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3,726,799

WATER BASED ROLLING LUBRICANT

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29 Claims

ABSTRACT OF THE DISCLOSURE

A coolant-lubricant for the cold rolling of aluminum and other light metals comprising an oil-in-water emulsion wherein the nonaqueous fraction of said emulsion consists essentially of from about 45 to 90% of a light petroleum oil, from about 5 to 50% by weight of esters of fatty acids, from about 5 to 50% by weight of fatty alcohols, between about 0.05 and 1.0% by weight of an oil-soluble emulsifier and preferably between about 0.05 and 1.0% by weight of an oil-insoluble emulsifier. The nonaqueous fraction of said emulsion amounts to between about 3 and 20% of the total weight of the emulsion. Preferably, the water phase of the emulsion has an alkali metal salt concentration of between about 10 and 400 parts per million and a pH level between about 5.0 and 7.4.

BACKGROUND

This invention relates to the cold rolling of light metals such as aluminum and magnesium. As used herein the terms "aluminum," "magnesium," and "light metals" include the pure metals as well as the alloys thereof.

For many years the aluminum and other light metal industries have attempted to use oil-in-water emulsions as coolant-lubricants in the cold rolling of sheet metal products. Oil-in-water emulsions provide a substantial increase in cooling rates over the previously employed oil base lubricants. The major advantage resulting from the improved cooling rates is an improved mill roll shape control. Attendant with the increased cooling rates are higher mill speeds and greater reductions per pass. However, when the prior oil-in-water emulsions were used the surface finish of the resultant sheet products was severely impaired. Water stain, brown stain, smut and other surface irregularities rendered the sheet products undesirable, and for most purposes unacceptable. Water stain, which is a white haze or a splotchy appearance, is caused by the reaction of water with the surface of the workpiece. Brown stain forms during heat treatments after rolling, such as annealing, due to the thermal decomposition of the oil components which remain on the sheet after rolling. The formation of a dark smut which occurs during rolling also is due to the thermal decomposition of the organic components. The dark smut and brown stain can be minimized by utilizing lubricity agents with relatively short carbon chains, but this may not eliminate the problem. The brown stain is a permanent discoloration of the sheet surface which is difficult to remove. The smut is easily removed by wiping with a cloth or the like, but this requires an additional processing step which is not desired.

A common problem associated with the prior art emulsion and dispersions was the inability to prevent the build-up of metal and oxide particles on the roll surface and the embedding of the particles into the surface of the workpiece.

If the speed of the mill and/or the amount of reduction per pass exceeds the lubrication properties of the emulsion, the surface of the sheet exhibits an irregularity commonly termed "herringbone effect," which is caused by failure of the lubricant film, allowing steel-to-aluminum contact and consequent welding of aluminum to the roll.

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The nonaqueous fraction of the prior emulsions usually included a base petroleum oil, fatty acids, fatty acid esters, fatty oils or combinations thereof, and various types of emulsifiers. Others, such as McLean et al. in U.S. 3,505,849, have proposed that an oil-free aqueous dispersion of fatty acids, fatty alcohols, fatty esters, fatty amines and fatty acid amides, or combinations thereof, be used for cold rolling.

SUMMARY OF INVENTION

The oil-in-water emulsion of the present invention provides for the substantial improvement in the rolling aluminum and other light metals without the prior art problems of water stain, brown stain, and various other surface imperfections on the resultant sheet products. The nonaqueous or oil fraction of the emulsion comprises from about 45 to about 90% by weight of a light petroleum oil, between about 5 and 50% by weight of a fatty acid ester, between about 5 and 50% of a fatty alcohol and between about 0.05 and 1.0% by weight of a substantially water-insoluble, oil-soluble emulsifier. Preferably, the nonaqueous fraction also includes between about 0.05% and 1.0% by weight of an oil-insoluble non-ionic emulsifier. The nonaqueous fraction amounts to between about 3 and 20% of the total weight of the emulsion. Substantially improved reductions per pass can be obtained when the aqueous phase of the emulsion contains an alkali metal salt concentration between about 10 and 400 parts per million. For a stable oil-in-water emulsion during rolling, the pH of the aqueous fraction is maintained between 5.0 and 7.4.

