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SCROLL COMPRESSOR

Abstract

A scroll compressor includes a housing, a rotary shaft, a motor, a controller, a compression mechanism including a fixed scroll and an orbiting scroll, an eccentric shaft, and a bushing. An orbital radius of the orbiting scroll changes with swinging of the bushing about the eccentric shaft. The controller performs a startup operation to discharge liquefied refrigerant from the compression mechanism before performing a normal operation. In the startup operation, the controller performs a startup reverse rotation in which the controller rotates the motor in reverse and swings the bushing, a startup forward rotation, after the startup reverse rotation, in which the controller rotates the motor forward while reducing an acceleration in a rotational speed of the motor, a startup liquid discharge in which the controller rotates the motor at the predetermined rotational speed.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-021660 filed on Feb. 16, 2024, the entire disclosure of which is incorporated herein by reference.

[0002] The present disclosure relates to a scroll compressor.

BACKGROUND ART

[0003] A scroll compressor includes a housing, a rotary shaft, a motor, and a compression mechanism. The rotary shaft is rotatably supported by the housing. The motor rotates the rotary shaft. The compression mechanism is driven by the motor, and compresses refrigerant. The compression mechanism includes a fixed scroll and an orbiting scroll. The fixed scroll has a fixed scroll base plate having a disc shape, and a fixed scroll spiral wall. The fixed scroll spiral wall extends from the fixed scroll base plate. The orbiting scroll includes an orbiting scroll base plate having a disc shape, and an orbiting scroll spiral wall. The orbiting scroll base plate faces the fixed scroll base plate. The orbiting scroll spiral wall extends from the orbiting scroll base plate toward the fixed scroll base plate. The orbiting scroll spiral wall meshes with the fixed scroll spiral wall. The orbiting scroll and the fixed scroll cooperate to compress refrigerant with rotation of the rotary shaft.

[0004] For example, Japanese Patent Application Publication No. H08-159052 discloses a rotary shaft including an eccentric shaft. The eccentric shaft extends parallel to an axis of the rotary shaft at a position eccentric to an axis of the rotary shaft. A bushing is mounted on the eccentric shaft. The bushing is swingable about the eccentric shaft. Swinging of the bushing about the eccentric shaft varies an orbital radius of the orbiting scroll.

[0005] In this scroll compressor, refrigerant may be cooled and liquefied when the scroll compressor is stopped. When the scroll compressor starts in a state in which liquefied refrigerant exists, liquid compression occurs in the compression mechanism when liquefied refrigerant is being discharged from the compression mechanism. When liquid compression occurs in the compression mechanism, loads are applied to both the fixed scroll spiral wall and the orbiting scroll spiral wall, which may lead to issues such as deformation of the fixed scroll spiral wall and the orbiting scroll spiral wall. Therefore, there is a demand for efficiently discharging liquefied refrigerant from the compression mechanism while loads applied to the fixed scroll spiral wall and the orbiting scroll spiral wall are suppressed at the start of the scroll compressor.

SUMMARY

[0006] In accordance with an aspect of the present disclosure, there is provided a scroll compressor including a housing; a rotary shaft rotatably supported by the housing; a motor configured to rotate the rotary shaft; a controller configured to control driving of the motor; a compression mechanism driven by the motor and configured to compress refrigerant, the compression mechanism including: a fixed scroll that includes a fixed scroll base plate having a disk shape, and a fixed scroll spiral wall extending from the fixed scroll base plate; and an orbiting scroll that includes an orbiting scroll base plate having a disk shape and facing the fixed scroll base plate, and an orbiting scroll spiral wall extending from the orbiting scroll base plate and meshing with the fixed scroll spiral wall, the orbiting scroll and the fixed scroll cooperating to compress refrigerant with rotation of the rotary shaft; an eccentric shaft extending from the rotary shaft at a position eccentric to an axial line of the rotary shaft, the eccentric shaft extending parallel to the axial line of the rotary shaft; and a bushing mounted on the eccentric shaft and swingable about the eccentric shaft, the bushing

swinging about the eccentric shaft to change an orbital radius of the orbiting scroll. The controller performs a startup operation to discharge liquefied refrigerant from the compression mechanism before performing a normal operation in which the motor is driven at a command rotational speed. In the startup operation, the controller performs a startup reverse rotation in which the motor rotates in reverse and the bushing swings to reduce the orbital radius of the orbiting scroll so that a gap between the fixed scroll spiral wall and the orbiting scroll spiral wall is increased, the controller performs a startup forward rotation, after the startup reverse rotation, in which the motor rotates forward while an acceleration in a rotational speed of the motor is reduced as compared to the acceleration in the rotational speed in the startup reverse rotation to maintain a posture of the bushing, and the controller performs a startup liquid discharge, when the rotational speed of the motor reaches a predetermined rotational speed by performing the startup forward rotation, in which the motor is driven at the predetermined rotational speed to cause the orbiting scroll to make orbital motion so that the liquefied refrigerant is discharged from the compression mechanism.
[0007] Other aspects and advantages of the disclosure will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0008] The disclosure, together with objects and advantages thereof, may best be understood by reference to the following description of the embodiments together with the accompanying drawings in which:
[0009] FIG. **1** is a cross-sectional view of a scroll compressor according to an embodiment;
[0010] FIG. **2** is a front view illustrating a bushing and an eccentric shaft;
[0011] FIG. **3** is a cross-sectional view illustrating a fixed scroll and an orbiting scroll;
[0012] FIG. **4** is a cross-sectional view illustrating the fixed scroll and the orbiting scroll; and
[0013] FIG. **5** is a chart indicating a change in a rotational speed of a motor.
DETAILED DESCRIPTION OF THE EMBODIMENTS
[0014] The following will describe an embodiment of a scroll compressor with reference to FIGS. **1** to **5**. The scroll compressor of the present embodiment is used for a vehicle air conditioner.
Overview of Scroll Compressor
[0015] As illustrated in FIG. **1**, a scroll compressor **10** includes a housing **11** having a tubular shape. The housing **11** includes a motor housing **12**, a shaft support housing **13**, and a discharge housing **14**. The motor housing **12**, the shaft support housing **13**, and the discharge housing **14** are made of a metal material. The motor housing **12**, the shaft support housing **13**, and the discharge housing **14** are made of, for example, aluminum. The scroll compressor **10** includes a rotary shaft **15**. The rotary shaft **15** is accommodated in the housing **11**.
[0016] The motor housing **12** includes an end wall **12***a* having a plate shape, and a peripheral wall **12***b* having a tubular shape. The peripheral wall **12***b* extends in a tubular shape from an outer peripheral portion of the end wall **12***a*. An axial direction of the peripheral wall **12***b* coincides with an axial direction of the rotary shaft **15**. The motor housing **12** has a plurality of internally threaded holes **12***c*. The internally threaded holes **12***c* are formed at an opening end of the peripheral wall **12***b*. For the sake of description, only one of the internally threaded holes **12***c* is illustrated in FIG. **1**. The motor housing **12** has an inlet port **12***h* through which refrigerant is drawn into the housing **11**. The inlet port **12***h* is formed in the peripheral wall **12***b* on the end wall **12***a* side. The inlet port **12***h* provides communication between an inside and an outside of the motor housing **12**.
[0017] The motor housing **12** has a bearing holder **12***d* having a cylindrical shape. The bearing holder **12***d* protrudes from a central portion of an inner surface of the end wall **12***a*. A first end of

