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LUBRICATING AND COOLING COMPOUND FOR COLD REDUCING MILLS

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This invention relates to lubricating and cooling compounds for use in the cold reduction of metal. More particularly, the invention relates to lubricating and cooling compounds for use in lubricating and cooling the metal and the working rolls in the cold rolling of metal.

Among the objects of the invention is the provision of improved compounds for lubricating and cooling the metal being reduced in the rolls in a cold mill.

A further object is the provision of lubricating and cooling compounds which stand up under more severe loads than prior art compositions, thereby preventing metal to metal contact during cold rolling operations and consequently minimizing roll wear.

A still further object is the provision of lubricating and cooling compounds which do not carbonize during use and which prevent adherence of oils or dirt to the metal being rolled, thereby facilitating subsequent cleaning of the same.

These and further objects of the invention will be apparent in the following description.

In the formation of metal of thinner gauges, such as thin plates, strips, and sheets, it is now customary to carry out the latter part of the reduction of the metal from the ingot in cold rolling mills. Thus, reduction in gauge of strips and sheets in modern practice from thicknesses approximating .09 inch is usually effected in continuous cold mills, which require the application of very high screw-down pressures in order to effect the desired reduction of the cold metal.

Because of the extremely high unit pressures existing between the strip and the rolls in the cold rolling mill, there is developed a large amount of heat in the pass. This heat is absorbed both by the rolls and by the strip passing between them. Unless the heat is dissipated, it may, after a period of operation, affect the strength of the rolls by overheating them and heat the strip to a point where a temperature of temper colors is reached or even surpassed. Thus, it is customary to employ in the cold rolling of strip a cooling liquid which is sprayed on the rolls and the strip to carry away much of the heat so developed.

Since metal to metal contact between the rolls and the strip is undesirable, due to a large amount of wear to the rolls which this would entail, it has been customary to use as a cooling compound one which also has lubricating properties, such that it will stand up under the high unit pressures between the rolls and the strip, thus preventing metal to metal contact between rolls and strip. Because of their dual function, lubricating and cooling compounds used in the

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past have been compromises; that is, they could not be compounds which possessed the highest heat capacity such as water, which is ideal for cooling purposes, because such compounds are not good lubricants. On the other hand they could not be oils alone, which would make the best lubricants, because of their low heat capacity. There have, therefore, been used in the past as lubricating and cooling compounds for cold reducing mills mixtures or emulsions of water and lubricating oils which possess both high heat capacity and good lubricating qualities.

In order to make such mixtures or emulsions of water and oil as stable as possible, emulsifying agents of various types, among them being sodium or potassium hydroxide, have been employed. When used in a system of water and palm oil, sodium hydroxide, for instance, prevents the breaking of the emulsion on standing in cooling tanks and inhibits corrosion to a certain extent. In addition, sodium hydroxide facilitates the general handling of the resulting lubricating and cooling compound. Whereas judicious proportioning of oil, water, and emulsifying compound, such as sodium or potassium hydroxide, provides an adequate cooling medium, the lubricating characteristics of the mixture do not reach the desired high values.

It has been proposed, in order to improve the lubricating qualities of such oil, water, and emulsifying compound mixture, to add to it small quantities of certain inorganic radicals, namely, phosphate and borate, such additions being, for example, in the form of phosphoric acid, monosodium phosphate, di-sodium phosphate, trisodium phosphate, or the corresponding phosphoric acid salts of potassium or ammonium. Whereas such additions result in an improvement in the stability of the emulsion and its lubricating qualities, the resulting compound still leaves something to be desired as a lubricant, since it is prone to break down under extremely high unit pressures over extended periods of time.

