

Description

Title of Invention

LUBRICANT FOR INJECTION

Technical Field

[0001]

The present invention relates to a lubricant intended to be injected into a micro-gap, such as used for, e.g., between sliding surfaces of a bicycle, and the like.

Background Art

[0002]

Oil and wax are known as a lubricant to be injected into a sliding part. As a higher-performance lubricant, a mixture is also known which consists of oil and/or wax and a solid lubricant component with a low coefficient of friction.

Citation List

Patent Literature

[0003]

PTL 1: Japanese Unexamined Patent Publication No. 2020-33491

Summary of Invention

Technical Problem

[0004]

A lubricant including oil and/or wax as a medium as described above has an excellent adhesion ability to a required place, but has an issue of being hard to penetrate into a micro-gap in a bicycle chain, a gear and/or the like, for example.

Oil, wax or the like is forcibly pushed into a gap from outside. This may cause excess wax or the like to adhere to not only a sliding part but also an outer peripheral

face. Then, a foreign substance, such as sand, dust particles and/or the like, may adhere to the oil or wax, resulting in forming a clump. In regard to a bicycle chain and/or the like, during driving, the solidified wax or the like may also fly in all directions from the chain and/or the like.

[0005]

It is an object of the present invention to provide a lubricant for injection capable of smoothly penetrating into a micro-gap to achieve low friction without protruding outside and without allowing adhesion of a foreign substance thereto.

Solution to Problem

[0006]

A first aspect of the present invention provides a lubricant for injection to be injected into a micro-gap between sliding surfaces, the lubricant for injection consisting only of tungsten disulfide powder and a volatile solvent, wherein a percentage of the tungsten disulfide powder content is less than 25wt%.

[0007]

In a second aspect of the present invention, the volatile solvent is lower alcohol.

Advantageous Effects of Invention

[0008]

According to the first aspect of the present invention, a lubricant in a low-viscosity liquid form is easily injected into a micro-gap. The lubricant injected spreads over the sliding surfaces. Then, after evaporation of the volatile solvent, only the tungsten disulfide remains on the sliding surfaces to achieve low friction.

Further, the lubricant includes no adhesive substance such as oil and wax. Therefore, there is not any chance that dust particles and/or the like will adhere to the lubricant to form a clump and also the clump will fly in all directions.

[0009]

Because the tungsten disulfide does not protrude out of the required place, the tungsten disulfide is not wasted.

Furthermore, in use for bicycle, while a chain remains mounted on a bicycle, the lubricant in a low-viscosity liquid form is able to be injected into a micro-gap. For example, if a chain is coated with wax, the wax should be heated to liquid form, and then the chain removed from the bicycle should be immersed in the wax for wax penetration. However, use of the lubricant according to the present invention obviates all need to take time and effort to melt wax, to remove the chain from the bicycle, to re-mount the chain, and the like.

[0010]

According to the second aspect of the present invention, the lubricant with low viscosity is easily injected into a micro-gap. In addition, the volatile solvent is aqueous. This eliminates the need to wipe off the liquid protruding out of the gap.

Brief Description of Drawings

[0011]

Fig. 1 is an explanatory diagram of a vertical penetration test method to verify the lubricant penetration ability into a micro-gap.

Fig. 2 is a photograph showing the results of the vertical penetration test.

Fig. 3 is an explanatory diagram of a horizontal penetration test method in embodiments.

Fig. 4 shows schematic diagrams showing the results of the horizontal penetration test, in which (a) is a sample F (30wt%) and (b) is a sample G (25wt%).

Fig. 5 is a table showing the results of the horizontal penetration test.

Fig. 6 is a graph showing the results of the horizontal penetration test,

Fig. 7 is a photograph showing diffusion states of the lubricants in embodiments.

Fig. 8 is a table showing the results of a diffusion test.

Fig. 9 is a partially cross-sectional view of a bicycle chain.

Fig. 10 is a table showing the result of a driving test.

Description of Embodiments

[0012]

One embodiment according to the present invention will be described below.

A lubricant for injection according to the embodiment is in liquid form, which is composed only of isopropyl alcohol and tungsten disulfide by mixing tungsten disulfide powder with isopropyl alcohol as a volatile solvent.