the rotary shaft **15** corresponding to one end of the rotary shaft **15** in the axial direction is inserted into the bearing holder **12***d*. The scroll compressor **10** includes a bearing **16**. The bearing **16** is, for example, a rolling bearing. The bearing **16** is disposed between an inner peripheral surface of the bearing holder **12***d* and an outer peripheral surface of the first end of the rotary shaft **15**. The first end of the rotary shaft **15** is supported by the motor housing **12** via the bearing **16**.
[0018] The shaft support housing **13** has an end wall **17** having a plate shape and a peripheral wall **18** having a tubular shape. The peripheral wall **18** extends in a tubular shape from an outer peripheral portion of the end wall **17**. An axial direction of the peripheral wall **18** coincides with the axial direction of the rotary shaft **15**. The shaft support housing **13** has a flange wall **19** having an annular shape. The flange wall **19** extends outwardly in a radial direction of the rotary shaft **15** from an end of an outer peripheral surface of the peripheral wall **18** opposite from the end wall **17**.
[0019] The shaft support housing **13** has an insertion hole **17***a* having a circular hole shape. The insertion hole **17***a* is formed at the center of the end wall **17**. The insertion hole **17***a* extends through the end wall **17** in a thickness direction thereof. The rotary shaft **15** is inserted through the insertion hole **17***a*. A distal end surface **15***e* of the rotary shaft **15** on a second end side of the rotary shaft **15** corresponding to the other end thereof in the axial direction is positioned inside the peripheral wall **18**.
[0020] The scroll compressor **10** includes a bearing **21**. The bearing **21** is, for example, a rolling bearing. The bearing **21** is disposed between an inner peripheral surface of the peripheral wall **18** and the outer peripheral surface of the rotary shaft **15**. The rotary shaft **15** is rotatably supported by the shaft support housing **13** via the bearing **21**. Thus, the shaft support housing **13** rotatably supports the rotary shaft **15**. Accordingly, the rotary shaft **15** is rotatably supported by the housing **11**.
[0021] The shaft support housing **13** has a plurality of bolt insertion holes **19***a*. The bolt insertion holes **19***a* are formed in an outer peripheral portion of the flange wall **19**. The bolt insertion holes **19***a* each extend through the flange wall **19** in a thickness direction thereof. The bolt insertion holes **19***a* of the flange wall **19** are in communication with their associated internally threaded holes **12***c* of the motor housing **12**. For the sake of description, only one of the bolt insertion holes **19***a* is illustrated in FIG. **1**.
[0022] The scroll compressor **10** includes a motor chamber **20**. The motor chamber **20** is defined by the motor housing **12** and the shaft support housing **13**. Thus, the motor housing **12** and the shaft support housing **13** cooperate to define the motor chamber **20**. In this way, the motor chamber **20** is formed in the housing **11**. The motor chamber **20** is in communication with the inlet port **12***h*. Refrigerant is drawn into the motor chamber **20** through the inlet port **12***h*.
[0023] The scroll compressor **10** includes a motor **22**. The motor **22** is accommodated in the motor chamber **20**. The motor **22** includes a stator **23** having a tubular shape, and a rotor **24** having a tubular shape. The rotor **24** is disposed inside the stator **23**. The rotor **24** rotates together with the rotary shaft **15**. The stator **23** surrounds the rotor **24**. The rotor **24** includes a rotor core **24***a* fixed to the rotary shaft **15**, and a plurality of permanent magnets (not illustrated) disposed in the rotor core **24***a*.
[0024] The stator **23** includes a stator core **23***a* having a tubular shape, and a motor coil **23***b*. The stator core **23***a* is fixed to the inner peripheral surface of the peripheral wall **12***b* of the motor housing **12**. The motor coil **23***b* is wound around the stator core **23***a*.
[0025] The scroll compressor **10** includes a controller **60**. The controller **60** controls driving of the motor **22**. The controller **60** is an inverter device that controls a switching operation of switching elements. The controller **60** may be, for example, one or more processors (control circuits) that operate according to one or more dedicated hardware circuits and/or a computer program (software). The processors include the CPU as well as a memory such as RAM and ROM, and the memory stores program codes or instructions for causing the processors to perform various processing. The memory, that is, a computer-readable medium, includes any available media that

can be accessed by general-purpose or dedicated computers.

