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2,839,159

LUBRICATION OF INDUSTRIAL MACHINERY

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This invention relates to the lubrication of industrial machinery. More particularly, it is concerned with those lubricating systems wherein large amounts of lubricating oil are circulated through the bearings to be lubricated and the oil becomes contaminated with water.

An example of the type of lubricating system to which this invention is directed is the lubrication of steam turbines. The lubrication of the bearings of steam turbines is usually carried out by force feed circulation of large quantities of lubricating oil, the lubricating oil acting both to cool and lubricate the bearings. In being pumped through the bearings, the oil is subjected to relatively high temperatures, and it is contaminated by steam condensate from the steam used to operate the turbine. After leaving the bearings, the oil is therefore cooled and purified prior to being recirculated. Accordingly, the oil circulation system for the lubrication of steam turbines generally includes cooling means, a large capacity settling tank for separating the bulk of the water and gross impurities from the oil, and in addition a centrifuging or filtering device to remove oil oxidation products which become insoluble in the oil. In a system of this kind, the lubricating oil is subjected to very severe conditions. It undergoes continuous temperature changes from the bearings to the cooler, it becomes contaminated with water, and in its rapid circulation it is exposed to oxidizing conditions. These conditions tend to build up in the oil relatively large amounts of acidic oil oxidation products which are corrosive.

Similar severe conditions are encountered in lubricating the steam-heated drying rolls used in the drying of various manufactured products, particularly in the manufacture of paper. In the circulating lubricating systems of paper mill rolls, the oil being pumped through the bearings is contaminated by a portion of the water evaporated from the wet paper mix on the heated rollers and/or by leakage of process steam used for heating the rollers. The wet oil is then circulated from the region in which lubrication is effected to a settling tank where the bulk of the entrained water is settled out. The settled oil is then filtered through a plurality of cloth bag filters which are stretched over hollow metal frames. The filtered oil is removed from the space within the metal frames and is recirculated to the lubricating zone. The contamination of the oil with water and its exposure to oxidizing conditions subject the lubricating oil to severe deteriorating influences and result in the accumulation of corrosive acidic oxidation products.

In systems of the character described, it is common practice to add oil-soluble organic compounds known as oxidation inhibitors to the lubricating oil. Although such oxidation inhibiting additives are efficient in reducing the rate of oxidation of the oil, and thereby the rate of formation of acidic oil oxidation products, they nevertheless do not completely prevent oxidation. Since the oil capacity of such lubricating systems is large, ranging from several hundred to several thousand gallons of

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lubricating oil, the total quantity of acidic oxidation products present in the oil becomes quite substantial notwithstanding the purification procedures generally practiced in the art. Some water always remains entrained in the lubricating oil, and in the presence of water, the acidic oil oxidation products are corrosive to the materials of which the lubricating system is fabricated. For example, it has been observed that the tensile strength of the Paige cloth (78% cotton, 22% wool) bag filters employed in the lubricating systems of paper mill rolls is rapidly reduced in service with a concomitantly rapid rotting of the bag, and furthermore holes ultimately appear in the metal frames over which the bag filters are stretched.

The accumulation of acidic oil oxidation products in large capacity lubricating systems which become contaminated with water has the further disadvantage of resulting in the formation of emulsions which are difficult to break. When stable emulsions are formed, the oil tends to lose its lubricating qualities and must be replaced by new oil. In such large capacity systems, replacement of the oil represents a major item of cost.

We have now discovered that, in lubrication systems of the type described, the service life of a lubricating oil containing 2,6-ditertiarybutyl-4-methyl phenol as an antioxidant can be prolonged and the disadvantageous effects of the acidic oxidation products of the oil can be mitigated by immersing or suspending metallic magnesium in the flowing lubricating oil of the circulating system. The metallic magnesium acts to reinforce the effect of the antioxidant, and to increase the antioxidant life of the lubricating oil and decrease the amount of acidic oil oxidation products present in the lubricating system. Accordingly, the corrosion induced by the acidic oxidation products and the tendency to form stable emulsions are reduced.

In the practice of our invention, the magnesium metal can be immersed in the flowing stream of oil at any suitable point. However, it is preferred that the magnesium be immersed in the flowing oil at a point in the circulating system where the bulk of the entrained water has been separated from the oil, for example, in the stream of oil leaving the settling tank. It is also preferred that the magnesium be electrically insulated from the metal parts of the circulating system by any suitable non-conducting material. While good results can be obtained even if there is contact between the magnesium and the metal parts of the system, such contact will, in the presence of the acidic oil oxidation products and the entrained water in the oil, set up local galvanic currents resulting in an electrochemical consumption of the magnesium.

