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System and method of starting air compressor in low-temperature state

Abstract

A system for starting an air compressor in a low-temperature state includes a motor configured to generate rotation force according to a control signal of a controller, a piston configured to compress air through reciprocating motion using rotation force of the motor, an oil pump configured to provide oil stored in an oil pan to a rotation axis of the motor, an oil supply line configured to connect the oil pan to the oil pump, a recovery line configured to connect a discharge port of the oil pump to the oil supply line, and a valve connected to the recovery line and controlled by the controller, where the controller controls an on/off state of the valve based on a temperature of the motor, revolutions per minute (RPM) of the motor, or a pressure of the oil pump.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims under 35 U.S.C. § 119(a) the benefit of Korean Patent Application No. 10-2021-0002557 filed on Jan. 8, 2021, the entire contents of which are incorporated herein by reference.

BACKGROUND

(a) Technical Field

(2) The present disclosure relates to a system and method of starting an air compressor in a low-temperature state for reducing an initial load of a motor in the low-temperature state.

(b) Description of the Related Art

(3) An electric air compressor for generating compressed air for braking is applied to a commercial electric vehicle (EV) or a commercial fuel cell electric vehicle (FCEV). The electric air compressor is classified into a reciprocating-type air compressor, a screw type air compressor, and a scroll type air compressor depending on an operation method, and the reciprocating-type air compressor typically is applied to a commercial vehicle that requires high durability.

(4) An oil pump is applied to the reciprocating-type air compressor, and thus a lubricant is applied to a friction area at which a piston and a crank shaft contact each other. In this case, components for

lubrication include an oil pan, a suction pipe, an oil pump (an external or internal gear pump), and a relief valve, and the same components are included in a reciprocating-type electric air compressor of a commercial vehicle.

(5) However, as an initial load applied to a motor becomes excessive when the motor is initially operated, a controller is not capable of ensuring a gain value for controlling the motor, and thus there is a problem in that the responsiveness of the motor is degraded. There is a problem in that, as the responsiveness of the motor is degraded, a long time is required until an air compressor is normally operated, and noise is generated due to an excessive initial load when the air compressor is initially operated.

SUMMARY

(6) The present disclosure provides a system and method of starting an air compressor in a low-temperature state for controlling an on/off state of a solenoid valve in order to an initial load of a motor in a low-temperature state.

(7) An embodiment of the present disclosure provides a system for starting an air compressor in a low-temperature state. The system for starting an air compressor in a low-temperature state includes a motor configured to generate rotation force according to a control signal of a controller, a piston configured to compress air through reciprocating motion using rotation force of the motor, an oil pump configured to provide oil stored in an oil pan to a rotation axis of the motor, an oil supply line configured to connect the oil pan to the oil pump, a recovery line configured to connect a discharge port of the oil pump to the oil supply line, and a valve connected to the recovery line and controlled by the controller, wherein the controller controls an on/off state of the valve based on a temperature of the motor, revolutions per minute (RPM) of the motor, or a pressure of the oil pump.

(8) For example, when the motor is initially driven, if the temperature of the motor is less than or equal to a preset temperature, the controller may open the valve between the discharge port of the oil pump and a suction port of the oil pump.

(9) For example, the preset temperature may a subzero temperature at which viscosity of the oil increases.

(10) For example, when the motor is driven, a pressure between the discharge port and the suction port may become in an equilibrium state, the oil pump may be rotated in a no-load state, and the oil may not flow even if the oil pump is operated.

(11) For example, when the revolutions per minute (RPM) of the motor reach preset target revolutions per minute (RPM), the controller may close the valve, and as the valve is closed, pressure equilibrium between the suction port and the discharge port may be broken, and the oil pump may supply the oil stored in the oil pan to the rotation axis.

(12) For example, when the motor is initially driven, if a temperature of the motor is greater than a preset temperature, the controller may maintain the valve between the discharge port of the oil pump and a suction port of the oil pump in a closed state.

