

1

3,124,531

METAL WORKING LUBRICANT

Joshua C. Whetzel, Jr., Fox Chapel, and Sayre Rodman,
Oakmont, Pa., assignors to Far-Best Corporation, Los
Angeles, Calif., a corporation of California
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This invention relates to improved lubricants for use
in working metal as by rolling, drawing or forging alumi-
num or other metal and is described herein particularly
as applied to the rolling of aluminum sheets and foil.

While rolling aluminum and aluminum alloys to pro-
duce sheet or foil, lubricants are used to decrease friction
between the metal and rolls of the rolling mill and to pro-
mote good surface finish. These lubricants also serve as
heat transfer fluids to remove heat generated in the rolls
and metal during rolling. In addition to the above uses,
lubricants should be compounded so as to minimize stain
on the surface of the metal during anneal cycles or in stor-
age. These lubricants should be non-toxic to mill per-
sonnel in use and also non-toxic to subsequent users of
the metal if residual films of lubricant remain on the
metal surface. Further, these lubricants should not pos-
sess objectionable odors and they should satisfy the usual
criteria of availability and economy.

Lubricants used for rolling of aluminum are almost al-
ways mixtures of polar or "oiliness" additives with light
mineral or hydrocarbon oils or distillates.

The additives employed for aluminum rolling are gen-
erally fats, such as palm oil or lanolin, or other esters of
fatty acids, such as butyl stearate. The purpose of these
additives is to provide the light mineral oil or mineral
distillate with more "oiliness" or "boundary" lubricating
ability than it would otherwise possess. Generally, these
fatty esters, being closely related chemically, all work in
about the same way. They show characteristic relation-
ships between concentration in a lubricant and resultant
effects.

The effect of additives in rolling lubricants is to im-
prove the lubricating ability of the oil, thus decreasing
friction in the roll bite between rolls and metal. By re-
sultant effects, a decrease in friction allows greater and
more efficient reduction in thickness of the metal being
rolled. These additives also, through their chemical or
polar action, serve to decrease the tendency of the metal
to weld to or "pick up" on the surface of the rolls during
rolling.

For most rolling jobs, the concentration of additive in
the light petroleum oil or distillate will range from 1 to
about 10%.

At intermediate stages in the manufacture of aluminum
sheet or foil, the rolled strip metal must be annealed or
heat treated to soften its structure. In a majority of cases,
probably, the final manufacturing step before shipment
will be an annealing treatment. The typical heat treating
cycles demand that the metal be heated for a period of
time at temperatures ranging from about 650° F. to about
900° F., usually in an inert atmosphere. Because of in-
dustry practices, the rolling lubricant is allowed to remain

2

on the metal surface during this operation. Thus, care-
ful attention must be given to the tendencies of both addi-
tive and base oil to form residues as a result of such heat-
ing. These residues which commonly occur to a minor
extent are called "stains" and appear on the metal surface
as a discoloration, marring the luster and value of the
product.

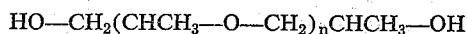
Of prime importance in considering the "staining" tend-
encies of a potential additive or base oil is the boiling
range of these materials and their heat degradation (crack-
ing or polymerization) behavior in atmospheres of the
type found in annealing furnaces.

The vehicle used for rolling, light mineral or petroleum-
derived light oils and distillates, will vary in viscosity in
usual work from about 30 to about 60 Saybolt seconds,
universal, at 100° F. The choice of viscosity for a par-
ticular rolling job will vary with the particular require-
ments. Reduction per pass, assuming equivalent rolling
loads and equivalent additive concentration, normally in-
creases with increasing oil viscosity. Capacity of a lubri-
cant to remove heat from the rolls and metal will vary
inversely with increasing viscosity. Also, finish or luster
of the rolled metal is somewhat dependent upon the vis-
cosity of the lubricant used in rolling, so long as other
factors, unrelated to lubrication, remain equal. And, in
addition, the amount or degree of stain remaining on the
rolled product after annealing will vary directly with oil
viscosity and boiling range.

Therefore, to provide the desired properties and neces-
sary requirements in particular cases of rolling, we find
relatively well defined lubricants in general use. For
heavier so-called "sheet" gauges or on breakdown mills
rolling sheet destined for lighter gauges, light mineral oils
with viscosities of about 38 to 45 Saybolt seconds, uni-
versal, at 100° F., are used compounded with about 1 to
5% of fatty oils or fatty acid esters. In the manufacture
of light gauge aluminum sheet and foil, close control of
roll temperature is necessary to control roll shape and
thus good heat transfer fluids are needed. This require-
ment dictates the use of lighter distillates, such as kero-
sene, in the viscosity range of 30 to 35 Saybolt seconds,
universal, at 100° F. Also, in such application, less re-
duction is often taken and, at the same time, luster, finish
and stain requirements are very strict. All of the require-
ments dictate the use of light distillates, such as kerosene,
usually compounded with 5% or less of fatty oils or fatty
acid esters.

