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(54) **ELECTRIC COMPRESSOR**

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(57) **ABSTRACT**

A compressor includes a motor unit formed of a stator and a rotor, a compressor mechanism driven by the motor unit, and an enclosed container accommodating the foregoing elements. The compressor mechanism includes a cylinder block equipped with a compressing chamber and a piston. A shaft directly coupled to the rotor that drives the piston is supported by a double-sided bearing system, namely, a main bearing and a sub bearing. This structure allows preventing the shaft from slanting, and reducing a loss and a noise caused by sliding. As a result, a low profile, highly reliable and efficient compressor is obtainable.

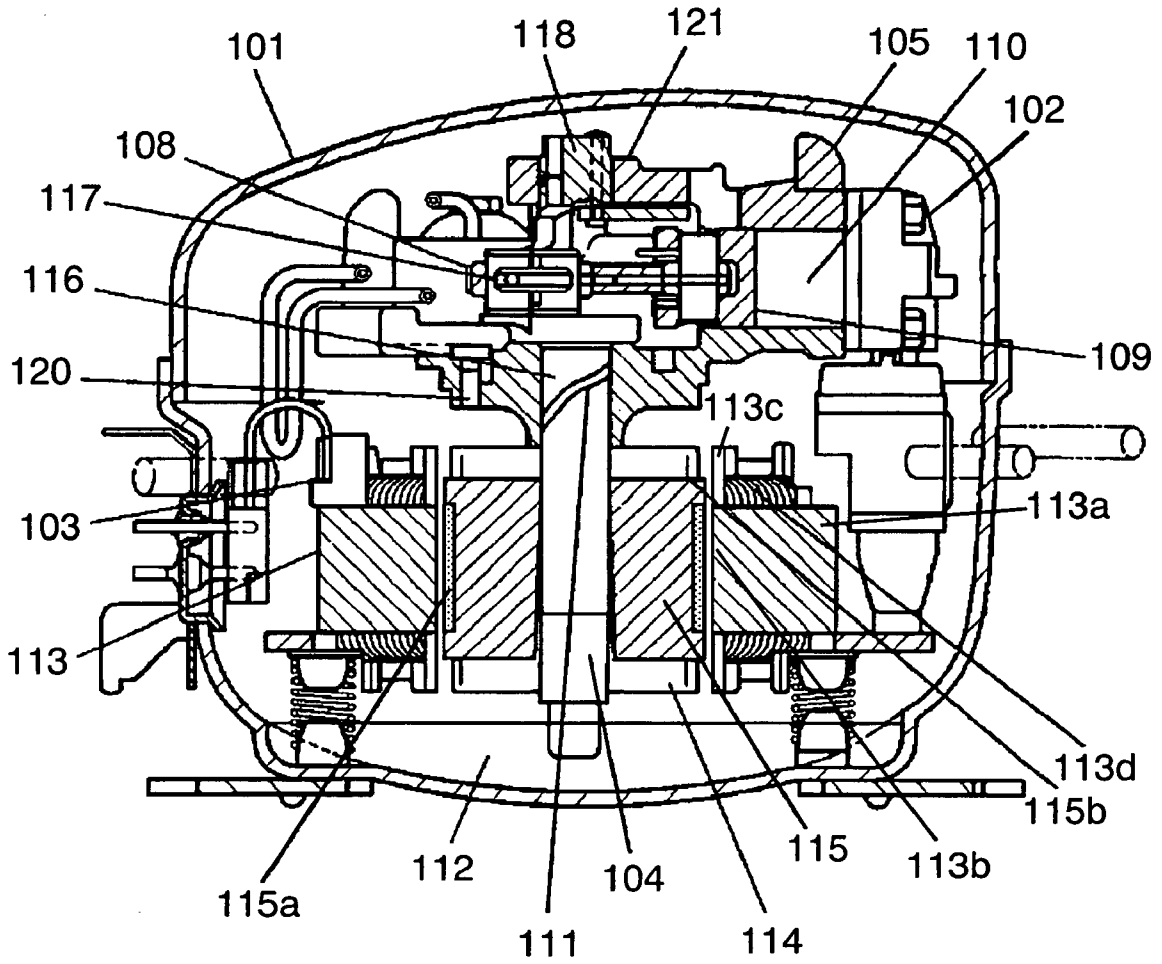


FIG. 1

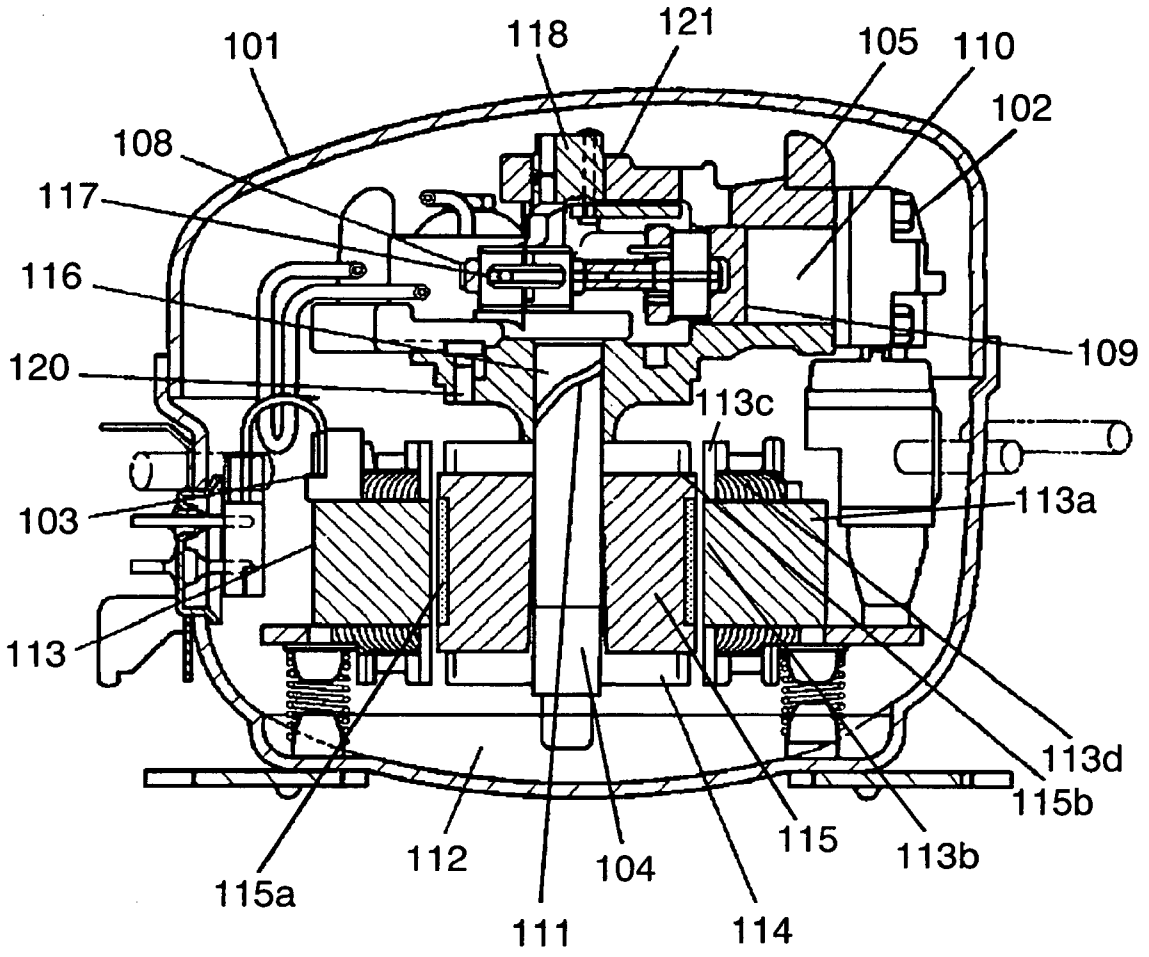

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FIG. 2

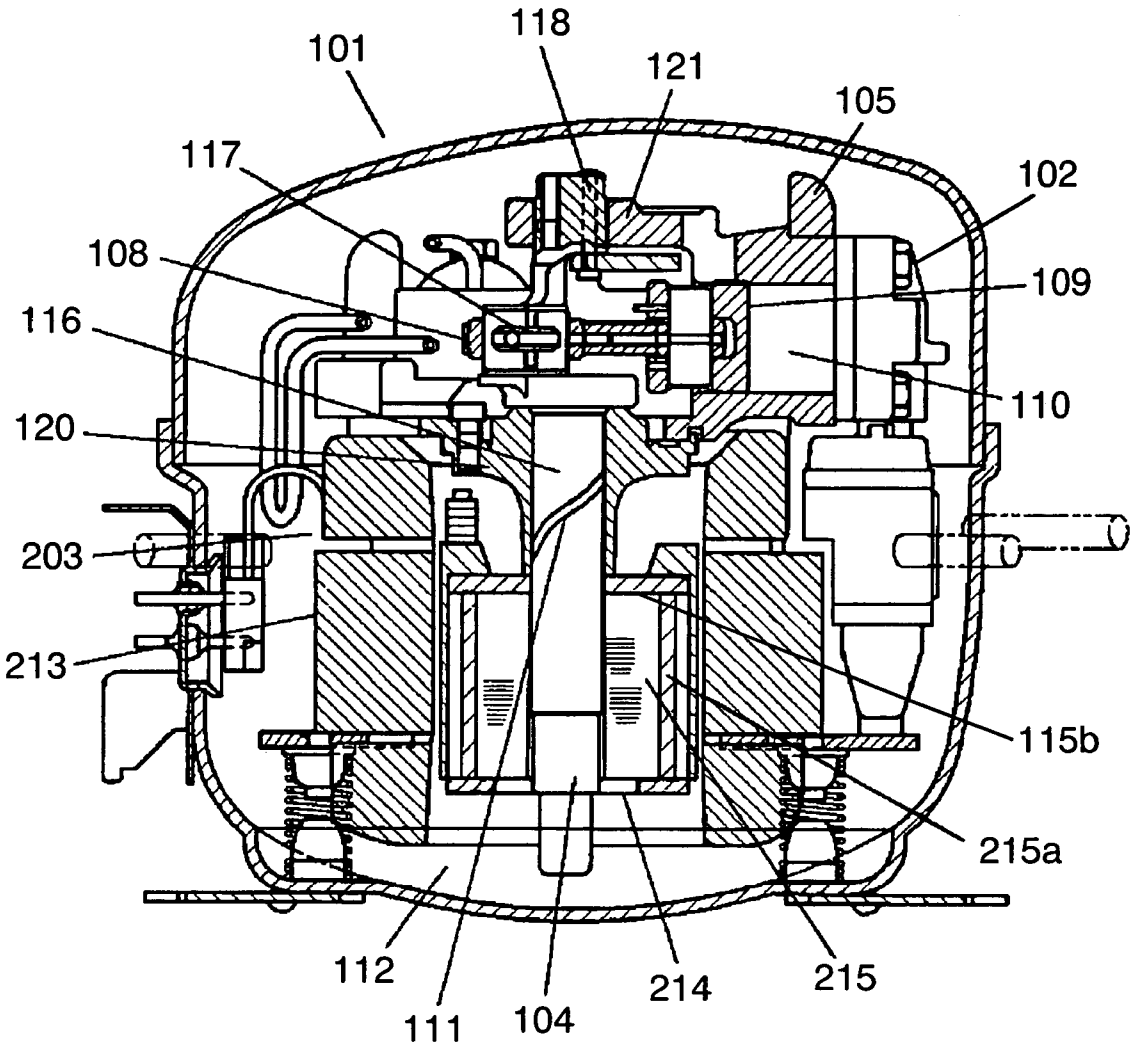

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FIG. 3

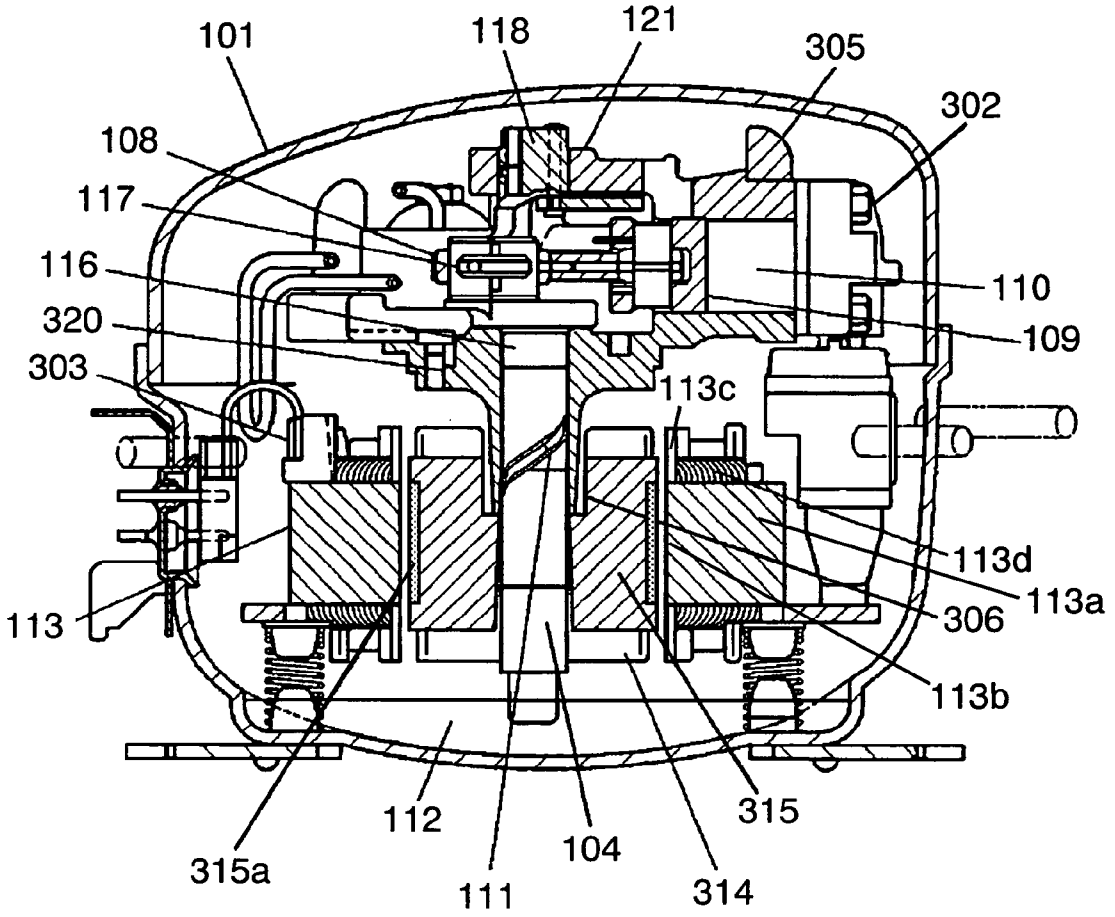

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315a
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FIG. 4

