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(54) COPPER ALLOY TO BE USED IN SLIDING MEMBER, CASTING, SLIDING MEMBER, AND METHOD FOR PRODUCING SAME

(57) The present invention provides a copper alloy for a sliding member which contains tin, sulfur, iron and phosphorus as its main components, but in which even if no iron is contained or the iron content is reduced, sliding properties are obtained which are equal or superior to the sliding properties of a conventional copper alloy. The present invention also provides a production method for producing a sliding member by casting the copper alloy. The copper alloy of the present invention consists of not less than 3.0% by mass and not more than 16.0% by mass of tin; not less than 0.3% by mass and not more than 1.0% by mass of sulfur; less than 0.3% by mass of iron; not less than 0.04% by mass and not more than 0.5% by mass of phosphorus; and a balance consisting of copper and unavoidable impurities.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a copper alloy used in a sliding member, and containing no lead as its main component.

BACKGROUND ART

[0002] Conventionally used copper alloys contain a predetermined amount of lead to improve the sliding and cutting properties, and CAC603 or the like has been used as sliding members. However, in recent years, since it is required to take account of the RoHS Directive or other environmental concerns, copper alloys in which no lead is used or the amount of lead used is reduced have been developed.

[0003] For example, the below-identified Patent Document 1 discloses, in its Example, a copper alloy for a sliding member consisting of not less than 5.14% by mass and not more than 15.54% by mass of tin; not less than 0.42% by mass and not more than 1.04% by mass of sulfur; not less than 0.31% by mass and not more than 3.43% by mass of iron; not less than 0.012% by mass and not more than 0.033% by mass of phosphorus; and a balance consisting of copper and unavoidable impurities.

[0004] Also, the below-identified Patent Document 2 discloses, as a copper alloy having improved machinability, a copper alloy wrought material consisting of tin, phosphorus, sulfur, and a balance consisting of copper and unavoidable impurities, the copper alloy wrought material containing a dispersed sulfide whose average diameter is 0.1 to 10 μm and whose area ratio is 0.1 to 10% in a cross section perpendicular to the longitudinal direction of the wrought material.

PRIOR ART DOCUMENT(S)

PATENT DOCUMENT(S)

[0005]

Patent Document 1: Japanese Patent No. 4658269
Patent Document 2: Japanese Patent No. 5916464

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] However, the copper alloy of Patent Document 1 has a problem in that if the iron content is smaller than a predetermined amount, the sliding properties are insufficient.

[0007] Also, Patent Document 2 discloses the effect of machinability of a copper alloy containing tin, sulfur and phosphorus other than iron, but Patent document 2 is silent about the sliding properties. Generally, copper alloys having good machinability and suitable for cutting are not suitable for sliding applications.

[0008] Also, a copper alloy in which the iron content is large has a problem in that cast defects tend to occur, thus causing many defective products when producing the copper alloy by casting.

[0009] In view of the above, it is an object of the present invention to provide (i) a copper alloy for a sliding member which contains tin, sulfur, iron and phosphorus as its main components, but in which even if no iron is contained or the iron content is reduced, sliding properties are obtained which are equal or superior to the sliding properties of a conventional copper alloy; and (ii) a copper alloy for a sliding member that has sliding properties and good castability.

MEANS FOR SOLVING THE PROBLEMS

[0010] In order to achieve the above object, the present invention provides a copper alloy for a sliding member according to a first embodiment, the copper alloy consisting of: not less than 3.0% by mass and not more than 16.0% by mass of tin; not less than 0.3% by mass and not more than 1.0% by mass of sulfur; less than 0.3% by mass of iron; not less than 0.04% by mass and not more than 0.5% by mass of phosphorus; and a balance consisting of copper and unavoidable impurities.

[0011] For the copper alloy of the present invention, it is possible to select a second embodiment in which some of the contents in the first embodiment are limited, i.e., the tin content is not less than 6.0% by mass and not more than 15.0% by mass, and the iron content is not less than 0.005% by mass and less than 0.3% by mass.

[0012] For the copper alloy of the present invention, it is possible to select a third embodiment in which some of the

contents in the first embodiment are limited, i.e., the tin content is not less than 9.0% by mass and not more than 11.0% by mass, the sulfur content is not less than 0.5% by mass and not more than 1.0% by mass, and the iron content is not less than 0.005% by mass and less than 0.05% by mass.

[0013] For the present invention, it is possible to select a cast member formed of the copper alloy according to any one of the first to third embodiments.

