

SPECIFICATION

Title of Invention: LUBRICATING OIL FOR ROLLING AND ROLLING METHOD

Technical Field

[0001]

The present invention relates to a lubricating oil for rolling and a rolling method using the lubricating oil.

Background Art

[0002]

A rolling process is a type of plastic working process in which a die serving as a rolling tool is pressed against a material to be processed to mold the material into a desired shape while rotating the material to be processed using a frictional force and a tangential force. The advantage of this rolling process is as follows: rolling can be performed while imparting a compressive residual stress; cutting debris is not generated unlike a cutting process, and therefore, a material to be processed can be saved; and a step of producing a processed product is simpler than when using a cutting process which further requires steps such as grinding, heating, or the like. Accordingly, the rolling process attracts attention in terms of resource saving and improvement of production

efficiency.

On the other hand, a lubricating oil to be used for rolling is required to have high working performance under severe lubricating conditions as follows: tool wear is reduced, and at the same time, the shape of a processed product is controlled, and further, the surface roughness of the processed product is improved.

Therefore, as a conventional rolling oil, a lubricating oil which contains an oiliness improver and an extreme pressure agent to enhance the workability has been used for the purpose of enhancing the working performance and prolonging the life of a rolling tool. For example, Patent Document 1 discloses a rolling oil containing an oiliness improver and an extreme pressure agent such as a monoester, a dicarboxylate, a thiophosphite, and a triazole compound.

Further, for the same reason, conventionally, as a lubricating oil for rolling, a lubricating oil for metal working such as a cutting oil which contains an oiliness improver and an extreme pressure agent and has high working performance is often diverted for a lubricating oil for rolling. For example, in Patent Document 2 and Patent Document 3, it is described that with respect to the invention of a cutting oil, the cutting oil can also be diverted for rolling (see, for example, paragraph [0109] of

Patent Document 2, and paragraph [0158] of Patent Document 3).

[0003]

On the other hand, a rolling process is applied to a threading process, a gear cutting process, a grooving process, a burnishing process, etc., however, high working performance is required for all processes.

Among the rolling processes, particularly, a worm rolling process whose difficulty level is considered to be high is required to provide a processed product having a hard tooth surface, a small surface roughness, and high gear accuracy.

In order to meet such a requirement, it is experimentally known that as a rolling method for improving the gear accuracy of a worm, a rolling method in which a rolling amount, that is, a die push-in depth per one operation is reduced, and at the same time, a die rotation speed is increased is effective.

However, it was found that in the worm rolling process, if a die rotation speed is increased, peeling occurs in a bottom portion of a tooth surface of a worm. In other words, peeling occurs in a bottom portion of a tooth surface of the rolled worm, resulting in obtaining a processed product having poor appearance. Moreover, this peeling phenomenon cannot be suppressed even if the extreme

pressure property or the like of the rolling oil is enhanced, and the current situation is that a solution therefor has not yet been found out.

In light of such a situation, for a threading process, a gear cutting process, a grooving process, a burnishing process, or the like, a lubricating oil for rolling and a rolling method having higher working performance have been demanded, and particularly, a lubricating oil for worm rolling and a worm rolling method having high working accuracy and capable of suppressing the occurrence of peeling in a bottom portion of a tooth surface have been strongly demanded to be proposed.

Prior Art Documents

Patent Documents

[0004]

Patent Document 1: WO 2009/119669

Patent Document 2: JP-A-2005-187650

Patent Document 3: JP-A-2005-272818

Summary of the Invention

Problem to be Solved by the Invention

[0005]

An object of the present invention is to provide a lubricating oil for rolling having excellent working

performance, particularly a lubricating oil for rolling having high working accuracy and capable of suppressing the occurrence of peeling in a bottom portion of a tooth surface of a worm in a worm rolling process so that the appearance of the tooth surface can be improved.

Another object of the present invention is to provide a rolling method having high working performance using the lubricating oil for rolling.