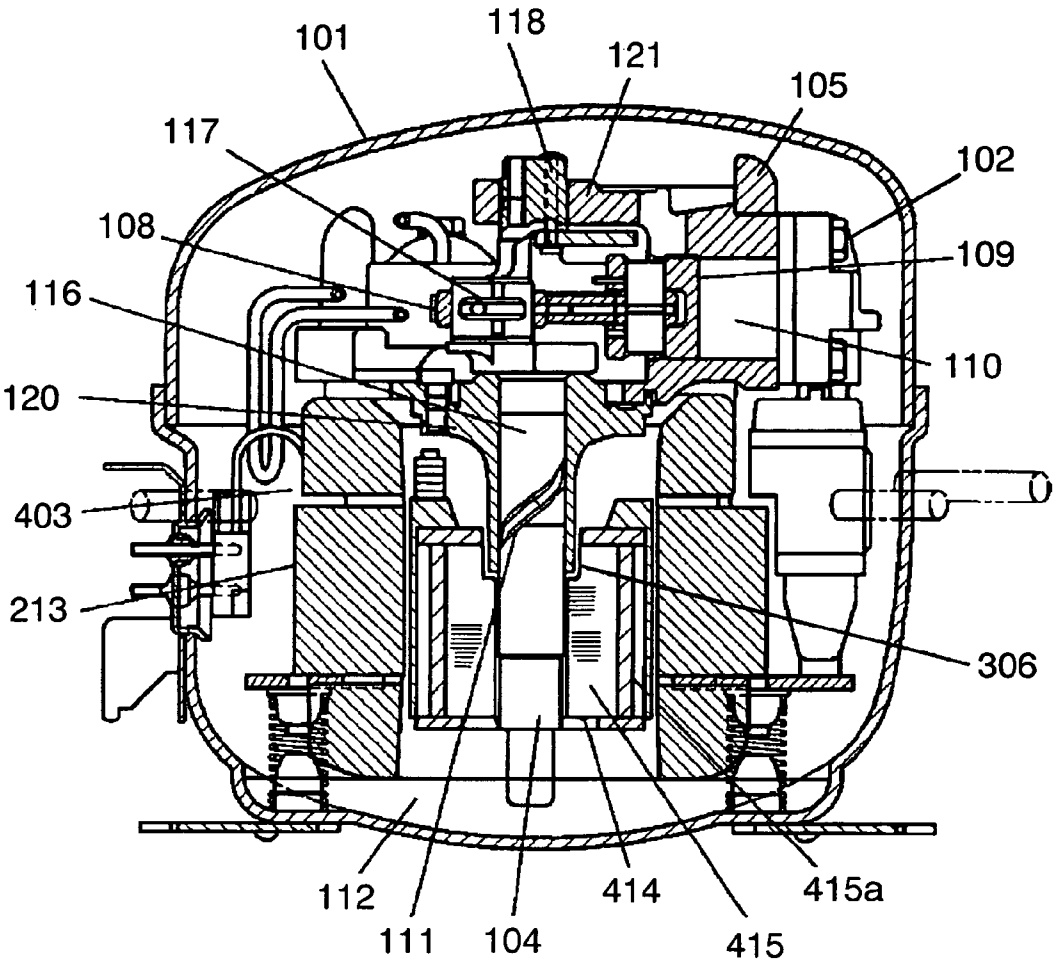
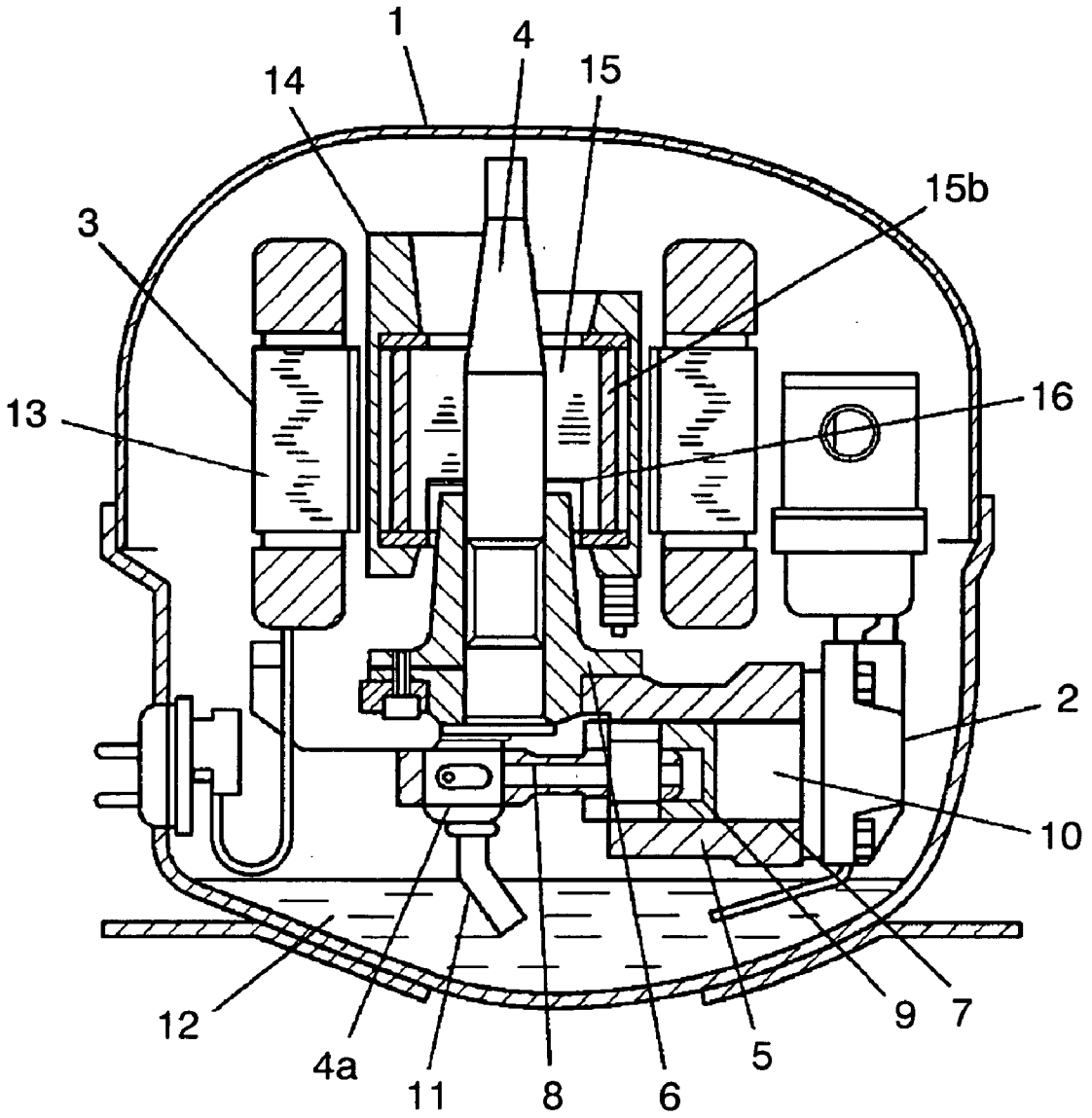

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415a

FIG. 5 PRIOR ART



ELECTRIC COMPRESSOR

FIELD OF THE INVENTION

[0001] The present invention relates to electric compressors used in refrigerators with freezers or air-conditioners.