We have found that the addition of an organic hydroxy-acid to the system of water, lubricating oils of which palm oil is typical, and an inorganic salt yielding free base by hydrolysis and forming a soluble soap with the oil, produces a cooling and lubricating composition which, while retaining the desirable cooling characteristics of previous oil and water emulsions, possess outstandingly improved qualities as a lubricant. Broadly our invention consists of a system composed of water, to which is added from 0.5 to 10% by weight of any saponifiable oil, preferably containing some free fatty acid, from 0.05 to 2% of

an inorganic salt yielding free base by hydrolysis and forming a soluble soap with the oil, and from .05 to 2% of an organic hydroxy-acid having a low dissociation constant and consequently a buffering reserve of undissociated molecules.

In making the lubricating and cooling compound, the organic hydroxy-acid should be added to the water after the oil and the emulsifying base, in order to insure the optimum formation of the emulsion and the subsequent uniform coalescence of oil into particles of optimum size throughout the system by the action of the organic hydroxy-acid. Typical of the oils which may be used in the compound of the present invention are palm oil itself or palm oil in combination with stearic acid, palmitic acid, or other similar fatty acids. It is to be understood, however, that the invention is not limited to the use of such specific oils, and that any vegetable or animal oil preferably having some free fatty acid, may be used. The emulsifying inorganic salt preferably should be the salt of a weak di-basic or tri-basic acid, such as H_3PO_4 or H_2CO_3 and a soluble soap forming base such as KOH, NaOH, or NH_4OH. Typical of such salt is potassium phosphate, although it is obvious that sodium phosphate, ammonium phosphate, and the corresponding carbonates may be used. It is preferred to use potassium salts, however, because soaps of potassium are liquid in addition to being soluble, whereas sodium soaps are hard and tend to gel at room temperatures, and ammonium soaps have undesirable dissociation characteristics.

The acid employed is one or more of the organic hydroxy-acids, preferably citric, lactic, tartaric, malic, or gluconic acid. All these acids have a low dissociation constant and consequently a buffering reserve of undissociated molecules. It is desirable that the acid employed have a binary or tertiary ionization. The acid content range of the composition, given above, is on the basis of solid commercial citric, tartaric, malic, and gluconic acids and of 44% commercial lactic acid.

The improvement in lubricating value of compounds made in accordance with our invention has been repeatedly demonstrated. In the testing of lubricants to determine whether or not they are suitable for various uses, particularly those in which the service is severe, the Faville-LeVally (Falex) lubricant tester is of great value. Such tester was employed in this instance. The tester consists of a terminal bearing or spindle fixed to a shaft rotating at constant speed and suspended in the lubricant to be tested. On opposite sides of the terminal bearing and likewise suspended in the lubricant are bearing blocks having V-shaped grooves therein, so that the terminal bearing rotates in the grooves. The bearing blocks may be advanced toward each other by the jaws of a load applying mechanism, jaw load being regulated by means of a ratchet wheel turned by an eccentric feed arm. Measurement of the wear of the terminal bearing in the bearing blocks is made by counting the peripheral notches through which the ratchet wheel is advanced. Jaw load is registered in pounds, and torque applied to the terminal bearing is measured in pound-inches on separate gauges of the tester. In the tests, whose results are recorded in the following Tables I and II, the time was recorded in decimal hours by a stop watch graduated in that manner.

New sets of terminal bearings and bearing

blocks and 60 cubic centimeter quantities of each particular lubricant were employed in each test. In order to approximate as nearly as possible the conditions encountered in service by a cold rolling mill lubricant, a final constant jaw load of 2500 pounds was employed. After a .05 hour break-in period at 250 pounds jaw load, a period of increasing load (250 to 2500 lbs.) of approximately .03 hour duration was used in each test. In each of the tests recorded below, the actual test period at 2500 pounds jaw load has continued for .30 hour. The preliminary break-in period served the purposes of eliminating surface irregularities on the terminal bearing and bearing blocks and in distributing the lubricant evenly over the bearing surfaces. The increasing load period was accomplished by engaging the feeder to apply the load automatically and continuously at a constant rate. The feeder was disengaged at the start of the constant 2500 pound load test period, and was subsequently applied only when wear caused the jaw load gauge reading to drop below 2500 pounds. The number given in Table II for each sample, under each particular time, represents the total number of notches which the feed wheel of the Falex tester was advanced up to that particular time in order to maintain the 2500 pound load on the bearing blocks, and thus is a direct measure of the wear on the terminal bearing and the bearing blocks. The temperature which the lubricant reached at the end of .30 hour was recorded in each test.

