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2,994,408

HIGH TEMPERATURE LUBRICANT

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This invention relates to lubrication under high temperature and high speed conditions. More particularly, it pertains to the lubrication of metal surfaces subjected to temperatures of about 800° F. as encountered in aircraft gas turbine engines, and the like, with a vaporous lubricating composition.

In copending patent applications Serial No. 609,087, filed September 11, 1956, which matured into U.S. Patent 2,971,609, and Serial No. 462,830, filed October 18, 1954, which matured into U.S. Patent 2,841,244, there is described lubrication with vaporous lubricants, the load carrying or wear inhibiting properties of which are improved by use of a vaporous lubricant containing reactive sulfur, halogen and/or phosphorus containing compounds. These compounds can be introduced with the vaporous lubricant or the surfaces to be protected can be pretreated with these surface-reactive additives so as to preform a load-carrying or wear-inhibiting protective film on the contacting metal surfaces.

Compositions described in these applications are excellent lubricants even at temperatures as high as 700° F. However, it has been observed that above 700° F., especially at temperatures of about 800° F. or higher such as 1000° F. or above, sulfur or sulfur compounds present either as an additive or as a natural constituent in a hydrocarbon such as a petroleum hydrocarbon, used as a component of a vaporous air-hydrocarbon lubricant mixture as described in the above-mentioned applications, are ineffective to prevent wear but rather cause, or at least permit wear, of metal surfaces. Also, halogen-containing compounds which are effective load carrying and wear inhibiting agents in vaporous lubricant mixtures described in the above-mentioned applications are ineffective at temperatures of around 800° F. or higher.

It has now been found that unexpectedly superior lubrication can be provided for metal surfaces subjected to temperatures of about 800° F. or higher up to about 1000° F. and high speeds by contacting or blanketing the surfaces to be lubricated with a vaporous lubricant mixture comprising a substantial or major proportion of air and a minor amount of a vaporized non-carbonizing, essentially sulfur-free and essentially aromatic-free liquid hydrocarbon having an end boiling point substantially below the operating temperature of the bearing surface, preferably in the temperature range of from about 150° F. to about 600° F., the weight ratio of the two components being from about 7:1 to about 10:1 respectively; said mixture containing a minor amount of from about 0.01% to 5%, preferably from about 0.1% to 1%, of a chemically reactive metal-free hydrocarbon soluble phosphorus compound.

Instead of air, other free-oxygen-containing gaseous materials can be used, such as other mixtures of free oxygen and nitrogen, as well as oxygen per se. In such a case the ratio of the oxygen to hydrocarbon should be adjusted accordingly so that the ratio of free oxygen to hydrocarbon is equivalent to that of the free oxygen to hydrocarbon in the air-hydrocarbon mixtures specified above. Thus, expressed in terms of free oxygen, the weight ratio of oxygen to hydrocarbon is from about 7:5 to about 2:1, respectively.

The vaporous lubricant used to lubricate the metal surface comprises a mixture of free oxygen, which can be

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supplied in admixture with an inert gas such as nitrogen as in air, and a sulfur-free essentially aromatic-free liquid hydrocarbon, or mixture of hydrocarbon substances having an end boiling point below the operating temperature of the bearing surface and which at the operating temperature does not tend to form carbonaceous or abrasive deposits. The hydrocarbon substance is preferably a sulfur-free liquid petroleum hydrocarbon, generally a mixture of petroleum hydrocarbons, having a boiling point in the range of from about 150° F. to about 600° F. The ratio of oxygen to the hydrocarbon material in the vaporous lubricant mixture is critical for the present purpose. Thus, when the ratio of such gases is too small the deposition of carbon on the bearing results in failure, and similarly when the proportion of such gases is too large oxidation of the bearing surfaces and consequent failure occurs. It has been found that the proportion of oxygen can be controlled to provide sufficient oxidation of the hydrocarbon material and avoid pyrolysis to free carbon or to highly carbonaceous residues and at the same time avoid substantial oxidation to carbon dioxide, the oxidation product of the carbon being largely carbon monoxide, thereby providing an effective reducing atmosphere and minimizing oxidative attack on the metal bearing surfaces.

The readily vaporizable sulfur-free, essentially aromatic-free hydrocarbon portion of the lubricant can be suitable hydrocarbons and mixture thereof preferably of the paraffinic and/or naphthenic type. They are readily prepared from petroleum fractions by suitable refining to remove sulfur and sulfur compounds as well as excessive amounts of aromatics and the like. Such materials include light petroleum fractions, boiling in the range of from about 150° F. to about 600° F., or pure liquid aliphatic and/or cycloaliphatic hydrocarbons having from 7 to 16 carbon atoms.

