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LUBRICATING AND COOLING COMPOUND FOR COLD REDUCING MILLS

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1 Claim. (Cl. 252—49.5)

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This invention relates to compounds for use in the cold reduction of metallic strip, particularly, steel strip, to provide simultaneously cooling and lubrication.

In the normal course of its manufacture, steel, made according to approved methods in any suitable furnace, is cast into ingot molds, the solidified ingots are removed from the ingot molds, and heated in soaking pits to a proper temperature. On reaching this temperature, ingots are rolled in the blooming mills, being reduced to slabs of suitable dimensions. These slabs are rolled, either directly or after an intermediate heating, to a proper temperature in continuous mills to strip of suitable widths and thicknesses, the latter usually not exceeding 0.090 inch. After leaving the hot mill, the strip is commonly wound into coils of suitable dimensions, and then freed from oxides covering its surface by means of electrolytic pickling, though other suitable means for removing the scale can be used here. Pickled strip is then cold reduced in continuous mills to the desired gauge. This reduction to gauge, which frequently is quite pronounced as when 0.090 inch hot rolled strip is reduced to 0.014 inch, calls for a large power consumption associated with screw-down pressures in the neighborhood of 5,000,000 pounds, which necessarily generates a large amount of heat absorbed both by the rolls or by the strip passing between them.

Heat generated in this manner is in a position to affect both the strength of the rolls, by overheating them above the permissible limits, and to heat the strip passing between heated rolls to the point when a temperature of temper colors is reached, or even surpassed. Leaving the rolls and passing through the atmosphere discolors the strip to the extent requiring subsequent cleaning treatments when tinplate manufacture, or making of deep-drawing-quality steel sheets are involved. In order to avoid this deterioration of the surface, weakening of the mill and excessive power consumption associated with high friction, inherent to metal-to-metal contact, some suitable medium for cooling and lubricating the mill and the products passing through it is required.

Operators of cold reduction mills and of similar devices found, long ago, that both friction created and the heat generated during the rolling processes must be avoided and dissipated by some means adequate for achieving this purpose without affecting the quality or characteristics of the finished product. A self-evident solution of the first problem pointed to the use of lubricants

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preventing a metal-to-metal contact. A large number of substances possessing lubricating characteristics have been tried in related arts and could be applied without any basic modifications directly to the rolling mill stands and the stock passing through them. Many have been found to be adequate in meeting the demands for efficient lubrication under conditions associated with the cold rolling mill practice. However, the physical properties of most lubricants known, principally their low heat capacity, imposed difficult demands from the second standpoint, appropriate elimination of heat generated by mechanical deformations taking place during the rolling processes. Lubricants were not capable of absorbing heat either by direct absorption of it or by conveying heat through their body by convection phenomena at a sufficient rate.

Paralleling the practice of related arts, first attempts towards lubricating and cooling cold rolling mills imitated the practice generally found common in application to other machinery for power generating or mechanical working of metals. Lubricants were fed in a proper manner in limited amounts between the surfaces of contact of strip and rolls and were expected to provide an adequate prevention of metal-to-metal contact. By a proper selection of suitable lubricants, the question of an efficient friction elimination in the rolling mills had been solved at an early date with entirely satisfactory results. However, the problem of necessary cooling escaped an adequate solution until the suggestion of flooding mills with an excessive amount of lubricant was adapted which was able to remove a sufficient quantity of heat on account of large volume used in spite of the low heat capacity of it. Flooding the mills with lubricants occupied, for a long time, the preferred position as means for controlling their operation.

In the selection of lubricants suitable for application to the cold rolling mills, a wide choice was left to the operators who could easily borrow from the wide experience of other arts already possessing an ample volume of information bearing on this subject. Organic, vegetable and mineral oils were successfully tried both on an experimental and production scale, but the selection of a suitable substance was gradually limited to a few oils which could produce the results equally favorable from the cooling and lubrication standpoint and from their effect on the surface of the rolled materials. Palm oil occupied the foremost position among the lubricants of this type.

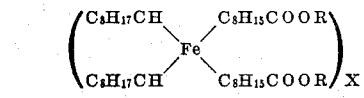
When any oil other than palm oil is used, the

strip leaving the mills comes out rather dark indicating that a substantial amount of oil has been decomposed under the action of the rolls into elemental carbon. The latter becomes imbedded in the pores of steel surface. Carbon particles of this character are inert from the chemical standpoint and pass through the pickling solutions without being affected in any way. Pickling, as usually conducted in the steel mills, is entirely impotent to remove these particles of carbon and they remain in the metal even after being subjected to the annealing processes which burn the carbon, but only to a certain extent. Besides affecting deleteriously the appearance of sheets, they introduce grave complications when these sheets must be coated in the usual manner, such as tinning, for example, because in the tinning process tin bridges over carbon particles and some acid and flux are retained around them, later seeping out from the pores and destroying the coating. Palm oil appears to have a lesser tendency towards decomposing into elemental carbon, but, similarly to other oils, undergoes a series of changes which can be illustrated by the reference to its specific behavior under conditions associated with the cold rolling practice.

