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(54) HERMETIC REFRIGERANT COMPRESSOR AND FREEZING/REFRIGERATING APPARATUS USING THE SAME

(57) A hermetic refrigerant compressor (100) includes a sealed container (101) in which lubricating oil (103) having a kinematic viscosity in a range of 1 to 9 mm^2/S at 40°C is stored, the lubricating oil (103) containing a sliding modifier that is either sulfur or a sulfur-containing compound. A compression element (107) includes a shaft part that is a crank shaft (108). In a case where a sliding surface of a main shaft (109) is a single sliding surface, a length of the single sliding surface in an axial direction is a single sliding length L, whereas in a case where the sliding surface is divided into a plurality of sliding surfaces, a length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L, and a ratio L / D of the single sliding length L to an external diameter D of the main shaft (109) is less than or equal to 0.51. Further, when a total of the lengths of the plurality of sliding surfaces in the axial direction is a total sliding length Lt, a ratio Lt / D of the total sliding length Lt to the external diameter D may be less than or equal to 1.26.

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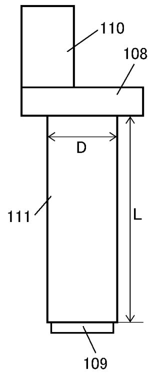
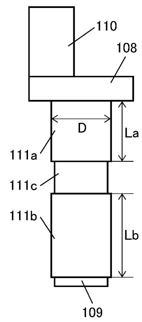
Fig. 3A



L/D ≤ 0.51

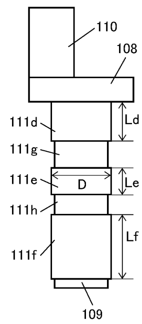
Fig. 3B



La < Lb
L = La
L/D ≤ 0.51

Lt = La + Lb
Lt/D ≤ 1.26

Fig. 3C



Le < Ld < Lf
L = Le
L/D ≤ 0.51

Lt = Ld + Le + Lf
Lt/D ≤ 1.26

Description

Technical Field

[0001] The present invention relates to a hermetic refrigerant compressor for use in, for example, a refrigerator or an air conditioner and also to a refrigerator-freezer using the hermetic refrigerant compressor.

Background Art

[0002] In recent years, from the viewpoint of global environment conservation, the development of a high-efficient hermetic refrigerant compressor that uses less fossil fuels has been conducted. For example, in order to realize high efficiency, it has been proposed to form various films on sliding surfaces of slide members included in the hermetic refrigerant compressor, and to use lubricating oil having a reduced viscosity.

[0003] The hermetic refrigerant compressor includes a sealed container in which the lubricating oil is stored. The sealed container also accommodates an electric element and a compression element. The compression element includes, as the slide members, for example, a crank shaft, a piston, and a connecting rod serving as a coupler. A main shaft of the crank shaft and a main bearing, the piston and a bore, a piston pin and the connecting rod, and an eccentric shaft of the crank shaft and the connecting rod, etc., form slide parts with each other.

[0004] For example, Patent Literature 1 discloses a reciprocating compressor (hermetic refrigerant compressor) using lubricating oil having a low viscosity. The reciprocating compressor is configured such that, among the slide members, the piston and the connecting rod are each made of a ferrous sintered material and are steam-treated, and then a steam layer is removed from the surface of the piston by cutting, whereas the connecting rod is subjected to nitriding after being steam-treated. In Patent Literature 1, the lubricating oil used in the reciprocating compressor thus configured has a kinematic viscosity in the range of 3 mm^2/S to 10 mm^2/S at 40°C.

[0005] If the lubricating oil has a low viscosity, an oil film is not easily formed. In this respect, in the hermetic refrigerant compressor disclosed by Patent Literature 1, the surfaces of the slide members forming the slide parts are subjected to special treatment so that even with the use of the lubricating oil having a low viscosity, wear or seizing of the piston and the connecting rod will be prevented.

Citation List

Patent Literature

[0006] PTL 1: Japanese Laid-Open Patent Application Publication No. 2011-021530

Summary of Invention

Technical Problem

[0007] Incidentally, the crank shaft included in a hermetic refrigerant compressor constitutes a shaft part of the compression element driven by the electric element, and the shaft part is pivotally supported in a rotatable manner by a bearing part. By reducing the sliding area of each of the shaft part and the bearing part (pivotally supporting part), further increased efficiency can be obtained. However, reduction in the sliding area causes lowered wear resistance.

[0008] The above-described reciprocating compressor (hermetic refrigerant compressor) disclosed by Patent Literature 1 uses the low-viscosity lubricating oil, which has a kinematic viscosity in the range of 3 mm^2/S to 10 mm^2/S at 40°C. However, wear resistance to be improved in Patent Literature 1 is the wear resistance of the piston and the connecting rod, and unlike the crank shaft, the piston and the connecting rod are not pivotally supported by the bearing part. Accordingly, in the case of improving the wear resistance of the piston and the connecting rod, unlike the case of the crank shaft, the sliding area of the pivotally supporting part would not be reduced in order to achieve high efficiency.

[0009] The present invention has been made in order to solve the above-described problems. An object of the present invention is to provide a hermetic refrigerant compressor that makes it possible to achieve high reliability of the shaft part that is pivotally supported by the bearing part even with the use of lubricating oil having a reduced viscosity.

Solution to Problem

[0010] In order to solve the above-described problems, a hermetic refrigerant compressor according to the present invention includes a sealed container in which lubricating oil having a kinematic viscosity in a range of 1 mm^2/S to 9 mm^2/S at 40°C is stored, the sealed container accommodating an electric element and a compression element, the compression element being driven by the electric element and configured to compress a refrigerant. The compression element includes: a shaft part that is a crank shaft including a main shaft and an eccentric shaft; and a bearing part that pivotally supports the shaft part, the bearing part including a main bearing and an eccentric bearing, the main bearing pivotally supporting the main shaft, the eccentric bearing pivotally supporting the eccentric shaft. The main shaft includes a sliding surface that slides on the main bearing, the sliding surface being either a single sliding surface or divided into a plurality of sliding surfaces. In a case where the sliding surface is the single sliding surface, a length of the single sliding surface in an axial direction is a single sliding length L, whereas in a case where the sliding surface is divided into the plurality of sliding surfaces, a length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L, and a ratio L / D of the single sliding length L to an external diameter D of the main shaft is less than or equal to 0.51. The lubricating oil contains a sliding modifier that is either sulfur or a sulfur-containing compound.

[0011] According to the above configuration, the lubricating oil is low-viscosity oil; the ratio L / D of the single sliding length L to the external diameter D is less than or equal to 0.51 regardless of whether the sliding surface of the main shaft is a single sliding surface or a plurality of sliding surfaces; and the lubricating oil contains the sulfur-based sliding modifier. Owing to these features, even though the lubricating oil is low-viscosity oil and the sliding area is reduced such that the ratio L / D is less than or equal to 0.51, favorable wear resistance of the slide part can be realized by the sulfur-based sliding modifier. Consequently, the hermetic refrigerant compressor can be obtained, which makes it possible to achieve high reliability of the shaft part, which is pivotally supported by the bearing part, even with the use of the lubricating oil having a reduced viscosity.

[0012] A refrigerator-freezer according to the present invention includes a refrigerant circuit including: the hermetic refrigerant compressor configured as above; a radiator; a decompressor; and a heat absorber. In the refrigerant circuit, the hermetic refrigerant compressor, the radiator, the decompressor, and the heat absorber are connected by piping in an annular manner.

[0013] According to the above configuration, in the hermetic refrigerant compressor, the low-viscosity lubricating oil is used; the sliding area is reduced; and the shaft part has high reliability. Since the refrigerator-freezer includes the hermetic refrigerant compressor, which is highly efficient and highly reliable, the power consumption of the refrigerator-freezer can be reduced, and also, the refrigerator-freezer can be made highly reliable.

[0014] The above and other objects, features, and advantages of the present invention will more fully be apparent from the following detailed description of preferred embodiments with accompanying drawings.