BACKGROUND OF THE INVENTION

[0002] An electric compressor (hereinafter referred to simply as a compressor) employed in freezers of home-use refrigerators has undergone improvements for more efficient performance, such as use of lubricant oil of lower viscosity, use of inverter driving, and employment of synchronous motor. Those improvements have been done for reducing power consumption of the compressor. At the same time, the compressor is required to be more compact for increasing a volume efficiency of the refrigerator.

[0003] A conventional compressor is disclosed, e.g. in Japanese Patent Application Non-Examined Publication No. 2001-73948. This compressor is improved its stator and main bearing. **FIG. 5** shows a vertical sectional-view of this compressor. In **FIG. 5**, enclosed container **1** of the compressor pools lubricant oil **12** at its bottom section. Container **1** accommodates motor unit **3** formed of stator **13** and rotor **14**, and compressor mechanism **2** driven by motor unit **3**.

[0004] Compressor mechanism **2** is detailed hereinafter. Cylinder block **5**, forming generally cylindrical cylinder **7**, is equipped with bearing **6** which rotatably supports shaft **4** and crosses with cylinder **7** at approx. right angles. Bearing **6** is made of aluminum-based material, i.e. non-magnetic material. Shaft **4** is equipped with eccentric section **4***a* and inserted into bearing **6**. Rotor **14** is rigidly mounted to shaft **4**.

[0005] Piston **9** slides in cylinder **7** and forms compressing chamber **10**, and it is coupled to eccentric section **4***a* via connecting rod **8** which works as a linking means. Lubricating tube **11** is mounted to a tip of eccentric section **4***a*.

[0006] Next, motor unit **3** is detailed hereinafter. Motor unit **3** is a two-pole induction motor comprising stator **13** and rotor **14**. Stator **13** is formed by winding wires on a stator iron-core made of laminated electromagnetic steel plates, and rotor **14** is formed of rotor iron-core **15** having interior permanent-magnet **15***b*. Rotor iron-core **15** has hollow bore **16** at its end face on compressor mechanism **2** side, and bearing **6** extends into bore **16**.

[0007] An operation of the foregoing conventional reciprocating compressor is described hereinafter. Rotation of rotor **14** entails shaft **4** to spin, and the rotation of eccentric section **4***a* of shaft **4** is transferred to piston **9** via connecting rod **8**, so that piston **9** reciprocates in compressing chamber **10**. This operation sucks refrigerant gas supplied from a cooling system (not shown) into compressing chamber **10**, then compresses the gas, and discharges successively the gas to the cooling system again such as a refrigerator or an air-conditioner.

[0008] The rotation of shaft **4** causes lubricating tube **11** placed at the lower end of shaft **4** to rotate, so that lubricant oil **12** is drawn up by pumping operation due to the centrifugal force of tube **11**. As a result, bearing **6**, cylinder **7**, connecting rod **8** and piston **9** are lubricated.

[0009] The foregoing structure; however, produces magnetic attraction that attracts rotor **14** to a space of shorter distance if the distance between rotor **14** and stator **13** is not uniform (eccentric). In particular, when permanent magnet **15***b* built-in rotor iron-core **15** is made of rare-earth material, i.e. the magnet has intense magnetic force, the greater magnetic attraction is produced at a greater eccentricity of the space.

[0010] As a result, shaft **4** inserted in bearing **6** slants and hits against bearing **6**. If shaft **4** rotates within bearing **6** in this condition, the sliding faces of both bearing **6** and shaft **4** sometime incur abrasion.

[0011] Another prior art of the foregoing conventional compressor discloses a structure where an end-face of a main bearing made of iron-based material is not laid over an end-face of a rotor iron core on a compressor mechanism side. In this case, if bearing **6**, i.e. single-sided bearing, maintains the necessary bearing length, a total length of shaft **4** is obliged to increase, which entails a longer distance between bearing **6** and the gravity center of rotor **14**. As a result, abrasion sometimes occurs on the sliding faces of both bearing **6** and shaft **4**. This is because the magnetic attraction produced between rotor **14** and stator **13** works as strong moment within bearing **6**, so that shaft **4** hits more strongly against bearing **6**.

SUMMARY OF THE INVENTION

[0012] The present invention addresses the problems discussed above, and aims to provide a highly reliable and efficient compressor. The compressor of the present invention comprises the following elements:

[0013] (a) a motor unit including a stator with windings, and a rotor with a rotor iron-core and a permanent magnet;

[0014] (b) a compressor mechanism driven by the motor unit and including the following sub-elements;

[0015] (b-1) a shaft including an eccentric shaft section, a main shaft section and a sub shaft section, the main shaft section and the sub shaft section sandwiching the eccentric shaft section vertically and being placed coaxially;

[0016] (b-2) a cylinder block including a compressing chamber;

[0017] (b-3) a main bearing, disposed in the cylinder block such that the main bearing crosses with an axial core of the compressing chamber at right angles, for rotatably supporting the main shaft section;

[0018] (b-4) a sub bearing, disposed in the cylinder block, for rotatably supporting the sub shaft section;

[0019] (b-5) a piston for reciprocating in the compressing chamber;

[0020] (b-6) a linking means for coupling the piston with the eccentric shaft section; and

[0021] (c) an enclosed container for pooling lubricant oil and accommodating the motor unit and the compressor mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] **FIG. 1** shows a vertical sectional view of a compressor in accordance with a first exemplary embodiment of the present invention.

[0023] **FIG. 2** shows a vertical sectional view of a compressor in accordance with a second exemplary embodiment of the present invention.

[0024] **FIG. 3** shows a vertical sectional view of a compressor in accordance with a third exemplary embodiment of the present invention.

[0025] **FIG. 4** shows a vertical sectional view of a compressor in accordance with a fourth exemplary embodiment of the present invention.