Palm oil is composed of oleic, linoleic, myristic, palmitic, stearic, and lignoceric acids containing, therefore, about 15 per cent of unsaturated acids and 50 per cent of saturated acids. On this account, the chemical and mechanical stability of the oils is rather low, and many changes are liable to occur under conditions associated with the rolling mill practice, especially with cold rolling mills.

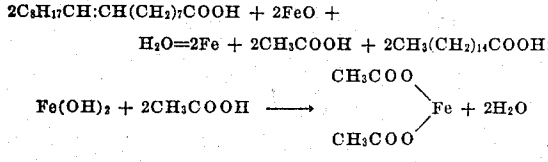
During the rolling of metallic strip or similar products, the pressures involved are exceptionally high, particularly at the bite of the rolls, and the momentary temperatures, which can be generated at this point, frequently reach very high values. Under such pressure and heat conditions, many changes in the original properties of the oil might occur, and frequently are observed in the steel mills. It has been suggested that a series of iron soaps can be formed, unsaturated acids be polymerized, and acids can decompose with the formation of volatile corrosive acids of a lower carbon content. Furthermore, the conditions are inducive to the formation of several metal-organic compounds possessing an exceptionally high molecular weight. The presence of them in the original oil might, and usually does, greatly increase the viscosity of such mixtures, considerably interfere with the cleaning and scrubbing operations to which finished objects must be subjected, cause corrosion and pitting due to the presence of lower-carbon acids, and increase the melting point together with the viscosity of the oil.

For a greater clarity of the understanding of the phenomena with which the present invention is concerned, it seems to be appropriate to dwell, at a certain length, on the mechanism associated with the changes in composition of the palm oil occurring in the rolling operations. Metallic soap formation, leading to complications in cleaning, appears to be less important in the light of recent research than held formerly, since only very minute amounts of metallic oxides combined with an acid base are actually present in the oil as a solution of iron soaps. As some ferric oxide is liable to be reduced to the ferrous state, both ferric and ferrous oxides are commonly found in the system. Ferrous oxide acts on the palm oil in a manner quite different from the ferric oxide, which is responsible for the formation of polymeric compounds which are of a much higher molecular weight than the original palm oil. These polymers greatly increase the viscosity of the remaining oil. The reaction may be typified as leading to the formation of compounds belonging to the type represented by the formula below:



At the olefin bond of two molecules of unsaturated acids, the ferric iron enters a chelate bond and supplies the last valence required to form the chelate ring which is a nucleus of the high molecular weight polymeric bodies.

Since palm oil consists of more than 50 per cent of unsaturated fatty acid esters, the presence of metallic oxides can be held to promote the reaction which leads to splitting of the high-molecular-weight glycerides and the formation of appreciable amounts of chemically active low-molecular-weight acids, such as acetic, formic, and propionic acids. These acids are quite corrosive in nature, and react with high proportions of iron to form ferric or ferrous salts of these acids. A typical reaction of this group may be represented as follows:



In other words, oleic acid in combination with a metallic oxide and water forms metal, acetic acid, and palmitic acid. Then metal hydroxide in contact with acetic acid forms metal acetate and water.

These observations indicate that, besides the usual contamination of the oil with particles of solid carbon, metallic oxides, and minute pieces of metal naturally to be expected in a rolling mill operation, the contamination of the chemical nature proceeds at a comparatively rapid rate.

Since the effect of temperature, besides having the above mentioned results on the performance of mills and quality of strip produced, undoubtedly effects to a great extent the speed and the character of the decomposition of the oil of the type described, steel mill operators proposed long ago to decrease the temperature of the lubricating oils and improve their heat absorption capacity by combining them with some substances possessing a greater cooling power and specific heat than the oils themselves under conditions leading to an efficient lubrication combined with an adequate cooling effect. From the very beginning, water was the preferred addition of this type, and at present it occupies the predominant place among the carriers employed in combination with lubricants for these applications.