Advantageous Effects of Invention

[0015] The present invention is configured as described above, and has an advantage of being able to provide a hermetic refrigerant compressor that makes it possible to achieve high reliability of the shaft part, which is pivotally supported by the bearing part, even with the use of the lubricating oil having a reduced viscosity.

Brief Description of Drawings

[0016]

FIG. 1 is a schematic sectional view showing one example of the configuration of a refrigerant compressor according to an embodiment of the present disclosure.

FIG. 2 is a schematic side view showing one example of the configuration of a crank shaft included in the refrigerant compressor shown in FIG. 1.

FIG. 3A is a schematic diagram showing one configuration example in a case where a sliding surface of the crank shaft shown in FIG. 2 is a single sliding surface; and FIG. 3B and FIG. 3C are schematic diagrams each showing one configuration example in a case where the sliding surface of the crank shaft shown in FIG. 2 is divided into a plurality of sliding surfaces.

FIG. 4 is a schematic diagram showing one example of the configuration of a refrigerator-freezer including the refrigerant compressor shown in FIG. 1.

Description of Embodiments

[0017] A hermetic refrigerant compressor according to the present disclosure includes a sealed container in which lubricating oil having a kinematic viscosity in a range of 1 mm^2/S to 9 mm^2/S at 40°C is stored, the sealed container accommodating an electric element and a compression element, the compression element being driven by the electric element and configured to compress a refrigerant. The compression element includes: a shaft part that is a crank shaft including a main shaft and an eccentric shaft; and a bearing part that pivotally supports the shaft part, the bearing part including a main bearing and an eccentric bearing, the main bearing pivotally supporting the main shaft, the eccentric bearing pivotally supporting the eccentric shaft. The main shaft includes a sliding surface that slides on the main bearing, the sliding surface being either a single sliding surface or divided into a plurality of sliding surfaces. In a case where the sliding surface is the single sliding surface, a length of the single sliding surface in an axial direction is a single sliding length L, whereas in a case where the sliding surface is divided into the plurality of sliding surfaces, a length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L, and a ratio L / D of the single sliding length L to an external diameter D of the main shaft is less than or equal to 0.51. The lubricating oil contains a sliding modifier that is either sulfur or a sulfur-containing compound.

[0018] According to the above configuration, the lubricating oil is low-viscosity oil; the ratio L / D of the single sliding length L to the external diameter D is less than or equal to 0.51 regardless of whether the sliding surface of the main shaft is a single sliding surface or a plurality of sliding surfaces; and the lubricating oil contains the sulfur-based sliding modifier. Owing to these features, even though the lubricating oil is low-viscosity oil and the sliding area is reduced such that the ratio L / D is less than or equal to 0.51, favorable wear resistance of the slide part can be realized by the sulfur-based sliding modifier. Consequently, the hermetic refrigerant compressor can be obtained, which makes it possible to achieve high reliability of the shaft part, which is pivotally supported by the bearing part, even with the use of the lubricating oil having a reduced viscosity.

[0019] In the hermetic refrigerant compressor configured as above, in the case where the sliding surface is divided into the plurality of sliding surfaces, when a total of the lengths of the plurality of sliding surfaces in the axial direction is a total sliding length Lt, a ratio Lt / D of the total sliding length Lt to the external diameter D may be less than or equal to 1.26.

[0020] According to the above configuration, in the case where the sliding surface is divided into the plurality of sliding surfaces, the sliding area is reduced such that not only is the ratio L / D less than or equal to 0.51, but also the ratio Lt / D of the total sliding length Lt to the external diameter D is less than or equal to 1.26. Accordingly, in a state where the low-viscosity lubricating oil is used and the sliding area is reduced, the wear resistance of the slide part derived from the sulfur-based sliding modifier can be more improved.

[0021] In the hermetic refrigerant compressor configured as above, the ratio L / D may be greater than or equal to 0.15.

[0022] According to the above configuration, if the ratio L / D is greater than or equal to 0.15, the sliding area is not reduced excessively. For this reason, in a state where the low-viscosity lubricating oil is used and the sliding area is reduced, suitable wear resistance of the slide part can be realized by the sulfur-based sliding modifier.

[0023] In the hermetic refrigerant compressor configured as above, the ratio Lt / D may be greater than or equal to 0.3.

[0024] According to the above configuration, if the ratio Lt / D is greater than or equal to 0.3, the sliding area is not reduced excessively even in the case where the sliding surface is divided into the plurality of sliding surfaces. For this reason, in a state where the low-viscosity lubricating oil is used and the sliding area is reduced, suitable wear resistance of the slide part can be realized by the sulfur-based sliding modifier.

[0025] In the hermetic refrigerant compressor configured as above, a content of the sliding modifier in the lubricating oil in terms of an atomic weight of sulfur may be greater than or equal to 100 ppm.

[0026] According to the above configuration, the sulfur-based sliding modifier is added to the lubricating oil, such that the sliding modifier content therein in terms of the atomic weight of sulfur is greater than or equal to 100 ppm. Accordingly, in a state where the low-viscosity lubricating oil is used and the sliding area is reduced, suitable wear resistance of the slide part derived from the sulfur-based sliding modifier can be realized.

[0027] In the hermetic refrigerant compressor configured as above, the lubricating oil may further contain a phosphorus-based extreme-pressure additive.

[0028] According to the above configuration, in addition to the sulfur-based sliding modifier, the phosphorus-based extreme-pressure additive is added to the lubricating oil, and thereby, for example, wear of the slide part can be reduced favorably.

[0029] In the hermetic refrigerant compressor configured as above, the electric element may be inverter-driven at a plurality of operating frequencies.

[0030] According to the above configuration, in the case where the electric element is inverter-driven, regardless of whether low-speed operation is being performed or high-speed operation is being performed, the wear resistance of the slide part derived from the sulfur-based sliding modifier can be realized. Therefore, the reliability of the hermetic refrigerant compressor can be improved.

[0031] A refrigerator-freezer according to the present disclosure includes a refrigerant circuit including: the hermetic refrigerant compressor configured as above; a radiator; a decompressor; and a heat absorber. In the refrigerant circuit, the hermetic refrigerant compressor, the radiator, the decompressor, and the heat absorber are connected by piping in an annular manner.

[0032] According to the above configuration, in the hermetic refrigerant compressor, the low-viscosity lubricating oil is used; the sliding area is reduced; and the shaft part has high reliability. Since the refrigerator-freezer includes the hermetic refrigerant compressor, which is highly efficient and highly reliable, the power consumption of the refrigerator-freezer can be reduced, and also, the refrigerator-freezer can be made highly reliable.

[0033] Hereinafter, representative embodiments of the present invention are described with reference to the drawings. In the drawings, the same or corresponding elements are denoted by the same reference signs, and repeating the same descriptions is avoided below.

(Embodiment 1)

[Configuration of Refrigerant Compressor]

[0034] First, a representative configuration example of a hermetic refrigerant compressor according to Embodiment 1 of the present disclosure is specifically described with reference to FIG. 1 and FIG. 2. FIG. 1 is a schematic sectional view showing one example of the configuration of a hermetic refrigerant compressor 100 according to Embodiment 1 of the present disclosure (hereinafter, the hermetic refrigerant compressor 100 may be simply referred to as "refrigerant compressor 100"). FIG. 2 is a schematic side view showing one example of the configuration of a crank shaft 108, which is a shaft part included in the refrigerant compressor 100.

[0035] As shown in FIG. 1, the refrigerant compressor 100 includes a sealed container 101 filled with a refrigerant that is, for example, R600a. Mineral oil is stored in the bottom of the sealed container 101 as lubricating oil

103. In the present disclosure, the lubricating oil 103 has a kinematic viscosity in the range of 1 mm^2/S to 9 mm^2/S at 40°C. It should be noted that, in Embodiment 1, although the lubricating oil 103 is low-viscosity mineral oil, the lubricating oil 103 is not thus limited as described below. Also, as described below, the lubricating oil 103 contains at least a sulfur-based sliding modifier (or a wear inhibitor). The lubricating oil 103 may further contain an extreme-pressure additive.