[0014] For the present invention, it is possible to select a sliding member comprising the cast member, which is formed of the copper alloy according to any one of the first to third embodiments.

[0015] The present invention also provides a production method for producing a sliding member, the production method comprising: melting a material such that copper alloy components thereof comprise not less than 3.0% by mass and not more than 16.0% by mass of tin, not less than 0.3% by mass and not more than 1.0% by mass of sulfur, less than 0.07% by mass of iron, and not less than 0.04% by mass and not more than 0.5% by mass of phosphorus; and casting the melted material.

[0016] For the production method of the present invention, it is possible to select an embodiment in which the tin content is not less than 6.0% by mass and not more than 15.0% by mass, and the iron content is not less than 0.005% by mass and less than 0.05% by mass.

EFFECTS OF THE INVENTION

[0017] With respect to the copper alloy of the present invention, even if the iron content is reduced, by appropriately adjusting the phosphorus content, sliding properties are obtainable which are equal or superior to the sliding properties of a conventional copper alloy for a sliding member. Good castability is obtainable in a similar metal composition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1A is an evaluation cross-sectional photograph of a fracture portion of Example 9 in a castability test.
Fig. 1B is an evaluation cross-sectional photograph of a fracture portion of Example 10 in a castability test.
Fig. 1C is an evaluation cross-sectional photograph of a fracture portion of Comparative Example 6 in a castability test.

BEST MODE FOR CARRYING OUT THE INVENTION

[0019] A copper alloy for a sliding member according to the present invention is described below. The copper alloy for a sliding member consists of predetermined amounts of tin, sulfur, iron and phosphorus; and a balance consisting of copper and unavoidable impurities.

[0020] The copper alloy needs to contain not less than 3.0% by mass of tin. Tin improves the matrix strength of the copper alloy, improves the wear resistance, and keeps the sliding properties good, but if the tin content is less than 3.0% by mass, these effects will be insufficient. On the other hand, the tin content needs to be not more than 16.0% by mass. If the tin content is more than 16.0% by mass, the counterpart component may be significantly worn, and good sliding properties may not be obtained. Also, in order to obtain a copper alloy balanced with respect to properties required for a sliding member such as strength, elongation, and hardness and wear amount relating to wear resistance, the tin content is preferably not less than 6.0% by mass and not more than 15.0% by mass, and more preferably not less than 9.0% by mass and not more than 11.0% by mass.

[0021] The copper alloy needs to contain not less than 0.3% by mass of sulfur. Sulfur reacts with one or both of copper and iron, thereby forming a sulfide. The sulfide has solid lubricity, reduces the friction coefficient, improves compatibility, and provides good sliding properties in a sliding state. If the sulfur content is less than 0.3% by mass, these effects will not be obtained or will be insufficient. The sulfur content is preferably not less than 0.5% by mass. On the other hand, the sulfur content needs to be not more than 3.0% by mass, because if the sulfur content is more than 3.0% by mass, sulfur is likely to reduce the strength. Also, in order to obtain sufficient sliding properties, the sulfur content is preferably not more than 1.0% by mass, and more preferably not more than 0.7% by mass.

[0022] The copper alloy needs to contain less than 0.3% by mass of iron. If the iron content is not less than 0.3% by mass, the hardness of the copper alloy will increase significantly, and thus when the copper alloy is used as a sliding member, the sliding member is likely to attack and wear the counterpart component, or the elongation will decrease, thereby reducing the performance of the product. On the other hand, the wear resistance tends to worsen as the iron component decreases. This is because, in view of the fact that iron together with sulfur forms a Fe-S compound that improves the sliding properties of the copper alloy, iron is desirably contained to form the amount of Fe-S compound required to ensure necessary sliding properties. Therefore, in order to obtain a copper alloy having hardness and sliding properties in a balanced manner, the iron content is preferably not less than 0.005% by mass and less than 0.3% by mass, and more preferably not less than

0.005% by mass and not more than 0.05% by mass.

[0023] Also, the copper alloy needs to contain less than 0.3% by mass of iron in view of castability. This is because if the iron content is not less than 0.3% by mass, casting defects are likely to exist in the product after casting. Also, in order to ensure sufficient castability, the iron content is preferably not more than 0.07% by mass.