The following Tables I and II give the results of tests on the Falex device employing three lubricants, Nos. 1, 2 and 3, made up of water, palm oil, and potassium phosphate in the amounts indicated, three lubricants, made in accordance with the present invention, Nos. 4, 5, and 6, made up of water, palm oil, potassium phosphate, and solid commercial citric acid, in the proportions given, and four lubricants, also made in accordance with the present invention, Nos. 7, 8, 9, and 10, made up of water, palm oil, potassium phosphate, and 44% commercial lactic acid, in the amounts indicated.

TABLE I

[LUBRICANT COMPOSITION, PER CENT BY WEIGHT (REMAINDER WATER)]

Lubricant No.	Palm Oil	K_3PO_4	Citric Acid	Lactic Acid
1	1.00	0.10		
2	1.00	0.20		
3	1.00	0.30		
4	1.00	0.05	0.06	
5	1.00	0.10	0.115	
6	1.00	0.40	0.23	
7	1.00	0.10		0.16
8	1.00	0.10		0.33
9	1.00	0.10		0.67
10	2.00	0.20		0.53

TABLE II

Lubricant No.	Notches Wear under a 2500 lb. load							Final Temperature of Lubricant, °F.
	.025 hour	.05 hour	.10 hour	.15 hour	.20 hour	.25 hour	.30 hour	
1	18	25	44	64	74	88	92	176
2	33	48	71	87	116	144	165	176
3	54	77	110	146	173	200	218	185
4	31	35	40	45	48	50	55	162
5	11	14	18	24	29	31	33	175
6	15	20	25	26	28	30	30	167
7	18	20	23	25	26	27	29	168
8	11	15	15	15	25	25	27	170
9	17	19	21	26	28	29	31	180
10	15	18	20	22	24	25	31	181

The bearing blocks employed in the tests on the Falex machine have bearing surfaces in the form of a V and contact the terminal bearing, at least theoretically, along a line. Consequently, the load in pounds per square inch imposed upon the terminal bearing and the bearing blocks is on the order of thousands of times greater than the 2500 pound jaw load. Thus, the test duplicates or surpasses the conditions which the lubricant meets in actual service, as far as pressures are concerned, in the cold rolling of metals. Furthermore, the function of the lubricating and cooling compound in the tests is the same in other respects that it must perform on the cold reduction mill. That is, it must lubricate the bearing, offsetting the friction normal to such high pressure loading, and at the same time it must dissipate the heat produced by friction. The better the lubricant, the less is the wear, and the better the coolant, the lower is the operating temperature. The test on the Falex machine is, in one respect, more severe than actual cold rolling operations. In the test, only 60 cubic centimeters of lubricant is used, and consequently, it does not have much opportunity to dissipate heat. In actual rolling mill practice, on the other hand, the lubricant is continuously circulated back to a sump where it is cooled and cleaned prior to its recirculation.

The results of the ten tests recorded in the above tables strikingly illustrate the improvement brought about by the addition to the lubricant of small amounts or organic hydroxy-acids, such as citric and lactic acids. The two important figures in Table II, in determining the worth of a lubricant for cold rolling purposes, are the total notches wear at the end of the test, that is, at .30 hour, and the final temperature of the lubricant. As can be seen, with the use of lubricants Nos. 1, 2, and 3, although the final temperatures are not unduly high, reaching a maximum of 185° F. in the case of lubricant No. 3, the wear in each instance is substantial, from 92 notches with lubricant No. 1 to 218 notches with lubricant No. 3. Such large amounts of wear indicate that, whereas these compositions may function satisfactorily as coolants, they leave much to be desired as lubricants.