(13) For example, when the pressure of the oil pump reaches a preset maximum pressure after the motor and the oil pump are operated, the controller may maintain the pressure of the oil pump to be the preset maximum pressure or less by opening the valve.

(14) For example, the controller may set the preset maximum pressure to be less and may increase efficiency of the motor.

(15) For example, the rotation axis may connect the motor, the piston, and the oil pump, and an oil path in which oil flows may be defined in the rotation axis.

(16) An embodiment of the present disclosure provides a method of starting an air compressor in a low-temperature state. The method of starting an air compressor in a low-temperature state includes monitoring, by a controller, whether a temperature of a motor for driving the air compressor is less than or equal to a preset temperature, comparing, by the controller, the temperature of the motor with the preset temperature and controlling a valve on a line for connecting a suction port to a

discharge port of an oil pump driven by rotation force generated by the motor, and opening, by the controller, the valve when the pressure of the oil pump reaches a preset maximum pressure through operations of the motor and the oil pump.
(17) For example, the comparing, by the controller, the temperature of the motor with the preset temperature and controlling the valve may include opening the valve when the temperature of the motor is less than or equal to the preset temperature, and maintaining the valve in a closed state when the temperature of the motor is greater than the preset temperature.
(18) For example, when the valve is open, the discharge port and the suction port of the oil pump may be connected to each other, a pressure on the line may become in an equilibrium state, and the oil pump is rotated in a no-load state by rotation force of the motor.
(19) For example, when revolutions per minute (RPM) of the motor reach preset revolutions per minute (RPM) after the valve is open, the controller may close the valve to allow the oil pump to provide oil to a rotation axis of the motor.
(20) For example, after the valve is open, the controller may perform air purge of the air compressor and turning off of the motor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The above and other features of the present disclosure will now be described in detail with reference to certain exemplary embodiments thereof illustrated in the accompanying drawings which are given hereinbelow by way of illustration only, and thus are not limitative of the present disclosure, and wherein:
(2) FIG. **1** is a diagram showing an air compressor according to an embodiment of the present disclosure;
(3) FIG. **2** is a diagram showing an example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure;
(4) FIG. **3** is a diagram showing another example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure;
(5) FIG. **4** is a diagram showing another example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure; and
(6) FIG. **5** is a flowchart showing a driving method when an air compressor is in a low-temperature state according to an embodiment of the present disclosure.
DETAILED DESCRIPTION
(7) It is understood that the term "vehicle" or "vehicular" or other similar term as used herein is inclusive of motor vehicles in general such as passenger automobiles including sports utility vehicles (SUV), buses, trucks, various commercial vehicles, watercraft including a variety of boats and ships, aircraft, and the like, and includes hybrid vehicles, electric vehicles, plug-in hybrid electric vehicles, hydrogen-powered vehicles and other alternative fuel vehicles (e.g., fuels derived from resources other than petroleum). As referred to herein, a hybrid vehicle is a vehicle that has two or more sources of power, for example both gasoline-powered and electric-powered vehicles.
(8) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Throughout the specification, unless explicitly described to the contrary, the word "comprise" and variations such as "comprises" or "comprising" will be understood to imply the inclusion of stated elements but not the exclusion of any other elements. In addition, the terms "unit", "-er", "-or", and "module" described in the specification mean units for processing at least one function and operation, and can be implemented by hardware components or software components and combinations thereof.

(9) Further, the control logic of the present disclosure may be embodied as non-transitory computer readable media on a computer readable medium containing executable program instructions executed by a processor, controller or the like. Examples of computer readable media include, but are not limited to, ROM, RAM, compact disc (CD)-ROMs, magnetic tapes, floppy disks, flash drives, smart cards and optical data storage devices. The computer readable medium can also be distributed in network coupled computer systems so that the computer readable media is stored and executed in a distributed fashion, e.g., by a telematics server or a Controller Area Network (CAN).