[0024] The copper alloy needs to contain not less than 0.04% by mass of phosphorus. Phosphorus has the effect of forming a Cu-P compound together with copper, thereby increasing the hardness of the entire copper alloy. In the copper alloy of the present invention, even if the iron component is reduced, it is possible to ensure sliding properties by including phosphorus in the above range. On the other hand, the phosphorus content needs to be not more than 0.5% by mass, because if more than 0.5% by mass of phosphorus is present, the hardness of the entire copper alloy will increase significantly, so that the seizure resistance will decrease.

[0025] The copper alloy preferably contains copper and unavoidable impurities as the elements other than the above-mentioned elements. The amount of elements contained as unavoidable impurities is preferably as small as possible, and more preferably is equal to or below the detection limit. Such elements are, e.g., molybdenum and nickel.

[0026] Examples of the sliding member in which the copper alloy of the present invention is used include, e.g., a linear bushing and a cylinder liner that include a rolling bearing or a sliding bearing. By using the copper alloy of the present invention at a portion of such a sliding member that requires sliding properties, it is possible to obtain balanced sliding properties. As a suitable production method for producing the sliding member according to the present invention, it is possible to use, for example, a casting method such as gravity casting, centrifugal casting or die casting. In a cast member obtained by such a casting method, the occurrence of casting defects is reduced as described above. Also, the cast member exhibits a good balance with respect to strength, elongation, and hardness and wear amount relating to wear resistance, and can be suitably used as the sliding member.

EXAMPLE

(Mechanical property test)

[0027] In each of Examples 1 to 8 and Comparative Examples 1 to 5, a raw material was prepared such that the components after casting would consist of predetermined % by mass of components as shown in table 1; and a balance consisting of copper and unavoidable impurities, the raw material was heated to 1200°C and melted to obtain a copper alloy, and the copper alloy was cast by the gravity casting method using a casting mold.

(Tensile test and elongation test)

[0028] Using the cast copper alloy after the above heat treatment, a test piece of 14A was prepared which includes a parallel portion having a diameter of 5 mm, and which is based on JIS Z2241. Using the test piece, a tensile test was conducted (with Instron 5982, made by Instron Corporation), and the test piece was evaluated by the tensile strength and the elongation when the test piece broke.

(Tensile test evaluation criteria)

[0029]

○○: 300 MPa or more
○: 200 MPa or more and less than 300 MPa
△: 100 MPa or more and less than 200 MPa
×: Less than 100 MPa

(Elongation test evaluation criteria)

[0030]

○○: 24% or more
O: 16% or more and less than 24%
△: 8% or more and less than 16%
×: less than 8%

(Hardness test)

[0031] A Brinell hardness test was conducted (with BO3, made by Imai Seiki Co., Ltd.) with respect to the cast copper alloy after the above heat treatment, and the alloy was evaluated by Brinell hardness. The test conditions are as follows: the test force was 500 kgf, and a cemented carbide ball having a diameter of 10 mm was used as an indenter.

(Hardness test evaluation criteria)

[0032]

○○: 80HB or more and less than 120HB
O: 60HB or more and less than 80HB
△: 40HB or more and less than 60HB
×: less than 40HB, or not less than 120HB

(Wear amount confirmation test)

[0033] By machining the cast copper alloy after the above heat treatment, a disk having an outer diameter of 70 mm and a thickness of 6 mm was prepared. The friction surface was finished with #80 waterproof paper.

[0034] Next, with respect to the friction surface of the prepared disk of each Example, a friction test was conducted using a friction test machine (made by UMT-TriboLab, Bruker). In the friction test, while bringing a ball having a diameter of 10 mm and made of high oxygen chromium bearing steel (SUJ2) into contact with the disk; and pressing the ball against the friction surface with a load of 10N, the ball was reciprocated at a friction speed of 20 mm/s for 15 minutes with an amplitude of 2 mm (±1 mm). After the friction test, using a 3D shape measuring machine (VR-5200, Keyence Corporation), the amount of wear was calculated from the width and depth of a worn portion of the disk friction surface.

(Wear amount confirmation test evaluation criteria)

[0035]

○○: 0.15 mm^3 or less

O: 0.16 mm^3 or more and 0.30 mm^3 or less

△: 0.31 mm^3 or more and 0.45 mm^3 or less

×: 0.46 mm^3 or more

(Overall evaluation criteria for mechanical property test)

[0036]

○○: All of the evaluation results are ○○

O: One or more of the evaluation results are ○, and the others are ○○

△: One or more of the evaluation results are △, and the others are ○○ or ○

×: At least one of the evaluation results is ×

[Table 1]

