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COOLANT AND LUBRICANT COMPOSITION AND METHOD FOR COLD WORKING METAL

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This application is a continuation-in-part of application Serial No. 63,277 filed October 18, 1960, now abandoned, which in turn, is a continuation-in-part of application Serial No. 723,988 filed March 26, 1958, and now abandoned.

This invention relates to rolling oils and processes for rolling ferrous and non-ferrous metals employing such rolling oils.

Prior to our invention, cold reduction for continuous reduction of the thickness of metals, at high speeds, employed lubricants applied to the metal or to the work rolls of the mill. Such oils termed rolling oils have been used in production of flat products, angles, moldings, architectural shapes, pipes, tubes and other products. The most important rolling operation is the high speed production of heavy gage sheet steel, tin plate, sheet steel for galvanizing and stainless steel sheets.

The common rolling lubricants were either vegetable, animal or mineral oils, for example, palm oil, tallow oils, straight mineral oils and others. Such oils have been applied to the metal and rolls with a separate, simultaneously applied stream of water. Such procedures are referred to as "direct application." In other procedures, the water and oil were combined and were applied as a dispersion or mechanical mixture. Such systems are referred to as "recirculating systems." In such systems, the oil may be returned for a limited number of cycles. In the direct application systems, the oil is usually discarded after a single use. Great difficulty has been experienced in producing uniform batches of rolling oil or lubricant dispersions which would permit efficient operation of cold-rolling mills. Most of the lubricants employed in the prior art have been developed on a trial-and-error basis, and it has always been a problem to obtain the correct proportions at a given time under a specific set of circumstances. As a result, difficulty known as "solution trouble" frequently arises, causing frictional pick-up on the rolls, skidding and poor shape of the strip (wavy edge, full center or hot streaks), resulting in high power consumption and necessitating operation of the mill at low speed. A further problem is that many of the ingredients used as lubricants vary widely in composition and, consequently, it is very difficult to maintain the desired mixture at all times.

Further, it proved difficult to remove the prior art oils. These prior art oils tend to stain the surface. The resultant rolled metal thus were contaminated with lubricant residues which interfere with subsequent operations, such as electroplating, lacquering or lithography. Such residues may not be readily removed by detergents. The prior art oils do not possess good "burn off" characteristics.

We have invented a composition adapted to be used straight, but preferably in low concentration dispersed in water, which satisfactorily meets all the special requirements for cooling and lubricating strip as it is being cold rolled.

The composition of our invention arises from our discovery that rolling oils are greatly improved in performance if the fatty acid or glyceryl ester employed as the prior art rolling oil, in the form of mineral, vegetable, animal oils and fats is replaced in whole or in part, by a compound, containing an acyl radical, of molecular weight higher than the molecular weight of the acid or ester of the natural lubricant. We employ the term natural lubricant as a collective term for the mineral or fatty oils, for example, vegetable, animal oil and fats since they are derived from mineral oil, i.e., petroleum or from vegetable or animal matter respectively. For example, the higher molecular weight compound may be a dimer of about two times the molecular weight of the monomer fatty acid radical, or a trimer of about three times the molecular weight of the monomer fatty acid radical, may be used in place of, or in addition to, the ester or acid of the natural lubricant.

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It has long been known that the unsaturated fatty acids of the C_{16} to C_{22} carbon atoms or their alkyl esters, may be polymerized to form dimeric and trimeric polymer forms of the monomeric acid or ester. Such polymers are described in U.S. Letters Patents and in the prior art. These are here referred to as a further description of the polymer acids employed in our invention.

By way of illustration, and not as a limitation of our invention, reference may be had to the following patents and literature for further description of the polymeric acids and esters, and methods for their manufacture; T. F. Bradley et al., Industrial Engineering Chemistry, vol. 32 (1940), pages 694–697 and pages 802–809; vol. 33, 1941, pages 86–89; Moore Paint Oil and Chemical Review of January 4, 1951, in an article entitled, "Dimer Acids"; U.S. Patents 2,482,761, 2,793,219, 2,793,220.

