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METHOD AND COMPOSITIONS FOR ROLLING LIGHT METALS

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This application is a continuation-in-part of my copending application filed May 21, 1954, Serial No. 431,-571.

This invention relates to lubricants for use in working and protectively coating aluminum and magnesium, and alloys containing greater than 70 percent by weight of one of these metals. More particularly, the present invention concerns an improved method of rolling aluminum and magnesium, and said alloys of these metals, by using certain lubricants as hereinafter described.

Many problems are encountered in shaping a piece of light metal such as aluminum or magnesium sheet by passing it between converging steel rolls. One of the most troublesome of these problems relates to roll contamination, or "pick-up" as it is called, whereby particles of the light metal are torn from the surfaces of the sheet and picked up by the surfaces of the rolls. This pick-up of metal adversely affects the surface finish of the sheet being rolled and leaves it rough and marred by imperfections. Furthermore, unless this pick-up is removed from the rolls, e.g., with wire brushes, it is rolled back onto the sheet, together with particles of iron from the rolls, thereby contaminating the rolled sheet and causing additional imperfections. As is well known, roll pick-up increases in severity with rise in temperature of the rolling surface as well as of the metal being rolled and is more severe in rolling magnesium than aluminum. In commercial rolling practice, lubricants such as mineral, vegetable, and animal oils have been interposed between the roll surfaces and the light metal being rolled in attempting to reduce roll pick-up. Unfortunately, however, such lubricants are not very effective in this capacity. In fact, prior to the present invention, no lubricant was known which would prevent roll pick-up of magnesium at elevated rolling temperatures, e.g., during hot rolling.

The use of conventional lubricants in rolling light metals also introduces other problems which are frequently as serious or more so than the problem of roll pick-up itself. For example, some of these rolling lubricants lower the coefficient of friction between the rolls and the metal being rolled to such a degree that entry of the light metal into the rolls is seriously hindered. Frequently, these lubricants form carbonaceous deposits on the light metal surface during rolling or during annealing following rolling. Staining of the rolled metal surface is often a particularly acute problem during hot rolling when water to cool the rolls is employed with conventional lubricants. In Addition, many of these lubricants require special organic solvents to remove them from the rolled metal surface or are otherwise difficultly removable therefrom.

It is therefore an object of this invention to provide a lubricant for use in rolling aluminum and magnesium, and alloys containing greater than 70 percent by weight of one of these metals, said lubricants being readily available and relatively inexpensive, substantially non-staining and non-corrosive to the light metal, easily removable from the light metal after rolling, and non-carbonizing on the rolled metal surfaces during annealing. More particularly, it is an object of this invention to provide an improved method of rolling aluminum and magnesium, and said alloys of these metals, whereby roll contamination and the effects thereof at the interface of the roll and

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metal are prevented or substantially decreased. A related object is to provide a rolled light metal surface which has good physical properties and is protectively coated against corrosion and abrasion. Other objects and advantages will be apparent from the description, which described but does not limit the invention.

These objects are accomplished in accord with the present invention as hereinafter explained. It has now been found that roll contamination during the rolling of light metals and the effects thereof at the interface of the roll and metal can be prevented or substantially decreased by maintaining at said interface, a lubricating composition consisting essentially of an alkali metal alkyl phosphate and a polypropylene glycol, especially aqueous solutions thereof.

Suitable alkali metal alkyl phosphate compounds for use in accord with the invention are those having from 1 to 18 carbon atoms in the alkyl group. Alkali metal monoalkyl phosphates having from 8 to 18 carbon atoms in the alkyl group such as octyl, decyl, dodecyl, tridecyl, cetyl, and octadecyl metal phosphates are preferred for best results. In the metal alkyl phosphates employed in the invention, the metal may be any of the alkali metals, usually sodium, potassium, or lithium. Thus, the metal alkyl phosphates include disodium decyl phosphate, dipotassium dodecyl phosphate, and dilithium tridecyl phosphate. Of these compounds, the disodium monoalkyl phosphates are usually employed, e.g. disodium octyl phosphate and disodium cetyl phosphate.

Almost any polypropylene glycol may be used to dissolve metal alkyl phosphate compounds to form lubricating compositions suitable per se for metal-working operations. In hot-rolling light metals at temperatures above about 250° F., however, aqueous solutions of alkali metal alkyl phosphates and polypropylene glycols are generally preferred since water is desirable to cool the rolls. In such use, water-soluble porpylene glycols having average molecular weights up to about 1000 are suitable, i.e., polypropylene glycols having an average of less than 18 oxypropylene units in the polyoxypropylene chain. Those of these polypropylene glycols having an average of from about 5 to about 14 oxypropylene units in the molecule, i.e., polyproylene glycols in the molecular weight range of about 300 to about 800, are preferred for best results.