	Component (mass %)					Evaluation result				
	Tin	Sulfur	Iron	Phosphorus	Copper	Tensile strength	Elongation	Hardness HB	Wear amount	Overall result
Example 1	10.4	0.55	0.003	0.14	Balance	286 ○	22.7 ○	88.8 ○○	0.15 ○○	○
Example 2	10.4	0.53	0.009	0.14	Balance	302 ○○	29.9 ○○	86.9 ○○	0.12 ○○	○○
Example 3	10.6	0.47	0.17	0.15	Balance	321 ○○	22.0 ○	91.8 ○○	0.12 ○○	○
Example 4	6.3	0.63	0.02	0.14	Balance	273 ○	28.5 ○○	68.3 ○	0.15 ○○	○
Example 5	13.1	0.59	0.03	0.14	Balance	353 ○○	16.7 ○	102.0 ○○	0.13 ○○	○
Example 6	10.6	0.48	0.04	0.16	Balance	327 ○○	21.1 ○	91.7 ○○	0.24 ○○	○
Example 7	10.2	0.56	0.04	0.06	Balance	322 ○○	29.8 ○○	84.0 ○○	0.14 ○○	○○
Example 8	10.1	0.58	0.02	0.43	Balance	321 ○○	25.1 ○○	93.2 ○○	0.07 ○○	○○
Comparative Example 1	10.4	0.49	2.03	0.14	Balance	378 ○○	15.4 △	100.5 ○○	0.12 ○○	△
Comparative Example 2	1.8	0.68	0.03	0.12	Balance	254 ○	23.2 ○	55.1 △	0.11 ○○	△
Comparative Example 3	18.6	0.38	0.04	0.14	Balance	382 ○○	0.3 ×	163.2 ×	0.13 ○○	×
Comparative Example 4	10.5	0.22	0.03	0.14	Balance	406 ○○	36.5 ○○	86.2 ○○	0.31 △	△
Comparative Example 5	11.0	1.42	0.05	0.13	Balance	109 △	3.6 ×	94.1 ○○	0.16 ○	×
Note: The iron content in Example 1 is due to unavoidable impurities (not intentionally added)										

[0037] Table 1 shows that, in each of Examples 1 to 8, the content of each component is within the range of the present invention, and thus the copper alloy has good properties with respect to tensile strength, elongation, hardness, and wear resistance, which are necessary for use as a sliding member. Especially Examples 2, 7, and 8 show that if the phosphorus content is not less than 0.04% by mass, which is larger than the amounts described in Examples of Patent Document 1, even if the iron content is less than 0.05% by mass, the copper alloy has very good properties.

[0038] Since, in Comparative Example 1, the iron content is larger than the range of the present invention, the copper alloy has low elongation properties. Also, since, in Comparative Example 2, the tin content is smaller than the range of the present invention, and, in Comparative Example 3, the tin content is conversely larger than the range of the present invention, the copper alloy of Comparative Example 2 has low hardness properties, and the copper alloy of Comparative Example 3 has low hardness and elongation properties. Also, since, in Comparative Example 4, the sulfur content is smaller than the range of the present invention, and, in Comparative Example 5, the sulfur content is conversely larger than the range of the present invention, the copper alloy of Comparative Example 4 has low wear resistance, and the copper alloy of Comparative Example 5 has low tensile strength and elongation properties.

(Castability test)

[0039] In each of Examples 9 and 10 and Comparative Example 6, a raw material was prepared such that the components after casting would consist of predetermined % by mass of components as shown in table 2; and a balance consisting of copper and unavoidable impurities. Using the raw material, a tensile test piece was prepared by the same melting, casting, and machining steps as in the above tensile test. Then, a tensile test was conducted with respect to the test piece under the same conditions, and the test piece was evaluated by observing the fracture surface after the tensile test.

(Castability test evaluation criteria)

[0040]

O: No casting defects are present on the fracture surface
×: Casting defects are present on the fracture surface

[Table 2]

	Component (mass %)					Castability evaluation result
	Tin	Sulfur	Iron	Phosphorus	Copper	
Example 9	9.8	0.49	0.002	0.06	Balance	○
Example 10	9.9	0.49	0.07	0.06	Balance	○
Comparative Example 6	10.5	0.49	0.46	0.07	Balance	×
Note: The iron content in Example 9 is due to unavoidable impurities (not intentionally added)						

[0041] As shown in table 2, the iron contents in Examples 9 and 10 are within the range of the present invention, whereas the iron content in Comparative Example 6 is larger than the range of the present invention. As a result, in Examples 9 and 10, no casting defects are present as shown in Figs. 1A and 1B, and the copper alloys have good castability, whereas, in Comparative Example 6, casting defects are present as shown in Fig. 1C, and the copper alloy has inferior castability.