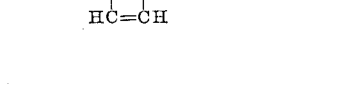
These processes cause polymerization of unsaturated monomer fatty acids, for example, of C_{18} to C_{22} carbon atoms, or esters thereof of vegetable, animal or oils of synthetic origin. For example, polybasic acids may be obtained by polymerization of oleic and recinoleic, linoleic, linolenic, lineolaidic, eleostearic acids or their esters. These esters may be the lower alkyl esters, for example, the methyl, ethyl, propyl or butyl ester, that is, the C_1 to C_4 alkyl esters of the acids. Thus, for example, the propyl ester may be glyceryl ester or the hydroxypropyl ester, i.e., propane polyol esters. Other singly or doubly unsaturated fatty acids or their esters of suitable chain length, will also produce polymer acids or their polymer esters. The above polymerization produces the dimeric forms in which two of the monomeric radicals are joined. In the usual case, however, some trimer form is also produced in which three monomers are condensed and also a small amount of the unreacted monomeric acid or ester may also be present in the reaction product. The average carbon content of the mixture of these polymers depends on the degree of the polymerization in the polymer reaction and the content in the polymer of the monomer, trimer, tetramer and higher polymers of the monomer. The structure of these polymers have not been fully elucidated, Bradley and Moore cited above have postulated structures.

Bradley (J.I.E.C.), vol. 32, page 806, gives the following structure:

For dimer of linoleic acid esters:

$$CH_3(CH_2)_4CH{=}CHCH_2{-}CH{=}CH(CH_2)_7COOR$$

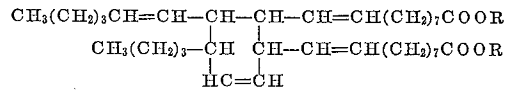
produces the dimer, dilinoleic acid:



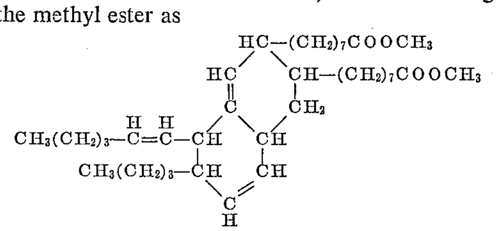
Eleostearic esters:

$CH_3(CH_2)_3(CH{=}CH)_3(CH_2)_7COOR$

produces the dimer, dieleostearic ester



For the trimer of the eleostearic ester, that is, the bicyclic dimer of the eleostearic ester, the formula is given for the methyl ester as



There may also be formed, a tetrameric form by further polymerization and some unreacted monomer is present. The number of carbons present in the mixture of polymers thus depends upon the chain length of the monomer. The average number of carbons in the product may vary from 32 to 54 carbon atoms.

The polymer acid is further characterized in that the carboxyl groups are seperated from each other by relatively long carbon to carbon chain. Thus, for example, linoleic acid may form a mixture of dilinoleic acid molecule with 36 carbon atoms, and trilinoleic acid molecules having 54 carbon atoms. Usually mixtures are formed containing some monomer, thus producing a polymer mixture of C_{18}, C_{36} and C_{54} molecules. As reported by Mason referred to above, the dimers of the C_{18} whose molecular weight would be 560 and having an equivalent weight of 280, because of the presence of trimers and some monomers, such polymers have, for example, an equivalent weight of about 300, with an average composition of 85% dimer, 12% trimer and 5% monomer. Since the polymerization product may include as well, some monomeric form of the C_{18} monomer, the number of carbon atoms may be reduced below 36. Thus, the average number of carbons in the molecules forming the polymer mixture, may range from 32 to 54 carbon atoms.

