



EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.09.2019 Bulletin 2019/39

(51) Int Cl.:
F04B 39/00 (2006.01)

(21) Application number: **17870945.7**

(86) International application number:
PCT/JP2017/041307

(22) Date of filing: **16.11.2017**

(87) International publication number:
WO 2018/092849 (24.05.2018 Gazette 2018/21)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **18.11.2016 JP 2016224663**

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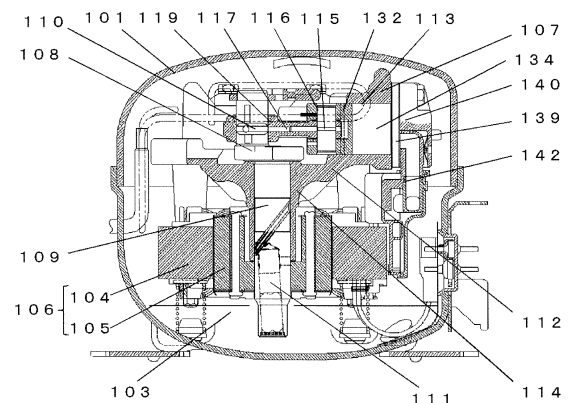
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(54) **REFRIGERANT COMPRESSOR AND REFRIGERATION DEVICE WITH SAME**

(57) A refrigerant compressor includes: an electric component (106); a compression component (107) driven by the electric component to compress a refrigerant; and a sealed container (101) accommodating the electric component and the compression component. The compression component includes: a shaft part (109, 110) rotated by the electric component; and a bearing part (114, 119) slidably contacting the shaft part such that the shaft part is rotatable. A film (160) having hardness equal to or more than hardness of a sliding surface of the bearing part is provided on a sliding surface of the shaft part. Surface roughness of the sliding surface of the bearing part is smaller than surface roughness of the sliding surface of the shaft part.

FIG.1



Description

Technical Field

[0001] The present invention relates to a refrigerant compressor for use in a refrigerator, an air conditioner, and the like, and a freezer including the refrigerant compressor.

Background Art

[0002] In order to reduce the use of fossil fuels from the viewpoint of the protection of the global environment, highly efficient refrigerant compressors have been developed in recent years. Therefore, according to a sealed compressor of PTL 1, cast iron subjected to an insoluble film treatment using, for example, manganese phosphate is used as one of sliding surfaces of a compression machine, and carbon steel is used as the other sliding surface. According to a rotary compressor of PTL 2, an iron-based sintered alloy subjected to a soft-nitriding treatment is used as at least one of a roller and a vane plate which slide on each other.

Citation List

Patent Literature

[0003]

PTL 1: Japanese Laid-Open Patent Application Publication No. 7-238885

PTL 2: Japanese Examined Patent Application Publication No. 55-4958

Summary of Invention

Technical Problem

[0004] For example, a typical refrigerant compressor shown in Fig. 10 includes sliding members, such as a main shaft 8 that rotates and a main bearing 14 supporting the main shaft 8. When the main shaft 8 starts rotating relative to the main bearing 14, large frictional resistance force is generated between the main shaft 8 and the main bearing 14. Further, in recent years, in order to improve the efficiency of the refrigerant compressor, the viscosity of lubricating oil 2 supplied between the sliding surfaces is lowered, and the dimensions of the sliding surfaces are shortened. Thus, lubrication conditions are becoming severe. Therefore, for example, even when the manganese phosphate-based film is provided on the sliding surface as in PTL 1, the film quickly abrades, and an input to the refrigerant compressor becomes high. On this account, the efficiency of the refrigerant compressor deteriorates.

[0005] Further, in order to improve the efficiency of the refrigerant compressor, the reduction in speed (for ex-

ample, less than 20 Hz) by inverter drive is being promoted in recent years. Under such circumstances, an oil film between the sliding surfaces becomes thin, so that contact between the sliding surfaces by a large number of minute projections on the surfaces frequently occurs, and the input to the refrigerant compressor becomes high. Further, for example, when the hard soft-nitriding-treated film is provided on the sliding surface as in PTL 2, the film coats the projections on the sliding surface, so that the progress of the abrasion of the projections slows down, and the high input state continues for a long period of time. Thus, the efficiency of the refrigerant compressor deteriorates.

[0006] The present invention was made in light of these, and an object of the present invention is to provide a refrigerant compressor whose efficiency is prevented from deteriorating, and a freezer including the refrigerant compressor.

Solution to Problem

[0007] To achieve the above object, a refrigerant compressor according to the present invention includes: an electric component; a compression component driven by the electric component to compress a refrigerant; and a sealed container accommodating the electric component and the compression component. The compression component includes a shaft part rotated by the electric component and a bearing part slidably contacting the shaft part such that the shaft part is rotatable. A film having hardness equal to or more than hardness of a sliding surface of the bearing part is provided on a sliding surface of the shaft part. Surface roughness of the sliding surface of the bearing part is smaller than surface roughness of the sliding surface of the shaft part.

[0008] A freezer according to the present invention includes: a heat radiator; a decompressor; a heat absorber; and the above refrigerant compressor.

Advantageous Effects of Invention

[0009] By the above configurations, the present invention can provide the refrigerant compressor whose efficiency is prevented from deteriorating, and the freezer including the refrigerant compressor.

Brief Description of Drawings

[0010]

Fig. 1 is a sectional view showing a refrigerant compressor according to Embodiment 1.

Fig. 2 is a SIM image showing one example of an observation result of an oxide film by a SIM (scanning ion microscope), the oxide film being used in the refrigerant compressor of Fig. 1.

Fig. 3 is a graph showing hardness of a main shaft of Fig. 1 in a depth direction and hardness of a main

bearing of Fig. 1 in the depth direction.

Fig. 4A is a graph showing a curved line of a time-series change of an input to the refrigerant compressor of Fig. 1.

Fig. 4B is a graph showing a curved line of a time-series change of a COP of the refrigerant compressor of Fig. 1.

Fig. 5 is a diagram for explaining a compressive load in the refrigerant compressor of Fig. 1.

Fig. 6 is a sectional view showing a sliding surface of the main bearing and a sliding surface of the main shaft in a direction perpendicular to a central axis of the main bearing, each sliding surface being not provided with a surface roughness improved range.

Fig. 7 is a sectional view showing the sliding surface of the main bearing and the sliding surface of the main shaft in a direction perpendicular to the central axis of the main bearing of Fig. 1.

Fig. 8 is a sectional view showing the sliding surface of the main bearing and the sliding surface of the main shaft in a direction parallel to the central axis of the main bearing of Fig. 1.

Fig. 9 is a sectional view schematically showing a freezer according to Embodiment 2.

Fig. 10 is a sectional view showing a conventional refrigerant compressor.

Description of Embodiments

[0011] A refrigerant compressor according to a first aspect of the present invention includes: an electric component; a compression component driven by the electric component to compress a refrigerant; and a sealed container accommodating the electric component and the compression component. The compression component includes a shaft part rotated by the electric component and a bearing part slidably contacting the shaft part such that the shaft part is rotatable. A film having hardness equal to or more than hardness of a sliding surface of the bearing part is provided on a sliding surface of the shaft part. Surface roughness of the sliding surface of the bearing part is smaller than surface roughness of the sliding surface of the shaft part.

[0012] With this, the abrasion resistance of the sliding member can be improved. In addition, even if the oil film is thin, the occurrence of the solid contact by the projections can be reduced. Therefore, the refrigerant compressor whose efficiency is prevented from deteriorating can be provided.

[0013] The refrigerant compressor according to a second aspect of the present invention may be configured such that in the refrigerant compressor according to the first aspect, the surface roughness of at least a part of the sliding surface of the bearing part is smaller than the surface roughness of the sliding surface of the shaft part. With this, the occurrence of the solid contact by the projections can be reduced, and the productivity can be improved.

[0014] The refrigerant compressor according to a third aspect of the present invention may be configured such that in the refrigerant compressor according to the first or second aspect, a dimension of a range of the sliding surface of the bearing part is $1/10$ or more and $1/2$ or less of a dimension of the sliding surface of the shaft part in a center axis direction of the bearing part, the range having the surface roughness smaller than the surface roughness of the sliding surface of the shaft part, and the range of the sliding surface of the bearing part is set at an end position of the bearing part in the center axis direction. With this, even if one-side hitting occurs between the shaft part and the bearing part, the occurrence of the solid contact by the projections can be reduced, and the productivity can be improved.

[0015] The refrigerant compressor according to a fourth aspect of the present invention may be configured such that in the refrigerant compressor according to any one of the first to third aspects, arithmetic average roughness R_a of a range of the sliding surface of the bearing part is $0.01\text{ }\mu\text{m}$ or more and $0.2\text{ }\mu\text{m}$ or less, the range having the surface roughness smaller than the surface roughness of the sliding surface of the shaft part. With this, the occurrence of the solid contact by the projections can be reduced, and the formation state of the oil film and the productivity can be improved.

[0016] The refrigerant compressor according to a fifth aspect of the present invention may be configured such that in the refrigerant compressor according to any one of the first to fourth aspects, the electric component is configured to be inverter-driven at a plurality of operation frequencies. With this, at the time of both a high-speed operation in which the rotational frequency increases and a low-speed operation in which the amount of oil supplied to each sliding surface decreases, the formation of the oil film can be promoted by the film having excellent abrasion resistance and the action of easing a contacting/sliding state.

[0017] The freezer according to a sixth aspect of the present invention includes any one of the above sealed compressors. The energy saving of the freezer can be realized by the refrigerant compressor whose efficiency is prevented from deteriorating.

[0018] Hereinafter, embodiments of the present invention will be explained with reference to the drawings. It should be noted that the present invention is not limited to these embodiments.

Embodiment 1

Refrigerant Compressor

[0019] As shown in Fig. 1, the refrigerant compressor according to Embodiment 1 includes a sealed container 101. The sealed container 101 is filled with R600a as refrigerant gas, and mineral oil as lubricating oil 103 is stored in a bottom portion of the sealed container 101.