Alkali metal alkyl phosphates are good metal working lubricants in their own right and, when admixed or dissolved in polypropylene glycols, form novel metal working compositions. These compositions may be prepared by heat dissolution of a minor proportion, i.e., less than 50 weight percent, of the metal alkyl phosphate in a major proportion, i.e., greater than 50 weight percent, of the polypropylene glycol. These proportions are not critical and almost any concentration of the metal alkyl phosphate from the maximum amount soluble down to 0.1 percent or less may be used in metal working operations, e.g., in the rolling of light metals. In such use, good results are obtained by using from 1 to 10 percent of the alkali metal alkyl phosphate based on the weight of the polypropylene glycol.

When employing these compositions in the rolling of light metals such as aluminum and magnesium a coating of the lubricant may be applied either to the roll surfaces or to the light metal to be rolled. For example, when cold-rolling light metals such as aluminum or magnesium at a temperature below about 250° F., the lubricant can be continuously and uniformly distributed on the surfaces of the rolls, e.g., by wiping it thereupon with two or more felt applicators saturated in the lubricant.

In hot-rolling light metals at a temperature above about 250° F., it is usually desirable to employ a solution of the alkali metal alkyl phosphate and the polypropylene glycol in water in order more effectively to cool the rolls and maintain them at an even temperature. Such a solution may be prepared by first forming a solution of the alkali metal alkyl phosphate in a suitable polypropylene glycol as hereinbefore described and then dissolving an effective proportion, e.g., from 1 to 20 weight percent or more of the polyglycol solution, in water. Alternatively the alkali metal alkyl phosphate and the polypropylene glycol may be added separately to water either as the commercially pure materials or as aqueous concentrates thereof. Conveniently, the alkali metal alkyl phosphate, or an aqueous concentrate thereof, is first dissolved in water to give an aqueous solution having a metal alkyl phosphate concentration of at least 0.01 percent, and preferably from 0.1 to 10 percent by weight. To such an aqueous solution of the metal alkyl phosphate is added the polypropylene glycol in an amount sufficient to give it, viz. the polypropylene glycol, a concentration greater than 1 percent, and preferably from 5 to 30 percent by weight or more of the total solution. In hot-rolling sheets of light metals to obtain maximum smoothness with little if any pick-up, the optimum concentration of the polypropylene glycol in an aqueous alkali metal alkyl phosphate solution will depend not only on the solubility and molecular weight of the polypropylene glycol but also on the identity and concentration of the metal alkyl phosphate. The optimum concentrations can easily be determined by trial. Excellent results have been obtained in hot-rolling light metals with the aid of a lubricant consisting of an aqueous solution, of approximately 0.5 percent (by weight) of disodium octyl phosphate and 15 to 30 percent of a polypropylene glycol having an average molecular weight of about 400. Such solutions do not readily dissolve or emulsify the mineral oils and greases used in lubricating the journals of the rolls and are therefore not easily contaminated by journal lubricants. This prolongs the useful life of the lubricants of the invention and lessens the possibility of tramp oil stains being present on the rolled surfaces of light metals.

The hot-rolling of light metals is ordinarily carried out in accord with the invention by heating the metal to be rolled to a hot-rolling temperature, e.g., above about 250° F. and preferably at least 400 °F., and passing the heated metal through steel rolls whose surfaces are covered with a lubricating solution as hereinbefore described, e.g., by spraying or flooding it upon the rolls. Good surface finishes may be obtained when sheets of light metals are rolled with the lubricant compositions of the invention at reductions in thickness up to 50 percent per pass or higher. Usually an aqueous lubricating solution consisting of an alkali metal alkyl phosphate and a polypropylene glycol having an average molecular weight in the range of from about 300 to about 1000 is employed in hot-rolling. The water solubilities of these polypropylene glycols decrease as the temperature is increased as shown in the following table wherein P–400 and P–750 are polypropylene glycols having average molecular weights of 400 and 750 respectively.

Solubility in grams/1,000 grams of H_2O	P–400	P–750
Water at 77° F.	α	30
Water at 167° F.	0.1	0.1

These polypropylene glycols are, therefore, displaced from aqueous lubricating solutions during hot-rolling when the solutions come into contact with the hot metal to be rolled. In this manner, a uniform film of the lubricant is distributed over the surface of the light metal.