I have found that such polymerized fatty acids, when employed as such or esters, for example, alkyl esters such as the polyol or amido esters, in place of, or in addition to the fatty acids and fatty acid esters of the prior art rolling oils, produce a highly improved rolling oil and metal working process.

In general terms, our composition consists essentially of a polymerized fatty acid or its ester, preferably a dimer or trimer, or mixtures thereof, of a straight chain compound, which polymerized fatty acid, contains an average of from 32 to 54 carbon atoms. Preferably, we employ mixtures of dimers and trimers of the doubly unsaturated C_{18} fatty acids or their esters, which produces a dimer of 36 carbons, and trimer of 54 carbons.

The polymer of linoleic acid were sold prior to the filing date of the parent application, Serial No. 63,277. Such products have been commercially available since prior to the filing date of the parent application. A product was sold as Empol 1022, a polymerized fatty acid and stated to be C_{36} dibasic acid resulting from the polymerization or dimerization of C_{18} unsaturated fatty acids. This is a liquid which is quite viscous and having typical characteristics as follows: dimer content of 75%, trimer content 22%, monomer content 3%, specific gravity of 0.95 measured at 15.5° centigrade against water 15.5° centigrade, and having viscosity of about 10,000 centistokes at 25° centigrade. This material has an acid value of 180 minimum, a saponification value of 185 minimum and the equivalent weight of 289 to 304 per carboxylic acid group. Another such polymer acid was sold as Emery 3065–S. This had an acid value of 186 to 194, a saponification of 191 to 199, an equivalent of 289 to 282 per carboxylic acid group, and had the following typical composition: dimer 76 to 78%, trimer 22 to 24%, monomer 1%, specific gravity 0.947 at 15.6° centigrade/15.6° centigrade. Another form of the dimer was sold as Emery 3079–S, and had an acid value of 188 to 192, saponification value of 194 to 198, neutralization equivalent of 292 to 298, and had the following typical analysis: dimer 94 to 98%, trimer 2 to 5%, monomer 1%, specific gravity 0.947 at 15.6° centigrade/15.6° centigrade.

Moore, supra, reports a composition for the polymer produced from linoleic acids containing 85% dilinoleic acid, 12% trilinoleic acid and 3% monomer linoleic acid.

A preferred polymer is the dimer acid sold by the Textilana Corporation of Hawthorne, Los Angeles County, California, under the trade name Textilana 2116. This is understood to be substantially the dimer of linoleic acid containing some trimer and tetramer, acid value of from 150 to 170, with an equivalent weight of 330 to 374 per carboxylic acid group, and a viscosity of 39,000 to 41,000 centipoises measured on a Brookfield Syncho-Lectric Viscometer. Such products have long been commercially available as it was well known in the art prior to our invention.

All of the above compounds are polymer acids containing predominantly the dimer form in which two monomer molecules have condensed. They contain also some trimer forms in which three monomer molecules have condensed. They also contain a minor amount of monomer. They may also contain some tetramers formed from four monomer molecules. The molecular weight of the individual polymer molecules is thus from 2 to about 4 times the molecular weight of the monomer. The weighted average molecular weight of the polymer mixture, which may include the monomer, thus, may be from less than 2, to less than 4 times the molecular weight of the monomer. In the above examples, the weighted average molecular weight ranges from about 2 to 2.25 times the molecular weight of the monomer, calculated as 280, i.e., the molecular weight of linoleic acid.

We prefer to employ this polymerized fatty acid together with a lubricating oil, such as a mineral oil or a fatty oil of animal or vegetable origin such as sperm oil, lard oil, tallow oil or cottonseed oil. Such oils normally contain some free fatty acids as well as their glycerides. We refer to such esters and their free fatty acids as fatty acyl compounds. A portion, or all of the polymer acids may be replaced by an ester and acid esters of the polymer acid, for example, an ester of a low molecular weight diol or triol. Examples of polyol esters are the hydroxy propyl or glycerol esters of the polymeric acid or amido partial esters of the polymer acid, formed by reaction between an hydroxyl amine and the polymer acid so as not to esterify or amidate all the carboxylic groups of the polymer acids, as will be understood by those skilled in this art from the term amido partial ester polymer acid. For some purposes, the partial substitution of mineral oil for animal oil or vegetable oil, may be made.