[0020] The sealed container 101 accommodates an

electric component 106 and a compression component 107. The electric component 106 includes a stator 104 and a rotor 105 that rotates relative to the stator 104. The compression component 107 is a mechanism driven by the electric component 106 to compress a refrigerant. The compression component 107 is, for example, a reciprocating mechanism and includes a crank shaft 108, a cylinder block 112, and a piston 132.

[0021] The compression component 107 includes the crank shaft 108, the cylinder block 112, and the piston 132. The crank shaft 108 includes a main shaft 109 and an eccentric shaft 110. The main shaft 109 is a shaft part having a columnar shape. A lower portion of the main shaft 109 is press-fitted and fixed to the rotor 105. An oil supply pump 111 communicating with the lubricating oil 103 is provided at a lower end of the main shaft 109. The eccentric shaft 110 is a shaft part having a columnar shape and is arranged eccentrically with respect to the main shaft 109.

[0022] The cylinder block 112 is made of, for example, an iron-based material, such as cast iron, and includes a cylinder bore 113 and a main bearing 114. The cylinder bore 113 has a cylindrical shape and includes an internal space. An end surface of the cylinder bore 113 is sealed by a valve plate 139.

[0023] The main bearing 114 is a bearing part having a cylindrical shape. An inner peripheral surface of the main bearing 114 supports the main shaft 109. The main bearing 114 is a journal bearing supporting a radial load of the main shaft 109. Therefore, the inner peripheral surface of the main bearing 114 and an outer peripheral surface of the main shaft 109 are opposed to each other, and the main shaft 109 slides on the inner peripheral surface of the main bearing 114. As above, a portion of the inner peripheral surface of the main bearing 114 and a portion of the outer peripheral surface of the main shaft 109 which portions slide on each other are sliding surfaces. The main bearing 114 including the sliding surface and the main shaft 109 including the sliding surface constitute a pair of sliding members.

[0024] One end portion of the piston 132 is inserted in the internal space of the cylinder bore 113 such that the piston 132 can reciprocate by the rotation of the main shaft 109. With this, a compression chamber 134 surrounded by the cylinder bore 113, the valve plate 139, and the piston 132 is formed. A piston pin 115 is locked to a piston pin hole 116 of the other end portion of the piston 132 so as not to be rotatable, and the other end portion of the piston 132 is coupled to one end portion of a connecting rod (coupler) 117 by the piston pin 115. An eccentric bearing 119 is provided at the other end portion of the connecting rod 117, and the eccentric shaft 110 supported by the eccentric bearing 119 and the piston 132 are coupled to each other.

[0025] The eccentric bearing 119 is a bearing part having a cylindrical shape. An inner peripheral surface of the eccentric bearing 119 supports the columnar eccentric shaft 110 of the crank shaft 108. The eccentric bearing

119 is a journal bearing supporting a radial load of the eccentric shaft 110. Therefore, the inner peripheral surface of the eccentric bearing 119 and an outer peripheral surface of the eccentric shaft 110 are opposed to each other, and the eccentric shaft 110 slides on the inner peripheral surface of the eccentric bearing 119. A portion of the inner peripheral surface of the eccentric bearing 119 and a portion of the outer peripheral surface of the eccentric shaft 110 which portions slide on each other are sliding surfaces. The eccentric bearing 119 including the sliding surface and the eccentric shaft 110 including the sliding surface constitute a pair of sliding members.

[0026] A cylinder head 140 is fixed to the valve plate 139 at an opposite side of the cylinder bore 113. The cylinder head 140 covers an ejection hole of the valve plate 139 to form a high-pressure chamber (not shown). A suction tube (not shown) is fixed to the sealed container 101 and connected to a low-pressure side (not shown) of a refrigeration cycle. The suction tube introduces the refrigerant gas from the refrigeration cycle into the sealed container 101. A suction muffler 142 is sandwiched between the valve plate 139 and the cylinder head 140.

Film

[0027] The main shaft 109 is constituted by a base member 150 and a film coating the surface of the base member 150. The base member 150 is formed by an iron-based material, such as gray cast iron (FC cast iron). The film constitutes, for example, the surface of the main shaft 109 and has hardness equal to or more than hardness of the sliding surface of the main bearing 114. One example of the film is an oxide film 160. For example, the gray cast iron as the base member 150 is oxidized by using known oxidizing gas, such as carbon dioxide gas, and a known oxidation facility at several hundreds of degrees Celsius (for example, 400 to 800°C). With this, the oxide film 160 can be formed on the surface of the base member 150.

[0028] Fig. 2 is an image (SIM image) when the main shaft 109 formed by coating the base member 150 with the oxide film 160 is observed with a SIM (scanning ion microscope). In Fig. 2, a protective film (resin film) for protecting an observation sample is formed on a first portion 151. A direction parallel to the surface of the oxide film 160 is referred to as a lateral direction, and a direction perpendicular to the surface of the oxide film 160 is referred to as a vertical direction.

[0029] The dimension (film thickness) of the oxide film 160 in the vertical direction is about 3 μm. The oxide film 160 includes the first portion 151, a second portion 152, and a third portion 153, and these portions are laminated in this order from the surface toward the base member 150. This laminating direction is parallel to the vertical direction.

[0030] The first portion 151 constitutes the surface of the oxide film 160 and is formed on the second portion 152. The first portion 151 is formed by a structure of fine

crystals. As a result of EDS (energy dispersive X-ray spectrometry) and EELS (electron ray energy loss spectrometry), a component contained most in the first portion 151 is diiron trioxide (Fe_2O_3), and the first portion 151 also contains a silicon (Si) compound. The first portion 151 includes two portions (a first-a portion 151a and a first-b portion 151b) which are different in crystal density from each other.

[0031] The first-a portion 151a is formed on the first-b portion 151b and constitutes the surface of the oxide film 160. The crystal density of the first-a portion 151a is lower than the crystal density of the first-b portion 151b. The first-a portion 151a contains gap portions 158 (black portions in Fig. 2) and acicular structures 159 in some places. The acicular structures 159 are vertically long. For example, a minor-axis length of the acicular structure 159 in the vertical direction is 100 nm or less, and a ratio (aspect ratio) obtained by dividing the length in the vertical direction by the length in the lateral direction is 1 or more and 10 or less.

[0032] The first-b portion 151b is a structure formed by spreading fine crystals 155 having a particle diameter of 100 nm or less. Although the gap portions 158 and the acicular structures 159 are observed in the first-a portion 151a, they are hardly observed in the first-b portion 151b.

[0033] The second portion 152 is formed on the third portion 153 and contains vertically long columnar structures 156. For example, the length of the columnar structure 156 in the vertical direction is about 100 nm or more and 1 μm or less, and the length of the columnar structure 156 in the lateral direction is about 100 nm or more and 150 nm or less. The aspect ratio of the columnar structure 156 is about 3 or more and 10 or less. According to the analytical results of the EDS and the EELS, a component contained most in the second portion 152 is triiron tetroxide (Fe_3O_4), and the second portion 152 also contains a silicon (Si) compound.

[0034] The third portion 153 is formed on the base member 150 and contains laterally long lamellar structures 157. For example, the length of the lamellar structure 157 in the vertical direction is several tens of nanometers or less, and the length of the lamellar structure 157 in the lateral direction is about several hundreds of nanometers. The aspect ratio of the lamellar structure 157 is 0.01 or more and 0.1 or less, i.e., the lamellar structure 157 is long in the lateral direction. According to the analytical results of the EDS and the EELS, a component contained most in the third portion 153 is triiron tetroxide (Fe_3O_4), and the third portion 153 also contains a silicon (Si) compound and a silicon (Si) solid solution component.

[0035] In Fig. 2, the oxide film 160 is constituted by the first portion 151, the second portion 152, and the third portion 153, and these first to third portions 151 to 153 are laminated in this order. However, the configuration of the oxide film 160 and the order of the lamination are not limited to these.

[0036] For example, the oxide film 160 may be consti-

tuted by a single layer that is the first portion 151. The oxide film 160 may be constituted by two layers that are the first portion 151 and the second portion 152 such that the first portion 151 forms the surface of the oxide film 160. The oxide film 160 may be constituted by two layers that are the first portion 151 and the third portion 153 such that the first portion 151 forms the surface of the oxide film 160.

[0037] The oxide film 160 may contain a composition other than the first portion 151, the second portion 152, and the third portion 153. The oxide film 160 may be constituted by four layers that are the first portion 151, the second portion 152, the first portion 151, and the third portion 153 such that the first portion 151 forms the surface of the oxide film 160.

[0038] The configuration of the oxide film 160 and the order of the lamination are easily realized by adjusting conditions. A typical condition is a method of producing (forming) the oxide film 160. A known method of oxidizing an iron-based material can be suitably used as the method of producing the oxide film 160. However, the present embodiment is not limited to this. Conditions in the producing method are suitably set in accordance with conditions, such as the type of the iron-based material forming the base member 150, the surface state (for example, polishing finish) of the base member 150, and a physical property of the desired oxide film 160.

Operations of Refrigerant Compressor

[0039] Electric power supplied from a commercial power supply (not shown) is supplied to the electric component 106 through an external inverter drive circuit (not shown). With this, the electric component 106 is inverter-driven at a plurality of operation frequencies, and the rotor 105 of the electric component 106 rotates the crank shaft 108. The eccentric motion of the eccentric shaft 110 of the crank shaft 108 is converted into the linear motion of the piston 132 by the connecting rod 117 and the piston pin 115, and the piston 132 reciprocates in the compression chamber 134 of the cylinder bore 113. Therefore, the refrigerant gas introduced through the suction tube into the sealed container 101 is sucked in the compression chamber 134 from the suction muffler 142. Then, the refrigerant gas is compressed in the compression chamber 134 and ejected from the sealed container 101.

[0040] In accordance with the rotation of the crank shaft 108, the lubricating oil 103 is supplied from the oil supply pump 111 to the sliding surfaces to lubricate the sliding surfaces. In addition, the lubricating oil 103 forms a seal between the piston 132 and the cylinder bore 113 to seal the compression chamber 134.