Means for Solving the Problems

[0006]

The present inventors made intensive studies for achieving the above objects, and as a result, they unexpectedly found out that by using a lubricating oil having a friction coefficient of a predetermined value or more as a lubricating oil for rolling, the above-described objects can be effectively achieved. The present invention has been completed based on this finding.

[0007]

That is, the present invention provides:

1. a lubricating oil for rolling containing a mineral oil and/or a synthetic oil as the main component and having a friction coefficient of 0.2 or more;
2. the lubricating oil for rolling according to the above 1, wherein the lubricating oil has a friction

coefficient of from 0.2 to 0.4;

3. the lubricating oil for rolling according to the above 1 or 2, wherein the lubricating oil has a kinematic viscosity at 40°C of from 2 to 15 mm²/s;

4. the lubricating oil for rolling according to any one of the above 1 to 3, further containing a friction coefficient improver;

5. the lubricating oil for rolling according to any one of the above 1 to 4, wherein the lubricating oil is used for threading, gear cutting, grooving, or burnishing;

6. the lubricating oil for rolling according to any one of the above 1 to 5, wherein the lubricating oil is used for worm rolling;

7. a rolling method using the lubricating oil for rolling according to any one of the above 1 to 6;

8. the rolling method according to the above 7, wherein the rolling is worm rolling; and

9. the worm rolling method according to the above 8, wherein the rolling is performed under the conditions that a die push-in speed is from 0.02 to 8 m/s, a die rotation speed is from 5 to 550 rpm, and a die peripheral speed is from 0.04 to 3.14 m/s.

Effects of the Invention

[0008]

According to the present invention, a lubricating oil for rolling having excellent working performance, particularly a lubricating oil for rolling having high working accuracy and capable of suppressing the occurrence of peeling in a bottom portion of a tooth surface of a worm in a worm rolling process so that the appearance of the tooth surface can be improved can be provided.

Further, according to the present invention, a rolling method having high working performance using the lubricating oil for rolling can be provided.

Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 is a view showing the shape of a tool (a round die) used in Examples of the present invention.

[Fig. 2] Fig. 2 is a view showing the shape of a material to be processed used in Examples of the present invention.

Embodiments of the Invention

[0010]

[Lubricating Oil for Rolling]

The present invention is directed to a lubricating oil for rolling containing a mineral oil and/or a synthetic oil as the main component and having a friction coefficient

of 0.2 or more.

Hereinafter, a lubricating oil for rolling (hereinafter sometimes abbreviated as "a lubricating oil") of the present invention in the case where the rolling is worm rolling will be described.

The lubricating oil of the present invention contains a mineral oil and/or a synthetic oil as the main component.

The main component as used herein refers to a component contained in an amount of 50% by mass or more, preferably 60% by mass or more, more preferably 70% by mass or more, particularly preferably 80% by mass or more with respect to the total amount of the lubricating oil. The main component may be contained in an amount of 100% by mass, in other words, the lubricating oil may consist of a mineral oil and/or a synthetic oil.

[0011]

As the mineral oil, for example, an atmospheric distillate fraction of crude petroleum, or a fraction obtained by vacuum distillation of an atmospheric residue obtained by atmospheric distillation, or a naphthenic mineral oil or a paraffinic mineral oil obtained by purification of such a fraction through one or more treatments such as hydrodesulfurization, solvent deasphalting, solvent extraction, hydrocracking, hydrodewaxing, solvent dewaxing, hydrotreating, a clay

treatment, and a sulfuric acid treatment can be exemplified. Further, a wax-isomerized isoparaffinic mineral oil (a wax-isomerized mineral oil) obtained by isomerization of a mineral oil-based wax can be preferably exemplified.