DESCRIPTION OF THE INVENTION

The base oil of the present invention is essentially a paraffinic, isoparaffinic, or naphthenic hydrocarbon oil, or a combination thereof with a viscosity of about 30 to about 100 SSU at 100° F., preferably between about 30 and 70 SSU. The demulsability of the oil with water must be rapid. The hydrocarbon oil acts as a diluent and also minimizes the thermal decomposition of the lubricity agents, i.e. the fatty acid esters and fatty alcohols, during rolling. It has been found that with less than about 35% by weight hydrocarbon oil in the nonaqueous fraction, the lubricity agents tend to thermally decompose during rolling, causing a severe smut formation. Preferably, the light hydrocarbon oil is between about 45% and 90% by weight of the nonaqueous fraction. Suitable hydrocarbon oils include Texaco 420-300 oil, Humble Oil Company's Somentor 50 and Phillips Petroleum Company's Soltrol 250, which have the following typical properties:

TABLE I

	Texaco 420-300	Humble Somen- tor 50	Phillips Soltroll 250
Gravity, °API at 60° F.....	37.1	42.4	0.812
Specific gravity 60/60.....	0.84	0.812	0.812
Viscosity, SSU at 100° F.....	41.8	50.7	44.0
Flash point, COC, ° F.....	280	230	260
Four point, ° F.....	-10	-70	
Naphthene carbon.....	33.3		
Paraffin carbon.....	60.3	83.3	

The oil phase of the present invention includes from about 5 to 50%, preferably between 5 and 35%, by weight of the oil fraction of long chain fatty alcohols, having a chain length from about 10 to 20 carbon atoms. Suitable alcohols include lauryl, myristyl, cetyl, stearyl, oleyl, linoleyl alcohols and the like. Preferably, the alcohols are saturated because the saturated alcohols are more thermally stable than unsaturated alcohols. Most fatty alcohols commercially available in large quantities are mixtures of fatty alcohols having various numbers of carbon atoms in the long alkyl chain. For example, lauryl

alcohol typically contains about 1% C10 alcohol, 65% C12 alcohol, 24% C14 alcohol and about 10% C16 alcohol.

The emulsion also contains from 5 to 50%, preferably 5 to 35%, by weight of the oil phase of a lower alkyl ester of a fatty acid, having from 10 to 20 carbon atoms. The lower alkyl group contains from 1 to 5 carbon atoms. Suitable esters include the methyl, propyl, isopropyl, butyl, isobutyl and pentyl esters of capric, lauric, myristic, palmitic, stearic, oleic and linoleic acids. The commercially available esters are also usually mixtures of esters of various long chain fatty acids. Of the lubricity agents described above, lauryl alcohol and butyl stearate have been found particularly useful.

The fatty alcohols in the oil-in-water emulsion of the present invention are particularly suitable for cold rolling light metal products because of their superior (to the fatty acids, fatty acid esters, and fatty oils) load bearing or lubrication properties and their thermal stability when diluted in a light hydrocarbon base oil. The combination of the fatty alcohol with a fatty acid ester has a synergistic effect in that it provides for better rolling characteristics and metal surface quality than the alcohol alone at equivalent concentrations and it also improves the thermal stability of both lubricity agents. Moreover, the utilization of both the fatty alcohol and fatty acid ester renders the balance of the emulsifier or emulsifiers with the rest of the constituents in the emulsion considerably less critical.