When such composition is dispersed in water at a concentration of from 2 to 20% by volume, the acid and the ester, if used, impart polar characteristics to the oil. As a result, the oil phase will wet the strip and adhere to it for good lubrication, yet the water phase will have sufficient contact with the strip to cool it and still be capable of rapid separation from the strip so that the maximum amount of water will contact the strip for optimum cooling. The acid and ester have polar characteristics which aid in dispersion of the oil on agitation. The dispersion is only temporary, however, since the oil and water phases separate promptly on standing. However, if additional stability of the dispersion is desirable, an emulsifier, for example, a non-toxic emulsifier such as Nitrene OE, understood to be a polyglycol fatty acid ester complexed with a fatty amide, may be used. Other well known emulsifiers or dispersion stabilizers, preferably of the non-ionic type, such as is listed in Detergents and Emulsifiers, published by John W. McCutcheon, Inc., of New York, may be used.

More particularly, our composition preferably includes from 75 to 97% of the fatty acid compounds of the fat or oil of the above-mentioned group, and from 3 to 25% of the polymerized fatty acid or their esters, or amido esters, of the aforementioned group.

We have discovered that polymeric fatty acids of the types designated are, surprisingly, liquid at room temperature and, although they have a high viscosity, do not tend to thicken or solidify. These acids are not as readily saponifiable as are normal fatty acids. They are not as reactive generally, and are more stable thermally and have a higher vaporization point. Such properties give to a water dispersion of our composition a higher load-bearing capacity.

The invention may be more fully understood by reference to the following typical examples, in which all proportions are by weight:

Example 1

The composition containing 95% by weight of tallow, 5% by weight of fatty acid dimer is employed in the rolling operation according to the procedures previously described, either in the direction application or in the recirculation systems. Preferably, we employ the oil in the recirculation system by mixing it with from 98 to 80% by volume of water and recirculating the mixture.

The dimer may have an average value of the number of carbons per mol of from 32 to 54. The dimer acid produced from linoleic acid is an example of such a dimer acid, as described above. In the following examples, the percentages are by weight.

Example 2

Instead of 95% tallow and 5% fatty acid dimer of Example 1, I may use in the above process, for example, as in Example 1, 40% lard and 40% sperm oil and 20% of fatty acid dimer of Example 1.

Example 3

The rolling oil employed in the above examples may employ the fatty-acid dimer of Example 1, may be 25% by weight and 55% by weight of sperm oil, and 20% by weight of a mineral oil which may have viscosity in the range of from 100 to 1000 Saybolt seconds Universal at 100° F.

Example 4

The fatty-acid dimer of Examples 1–3, may be replaced by 15% of an amido partial ester of the trimer form of the polymeric acid referred to in Example 1, the remaining 85% of the rolling oil may be sperm oil.

Example 5

The fat in the rolling oil employed in the process of Example 1, may consist of 50% lard, 25% cottonseed oil, and a polymer of 15% of the fatty-acid dimer of Example 1, and 10% of the amido partial ester of the dimer of Example 1.

Example 6

The oil fraction in the rolling oil employed in the process of Example 1, may be 80% by weight of cottonseed oil, and the dimer of Example 1, may be replaced by 10% of a polymeric acid of about 32 to 54 carbon atoms, and 10% by weight of hydroxypropyl ester thereof. For example, the polymer may be that of Example 1, and the hydroxypropyl ester may be the monoester of the polymeric acid esterified by dihydroxy propane.