[0012]

On the other hand, as the synthetic oil, for example, an aliphatic synthetic oil such as polybutene or a hydrogenated product thereof, an α -olefin oligomer (a poly- α -olefin) having 8 to 14 carbon atoms such as 1-decene oligomer, or a hydrogenated product thereof; an aromatic synthetic oil such as an alkyl benzene or an alkyl naphthalene; a naphthenic synthetic oil such as a hydrocarbon having a cyclohexane ring can be exemplified.

Among these mineral oils and synthetic oils, a naphthenic mineral oil, a paraffinic mineral oil, polybutene or a hydrogenated product thereof, or an α -olefin oligomer having 8 to 14 carbon atoms or a hydrogenated product thereof is preferred.

[0013]

In the lubricating oil of the present invention, one type of mineral oils and synthetic oils can be used alone or two or more types selected from these oils can be used in admixture. That is, one type or two or more types of mineral oils may be used, one type or two or more types of synthetic oils may be used, or one or more types of mineral

oils and one or more types of synthetic oils may be used in admixture.

[0014]

The lubricating oil of the present invention is required to have a friction coefficient of 0.2 or more. If the lubricating oil has a friction coefficient less than 0.2, the working performance may be deteriorated. For example, if a lubricating oil having a friction coefficient less than 0.2 is used in a worm rolling process, sliding may occur between a material to be processed and a die to cause peeling in a bottom portion of a tooth surface of a rolled worm, and therefore, a processed product having poor appearance may be produced.

On the other hand, the upper limit of the friction coefficient of the lubricating oil is not particularly limited, however, from the viewpoint of ease of availability, the upper limit thereof is preferably about 0.4. Accordingly, the friction coefficient of the lubricating oil of the present invention is preferably from 0.2 to 0.4, particularly preferably from 0.20 to 0.40.

Incidentally, the above-described friction coefficient is a value obtained by measurement according to the "Soda-type pendulum test method" defined in JASO-M 314-88 under the conditions that the oil temperature is 60°C.

[0015]

The lubricating oil of the present invention preferably has a kinematic viscosity at 40°C of from 2 to 15 mm²/s. If the kinematic viscosity of the lubricating oil at 40°C is 2 mm²/s or more, there is no fear of deterioration of the workability of the lubricating oil due to evaporation loss, and if the kinematic viscosity thereof at 40°C is 15 mm²/s or less, there is also no fear of excessive increase in the flow resistance of the lubricating oil. In view of this, the kinematic viscosity of the lubricating oil at 40°C is more preferably from 3 to 10 mm²/s.

[0016]

In the present invention, for the purpose of further increasing the friction coefficient of the lubricating oil, a friction coefficient improver can be blended. Representative examples of the friction coefficient improver in the present invention include a metallic detergent and a bicyclo[2.2.1]heptane derivative.

Preferred examples of the metallic detergent include a sulfonate, a phenate, and a salicylate containing an alkaline earth metal such as Ca, Mg, or Ba. These may be neutral, basic, or perbasic. Above all, Ca sulfonate, Ca phenate, Ca salicylate, and the like, each of which is perbasic, for example, has a base value as measured by a perchloric acid method of 200 mgKOH/g or more, more

preferably 300 mgKOH/g or more, particularly from 300 to 500 mgKOH/g, are preferred, and Ca sulfonate is particularly preferred.

[0017]

Further, preferred examples of the bicyclo[2.2.1]heptane derivative include compounds having two or more bicyclo[2.2.1]heptane rings. Above all, for example, compounds having two bicyclo[2.2.1]heptane rings and also having 15 to 22 carbon atoms in total such as 2-methyl-3-methyl-2-[(3-methylbicyclo[2.2.1]hept-2-yl)methyl]bicyclo[2.2.1]heptane, and 2-methyl-3-methyl-2-[(2-methylbicyclo[2.2.1]hept-3-yl)methyl]bicyclo[2.2.1]heptane are preferred.