The form in which the magnesium metal is employed is not critical, except that it is undesirable to use the metal in such finely divided condition that it would impose a substantial resistance to flow of the lubricating oil. Preferably, the magnesium is employed in the form of relatively large pieces such as sheets, ribbons, rods, turnings or strips. It is not necessary to use the magnesium in substantially pure form, as it exists for example in anodic magnesium (99.9%), but since the magnesium is the effective agent in our invention, use of the substantially pure metal will be more efficient. However, satisfactory results can be obtained with magnesium alloys. For example, the various Dowmetals, containing from about 85 to 99% magnesium with various alloying ingredients, such as manganese, aluminum, zinc, copper and cadmium, are suitable. In general, satisfactory results are obtained when there is employed an amount of magnesium metal of from 0.01 to 0.1 percent by weight of the total oil in the circulating system.

As has been stated, the lubricating oils employed in the circulating systems of our invention contain 2,6-di-tertiarybutyl-4-methyl phenol as the oil-soluble organic chemical antioxidant. As shown for example in U. S. Patent 2,265,582, 2,6-di-tertiarybutyl-4-methyl phenol is itself a good antioxidant for lubricating oils. It can be used in small amounts, say from about 0.1 to 1.25 percent by weight, in various oils including turbine oils.

In the practice of our invention, we have observed that the magnesium metal is etched and suffers a relatively small loss in weight. Eventually, after a substantial period of time, the magnesium no longer exerts the protective effects heretofore described, notwithstanding that the greater part of the metal is not consumed. From this observation, it is clear that the action of the magnesium in the lubricating systems described is not one of merely neutralizing the acidic oil oxidation products that are formed. If the action were merely one of neutralization, the protective effect of the magnesium should continuously be exerted until all of the magnesium has been consumed. It is therefore our belief, without being limited thereto, that the magnesium acts in a catalytic manner, that is, as an inhibitor or negative catalyst, similar to the small amounts of organic chemical antioxidants conventionally added to mineral lubricating oils to inhibit oxidation. It is to be noted that the organic chemical antioxidants also exert their effect for limited though substantial periods of time and thereafter become ineffective.

We are aware of the fact that cathodic protection employing sacrificial metals, particularly magnesium, has been used to prevent corrosion in essentially aqueous systems. In such systems, protection against corrosion is obtained electrochemically because of the anodic character of the magnesium in relation to the other metals which are being protected against corrosion, the magnesium being preferentially attacked. However, in such systems, protection against corrosion is obtained as long as the magnesium is present in the form of the free metal. In contrast thereto, in our invention the magnesium ceases to be effective long before it is entirely consumed. Therefore, while there is a loss of magnesium in the practice of our invention, that loss is unrelated to the simple consumption of magnesium in cathodic protection systems, the magnesium metal in our invention acting in an entirely different manner.

We have also observed that with lubricating oils containing no 2,6-di-tertiarybutyl-4-methyl phenol, metallic magnesium itself exerts no effect in prolonging the antioxidant life of the oil. From this observation, it appears that the metallic magnesium acts as a synergist for the 2,6-di-tertiarybutyl-4-methyl phenol.

It is apparent from the foregoing that in the practice of our invention, we obtain the new and unexpected results of increasing the service life of the lubricating oil and of decreasing the corrosive effects of the acidic oil oxidation products.

We have demonstrated the beneficial effects of our invention in the laboratory through the use of a standard test of the American Society for Testing Materials, D943-47T, entitled "Oxidation Characteristics of Inhibited Steam Turbine Oils." The conditions of this test are such as to approximate under aggravated circumstances the conditions to which a lubricating oil is subjected in circulating lubricating systems of large capacity wherein the lubricant is contaminated with water. Briefly, the test comprises subjecting 300 ml. of the lubricating oil sample to a flowing stream of oxygen in the presence of 60 ml. water and an iron-copper catalyst and determining the time required for the acidic oil oxidation products to build up to a neutralization value (acid number) of 2.0. The flow of oxygen is maintained at 3 liters per hour. It has been recognized in the art that lubricating oils in which the amount of acidic organic oxidation products is greater than that represented by an acid

number of 2.0 are no longer serviceable because of corrosivity, the formation of sludge and stable emulsions and the general deterioration of lubricating qualities.

It is to be noted that during the course of the test, the flowing stream of oxygen intimately mixes the oil and water layers, thus resembling the conditions encountered in lubricating steam turbines, etc. The iron and copper catalyst metals represent the metals normally found in industrial machinery and simulate the catalytic deteriorating influences of these metals on the oil in the presence of water and oxygen.

In carrying out our tests, we subjected a lubricating oil suitable for paper mill rolls and another lubricating oil suitable for lubricating steam turbines to the above-described ASTM test D943-47T, modified by immersing carefully weighed strips of magnesium alloy or substantially pure magnesium of the approximate dimensions $\frac{1}{2}$ in. x $\frac{3}{4}$ in. x $\frac{1}{8}$ in. in the oil layer in the test apparatus and determining the time required for the oil to reach an acid number of 2.0. Blank tests were run under identical conditions in the absence of the magnesium metal. The paper mill oil contained 1 percent by weight of 2,6-di-tertiarybutyl-4-methyl phenol, and the turbine oil contained 1.25 percent by weight of this antioxidant. The results are shown in the following table.