[0026] The controller **60** is electrically connected to an air conditioning ECU **61**. The air conditioning ECU **61** controls the entire vehicle air conditioner. The air conditioning ECU **61** is configured to obtain a cabin temperature, a set temperature, and the like. The air conditioning ECU **61** sends various commands such as an operation command for the motor **22** and a stop command for the motor **22** to the controller **60**. The various commands from the air conditioning ECU **61** are commands that the controller **60** receives externally.

[0027] The controller **60** periodically turns the switching elements ON and OFF based on the commands from the air conditioning ECU **61**. Specifically, the controller **60** performs pulse width modulation control (PWM control) for the switching elements based on the commands from the air conditioning ECU **61**. More specifically, the controller **60** generates a control signal using a carrier signal (carrier wave signal) and a command voltage value signal (comparison target signal). Then, the controller **60** converts direct current power into alternating current power by using the generated control signals to perform ON/OFF control of the switching elements. The converted alternating current power is supplied to the motor coil **23***b* as driving power. This rotates the rotor **24**, and the rotary shaft **15** rotates integrally with the rotor **24**. Accordingly, the motor **22** rotates the rotary shaft **15**.

[0028] Here, a state in which the motor **22** rotates forward, i.e., clockwise, corresponds to a state in which the rotor **24** rotates forward. On the other hand, a state in which the motor **22** rotates in reverse, i.e., counterclockwise, corresponds to a state in which the rotor **24** rotates in reverse. When the motor **22** rotates forward, the rotary shaft **15** rotates in a normal direction. At this time, a direction in which electric current flows from the controller **60** to the motor coil **23***b* while the motor **22** is rotating forward is defined as a first direction. Then, the motor **22** rotates in reverse when the direction of the electric current flowing from the controller **60** to the motor coil **23***b* is switched to a second direction, which is opposite to the first direction. Thus, the rotary shaft **15** rotates in a reverse direction opposite to the normal direction.

[0029] The controller **60** is capable of controlling a rotational speed of the motor **22** by estimating a position (rotation angle) of the rotor **24** based on the electric current flowing from the controller **60** to the motor coil **23***b*, without using a sensor such as a resolver that detects the position of the rotor **24**. Accordingly, the controller **60** is configured to obtain the rotational speed of the motor **22** based on the electric current flowing from the controller **60** to the motor coil **23***b*.

[0030] The scroll compressor **10** includes a compression mechanism C**1**. The compression mechanism C**1** includes a fixed scroll **25** and an orbiting scroll **26**. The compression mechanism C**1** is of the scroll type. The orbiting scroll **26** makes orbital motion relative to the fixed scroll **25** with the rotation of the rotary shaft **15**. Then, the orbiting scroll **26** and the fixed scroll **25** cooperate to compress refrigerant with the rotation of the rotary shaft **15**. Therefore, the compression mechanism C**1** is driven by the motor **22** and compresses refrigerant.

[0031] The fixed scroll **25** has a fixed scroll base plate **25***a*, and a fixed scroll spiral wall **25***b*. The fixed scroll base plate **25***a* has a disk shape. A discharge port **25***h* is formed at the center of the fixed scroll base plate **25***a*. The discharge port **25***h* has a circular hole shape. The discharge port **25***h* extends through the fixed scroll base plate **25***a* in a thickness direction thereof. The fixed scroll spiral wall **25***b* extends from the fixed scroll base plate **25***a*. In addition, the fixed scroll **25** has an outer peripheral wall **25***c*. The outer peripheral wall **25***c* extends from an outer peripheral portion of the fixed scroll base plate **25***a*. The outer peripheral wall **25***c* surrounds the fixed scroll spiral wall **25***b*.

[0032] The scroll compressor **10** includes a valve mechanism **25***v*. The valve mechanism **25***v* is mounted on a surface of the fixed scroll base plate **25***a* opposite to the fixed scroll spiral wall **25***b*. The valve mechanism **25***v* is configured to open or close the discharge port **25***h*.

[0033] The orbiting scroll **26** includes an orbiting scroll base plate **26***a* and an orbiting scroll spiral wall **26***b*. The orbiting scroll base plate **26***a* has a disk shape. The orbiting scroll base plate **26***a* faces the fixed scroll base plate **25***a*. The orbiting scroll spiral wall **26***b* extends from the orbiting scroll base plate **26***a* toward the fixed scroll base plate **25***a* and meshes with the fixed scroll spiral wall **25***b*. The orbiting scroll **26** is disposed inside the outer peripheral wall **25***c*. The orbiting scroll **26** makes orbital motion inside the outer peripheral wall **25***c*. A distal end surface of the fixed scroll spiral wall **25***b* is in contact with the orbiting scroll base plate **26***a*. A distal end surface of the orbiting scroll spiral wall **26***b* is in contact with the fixed scroll base plate **25***a*.

[0034] The scroll compressor **10** has a compression chamber **27**. The compression chamber **27** is defined by the fixed scroll base plate **25***a*, the fixed scroll spiral wall **25***b*, the orbiting scroll base plate **26***a*, and the orbiting scroll spiral wall **26***b*. Thus, the compression chamber **27** is defined between the fixed scroll **25** and the orbiting scroll **26**. Refrigerant from an outside is drawn into and compressed in the compression chamber **27**.

[0035] The scroll compressor **10** includes a boss **28**. The boss **28** protrudes in a tubular shape from a central portion of an end surface **26***e* of the orbiting scroll base plate **26***a* opposite to the fixed scroll base plate **25***a*. The boss **28** has a cylindrical shape. An axial direction of the boss **28** coincides with the axial direction of the rotary shaft **15**.