Essential to the present invention is the inclusion of an emulsifier which is soluble in the base oil and lubricity agents of the present invention but substantially insoluble in water. The emulsifier may be dispersible in water, however. One function of the oil-soluble emulsifier is to insure a substantially water-free layer of lubricant on the sheet material during rolling. Sufficient amounts of the oil-soluble emulsifier are used to provide an oil-in-water emulsion in which the majority of the volume of the oil fraction is composed of oil globules from about 2 to about 10 microns in diameter, which will remain stable for at least 15 minutes upon standing. In terms of the art, the oil-in-water emulsion of the present invention is termed a "loose" emulsion in that the emulsion in the quiescent state tends to separate some free oil or break down in about an hour after emulsification. "Tight" emulsions generally are emulsions which have the majority of the oil fraction volume composed of globules less than 2 microns and which tend to be stable for days, weeks, and in some cases, months after emulsification. Although termed loose, the emulsion of the present invention has little or no tendency to break down during rolling. The oil phase does preferentially align itself adjacent to the workpiece, and the mill rolls due to the natural attraction thereto of the polar portions of the fatty acid ester and fatty alcohol molecules. This, however, is not considered as an emulsion breakdown as it is understood in the art.

To maintain the loose emulsion of the present invention, the level of the oil-soluble emulsifier is kept between 0.05 and 1.0%, preferably between 0.1 and 0.5%, by weight of the oil fraction. Suitable emulsifiers include the alkylaryl polyethyleneoxy and alkylpolyethyleneoxy phosphoric acid monoesters such as Antara LM-400 and Antara LM-200 (GAF Corp.) and the glycerol monoesters of unsaturated hydroxylated fatty acids such as Surfactol 13 (Baker Castor Oil Co.) which is glycerol mono-ricinoleate.

Preferably, the oil fraction of the present invention also contains an oil-insoluble nonionic emulsifier which is slightly soluble in water or at least dispersible in water. The function of the oil-insoluble emulsifier, among others, is to affect a rapid and complete displacement of water on the workpiece, thus permitting deposition of a thin layer of the oil fraction. This water removing function is critical when the workpiece entering the mill has water on the surface thereof. Apparently, due to the high moisture content of the atmosphere surrounding the entry

side of the mill, a thin layer of moisture condenses on the sheet which, if not displaced with oil, will cause water stain. The exact mechanism of removing water by the oil-insoluble emulsifier is presently not well understood. However, it has been found that both of the oil-soluble and oil-insoluble emulsifiers must be present to affect the deposition of a dry oil film on the metal being rolled. The oil-insoluble emulsifier must be maintained between about 0.05 and 1.0% by weight, preferably between 0.1 and 0.5% of the nonaqueous fraction. For substantially improved results the weight ratio of the oil-soluble emulsifier to oil-insoluble emulsifier should be maintained between 1:1 and 1:10. Suitable nonionic emulsifiers include polyglycol esters of long chain fatty acids having been 10 and 20 carbon atoms, polyoxyalkylene ethers of long chain alkanes and ethoxylated castor oils. Examples of suitable nonionic emulsifiers are Brij 76 and Brij 92 produced by the Atlas Chemical Industries, Inc., which are respectively a polyoxyethylene stearyl ether and polyoxyethylene oleyl ether; Unisol 4-0, produced by the Universal Chemicals Corp., which is a polyglycol ester of oleic acid, Surfactol 380, Surfactol 365 and Surfactol 318, produced by the Baker Castor Oil Co., which are ethoxylated castor oils.

The need for the water-soluble emulsifier can be minimized by maintaining the metal surface of the entry side of the mill at a temperature above the dew point of the atmosphere to prevent condensation. However, this is not desirable because an additional heating step would be introduced into the process lines.

Although the above emulsifiers are termed oil-insoluble and oil-soluble, the combination of the two emulsifiers in the emulsion provides for an oil component concentration of between 300 and 1000 p.p.m. in the water phase.

It has also been found that the amount of inorganic alkali metal salt in the aqueous portion of the emulsion significantly affects the lubrication properties of the emulsion. A lithium, potassium and sodium salt concentration between about 10 and 400 p.p.m. provides for a substantial increase in reduction per pass—e.g. increases up to 50% or more with the common alloys. Suitable alkali metal salts include the chloride, fluoride, bromide, iodide and sulfate salts of lithium, potassium and sodium. Particularly effective and readily available are sodium sulfate and sodium chloride.