[0036] The sealed container 101 also accommodates an electric element 106 and a compression element 107. The electric element 106 is constituted by a stator 104 and a rotor 105. The compression element 107 is a reciprocating element driven by the electric element 106. The compression element 107 includes, for example, the crank shaft 108, a cylinder block 112, and a piston 120.

[0037] The crank shaft 108 is constituted by, also as shown in FIG. 2, a main shaft 109 and an eccentric shaft 110. The rotor 105 is fixed to the main shaft 109 by press-fitting. The eccentric shaft 110 is formed such that it is eccentric with the main shaft 109. In Embodiment 1, the outer peripheral surface of the main shaft 109 of the crank shaft 108 includes a first sliding surface 111a, a second sliding surface 111b, and a non-sliding outer peripheral surface 111c. In addition, an unshown oil-feeding pump is provided at the lower end of the crank shaft 108.

[0038] In Embodiment 1, for example, the cylinder block 112 is made of cast iron. The cylinder block 112 forms a substantially cylindrical bore 113, and includes a main bearing 114, which pivotally supports the main shaft 109 of the crank shaft 108. The inner peripheral surface of the main bearing 114 is slidably in contact with the first sliding surface 111a and the second sliding surface 111b of the outer peripheral surface of the main shaft 109, but is not in contact with the non-sliding outer peripheral surface 111c.

[0039] It should be noted that, as shown in FIG. 1, the eccentric shaft 110 of the crank shaft 108 is positioned in the upper side of the refrigerant compressor 100, whereas the main shaft 109 of the crank shaft 108 is positioned in the lower side of the refrigerant compressor 100. Therefore, this upper-lower positional relationship (direction) is utilized when describing positions on the crank shaft 108 herein. For example, the upper end of the eccentric shaft 110 faces the inner upper surface of the sealed container 101, and the lower end of the eccentric shaft 110 is connected to the main shaft 109. The upper end of the main shaft 109 is connected to the eccentric shaft 110, and the lower end of the main shaft 109 faces the inner lower surface of the sealed container 101. The lower end portion of the main shaft 109 is immersed in the lubricating oil 103.

[0040] In the present disclosure, the term "sliding surface" means a surface that is a portion of the outer peripheral surface of the shaft part, the portion being slidably in contact with the inner peripheral surface of a bearing part. The non-sliding outer peripheral surface 111c constitutes a portion of the outer peripheral surface of the main shaft 109. However, unlike the first sliding surface 111a and the second sliding surface 111b, the non-sliding outer peripheral surface 111c is a surface that is recessed (or receding) from the sliding surfaces (the first sliding surface 111a and the second sliding surface 111b), such that the non-sliding outer peripheral surface 111c is not in contact with the inner peripheral surface of the bearing part. In other words, the portions of the main shaft 109 serving as the sliding surfaces are greater in diameter or radius than the portion of the main shaft 109 serving as the non-sliding outer peripheral surface 111c.

[0041] The piston 120 is inserted in the bore 113 in a reciprocable manner, and thereby a compression chamber 121 is formed. A piston pin 115 having, for example, a substantially cylindrical shape is disposed parallel to the eccentric shaft 110. The piston pin 115 is locked to a piston pin hole formed in the piston 120 in a non-rotatable manner.

[0042] A coupler 117 is, for example, constituted by an aluminum casting product. The coupler 117 includes an eccentric bearing 119, which pivotally supports the eccentric shaft 110, and the coupler 117 couples the eccentric shaft 110 and the piston 120 via the piston pin 115. The end face of the bore 113 is sealed by a valve plate 122.

[0043] It should be noted that, in the present disclosure, the main shaft 109 and the eccentric shaft 110 included in the crank shaft 108 are collectively referred to as the "shaft part". Also, the main bearing 114 of the cylinder block 112, which pivotally supports the main shaft 109, and the eccentric bearing 119 of the coupler 117, which pivotally supports the eccentric shaft 110, are collectively referred to as the "bearing part".

[0044] A cylinder head 123 forms an unshown high-pressure chamber, and is fixed to the valve plate 122 at the opposite side to the bore 113. An unshown suction tube is fixed to the sealed container 101, and also connected to the low-pressure side (not shown) of a refrigeration cycle, such that the suction tube leads the refrigerant gas into the sealed container 101. A suction muffler 124 is held in a sandwiched manner between the valve plate 122 and the cylinder head 123.

[0045] The main shaft 109 of the crank shaft 108 and the main bearing 114, the piston 120 and the bore 113, the piston pin 115 and a connecting rod of the coupler 117, and the eccentric shaft 110 of the crank shaft 108 and the eccentric bearing 119 of the coupler 117, etc., form slide parts with each other.

[0046] In the refrigerant compressor 100 thus configured, first, electric power is supplied from an unshown commercial power supply to the electric element 106 to cause the rotor 105 of the electric element 106 to rotate. The rotor 105 causes the crank shaft 108 to rotate, and eccentric motion of the eccentric shaft 110 from the coupler 117 drives the piston 120 via the piston pin 115. The piston 120 makes reciprocating motion in the bore 113, sucks the refrigerant gas that has been led into the sealed container 101 through the suction tube from the suction muffler 124, and compresses the sucked refrigerant gas in the compression chamber 121.

[0047] It should be noted that a specific method adopted herein for driving the refrigerant compressor 100 is not particularly limited. For example, the refrigerant compressor 100 may be driven by simple on-off control, or may be inverter-driven at a plurality of operating frequencies. In the case where the refrigerant compressor 100 is inverter-driven, in order to optimize the operation control of the refrigerant compressor 100, low-speed operation or high-speed operation is performed. When the low-speed operation is performed, the amount of oil fed to each slide part decreases, whereas when the high-speed operation is performed, the rotation speed of the electric element 106 increases. Here, in the refrigerant compressor 100, the wear resistance of the main shaft 109 can be improved as described below. Consequently, the reliability of the refrigerant compressor 100 can be improved.

[0048] Among the plurality of slide parts included in the refrigerant compressor 100, the main shaft 109 of the crank shaft 108 is rotatably fitted to the main bearing 114, and thereby a slide part is formed. Therefore, for the sake of convenience of the description, the slide part thus formed by the main shaft 109 and the main bearing 114 is referred to as a "main shaft slide part". Similarly, the eccentric shaft 110 of the crank shaft 108 is rotatably fitted to the eccentric bearing 119, and thereby a slide part is formed. Therefore, for the sake of convenience of the description, the slide part thus formed by the eccentric shaft 110 and the eccentric bearing 119 is referred to as an "eccentric shaft slide part". Also, the "main shaft slide part" and the "eccentric shaft slide part" are collectively referred to as a "shaft slide part".

[0049] In accordance with the rotation of the crank shaft 108, the oil-feeding pump feeds the lubricating oil 103 to each slide part, and thereby each slide part is lubricated. It should be noted that the lubricating oil 103 serves to seal between the piston 120 and the bore 113.

[Configuration of Shaft Slide Part]

[0050] Next, one example of a specific configuration of the shaft slide part according to the present disclosure is specifically described with reference to FIG. 3A to FIG. 3C. FIG. 3A is a schematic diagram showing one configuration example in a case where the sliding surface of the crank shaft 108 shown in FIG. 2 is a single sliding surface. FIG. 3B and FIG. 3C are schematic diagrams each showing one configuration example in a case where the sliding surface of the crank shaft 108 shown in FIG. 2 is divided into a plurality of sliding surfaces.

[0051] In the example shown in FIG. 2, the main shaft 109 of the crank shaft 108, which is the shaft part, is configured to include the first sliding surface 111a and the second sliding surface 111b. In other words, the sliding surface of the main shaft 109 is divided into a plurality of sliding surfaces. The configuration of the main shaft 109 shown in FIG. 2, i.e., the configuration in which the sliding surface is divided into two sliding surfaces, corresponds to the schematic diagram shown in FIG. 3B. However, the shaft part according to the present disclosure is not thus limited. The sliding surface of the main shaft 109 may be a single sliding surface. For example, as shown in FIG. 3A, the outer peripheral surface of the main shaft 109 need not be divided into a plurality of sliding surfaces, but instead, the main shaft 109 may have only one sliding surface 111.