(10) The attached drawings for illustrating exemplary embodiments of the present disclosure are to be referred to in order to gain a sufficient understanding of the present disclosure, the merits thereof, and the objectives accomplished by the implementation of the present disclosure. The present disclosure may, however, be embodied in many different forms, and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the present disclosure to one of ordinary skill in the art. Meanwhile, the terminology used herein is for the purpose of describing particular embodiments and is not intended to limit the present disclosure. Like reference numerals in the drawings denote like elements.

(11) The detailed description is used to exemplify the present disclosure. The description herein is given to show exemplary embodiments of the present disclosure, and the present disclosure may be used in various other combinations, changes, and environments. That is, the present disclosure may be changed or modified within the scope of the concept of the present disclosure disclosed in the specification, the equivalent scope of the given disclosure, and/or the scope of the technology or knowledge in the art. The described embodiment is the ideal embodiment for implementing the technological spirit of the present disclosure, but may be changed in various forms required in detailed applications and use of the present disclosure. Thus, the detailed description of the present disclosure herein is merely exemplary, and is not intended to limit the present disclosure. The following claims are to be interpreted as including other embodiments.

(12) FIG. **1** is a diagram showing an air compressor according to an embodiment of the present disclosure. FIG. **2** is a diagram showing an example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure.

(13) Referring to FIGS. **1** and **2**, an air compressor **1** may include a motor **100**, a piston **200**, an oil pump **300**, and an oil pan **400**. The air compressor **1** may be controlled by a controller **50**. The controller **50** optionally may include an inverter (not shown) for controlling the motor **100**. The air compressor **1** according to an embodiment of the present disclosure may be applied to a commercial electric vehicle (EV) or a commercial fuel cell electric vehicle (FCEV).

(14) The motor **100** may be disposed at one side of the air compressor **1** and may generate rotation force. The rotation force generated by the motor **100** may be transferred to a rotation axis **150**. The motor **100** may be controlled according to a control signal received from the controller **50**.

(15) The piston **200** may compress air through reciprocating motion using the rotation force of the motor **100**. The air compressed by the piston **200** may be provided to a pneumatic brake (not shown) or an air suspension (not shown) of the commercial vehicle. An eccentricity unit (not shown) for converting rotational motion of the rotation axis **150** into reciprocating motion may be provided in the air compressor **1**, and the piston **200** may reciprocate through the eccentricity unit (not shown).

(16) The oil pump **300** may provide oil stored in the oil pan **400** to the rotation axis **150**. The oil

pump **300** may include an external or internal gear pump and may be rotated by rotation force of the rotation axis **150**. The oil pump **300** may include a suction port **300***a* to which oil is introduced from the oil pan **400** and a discharge port **300***b* from which oil is discharged. The oil pump **300** may be disposed at the other side of the air compressor **1**. That is, the oil pump **300** and the motor **100** may be disposed to face each other based on the piston **200**. The rotation axis **150** may connect the motor **100** to the oil pump **300**.

(17) An oil supply line **10** may connect the oil pan **400** to the oil pump **300**. That is, oil stored in the oil pan **400** may flow to the oil pump **300** along the oil supply line **10** according to an operation of the oil pump **300**. The oil supply line **10** may be connected to the suction port **300***a* of the oil pump **300**. The oil supply line **10** may be disposed out of a housing that defines an outer shape of the air compressor **1**.

(18) Oil discharged through the discharge port **300***b* of the oil pump **300** may flow to a recovery line **20** and a discharge line **30**. The recovery line **20** may connect the discharge port **300***b* of the oil pump **300** to the oil supply line **10**. The discharge line **30** may supply oil to the rotation axis **150**. The discharge line **30** may be a line branched from the recovery line **20**.

(19) A valve **500** may be installed on the recovery line **20**. The valve **500** may control opening and closing of the recovery line **20**. For example, the valve **500** may be a solenoid valve that is turned on/off according to a control signal of the controller **50**.