Specifically, isopropyl alcohol of a purity of 99.9% or greater is added to a weighed amount of tungsten disulfide powder, which are placed in a container, and then the container is capped and shaken for mixing, where the content of tungsten disulfide powder is varied to prepare lubricants with different concentrations.

[0013]

The lubricant prepared is in liquid form, where it seems that the higher the percentage of tungsten disulfide powder content, the higher the viscosity becomes somewhat.

The tungsten disulfide powder is powder with an average particle size of 0.5 μm , a coefficient of static friction of 0.07, and a coefficient of kinetic friction of 0.03.

The lubricant according to the embodiment is injected into a micro-gap which forms sliding surfaces. Thereupon, the isopropyl alcohol evaporates in the micro-gap in a short amount of time, and the tungsten disulfide powder alone remains on the sliding surfaces.

The tungsten disulfide powder is a substance with an extremely low coefficient of friction as described above. Therefore, after the evaporation of isopropyl alcohol, the tungsten disulfide powder is expected to function as a solid lubricant.

[0014]

Vertical Penetration Test

The following description is about a test for verifying the ability of the lubricant according to the embodiment to penetrate into a micro-gap.

Fig. 1 is a test jig used in the vertical penetration experiment.

In the test, as illustrated in Fig. 1, spacers 3, 4 are placed between a pair of glass plates 1, 2, with a facing interval d between the glass plates 1, 2 being adjusted to 60 μm for use. Each of the glass plates 1, 2 is a prepared glass slide with a length S of 76 mm, a width W of 25 mm and a flat and smooth surface.

[0015]

While the glass plates 1, 2, as described above, were erected with the width W oriented in the vertical direction, a drop of the lubricant was dripped between the glass plates 1, 2 from above by use of a dropper 5 mounted at a leading end of a bottle (not shown). After that, a penetration distance of the lubricant from the upper edges of the glass plates 1, 2 between the glass plates 1, 2 in question was measured.

Samples of the drops of the lubricants are four: a sample A with 60wt% of the percentage of tungsten disulfide powder content; a sample B with 50wt%; a sample C with 45wt%; and a sample D with 40wt%.

It is noted that the interval of 60 μm corresponds to a gap g_1, g_2, g_3, g_4 between parts of a bicycle chain illustrated in Fig. 9. Although the gap g_1, g_2, g_3, g_4 between parts of the bicycle chain can be considered to differ depending on a manufacturer of bicycle chains, specifications and/or the like, it is considered that the gaps are not much remote from the interval of 60 μm , irrespective of the manufacture of bicycle chains, specifications and/or the like.

[0016]

Results of Vertical Penetration Test

Fig. 2 shows the results of the penetration test in which lubricants with different percentages of tungsten disulfide powder content were caused to penetrate between the above-described glass plates 1, 2. Fig. 2 is a photograph taken through the surface of the glass plate 1.

For the percentages of tungsten disulfide powder content, the photograph shows the samples A, B, C, D arranged in this order from the left in Fig. 2. In the photograph, a black portion spreading between the glass plates 1, 2 is the tungsten disulfide powder in the lubricant. As presented in Fig. 2, a reaching distance of the tungsten disulfide powder from an upper end 1a of the glass plate 1 was 2.60 mm in the sample A, 3.25 mm in the sample B, 5.15 mm in the sample C, and 5.70 mm in the sample D.

[0017]

From the test results, at or above 50wt% of the percentage of tungsten disulfide powder content, the tungsten disulfide powder remained arching on the upper edges of

the glass plates 1, 2 without penetration of the total amount of drop of the lubricant between the glass plates 1, 2, and thus the penetration distance was less than 4 mm.

Comparatively, when the percentage of tungsten disulfide powder content is at or below 45wt% corresponding to the sample C, the total amount of drop of the lubricant penetrated between the glass plates 1, 2 and the penetration distance reached 5 mm or longer. Also, there was no tungsten disulfide powder remaining on the upper edges of the glass plates 1, 2.

Such results are considered to be because as the percentage of tungsten disulfide powder content is increased, the viscosity of the lubricant becomes higher.