[0052] A specific manner of dividing the sliding surface into a plurality of sliding surfaces is not particularly limited. Typically, between a plurality of sliding surfaces, a recess that is recessed (or receding) from the sliding surfaces toward the center axis may be formed. The recess constitutes the non-sliding outer peripheral surface 111c as shown in FIG. 2 and FIG. 3B. A specific shape of the recess is not particularly limited. For example, the depth of the recess may be set to any depth, so long as the set depth will not affect, for example, the stiffness and strength of the main shaft 109. Similarly, the width of the recess (i.e., the distance between the plurality of sliding surfaces) is not particularly limited. The width of the recess can be suitably set in accordance with how much the sliding surface is to be narrowed down (i.e., in accordance with an intended reduction or decrease in the sliding area).

[0053] In the case of dividing the sliding surface into a plurality of sliding surfaces, the plurality of sliding surfaces is not particularly limited to a specific number of surfaces. As shown in FIG. 2 and FIG. 3B, the sliding surface may be divided into the first sliding surface 111a and the second sliding surface 111b, i.e., a total of two sliding surfaces. Alternatively, as shown in FIG. 3C, the sliding surface may be divided into a first sliding surface 111d, a second sliding surface 111e, and a third sliding surface 111f, i.e., a total of three sliding surfaces, or may be divided into four or more sliding surfaces. In the configuration shown in FIG. 3C, a first non-sliding outer peripheral surface 111g, which is the same recess as the non-sliding outer peripheral surface 111c, is positioned between the first sliding surface 111d and the second sliding surface 111e, and a second non-sliding outer peripheral surface 111h is positioned between the second sliding surface 111e and the third sliding surface 111f.

[0054] In the present disclosure, the ratio of the length of a sliding surface of the shaft part in the axial direction to the external diameter (the diameter) of a portion of the shaft part, the portion serving as the sliding surface, is set to less than or equal to a predetermined value, and thereby the sliding area can be reduced without substantially affecting the wear resistance. Specifically, in a case where the sliding surface is a single sliding surface (e.g., see FIG. 3A), the length of the single sliding surface in the axial direction is a single sliding length L, whereas in a case where the sliding surface is divided into a plurality of sliding surfaces (e.g., FIG. 3B or FIG. 3C), the length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L. Here, when the external diameter (the diameter) of a portion of the shaft part, the portion serving as the sliding surface, is an external diameter D, the shaft part is designed such that the ratio L / D of the single sliding length L to the external diameter D of the shaft part is less than or equal to 0.51.

[0055] For the sake of convenience of the description of the external diameter D and the single sliding length L, FIG. 3A is illustrated such that the length L of the single sliding surface 111 (i.e., the single sliding length L) is greater than the external diameter D. If the length L of the single sliding surface 111 relative to the external diameter D is exactly as illustrated in FIG. 3A, the ratio L / D is greater than 0.51. However, in reality, for example, by forming a recess (a non-sliding outer peripheral surface) on the upper portion (the eccentric shaft 110 side) or the lower portion (the lubricating oil 103 side) of the main shaft 109 as seen from the single sliding surface 111, the ratio L / D can be set to less than or equal to 0.51 ($L / D \leq 0.51$).

[0056] In FIG. 3B, the sliding surface is divided into the first sliding surface 111a and the second sliding surface 111b. In the example shown in FIG. 3B, the length La of the upper first sliding surface 111a in the axial direction is less than the length Lb of the lower second sliding surface 111b in the axial direction (La < Lb). In this case, the first sliding surface 111a is the "sliding surface having the least length". Accordingly, the length La of the first sliding surface 111a is the single sliding length L (L = La). In this example, on the first sliding surface 111a, the La / D is required to be less than or equal to 0.51.

[0057] It should be noted that, similar to FIG. 3A, FIG. 3B is illustrated such that the length La of the first sliding surface 111a is greater than the external diameter D for the sake of convenience of the description of the external diameter D and the length La. Also in this case, the ratio L / D can be set to less than or equal to 0.51 by, for example, increasing the length of the non-sliding outer peripheral surface 111c in the axial direction or forming an unshown non-sliding outer peripheral surface (a recess) on the upper side of the first sliding surface 111a.

[0058] In FIG. 3C, the sliding surface is divided into the first sliding surface 111d, the second sliding surface 111e, and the third sliding surface 111f. In the example shown in FIG. 3C, the length Le of the middle second sliding surface 111e in the axial direction is less than the length Ld of the upper first sliding surface 111d in the axial direction, and the length Ld is less than the length Lf of the lower third sliding surface 111f in the axial direction (Le < Ld < Lf). In this case, the second sliding surface 111e is the "sliding surface having the least length". Accordingly, the length Le of the second sliding surface 111e is the single sliding length L (L = Le). In this example, on the second sliding surface 111e, the Le / D is required to be less than or equal to 0.51.

[0059] In the present disclosure, the lower limit value of the ratio L / D is not particularly limited. One preferable example of the lower limit value is 0.15 or greater. Accordingly, a preferable range of the ratio L / D in the present disclosure is the range of 0.15 to 0.51. A more preferable lower limit of the ratio L / D is 0.30. A further preferable lower limit of the ratio L / D is 0.42.

[0060] In a case where the ratio L / D is greater than 0.51, if low-viscosity oil (having a kinematic viscosity in the range of 1 mm^2/S to 9 mm^2/S at 40°C) is used as the lubricating oil 103, even if the aforementioned sulfur-based sliding modifier, which will be described below, is added to the lubricating oil 103, sufficient wear resistance cannot be obtained. On the other hand, in a case where the ratio L / D is less than 0.15, although depending on various conditions of the shaft part, there is a risk of the sliding surface becoming too narrow. Generally speaking, if the ratio L / D is greater than or equal to 0.15, the sliding area is not reduced excessively. Therefore, even if low-viscosity oil is used as the lubricating oil 103, suitable wear resistance of the shaft slide part can be realized by the sulfur-based sliding modifier.

[0061] In the present disclosure, in a case where the sliding surface is divided into a plurality of sliding surfaces, preferably, the ratio L / D satisfies not only the condition of being less than or equal to 0.51, but also the following condition: when the total of the lengths of the plurality of sliding surfaces in the axial direction is a total sliding length Lt, the ratio Lt / D of the total sliding length Lt to the external diameter D is less than or equal to 1.26 ($Lt / D \leq 1.26$).

[0062] For instance, in the example shown in FIG. 3B, the sum of the length La of the first sliding surface 111a and the length Lb of the second sliding surface 111b is the total sliding length Lt (Lt = La + Lb). Therefore, in this example, it will suffice if $La + Lb \leq 1.26$. Also, in the example shown in FIG. 3C, the sum of the length La of the first sliding surface 111d, the length Le of the second sliding surface 111e, and the length Lf of the third sliding surface 111f is the total sliding length Lt (Lt = Ld + Le + Lf). Therefore, in this example, it will suffice if $Ld + Le + Lf \leq 1.26$.

[0063] As described above, in a case where the sliding surface is divided into a plurality of sliding surfaces, if the ratio L / D is less than or equal to 0.51 and the ratio Lt / D is less than or equal to 1.26, then in a state where low-viscosity oil is used as the lubricating oil 103 and the sliding area is reduced, the wear resistance of the shaft slide part derived from the sulfur-based sliding modifier can be more improved.

[0064] In the present disclosure, the lower limit value of the ratio Lt / D is not particularly limited. One preferable example of the lower limit value is 0.3 or greater. Accordingly, a preferable range of the ratio Lt / D in the present disclosure is 0.3 to 1.26. A more preferable lower limit of the ratio Lt/D is 0.60. A further preferable lower limit of the ratio Lt / D is 0.99. Generally speaking, if the ratio Lt / D is greater than or equal to 0.3, the sliding area is not reduced excessively even in a case where the sliding surface is divided into a plurality of sliding surfaces. For this reason, even if low-viscosity oil is used as the lubricating oil 103, suitable wear resistance of the shaft slide part can be realized by the sulfur-based sliding modifier.