In the operation of jet aircraft vaporizable products which are particularly suitable for admixture with air or the like for the intended purpose of this invention include hydrocarbon mixtures meeting specification requirements for JP-1, JP-3, JP-4 or JP-5 fuels, but which have been essentially desulfurized and dearomatized so that the total sulfur in the end product is less than 0.01% by weight or nil, and the aromatic content is low, i.e. not more than 15% or preferably not over 5% by weight. A particularly suitable hydrocarbon is a desulfurized JP-4 fuel being at least 86-90% saturates and having an end boiling point of about 460° F., a Reid vapor pressure in pounds per square inch of 2 and a freezing point of about -76° F. Other products which are suitable for forming the air-hydrocarbon lubricant blend include essentially desulfurized and de-aromatized fractions from standard aircraft gas turbine lubricating oils (MIL-O-6081) which fractions have an end point below 600° F. and a pour point of about -70° F., or pure hydrocarbons such as the C₆-C₁₆ aliphatic or cycloaliphatic hydrocarbons, preferably C₇-C₁₂ aliphatic hydrocarbons and mixtures thereof, e.g., heptane, octane, isooctane, nonane, decane, methylcyclopentane, methylcyclohexane, and the like.

The additives which impart load-carrying, wear-inhibiting properties to the vaporous lubricants when used at temperatures of at least 800° F. are chemically reactive metal-free hydrocarbon soluble phosphorus compounds such as organic phosphorus esters. Compounds of this type include the partial and full organic phosphites, esters such as the alkyl, cycloalkyl or aryl phosphites, e.g. mono-, di-, or tri-, methyl, ethyl, isopropyl, butyl, hexyl, octyl, cyclohexyl, phenyl phosphites, the preferred being the di- or tri-(branched-chain alkyl) phosphites, phosphates or phosphonates such as tri-isopropyl phosphite.

The vaporous lubricant blend can be sprayed or atomized onto the surface to be lubricated such as gears and bearings so that the entire surface is enveloped or blanketed in a vaporous lubricant. Also, the lubricant may be vaporized into the air stream at any convenient location and the mixture conducted to the surface to be lubricated.

The lubricant mixture of air and sulfur-free hydrocarbon can be used as a conventional mist lubricant during the periods of operation when machine parts are at temperatures below the end boiling point of the lubricant.

In order to demonstrate the effectiveness of vaporous lubricants of this invention at elevated temperatures and high speeds, a high-speed bearing assembly, as shown in FIGURE 2 of the Sorem et al. paper "High-Temperature Bearing Operation in Absence of Liquid Lubricants," July-August 1956 issue of Lubrication Engineering, was lubricated with compositions shown in Table I below and the results are tabulated therein.

The test conditions were: Spindle rotations 10,500 r.p.m.; bearing break-in time, 4 hours, using white medicinal oil after which the oil was removed, the temperature increased to 800° F. and the bearing lubricated with the compositions shown in Table I for 22 hours or until bearing failure occurred.

TABLE I
Test results

Composition	Time of Test Run and Condition of Bearing	Change in Radical Internal Clearance ¹ , inches×10 ⁻⁴
1. Dry.....	1 min....	
2. Air-JP-4 blend in 7:1 ratio, respectively.	22 hrs....	rings and balls pitted and worn. +19
3. Air-n-heptane in 7:1 ratio, respectively.	22 hrs....	+15
4. Composition 3+0.12% wt. CS ₂ .	22 hrs....	+20
5. Composition 3+0.12% wt. CCl ₄ .	22 hrs....	+10
6. Composition 3+0.66% wt. Triisopropyl phosphite.	22 hrs....	bearings in excellent condition. -2

¹ Standard bearing radical internal clearance measuring instrument used, made by Sheffield Corporation of Dayton, Ohio.

From the above tests it can be noted that sulfur and chlorine-containing compounds cause either wear or are essentially ineffective in preventing wear (Compositions 4 and 5) when compared to vaporous lubricants (Compositions 2 and 3) which do not contain a wear inhibitor, whereas the addition of a phosphorous-containing compound such as triisopropyl phosphite (Composition 6)

to Composition 3 prevented wear and the bearings were in excellent condition after the test run.

Lubricants of this invention are particularly applicable for ball and roller bearings of gas turbine engines where operating temperatures are high and can also be used for lubrication of various other machines and equipment operating at high temperatures and speeds. Lubricating by the method of this invention can be modified to meet other high temperature requirements and can be applied to any mechanisms operating at high temperature speeds and loads such as conveyor belts, furnace belts and the like.

We claim as our invention:

1. A process for lubricating engines operating at temperatures of 800° F. which comprises blanketing the parts requiring lubrication with a blend of air and essentially sulfur-free and aromatic-free hydrocarbon having a boiling range of 160-600° F. in the weight ratio of 7:1 to 10:1, respectively, and containing about 0.01% to about 5% of a trialkyl phosphite.

2. A process for lubricating engines operating at temperatures of 800° F. which comprises blanketing the parts requiring lubrication with a blend of air and essentially sulfur-free and aromatic-free hydrocarbon having a boiling range of 160-600° F. in the weight ratio of 7:1 to 10:1, respectively, and containing about 0.01% to about 5% of triisopropyl phosphite.

3. A process of lubricating engines operating at temperatures of at least 800° F. which comprises blanketing the parts requiring lubrication with a blend of air and heptane in the weight ratio of 7:1 to 10:1, respectively, and containing from about 0.01% to about 5% by weight of triisopropyl phosphite.

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