Hardness

[0041] Fig. 3 is a graph showing the hardness of the main shaft 109 in the depth direction and the hardness of the main bearing 114 in the depth direction. It should

be noted that the hardness is shown by Vickers hardness. A nano indentation apparatus (triboindenter) produced by Scienta Omicron, Inc. is used for the measurement of the hardness.

[0042] Performed in the measurement of the hardness of the main shaft 109 is a step in which an indenter is pressed against the surface of the main shaft 109 to apply a load to the surface for a certain period of time. Then, in the next step, the application of the load is stopped once, and the indenter is again pressed against the surface of the main shaft 109 to apply a load higher than the previous load to the surface for a certain period of time. Such steps in which the applied loads are stepwisely increased are repeatedly performed 15 times. Further, the loads in the respective steps are set such that the highest load becomes 1 N. After each step, the hardness and depth of the oxide film 160 and the hardness and depth of the base member 150 in the main shaft 109 are measured.

[0043] In the measurement of the hardness of the main bearing 114, a part of the main bearing 114 is cut by a fine cutter. The hardness of this part of the main bearing 114 is measured by applying a load of 0.5 kgf to the inner peripheral surface of the main bearing 114 by using the indenter.

[0044] As shown in Fig. 3, each of the hardness of the oxide film 160 and the hardness of the base member 150 in the main shaft 109 is equal to or more than the hardness of the main bearing 114. As above, since the hardness of the main shaft 109 is made equal to or more than the hardness of the main bearing 114 by the oxide film 160, the abrasion resistance improves. In addition, the oil film between the pair of sliding members is secured, and a highly-efficient operation in which the input to the refrigerant compressor is low from the initial stage of the operation is realized.

[0045] The hardness is one of mechanical properties of the surface of an object, such as a substance or a material, or the vicinity of the surface of the object. The hardness denotes the unlikelihood of the deformation of the object and the unlikelihood of the damage of the object when external force is applied to the object. Regarding the hardness, there are various measurement means (definitions) and their corresponding values (measures of the hardness). Therefore, the measurement means corresponding to a measurement target may be used.

[0046] For example, when the measurement target is a metal or a nonferrous metal, an indentation hardness test method (such as the above-described nano indentation method, the Vickers hardness method, or the Rockwell hardness method) is used for the measurement.

[0047] Further, for the measurement targets, such as resin films and phosphate films, which are difficult to be measured by the indentation hardness test method, an abrasion test such as a ring-on-disk test is used. In one example of this measurement method, a test piece is prepared by forming a film on the surface of a disk. With

the test piece immersed in oil, the test piece is rotated at a rotational speed of 1m/s for an hour while applying a load of 1000 N to the film by a ring. With this, the ring slides on the film. The state of the sliding surface of the film and the state of the sliding surface of the surface of the ring are observed. As a result, it may be determined that one of the ring and the film which one is larger in abrasion loss has lower hardness.

10 Surface Roughness

[0048] As shown in Fig. 7, the surface roughness of the sliding surface of the main bearing 114 is smaller than the surface roughness of the sliding surface of the main shaft 109. The surface roughness of the sliding surface of the main shaft 109 corresponds to the surface roughness of the film of the main shaft 109.

[0049] As shown in Fig. 8, a range (surface roughness improved range 114a) having the surface roughness smaller than the surface roughness of the main shaft 109 is provided at a part of a sliding surface 114b of the main bearing 114. The surface roughness improved range 114a is provided at an end position of the main bearing 114 in a center axis direction of the main bearing 114, and for example, is provided at an upper end portion of the sliding surface 114b of the main bearing 114. However, the surface roughness improved range 114a may be provided at a lower end portion of the sliding surface 114b of the main bearing 114. Therefore, the surface roughness improved range 114a is only required to be provided at at least one of the upper end portion and lower end portion of the sliding surface 114b of the main bearing 114.

[0050] The surface roughness improved range 114a extends from an end (an upper end, a lower end) of the sliding surface 114b of the main bearing 114 in the center axis direction of the main bearing 114 and has a dimension (width) C. Further, the surface roughness improved range 114a extends over the entire periphery in the circumferential direction of the inner peripheral surface of the main bearing 114. The width C is 1/10 or more and 1/2 or less of a dimension (width) D of the sliding surface 114b of the main bearing 114. The sliding surface 114b is a range of the inner peripheral surface of the main bearing 114 to which range the outer peripheral surface of the main shaft 109 is opposed and on which range the outer peripheral surface of the main shaft 109 slides. Therefore, for example, when a chamfered portion 114c is provided on the inner peripheral surface of the main bearing 114, the chamfered portion 114c is not included in the sliding surface 114b. The sliding surface 114b is not a portion where the main shaft 109 and the main bearing 114 slide on each other at all times but a portion where the main shaft 109 and the main bearing 114 may slide on each other.

[0051] Even if one-side hitting occurs between the main shaft 109 and the main bearing 114, the occurrence of solid contact by the minute projections on the sliding

surfaces can be reduced by the surface roughness improved range 114a. In addition, since the small surface roughness portion (surface roughness improved range 114a) which requires processing time is small, the productivity can be improved.

[0052] If the width C of the surface roughness improved range 114a is set to less than 1/10 of the width D, the oil film between the sliding surface of the main shaft 109 and the sliding surface of the main bearing 114 cannot be kept, and the input to the refrigerant compressor increases. Further, even if the width C of the surface roughness improved range 114a is set to more than 1/2 of the width D, the input does not become lower than the input when the width C is set to 1/2 of the width D, and in addition, the processing cost increases.

[0053] For example, arithmetic average roughness Ra of the surface roughness improved range 114a is 0.01 μm or more and 0.2 μm or less. With this, the occurrence of the solid contact by the minute projections on the sliding surfaces can be reduced. In addition, the oil film between the sliding surfaces can be kept, and the productivity can be improved.

[0054] If the arithmetic average roughness Ra of the surface roughness improved range 114a is larger than 0.2 μm , the oil film between the sliding surfaces cannot be kept, and the input to the refrigerant compressor increases. Further, even if the arithmetic average roughness Ra is smaller than 0.01 μm , the input does not decrease, and in addition, the processing cost increases. Thus, the productivity deteriorates.

[0055] As above, the surface roughness of the main bearing 114 is made smaller than the surface roughness of the main shaft 109. With this, even when the surface of the main shaft 109 is made hard by the film, the improvement of the abrasion resistance, the easing of the local contact, and the promotion of the formation of the oil film are realized between the main shaft 109 and the main bearing 114. Therefore, the highly-efficient refrigerant compressor can be provided, which is high in long-term reliability and in which the input to the refrigerant compressor is low and stable from the initial stage of the operation.

Performance of Refrigerant Compressor

[0056] Fig. 4A shows a time-series change of the input to the refrigerant compressor, and Fig. 4B shows a time-series change of a COP (Coefficient of Performance) of the refrigerant compressor. The COP is a coefficient used as an index of energy consumption efficiency of a refrigerant compressor of a freezer/refrigerator or the like. The COP is a value obtained by dividing a freezing capacity (W) by an input (W).

[0057] Herein, the input and the COP when the refrigerant compressor performs the low-speed operation at the operation frequency of 17 Hz are obtained. Further, according to the refrigerant compressor of the present embodiment, the surface roughness of the main bearing

114 is smaller than the surface roughness of the main shaft 109. On the other hand, according to a conventional refrigerant compressor, the surface roughness improved range 114a is not provided at the main bearing 114.

[0058] As shown in Fig. 4A, in both the refrigerant compressor of the present embodiment and the conventional refrigerant compressor, the input immediately after the operation start (hereinafter referred to as an "initial input") is the highest. Then, the input gradually decreases with the lapse of the operating time and finally becomes a constant value (hereinafter referred to as a "steady input") which changes little. Further, the initial input to the refrigerant compressor of the present embodiment is lower than that to the conventional refrigerant compressor, and a time (transition time) it takes to change from the initial input to the steady input in the refrigerant compressor of the present embodiment is shorter than that in the conventional refrigerant compressor. A transition time t1 of the refrigerant compressor of the present embodiment is about 1/2 of a transition time t2 of the conventional refrigerant compressor. Thus, as shown in Fig. 4B, the COP of the refrigerant compressor of the present embodiment is stabilized more quickly and is improved more than that of the conventional refrigerant compressor.

[0059] This will be considered as below with reference to Figs. 5 to 7. Fig. 5 is an action diagram of a compressive load in the refrigerant compressor. Fig. 6 is an enlarged view showing the sliding surface of the main bearing 114 and the sliding surface of the main shaft 109 in the refrigerant compressor of the present embodiment before the surface roughness improved range 114a is provided at the main bearing 114. Fig. 7 is an enlarged view showing the sliding surface of the main bearing 114 and the sliding surface of the main shaft 109 in the refrigerant compressor of the present embodiment in which the surface roughness improved range 114a is provided at the main bearing 114. By the surface roughness improved range 114a, the surface roughness of the main bearing 114 is made smaller than the surface roughness of the main shaft 109.

[0060] The refrigerant compressor according to the present embodiment is a reciprocating type, and pressure in the sealed container 101 is lower than a compressive load P in the compression chamber 134. Typically, with the compressive load P acting on the eccentric shaft 110, the main shaft 109 connected to the eccentric shaft 110 is supported by the single main bearing 114 in a cantilever manner.

[0061] Therefore, as described in a literature (Collection of Papers of Annual Meeting of The Japan Society of Mechanical Engineers, Vol. 5-1 (2005) page 143) written by Ito and others, the crank shaft 108 including the main shaft 109 and the eccentric shaft 110 whirls in an inclined state in the main bearing 114 by the influence of the compressive load P. A component P1 of the compressive load P acts on the sliding surface of the main shaft 109 and the opposing sliding surface of the upper end portion of the main bearing 114. Further, a compo-

nent P2 of the compressive load P acts on the sliding surface of the main shaft 109 and the opposing sliding surface of the lower end portion of the main bearing 114. Thus, so-called one-side hitting occurs.