[0042] Thus, with respect to a copper alloy for a sliding member containing tin, sulfur, iron and phosphorus as its main components, by adjusting the iron and phosphorus contents, i.e., by containing no iron or reducing the iron content compared to a conventional copper alloy; and increasing the phosphorus content, it is possible to make the copper alloy have sliding properties equal or superior to the sliding properties of a conventional copper alloy. Also, by reducing the iron content, it is possible to make the copper alloy have good castability.

Claims

1. A copper alloy for a sliding member, the copper alloy consisting of:

not less than 3.0% by mass and not more than 16.0% by mass of tin;
not less than 0.3% by mass and not more than 1.0% by mass of sulfur;
less than 0.3% by mass of iron;
not less than 0.04% by mass and not more than 0.5% by mass of phosphorus; and
a balance consisting of copper and unavoidable impurities.

2. The copper alloy according to claim 1, wherein the tin content is not less than 6.0% by mass and not more than 15.0% by mass, and the iron content is not less than 0.005% by mass and less than 0.3% by mass.

3. The copper alloy according to claim 1 or 2, wherein the iron content is not less than 0.005% by mass and less than 0.05% by mass.

4. A cast member formed of the copper alloy according to any one of claims 1 to 3.

5. A sliding member comprising the cast member, which is formed of the copper alloy according to any one of claims 1 to 3.

6. A production method for producing a sliding member, the production method comprising:

melting a material prepared such that components thereof after casting comprise not less than 3.0% by mass and not more than 16.0% by mass of tin, not less than 0.3% by mass and not more than 1.0% by mass of sulfur, less than 0.07% by mass of iron, and not less than 0.04% by mass and not more than 0.5% by mass of phosphorus; and
casting the melted material.

7. The production method according to claim 6, wherein the tin content is not less than 6.0% by mass and not more than 15.0% by mass, and the iron content is not less than 0.005% by mass and less than 0.05% by mass.