[0065] It should be noted that, in the examples shown in FIG. 3A to FIG. 3C, the main shaft 109 of the crank shaft 108 is referred to as the shaft part, and the ratio L / D and the ratio Lt / D are described about the main shaft 109. However, the present disclosure is not thus limited. The same is true of the eccentric shaft 110. Specifically, in a case where a sliding surface of the eccentric shaft 110, the sliding surface being configured to slide on the eccentric bearing 119, is a single sliding surface, the length of the single sliding surface in the axial direction is the single sliding length L, whereas in a case where the sliding surface of the eccentric shaft 110 is divided into a plurality of sliding surfaces, the length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L. In these cases, the ratio L / D of the single sliding length L to the external diameter D of the eccentric shaft 110 is required to be less than or equal to 0.51. Also, when the total of the lengths of the plurality of sliding surfaces of the eccentric shaft 110 in the axial direction is the total sliding length Lt, the ratio Lt / D of the total sliding length Lt to the external diameter D of the eccentric shaft 110 is required to be less than or equal to 1.26.

[0066] Therefore, in the refrigerant compressor 100 according to the present disclosure, at least one of the main shaft 109 and the eccentric shaft 110, which constitute the shaft part, is required to have a ratio L / D of less than or equal to 0.51. Similarly, at least one of the main shaft 109 and the eccentric shaft 110 is required to have a ratio Lt / D of less than or equal to 1.26.

[Configuration of Lubricating Oil]

[0067] Next, a more specific configuration of the lubricating oil 103 stored in the sealed container 101 is specifically described.

[0068] The lubricating oil 103 according to the present disclosure is not particularly limited, so long as the lubricating oil 103 has a kinematic viscosity in the range of 1 mm^2/S to 9 mm^2/S at 40°C. Typically, for example, at least one oil substance selected from the group consisting of mineral oil, alkyl benzene oil, and ester oil can be suitably used as the lubricating oil 103. Only one of these oil substances may be used as the lubricating oil 103, or a suitable combination of two or more of the oil substances may be used as the lubricating oil 103. The definition of the combination of two or more of the oil substances herein includes not only a combination of two different oil substances that are both, for example, mineral oils, but also a combination of, for example, at least one oil substance that is a mineral oil and at least one oil substance that is an alkyl benzene oil (or at least one oil substance that is an ester oil).

[0069] The lubricating oil 103 according to the present disclosure contains not only the above oil substance(s) but also the aforementioned sulfur-based sliding modifier. The sulfur-based sliding modifier may be any sulfur-based sliding modifier, so long as the sulfur-based sliding modifier allows the material of the shaft part (shaft part material) and sulfur to react with each other. Accordingly, the sliding modifier may be sulfur, or may be a sulfur compound that contains sulfur and that is reactive with the shaft part material. For example, if the material of the shaft part is a ferrous material, then examples of sulfur compounds usable as the sliding modifier include a sulfurized olefin, a sulfide-based compound (e.g., dibenzyl disulfide (DBDS)), a xanthate, a thiadiazole, a thiocarbonate, a sulfurized oil or fat, a sulfurized ester, a dithiocarbamate, and a sulfurized terpene.

[0070] The sulfur-based sliding modifier content in the lubricating oil 103 is not particularly limited. Preferably, the sliding modifier is added to the lubricating oil 103, such that the sliding modifier content therein in terms of the atomic weight of sulfur is greater than or equal to 100 ppm. The lower limit value of the addition amount of the sliding modifier (i.e., the lower limit value of the sliding modifier content) being 100 ppm in terms of the atomic weight of sulfur is greater than the upper limit value of a general addition amount of a sulfur-based extreme-pressure additive that will be described below.

[0071] If the sliding modifier content (the addition amount of the sliding modifier) is less than 100 ppm in terms of the atomic weight of sulfur, although depending on various conditions, there is a risk that suitable wear resistance of the shaft slide part cannot be realized in a state where low-viscosity oil is used as the lubricating oil 103 and the sliding area of the shaft slide part is reduced. A preferable lower limit of the sulfur-based sliding modifier content is, for example, greater than or equal to 150 ppm in terms of the atomic weight of sulfur. Also, a preferable upper limit of the sulfur-based sliding modifier content is, for example, less than or equal to 1000 ppm, and more preferably less than or equal to 500 ppm, in terms of the atomic weight of sulfur.

[0072] A compound that is the same as a known sulfur-based extreme-pressure additive can be used as the sulfur-based sliding modifier in the present disclosure. However, alternatively, a compound that is more reactive with the shaft part material than a known extreme-pressure additive can be used as the sulfur-based sliding modifier in the present disclosure. Further alternatively, a known extreme-pressure additive in an amount greater than a general addition amount (i.e., greater than a general additive content) may be added to the lubricating oil 103.

[0073] Generally speaking, an extreme-pressure additive is a compound containing an active element such as sulfur, halogen, or phosphorus, and chemically reacts with the surface of the material of which a slide part is made (i.e., chemically reacts with a sliding surface) to form a film. The presence of the film suppresses, for example, wear, seizing, or fusion of slide members.

[0074] It is known that sulfur-containing compounds easily react with copper. For example, Reference Literature 1 (Japanese Laid-Open Patent Application Publication No. 2006-117720) discloses that although sulfur-containing anti-wear agents are effective to prevent corrosion wear of a lead-containing slide member, such a sulfur-containing anti-wear agent tends to cause sulfurized corrosion of a slide member that contains a non-ferrous base metal different from lead, for example, copper (see paras. [0006] to [0007] of Reference Literature 1).

[0075] In the refrigerant compressor 100, copper wire is used as the winding of the electric element 106. Also, in a refrigerator-freezer using the refrigerant compressor 100, generally speaking, copper pipes are often used as refrigerant piping. As previously described, copper tends to corrode by reacting with a sulfur-containing compound. For this reason, when using a sulfur-based extreme-pressure additive, it is necessary to take measures to avoid or hinder the corrosion of a member made of copper (or a copper-containing member) included in the refrigerant compressor 100 or the refrigerator-freezer, thereby preventing lowering of the reliability thereof.

[0076] The applicant of the present application discloses, in Reference Literature 2 (Japanese Patent No. 5671695), that in the case of using a sulfur-based extreme-pressure additive in the refrigerator oil of a refrigerator-freezer, a sulfur-based extreme-pressure additive in which the number of sulfur cross-links is 3 or less is used so that the sulfur-based extreme-pressure additive will not react with copper in a refrigerant circulation passage. Preferably, a metal deactivator is used together with the sulfur-based extreme-pressure additive.

[0077] In this respect, the inventors of the present invention have conducted diligent studies including experimental verification. As a result of the studies, they have found that in the case of using low-viscosity oil as the lubricating oil 103 and reducing the sliding area of the shaft slide part such that the aforementioned ratio L / D is less than or equal to 0.51, not only is favorable wear resistance realized, but also the corrosion of a member made of copper (or a copper-containing member) can be substantially avoided by using a sulfur-based compound having higher reactivity as the sliding modifier or by increasing the adding amount of the sliding modifier (i.e., by increasing the sliding modifier content).

[0078] Further, in the refrigerant compressor 100 according to the present disclosure, a known extreme-pressure additive may be added to the lubricating oil 103 in addition to the sulfur-based sliding modifier. A specific extreme-pressure additive to be added to the lubricating oil 103 is not particularly limited, and a known extreme-pressure additive can be suitably used. Examples of known extreme-pressure additives that can be suitably used include a phosphorus-based compound, such as a phosphate ester, and a halogenated compound, such as a chlorine-based hydrocarbon or a fluorine-based hydrocarbon. Only one of these extreme-pressure additives may be added to the lubricating oil composition, or a suitable combination of two or more of the extreme-pressure additives may be added to the lubricating oil composition.

[0079] Among these extreme-pressure additives, a phosphorus-based compound can be used preferably. Typical examples of the phosphorus-based compound include tricresyl phosphate (TCP), tributyl phosphate (TBP), and triphenyl phosphate (TPP). Among these, TCP is particularly preferable. In addition to the sulfur-based sliding modifier, a phosphorus-based extreme-pressure additive may be added to the lubricating oil 103, and thereby, for example, wear of the shaft slide part can be reduced favorably.