The emulsion of the present invention can be prepared by first mixing the base oil, lubricity agents and one or more emulsifiers into a neat oil and then mixing the neat oil with water to form the emulsion. The alkali metal salt, if used, can be mixed with the water in any convenient manner. Mechanical as well as sonic devices can be employed to mix the neat oil and water to form the oil-in-water emulsion.

The workpiece to be rolled as well as the mill rolls are flooded with the emulsion as the workpiece enters the rolls. Preferably, the emulsion is removed from the sheet after rolling by suitable means such as mechanical wipers, air blasts, vacuum devices or combinations thereof. The emulsion tends to form water stain if not removed from the sheet before the sheet is coiled. However, a thin, dry oil film remains on the sheet after the emulsion is removed, which has no detrimental effects on the surface characteristics of the metal.

The operating temperature of the emulsion should be maintained between about 70 and 130° F., preferably between about 90 and 110° F. Below 70 the emulsion tends to invert, i.e., change to a water-in-oil emulsion, and above 130° F. it tends to be unstable and breaks down to separate water and oil phases. Both of these phenomena are detrimental to the lubricity characteristics of the emulsion. During rolling, the emulsion becomes dirty due to the pickup of the metallic particles, decomposition products and other contaminants, which should be removed with some degree of regularity due to their detrimental effect on the surface characteristics of the metal and rolling efficiency. The oil-in-water emulsion is ex-

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tremely difficult to filter because of the relative size of the oil globules to the metal particles. It has been found that by heating the emulsion up to about 150°, e.g. between 140 and 190° F., the emulsion can be easily separated into separate water and oil phases by suitable means such as by centrifuging. The oil phase, which contains substantially all of the contaminant, can be filtered by a suitable filtering means. The emulsion then is reconstituted and recycled for rolling. If necessary, additions can be made to the oil phase at this time to maintain emulsion functionality. Over a period of time, the pH of the aqueous phase shifts toward the alkaline side, which detrimentally affects the lubricity characteristics of the emulsion. However, the pH is easily adjusted by suitable acidifying agents such as sulfuric acid. The buildup of metallic oxide particles on the roll surface and the embedding of the particles into the surface of the workpiece are minimized by the present emulsion.

To minimize oxidation of the lubricity agents, particularly those left on the sheet after rolling, antioxidants such as 2,6 ditertiary butyl-4 methyl phenol, commonly termed butylated hydroxytoluene (BHT) in amounts from 0.05 to about 0.50% by weight of the oil fraction are added to the oil phase before emulsification.

The following examples are given to further illustrate the invention.

TABLE II.—EMULSION COMPOSITION

Example Number	Base oil	Lubricity agents	Emulsifiers	Neat oil percent of emulsifiers	Water
1	420-300, 50%	Butyl stearate, 25%; lauryl alcohol, 25%	LM-400, 0.14%; 4-0, 0.40%	10	Deionized.
2	Somentor 50, 50%	do	LM-400, 0.11%; 4-0, 0.42%	10	Do.
3	Humble 3190, 49.6%	do	LM-400, 0.10%; 4-0, 0.22%	10	Do.
4	Humble 3190, 47%	Butyl stearate, 23.9%; lauryl alcohol, 23.9%	LM-400, 1.31%; 4-0, 3.86%	10	Do.
5	Humble 3190, 79.7%	Butyl stearate, 10%; lauryl alcohol, 10%	Surfactol 13, 0.06%; Brij 76, 0.24%	10	Do.
6	Humble 3190, 69.7%	Butyl stearate, 25%; lauryl alcohol, 5%	Surfactol 13, 0.05%; Brij 92, 0.25%	10	Do.
7	Somentor 50, 50%				