In all of lubricants Nos. 4 to 10, inclusive, including either citric or lactic acid, the coolant properties are satisfactory and in general better than those of lubricants Nos. 1, 2, and 3, as evidenced by the, in general, lower final temperature of the lubricant, and the lubricating properties are very much improved over those of the first three lubricants not containing such organic hydroxy-acids. Thus, the wear on the terminal bearing and bearing blocks with lubricants Nos. 4 to 10, inclusive, ranges from a minimum of 27 notches, in the case of lubricant No. 8, to a maximum of 55 notches in the case of lubricant No. 4. Lubricant No. 4 is still very much superior to lubricant No. 1, which gave the minimum wear, 92 notches, of the three prior art lubricants tested. In addition lubricant No. 4 combines excellent cooling properties with its high lubricating value, as shown by the final lubricant temperature of 162° F.

The lubricant of the present invention also shows marked advantages over those containing only palm oil, water, and lactic acid. In a second test with the Falex tester, the results of which are set out in Tables III and IV, a series of four additional samples, Nos. 11 to 14, inclusive, were made, samples Nos. 11 and 12 being made in a manner similar to samples 5 and 8 above, respectively, and samples Nos. 13 and 14 being made in accordance with the patent to Spangler, No. 2,246,549. The compositions of such four samples are as follows, the acids employed being solid commercial citric acid and 44% commercial lactic acid in the amounts indicated.

TABLE III

[Lubricant composition, per cent by weight (remainder water)]

Lubricant No.	Palm Oil	Lactic Acid	Citric Acid	K_3PO_4
11	1.00	----------	0.11	0.10
12	1.00	0.33	----------	0.10
13	1.00	0.33	----------	----------
14	15.00	1.70	----------	----------

Each of lubricants Nos. 11 to 14, inclusive, was tested in separate runs, both (A) directly after mixing and (B) after mechanical emulsification, provided by subjecting them to a preliminary Falex run. After each interval of .05 hour readings were taken of the total number of notches which the adjusting means for the jaws of the Falex device were advanced from zero to that point to maintain a constant 2500 pound load between pin and V-blocks and the temperature of the lubricant. The initial temperature of the lubricant in each test run was 160° F. At the end of each time interval the temperature of the lubricant in degrees Fahrenheit was recorded; such temperature is given in Table IV below under each time interval.

TABLE IV

Notches

Lubricant No.	Time, hours									
	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
11-A	10 168°	15 170°	---- 175°	---- 177°	20 181°	---- 183°	---- 185°	21 187°	22 190°	22 195°
11-B	0 181°	0 187°	3 192°	4 199°	15 205°	16 205°	23 206°	39 206°	103 207°	178 207°
12-A	14 177°	23 185°	25 189°	28 198°	32 203°	40 205°	57 206°	71 207°	97 206°	211 207°
12-B	10 185°	14 195°	15 200°	21 204°	24 206°	25 207°	29 207°	188 207°	425 Boiling	Failed at 26 min.
13-A	Failure-Blocks, Seized to pin at —2 min.—1900#.									
13-B	185° F. Steel Pin-Sheared.									
14-A	Impossible.									
14-B	Failure-Steel Pin Sheared at 1900#. 161° F. Impossible.									

As can be seen from the test results set out in Table IV, lubricants Nos. 13 and 14, containing only palm oil, lactic acid, and water, were very definitely inferior to lubricants Nos. 11 and 12 made in accordance with the present invention, lubricants Nos. 13 and 14 possessing so little lubricating properties that the terminal bearing or pin soon seized to the blocks and sheared. Tests 13—B and 14—B are reported as impossible, since the mechanical emulsification of mixture by a run in the Falex tester obviously could not be accomplished, due to the failure of the terminal bearing in tests 13—A and 14—A.

The reason for the remarkable improvement in lubricating properties of lubricating and cooling compounds within the scope of the present invention is not fully understood, but it is thought that the addition of organic hydroxy-acids, such as citric and lactic acids, to a basic coolant of the palm oil-potassium phosphate type produces two essential results:

1. The provision of a buffering agent by means of which the hydrogen ion concentration is kept constant while the soap supply is replenished.