[0080] The amount of the extreme-pressure additive to be added to the lubricating oil composition is not particularly limited. For example, in a case where the lubricating oil 103 (oil substance) is a low-polarity substance such as mineral oil or alkyl benzene oil, a suitable addition amount of the extreme-pressure additive is in the range of 0.5 to 8.0% by weight, and more preferably in the range of 1 to 3% by weight.

[0081] Further, in the refrigerant compressor 100 according to the present disclosure, known various additives may be added to the lubricating oil 103 in addition to the sliding modifier and the extreme-pressure additive. Those known in the field of the lubricating oil 103 can be suitably used as the various additives to be added to the lubricating oil 103. Typical examples of such additives include an oily agent, an antioxidant, an acid-acceptor, a metal deactivator, a defoaming agent, an anti-corrosive agent, and a dispersant. In other words, the lubricating oil 103 used in the refrigerant compressor 100 according to the present disclosure is a lubricating oil composition constituted by at least the oil substance and the sliding modifier. The lubricating oil composition may contain an extreme-pressure additive (in particular, a phosphorus-based extreme-pressure additive), and may also contain other additives.

[0082] As described above, the refrigerant compressor 100 according to the present disclosure satisfies the following conditions: (1) the lubricating oil 103 has a kinematic viscosity in the range of 1 mm^2/S to 9 mm^2/S at 40°C; (2) the ratio L / D of the single sliding length L to the external diameter D of the shaft part is less than or equal to 0.51; and (3) a sulfur-based sliding modifier is used. Further, in a case where the sliding surface is divided into a plurality of sliding surfaces, the refrigerant compressor 100 preferably satisfies the following condition (4): the ratio Lt / D of the total sliding length Lt to the external diameter D is less than or equal to 1.26. By satisfying these conditions, the shaft part and the bearing part can be lubricated favorably, which makes it possible to favorably suppress wear of the shaft slide part. Consequently, the reliability of the refrigerant compressor 100 can be further improved.

[0083] It should be noted that the refrigerant compressor 100 according to the present disclosure may be inverter-driven at a plurality of operating frequencies as previously mentioned. In a case where the refrigerant compressor 100 is inverter-driven, there are two operation modes of the electric element 106, in one of which the electric element 106 is operated at a low rotation speed (low-speed operation), and in the other of which the electric element 106 is operated at a high rotation speed (high-speed operation). When the electric element 106 is operated at a low rotation speed, the amount of lubricating oil 103 supplied to the shaft slide part decreases. In the present disclosure, although the sliding area of the shaft slide part is reduced, even when the amount of lubricating oil 103 supplied to the shaft slide part decreases, favorable wear resistance can be realized.

[0084] Also, even when the rotation speed of the electric element 106 shifts from the low rotation speed to the high rotation speed (i.e., even when the rotation speed of the electric element 106 increases), favorable wear resistance can be realized. Therefore, in a case where the refrigerant compressor 100 is inverter-driven, regardless of whether the low-speed operation is being performed or the high-speed operation is being performed, the wear resistance of the shaft slide part derived from the sulfur-based sliding modifier can be realized. Consequently, the reliability of the refrigerant compressor 100 can be improved, and also, the operating efficiency can be improved.

[0085] As described above, in the refrigerant compressor 100 according to the present disclosure, the lubricating oil 103 is low-viscosity oil; the ratio L/D of the single sliding length L to the external diameter D is less than or equal to 0.51 regardless of whether the sliding surface of the shaft part is a single sliding surface or a plurality of sliding surfaces; and the lubricating oil 103 contains a sulfur-based sliding modifier. Owing to these features, even though the lubricating oil 103 is low-viscosity oil and the sliding area is reduced such that the ratio L / D is less than or equal to 0.51, favorable wear resistance of the slide part can be realized by the sulfur-based sliding modifier. Consequently, the hermetic refrigerant compressor can be obtained, which makes it possible to achieve high reliability of the shaft part, which is pivotally supported by the bearing part, even with the use of the lubricating oil 103 having a reduced viscosity.

(Embodiment 2)

[0086] In Embodiment 2, one example of a refrigerator-freezer that includes the refrigerant compressor 100 described above in Embodiment 1 is specifically described with reference to FIG. 4. FIG. 4 is a schematic diagram showing a schematic configuration of the refrigerator-freezer including the refrigerant compressor 100 according to Embodiment 1. Therefore, in Embodiment 2, only a fundamental configuration of the refrigerator-freezer is briefly described.

[0087] As shown in FIG. 4, the refrigerator-freezer according to Embodiment 2 includes, for example, a body 275, a dividing wall 278, and a refrigerant circuit 270. The body 275 is constituted by a thermally-insulated box, a door, and so forth. The box is configured to have one opening face, and the door is configured to open/close the opening of the box. The interior of the body 275 is divided by the dividing wall 278 into a product storage space 276 and a machinery room 277. An unshown air feeder is provided in the storage space 276. It should be noted that the interior of the body 275 may be divided into, for example, spaces that are different from the storage space 276 and the machinery room 277.

[0088] The refrigerant circuit 270 is configured to cool the inside of the storage space 276. For example, the refrigerant circuit 270 includes the refrigerant compressor 100 described above in Embodiment 1, a radiator 272, a decompressor 273, and a heat absorber 274, which are connected by piping in an annular manner. The heat absorber 274 is disposed in the storage space 276. Cooling heat of the heat absorber 274 is stirred by the unshown air feeder so as to circulate inside the storage space 276 as indicated by a dashed arrow in FIG. 4. In this manner, the inside of the storage space 276 is cooled.

[0089] As described above in Embodiment 1, the refrigerant compressor 100 included in the refrigerant circuit 270 satisfies the following conditions: (1) the lubricating oil 103 has a kinematic viscosity in the range of 1 mm^2/S to 9 mm^2/S at 40°C; (2) the ratio L / D of the single sliding length L to the external diameter D of the shaft part is less than or equal to 0.51; and (3) a sulfur-based sliding modifier is used. Further, in a case where the sliding surface is divided into a plurality of sliding surfaces, the refrigerant compressor 100 preferably satisfies the following condition (4): the ratio Lt / D of the total sliding length Lt to the external diameter D is less than or equal to 1.26. By satisfying these conditions, the reliability of the refrigerant compressor 100 can be further improved.

[0090] As described above, the refrigerator-freezer according to Embodiment 2 includes the above-described refrigerant compressor 100 according to Embodiment 1. In the refrigerant compressor 100, the low-viscosity lubricating oil 103 is used; the sliding area of the shaft slide part is reduced; and the shaft part has high reliability. Since the refrigerator-freezer includes the hermetic refrigerant compressor, which is highly efficient and highly reliable, the power consumption of the refrigerator-freezer can be reduced, and also, the refrigerator-freezer can be made highly reliable.

[0091] It should be noted that the present invention is not limited to the embodiments described above, and various modifications can be made within the scope of the Claims. Embodiments obtained by suitably combining technical means that are disclosed in different embodiments and variations also fall within the technical scope of the present invention.

[0092] From the foregoing description, numerous modifications and other embodiments of the present invention are obvious to a person skilled in the art. Therefore, the foregoing description should be interpreted only as an example and is provided for the purpose of teaching the best mode for carrying out the present invention to a person skilled in the art. The structural and/or functional details may be substantially modified without departing from the spirit of the present invention.

Industrial Applicability

[0093] As described above, the present invention makes it possible to provide a refrigerant compressor that uses low-viscosity lubricating oil and yet has excellent reliability and to provide a refrigerator-freezer using the refrigerant compressor. Therefore, the present invention is widely applicable to various equipment that uses a refrigeration cycle.