An object of our invention is to provide a more useful
additive than has been known previously for use in light
mineral oils and distillates to form a lubricant for metal
working, particularly to lubricate the rolling of aluminum
sheet and foil.

We have found that the combination of fatty alcohols
of the general formula $R-OH$, where R is a straight
paraffinic chain of from 10 to 20 carbon atoms, either
saturated or partially unsaturated, and polypropylene gly-
cols of the general formula



and average molecular weight ranging from 134 through

4000, possess unexpected excellent properties as additives for rolling aluminum sheet and foil when dissolved in light petroleum oils and distillates having viscosities ranging between 30 and 80 Saybolt seconds, universal, at 100° F., the viscosity preferably being between 30 and 60 Saybolt seconds, universal, at 100° F.

Fatty alcohols are produced by high pressure catalytic hydrogenation or sodium reduction of fatty acids or fatty acid esters derived from fats. The commercial grades of

The lower members of the polypropylene glycol series (below 750 average molecular weight) are almost completely insoluble in the usual light mineral oils and distillates used for rolling aluminum. One of the purposes of the fatty alcohol in the mixture is to provide a coupling action, thus providing mutual solubility of the glycol and mineral oil.

Typical compositions according to the invention are given in Table 1.

Table 1

[Components, parts per 100, by weight]

Composition No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Name of Component:																				
Coml. Lauryl Alc.	3		3				3													
Coml. Oleyl Alc.		3		3	2	3		3	3.95	3.825	3.65	3.3	2.6	2	2	3	12	6	1.5	.75
Tallow Alcohol									.05	.175	.35	0.7	1.4				4	2	.5	.25
Dipropylene Glycol	1		1	1			1	1												
Polypropylene Glycol 150		1			2	1														
Polypropylene Glycol 425														2						
Polypropylene Glycol 1025															2					
Polypropylene Glycol 3000																2				
Kerosene, 31 SUS, 100° F.	96	96																		
Light Min. Oil, 37 SUS, 100° F.			96	96	96	96	96		96	96	96	96	96	96	96	96	84	92	98	99
Light Min. Oil, 58 SUS, 100° F.								96												

fatty alcohols are mixtures of several different alcohols, reflecting the mixtures of fatty acids in the fat from which they were derived. Thus, in the terminology of these materials, we have mixtures known as "coconut" or "tallow" alcohols, meaning that they were derived from coconut oil or tallow.

Typical mixtures of fatty alcohols which are suitable for use in this invention are as follows.

CHEMICAL ANALYSIS

	Com. Lauryl Alc.	Coml. Oleyl Alc.	Coml. "Tallow" Alc.
Hydroxyl Value	285-300	210-230	234
Saponification Value	2.0	3.0	5.0
Acid Value	1.0	0.1	0.1
Iodine Value	1.0	60-75	1.0

COMPOSITION, BY TYPE OF ALCOHOL, PERCENT

Alcohol	Chain Length, Carbon Atoms	Coml. Lauryl Alc.	Coml. Oleyl Alc.	Coml. "Tallow" Alc.
Decyl	10	2		
Lauryl	12	66	5	4
Myristyl	14	23	15	44
Cetyl	16	9	35	24
Oleyl	18		35	
Stearyl	18		5	28
Arachidonyl	20		5	

Polypropylene glycols, the other component of our novel mixture, are synthetic organic chemicals derived from polymerization of propylene oxide. They are colorless liquids, identified by their average molecular weights, which range from 134 (dipropylene glycol) through 4000, the highest member of the homologous series now in commercial production. Typical specifications of a few members of this series follow:

AVERAGE MOLECULAR WEIGHT

	150	425	750	1025	3000
Specific Gravity, 20/20° C.	1.0246	1.0114	1.004 (25°C)	1.0070	1.001 (25°C)
Viscosity, Centistokes, 210° F.	3.0	4.5	7.8	10.9	50.9
Flash Point, ° F.	250	385	495	420	440
Solubility in Water, 20° C, percent	(1)	(1)	(1)	0.2	<0.1
Solubility in Heptane, 20° C, percent	(2)	50	(1)	(1)	(1)

¹ Complete.
² Insoluble.

The mixtures of fatty alcohols and polypropylene glycols of our invention are unique in that the combination of the materials is a better lubricant than equivalent concentrations of either the fatty alcohols or the polypropylene glycols alone. The following Table 2 illustrates this phenomenon. The data were obtained under actual rolling conditions, rolling aluminum strip of the thickness indicated on a rolling mill equipped with instruments for measuring rolling loads. The comparative figures given are reductions in thickness of the strip, in one pass, at constant rolling load, as indicated. Reduction under these conditions is a direct function of decrease in friction caused by the lubricant.