[0026] **FIG. 5** shows a vertical sectional view of a conventional compressor.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0027] Exemplary embodiments of the present invention are demonstrated hereinafter with reference to the accompanying drawings.

Exemplary Embodiment 1

[0028] **FIG. 1** shows a vertical sectional view of a compressor in accordance with a first exemplary embodiment of the present invention. In **FIG. 1**, enclosed container **101** accommodates compressor mechanism **102** and motor unit **103** that drives the compressor mechanism. The refrigerant filled in container **101** is a hydrocarbon refrigerant such as R134a of which ozone-destroying coefficient is zero (0), or R600a having a low global-warming coefficient. Container **101** also pools lubricant oil **112** mutually soluble with the refrigerant and having viscosity of 5-10 [cts] at its bottom.

[0029] Next, compressor mechanism **102** is detailed hereinafter. Shaft **104** includes eccentric shaft section **117**, main-shaft section **116** and sub-shaft section **118**. Main-shaft section **116** and sub-shaft section **118** sandwich eccentric shaft section **117** vertically and are disposed coaxially. Lubricating mechanism **111** formed on shaft **104** communicates into lubricant oil **112** at its first end and communicates with the upper end of shaft **104** to open at its second end.

[0030] Cylinder block **105** is made from cast-iron, and is integrally formed of cylindrical compressing chamber **110** and main bearing **120** which rotatably supports main shaft section **116**. Sub-bearing **121** rotatably supporting sub-shaft section **118** is fixed to cylinder block **105**. Piston **109** is inserted into compressing chamber **110** in a slidable manner. Connecting rod **108** working as a linking means couples piston **109** with eccentric shaft section **117**.

[0031] Motor unit **103** is detailed hereinafter. It is an inverter-driven motor formed of stator **113** and rotor **114**, and driven at any plural frequencies such as 30 Hz, 50 Hz, 70 Hz, and 80 Hz. Stator **113** is constructed as this: a plurality of teeth **113***b* radially formed is disposed at iron core **113***a*, and windings **113***d* are provided to teeth **113***b* via insulating material **113***c* to form a motor of a concentrated winding structure. Rotor **114** is fixed to main-shaft section **116** of shaft **104** and includes permanent magnet **115***a* built in rotor iron-core **115**. Permanent magnet **115***a* is made of, e.g. rare-earth magnet such as neodymium, iron, boron-based ferromagnetic materials.

[0032] Assume that there is a virtual plane which includes end section **115***b* of rotor iron-core **115** on the compressor mechanism side and is generally orthogonal to the axial core of main shaft section **116**. Main bearing **120** is structured so as not to cross with this virtual plane.

[0033] An operation of the compressor discussed above is demonstrated hereinafter. When a current runs through stator **113**, rotor **114** spins shaft **104**, and eccentric motion of eccentric shaft section **117** is transferred to piston **109** via connecting rod **108**, thereby reciprocating piston **109** in compressing chamber **110**. This operation sucks the refrigerant gas from the cooling system (not shown) to chamber **110**, and compresses the gas, then discharges the gas to the cooling system again.

[0034] Lubricating mechanism **111** formed on shaft **104** pumps up lubricant oil **112**, which is then discharged from an upper end of shaft **104**.

[0035] Permanent magnet **115**a built in rotor iron-core **115** is made of, e.g. rare-earth material having intense magnetic force, so that it produces extraordinary intense magnetic attraction at a place where a distance between rotor **114** and stator **113** is small.

[0036] However, when shaft **104** of this structure receives an unbalanced load caused by the magnetic attraction generated between rotor **114** and stator **113**, a distance between two fulcrums is approx. doubled comparing with the conventional structure discussed previously. Because in the case of the conventional structure, the single-sided bearing receives the unbalanced load at its upper and lower ends as the fulcrums arranged in the diagonal direction with respect to the center axis of shaft **104** placed in the inner wall of the main bearing. On the other hand, a double-sided bearing employed in the structure of the first embodiment receives the unbalanced load at its inner wall end on the counter side to the sub-bearing and at an inner wall end of the sub-bearing on the counter side to the main bearing along a diagonal direction with respect to the axis center of shaft **104**.

[0037] The extension of the distance between the fulcrums reduces a slant angle of shaft **104** within the bearing, so that shaft **104** scarcely hits against the bearing. As a result, sliding loss due to the hitting can be prevented and the compressor can maintain efficient operation. At the same time, a sliding noise due to the hitting can be suppressed, so that a compressor with a lower noise is obtainable. The load to shaft **104** in operation is received at eccentric shaft section **117** (fulcrum) as a center, to which a compressing load from piston **109** is applied, and upper and lower ends, so that the load can be distributed generally even to this fulcrum. Comparing with the single-sided bearing, in which the load concentrates on its one end, the sliding face of shaft **104** has better reliability.

[0038] Shaft **104** receives the load in operation at its wide area with little interference with the bearing, so that contact pressure of main bearing **120** and sub bearing **121** lowers, which can shorten the length of main bearing **120**. As a result, the total height of the compressor can be lowered.

Further, a reduction of the sliding length can lower viscosity resistance at the sliding section, so that the efficiency is improved.

[0039] Main bearing **120** is integrally formed with cylinder bock **105**, i.e. made of cast-iron that is iron-based material, however, since bearing **120** is placed so as not to touch at rotor iron-core **115**, the magnetic flux of permanent magnet **115***a* built in iron-core **115** seldom interferes with main bearing **120**. As a result, eddy-current loss scarcely occurs in the main bearing, and the higher efficiency can be expected.