[0018]

On the other hand, it is considered that the lower the percentage of tungsten disulfide powder content, the lower the viscosity of the lubricant becomes to improve the penetration ability. For example, it is verified that, in a sample E (not shown) with 12.5wt% of the percentage of tungsten disulfide powder content, the lubricant dripped from above the glass plates 1, 2 has penetrated to 25 mm at the lower ends of the glass plates 1, 2.

It was found from the results that when 45wt% or higher tungsten disulfide is contained, the total amount of lubricant dripped is incapable of penetrating into the micro-gap of 60 μm .

[0019]

Horizontal Penetration Test

Subsequently, a horizontal penetration test illustrated in Fig. 3 has been carried out. In the horizontal penetration test, the same glass plates 1, 2 as those used in the vertical penetration test shown in Fig. 1 were placed horizontally and the dropper 5 was used to apply only a drop of the lubricant between the glass plates 1, 2 from a single injection portion p.

Seven samples were used in the test, which were: a sample F with 30wt% of the percentage of tungsten disulfide powder content; a sample G with 25wt%; a sample H with 24wt%; a sample I with 23wt%; a sample J with 22wt%; a sample K with 21wt%; and a sample L with 20wt%.

[0020]

A penetration sate of each of the samples was photographed, and the penetration area was calculated using image processing software.

In the horizontal penetration test, the lubricant penetrated by being pressed into the micro-gap between the glass plates 1, 2 with a pressing force by the dropper 5, and gravity has not so much influence unlike in the case of the vertical penetration test. This is considered to be closer to the condition of actual injection from a gap g1 of the bicycle chain toward a pin 11 (see Fig. 9).

[0021]

Results of Horizontal Penetration Test

Figs. 4(a), 4(b) show schematic diagrams of the penetration states of the sample F with the percentage of tungsten disulfide powder content (30wt%) and the sample G with the percentage of tungsten disulfide powder content (25wt%). The sample F exhibited spreading along the edges of the glass plates 1, 2 on both sides of the injection portion p as illustrated in Fig. 4(a), but hardly penetrated in the injection direction shown by the arrow. Comparatively, it was verified that the sample G penetrated in the arrow direction as illustrated in Fig. 4(b). It is noted that all the samples F to L with 25wt% or lower of the percentage of powder content penetrated in the arrow direction.

[0022]

Fig. 5 is a table showing the penetration areas calculated using the image processing software, while Fig. 6 is a graph of the results in Fig. 5. As shown in Fig. 5 and Fig. 6, an increase in penetration area based on a change in percentage of power content is sharply raised when it is at or below 25wt%.

[0023]

It is found from the results that, similarly to in the vertical penetration test, in the horizontal penetration test, the lower the percentage of tungsten disulfide powder content, the more the penetration is facilitated to increase the penetration area. In particular, it was found from the results in Fig. 5, Fig. 6, that, at 25wt% of the percentage of tungsten disulfide powder content, the penetration ability of the lubricant was changed and also the percentage of change of the penetration area was changed.

In other words, it was found that when the percentage of tungsten disulfide powder content is at or below 25wt%, the penetration ability was steeply increased.

[0024]

On the other hand, it was found that, when the percentage of tungsten disulfide powder content is 30wt%, the penetration ability into a micro-gap from the injection portion p was low, so that the tungsten disulfide powder solidified along the opening part. Therefore, an additional injection is difficult, and it is difficult to extend the lubricant throughout the micro-gap.

Thus, it is considered that, for use as a lubricant for injection to be injected into a micro-gap between the sliding surfaces such as in a bicycle chain and/or bearing, the percentage of tungsten disulfide powder content is preferably equal to or lower than 25wt%.

[0025]

Diffusion Test

Next, a diffusion test was carried out in which the percentage of tungsten disulfide powder content is varied to check how much the tungsten disulfide powder in the lubricant spreads.

Three test samples were used: the sample A with 60wt% of the percentage of tungsten disulfide powder content; the sample E with 12.5wt%; and a sample M with 1.0wt%.

A drop of each of the samples A, E, M was dripped on a sheet of paper horizontally placed by use of the dropper, and the diffusion area was measured. The measurement was performed 10 times on each of the samples A, E, M.

[0026]

Results of Diffusion Test

Fig. 7 is a photograph showing the diffusion states of the dripped lubricants.