FIG. 1A

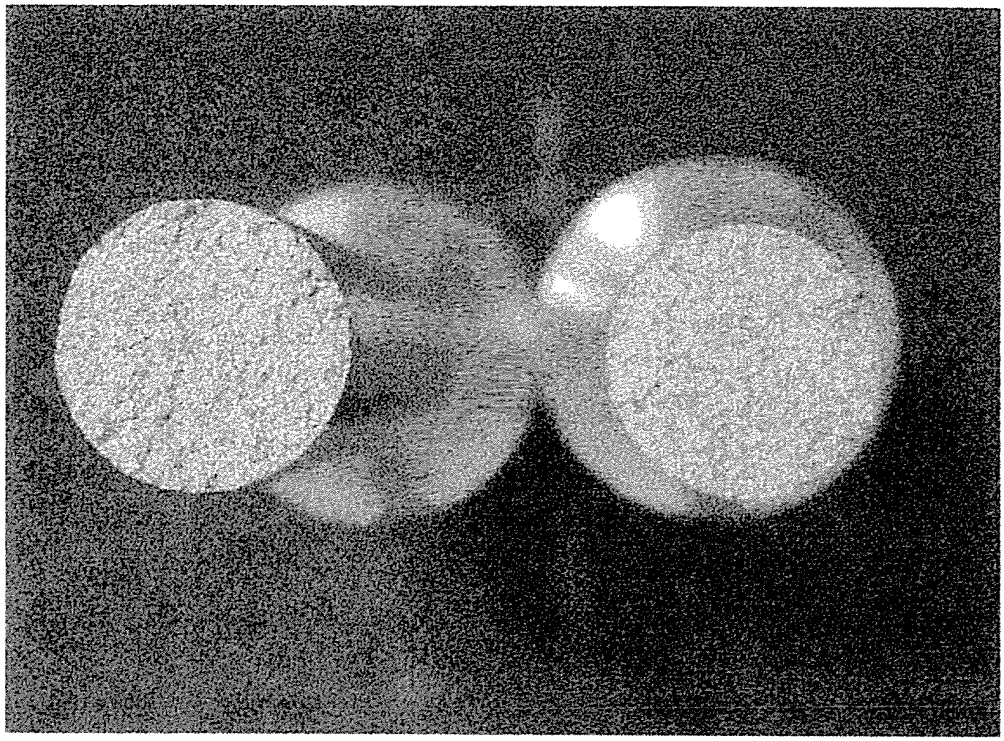
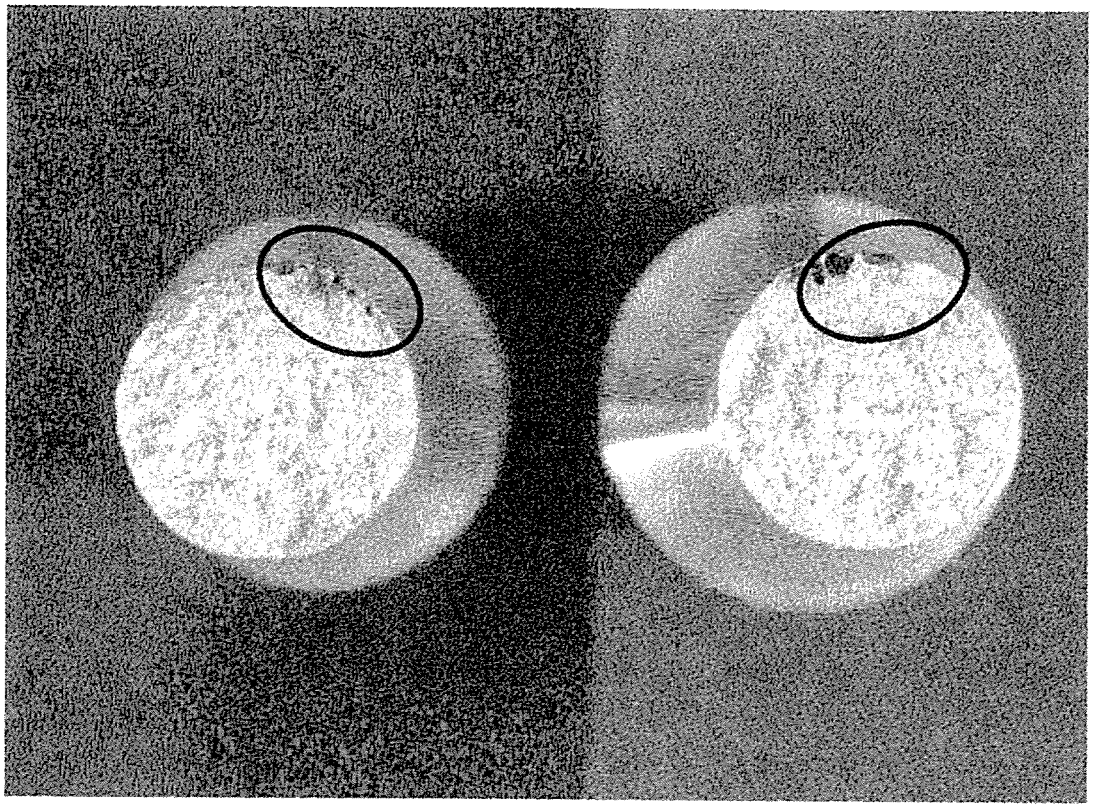


FIG. 1B

FIG. 1C



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/013563

A. CLASSIFICATION OF SUBJECT MATTER

C22C 9/02(2006.01)i; ***C22F 1/00***(2006.01)i; ***C22F 1/08***(2006.01)i
FI: C22C9/02; C22F1/00 602; C22F1/00 611; C22F1/00 630D; C22F1/00 631A; C22F1/00 682; C22F1/00 691B; C22F1/00 691C; C22F1/08 J

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C9/02; C22F1/00; C22F1/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2014-001448 A (KURIMOTO LTD) 09 January 2014 (2014-01-09) paragraphs [0022], [0024]	1-2, 4-5
A		3, 6-7
X	JP 2019-137913 A (KURIMOTO LTD) 22 August 2019 (2019-08-22) paragraphs [0029]-[0035], example 1	6-7
A		1-5
A	JP 2020-183580 A (MIBA GLEITLAGER AUSTRIA GMBH) 12 November 2020 (2020-11-12)	1-7
A	JP 2018-194024 A (KURIMOTO LTD, UNIV MEIJO) 06 December 2018 (2018-12-06)	1-7
A	JP 2015-021176 A (KURIMOTO LTD, SANKYO OILLESS IND INC) 02 February 2015 (2015-02-02)	1-7

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 June 2023	**20 June 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-150649 A (KURIMOTO LTD) 08 July 2010 (2010-07-08)	1-7

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/013563

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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 4658269 B **[0005]**
- JP 5916464 B **[0005]**