TABLE III

Example Number	Alloy	Initial thickness, inch	Thickness 1st pass	Thickness 2nd pass	Thickness 3rd pass	Surface quality after rolling
1	2024	0.125	0.060	0.042	0.026	Excellent.
2	2024	0.125	0.059	0.042	0.025	Do.
3	2024	0.125	0.059	0.042	0.026	Do.
4	2024	0.125	0.059	0.042	0.264	Grey cast due to water stain.
5	2024	0.125	0.060	0.042	0.029	Excellent.
6	2024	0.125	0.060	0.043	0.029	Do.
7	1145	0.014	0.003	0.0014		Do.

Examples 1 through 6 were rolled on a 2-hi Schmitz mill with mill rolls 13 x 36 inches. Example 7 was rolled on a 2-hi Schmitz mill with mill rolls 10 x 23 inches. Example 4 was included to show the detrimental effect of an excess of emulsifiers.

To illustrate the effectiveness of an alkali metal salt level above 10 p.p.m., a 250-pound coil of 3003 aluminum alloy was rolled using the emulsion composition of Example 2. The first half of the coil was rolled with a reduction from 0.026 to 0.0158 inch (about a 40% reduction). The last half of the coil was rolled after 16 p.p.m. NaCl was added to the emulsion with a reduction in thickness of from 0.026 to 0.010 inch (about a 62% reduction). In both instances all other controllable conditions were kept constant. The surface conditions of both halves of the coil were excellent.

Other uses of the present invention have been contemplated. For example, by employing a more viscous base oil the present invention can be used in the rolling of ferrous products.

It is obvious that various modifications can be made to the present invention without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A neat oil comprising from about 35 to 90% by weight of hydrocarbon base oil, from about 5 to 50%

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by weight of at least one fatty alcohol selected from the group consisting of fatty alcohols having from 10 to 20 carbon atoms, from 5 to 50% by weight of at least one alkyl ester of a fatty acid selected from the group consisting of fatty acids having from 10 to 20 carbon atoms, said alkyl portion having from 1 to 5 carbon atoms, and from about 0.05 to 1.0% of a substantially water-insoluble, oil-soluble emulsifier.

2. The neat oil of claim 1 containing from 5 to 35% by weight of fatty alcohol and from 5 to 35% by weight of fatty acid ester.

3. The neat oil of claim 1 containing at least one water-insoluble, oil-soluble emulsifier selected from the group consisting of alkylaryl polyoxyethylene phosphoric acid monoester, alkylpolyoxyethylene phosphoric acid monoester and glycerol monoricinoleate.

4. The neat oil of claim 1 containing from 0.05 to 1.0% of a substantially oil-insoluble emulsifier.

5. The neat oil of claim 4 containing at least one oil-insoluble emulsifier selected from the group consisting of polyglycol esters of fatty acids having from 10 to 20 carbon atoms, polyoxyethylene ethers of long chain alkanes having from 10 to 20 carbon atoms and ethoxylated castor oils.

6. The neat oil of claim 1 containing lauryl alcohol and butyl stearate.

7. An oil-in-water emulsion suitable for the cold rolling of light metals comprising an oil phase comprising from 35 to 90% by weight of hydrocarbon base oil, from about 5 to 50% by weight of at least one fatty alcohol selected from the group consisting of fatty alcohols having from 10 to 20 carbon atoms, from 5 to 50% by weight of at least one alkyl ester of a fatty acid selected from the group consisting of fatty acids having from 10 to 20 carbon atoms, said alkyl portion having from 1 to 5 carbon atoms, and from about 0.05 to 1.0% of a substantially water-insoluble, oil-soluble emulsifier.

8. The oil-in-water emulsion of claim 7 comprising an oil phase containing from 5 to 35% by weight of fatty alcohol and from 5 to 35% by weight of fatty acid ester.