For each sample, the spreading on the sheet of paper was measured. More specifically, a long diameter and a short diameter of each spread area of the lubricant were measured and an area of a circle with the average diameter of them was defined as a diffusion area. The results are shown in Fig. 8.

[0027]

For each sample, the average value of 10 measurements was 168.1 mm² in the sample M with 1wt% of the percentage of tungsten disulfide powder content, 69.0 mm² in the sample E with 12.5wt%, and 5.4 mm² in the sample A of 60wt%. It is noted that in the sample A, the tungsten disulfide powder rose and solidified as it is, on the sheet of paper. This is thought to be because, in the ample A, due to the high percentage of powder content, isopropyl alcohol evaporated before the liquid diffuses adequately. On the other hand, in the sample F, due to the very large diffusion area, a very faint color is displayed on the photograph image.

[0028]

From the above-described test results, it was found that the lower the percentage of tungsten disulfide powder content, the wider the liquid lubricant spreads, but, even in the sample M with a low percentage of content, such as 1.0wt%, the tungsten disulfide powder adequately spreads together with the liquid.

[0029]

Driving Test

Next, a driving test of a bicycle injected with the lubricant was carried out in order to verify the efficacy of the lubricant according to the embodiments.

A chain 6 illustrated in Fig. 9 has chain structure of the bicycle used in the driving test. The chain 6 is essentially composed of outer plates 7, 7, inner plates 8., 8, rollers 9, bushings 10, and pins 11.

Then, the gap g1 is between the outer plate 7 and the inner plate 8. The gap g2 is between the inner plate 8 and an end face of the roller 9. The gap g3 is between the inner peripheral surface of the roller 9 and the outer peripheral surface of the bushing 10. The gap g4 is between the inner peripheral surface of the bushing 10 and the outer peripheral surface of the pin 11. Each of the gaps g1 to g4 is about 60 μm.

[0030]

The following is a test method.

As well as the gaps g1, g2, g3, hub bearings and freewheel ratchets were injected with the lubricant according to the embodiments and oil for a bicycle chain, and periods of

time required to drive a certain distance were compared. It is noted that the lubricant is assumed to penetrate via the gap g1 into the gap g4.

The lubricant in the embodiments is the sample E with isopropyl alcohol as a solvent and with 12.5wt% of the percentage of tungsten disulfide powder content, while the bicycle chain oil in a comparative example is Road Race SP/Blc-004 which is available from AZ Co., Ltd. Each of them was injected on a drop-by-drop basis into the vicinity of the gaps g1, g1 on both ends of the pin 11.

Further, the used bicycle chain is DURA-ACE CN-M9100 produced by Shimano.
[0031]

After the injection of each lubricant, actual bicycle riding was performed multiple times over the distance of 21.01 km along the same section of National Route 134.

It is noted that the equipment used, the components used, the bicycle, the tire air pressure, the bicycle rider were the same in all of the tests, and the driving distance and time were measured using an app (Strava) using GPS information.

[0032]

Results of Driving Test

Fig. 10 shows the result of the driving test.

As shown in Fig. 10, in the case of injecting the lubricant (the sample E) containing 12.5wt% tungsten disulfide powder in the embodiments according to the present invention, the driving time was 47 minutes and 50 seconds, and in the case of injecting common oil for bicycle chain, the driving time was 48 minutes and 40 seconds.

As described above, in the use of the lubricants according to the embodiments, the time is 50 seconds, about 1.71%, faster on average than the use of oil.

[0033]

It is noted that the test result obtained when using the lubricant according to the embodiments is the average value of the values of 23 measurements, and the test result obtained when using the oil is the average value of the values of 22 measurements. In whichever case, the average values were taken of 20 measurements or more, and a significant difference is not found.

It was verified from this fact that the lubricant containing isopropyl alcohol and

tungsten disulfide powder according to the embodiments provides lower frictional resistance than the oil for bicycle chain to lead to a reduction in power loss.

[0034]

The lubricant according to the embodiments is also liquid including isopropyl alcohol as a solvent and the percentage of tungsten disulfide powder content is less than 25wt%. Because of this, the lubricant according to the embodiments exhibits high penetration ability and high diffusion ability into micro-gaps and thus tends to extend across the gaps g1, g2, g3, g4 and the like.