Mere addition of water to a bulk of oil can be considered and has been found only as a makeshift for achieving this purpose. Practical immiscibility and difference in specific gravities tends to separate the mixtures into separate layers, each of which possesses properties unsuitable for the use as a lubricant and a cooling agent. Mechanical agitation taking place in the rolling process emulsifies these mixtures in a proper manner to produce the desired combination of cooling and lubrication, but they deteriorate rapidly or are entirely decomposed when the

mixtures in question are allowed either to run down into the settling tanks in the normal course of operating, or circulation is discontinued in the usual course of operation, commonly at the end of the week's run. While properly adjusted and maintained emulsions offer markedly improved properties as a mixture simultaneously effecting a proper lubricating effect and a cooling action, maintenance of such emulsions and adjusting them to the optimum dispersion ratio to be maintained throughout the operations presented very considerable difficulities.

Under conditions of cold rolling mill practice, mechanical agitation is frequently sufficient to form and maintain the proper state of dispersion of phases, but ancillary factors inherent to production operations frequently present the demands which emulsions formed by mechanical mixtures of oil and water cannot meet. It is generally held that surface tension as well as interfacial tension acting as a contractor force draws one of the components of an emulsion system into a series of spherical droplets and separates a mixture of two initially immiscible liquids into two single phases separated by the smallest possible interface. Surface tension of the emulsion system, namely, the surface tension of a liquid-to-liquid boundary surface called "interfacial tension," is reduced by adding an emulsifier to water. At the interface and between the phases of an emulsion two antagonistic forces are at work, namely, surface tension which tends to cause coalescence, and coherence of the film of the emulsifying agent which tends to resist coalescence. Therefore, the stability of emulsions depends on the relative magnitudes of these opposing forces.

Addition of a surface tension depressant or an emulsifier, such as sodium hydroxide, potassium hydroxide, and similar substances, used in proper amounts and employed by me in the present invention is well known in the art, and its application to the palm-oil water system is not claimed in the present invention. Sodium hydroxide prevents the breaking of emulsion on standing in collecting tanks, inhibits, to a certain extent, corrosion and facilitates the general handling of the resulting lubricating and cooling compound. Offering a considerable improvement in comparison with plain oil-water mixtures, emulsion systems, treated with emulsifying agents, do not always have the properties particularly desired from them as compounds intended for lubricating and cooling the stock and rolls of cold reduction mills. It can be stated that judicious proportioning of oil and water provides, in this case, an adequate cooling medium, but the lubricating characteristics of the mixture do not reach here the desired high values. Furthermore, the decomposition of oil under the pressure of the rolls mentioned above, though greatly reduced, is not fully eliminated.

I have found that addition of certain inorganic radicals, namely, of phosphate and borate, to these emulsions, consisting of either palm oil alone or its combinations with stearic acid, palmitic acids and similar fatty acids, greatly improves their value as lubricating compounds without affecting, in any way, their efficiency as cooling media. These additions increase the physical stability of the emulsions and to a great extent prevent the chemical decomposition of oils entering the system in a manner described above. Among additions which I have found particularly advantageous for introducing the desired inorganic radical in application to palm oil: water emulsions treated with an emulsifier, I prefer to use phosphoric acid, mono-sodium phosphate, di-sodium phosphate, tri-sodium phosphate, corresponding phosphoric acid salts of potassium or of ammonium, or a group of compounds containing the borate radical, namely, boric acid, sodium metaborate, sodium tetraborate, sodium perborate, potassium tetraborate, ammonium pentaborate, ammonium perborate, ammonium tetraborate. I have found, furthermore, that these compounds can be used either singly or in combination with each other within widely varying proportions, or the salts can be replaced with acids containing the desired radical, provided the content of alkali present is in excess of saturation limits of the acid added. My investigations have demonstrated that the amounts of the salts added, or their equivalent in corresponding acids, are limited to comparatively small proportions. The range of from 0.25 to 1 per cent covers the majority of applications of both types of salts, though, for phosphates, better results have been obtained with a somewhat more limited range, namely, 0.5 to 1.0 per cent. Larger amounts of these salts should be preferably avoided.

The exact mechanism of the action of these salts added to the well known emulsions of palm oil with water treated with an emulsifier needs further study for developing it fully, but the evidence already assembled suggests its effect being associated with the hydrogen ion concentration which is adjusted by the use of these salts. It is tentatively held at present that the hydrogen ion concentration has a definite effect on the stability of emulsions, though the maximum stability available with different hydrogen ion concentration does not follow a straight line curve. It can be assumed that the dependence of stability of an emulsion on this factor is parallel to that of the surface tension and viscosity of the oils used. Additions of the salts proposed by me apparently create hydrogen ion concentrations leading to the optimum stability. Furthermore, the buffering effect so created places the system in a physico-chemical state, in which the decomposition reactions of the oil, mentioned above, apparently do not have an equal facility to come to completion than in systems lacking this buffering action.