[0062] In Fig. 6, in the refrigerant compressor in which the surface roughness improved range 114a is not provided, a large number of minute projections exist on both the sliding surface of the main shaft 109 and the sliding surface of the main bearing 114. When the main shaft 109 inclines in the main bearing 114, local contact occurs, and surface pressure becomes high. Further, in the lower-speed operation, an oil film thickness h between the sliding surface of the main shaft 109 and the sliding surface of the main bearing 114 decreases, and the solid contact by the projections frequently occurs. In addition, when the sliding surface of the main shaft 109 is formed by the oxide film 160 having high abrasion resistance, sliding marks are made on the sliding surface of the main bearing 114 by the minute projections formed on the surface of the main shaft 109 and having high hardness, and the time of occurrence of solid contact X increases. Therefore, the initial input to the refrigerant compressor becomes high, and the transition time from the initial input to the steady input increases.

[0063] On the other hand, as shown in Fig. 7, in the refrigerant compressor according to the present embodiment, the surface roughness of the sliding surface of the main bearing 114 is made smaller than the surface roughness of the opposing sliding surface of the main shaft 109 by the surface roughness improved range 114a. With this, the solid contact by the projections can be reduced, and the formation of the oil film between the main shaft 109 and the main bearing 114 can be kept from the initial stage of the operation. Therefore, the initial input can be made low, and the transition time from the initial input to the steady input can be shortened. Further, since the oxide film 160 having high abrasion resistance is formed on the surface of the main shaft 109, the durability can also be secured.

[0064] By the oxide film 160, the main shaft 109 becomes hard and obtains improved abrasion resistance. In addition, the attacking property (opponent attacking property) of the main shaft 109 with respect to the main bearing 114 is reduced, and the contact property of the main shaft 109 at the initial stage of the sliding operation also improves. Therefore, in combination with the effect obtained by making the surface roughness of the main bearing 114 smaller than the surface roughness of the main shaft 109, the highly-efficient operation in which the input to the refrigerant compressor is low from the initial stage of the operation is realized.

[0065] Details of the increase in the abrasion resistance of the oxide film 160, the reduction in the opponent attacking property of the oxide film 160, and the improvement of the contact property of the oxide film 160 at the initial stage of the sliding operation are described in Japanese Patent Application Nos. 2016-003910 and 2016-003909 filed by the present applicant. One of the

reasons for these may be as below.

[0066] Since the oxide film 160 is an oxide of iron, the oxide film 160 is chemically more stable than the conventional phosphate film. Further, the film of the oxide of iron has higher hardness than the phosphate film. Therefore, by the formation of the oxide film 160 on the sliding surface, the generation, adhesion, and the like of the abrasion powder can be effectively prevented. As a result, the increase in the abrasion loss of the oxide film 160 itself can be effectively avoided, and the oxide film 160 exhibits high abrasion resistance.

[0067] In addition, as shown in Fig. 2, the first portion 151 of the oxide film 160 contains the silicon (Si) compound having higher hardness than the oxide of iron. Since the surface of the oxide film 160 is constituted by the first portion 151 containing the silicon (Si) compound, the oxide film 160 can exhibit higher abrasion resistance.

[0068] A component contained most in the first portion 151 constituting the surface of the oxide film 160 is diiron trioxide (Fe_2O_3). The crystal structure of diiron trioxide (Fe_2O_3) is rhombohedron, and the surface of the crystal structure of diiron trioxide (Fe_2O_3) is more flexible than the cubic crystal structure of triiron tetroxide (Fe_3O_4) located under the crystal structure of diiron trioxide (Fe_2O_3) and the crystal structures of a dense hexagonal crystal, face-centered cubic crystal, and body-centered tetragonal crystal of a nitriding film. Therefore, it is thought that the first portion 151 containing a large amount of diiron trioxide (Fe_2O_3) has more appropriate hardness, lower opponent attacking property, and better contact property at the initial stage of the sliding operation than a conventional gas nitriding film or a typical oxide film (triiron tetroxide (Fe_3O_4) film).

[0069] To be specific, the surface of the oxide film 160 constituting the surface of the main shaft 109 contains a large amount of diiron trioxide (Fe_2O_3) that is relatively hard, has the rhombohedral crystal structure, and is flexible. Therefore, the opponent attacking property is reduced, and the shortage of the oil film and the like are prevented. Further, the contact property at the initial stage of the sliding operation improves. In addition, in combination with the effect obtained by making the surface roughness of the main bearing 114 smaller than the surface roughness of the main shaft 109, the highly-efficient operation in which the input to the refrigerant compressor is low from the initial stage of the operation is realized.

[0070] Further, the second portion 152 and third portion 153 of the oxide film 160 contain the silicon (Si) compound and are located between the first portion 151 and the base member 150. Therefore, adhesive force of the oxide film 160 with respect to the base member 150 becomes strong. In addition, the amount of silicon contained in the third portion 153 is larger than that in the second portion 152. As above, the second portion 152 containing the silicon (Si) compound and the third portion 153 containing the silicon (Si) compound are laminated, and the third portion 153 containing a larger amount of silicon

contacts the base member 150. With this, the adhesive force of the oxide film 160 can be further increased. As a result, the proof stress of the oxide film 160 with respect to the load at the time of the sliding operation improves, and the abrasion resistance of the oxide film 160 further improves. Even if the first portion 151 forming the surface of the oxide film 160 abrades, the second portion 152 and the third portion 153 remain, so that the oxide film 160 exhibits more excellent abrasion resistance.

[0071] Further, from a different point of view, it is thought that the increase in the abrasion resistance of the oxide film 160, the reduction in the opponent attacking property of the oxide film 160, and the improvement of the contact property of the oxide film 160 at the initial stage of the sliding operation are realized by the following reasons.

[0072] To be specific, the first portion 151 constituting the surface of the oxide film 160 contains the silicon (Si) compound, and in addition, has a dense fine crystal structure. Therefore, the oxide film 160 exhibits high abrasion resistance.

[0073] The first portion 151 has the fine crystal structure, and the slight minute gap portions 158 are formed in some places among the fine crystals, or minute depressions and projections are formed on the surface of the first portion 151. Therefore, the lubricating oil 103 is easily held on the surface (sliding surface) of the oxide film 160 by capillarity. To be specific, since there are the slight minute gap portions 158 and/or the minute depressions and projections, the lubricating oil 103 can be held on the sliding surfaces even under a severe sliding state, i.e., so-called "oil holding property" can be exhibited. As a result, the oil film is easily formed on the sliding surface.

[0074] Further, in the oxide film 160, the columnar structures 156 (second portion 152) and the lamellar structures 157 (third portion 153) exist under the first portion 151 and closer to the base member 150. These structures are lower in hardness and softer than the fine crystals 155 of the first portion 151. Therefore, during the sliding operation, the columnar structures 156 and the lamellar structures 157 serve as "cushioning materials." With this, by the pressure applied to the surface of the fine crystals 155 during the sliding operation, the fine crystals 155 behave so as to be compressed toward the base member 150. As a result, the opponent attacking property of the oxide film 160 is significantly lower than that of the other surface treated films, and therefore, the abrasion of the sliding surface of the opponent member is effectively suppressed.

[0075] It should be noted that the function of the "cushioning materials" is exhibited even if only one of the second portion 152 and the third portion 153 is provided. Therefore, the second portion 152 or the third portion 153 is only required to be located under the first portion 151. It is preferable that both the second portion 152 and the third portion 153 be located under the first portion 151.

[0076] The oxide film 160 has the low opponent attacking property and can exhibit the satisfactory "oil holding

property." Therefore, an oil film forming ability of the shaft part including the oxide film 160 significantly improves. By the high oil film forming ability in combination with the effect obtained by making the surface roughness of the bearing part small, the highly-efficient operation in which the input to the refrigerant compressor is low from the initial stage of the operation is realized.

Modified Example

[0077] According to the above configuration, the main shaft 109 is used as the shaft part, and the main bearing 114 is used as the bearing part. However, the shaft part and the bearing part are not limited to these. For example, the eccentric shaft 110 may be used as the shaft part, and the eccentric bearing 119 may be used as the bearing part. Therefore, a film having hardness equal to or more than the hardness of the opposing bearing part may be provided on the surface of the shaft part, i.e., on at least one of the surface of the main shaft 109 and the surface of the eccentric shaft 110. Further, the surface roughness of the bearing part, i.e., at least one of the surface roughness of the main bearing 114 and the surface roughness of the eccentric bearing 119 may be made smaller than the surface roughness of the opposing shaft part.

[0078] In all the above configurations, the oxide film 160 is included on the surface of the shaft part. However, the film on the surface of the shaft part is not limited to this as long as the film has hardness equal to or more than the hardness of the bearing part. Examples of the film of the shaft part include a compound layer, a mechanical strength improved layer, and a layer formed by a coating method.

[0079] To be specific, when the base member 150 of the shaft part is an iron-based member, the film may be a film formed by a typical quenching method and a method of impregnating a surface layer with carbon, nitrogen, or the like. Further, the film may be a film formed by an oxidation treatment using steam and an oxidation treatment of performing immersion in a sodium hydroxide aqueous solution. Furthermore, the film may be a layer (mechanical strength improved layer) which is formed by cold working, work hardening, solute strengthening, precipitation strengthening, dispersion strengthening, and grain refining and in which a slip motion of a dislocation is suppressed, and the base member 150 is strengthened. Further, the film may be a layer formed by a coating method, such as plating, thermal spraying, PVD, or CVD.

[0080] In all the above configurations, the range (surface roughness improved range 114a) having the surface roughness smaller than the surface roughness of the main shaft 109 is provided on a part of the sliding surface of the main bearing 114. However, the surface roughness improved range 114a on the sliding surface of the main bearing 114 is not limited to this. The surface roughness improved range 114a may be provided on the entire sliding surface (entire sliding range) of the main bearing 114.

[0081] In all the above configurations, the iron-based

material is used as the material of the base member 150 of the shaft part. However, a material other than the iron-based material may be used as the material of the base member 150 as long as a film having hardness equal to or more than the hardness of the bearing part can be formed.

[0082] In all the above configurations, the effects in the example in which the refrigerant compressor is driven by the low-speed operation (for example, at the operation frequency of 17 Hz) are explained. However, the operation of the refrigerant compressor is not limited to this. Even when the refrigerant compressor performs the operation at a commercial rotational frequency or the high-speed operation at a high rotational frequency, the performance and reliability of the refrigerant compressor can be improved as with when the refrigerant compressor performs the low-speed operation.