[0040] Motor unit **103** is inverter-driven, so that it is driven at a high frequency such as 70-80 Hz in response to the load. At that time, motor unit **103** produces strong magnetic attraction, which tends to slant shaft **104**; however, since shaft **104** is supported by the double-sided bearing, i.e. main bearing **120** and sub bearing **121**, shaft **104** is prevented from slanting, and at the same time, sliding loss can be reduced. As a result, the compressor can maintain efficient operation, and prevent the shaft from hitting against the bearing, so that the reliability can be improved.

[0041] When motor unit **103** is driven at a low frequency such as 30 Hz, the double-sided bearing structure prevents shaft **104** from slanting because shaft **104** is supported by main bearing **120** and sub bearing **121**, so that the sliding loss can be reduced. Thus use of lubricant oil **112** of low viscosity such as 5-10 [cts] can assure the reliability.

[0042] Stator **113** includes plural teeth **113**b radially formed in iron-core **113***a*, and windings are provided to teeth **113***b* via insulating member **113***c*. This structure eliminates a coil-end which is needed in the distributed winding structure. As a result, the total heights of stator **113** and rotor **114** can be lowered, so that the total height of the compressor can be further lowered. The low profile of stator **113** and rotor **114** facilitates uniforming the clearance between stator **113** and rotor **114**. As a result, the magnetic attraction rarely occurs, so that an increase of an input current due to interference between stator **113** and rotor **114** as well as an increase of a noise can be avoided.

[0043] In this embodiment, connecting rod **108** is used as the linking means for coupling the piston with the eccentric shaft; however, a ball joint or a Scotch yoke can be used as the linking means.

Exemplary Embodiment 2

[0044] **FIG. 2** shows a vertical sectional view of a compressor in accordance with the second exemplary embodiment of the present invention. Similar elements to those in the first embodiment have the same reference marks, and the detailed descriptions thereof are omitted here. In **FIG. 2**, motor unit **203** is a two-pole synchronous motor comprising the following elements:

[0045] stator **213** formed of a stator iron-core wound with windings, the iron-core being formed by laminating electromagnetic steel sheets, and

[0046] rotor **214** formed of rotor iron-core **215** equipped with a secondary conductor, iron-core **215** being formed by laminating electromagnetic steel sheet.

[0047] Rotor iron-core **215** incorporates permanent magnet **215***a* made of, e.g. neodymium of rare-earth magnet, iron, boron-based ferromagnetic materials. Other structures remain unchanged as the first embodiment.

[0048] An operation of the foregoing compressor is demonstrated hereinafter. Motor unit **203** starts working as an induction motor, and when it comes around the synchronizing rpm, synchronous pull-in is carried out for synchronous operation.

[0049] Since permanent magnet **215***a* is made of ferromagnetic material having intense magnetic force, it produces extraordinary intense magnetic attraction at the place where a clearance between rotor **214** and stator **213** is small. However, the same structure as that in the first embodiment can overcome this problem. As a result, highly efficient operation of the synchronous motor is advantageously used for obtaining high energy efficiency. At the same time, the shaft of the compressor is prevented from hitting the bearing due to slant, so that the reliability can be improved.

Exemplary Embodiment 3

[0050] **FIG. 3** shows a vertical sectional view of a compressor in accordance with the third exemplary embodiment of the present invention. Similar elements to those in the first embodiment have the same reference marks, and the detailed descriptions thereof are omitted here.

[0051] In **FIG. 3**, enclosed container **101** accommodates compressor mechanism **302** and motor unit **303** that drives this compressor mechanism. Cylinder block **305** of compressor mechanism **302** is made from cast-iron and forms cylindrical compressing chamber **110**. Main bearing **320** for rotatably supporting main shaft section **116** of shaft **104** and sub-bearing **121** for rotatably supporting sub-shaft section **118** are rigidly mounted to cylinder block **305**.

[0052] Motor unit **303** comprising stator **113** and rotor **314** is an inverter-driven motor that is driven at plural frequencies. Rotor **314** is fixed to main-shaft section **116** of shaft **104** and includes permanent magnet **315***a* built in rotor iron-core **315**. Permanent magnet **315***a* is made of, e.g. rare-earth magnet such as neodymium, iron, boron-based ferromagnetic materials. Rotor iron-core **315** has hollow bore **306** at its end face on compressor mechanism **302** side. Main bearing **320** is made from aluminum alloy which is non-magnetic material, and extends into bore **306**.

[0053] An operation of the foregoing compressor is described hereinafter. When a current runs into stator **113**, rotor **314** spins shaft **104**, and eccentric motion of eccentric shaft section **117** is transferred to piston **109** via connecting rod **108**, so that piston **109** reciprocates in compressing chamber **110**. This operation sucks refrigerant gas supplied from a cooling system (not shown) into compressing chamber **110**, then compresses the gas, and discharges the gas into the cooling system again. Lubricating mechanism **111** formed on shaft **104** pumps up lubricant oil **112**, which is then discharged from an upper end of shaft **104**.

[0054] Permanent magnet **315***a* built in rotor iron-core **315** is made of, e.g. rare-earth material having intense magnetic force, so that it produces extraordinary intense magnetic attraction at a place where a clearance between rotor **314** and stator **113** is small.

[0055] When shaft **104** of this structure receives an unbalanced load caused by the magnetic attraction generated between rotor **314** and stator **113**, a distance between two fulcrums becomes far longer than that of the conventional structure discussed previously. On top of that, since main bearing **320** extends into bore **306**, the distance between the fulcrums becomes further longer. Because in the case of the conventional structure, the single-sided bearing receives the unbalance load at its upper and lower ends as fulcrums arranged in the diagonal direction with respect to the center axis of shaft **104** placed in the inner wall of the main bearing. On the other hand, the double-sided bearing employed in this third embodiment receives the unbalanced load at the following two fulcrums: its inner wall end on the counter side to the sub-bearing and at an inner wall end of the sub-bearing on the counter side to the main bearing along a diagonal direction with respect to the axis center of shaft **104**.