[0036] The orbiting scroll base plate **26***a* has a plurality of grooves **26***d*. The grooves **26***d* are formed around the boss **28** in the end surface **26***e* of the orbiting scroll base plate **26***a*. The grooves **26***d* are disposed at predetermined intervals in a circumferential direction of the rotary shaft **15**. For the sake of description, only one of the grooves **26***d* is illustrated in FIG. **1**. A ring member **29** having a ring shape is fitted into each of the grooves **26***d*. A pin **30** is inserted into the ring member **29**. The pin **30** protrudes from an end surface **13***e* of the shaft support housing **13** on the orbiting scroll **26** side.

[0037] The scroll compressor **10** includes an elastic plate **31**. The elastic plate **31** has an annular shape. The elastic plate **31** is held between the end surface **13***e* of the shaft support housing **13** and an opening end surface of the outer peripheral wall **25***c*. The elastic plate **31** constantly urges the orbiting scroll **26** toward the fixed scroll **25**.

[0038] The discharge housing **14** includes an end wall **14***a* having a plate shape, and a peripheral wall **14***b* having a tubular shape. The peripheral wall **14***b* extends in a tubular shape from an outer peripheral portion of the end wall **14***a*. An axial direction of the peripheral wall **14***b* coincides with the axial direction of the rotary shaft **15**. The peripheral wall **14***b* surrounds the fixed scroll **25**. Thus, the fixed scroll **25** is accommodated in the housing **11**.

[0039] The discharge housing **14** has a plurality of bolt insertion holes **14***c*. The bolt insertion holes **14***c* are formed in the peripheral wall **14***b*. For the sake of description, only one of the bolt insertion holes **14***c* is illustrated in FIG. **1**. The bolt insertion holes **14***c* are in communication with their associated bolt insertion holes **19***a* of the flange wall **19**.

[0040] Bolts B**1** inserted through the bolt insertion holes **14***c* and the bolt insertion holes **19***a* of the flange wall **19** are screwed into the internally threaded holes **12***c* of the motor housing **12**, respectively. As a result, the shaft support housing **13** is connected to the peripheral wall **12***b* of the motor housing **12**, and the discharge housing **14** is connected to the flange wall **19** of the shaft support housing **13**. Thus, the motor housing **12**, the shaft support housing **13**, and the discharge housing **14** are arranged in this order in the axial direction of the rotary shaft **15**. The fixed scroll **25** is held between the end wall **14***a* of the discharge housing **14** and the shaft support housing **13**. In this way, the fixed scroll **25** is fixed to the housing **11**.

[0041] The scroll compressor **10** includes an inlet passage **35**. The inlet passage **35** has a first groove **36**, a first hole **37**, a second groove **38**, and a second hole **39**. The first groove **36** is formed in a part of the inner peripheral surface of the peripheral wall **12***b* of the motor housing **12**. The first groove **36** is opened at the opening end of the peripheral wall **12***b*. The first hole **37** is formed in the outer peripheral portion of the flange wall **19** of the shaft support housing **13**. The first hole **37** extends through the flange wall **19** in the thickness direction thereof. The first hole **37** is in communication with the first groove **36**. The second groove **38** is formed in a part of an inner peripheral surface of the peripheral wall **14***b* of the discharge housing **14**. The second groove **38** is in communication with the first hole **37**. The second hole **39** is formed in the outer peripheral wall **25***c* of the fixed scroll **25**. The second hole **39** extends through the outer peripheral wall **25***c* in a thickness direction thereof. The second hole **39** is in communication with the second groove **38**. The second hole **39** is in communication with an outermost peripheral portion of the compression chamber **27**.

[0042] Refrigerant in the motor chamber **20** passes through the first groove **36**, the first hole **37**, the second groove **38**, and the second hole **39**, and is drawn into the compression chamber **27**. Refrigerant drawn into the compression chamber **27** is compressed in the compression chamber **27** with the orbital motion of the orbiting scroll **26**. In this way, the compression mechanism C**1** compresses refrigerant drawn into the housing **11**.

[0043] The scroll compressor **10** has a discharge chamber **40**. The discharge chamber **40** is defined between the fixed scroll base plate **25***a* and the end wall **14***a* of the discharge housing **14**. The discharge chamber **40** is connected to the discharge port **25***h*. Refrigerant compressed in the compression chamber **27** is discharged to the discharge chamber **40**. The discharge housing **14** has an outlet port **41**. The outlet port **41** is formed in the end wall **14***a* of the discharge housing **14**. Refrigerant discharged to the discharge chamber **40** is discharged through the outlet port **41** to an outside of the housing **11**.

[0044] The scroll compressor **10** includes an eccentric shaft **50**. The eccentric shaft **50** protrudes from the distal end surface **15***e* of the rotary shaft **15**, and extends parallel to an axial line L**1** of the rotary shaft **15** at a position eccentric to the axial line L**1** of the rotary shaft **15**. Thus, the rotary shaft **15** includes the eccentric shaft **50**. The eccentric shaft **50** is formed integrally with the rotary shaft **15**. An axial direction of the eccentric shaft **50** extends in the same direction as the axial direction of the rotary shaft **15**. The eccentric shaft **50** protrudes from the distal end surface **15***e* of the rotary shaft **15** toward the orbiting scroll **26**.

[0045] The scroll compressor **10** includes a bushing **51**. The bushing **51** has a cylindrical shape. A through hole **51***a* is formed inside the bushing **51**. Thus, the bushing **51** has the through hole **51***a*. The eccentric shaft **50** is inserted into the through hole **51***a*. Thus, the bushing **51** is inserted into the eccentric shaft **50**. The bushing **51** is disposed inside the boss **28**. Thus, the bushing **51** is disposed in the boss **28**.