(20) The controller **50** may control the motor **100** and the valve **500**. The controller **50** may control an on/off state of the motor **100** and revolutions per minute (RPM) of the motor **100**. The controller **50** may monitor the temperature of the motor **100**, the revolutions per minute (RPM) of the motor **100**, and the pressure of the oil pump **300**. The controller **50** may control an on/off state of the valve **500** based on the temperature of the motor **100**, the revolutions per minute (RPM) of the motor **100**, and the pressure of the oil pump **300**.

(21) For example, when a motor **10** is initially driven, if the temperature of the motor **100** is less than or equal to a preset temperature, the controller **50** may open the valve **500** between the discharge port **300***b* of the oil pump **300** and the suction port **300***a* of the oil pump **300**. As the motor **100** is driven and the valve **500** is open, the pressure between the discharge port **300***b* and the suction port **300***a* may become in an equilibrium state, and the oil pump **300** may be rotated in a no-load state. That is, the oil pump **300** may be rotated but may not pull up oil. In other words, oil may not flow even if the oil pump **300** is operated. The preset temperature may be a subzero temperature at which the viscosity of oil increases. For example, the preset temperature may be −25° C.

(22) When the discharge port **300***b* and the suction port **300***a* of the oil pump **300** are connected to each other, even if the motor **100** begins to be driven and the oil pump **300** is operated, a flow ratio of the discharge port **300***b* may be returned to the suction port **300***a* in which a low pressure is formed, and thus a vacuum pressure may not be formed and the pressure may be equilibrated. Accordingly, the oil pump **300** may be operated in a no-load state and oil may not be supplied to the rotation axis **150**, but the rotation axis **150** and a portion at which the rotation axis **150** and the piston **200** contact each other may be lubricated by oil that remains in an oil path defined in the rotation axis **150**.

(23) According to an embodiment of the present disclosure, when the air compressor **1** is a low-temperature state, the viscosity of oil may be increased and an initial load of the motor **100** may become excessive. Accordingly, a large amount of time taken to reach the target revolutions per minute (RPM) required by the motor **100** may be consumed, and the responsiveness of the motor **100** may be lowered. Thus, the controller **50** may reduce an initial load applied to the motor **100** by opening the valve **500** to rotate the oil pump **300** in a no-load state when the motor **100** is initially driven in a low-temperature state.

(24) FIG. **3** is a diagram showing another example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure. For the sake of brevity,