Table I

BLANK (NO MAGNESIUM EMPLOYED)

	Paper Mill Oil	Turbine Oil
Oxidation Test, ASTM D943-47T: Time Oxidized, Hours.....	250	1,150
MAGNESIUM ALLOY STRIP IN OIL LAYER		
Oxidation Test, ASTM D943-47T: Time Oxidized, Hours.....	475	1,272
Magnesium Loss, percent by Wt.....	7.5	7.6
ANODIC MAGNESIUM (99.9%) STRIP IN OIL LAYER		
Oxidation Test, ASTM D943-47T: Time Oxidized, Hours.....	620	1,620
Magnesium Loss, percent by Wt.....	4.7	14.5

As may be seen from the above table, the service life of the lubricating oil, as measured by the time required to reach an acid number of 2.0, was significantly increased by immersion of the magnesium therein, the substantially pure (anodic) magnesium having a greater effect.

In order to determine the effect of the metallic magnesium itself on a turbine oil containing no 2,6-di-tertiarybutyl-4-methyl phenol, a series of tests were run identical with those of the above table except that the turbine oil employed was the uncompounded base stock of the turbine oil of the above table. It was found that the use of the metallic magnesium produced no substantial difference in the service life of the uncompounded oil, the base stock without magnesium having a life of 200 hours and that with magnesium having a life of 190 hours. Since the magnesium has no effect of itself in prolonging the life of an uncompounded oil, but does prolong the life of an oil containing 2,6-di-tertiarybutyl-4-methyl phenol, it is apparent that the magnesium acts in some manner to synergize the effect of the antioxidant.

In order to demonstrate the effectiveness of our invention in reducing corrosivity, a similar series of tests as in the above table were carried out on a paper mill oil, but immersing in the oil layer strips of filter cloth (Paige cloth, 78% cotton, 22% wool) of the approximate dimensions $1\frac{1}{2}$ in. x 3 in. along with substantially pure magnesium strips. The loss of tensile strength of the filter cloth and the acid number of the oil were determined periodically as the test progressed. Blank tests were

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run under identical conditions without the magnesium. The results are shown in the following table.

Table II

	Oil With- out Mag- nesium	Oil With Magne- sium
Oxidation Test, ASTM D943-47T Tensile Strength, Perkins Tester, Percent Loss in Tensile Strength of Cloth Strips After:		
0 Hours.....	0	0
75 Hours.....	4	1
100 Hours.....	6	4
150 Hours.....	20	12
250 Hours.....	46	38
425 Hours.....	78	49
Acid Number after:		
100 Hours.....	0.16	0.16
150 Hours.....	0.99	0.26
250 Hours.....	2.20	0.52

The above results show that the corrosivity of the oil is materially reduced, as evidenced by a marked decrease in attack on the filter cloth and a decrease in the acid number of the oil.

The turbine oil used in the above tests was a highly refined paraffinic mineral lubricating oil having an API gravity of about 31, a viscosity at 100° F. of about 150 S. U. S., and a viscosity index of about 110. The paper mill roll oil used in the above tests was a refined paraffinic type mineral lubricating oil having an API gravity of about 27, a viscosity at 100° F. of about 975 S. U. S., and a viscosity index of about 97. In addition to the 2,6-ditertiarybutyl-4-methyl phenol, the paper mill oil contained about 1 percent by weight of sulfurized sperm oil as an extreme pressure agent. Obviously, other additives

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such as anti-rust agents, anti-foam agents, etc. may be added without departing from the spirit of the invention.

We claim:

1. In the lubrication of the bearings of industrial machinery of the type of steam turbines and steam-meated drying rolls, wherein the bearings tend to become heated and are cooled and lubricated by the circulation of large quantities of lubricating oil pumped through the bearings, thereby contaminating the oil with water and forming acidic oxidation products of the oil, the method of prolonging the service life of the lubricating oil and reducing the corrosive effects of the acidic oxidation products of the oil which comprises immersing metallic magnesium in the circulating oil, said oil containing 2,6-ditertiarybutyl-4-methyl phenol, the metallic magnesium being electrically insulated from the metals of the circulating lubricating oil system.

2. The method of claim 1, wherein the metallic magnesium is anodic magnesium.

3. The method of claim 1, wherein the metallic magnesium is present in an amount of from 0.01 to 0.1 percent by weight of the oil, and the 2,6-ditertiarybutyl-4-methyl phenol is present in an amount of from about 0.1 to 1.25 percent by weight of the oil.

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