[0046] As illustrated in FIG. **2**, the through hole **51***a* is formed in the bushing **51** with a center L**3** of the through hole **51***a* positioned eccentric to a center L**2** of the bushing **51**. Thus, a thickness of the bushing **51** at a portion closer to the center L**3** of the through hole **51***a* than the center L**2** of the bushing **51** is thinner than that at a portion closer to the center L**2** of the bushing **51** than the center L**3** of the through hole **51***a*. The center L**3** of the through hole **51***a* also corresponds to the center of the eccentric shaft **50**. The bushing **51** is swingable about the eccentric shaft **50**.

[0047] As illustrated in FIG. **1**, the scroll compressor **10** includes a balance weight **52**. The balance weight **52** is integrated into the bushing **51**. The balance weight **52** is formed integrally with the bushing **51**. The balance weight **52** protrudes outwardly from a portion of an outer peripheral surface of the bushing **51**. The balance weight **52** is accommodated in the peripheral wall **18** of the shaft support housing **13**.

[0048] The scroll compressor **10** includes a bearing **53**. The bearing **53** is a sliding bearing having a cylindrical shape. The bearing **53** is disposed inside the boss **28**. The bearing **53** is disposed between an inner peripheral surface of the boss **28** and the outer peripheral surface of the bushing **51**. The bushing **51** is rotatably supported by the boss **28** via the bearing **53**.

[0049] The rotation of the rotary shaft **15** is transmitted to the orbiting scroll **26** through the eccentric shaft **50**, the bushing **51**, and the bearing **53**. This causes the orbiting scroll **26** to rotate. The pins **30** in contact with their associated inner peripheral surfaces of the ring members **29** prevent the orbiting scroll **26** from rotating, but only allows the orbiting scroll **26** to make orbital motion. Thus, the orbiting scroll **26** makes orbital motion while the orbiting scroll spiral wall **26***b* is in contact with the fixed scroll spiral wall **25***b*. The volume of the compression chamber **27** reduces with orbital motion of the orbiting scroll **26**, thereby compressing refrigerant in the compression chamber **27**. The orbiting scroll **26** makes orbital motion inside the outer peripheral wall **25***c* with the rotation of the rotary shaft **15**. The balance weight **52** counterbalances a centrifugal force that acts on the orbiting scroll **26** when the orbiting scroll **26** makes orbital motion. This reduces the unbalance mass of the orbiting scroll **26**.

Driven Crank Mechanism

[0050] The center L**2** of the bushing **51** is positioned outward relative to the axial line L**1** of the rotary shaft **15** in the radial direction of the rotary shaft **15**. The center of the orbiting scroll base plate **26***a* coincides with the center L**2** of the bushing **51**. Then, a distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** corresponds to an orbital radius of the orbiting scroll **26**. Since swinging of the bushing **51** about the eccentric shaft **50** changes the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15**, the orbital radius of the orbiting scroll **26** changes. Therefore, in the scroll compressor **10**, the orbital radius of the orbiting scroll **26** is changed with the swinging of the bushing **51** about the eccentric shaft **50**. Accordingly, the eccentric shaft **50**, the bushing **51**, and the bearing **53** form a so-called driven crank mechanism **54** that changes the orbital radius of the orbiting scroll **26**. The driven crank mechanism **54** of this type has been known.

[0051] In view of a slight processing error and an assembling error occurring in the fixed scroll **25** and the orbiting scroll **26**, a gap (space) is provided between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b*.

[0052] When the rotary shaft **15** rotates in the normal direction with the forward rotation of the motor **22**, the bushing **51** swings about the eccentric shaft **50** according to a compressive load acting on the orbiting scroll **26**. Swinging of the bushing **51** about the eccentric shaft **50** increases the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15**, which increases the orbital radius of the orbiting scroll **26**.

[0053] As illustrated in FIG. **3**, when the orbital radius of the orbiting scroll **26** increases, the swinging of the bushing **51** about the eccentric shaft **50** is restricted at a time point at which the orbiting scroll spiral wall **26***b* is placed in contact with the fixed scroll spiral wall **25***b*. As a result, the orbital radius of the orbiting scroll **26** is fixed.

[0054] Furthermore, the rotation of the rotary shaft **15** is transmitted to the orbiting scroll **26** through the eccentric shaft **50**, the bushing **51**, and the bearing **53**, so that the orbiting scroll **26** rotates in the normal direction. At the time point at which the orbiting scroll spiral wall **26***b* comes into contact with the fixed scroll spiral wall **25***b*, the pins **30** and the ring members **29** come into contact. This prevents the orbiting scroll **26** from rotating, but only allows the orbiting scroll **26** to make orbital motion in the normal direction. The orbiting scroll **26** makes orbital motion in the normal direction while the orbiting scroll spiral wall **26***b* is in contact with the fixed scroll spiral wall **25***b*. As a result, the volume of the compression chamber **27** is reduced while leakage of refrigerant from the compression chamber **27** is suppressed, so that refrigerant is compressed.

[0055] In assembling the orbiting scroll **26** to the fixed scroll **25**, the bushing **51** is swung about the eccentric shaft **50** in a direction opposite to a direction in which the bushing **51** swings when the rotary shaft **15** rotates in the normal direction. Thus, the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** reduces, which reduces the orbital radius of the orbiting scroll **26**.

[0056] As illustrated in FIG. **4**, when the orbital radius of the orbiting scroll **26** reduces, the orbiting scroll spiral wall **26***b* is positioned relative to the fixed scroll spiral wall **25***b* at a position where the orbiting scroll spiral wall **26***b* is not in contact with the fixed scroll spiral wall **25***b*. Therefore, the orbiting scroll **26** may be easily assembled to the fixed scroll **25**. FIG. **4** illustrates a state in which the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is maximum.