[0018]

In the present invention, one type or two or more types of friction coefficient improvers selected from the above-described metallic detergents and bicyclo[2.2.1]heptane derivatives can be blended. The blending amount of the friction coefficient improver is preferably from 1 to 30% by mass, more preferably from 3 to 20% by mass, further more preferably from 5 to 15% by mass with respect to the total amount of the lubricating oil. If the blending amount of the friction coefficient improver is 1% by mass or more, an effect of further enhancing the friction coefficient is observed, however, even if the

blending amount thereof exceeds 30% by mass, a significant enhancement of the effect, which is economically worth the increase in the blending amount, cannot be expected.

[0019]

In the lubricating oil to be used in the present invention, other various types of additives may be blended as long as the friction coefficient satisfies the above-described requirement. Examples of such additives include an oiliness improver, an antioxidant, a corrosion inhibitor, and a defoaming agent.

Examples of the oiliness improver include fatty acid monoesters obtained from an aliphatic carboxylic acid having 12 to 24 carbon atoms and an aliphatic alcohol having 1 to 24 carbon atoms such as methyl stearate, butyl stearate, octyl stearate, and octyl palmitate. The blending amount of the oiliness improver is preferably from 1 to 20% by mass, more preferably from 3 to 15% by mass with respect to the total amount of the lubricating oil.

[0020]

Examples of the antioxidant include phenolic antioxidants such as 2,6-di-tert-butyl-4-methylphenol and 4,4'-methylenebis(2,6-di-tert-butylphenol); amine-based antioxidants such as 4,4'-dioctyldiphenylamine, 4,4'-dinonyldiphenylamine, and phenyl- α -naphthylamine. The blending amount of the antioxidant is preferably from 0.05

to 3.0% by mass, more preferably from 0.2 to 2.0% by mass with respect to the total amount of the lubricating oil.

Examples of the corrosion inhibitor include benzotriazole-based, benzimidazole-based, benzothiazole-based, and thiadiazole-based corrosion inhibitors. The blending amount thereof is preferably from 0.05 to 10% by mass, more preferably from 0.1 to 5% by mass with respect to the total amount of the lubricating oil.

Further, examples of the defoaming agent include dimethylpolysiloxane and fluoroether. The blending amount thereof is preferably from 0.00001 to 10% by mass, more preferably from 0.0001 to 5% by mass with respect to the total amount of the lubricating oil.

[0021]

[Rolling Method]

The rolling method of the present invention includes rolling using the above-described lubricating oil for rolling.

The rolling method includes threading, gear cutting, grooving, burnishing, and the like. Examples of the threading include lead screw threading and ball threading; examples of the gear cutting include worm gear cutting; examples of the grooving include varying pitch grooving; and examples of the burnishing include gear burnishing rolling.

[0022]

In the case where the rolling method using the lubricating oil for rolling of the present invention is worm rolling, rolling is preferably performed under the rolling conditions that a die push-in speed, and a die rotation speed and the like satisfy the following requirements (1) and (2).

(1) Die Push-in Speed

The die push-in speed is preferably from 0.02 to 8 m/s, more preferably from 0.3 to 2 m/s.

(2) Die Rotation Speed and Die Peripheral Speed

The die rotation speed is preferably from 5 to 550 rpm or the die peripheral speed is preferably from 0.04 to 3.14 m/s.

As described in the above (1), by setting the die push-in speed to a small value, and as described in the above (2), by setting the die rotation speed to a large value or the die peripheral speed to a large value, the gear accuracy of a processed product can be improved. Further, by using the above-described lubricating oil for worm rolling under such rolling conditions, the occurrence of peeling in a bottom portion of a tooth surface of a worm is suppressed. Accordingly, it is possible to suppress the occurrence of peeling in a bottom portion of a tooth surface and to form a worm having a small surface roughness

by rolling.

[0023]

Moreover, such a worm rolling method provides a high yield of a processed material since cutting debris is not generated as compared with a processing method using a cutting process, and can reduce cost for the material, and therefore can contribute to resource saving. Further, the method can perform processing at a high speed and therefore can reduce the processing time as compared with the cutting process.