Example 7

The oil in the rolling oil employed in the process of Example 1, may be 80% of whale oil, and 15% of the fatty-acid polymer of Example 6, and 5% of the glycerol ester of the polymer acid, for example, the monoglycerol ester of the polymer acid.

Of the several examples given, Example 2 is preferred for most strip-rolling operations.

Use of the composition of our invention effects material improvements in the rolling, cold reduction or extrusion of metals, resulting in better quality of product, reducing the power required and permitting maximum operating speed of the equipment involved. Our improved lubricant and coolant makes it possible to produce material with an even and uniform shape and with a good surface, free from frictional pick-up or similar defects attributable to poor lubrication or mill shape. It also affords greater flexibility in making both heavy and light reductions on a given concentration of lubricant without unfavorable effect on the shape of the material being processed.

A further advantage is that our composition makes possible a cold-reduced product with a surface free from undesirable residues which would interfere with subsequent electroplating, lacquering or lithographing operations. The lubricant may be readily removed by an alkaline or electrolytic cleaner or detergent washing and will have improved burn-off characteristics in the annealing, i.e., it leaves no undesirable residues on the surface of the strip after annealing.

The invention also permits the use of cheaper and more plentiful oils, which are not ordinarily usable in the cold reduction of metals, by the addition of a sufficient quantity of fatty-acid polymers or their esters. This makes possible the use of a wide variety of oils which, in case of shortages, import difficulties or high price, could be substituted in order to provide the most economical combinations.

Illustrative of the improvement and performance of the rolling oil of our invention, as compared to employing the glycerides of the prior art, i.e., the oils and fats alone, the following is given by way of illustration of the benefits obtained by the process of our invention employing the rolling oils of our invention.

Example 8

The following rolling oils were tested in the Timken Lubricant Test which gives the load in pounds above which seizure occurs between two loaded bearing surfaces on which the test oil is placed. This test is described in Lubricant Engineers Manual (Laboratory) published by the National Tube Division of the United States Steel Corporation, Pittsburgh 30, Pennsylvania. It is thus an empirical measure of the suitability of rolling oils. The higher the load at which seizure occurs, the better the rolling oil. The oils were mixed with water (10% oil by volume, and 90% water).

Oil:	Load in pounds at seizure
A Tallow (100%)	15
B 94% of A and 6% of Textilana 2116	70
C Sperm oil (100%)	10
D 90% Sperm oil 10% of Textilana 2116	40
E Palm oil	10
F 100 viscosity pale petroleum lubricating oil	2

Example 9

Previously degreased sheet stock, ¼" wide and 0.0061 inch thick work-hardened, low-carbon steel, was rolled employing rolling oil as given below, all under the same load conditions (6000 pounds vertical load) and at the same rolling speed of 500 feet per minute. The oil and water in all tests were maintained at about 50° C. to insure that the tallow was in melted condition. The oil was wiped on the strip at about 10 inches ahead of the mill rolls, and a stream of water, when used, was directed into the roll bite at the rate of about ½ gallon per minute.

Oil G was 100% tallow; 200 SSU at 100° F.

Oil H was 89.6% tallow; 10% Textilana 2116, and 0.4% non-ionic emulsifier

Oil I was 89.6% tallow; 7% of Empol 1022 and 0.4% non-ionic emulsifier

Oil J was 100% light mineral oil; 200 SSU at 100° F.

Oil K was 89.6% of the above light mineral oil; 10% Textilana 2116, and 0.4% emulsifier

Oil	Percent Reduction	
	Water on Roll	No Water on Roll
G	50.8	57.3
H	55.1	60.5
I	56.8	61.3
J	24	34.8
K	36	44.0

Percent reduction was measured as the decrease in thickness of the stock as a percent of the original thickness. For the same rolling conditions, the reduction of the strip was much greater when a portion of the fat or mineral oil was substituted by the polymer acid. Under the conditions of the mill, the use of water reduced the percent reduction, however, as a practical matter, the use of water is preferred since it acts to cool the rolls and the work.