Reference Signs List

[0094]

100: refrigerant compressor
101: sealed container
103: lubricating oil
106: electric element
107: compression element
108: crank shaft
109: main shaft (shaft part)
110: eccentric shaft (shaft part)
111: single sliding surface
111a: first sliding surface
111b: second sliding surface
111c: non-sliding outer peripheral surface
111d: first sliding surface
111e: second sliding surface
11 If: third sliding surface
111g: first non-sliding outer peripheral surface
111h: second non-sliding outer peripheral surface
112: cylinder block
114: main bearing (bearing part)
119: eccentric bearing (bearing part)
270: refrigerant circuit
272: radiator
273: decompressor
274: heat absorber

Claims

1. A hermetic refrigerant compressor comprising a sealed container in which lubricating oil having a kinematic viscosity in a range of 1 mm^2/S to 9 mm^2/S at 40°C is stored, the sealed container accommodating an electric element and a compression element, the compression element being driven by the electric element and configured to compress a refrigerant, wherein
the compression element includes:

    a shaft part that is a crank shaft including a main shaft and an eccentric shaft; and
    a bearing part that pivotally supports the shaft part, the bearing part including a main bearing and an eccentric bearing, the main bearing pivotally supporting the main shaft, the eccentric bearing pivotally supporting the eccentric shaft,

    the main shaft includes a sliding surface that slides on the main bearing, the sliding surface being either a single sliding surface or divided into a plurality of sliding surfaces,
    in a case where the sliding surface is the single sliding surface, a length of the single sliding surface in an axial direction is a single sliding length L, whereas in a case where the sliding surface is divided into the plurality of sliding surfaces, a length of one of the sliding surfaces in the axial direction, the one sliding surface having the least length in the axial direction among the plurality of sliding surfaces, is the single sliding length L, and a ratio L / D of the single sliding length L to an external diameter D of the main shaft is less than or equal to 0.51, and
    the lubricating oil contains a sliding modifier that is either sulfur or a sulfur-containing compound.

2. The hermetic refrigerant compressor according to claim 1, wherein
in the case where the sliding surface is divided into the plurality of sliding surfaces, when a total of the lengths of the plurality of sliding surfaces in the axial direction is a total sliding length Lt, a ratio Lt / D of the total sliding length Lt to the external diameter D is less than or equal to 1.26.

3. The hermetic refrigerant compressor according to claim 1 or 2, wherein
the ratio L / D is greater than or equal to 0.15.

4. The hermetic refrigerant compressor according to claim 2, wherein
the ratio Lt / D is greater than or equal to 0.3.

5. The hermetic refrigerant compressor according to any one of claims 1 to 4, wherein
a content of the sliding modifier in the lubricating oil in terms of an atomic weight of sulfur is greater than or equal to 100 ppm.

6. The hermetic refrigerant compressor according to any one of claims 1 to 5, wherein
the lubricating oil further contains a phosphorus-based extreme-pressure additive.

7. The hermetic refrigerant compressor according to any one of claims 1 to 6, wherein
the electric element is inverter-driven at a plurality of operating frequencies.

8. A refrigerator-freezer comprising a refrigerant circuit including:

the hermetic refrigerant compressor according to any one of claims 1 to 7;
a radiator;
a decompressor; and
a heat absorber, wherein
in the refrigerant circuit, the hermetic refrigerant compressor, the radiator, the decompressor, and the heat absorber are connected by piping in an annular manner.