[0057] When the bushing **51** swings about the eccentric shaft **50** in an opposite direction to the direction in which the bushing **51** swings when the rotary shaft **15** rotates in the normal direction, swinging of the bushing **51** is restricted until the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** increases. When the bushing **51** swings about the eccentric shaft **50** in the opposite direction to the direction in which the bushing **51** swings when the rotary shaft **15** rotates in the normal direction, swinging of the bushing **51** is restricted when the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** becomes minimum.

Normal Operation

[0058] FIG. **5** shows a change in the rotational speed of the motor **22**. A program for performing a normal operation to drive the motor **22** as shown in FIG. **5** is pre-stored in the controller **60**. Thus, the controller **60** performs the normal operation in which the motor **22** is driven at a command rotational speed for compressing refrigerant. In the normal operation, the controller **60** drives the motor **22** by sensorless control. The controller **60** estimates the position of the rotor **24** based on the electric current and input voltage to the motor **22** in the sensorless control.

[0059] Then, the controller **60** converts the electric current flowing to the motor **22** based on the estimated position of the rotor **24** into an excitation component current, i.e., a d-axis current, and a torque component current, i.e., a q-axis current. The controller **60** performs on-off control of the switching elements so that the d-axis current and the q-axis current become target values. Accordingly, in the normal operation, the motor **22** rotates at a command rotational speed N**1** sent from the air conditioning ECU **61**.

Startup Operation

[0060] A program for performing a startup operation to discharge liquefied refrigerant from the compression mechanism C**1** before the normal operation is performed is pre-stored in the controller **60**. Thus, the controller **60** performs the startup operation to discharge liquefied refrigerant from the compression mechanism C**1** before performing the normal operation. The controller **60** performs the startup operation upon receiving a startup command from the air conditioning ECU **61**. In addition, a program for switching an operation from the startup operation to the normal operation when the rotational speed of the motor **22** reaches the command rotational speed N**1** is pre-stored in the controller **60**.

[0061] A program for performing a startup reverse rotation, in the startup operation, in which the motor **22** rotates in reverse is pre-stored in the controller **60**. Therefore, the controller **60** performs the startup reverse rotation in which the motor **22** rotates in reverse in the startup operation. In the startup reverse rotation, the controller **60** causes the bushing **51** to swing to reduce the orbital radius of the orbiting scroll **26** so that the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased.

[0062] Specifically, in the startup reverse rotation, the controller **60** causes the bushing **51** to swing so as to maximize the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b*, as illustrated in FIG. **4**. In the startup reverse rotation, the controller **60** increases acceleration in the rotational speed of the motor **22** while rotating the motor **22** in reverse in order to cause the bushing **51** to swing so that the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is maximized. The “acceleration in the rotational speed of the motor **22**” indicates the change in the rotational speed of the motor **22** per unit of time. When the startup reverse rotation is performed, the bushing **51** swings about the eccentric shaft **50** so that the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** is reduced. The program for performing the startup reverse rotation first as the startup operation upon receiving the startup command from the air conditioning ECU **61** is pre-stored in the controller **60**.

[0063] Referring to FIG. **5**, in the startup operation, a program for performing a startup forward rotation in which the motor **22** rotates forward to maintain the posture of the bushing **51**, after the startup reverse rotation is performed, is pre-stored in the controller **60**. Thus, the controller **60**

performs, after the startup reverse rotation, the startup forward rotation in which the motor **22** rotates forward to maintain the posture of the bushing **51**. An inclination of the solid line indicating the change in the rotational speed of the motor **22** during the startup forward rotation is more gradual than an inclination of the solid line indicating a change in the rotational speed of the motor **22** during the startup reverse rotation. Therefore, the change in the rotational speed of the motor **22** per unit time during the startup forward rotation is smaller than the change in the rotational speed of the motor **22** per unit time during the startup reverse rotation. In this way, in the startup forward rotation, the controller **60** reduces the acceleration in the rotational speed of the motor **22** as compared to the acceleration in the rotational speed of the motor **22** in the startup reverse rotation.
[0064] In the startup operation, a program for performing a startup liquid discharge when the rotational speed of the motor **22** reaches a predetermined rotational speed Nx by performing the startup forward rotation is pre-stored in the controller **60**. Thus, the controller **60** performs the startup liquid discharge when the rotational speed of the motor **22** reaches the predetermined rotational speed Nx by performing the startup forward rotation. During the startup liquid discharge, the controller **60** causes the orbiting scroll **26** to make orbital motion by driving the motor **22** at the predetermined rotational speed Nx so that liquefied refrigerant is discharged from the compression mechanism C**1**.
[0065] In the startup operation, a program for performing a startup post-liquid discharge forward rotation after the motor **22** is driven to rotate at the predetermined rotational speed Nx is pre-stored in the controller **60**. Thus, in the startup operation, the controller **60** performs the startup post-liquid discharge forward rotation after the motor **22** is rotated at the predetermined rotational speed Nx. In the startup post-liquid discharge forward rotation, the controller **60** causes the bushing **51** to swing so that the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are placed in contact with each other, as illustrated in FIG. **3**.
[0066] As shown in FIG. **5**, an inclination of the solid line indicating a change in the rotational speed of the motor **22** during the startup post-liquid discharge forward rotation is substantially the same as the inclination of the solid line indicating the change in the rotational speed of the motor **22** during the startup reverse rotation. Therefore, the change in the rotational speed of the motor **22** per unit time during the startup post-liquid discharge forward rotation is substantially the same as the change in the rotational speed of the motor **22** per unit time during the startup reverse rotation. In the startup post-liquid discharge forward rotation, the controller **60** increases the acceleration in the rotational speed of the motor **22** and rotates the motor **22** forward in order to swing the bushing **51** so that fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are placed in contact with each other, after the motor **22** rotates at the predetermined rotational speed Nx.
[0067] A direction in which the bushing **51** swings during the startup post-liquid discharge forward rotation is opposite to the direction in which the bushing **51** swings during the startup reverse rotation. Specifically, during the startup post-liquid discharge forward rotation, the bushing **51** swings about the eccentric shaft **50** so that the distance between the center L**2** of the bushing **51** and the axial line L**1** of the rotary shaft **15** increases.
[0068] A program for performing a startup low acceleration forward rotation, in which the rotational speed of the motor **22** gradually approaches the command rotational speed N**1** in the normal operation after performing the startup post-liquid discharge forward rotation, is pre-stored in the controller **60**, in the startup operation. Therefore, in the startup operation, the controller **60** causes the rotational speed of the motor **22** to gradually approach the command rotational speed N**1** in the normal operation after performing the startup post-liquid discharge forward rotation. An inclination of the solid line indicating the change in the rotational speed of the motor **22** during the startup low acceleration forward rotation is more gradual than the inclination of the solid line indicating the change in the rotational speed of the motor **22** during the startup post-liquid discharge forward rotation. Thus, the change in the rotational speed of the motor **22** per unit time during the startup low acceleration forward rotation is smaller than the change in the rotational