Films of lubricant compositions employed in the method of the invention are sufficiently strong to prevent actual metal-to-metal contact and adhesion, viz. pick-up, of the light metal by steel rolling surfaces. Alkali metal

alkyl phosphate-polypropylene glycol films also reduce friction between the roll surfaces and the light metal being rolled, e.g., aluminum or magnesium sheet. This is a property distinct from and not necessarily related to the ability of the lubricant to prevent adhesion of metal surfaces. In addition, these films are unusually adherent to the surfaces of the metal being rolled.

Accordingly, smooth mat-like surfaces which have low corrosion rates (as measured by salt-water immersion tests), are obtained when aluminum and magnesium are rolled with the aid of lubricating compositions in accord with the invention. The coating remaining on the surface of the light metal after rolling serves to protect it from chemical attack and atmospheric oxidation long after rolling, even when the light metal is stored under adverse conditions such as exposure to air of relatively high humidity. For example, the coatings remaining on sheets of magnesium-base alloys rolled with aqueous lubricant compositions in accord with the invention are sufficiently protective that little or no magnesium oxide has been found, even by electron diffraction analysis, on the surfaces of sheets so rolled even after annealing them at 800° F. Such a coating also helps to preserve the light metal surface from mild mechanical abrasion brought about by sliding sheets of light metal over each other. Since these coatings are soluble in water, they may readily be removed by water dissolution. Or if desired, the organic portion of the lubricating coating, e.g., the polypropylene glycol, may be burned off the light metal sheet by heating in the presence of air at an elevated temperature of about 800° F. This burn-off may be carried out without forming carbonaceous deposits or otherwise adversely affecting the surfaces of the light metal sheet. The following examples illustrate but do not limit the invention.

Example 1

Magnesium-metal sheets were rolled on a commercial 2-high rolling mill employing an aqueous solution of disodium octyl phosphate and a polypropylene glycol as hereafter described.

A

Three 0.125 inch-thick sheets (6 inches wide by 10 feet long) of a magnesium-base alloy having a nominal composition of 3.0 percent by weight of aluminum, 1.0 percent zinc, and 0.3 percent manganese, balance magnesium of high purity, were heated to about 400° F. and passed between steel rolls heated to about 170° F. The rolls were flooded with a water solution consisting of 0.25 percent by weight of disodium octyl phosphate (in the form of Victor Stabilizer 85) and 15 percent by weight of a polypropylene glycol having an average molecular weight of about 400. Victor Stabilizer 85 is an aqueous solution consisting approximately of 52 percent (by weight) of disodium octyl phosphate, 19 percent monobasic sodium phosphate, and balance water. The magnesium-base alloy sheets were passed once through the rolls at reductions of 20, 30, and 40 percent, respectively. All the rolled sheets possessed good physical properties and the surfaces of all three were exceedingly smooth. They had a uniform mat-like appearance and were free from particles of foreign metals, e.g., steel, as well as rolled-back pick-up, i.e., particles of magnesium metal picked up by the rolls and then rolled back into the sheet. The corrodibility of the rolled sheets was not increased by rolling. No pick-up was observed on the rolls at the end of rolling.

B

Results similar to the preceding were obtained on rolling three more sheets of the same magnesium-base alloy with the aid of the same rolling solution and according to the same procedure described above except that the magnesium alloy sheets were rolled at 800° F. rather than at 400° F. The rolled surfaces of all sheets were uniformly smooth. No pick-up was observed on the rolls at the end of rolling.

C

A sheet of a magnesium-base alloy of the same composition and having a thickness of 0.185 inch was repeatedly rolled with the aid of an aqueous rolling solution similar in composition to that employed above. The magnesium alloy sheet was heated to about 650° F. and passed between rolls flooded with the rolling solution at reductions of about 20 percent per pass. After each pass, the rolled sheet was again heated to about 650° F. Rolling was stopped when the sheet thickness was 0.019 inch. The rolled surfaces of the sheet were uniformly smooth. No contamination, i.e., pick-up, was observed on the rolls after rolling.

D

Commercially pure magnesium sheets were rolled at 650° F. at reductions of 20 percent per pass in accord with the above-described general procedure and employing the same rolling solution as employed above. The rolled surfaces of the magnesium sheets were uniformly smooth. No pick-up was observed on the surfaces of the rolls after rolling.

E

Good results were obtained when commercially pure magnesium sheets were hot-rolled at reductions in excess of 20 percent per pass on steel rolls flooded with an aqueous lubricant solution similar in composition to that employed above except that a higher molecular weight polypropylene glycol having an average molecular weight of about 750 was used.