[0083] In all the above configurations, the refrigerant compressor is a reciprocating type. However, the refrigerant compressor may be the other type, such as a rotary type, a scroll type, or a vibration type. Further, the configuration in which (i) the shaft part includes the film having the hardness equal to or more than the hardness of the bearing part and (ii) the surface roughness of the bearing part is made smaller than the surface roughness of the bearing part is not limited to the refrigerant compressor and may be used in an apparatus including sliding surfaces, and with this, the same effects can be obtained. Examples of the apparatus including the sliding surfaces include a pump and a motor.

Embodiment 2

[0084] Fig. 9 is a schematic diagram showing a freezer according to Embodiment 2. Herein, the basic configuration of the freezer will be schematically explained.

[0085] In Fig. 9, the freezer includes a main body 301, a partition wall 307, and a refrigerant circuit 309. The main body 301 includes: a heat-insulation box body including an opening on one surface thereof; and a door body configured to open and close the opening. The partition wall 307 divides the inside of the main body 301 into a storage space 303 for articles and a machine room 305. The refrigerant circuit 309 is configured such that a refrigerant compressor 300, a heat radiator 313, a decompressor 315, and a heat absorber 317 are annularly connected to one another by pipes. The refrigerant circuit 309 cools the inside of the storage space 303.

[0086] The heat absorber 317 is arranged in the storage space 303 including a blower (not shown). As shown by arrows in Fig. 9, cooling air of the heat absorber 317 is stirred by the blower so as to circulate in the storage space 303. Thus, the inside of the storage space 303 is cooled.

[0087] The freezer configured as above includes the refrigerant compressor according to Embodiment 1 as the refrigerant compressor 300. With this, the film of the shaft part, such as the main shaft 109, of the refrigerant

compressor 300 has the hardness equal to or more than the hardness of the opposing bearing part such as the main bearing 114, and the surface roughness of the bearing part is smaller than the surface roughness of the shaft part. Therefore, the improvement of the abrasion resistance, the reduction in the local contact/slide, and the keeping of the formation of the oil film are realized between the shaft part and the bearing part. On this account, since the performance of the freezer improves, the energy saving by the reduction in the power consumption can be realized, and the reliability can be improved.

[0088] The foregoing has explained the refrigerant compressor according to the present invention and the freezer including the refrigerant compressor according to the present invention based on the above embodiments. However, the present invention is not limited to these. To be specific, the embodiments disclosed herein are merely illustrative in all aspects and should not be recognized as being restrictive. The scope of the present invention is defined by the scope of the claims, not by the above description, and is intended to include meaning equivalent to the scope of the claims and all modifications within the scope.

Industrial Applicability

[0089] As above, the present invention can provide a refrigerant compressor whose efficiency is prevented from deteriorating, and a freezer including the refrigerant compressor. Therefore, the present invention is widely applicable to various apparatuses using the refrigeration cycle.

Reference Signs List

[0090]

101	sealed container
106	electric component
107	compression component
109	main shaft (shaft part)
110	eccentric shaft (shaft part)
114	main bearing (bearing part)
119	eccentric bearing (bearing part)
160	oxide film (film)
300	refrigerant compressor

Claims

1. A refrigerant compressor comprising:

an electric component;
a compression component driven by the electric component to compress a refrigerant; and
a sealed container accommodating the electric component and the compression component, wherein:

the compression component includes

a shaft part rotated by the electric component and
a bearing part slidably contacting the shaft part such that the shaft part is rotatable;

a film having hardness equal to or more than hardness of a sliding surface of the bearing part is provided on a sliding surface of the shaft part; and
surface roughness of the sliding surface of the bearing part is smaller than surface roughness of the sliding surface of the shaft part.

2. The refrigerant compressor according to claim 1, wherein the surface roughness of at least a part of the sliding surface of the bearing part is smaller than the surface roughness of the sliding surface of the shaft part.

3. The refrigerant compressor according to claim 1 or 2, wherein:

a dimension of a range of the sliding surface of the bearing part is 1/10 or more and 1/2 or less of a dimension of the sliding surface of the shaft part in a center axis direction of the bearing part, the range having the surface roughness smaller than the surface roughness of the sliding surface of the shaft part; and
the range of the sliding surface of the bearing part is set at an end position of the bearing part in the center axis direction.

4. The refrigerant compressor according to any one of claims 1 to 3, wherein arithmetic average roughness Ra of a range of the sliding surface of the bearing part is 0.01 μm or more and 0.2 μm or less, the range having the surface roughness smaller than the surface roughness of the sliding surface of the shaft part.

5. The refrigerant compressor according to any one of claims 1 to 4, wherein the electric component is configured to be inverter-driven at a plurality of operation frequencies.

6. A freezer comprising:

a heat radiator;
a decompressor;
a heat absorber; and
the sealed compressor according to any one of claims 1 to 5.