Table 2

Lubricant Composition	Reduction, percent of .005 in. Aluminum Alloy 1100, Rolling Load 5500 lbs. per in. of Strip Width	
Comp. No. 4.....	64	
Comp. No. 14.....	64	
Comp. No. 15.....	65	
Comp. No. 16.....	64	
4 parts Polyprop. Gly. 1025, 96 parts Light Min. Oil, 37 SUS.....	59	
4 parts Polyprop. Gly. 3000 in 96 parts Same Oil.....	61	
4 parts Tallow Alcohol in 96 parts Same Oil.....	63	
4 parts Butyl Stearate in 96 parts Same Oil.....	58	
4 parts Palm Oil, 96 parts Same Oil.....	58	
4 parts Lanolin, 96 parts Same Oil.....	59	
Light Mineral Oil alone, 37 SUS.....	47	
	Reduction, Percent of .0033 in Aluminum Alloy 1100	
	Rolling Load 5200 lbs. per in. of Strip Width	Rolling Load 7500 lbs. per in. of Strip Width
Comp. No. 4.....	52.7	59.2
4 parts Tallow Alchol, in Light Min. Oil, 37 SUS (Saybolt seconds, universal).....	50.6	55.5

Lubricants of our invention are more efficient for rolling aluminum strip than the commonly used fats or fatty acid esters in a number of cases of rolling, using various gauge aluminum, various loads and various base oils, as the following Table 3 shows:

Table 3

Alum. Strip Gauge (in.).....	.011	.0033	.0033	.0033	.005
Rolling Load, lbs. per in. of Width.....	5,800	5,400	7,800	7,800	7,900
Composition of Lubricant:	Reduction, percent				
Comp. No. 1.....	66				
Comp. No. 2.....	69				
4 parts Palm Oil, 96 parts Kerosene.....	59				
4 parts Butyl Stearate, 96 parts Kerosene.....	63				
4 parts Lanolin, 4 parts Kerosene.....	63				
Kerosene, alone, no additive.....	40				
Comp. No. 3.....	53	58			
Comp. No. 4.....	51				
Comp. No. 5.....	52	58			
Comp. No. 6.....	52	57			
Comp. No. 7.....	52	59			
4 parts Palm Oil, in Light Min. Oil, 37 SUS.....	43	50			
4 parts Butyl Stearate, in Light Min. Oil, 37 SUS.....	46	50			
4 parts Lanolin, in Light Min. Oil, 37 SUS.....	48	53			
Light Min. Oil, 37 SUS, No Additive.....	30	38			
Comp. No. 8.....			58		69
4 parts Palm Oil, in Light Min. Oil, 58 SUS.....				55	65
4 parts Butyl Stearate, in Light Min. Oil, 58 SUS.....				56	66
4 parts Lanolin, in Light Min. Oil, 58 SUS.....				56	64
Light Min. Oil, alone, No Additive.....					57

For comparing a range of concentrations of our lubricant mixtures and a commercial product, we have chosen a typical ratio of alcohol to glycol, as described below. This has been compared to the same concentrations of butyl stearate, in a typical base oil, a light mineral oil, viscosity 37 SUS at 100° F.

The effect of additions of polypropylene glycol to a fatty alcohol in improving the lubricating properties is shown in the following Table 5, with reduction as a function of percent glycol, in a typical alcohol and glycol mixture. The total mixture was held constant at 4 parts by weight in a light mineral oil, 37 SUS at 100° F.

Table 5

Percent Polyprop. Glycol 150 in a Mixture of Tallow Alcohol and Polyprop. Gly. 150	Reduction, Percent, of .0033 in. Aluminum Alloy 1100, Rolling Load 7800 lbs. per in. of Strip Width
0	54.6
1.25	56.1
4.37	56.3
8.75	57.0
17.50	58.2
35.00	58.8

A definite improving effect of glycol content is noted at the initial addition level of 1.25%.