Example 10

A full scale rolling mill experiment employing a commercial 5-stand mill, four high, i.e., two work rolls and two back-up rolls for each stand. The roll width was 52 inches. The data given in the table below shows that the throughput for like reduction is much greater with the oil of our invention, than with prior art oil, and that by substituting a part of the fat with the polymer acid, a much greater production for like reduction, is made possible. In the following table, the rolling oil A was tallow containing about 90% of the glyceride and about 10% of free fatty acid, and about .4% of non-ionic emulsifier. The rolling oil B was composed of 92.6% of the above tallow, and 7% of Textilana 2116, and .4% of non-ionic emulsifier. The recirculation system employing water was employed. The oil-water mixture was about 4% oil and about 96% water.

Type of Oil	A	B	A	B	A	B
Width of Strip in inches	32½	32½	30¼	30¼	35	35
Gauge Entering Stand #1 in inches	0.075	0.075	0.080	0.080	0.080	0.080
Gauge Leaving Stand #5 in inches	0.0090	0.0090	0.0096	0.0096	0.0086	0.0086
Speed from Stand #1 [1]	600	775	600	775	500	600
Amperes at Stand #1 [2]	500	700	900	500	300	400
Speed from Stand #2	950	1,175	1,000	1,350	900	1,100
Amperes at Stand #2	3,300	3,900	4,000	4,000	3,000	4,400
Speed from Stand #3	1,550	1,950	1,600	2,250	1,500	1,700
Amperes at Stand #3	4,400	4,000	4,000	3,600	3,200	4,000
Speed from Stand #4	2,350	3,000	2,500	3,300	2,500	2,700
Amperes at Stand #4	3,200	4,000	4,400	4,400	4,000	4,000
Speed from Stand #5	3,900	4,800	4,000	5,200	3,800	4,400
Amperes at Stand #5	4,500	4,200	5,000	4,000	4,000	4,250
Percent Reduction [3]	88	88	88	88	88	88

[1] Speed from the stand is measured in feet per minute of the linear travel of the strips leaving the rolls of the stand indicated.

[2] Amperes are measured at the individual motors operating the indicated stand rolls.

[3] The percent reduction is based on the guage entering stand #1 and leaving stand #5.

There is thus a large increase in throughput, using oil B of our invention as compared with prior art rolling oils.

While we have described particular embodiments of our invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention, as set forth in the appended claims.

We claim:

1. A lubricant suitable for use as a cooling lubricant for cold-working metals consisting essentially of from about 75 to about 97% of a fatty oil, and from about 3 to about 25% of a polymer chosen from the group consisting of polymers of unsaturated fatty acids having carbon atoms in the range of about 32 to about 54 carbon atoms, hydroxy lower alkyl esters of said polymer acids and hydroxy lower alkyl amido partial esters of said polymer acids.

2. In the lubricant of claim 1, in which the polymer is a hydroxy lower alkyl amido partial ester of said polymer acids.

3. In the lubricant of claim 1, in which said polymer is the dimer of an unsaturated fatty acid.

4. In the lubricant of claim 1, in which the polymer is a hydroxy lower alkyl amido partial ester of said dimer of said unsaturated fatty acids.

5. A lubricant suitable for use as a cooling lubricant for cold-working metals consisting essentially of from about 75 to about 97% of a mixture of a fatty oil, and from about 3 to about 25% of a polymerized compound chosen from the group consisting of the dimers and trimers of unsaturated fatty acids and esters of unsaturated fatty acids and mixtures thereof, which dimers and trimers have carbon atoms in the range of about 32 to 54 carbon atoms, hydroxy lower alkyl esters thereof and hydroxy lower alkyl amido partial esters of said polymer acids.

6. In the lubricant of claim 5, in which the polymerized compound is a hydroxy lower alkyl amido partial ester of said polymers.

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