[0056] The extension of the distance between the fulcrums reduces a slant angle of shaft **104** within the bearing, so that shaft **104** scarcely hits against the bearing. As a result, sliding loss due to the hitting can be prevented and the compressor can maintain efficient operation. At the same time, a sliding noise due to the hitting can be suppressed, so that a compressor with a lower noise is obtainable. The load to shaft **104** in operation is received at eccentric bearing **117** (fulcrum) as a center, to which a compressing load from piston **109** is applied, and upper and lower ends, so that the load can be distributed generally even to this fulcrum. In comparison with the single-sided bearing, in which the load concentrates on its one end, the sliding face of shaft **104** has better reliability.

[0057] Since main bearing **320** is made of aluminum alloy, i.e. non-magnetic material, permanent magnet **315***a* built in rotor iron-core **315** does not produce eddy-current. Thus eddy-current loss can be eliminated, and high efficiency can be achieved.

[0058] Motor unit **303** is inverter-driven, so that it is driven at a high frequency in response to the load. At that time, motor unit **303** produces strong magnetic attraction, which tends to slant shaft **104**; however, since shaft **104** is supported by the double-sided bearing, i.e. main bearing **320** and sub bearing **121**, shaft **104** is prevented from slanting, and at the same time, sliding loss can be reduced. As a result, the compressor can maintain efficient operation, and prevent the shaft from hitting against the bearing, so that the reliability can be improved.

[0059] Stator **113** includes plural teeth **113***b* radially formed in iron-core **113***a*, and windings **113***d* are provided to teeth **113***b* via insulating member **113***c*. This structure eliminates a coil-end which is needed in the distributed winding structure. As a result, total heights of stator **113** and rotor **314** can be lowered, so that the total height of the compressor can be further lowered. The low profile of stator **113** and rotor **314** facilitates uniforming the clearance between stator **113** and rotor **314**, and as a result, the magnetic attraction rarely occurs, so that an increase of an input current due to interference as well as an increase of noise can be avoided.

Exemplary Embodiment 4

[0060] **FIG. 4** shows a vertical sectional view of a compressor in accordance with the fourth exemplary embodiment of the present invention. Similar elements to those in the third embodiment have the same reference marks, and the detailed descriptions thereof are omitted here.

[0061] In **FIG. 4**, motor unit **403** is a two-pole synchronous motor comprising the following elements:

[0062] stator **213** formed of a stator iron-core wound with windings, the iron-core being formed by laminating electromagnetic steel sheets, and

[0063] rotor **414** formed of rotor iron-core **415** equipped with a secondary conductor, iron-core **415** being formed by laminating electromagnetic steel sheets,

[0064] Rotor iron-core **415** incorporates permanent magnet **415***a* made of, e.g. neodymium of rare-earth magnet, iron, boron-based ferromagnetic materials. Other structures remain unchanged as the third embodiment.

[0065] An operation of the foregoing compressor is demonstrated hereinafter. Motor unit **403** starts working as an induction motor, and when it comes near the synchronizing rpm, synchronous pull-in is carried out for synchronous operation. Since permanent magnet **415***a* is made of ferromagnetic material having intense magnetic force, it produces extraordinary intense magnetic attraction at the place where a clearance between rotor **414** and stator **213** is small.

[0066] However, the same structure as that in the third embodiment can overcome this problem. As a result, highly efficient operation of the synchronous motor is advantageously used for obtaining high energy efficiency. At the same time, the shaft of the compressor is prevented from hitting the bearing caused by the slant, so that the reliability can be improved.

What is claimed is:

1. An electric compressor comprising:

(a) a motor unit including a stator with a winding, and a rotor with a rotor iron-core and a permanent magnet;

(b) a compressor mechanism driven by the motor unit and including:

(b-1) a shaft including an eccentric shaft section, a main shaft section and a sub shaft section, the main shaft section and the sub shaft section sandwiching the eccentric shaft section vertically and being placed coaxially,;

(b-2) a cylinder block including a compressing chamber;

(b-3) a main bearing, disposed in the cylinder block such that the main bearing crosses with an axial core of the compressing chamber at right angles, for rotatably supporting the main shaft section;

(b-4) a sub bearing, disposed in the cylinder block, for rotatably supporting the sub shaft section;

(b-5) a piston for reciprocating in the compressing chamber;

(b-6) a linking means for coupling the piston with the eccentric shaft section; and

(c) an enclosed container for pooling lubricant oil and accommodating the motor unit and the compressor mechanism.

2. The compressor of claim 1, wherein the main bearing does not cross with a plane which includes an end section of rotor iron-core on the compressor mechanism side and is orthogonal to an axial core of the main shaft section.

3. The compressor of claim 2, wherein the main bearing is made of iron-based material.

4. The compressor of claim 1, wherein the rotor iron-core has a hollow bore at its end section on the compressor mechanism side, and the main bearing extends into the bore.

5. The compressor of claim 4, wherein the main bearing is made of non-magnetic material.

6. The compressor of claim 1, wherein the permanent magnet is made of rare-earth material.

7. The compressor of claim 1, wherein the motor unit is driven at a plurality of frequencies including a frequency not lower than a commercial power frequency.

8. The compressor of claim 1, wherein the stator includes a plurality of teeth, and the winding is wound on the teeth via insulating material.

9. The compressor of claim 1, wherein the motor unit starts working as an induction motor, and when its rotation becomes near a synchronizing rotation, synchronous pull-in is carried out for synchronous operation.

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