Some of the novel lubricant additive mixtures of our invention are superior also from the anneal stain point of view. As mentioned previously, an excellent criterion of freedom from anneal stain is the boiling range of the material in question. Since the removal of lubricant from the aluminum sheet or foil during the heat treating cycles is essentially a distillation process, we have used distillation tests as a means of comparing their staining tendencies. We list below in Table 6 the temperatures at which the indicated percentages of materials were distilled and the quantity and type of residue, if any, which remained in the flask when distillation was complete. These residues denote the relative staining quality at the final tem-

Table 6

Composition	Temperature of Liquid at Which Indicated Percent of Volume was Distilled. (Atm. Pressure)							Residue
	Init. B. P.	10%	50%	80%	90%	95%	End Pt.	
4 parts Coml. Lauryl Alc., 1 part Polyprop. Gly. 150.	480	495	525	545	570	595	670	None.
3 parts Tallow Alc., 1 part Polyprop. Gly. 150.	503	532	593	626	649	680	785	Do.
Polyprop. Gly. 150.....	464	468	491	527	536	545	549	Do.
Butyl Stearate.....	670	685	710	735	735	775	875	Moderate Carbon and Varnish.
Palm Oil.....		750	775	815	850	885	935	Very large amts. Carbon and Residue.
Kerosene.....	390	400	410	425	435	440	460	None.
Light Min. Oil, 37 SUS.....	520	528	545	565	590	597	615	Do.

Table 4

Concentration of Additive in Light Min. Oil, %	Reduction, Percent of .0033 in. Aluminum Alloy 1100, Rolling Load 6500 lbs. per in. of Strip Width	
	Mixture: 3 parts Tallow Alcohol; 1 part Polyprop. Gly. 150	Butyl Stearate
1	47	43
2	53	46
4	56	51
8	59	53
16	61	59

peratures indicated. However, since much aluminum annealing is performed at temperatures below the final temperatures indicated in some cases, those materials with abnormally high end points on distillation would be unsatisfactory because of undistilled liquid residues which remain on the sheet surfaces. In this work, a neutral (natural gas) atmosphere was employed in line with the common practice in the industry. If oxidizing atmospheres had been employed, the results would have been different with, in most cases, more residues and higher final distillation temperatures.

Several comparisons can be drawn from these data. Since light mineral oils are invariably used, there would be no advantage in using an additive having a lower boiling range than they exhibit. It is desirable that the additive approach as closely as possible to the limit which

these oils set so that higher anneal temperatures need not be maintained simply to drive off additives present on the finished sheet. This is the fault from which fats and fatty esters suffer, as can be seen. Their end points in distillation are so high that operators are forced to heat their product much above temperatures necessary to heat treat the aluminum. These practices, of course, are wasteful and expensive of times and efficient use of the furnaces.

According to our invention, the lubricant comprises an additive dissolved in a light petroleum oil or distillate having a viscosity between 30 and 80 Saybolt seconds, universal, at 100° F., the additive constituting about 1 to 25%, by weight, of the oil or distillate, the additive being a mixture of fatty alcohols of the general formula $R-OH$, where R is a straight paraffinic chain of from 10 to 20 carbon atoms, either saturated or partially unsaturated, and polypropylene glycol having an average molecular weight between 134 and 4000, the polypropylene glycol amounting to about 1 to 75%, by weight, of the additive.

The invention is not limited to the preferred embodiment but may be otherwise embodied or practiced within the scope of the following claims.

We claim:

1. A metal working lubricant consisting essentially of an additive dissolved in a light petroleum oil having a viscosity between 30 and 80 Saybolt seconds, universal, at 100° F., the additive constituting about 1 to 25%, by weight, of the oil, the additive being a mixture of fatty alcohols of the general formula $R-OH$, where R is a straight paraffinic chain of from 10 to 20 carbon atoms with not more than one double bond, and polypropylene glycol having an average molecular weight between 134 and 4000, the polypropylene glycol amounting to about 1 to 75%, by weight, of the additive.

2. An additive for light petroleum oils and distillates to improve their lubricating properties, said additive con-

sisting essentially of a mixture of fatty alcohols of the general formula $R-OH$, where R is a straight paraffinic chain of from 10 to 20 carbon atoms with not more than one double bond, and polypropylene glycol having an average molecular weight between 134 and 4000, the polypropylene glycol amounting to about 1 to 75%, by weight, of the additive.

3. A metal working lubricant consisting essentially of an additive dissolved in a light petroleum oil having a viscosity between 30 and 80 Saybolt seconds, universal, at 100° F., the additive constituting about 1 to 25%, by weight, of the oil, the additive being a mixture of fatty alcohols of the general formula $R-OH$, where R is a straight paraffinic chain of from 10 to 20 carbon atoms with no double bonds, and polypropylene glycol having an average molecular weight between 134 and 4000, the polypropylene glycol amounting to about 1 to 75%, by weight, of the additive.

4. An additive for light petroleum oils and distillates to improve their lubricating properties, said additive consisting essentially of a mixture of fatty alcohols of the general formula $R-OH$, where R is a straight paraffinic chain of from 10 to 20 carbon atoms with no double bonds, and polypropylene glycol having an average molecular weight between 134 and 4000, the polypropylene glycol amounting to about 1 to 75%, by weight, of the additive.

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