Further, the cutting process often requires a heating process or a grinding process after performing the cutting process, however, a worm rolling method as described above may be able to omit such a process, and therefore, it can also be expected that the worm production time is considerably reduced.

Examples

[0024]

Next, the present invention will be described in further detail with reference to Examples, however, the present invention is by no means limited to these Examples.

Examples 1 to 7 and Comparative Example 1

By blending constituent components shown in Table 3

at a ratio shown in Table 3, each lubricating oil for rolling was prepared. Subsequently, the characteristics and physical properties of each lubricating oil were measured according to the methods described below and the performance thereof was evaluated. The results are shown in Table 3.

Incidentally, as the constituent components shown in Table 3, the following materials were used.

(1) Naphthenic mineral oil: a naphthenic mineral oil having characteristics shown in Table 2

(2) Paraffinic mineral oil: a paraffinic mineral oil having characteristics shown in Table 2

(3) Isoparaffinic synthetic oil: a synthetic oil having characteristics shown in Table 2, trade name "IP SOLVENT 1620", manufactured by Idemitsu Kosan Co., Ltd.

(4) Friction coefficient improver I: calcium sulfonate (manufactured by Chemtura Corporation, base value (measured by a perchloric acid method): 400 mgKOH/g)

(5) Friction coefficient improver II: a bicyclo[2.2.1]heptane derivative (2-methyl-3-methyl-2-[(3-methylbicyclo[2.2.1]hept-2-yl)methyl]bicyclo[2.2.1]heptane (manufactured by Idemitsu Kosan Co., Ltd.))

(6) Oiliness improver: butyl stearate (manufactured by Kao Corporation)

(7) Extreme pressure agent: dioctyl polysulfide

(manufactured by DIC Corporation)

[0025]

<Measurement Method for Characteristics and Physical Properties>

(1) Friction coefficient

The friction coefficient was measured according to the "Soda-type pendulum test" defined in JASO-M 314-88 using a Soda-type pendulum tester (Model II) at an oil temperature of 60°C.

(2) Kinematic viscosity

The kinematic viscosity was measured according to JIS K 2283.

(3) Density

The density was measured according to JIS K 2249.

[0026]

<Evaluation Method for Performance>

(4) Worm Gear Rolling Test

(i) Test Apparatus and Test Conditions

Rolling machine: GA-330A, manufactured by Nissei Co., Ltd.

Die: a round die having a shape shown in Fig. 1 and specifications shown in Table 1

Material to be processed: a material to be processed having a shape shown in Fig. 2 and made of S45C

Shape of workpiece: worm

Push-in speed: 0.14 m/s

Die rotation speed: 15 rpm

Lubricating oil feeding method: automatically
(injection from a lubricator attached to the apparatus)

(ii) Evaluation Method

With respect to a worm formed by rolling, a weight loss due to peeling in a bottom portion of a tooth surface was determined, and also the appearance (the ratio of the peeled area) of the worm was evaluated.

(Measurement Method for Weight Loss due to Peeling)

By using an electric balance HM-202 manufactured by A & D Co., Ltd., the weight of the material to be processed was measured before and after the test, and a difference in the weight was defined as a peeling amount.

(Evaluation Method for Appearance of Worm)

The ratio of the peeled area was determined, and the results of evaluation were assigned A, B, or C on the basis of the following evaluation criteria.

Evaluation Criteria for Appearance

A: The ratio of the peeled area was 5% or less.

B: The ratio of the peeled area was more than 5% but

less than 20%.

C: The ratio of the peeled area was 20% or more.