F

For purpose of comparison, several runs were carried out in the same manner as part B of this example but employing lubricants not in accord with the invention. Sheets of the same magnesium-base alloy were rolled at reductions of 30 percent per pass at a temperature of about 750° F. using the following lubricants: (1) a polypropylene glycol having an average molecular weight of about 400, viz. the same polypropylene glycol used as a component of the lubricant in parts A and B above, (2) a water solution consisting of 0.2 percent (by weight) of monobasic sodium phosphate and 15 percent of a polypropylene glycol having an average molecular weight of about 400, and (3) a water solution consisting of 0.4 percent (by weight) of tricresyl phosphate and 15 percent of a polypropylene glycol having an average molecular weight of about 400. In every run, heavy pick-up was encountered with each of the above lubricants.

Example 2

Fifty sheets of commercially pure magnesium were cold-rolled on a conventional 4-high commercial rolling mill employing a solution of disodium octyl phosphate in polypropylene glycol.

Unheated magnesium sheets .061 inch thick by 48 inches wide by 144 inches long were repeatedly passed at a temperature of about 70° F. between unheated steel rolls coated with a non-aqueous lubricating composition consisting of 0.25 percent by weight of disodium octyl phosphate in the form of Victor Stabilizer 85 dissolved in a polypropylene glycol having an average molecular weight of about 400. This lubricant was continuously wiped on the outer or back-up rolls and transmitted by them to the inner or work rolls. The magnesium sheets were rolled at reductions up to 6.5 percent per pass to a final thickness of about .031 inch. No pick-up occurred during rolling and the corrodibility of the rolled magnesium sheets was not increased by the action of the rolls, by the presence of the lubricant, or by any other substance remaining thereupon after rolling.

Example 3

Aluminum-base alloy sheets were rolled on a conventional 4-high rolling mill with an aqueous solution of disodium octyl phosphate and polypropylene glycol as described below.

Several sheets of an aluminum alloy 0.25 inch thick by 6 inches wide by 8 feet long and having a nominal composition of 4.5 percent by weight of copper, 1.5 percent magnesium, 0.6 percent manganese, 0.5 percent iron, and 0.5 percent silicon, balance aluminum, were cold-rolled at reduction of 50 percent per pass between unheated steel rolls. The unheated rolls were flooded with an aqueous solution of 0.25 percent by weight of disodium octyl phosphate in the form of Victor Stabilizer 85 and 15 percent by weight of a polypropylene glycol having an average molecular weight of about 400. Uniformly smooth rolled aluminum sheets having good surface finishes were obtained.

Similar results were observed upon hot-rolling aluminum alloy sheets of the same composition and using the same aqueous lubricant solution flooded on the rolls as described above. The aluminum alloy sheets at a temperature of approximately 650° F. were passed between the lubricated steel rolls heated to about 170° F. Rolling was carried out at reductions of 30 percent per pass. The rolled sheets possessed good physical properties and had uniformly smooth surfaces. Their corrosion rates were not increased by rolling.

Example 4

Magnesium was hot-rolled at 600° F. substantially as described in Example 1A except that instead of Victor Stabilizer 85 there was used 0.5 percent of disodium cetyl phosphate substantially free of monobasic sodium phosphate. In multiple tests at increasing reductions per pass, no significant pick-up was observed at reductions up to 40 percent and only slight pick-up was noted at higher reductions.

Examples 5–11

Aluminum or magnesium was hot-rolled with various lubricants with the results shown in the following table. The tests were similar to those of the preceding examples with the indicated changes. In every example shown in Table I there was no detectable pick-up, no slippage in the rolls, no difficult entry into the rolls and no staining of the sheets, even after annealing.

TABLE I—METAL ROLLING TESTS

Example	Lubricant	Metal	Temp., ° F.	Reduction per Pass, Percent
5	45% P400, 0.5% V-85, Balance, water.	Mg [a]	800	29
6	Same	Al [b]	800	60
7	30% P400, 1% V-85, Balance, water.	Mg [c]	800	31
8	10% P750, 1% V-85, Balance, water.	Mg [a]	800	48
9	10% 750, 0.5% V-85, Balance, water.	Mg [c]	600	50
10	10% P400, 0.5% V-85, Balance, water.	Al [b]	Cold	35
11	5% P400, 5% V-85, Balance, water.	Mg [c]	800	30

[a] Alloy HK31, essentially 3% Th, 1% Zr, 96% Mg.
[b] Al 2S, 99.99% Al.
[c] Alloy AZ31 esentially 3% Al, 1% Zn, 96% Mg.