speed of the motor **22** per unit time during the startup post-liquid discharge forward rotation. In this way, in the startup low acceleration forward rotation, the controller **60** reduces the acceleration in the rotational speed of the motor **22** as compared to the startup post-liquid discharge forward rotation and rotates the motor **22** forward, after performing the startup post-liquid discharge forward rotation.

Operation of Embodiment

[0069] The following will describe the operation of the present embodiment.

[0070] In the scroll compressor **10**, refrigerant may be cooled and liquefied when the scroll compressor **10** is stopped. Therefore, the controller **60** performs the startup operation to discharge liquefied refrigerant from the compression mechanism C**1** before performing the normal operation to drive the motor **22** by the sensorless control. In the startup operation, the controller **60**, firstly, performs the startup reverse rotation. When the startup reverse rotation is performed, the motor **22** rotates in reverse, which causes the bushing **51** to swing to reduce the orbital radius of the orbiting scroll **26** so that the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased. In this way, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased before the normal operation is performed.

[0071] Next, the controller **60** performs the startup forward rotation after the startup reverse rotation. In the startup forward rotation, the acceleration in the rotational speed of the motor **22** is reduced as compared to the startup reverse rotation, so that the posture of the bushing **51** is maintained even if the rotation of the motor **22** forward is accelerated. Therefore, even if the forward rotation of the motor **22** is accelerated, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is kept large.

[0072] Then, when the rotational speed of the motor **22** reaches the predetermined rotational speed Nx by performing the startup forward rotation, the controller **60** performs the startup liquid discharge in which the orbiting scroll **26** makes orbital motion by driving the motor **22** at the predetermined rotational speed Nx to discharge liquefied refrigerant from the compression mechanism C**1**. According to this, since the orbiting scroll **26** makes orbital motion with the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* kept large, liquid compression hardly occurs in the compression mechanism C**1**.

[0073] Next, the controller **60** performs the startup post-liquid discharge forward rotation after the motor **22** is driven to rotate at the predetermined rotational speed Nx. As a result, the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are placed in contact with each other. Furthermore, the controller **60** performs the startup low acceleration forward rotation after the startup post-liquid discharge forward rotation. As a result, the rotation speed of the motor **22** gradually approaches the command rotational speed N**1** in the normal operation. Then, the controller **60** switches the operation from the startup operation to the normal operation when the rotation speed of the motor **22** reaches the command rotational speed N**1**. Thus, the scroll compressor **10** compresses refrigerant with the compression mechanism C**1** in the normal operation.

Effects of Embodiment

[0074] The above-described embodiment offers the following effects.

[0075] (1) The controller **60** performs the startup operation to discharge liquefied refrigerant from the compression mechanism C**1** before performing the normal operation to drive the motor **22**. In the startup operation, the controller **60**, firstly, performs the startup reverse rotation. When the startup reverse rotation is performed, the motor **22** rotates in reverse, which causes the bushing **51** to swing to reduce the orbital radius of the orbiting scroll **26**, so that the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased. In this way, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased before the normal operation is performed. Next, the controller **60** performs the startup forward rotation after the startup reverse rotation. In the startup forward rotation, the acceleration in the rotational speed of the motor **22** is reduced as compared to the startup reverse rotation so that the posture of the bushing **51** is maintained even if the forward rotation of the motor **22** is accelerated. Therefore, even if the forward rotation of the motor **22** is accelerated, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is kept large. Then, when the rotational speed of the motor **22** reaches the predetermined rotational speed Nx by performing the startup forward rotation, the controller **60** performs the startup liquid discharge in which the orbiting scroll **26** makes orbital motion by driving the motor **22** at the predetermined rotational speed Nx to discharge liquefied refrigerant from the compression mechanism C**1**. According to this, since the orbiting scroll **26** makes orbital motion with the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* kept large, liquid compression hardly occurs in the compression mechanism C**1**. As a result, liquefied refrigerant may be discharged from the compression mechanism C**1** efficiently while loads applied to the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are suppressed.

[0076] (2) When the controller **60** performs the startup reverse rotation, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is maximized. Therefore, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is maintained at the maximum while the startup forward rotation is performed, and the orbiting scroll **26** makes orbital motion with the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* maintained at the maximum while the startup liquid discharge is performed. This makes liquid compression in the compression mechanism C**1** further less likely to occur. As a result, liquefied refrigerant may be discharged from the compression mechanism C**1** while loads applied to the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are suppressed.