[0027]

[Table 1]

Table 1

Normal module (mm)	2.5
Normal pressure angle (°)	12.3
Normal pitch (mm)	7.7
Number of threads	28
Lead angle (°)	21.7
Tip circle diameter (mm)	191.6
Pitch circle diameter (mm)	186.6
Root circle diameter (mm)	183.1

[0028]

[Table 2]

Table 2

	Naphthenic mineral oil	Paraffinic mineral oil	Isoparaffinic synthetic oil
Kinematic viscosity (40°C, mm ² /s)	8.99	2.24	1.25
Density (15°C, g/cm ³)	0.908	0.819	0.761
Friction coefficient (-)	0.24	0.42	0.45

[0029]

[Table 3]

Table 3

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Comparative Example 1
Constituent components of lubricating oil (blending ratio: mass%)	Naphthenic mineral oil	100	80	50	30	90	85	80
	Paraffinic mineral oil	-	20	50	50	-	-	-
	Isoparaffinic synthetic oil	-	-	-	-	10	-	-
	Friction coefficient improver I	-	-	-	15	10	-	-
	Friction coefficient improver II	-	-	-	-	-	10	-
	Oiliness improver	-	-	-	5	10	5	10
Characteristics and physical properties of lubricating oil	Extreme pressure agent	-	-	-	-	-	-	10
	Friction coefficient (-)	0.24	0.22	0.28	0.23	0.25	0.23	0.13
	Kinematic viscosity (40°C, mm ² /s)	8.99	6.10	3.90	6.04	4.79	9.16	10.45
	Density (15°C, g/cm ³)	0.9080	0.8901	0.8645	0.9000	0.8963	0.9130	0.9232
Performance of lubricating oil	Weight loss due to peeling (g)	0.011	0.010	0.005	0.015	0.013	0.022	0.322
	Appearance of worm	A	A	A	A	A	A	C

[0030]

According to Table 3, it is found that when a worm was formed by rolling using a lubricating oil having a friction coefficient of 0.2 or more, the weight loss due to peeling was extremely small, and also the appearance of the worm was favorable (Examples 1 to 7). On the other hand, when a lubricating oil having a friction coefficient less than 0.2 was used, the weight loss due to peeling was large, and also the appearance of the worm was not favorable (Comparative Example 1).

Industrial Applicability

[0031]

According to the present invention, a lubricating oil for rolling having excellent working performance, particularly a lubricating oil for rolling having high working accuracy and capable of suppressing the occurrence of peeling in a bottom portion of a tooth surface of a worm in a worm rolling process so that the appearance of a gear can be improved can be provided. Further, a rolling method having high working performance using the lubricating oil for rolling can be provided. Accordingly, the present invention can be effectively used as a lubricating oil for rolling and a rolling method capable of producing a worm and the like efficiently while saving resources.

CLAIMS

[Claim 1]

A lubricating oil for rolling, comprising a mineral oil and/or a synthetic oil as the main component and having a friction coefficient of 0.2 or more.

[Claim 2]

The lubricating oil for rolling according to claim 1, wherein the lubricating oil has a friction coefficient of from 0.2 to 0.4.

[Claim 3]

The lubricating oil for rolling according to claim 1 or 2, wherein the lubricating oil has a kinematic viscosity at 40°C of from 2 to 15 mm²/s.

[Claim 4]

The lubricating oil for rolling according to any one of claims 1 to 3, further comprising a friction coefficient improver.

[Claim 5]

The lubricating oil for rolling according to any one of claims 1 to 4, wherein the lubricating oil is used for threading, gear cutting, grooving, or burnishing.

[Claim 6]

The lubricating oil for rolling according to any one of claims 1 to 5, wherein the lubricating oil is used for worm rolling.

[Claim 7]

A rolling method using the lubricating oil for rolling according to any one of claims 1 to 6.

[Claim 8]

The rolling method according to claim 7, wherein the rolling is worm rolling.

[Claim 9]

The worm rolling method according to claim 8, wherein the rolling is performed under the conditions that a die push-in speed is from 0.02 to 8 m/s, a die rotation speed is from 5 to 550 rpm, and a die peripheral speed is from 0.04 to 3.14 m/s.