FIG.1

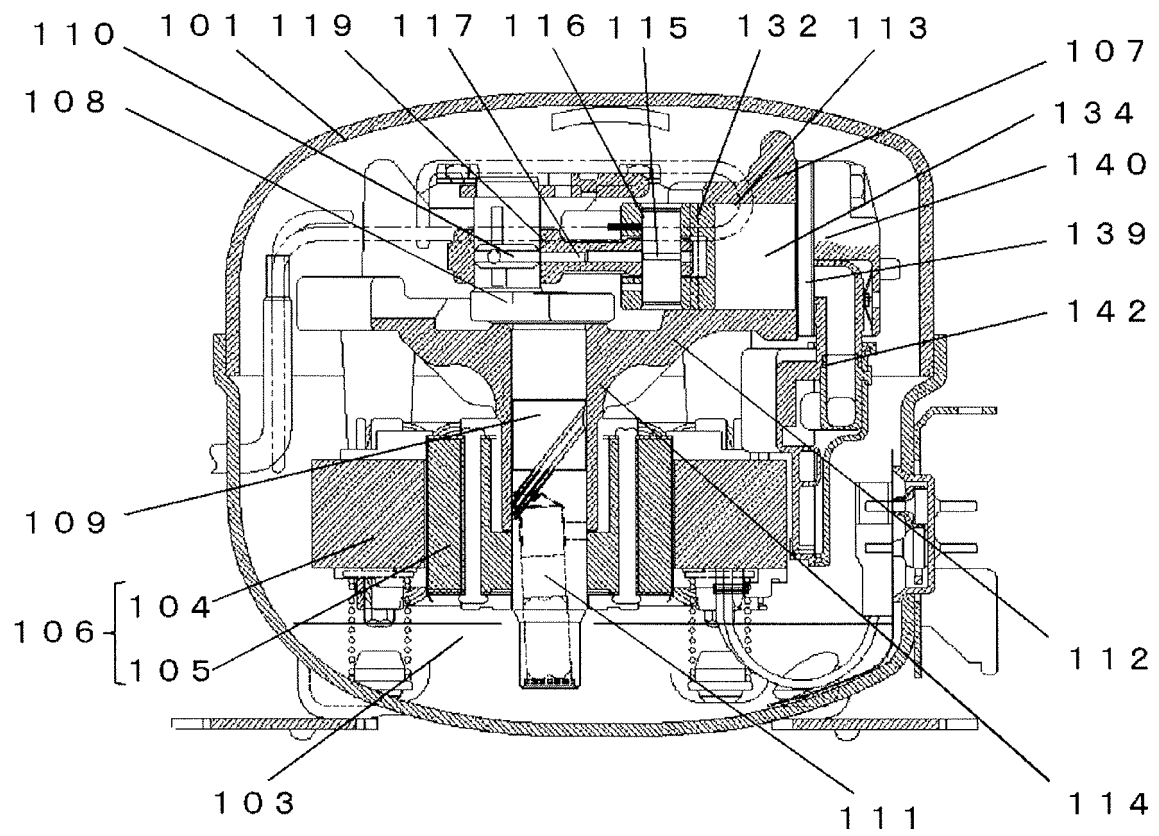


FIG.2

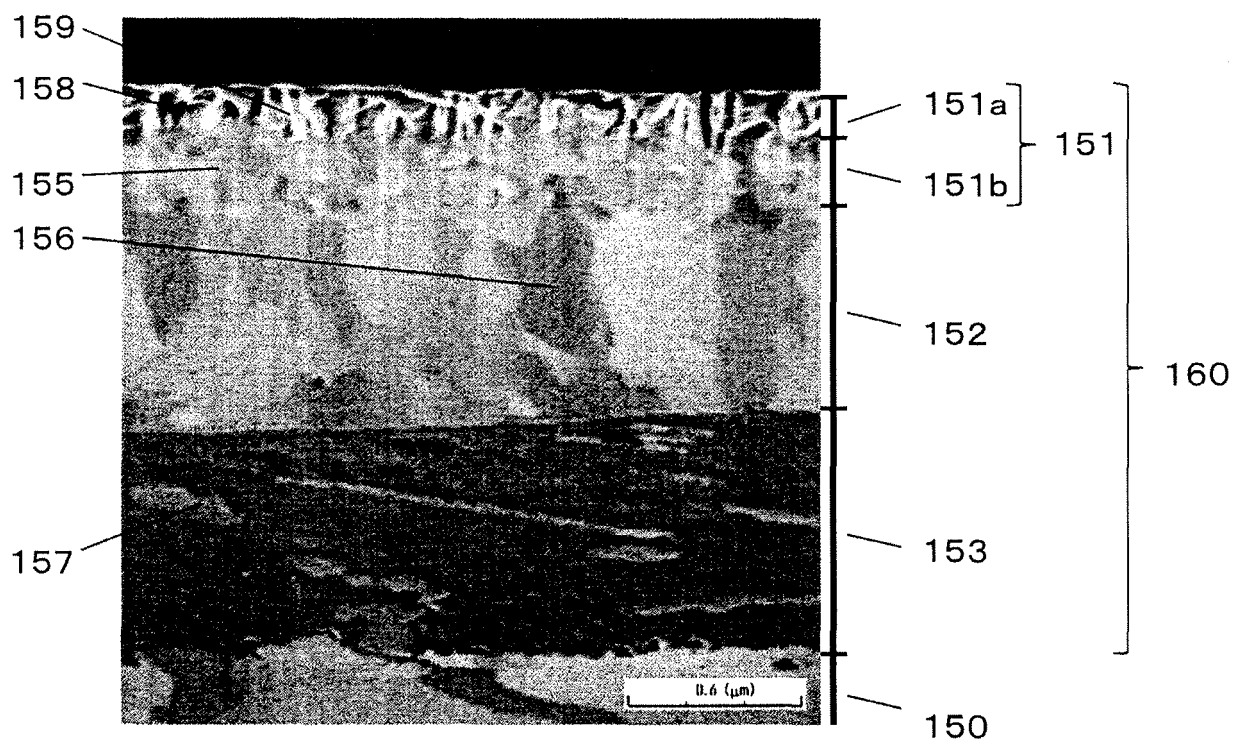


FIG.3

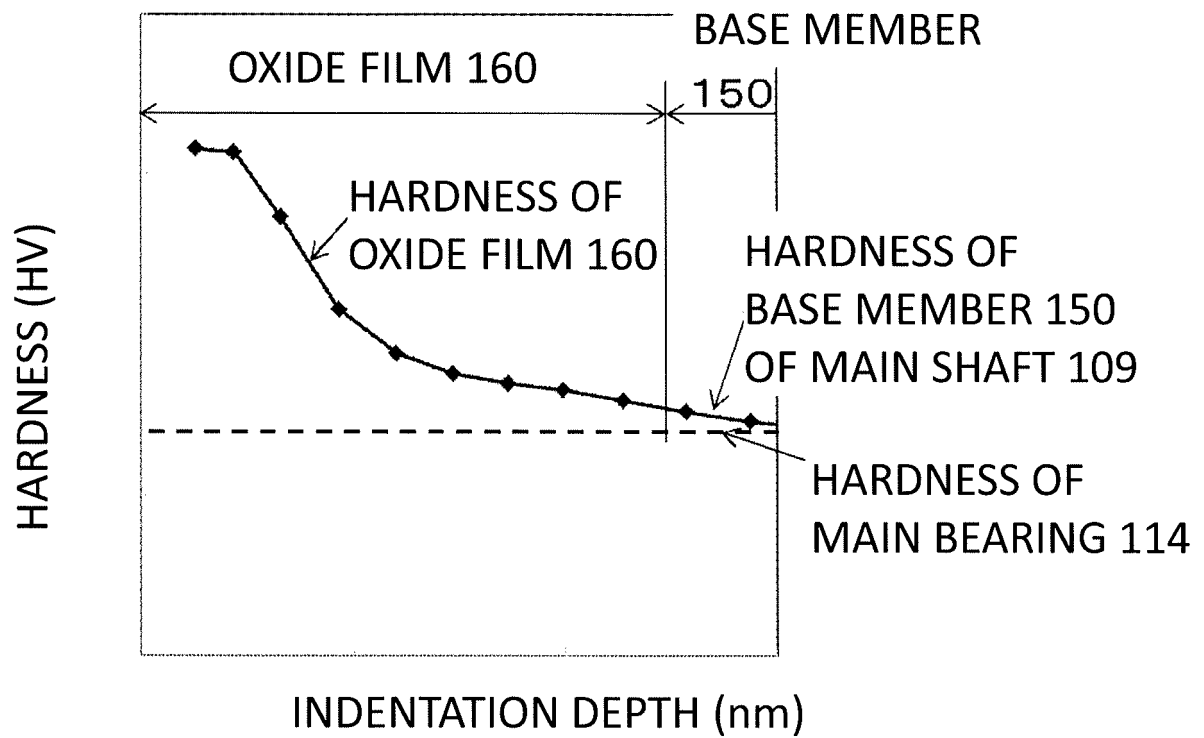


FIG.4A

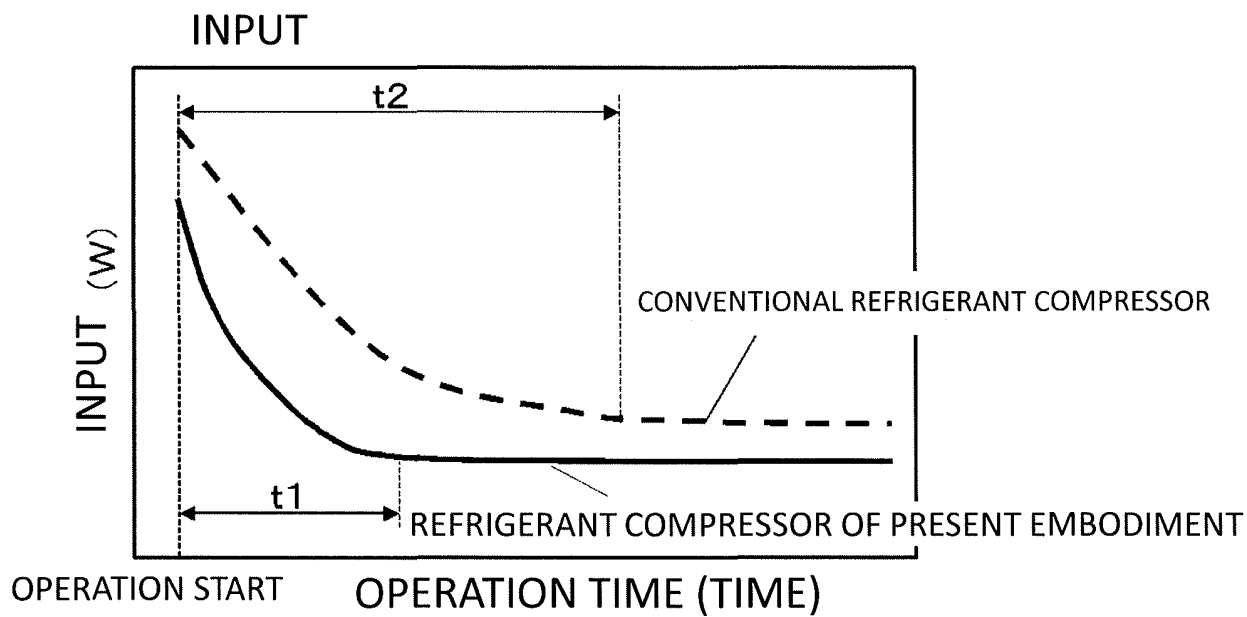


FIG.4B

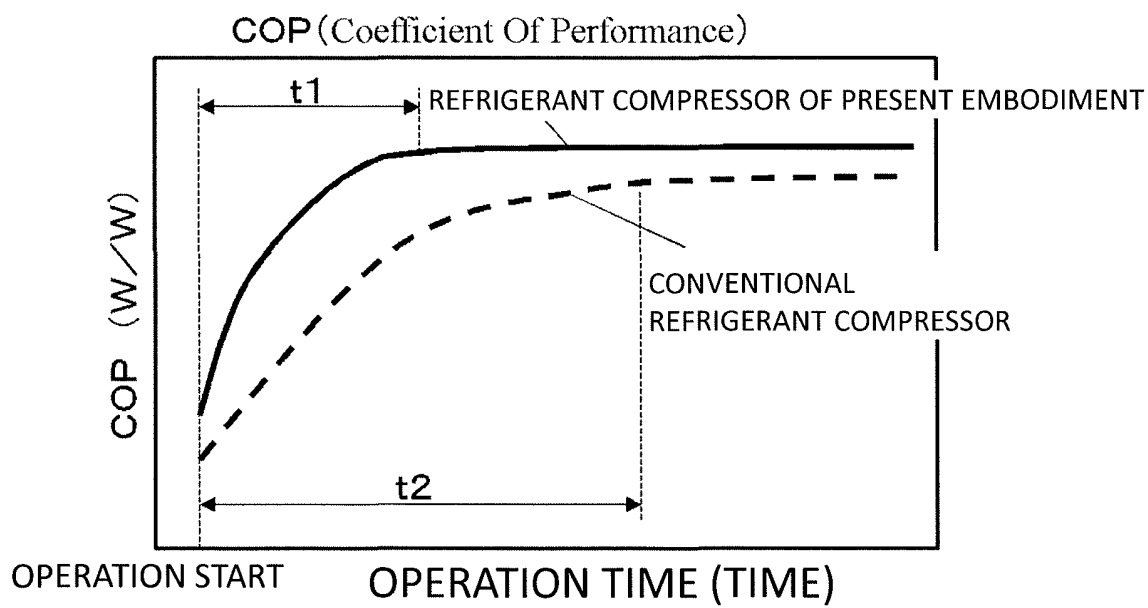


FIG.5

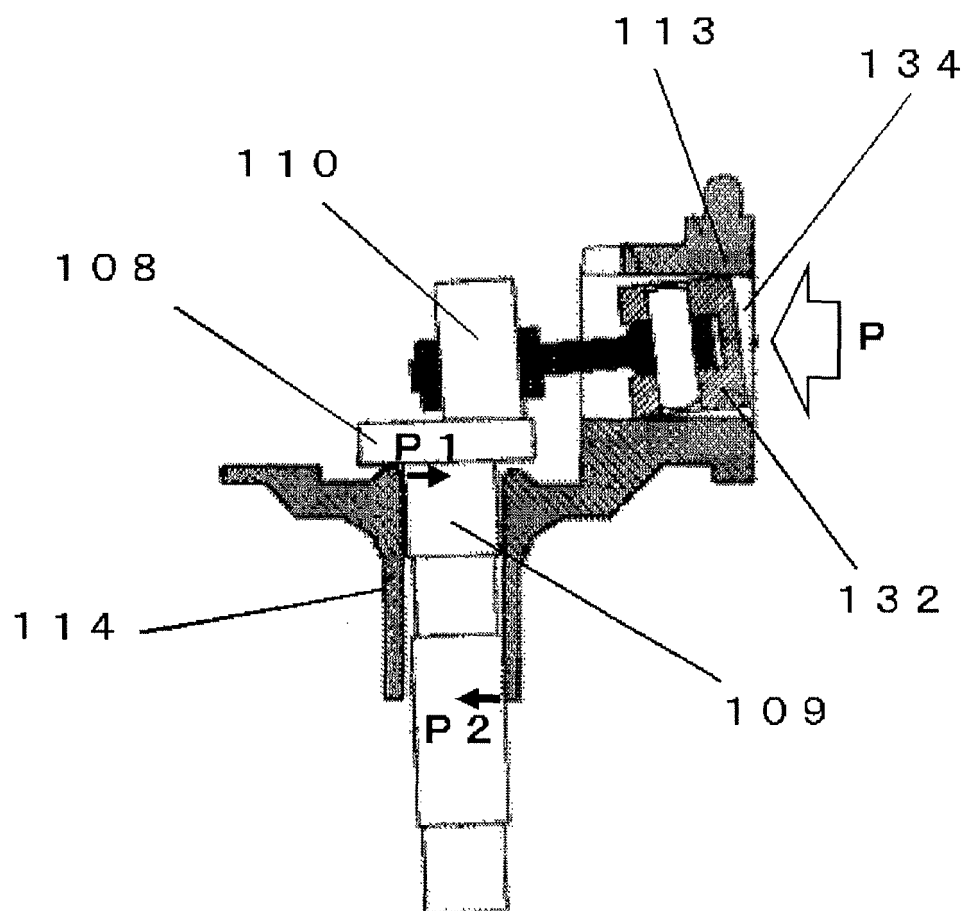


FIG.6

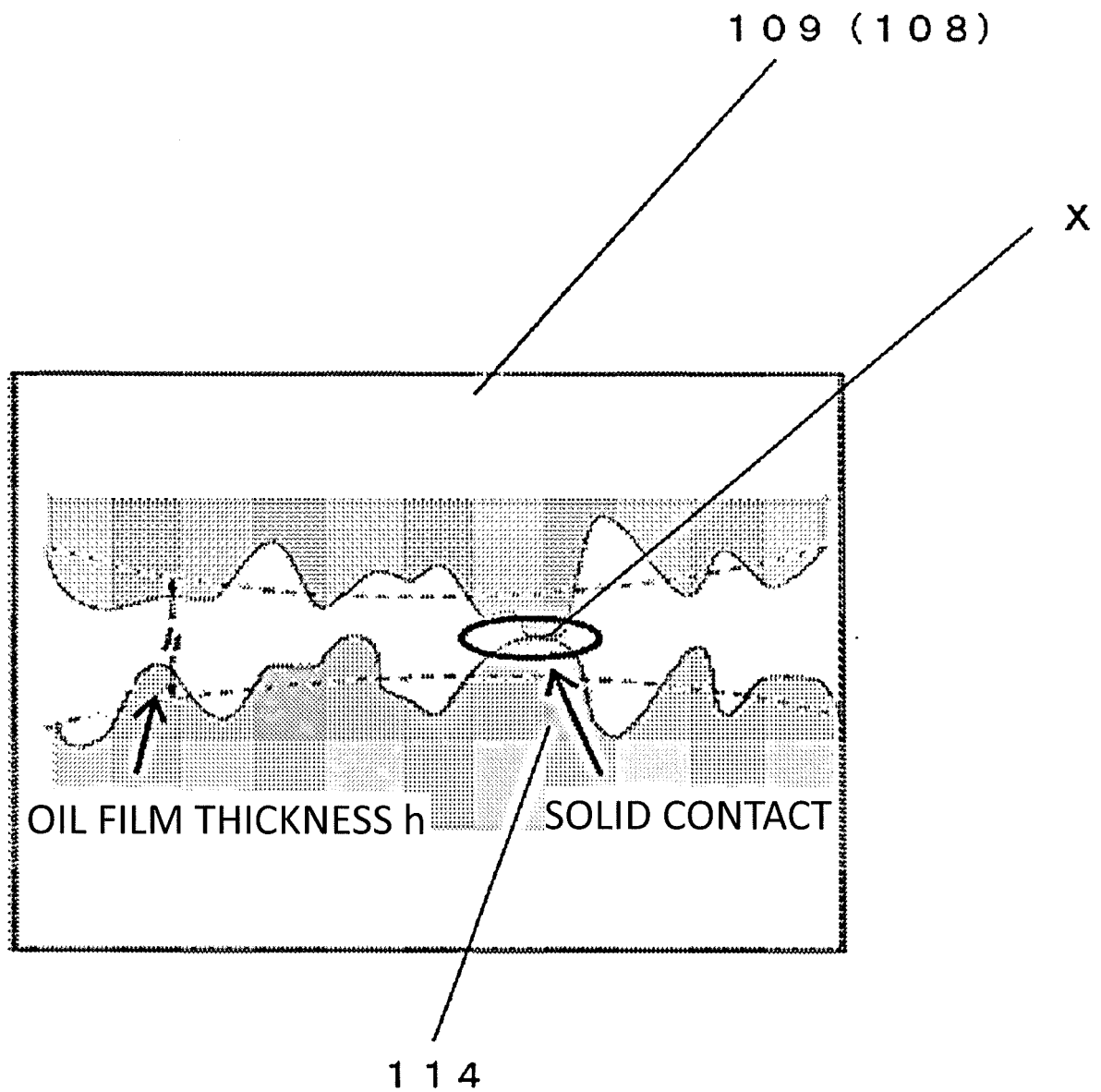


FIG.7

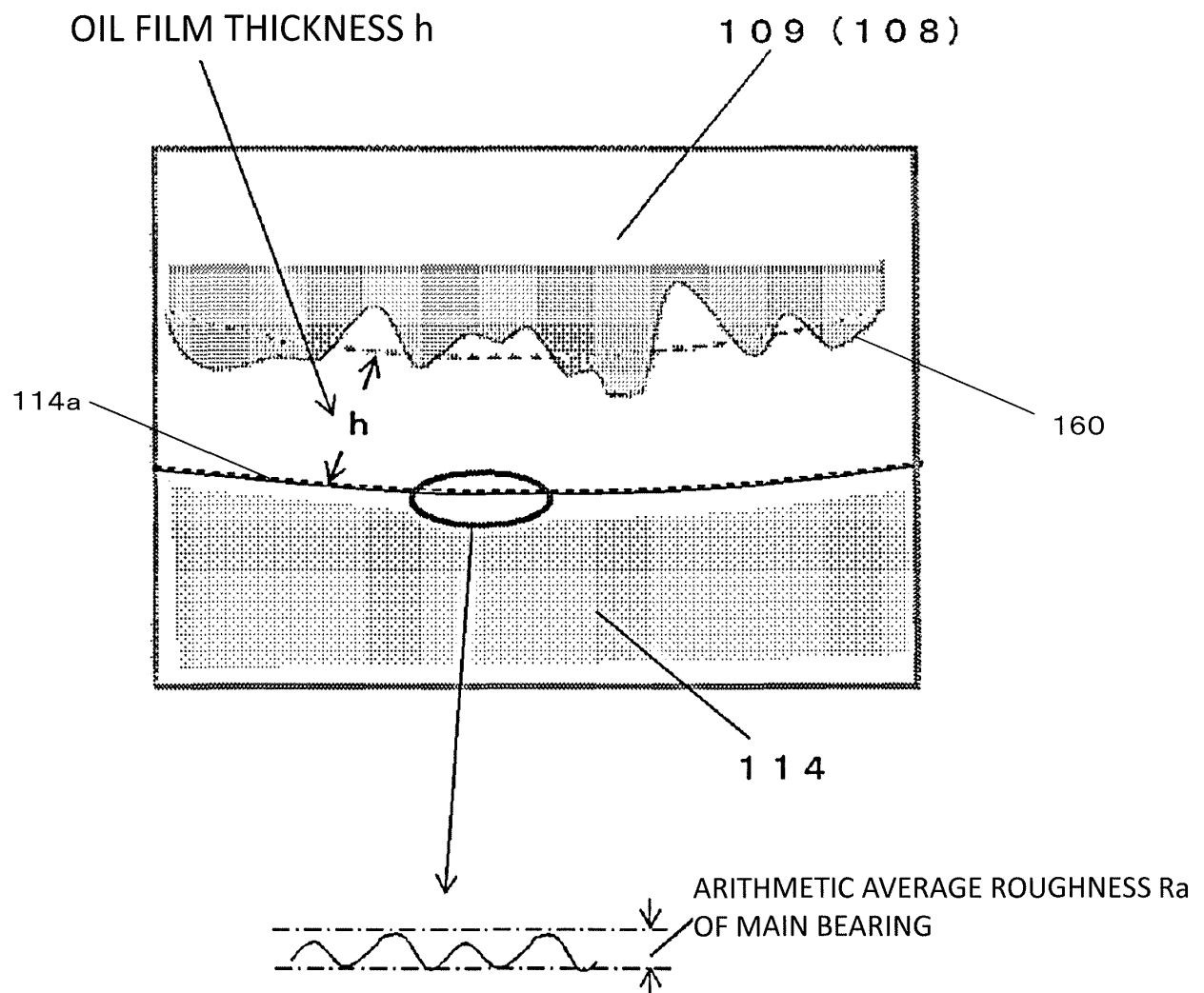


FIG.8

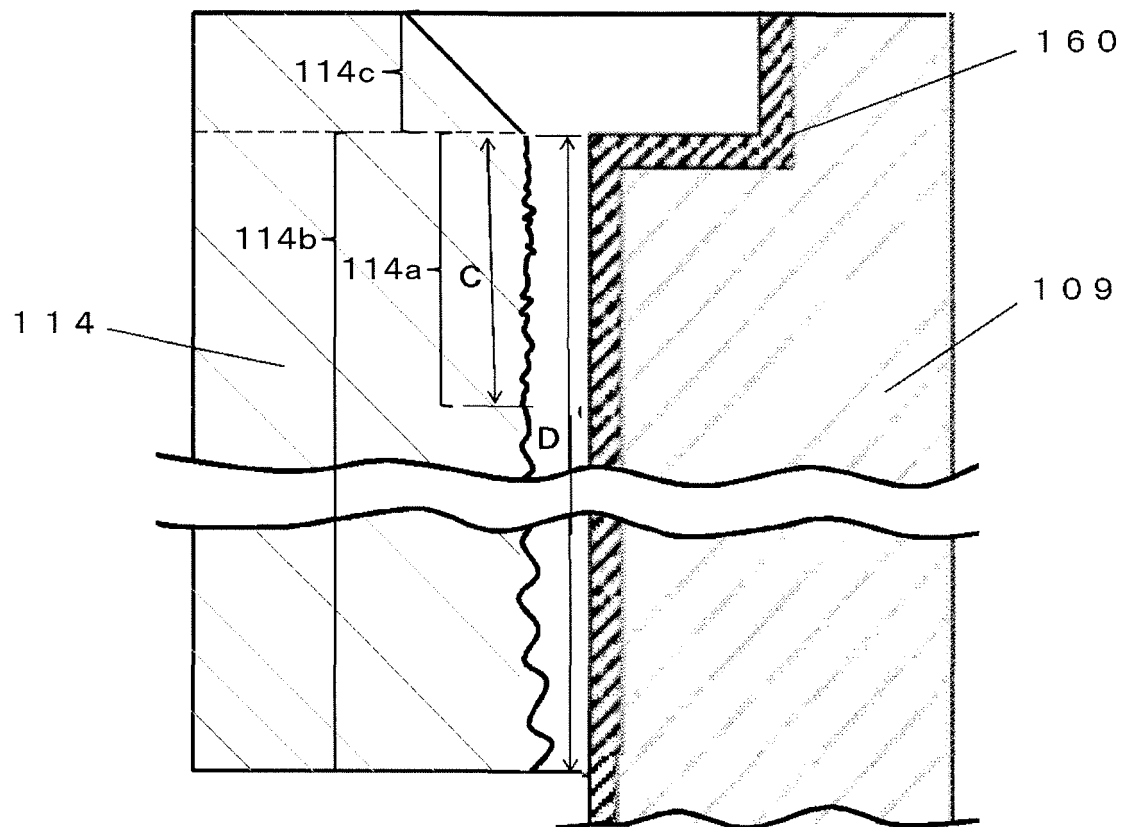


FIG.9

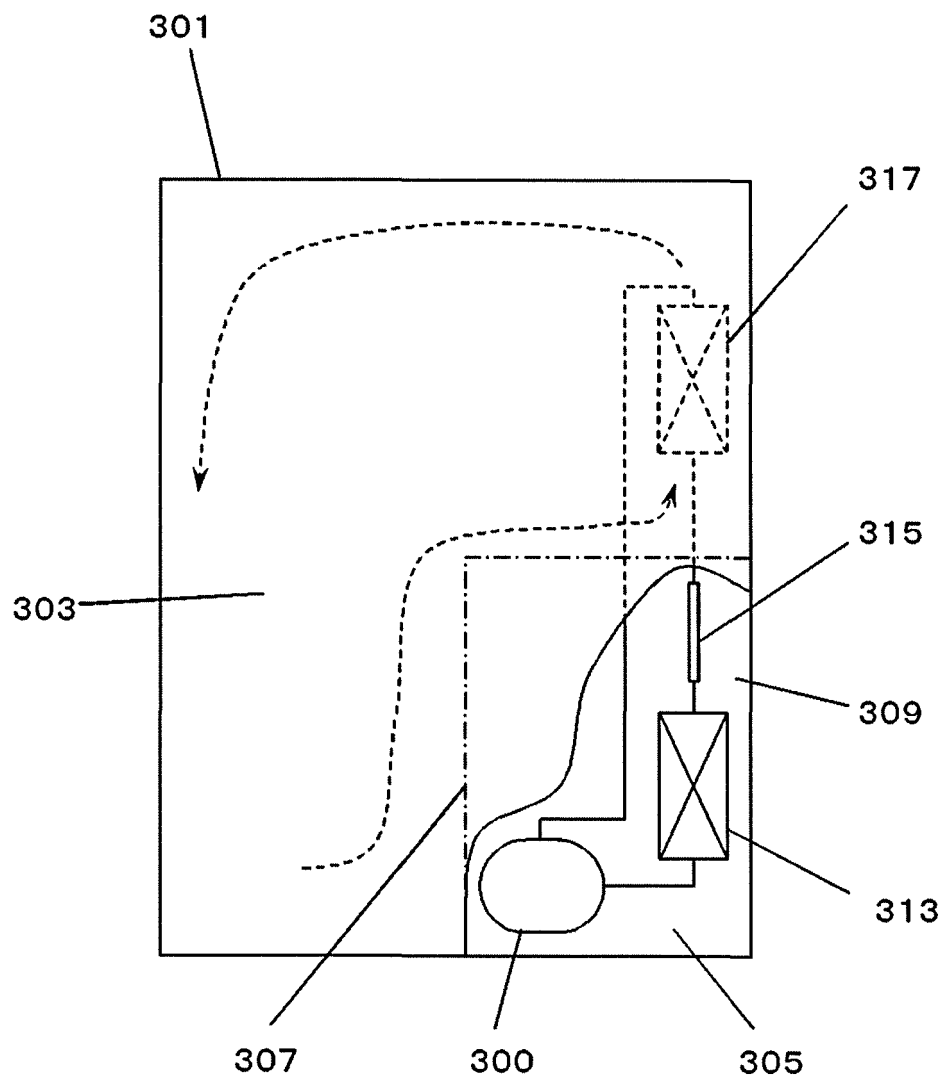
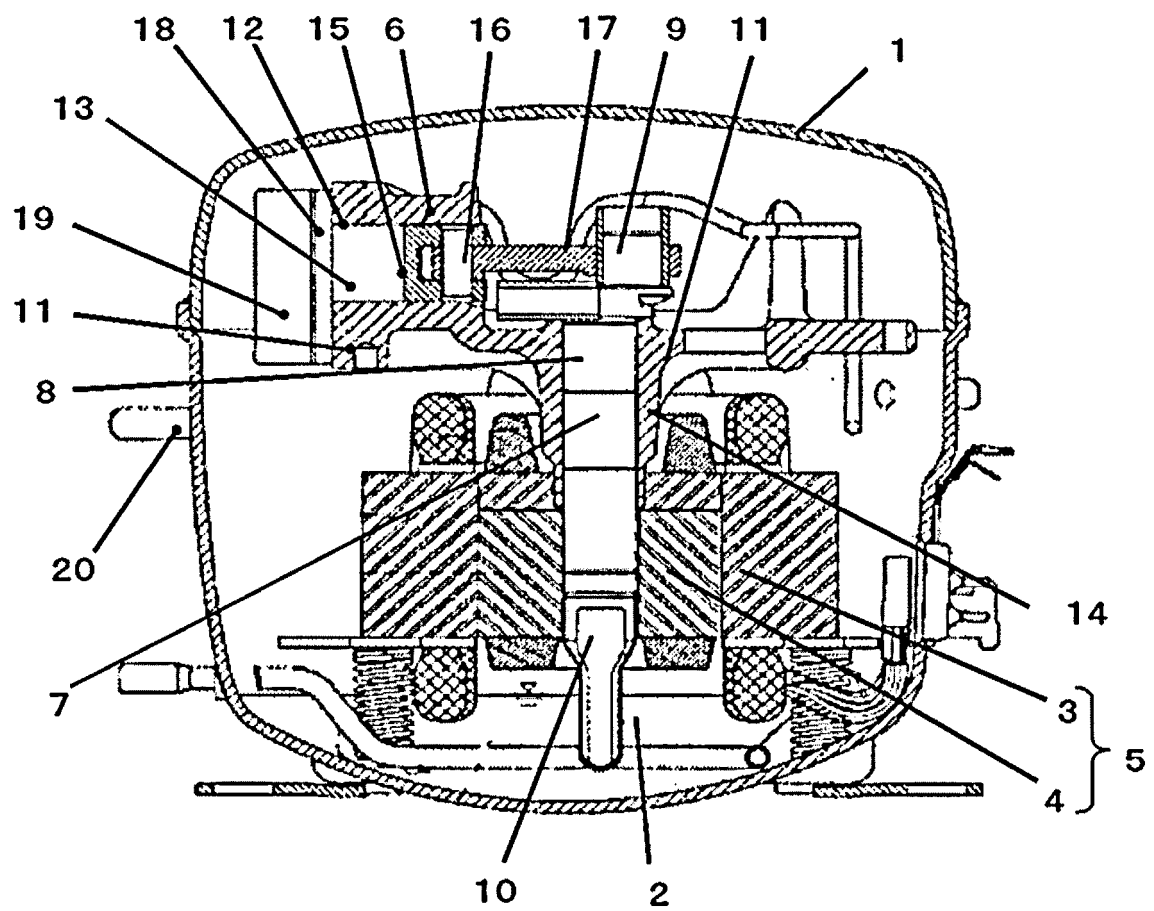


FIG.10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/041307

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F04B39/00 (2006.01) i

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)

Int.Cl. F04B39/00

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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.
Y	JP 2005-133586 A (HITACHI HOME & LIFE SOLUTION, INC.) 26 May 2005, paragraph [0028] (Family: none)	1-6
Y	JP 2002-147377 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 22 May 2002, paragraphs [0025], [0048] (Family: none)	1-6



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search
01 February 2018 (01.02.2018)Date of mailing of the international search report
13 February 2018 (13.02.2018)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/041307

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 49-013378 Y1 (SANYO ELECTRIC CO., LTD.) 02 April 1974, column 1, line 29 to column 2, line 10 (Family: none)	1-6
Y	JP 2014-196680 A (HITACHI, LTD.) 16 October 2014, paragraph [0032] & US 2014/0294643 A1, paragraph [0039]	1-6
A	US 2014/0291060 A1 (FENG, et al.) 02 October 2014, claim 15 (Family: none)	1-6

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 7238885 A [0003]
- JP 55004958 A [0003]
- JP 2016003910 A [0065]
- JP 2016003909 A [0065]

Non-patent literature cited in the description

- *Collection of Papers of Annual Meeting of The Japan Society of Mechanical Engineers*, 2005, vol. 5-1, 143 [0061]