descriptions of FIG. **3** that are similar to those described with respect to FIG. **2** will be omitted.
(25) Referring to FIG. **3**, after the motor **100** and the oil pump **300** are operated, the revolutions per minute (RPM) of the motor **100** may reach preset target revolutions per minute (RPM). When the revolutions per minute (RPM) of the motor **100** reach the preset target revolutions per minute (RPM), the controller **50** may close the valve **500**. As the valve **500** is closed, pressure equilibrium between the suction port **300***a* and the discharge port **300***b* may be broken, and thus the oil pump **300** may supply oil stored in the oil pan **400** to the rotation axis **150**. Oil may flow to the rotation axis **150** through the discharge line **30**. Flow of the oil that flows to the recovery line **20** may be blocked by the valve **500**.
(26) That is, when the motor **100** is initially driven, if the temperature of the motor **100** is greater than a preset temperature, the controller **50** may maintain the state in which the valve **500** between the discharge port **300***b* of the oil pump **300** and the suction port **300***a* of the oil pump **300** is closed. In this case, when the temperature of the motor **100** is greater than a preset temperature, the viscosity of oil may not be increased, and an initial load applied to the motor **100** may not be increased. Thus, the controller **50** may determine that no-load rotation of the oil pump **300** is not required and may not open the valve **500**.
(27) For example, the rotation axis **150** may be lubricated through oil that remains on the rotation axis **150** for connecting the motor **100** to the oil pump **300** until the revolutions per minute (RPM) of the motor **100** reach preset target revolutions per minute (RPM).
(28) For example, when the revolutions per minute (RPM) of the motor **100** reach the preset target revolutions per minute (RPM), the oil pump **300** may provide oil stored in the oil pan **400** to the rotation axis **150** by closing the valve **500**.
(29) FIG. **4** is a diagram showing another example of an operation of a system for starting an air compressor in a low-temperature state according to the present disclosure. For the sake of brevity, descriptions of FIG. **4** similar to those already described with respect to FIG. **2** or **3** will be omitted.
(30) Referring to FIG. **4**, after the motor **100** and the oil pump **300** are operated, the pressure of the oil pump **300** may reach a preset maximum pressure. When the pressure of the oil pump **300** reaches the preset maximum pressure, the controller **50** may open the valve **500** to maintain of the oil pump **300** in the preset maximum pressure or less. The suction port **300***a* and the discharge port **300***b* of the oil pump **300** may be connected to each other by opening the valve **500**.
(31) Oil may flow to the rotation axis **150** through the discharge line **30**, and oil that flows to the recovery line **20** may flow to the oil supply line **10**. As oil flows through the recovery line **20**, the pressure of the oil pump **300** may not be increased any further.
(32) The controller **50** may change the preset maximum pressure. When the preset maximum pressure is set to be low, the efficiency of the motor **100** or the efficiency of the air compressor may be increased. The controller **50** may set a maximum pressure appropriate for a vehicle in which the air compressor is installed.
(33) FIG. **5** is a flowchart showing a driving method when an air compressor is in a low-temperature state according to an embodiment of the present disclosure.
(34) Referring to FIG. **5**, when a motor is initially driven, a controller may monitor the temperature of the motor for driving the air compressor (S**100**).
(35) The controller may compare the temperature of the motor with a preset temperature. When the temperature of the motor is less than or equal to the preset temperature, the controller may open a valve disposed on a line that connects a suction port and a discharge port of an oil pump driven by rotation force generated by the motor. As the valve is open, the discharge port and the suction port of the oil pump may be connected to each other, and thus the pressure on the recovery line may be an equilibrium state. Accordingly, the oil pump may be rotated in a no-load state by the rotation force of the motor, and oil may not flow. However, when the temperature of the motor is greater than a preset temperature, the valve may be maintained in a closed state. When the motor is driven in the state in which the valve is closed, the oil pump may not be rotated in a no-load state to

prevent oil from flowing until the revolutions per minute (RPM) of the motor reach the target revolutions per minute (RPM) (S**200**, S**300**, and S**500**).
(36) When the temperature of the motor is less than or equal to the preset temperature and the valve is open, the controller may monitor whether the revolutions per minute (RPM) of the motor reach the target revolutions per minute (RPM). The oil pump may be rotated in a no-load state until the revolutions per minute (RPM) of the motor reach the target revolutions per minute (RPM) (S**400**).
(37) When the revolutions per minute (RPM) of the motor reach the target revolutions per minute (RPM), the controller may close the valve. As the valve is closed, pressure equilibrium between the suction port and the discharge port may be broken. Accordingly, oil may flow toward the oil pump according to the pressure of the suction port of the oil pump, and the oil pump may supply oil to the rotation axis (S**500**).
(38) When the pressure of the oil pump reaches a preset maximum pressure through operations of the motor and the oil pump, the controller may open the valve. When the pressure of the oil pump reaches the maximum pressure, it may not be required to compress air to be supplied to the pneumatic brake or the air suspension installed in the vehicle any longer. Thus, the controller may open the valve and may maintain the pressure of the oil pump in the maximum pressure or less (S**600**).
(39) After the pressure of the oil pump reaches the maximum pressure, the air compressor may purge air. After purging air, the air compressor may not need to compress air, and thus the motor may be turned off. The air compressor may be driven again when there is a need to compress air again (S**700**).
(40) According to an embodiment of the present disclosure, the controller may reduce an initial load applied to the motor by opening the valve to rotate the oil pump in a no-load state when the motor is initially driven in a low-temperature state.
(41) According to an embodiment of the present disclosure, the controller may set the maximum pressure of the oil pump according to a vehicle, thereby improving the efficiency of the air compressor.
(42) The present disclosure has been described in detail with reference to preferred embodiments thereof. However, it will be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the present disclosure, the scope of which is defined in the appended claims and their equivalents.