9. The oil-in-water emulsion of claim 7 comprising an oil phase containing at least one water-insoluble, oil-soluble emulsifier selected from the group consisting of alkylaryl polyoxyethylene phosphoric acid monoester, alkylpolyoxyethylene phosphoric acid monoester and glycerol monoricinoleate.

10. The oil-in-water emulsion of claim 7 comprising an oil phase containing from 0.05 to 1.0% of a substantially oil-insoluble emulsifier.

11. The oil-in-water emulsion of claim 10 comprising an oil phase containing at least one oil-insoluble emulsifier selected from the group consisting of polyglycol es-

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ters of fatty acids having from 10 to 20 carbon atoms, polyoxyethylene ethers of long chain alkanes having from 10 to 20 carbon atoms and ethoxylated castor oils.

12. The oil-in-water emulsion of claim 7 comprising from 3 to 20% by weight of an oil phase.

13. The oil-in-water emulsion of claim 7 comprising an aqueous phase containing from 10 to 400 parts per million of an inorganic alkali metal salt selected from the group consisting of the fluoride, bromide, iodide and sulfate salts of lithium, potassium and sodium.

14. The oil-in-water emulsion of claim 13 in which the inorganic alkali metal salt is selected from the group consisting of sodium chloride and sodium sulfate.

15. The method of cold rolling light metals comprising applying to the interface between the light metal and rolling surface an oil-in-water emulsion containing an oil phase comprising from 35 to 90% by weight of hydrocarbon base oil, from about 5 to 50% by weight of at least one fatty alcohol selected from the group consisting of fatty alcohols having from 10 to 20 carbon atoms, from 5 to 50% by weight of at least one alkyl ester of a fatty acid selected from the group consisting of fatty acids having from 10 to 20 carbon atoms, said alkyl portion having from 1 to 5 carbon atoms, and from about 0.05 to 1.0% of a substantially water-insoluble, oil-soluble emulsifier.

16. The method of claim 15 wherein the oil phase contains from 5 to 35% by weight of fatty alcohol and from 5 to 35% by weight of fatty acid ester.

17. The method of claim 15 wherein the oil phase contains at least one water-insoluble, oil-soluble emulsifier selected from the group consisting of alkylaryl polyoxyethylene phosphoric acid monoester, alkylpolyoxyethylene phosphoric acid monoester and glycerol monoricinoleate.

18. The method of claim 15 wherein the oil phase contains from 0.05 to 1.0% of a substantially oil-insoluble emulsifier.

19. The method of claim 18 wherein the oil phase contains at least one oil-insoluble emulsifier selected from the group consisting of polyglycol esters of fatty acids having from 10 to 20 carbon atoms, polyoxyethylene ethers of long chain alkanes having from 10 to 20 carbon atoms and ethoxylated castor oils.

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20. The method of claim 15 wherein the emulsion contains from 3 to 20% by weight of an oil phase.

21. The oil-in-water emulsion of claim 7 in which a majority of the oil fraction is composed of oil globules from about 2 to about 10 microns in diameter.

22. The neat oil of claim 1 in which the base oil has a viscosity between about 30 and 100 SSU.

23. The oil-in-water emulsion of claim 7 in which the base oil has a viscosity between about 30 and 100 SSU.

24. The method of claim 15 wherein the base oil has a viscosity of between about 30 and 100 SSU.

25. The method of claim 15 wherein the aqueous phase contains from 10 to 400 parts per million of an inorganic alkali metal salt selected from the group consisting of the fluoride, bromide, iodide and sulfate salts of lithium, potassium and sodium.

26. The method of claim 15 wherein the majority of the oil fraction is composed of oil globules from about 2 to about 10 microns in diameter.

27. The neat oil of claim 1 wherein the neat oil contains from 45 to 90% by weight of hydrocarbon base oil.

28. The oil-in-water emulsion of claim 7 wherein the oil phase contains from 45 to 90% by weight of hydrocarbon base oil.

29. The method of claim 15 wherein the oil phase contains from 45 to 90% by weight of hydrocarbon base oil.

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