISI 4140 steel of these tests, at a speed of 140 S. F. M. a dry life value of approximately 1.4 minutes was obtained. This factor which is in effect a machineability rating of the steel, is then used in the following formula to obtain the adjusted tool life for a specimen of this particular steel at any cutting speed.

$$\text{Adjusted tool life}=\frac{1.4 \text{ X observed tool life}}{\text{Tool life without oil at 140 S. F. M.}}$$

(All tool life values being in minutes)

In each test of a cutting oil a determination is made of dry tool life at 140 S. F. M. for the particular steel specimen being used and of the tool life with the cutting liquid being tested. The adjusted tool life which can then be obtained by the formula furnishes a reliable basis for comparing the efficiency of the various cutting oils by compensating for the machineability of the particular steel specimen. In the table above, the adjusted tool life values are given as the average of adjusted tool life values for the tests made at the same cutting speeds.

The results of the above-described lathe tests show markedly increased tool life for the cutting compositions of our invention as compared with the conventional cutting composition. The superiority is shown in the actual tool life values as well as the adjusted tool life values and at both cutting speeds employed in the tests.

Although the cutting liquid compositions of the invention are particularly adapted for application as a thin, high speed jet, as described herein, it should be understood that they are also useful and have important advantages when applied as cutting liquids by other methods, for example, by the conventional overhead method of application.

Obviously many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof and therefore only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. In a method of working metal in which a thin, high speed jet of cutting liquid is directed at a high velocity between the tool and the work, the improvement which comprises using as the cutting liquid an emulsion comprising a major amount of water and a minor amount of an emulsifiable cutting oil comprising from about 15 to 40 percent by weight of an oil-in-water emulsifying agent and from about 60 to 85 percent by weight of a mineral lubricating oil thickened by the addition of a water-insoluble metal soap of a saturated fatty acid, the amount of said soap being sufficient to thicken said oil to a grease consistency.

2. In a method of working metal in which a thin, high speed jet of cutting liquid is directed at a high velocity between the tool and the work, the improvement which comprising using as the cutting liquid an emulsion comprising a major amount of water and from about 5 to 20 volume percent of an emulsifiable cutting oil comprising from about 15 to 40 percent by weight of an oil-soluble sulfonate oil-in-water emulsifying agent and from about 60 to 85 percent by weight of a mineral lubricating oil thickened by the addition of a water-insoluble metal soap of a saturated fatty acid, the amount of said soap being sufficient to produce a thickened oil of grease consistency having an apparent viscosity at 77° F. greater than about 5 poises at a shear rate of 200 reciprocal seconds.

3. In a method of working metal in which a thin, high speed jet of cutting liquid is directed at a high velocity between the tool and the work, the improvement which comprises using as the cutting liquid an emulsion comprising a major amount of water and from about 5 to 20 volume percent of an emulsifiable cutting oil comprising from about 15 to 40 percent by weight of sodium mahogany sulfonate and from about 60 to 85 percent by weight of a thickened mineral oil having the consistency of a semi-fluid grease and an apparent viscosity at 77° F. greater than about 5 poises at a shear rate of 200 reciprocal seconds, said thickened mineral oil comprising a mineral lubricating oil having a Saybolt Universal viscosity at 210° F. below about 250 seconds and from about 4 to 40 percent by weight of a thickening agent composed of a water-insoluble metal soap of a fatty material which yields predominantly saturated fatty acids having from about 10 to 24 carbon atoms.

4. A soluble cutting oil comprising from about 15 to 40 percent by weight of an oil-in-water emulsifying agent and from about 60 to 85 percent by weight of a mineral lubricating oil thickened by the addition of a water-insoluble metal soap of a saturated fatty acid, the amount of said soap being sufficient to thicken said oil to a grease consistency.

5. A soluble cutting oil comprising from about 15 to 40 percent by weight of an oil soluble sulfonate oil-in-water emulsifying agent and from about 60 to 85 percent by weight of a mineral lubricating oil thickened by the addition of a water-insoluble metal soap of a saturated fatty acid, the amount of said soap being sufficient to produce a thickened oil of grease consistency having an apparent viscosity at 77° F. greater than about 5 poises at a shear rate of 200 reciprocal seconds.

6. A soluble cutting oil comprising from about 15 to 40 percent by weight of sodium mahogany sulfonate and from about 60 to 85 percent by weight of a thickened mineral oil having the consistency of a semi-fluid grease and an apparent viscosity at 77° F. greater than about 5 poises at 200 reciprocal seconds, said thickened mineral oil comprising a mineral lubricating oil having a Saybolt Universal viscosity at 210° F. below about 250 seconds and from about 4 to 40 percent by weight of a thickening agent composed of a water-insoluble metal soap of a fatty material which yields predominantly saturated fatty acids having from about 10 to 24 carbon atoms.

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