2. The enlargement of the oil globule size to promote more effective lubrication.

The emulsifying base, when added to the system of water and lubricating oil of which palm oil is typical, forms soluble soaps which are desirable in counterbalancing the formation of insoluble iron soaps which tend to form during the cold rolling operation. Apparently, however, the emulsion so formed in prior art lubricating and cooling compounds has a particle size which is too small to function in the optimum manner as a lubricant. It is thought that the organic hydroxy-acid coagulates the oil at many nuclei, forming fine oil globules, which globules are however, nevertheless larger than those which constituted the previous emulsion. It has been found that to produce optimum particle sizes of such oil globules the acid should be added only after dilution, that is, it should be the final addition to the coolant mix. The buffering of the acid makes the oil globules available at optimum size, while allowing replenishment of the soap supply.

It has been found that lubricating and cooling compounds made in accordance with the present invention are more uniform and have less tendency to stratify than those previously used, as typified by test lubricants Nos. 1, 2, and 3. This leads to less oil deposition on the cold strip, and consequently less dirty strip. What residue is carried over on the strip from the mill is readily removed in alkaline cleaning solutions, by virtue of the free soap molecules surrounding the otherwise insoluble foreign material.

This application is a continuation-in-part of application Serial No. 570,214, filed December 28, 1944.

Whereas we have theorized concerning the reason for the improvements resulting from the use of compositions made in accordance with our invention, we do not wish to be limited to such theory of operation. Having thus fully described the lubricating and cooling compounds of the present invention and their manner of production and use, what we desire to claim as novel is the following.

We claim:

1. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% saponifiable oil containing free fatty acid or

acids, 0.05 to 2.0% water soluble inorganic salt yielding free base by hydrolysis and forming a soluble soap with the oil, 0.05 to 2.0% aliphatic organic hydroxy-acid having a low dissociation constant, the remainder being substantially all water.

2. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% oil, said oil being essentially palm oil, 0.05 to 2.0% water soluble inorganic salt yielding free base by hydrolysis and forming a soluble soap with the oil, 0.05 to 2.0% aliphatic organic hydroxy-acid having a low dissociation constant and a buffering reserve of undissociated molecules, the remainder being substantially all water, said acid having been added to the compound after the oil and inorganic salt.

3. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% oil, said oil being essentially palm oil, 0.05 to 2.0% potassium phosphate, 0.05 to 2.0% citric acid, the remainder being substantially all water, said acid having been added to the compound after the oil and potassium phosphate.

4. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% oil, said oil being essentially palm oil, 0.05 to 2.0% potassium phosphate, 0.05 to 2.0% lactic acid, the remainder being substantially all water, said acid having been added to the compound after the oil and potassium phosphate.

5. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% saponifiable oil containing a free fatty acid or acids, 0.05 to 2.0% water soluble inorganic salt yielding free base by hydrolysis and forming a soluble soap with the oil, and from 0.05 to 2.0% aliphatic organic hydroxy-acid having a low dissociation constant and a buffering reserve of undissociated molecules, said acid having been added to the compound after the oil and the inorganic salt, the remainder being substantially all water.

6. A lubricating and cooling compound for cold reduction mills consisting of the following ingredients in per cent by weight: 0.5 to 10% oil, said oil being essentially palm oil, 0.05 to 2.0% water soluble alkali metal salt of a weak inorganic acid, said salt yielding free base by hydrolysis and forming a soluble soap with the oil, and from 0.005 to 2.0% aliphatic organic hydroxy-acid having a low dissociation constant and a buffering reserve of undissociated molecules, said acid having been added to the compound after the oil and the inorganic salt, the remainder being substantially all water.

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The following references are of record in the file of this patent:

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 8, line 55, claim 6, for "0.005" read *0.05*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of March, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.