[0077] (3) When the controller **60** performs the startup post-liquid discharge forward rotation, the bushing **51** swings so that the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* are placed in contact with each other. As a result, preparation for efficiently compressing refrigerant with the compression mechanism C**1** in the normal operation when the operation is switched from the startup operation to the normal operation may be made smoothly.

[0078] (4) In the startup operation, the controller **60** reduces the acceleration in the rotational speed of the motor **22** as compared to in the startup post-liquid discharge forward rotation and rotates the motor **22** in the forward direction, after the startup post-liquid discharge forward rotation. As a result, the rotational speed of the motor **22** gradually approaches the command rotational speed N**1** in the normal operation, and thus the motor **22** is driven precisely at the command rotational speed N**1** in the normal operation when the operation is switched from the startup operation to the normal operation and the controller **60** performs the normal operation.

[0079] (5) According to the present embodiment, for example, it is not necessary to reduce the rotational speed of the motor **22** to an extremely low level to discharge liquefied refrigerant from the compression mechanism C**1** for suppressing the loads applied to the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* at the start of the scroll compressor **10**. Therefore, the responsiveness of the scroll compressor **10** at the start may be improved.

Modification

[0080] The above-described present embodiment may be modified in various manners, as exemplified below. The above-described embodiment and the following modifications may be combined within the scope technically consistent with the present disclosure.

[0081] In the embodiment, the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* does not have to be maximized in the startup reverse rotation. In short, in the startup reverse rotation, the controller **60** only has to rotate the motor **22** in reverse and cause the bushing **51** to swing in order to reduce the orbital radius of the orbiting scroll **26** so that the gap between the fixed scroll spiral wall **25***b* and the orbiting scroll spiral wall **26***b* is increased.

[0082] In the embodiment, the controller **60** may switch the operation to the normal operation once the rotational speed of the motor **22** reaches the command rotational speed N**1** after performing the

startup post-liquid discharge forward rotation without performing the startup low acceleration forward rotation in the startup operation.
[0083] Although the controller **60** drives the motor **22** by the sensorless control in the normal operation in the above embodiment, the control of the controller **60** is not limited to the sensorless control. The controller **60** may estimate the position of the rotor **24** using a sensor such as a resolver to drive the motor **22**.
[0084] In the embodiment, the eccentric shaft **50** and the rotary shaft **15** do not have to be integrally formed, but the eccentric shaft **50** may be a separate part. In this case, the eccentric shaft **50** is attached to the distal end surface **15***e* of the rotary shaft **15**.
[0085] In the embodiment, the balance weight **52** and the bushing **51** may be separate parts.
[0086] Although the scroll compressor **10** is used for the vehicle air-conditioning device in the present embodiment, the use of the scroll compressor **10** is not limited to the vehicle air conditioner. The scroll compressor **10** may be used in any desirable manner as long as the scroll compressor **10** is used for compressing refrigerant.
[0087] In the embodiment, the scroll compressor **10** does not have to compress refrigerant, but may compress fluids such as air.

Claims

1. A scroll compressor comprising: a housing; a rotary shaft rotatably supported by the housing; a motor configured to rotate the rotary shaft; a controller configured to control driving of the motor; a compression mechanism driven by the motor and configured to compress refrigerant; the compression mechanism including: a fixed scroll that includes a fixed scroll base plate having a disk shape, and a fixed scroll spiral wall extending from the fixed scroll base plate; and an orbiting scroll that includes an orbiting scroll base plate having a disk shape and facing the fixed scroll base plate, and an orbiting scroll spiral wall extending from the orbiting scroll base plate and meshing with the fixed scroll spiral wall, the orbiting scroll and the fixed scroll cooperating to compress refrigerant with rotation of the rotary shaft; an eccentric shaft extending from the rotary shaft at a position eccentric to an axial line of the rotary shaft, the eccentric shaft extending parallel to the axial line of the rotary shaft; and a bushing mounted on the eccentric shaft and swingable about the eccentric shaft, the bushing swinging about the eccentric shaft to change an orbital radius of the orbiting scroll, wherein the controller performs a startup operation to discharge liquefied refrigerant from the compression mechanism before performing a normal operation in which the motor is driven at a command rotational speed, and in the startup operation, the controller performs a startup reverse rotation in which the motor rotates in reverse and the bushing swings to reduce the orbital radius of the orbiting scroll so that a gap between the fixed scroll spiral wall and the orbiting scroll spiral wall is increased, the controller performs a startup forward rotation, after the startup reverse rotation, in which the motor rotates forward while an acceleration in a rotational speed of the motor is reduced as compared to the acceleration in the rotational speed in the startup reverse rotation to maintain a posture of the bushing, and the controller performs a startup liquid discharge, when the rotational speed of the motor reaches a predetermined rotational speed by performing the startup forward rotation, in which the motor is driven at the predetermined rotational speed to cause the orbiting scroll to make orbital motion so that the liquefied refrigerant is discharged from the compression mechanism.
2. The scroll compressor according to claim 1, wherein in the startup reverse rotation, the controller causes the bushing to swing so as to maximize the gap between the fixed scroll spiral wall and the orbiting scroll spiral wall.
3. The scroll compressor according to claim 1, wherein in the startup operation, the controller performs a startup post-liquid discharge forward rotation, after the motor is driven at the predetermined rotational speed, in which the bushing swings so that the fixed scroll spiral wall and

the orbiting scroll spiral wall are placed in contact with each other.

4. The scroll compressor according to claim 3, wherein in the startup operation, after the startup post-liquid discharge forward rotation, the controller causes the motor to rotate forward while reducing the acceleration in the rotational speed of the motor as compared to the acceleration in the rotational speed in the startup post-liquid discharge forward rotation so that the rotational speed of the motor gradually approaches the command rotational speed in the normal operation.