I claim:

1. In a method of rolling the light metals, aluminum, magnesium and alloys containing at least 70 percent by weight of one of such metals, the improvement which consists of controlling roll contamination and the effects thereof by supplying at the interface of the roll and metal, a lubricant consisting essentially of a major proportion of a polypropylene glycol having a molecular weight of about 300 to 1000 and a minor proportion of an alkali metal alkyl phosphate having about 8 to 18 carbon atoms in the molecule.

2. In a method of rolling the light metals, aluminum, magnesium and alloys containing at least 70 percent by weight of one of such metals, the improvement which consists of controlling roll contamination and the effects thereof by supplying at the interface of the roll and metal, a lubricant consisting essentially of from 1 to 10 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule dissolved in a polypropylene glycol whose average molecular weight is in the range of from about 300 to about 800.

3. A method of rolling the light metals, aluminum, magnesium and alloys containing at least 70 percent by weight of one of such metals to prepare smooth light metal surfaces protectively coated against oxidation which comprises maintaining at the interface of the roll and the light metal, a lubricant consisting essentially of an aqueous solution of at least 0.01 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule and at least 1 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 300 to about 1000.

4. A method of rolling the light metals, aluminum, magnesium and alloys containing at least 70 percent by weight of one of such metals to prepare smooth light metal surfaces protectively coated against oxidation which comprises maintaining at the interface of the roll and the light metal, a lubricant consisting essentially of an aqueous solution of from 0.1 to 10 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule and from 5 to 30 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 300 to about 800.

5. A method according to claim 4 wherein the alkali metal monoalkyl phosphate is disodium octyl phosphate.

6. A method of rolling the light metals, aluminum, magnesium and alloys containing at least 70 percent by weight of one of such metals to prepare smooth light metal surfaces protectively coated against oxidation which comprises maintaining at the interface of the roll and the light metal, a lubricant consisting essentially of an aqueous solution of from 0.1 to 10 percent by weight of disodium octyl phosphate and from 15 to 30 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 400 to 800.

7. A water soluble lubricant composition consisting essentially of from 1 to 10 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule, dissolved in a polypropylene glycol whose average molecular weight is in the range of from about 300 to about 800.

8. A lubricant composition consisting essentially of an aqueous solution of at least 0.01 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule and at least 1 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 300 to about 1000.

9. A lubricant composition consisting essentially of an aqueous solution of from 0.1 to 10 percent by weight of an alkali metal monoalkyl phosphate having from 8 to 18 carbon atoms in the molecule and from 5 to 30 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 300 to about 800.

10. A lubricant composition according to claim 9 wherein the alkali metal monoalkyl phosphate is disodium octyl phosphate.

11. A lubricant composition consisting essentially of an aqueous solution of from 0.1 to 10 percent by weight of disodium octyl phosphate and from 15 to 30 percent by weight of a polypropylene glycol having an average molecular weight in the range of from about 400 to 800.

12. A method for hot-rolling magnesium comprising maintaining at the interface of the roll and the magnesium a lubricant consisting essentially of an aqueous solution of about 5 to 45% by weight of polypropylene glycol having an average molecular weight of about 400 to 800 and about 0.25 to 5% by weight of disodium octyl phosphate, the balance being water.

13. A method for hot-rolling magnesium comprising maintaining at the interface of the rolls and the magnesium a lubricant consisting essentially of an aqueous solution containing about 15% by weight of polypropylene glycol having an average molecular weight of about 400 and about 0.1% by weight of disodium octyl phosphate, the balance being water.

14. A water-soluble lubricant for the hot-rolling of magnesium consisting essentially of about one part by weight of disodium octyl phosphate and about 150 parts by weight of polypropylene glycol having an average molecular weight of about 400.

15. An aqueous lubricant for the hot-rolling of magsium consisting essentially of about 15% by weight of polypropylene glycol having a molecular weight of about 400 and about 0.1% by weight of disodium octyl phosphate, the balance being water.

16. A method for hot-rolling magnesium comprising maintaining at the interface of the rolls and the magnesium a lubricant consisting essentially of an aqueous solution containing about 15% by weight of polypropylene glycol having an average molecular weight of about 400 and about 0.5% by weight of disodium cetyl phosphate, the balance being water.

17. An aqueous lubricant for the hot-rolling of magnesium consisting essentially of about 15% by weight of polypropylene glycol having an avreage molecular weight of about 400 and about 0.5% by weight of disodium cetyl phosphate, the balance being water.

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