Fig. 1

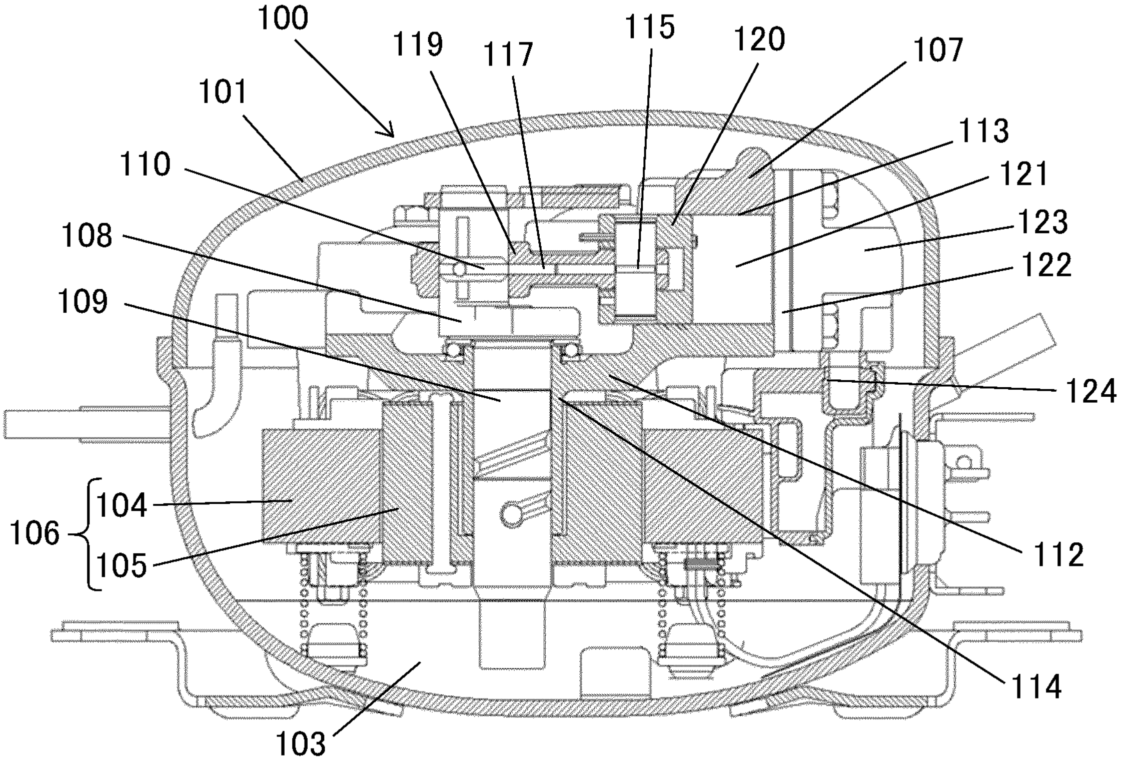

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Fig. 2

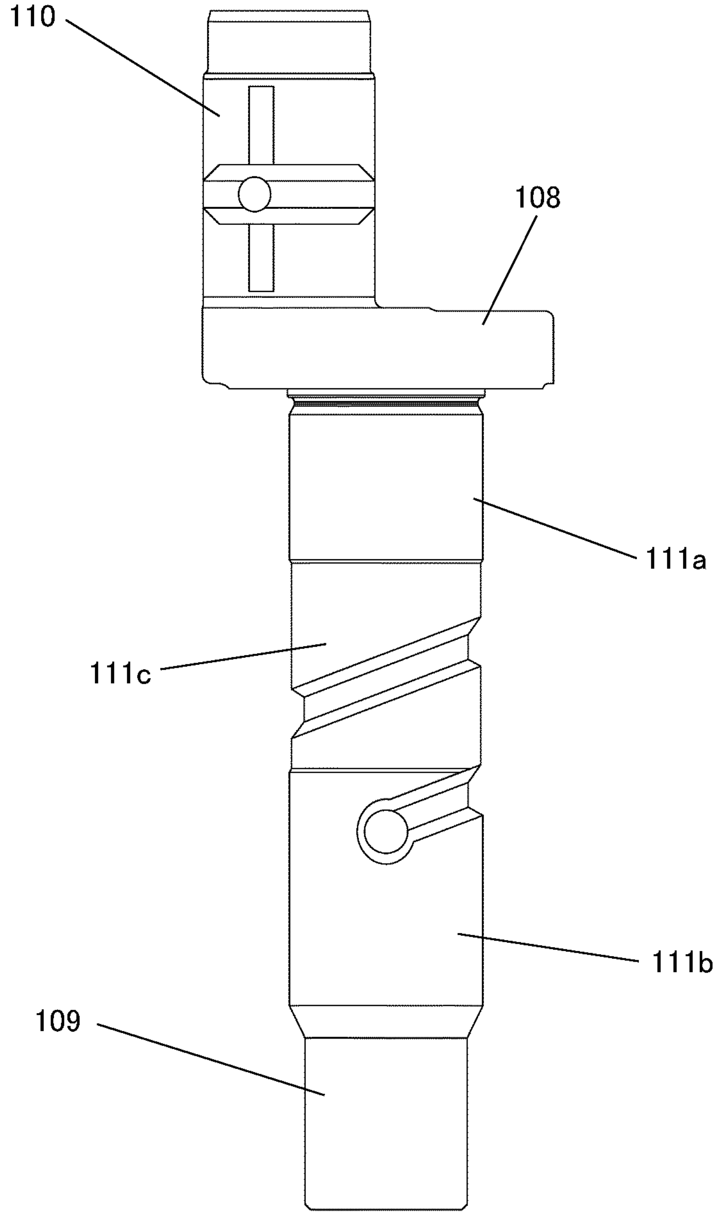
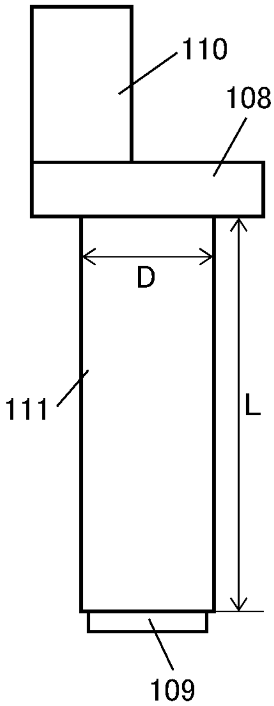
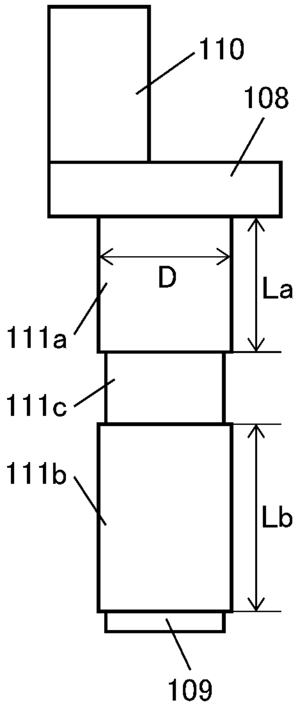


Fig. 3A



$L/D \leq 0.51$

Fig. 3B



$La < Lb$

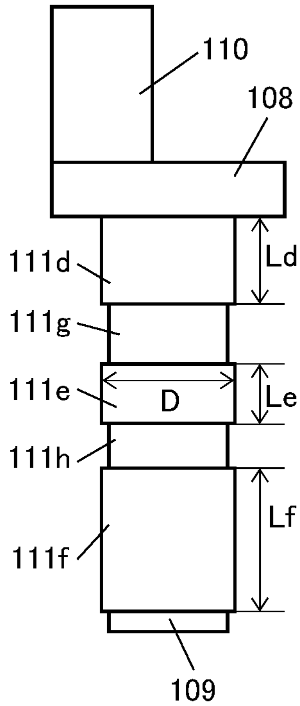
$L = La$

$L/D \leq 0.51$

$Lt = La + Lb$

$Lt/D \leq 1.26$

Fig. 3C



$Le < Ld < Lf$

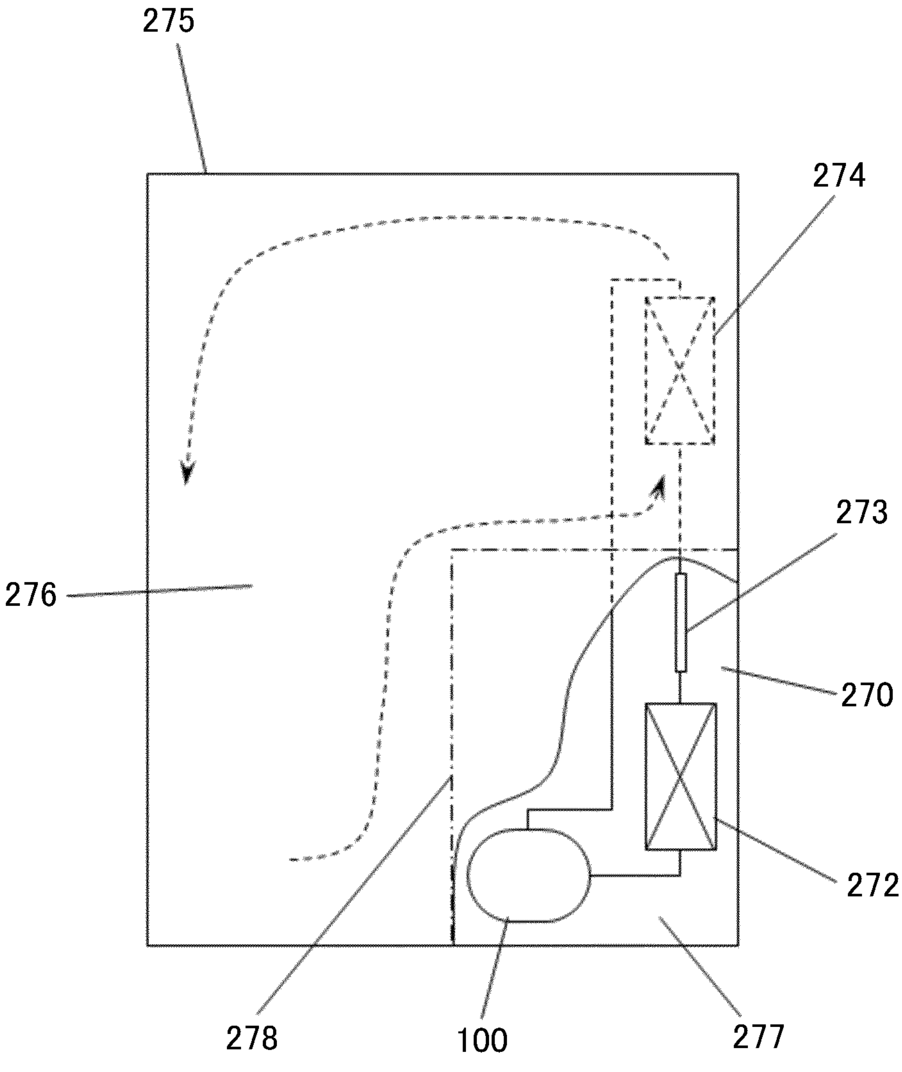
$L = Le$

$L/D \leq 0.51$

$Lt = Ld + Le + Lf$

$Lt/D \leq 1.26$

Fig. 4



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/025141

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F04B39/00(2006.01)i, F04B39/02(2006.01)i, F25B1/02(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, F04B39/02, F25B1/02

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	1971–2019
Registered utility model specifications of Japan	1996–2019
Published registered utility model applications of Japan	1994–2019

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 Y	WO 2018/101246 A1 (PANASONIC APPLIANCES REFRIGERATION DEVICES SINGAPORE) 07 June 2018, paragraphs [0030], [0040], [0048], [0125]-[0128], [0139], fig. 1, 5 (Family: none)	1-5, 7-8 6
Y	JP 2006-509899 A (EXXONMOBIL RESEARCH AND ENGINEERING CO.) 23 March 2006, paragraphs [0077], [0090]-[0092], [0108]-[0110] & US 2004/0154957 A1, paragraphs [0129], [0142]-[0146], [0164]-[0167] & WO 2005/017077 A2 & CA 2508117 A1 & KR 10-2005-0105978 A	6

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
12 September 2019 (12.09.2019)

Date of mailing of the international search report
24 September 2019 (24.09.2019)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/025141

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-161712 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 22 June 2006, paragraph [0067], fig. 1 (Family: none)	1-8
A	JP 2000-129250 A (TOSHIBA CORP.) 09 May 2000, paragraphs [0029], [0031], [0040], fig. 2 (Family: none)	1-8
A	JP 2008-297447 A (ADEKA CORPORATION) 11 December 2008, paragraphs [0030], [0036] (Family: none)	1-8

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2011021530 A **[0006]**
- JP 2006117720 A **[0074]**
- JP 5671695 B **[0076]**