Because isopropyl alcohol is a volatile solvent, it evaporates in a comparatively short amount of time after the injection of the lubricant in liquid form. Therefore, only the tungsten disulfide powder remains within the micro-gaps to exert fully the effects as a solid lubricant.

[0035]

Furthermore, the lubricant according to the embodiments includes no adhesive substance such as oil, wax and the like. Therefore, there is not any chance that the adhesive substance will cause sand, dust particles and/or the like to adhere thereto and form a clump and thus the clump will fly in all directions.

As described above, in the lubricant according to the embodiments, after the solvent evaporates, only the tungsten disulfide powder remains on the sliding surfaces to demonstrate the lubricating function to the fullest, so that the low friction effect is stable.

Furthermore, the lubricant according to the embodiments is in liquid form capable of being injected into a micro-gap because of a low viscosity. Because of this, unlikely the case of using a lubricant including wax, the need is eliminated to take time and effort such as to melt wax, remove and re-mount the chain from and to the bicycle and the like.

[0036]

In the above-described embodiments, isopropyl alcohol is used as a volatile solvent. However, as long as the liquid can evaporate in an adequate amount of time after the injection into the gaps, the solvent is not limited to isopropyl alcohol.

However, if a solvent evaporating at once due to too high volatility is used, this makes it difficult to maintain the liquid form of the lubricant exiting from the container,

leading to make it difficult to handle it. Because of this, a liquid with appropriate volatility is desirably selected.

[0037]

It is noted that, because lower alcohol, such as isopropyl alcohol, ethyl alcohol, methyl alcohol and the like, has the advantage that there is no need to wipe off the liquid protruding out of gaps because it is aqueous as well as has low viscosity to facilitate penetration into micro-gaps. Further, because isopropyl alcohol, ethyl alcohol, methyl alcohol and the like are a commonly used solvent and thus easily available, the lubricant using such alcohol may also enable a reduction in manufacturing cost.

[0038]

It also preferable that the percentage of tungsten disulfide powder content in the lubricant is less than 25wt% and is selected depending on injection point as appropriate. Further, if the solvent evaporates to increase excessively the powder concentrations with the passage of time, the same solvent can be used for dilution for use.

[0039]

For example, in the bicycle chain (DURA-ACE CN-M9100 produced by Shimano) such as illustrated in Fig. 9, the total area per link of the face-to-face surfaces of the gaps g1, g2, g3, g4 and the outer peripheral surfaces of the rollers 9, which are sliding surface, is about 215 mm². Sufficient concentration of tungsten disulfide powder in two drops of the lubricant to cover the area with at least one layer of tungsten disulfide powder was calculated to be about 3.9wt%. Stated another way, if the percentage of tungsten disulfide powder content is 3.9wt%, it is possible to provide the amount of tungsten disulfide powder required to coat all the sliding surfaces per link with two drops of the lubricant.

[0040]

Then, the lubricant with 12.5wt% (sample E) used in the above -described driving test contains the tungsten disulfide powder of more than triple the 3.9wt% as described above. Therefore, it is considered in the driving tests that a sufficient amount of tungsten disulfide powder to cover all the sliding surfaces was supplied by injection of two drops per link.

It is noted that the calculation was here performed assuming that the volume of a drop is 0.013 cm^3 , and each particle of the tungsten disulfide powder is spherical in shape with a diameter being $0.5 \text{ }\mu\text{m}$.

[0041]

In like manner with the above, the lubricant for injection according to the present invention may be also applied to lubricate sliding surface with micro-gaps of something other than the bicycle chain.

Further, if the percentage of tungsten disulfide powder content is less than 25wt%, the penetration ability into a micro-gap may be sufficiently offered. However, if the percentage of content is reduced to increase the penetration ability, the injection amount may be increased according to the sliding area requiring lubrication.

Industrial Applicability

[0042]

The lubricant for injection according to the present invention is suitable for lubrication of various micro-gaps.

CLAIMS

1. A lubricant for injection to be injected into a micro-gap between sliding surfaces, consisting only of tungsten disulfide powder and a volatile solvent,
wherein a percentage of the tungsten disulfide powder content is at or below 25wt%.
2. The lubricant for injection according to claim 1, wherein the volatile solvent is lower alcohol.