Although improvements in rolling mill performance observed with the use of compounds proposed by me are very definite, the figures representing it reflect mostly economic factors involved and, therefore, are less clear from the technical standpoint than may be desired. A better illustration of the improvement obtained thereby can be gathered from a series of laboratory tests conducted with so-called Falex wear machines. In these experiments, different proportions of phosphoric acid have been added to a standard emulsion composed of palm oil and water, emulsified with commercial potassium hydroxide, and the wear determined using the compounds produced as a lubricant.

In operating the Falex machine, a rotating steel pin is loaded on its sides by means of two steel blocks provided with a V-shaped groove fitting around the pin and loaded automatically by pressure gradually increasing to some predetermined amount. This rotating pin and the V-blocks pressing against it are immersed in a container of a definite volume filled with a lubricating compound to be investigated and provided with a proper thermocouple used for indicating its temperature through proper apparatus. The

temperature increase of the solution is caused by heat generated by the friction of V-blocks against the pin. This friction can be expressed as a function of the divisions on a graduated wheel which is used for an automatic increase of the pressure. A lower number of divisions corresponds to a lesser friction and to better lubricating properties of the corresponding lubricant.

In the following table are given the results of one of the series of experiments conducted by me, in which the final Falex test load was kept at 2000 pounds, and the time of the final test load was maintained at three minutes—

Test No.	Palm Oil Emulsion	H_3PO_4 added	Final Falex Torque	Temperature		No. Divisions of Falex Wear Test
				Begin	End	
	Per cent Oil	*Per cent*	*Pounds*	° *F.*	° *F.*	
629	1.0	0.041	29	135	170	6
627	6.0	0.082	30	135	178	11
628	10.0	0.082	23	135	180	12
606	1.0	none	25	135	175	6
623	6.0	none	26	135	170	24
621	10.0	none	27	135	182	34

In comparing the results for tests 629, 627, and 628 with those for tests 606, 623, and 621, it will be observed that the improvement in wear-resistance produced by adding phosphoric acid to the 6 and 10 per cent palm oil emulsions, was quite pronounced as can be seen from the lowering of the division number used on the scale of the machine by 218 and 283 per cent, respectively, for the same test load, following the acid addition.

In reduction of my invention to practice, I prefer to heat a proper amount of the palm oil to a temperature of around 140° F., dissolve the emulsifying agent, such as potassium hydroxide, in water, bring its temperature to about 140° F., and then slowly add this caustic solution with a constant agitation to the heated palm oil until a thorough emulsification is produced. After forming the said emulsion the desired amount of phosphoric or boric acid, or of their combination, or a proper amount of corresponding salts dissolved in a small amount of water is gradually added with continued agitation to provide the concentration of the corresponding radicals of about 0.25 to 1.00 per cent. In the case when alkali, such as commercial potassium hydroxide, is used the amount of the latter is adjusted to bring its concentration to about from 0.25 to 1.0 per cent, preferably about 0.5 per cent. This concentration can be held as sufficient to complete the reactions required. The emulsion produced in the manner described is too concentrated for practical applications and, in order to adapt it to mill operations, it is diluted to contain about

3.5 per cent of fatty oils by gradually pouring into it a proper volume of water and stirring the mixture continuously.

Though I have described the variables entering the present application in some detail, giving specific examples in the way of illustration, I do not limit my invention to the specific conditions described, since many changes, obvious to those skilled in the art, can be made in them, without departing from the teachings and the spirit of my invention within the scope of the appended claim.

The proportions given herein in percentage are with reference to weight. The preferred emulsion should contain about from 1 to 10% palm oil and about .2% of the phosphate emulsifier or about .25 to 1% of the borate emulsifier. The emulsifier added to the palm oil should be varied with the amount of palm oil used, .2% KOH being satisfactory for a palm oil content of 5%. In all cases the balance is water. Although the Falex test data are advanced herein only in connection with the phosphate emulsifier, this test has also shown the usefulness of the borate compound.

I claim:

A method of lubricating and cooling the rolls of a cold metal rolling mill including the application to the surfaces of contact of the rolls and the metal workpiece of an oil-in-water type emulsion containing not more than 10% palm oil and between approximately 0.25% and approximately 1.0% of a water-soluble salt selected from the group of sodium, potassium and ammonium salts of phosphoric and boric acids which increases the lubricating properties of the mixture during the cold rolling without materially affecting its cooling efficiency.

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