Claims

1. A system for starting an air compressor in a low-temperature state, the system comprising: a motor configured to generate rotation force according to a control signal of a controller; a piston configured to compress air through reciprocating motion using rotation force of the motor; an oil pump configured to provide oil stored in an oil pan to a rotation axis of the motor; an oil supply line configured to connect the oil pan to a suction port of the oil pump; a recovery line configured to connect a discharge port of the oil pump to the oil supply line; and a valve connected to the recovery line and controlled by the controller, wherein the controller controls an on/off state of the valve based on a temperature of the motor, revolutions per minute (RPM) of the motor, and a pressure of the oil pump, wherein oil discharged through the discharge port of the oil pump flows to the recovery line and a discharge line, wherein the discharge line supplies oil to the rotation axis; wherein, when the motor is initially driven, if the temperature of the motor is less than or equal to a preset temperature, the controller opens the valve between the discharge port of the oil pump and the suction port of the oil pump such that a pressure between the discharge port and the suction port reaches an equilibrium state, the oil pump is rotated in a no-load state, and the oil does not flow even if the oil pump is operated.
2. The system of claim 1, wherein the preset temperature is less than 0 degrees Celsius, which is a

temperature at which viscosity of the oil increases.

3. The system of claim 1, wherein when the revolutions per minute (RPM) of the motor reach preset target revolutions per minute (RPM), the controller closes the valve, and as the valve is closed, pressure equilibrium between the suction port and the discharge port is broken, and the oil pump supplies the oil stored in the oil pan to the rotation axis.
4. The system of claim 1, wherein when the motor is initially driven, if the temperature of the motor is greater than the preset temperature, the controller maintains the valve between the discharge port of the oil pump and the suction port of the oil pump in a closed state.
5. The system of claim 1, wherein when the pressure of the oil pump reaches a preset maximum pressure after the motor and the oil pump are operated, the controller maintains the pressure of the oil pump to be the preset maximum pressure or less by opening the valve.
6. The system of claim 5, wherein the controller sets the preset maximum pressure to be less and increases efficiency of the motor.
7. The system of claim 1, wherein: the rotation axis connects the motor, the piston, and the oil pump; and an oil path in which oil flows is defined in the rotation axis.
8. A method of starting an air compressor in a low-temperature state, the method comprising: monitoring, by a controller, whether a temperature of a motor for driving the air compressor is less than or equal to a preset temperature; comparing, by the controller, the temperature of the motor with the preset temperature and controlling a valve on a recovery line for connecting a suction port to a discharge port of an oil pump driven by rotation force generated by the motor; and opening, by the controller, the valve when a pressure of the oil pump reaches a preset maximum pressure through operations of the motor and the oil pump, wherein oil discharged through the discharge port of the oil pump flows to the recovery line and a discharge line and the discharge line supplies oil to the rotation axis; wherein comparing the temperature of the motor with the preset temperature and controlling the valve comprises: opening the valve when the temperature of the motor is less than or equal to the preset temperature; and maintaining the valve in a closed state when the temperature of the motor is greater than the preset temperature; and wherein, when the valve is open, the discharge port and the suction port of the oil pump are connected to each other, a pressure on the line reaches an equilibrium state, the oil pump is rotated in a no-load state by rotation force of the motor, and the oil does not flow even if the oil pump is operated.
9. The method of claim 8, wherein when revolutions per minute (RPM) of the motor reach preset revolutions per minute (RPM) after the valve is open, the controller closes the valve to allow the oil pump to provide oil to a rotation axis of the motor.
10. The method of claim 8, wherein after the valve is open, the controller performs air purge of the air compressor and turning off of the motor.