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(72) Inventors:
• **YASHIMA, Kan**
Takizawa-shi
Iwate 020-0643 (JP)
• **DOI, Takashi**
Takizawa-shi
Iwate 020-0643 (JP)

(74) Representative: **Becker Kurig Straus**
Patentanwälte
Bavariastrasse 7
80336 München (DE)

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(71) Applicant: **Mikuni Corporation**
Tokyo 101-0021 (JP)

(54) **OIL SUPPLY DEVICE AND METHOD OF CONTROLLING ELECTRIC OIL PUMP**

(57) The objective of the present invention is to provide an oil supply device in which a negative pressure in a pump chamber is reduced or eliminated when an electric oil pump is shut down, thereby preventing air from entering the pump chamber and allowing oil to be supplied or recirculated smoothly. This oil supply device (10) includes: an electric oil pump (11) in which a rotary volumetric change pump (20) provided with an inner rotor (21) and an outer rotor (22) is caused to operate by means of a motor (12); and an electric oil pump controller (13) which controls the motor in such a way that, when the electric oil pump (11) is to be shut down, the rotary volumetric change pump (20) is caused to temporarily stop, after which the rotary volumetric change pump (20) is caused to rotate by a predetermined angle in the opposite direction to the direction of rotation during oil supply, and is then shut down.

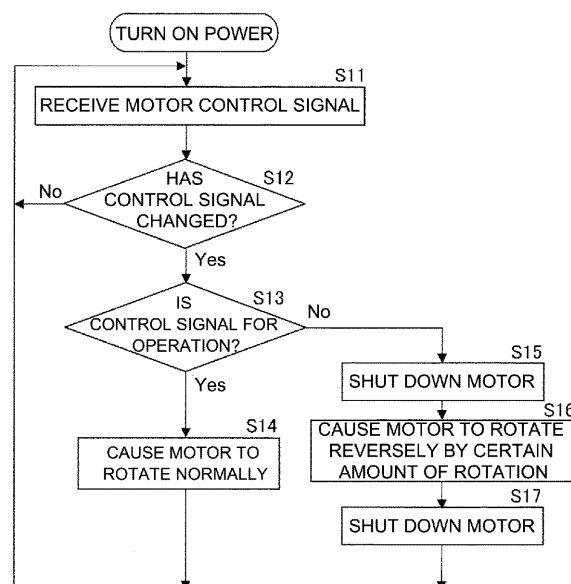


FIG. 3

Description

[Technical Field]

[0001] The present invention relates to an oil supply device in which negative pressure generated inside a pump chamber is reduced or eliminated when an electric oil pump is to be shut down, and a method of controlling an electric oil pump.

[Background Art]

[0002] Oil supply devices used for cooling a motor of a hybrid car, a generator, and the like employ an electric oil pump. Rotary volumetric change pumps are widely used as the electric oil pump (for example, refer to Patent Literature 1).

[0003] The operation of a rotary volumetric change pump is disclosed in Patent Literature 2, and the operation will be described simply using the drawings. Fig. 4 is an operation diagram for describing an operation of the rotary volumetric change pump in which a rotor rotates, in the order of (a), (b), (c), (d), and (e). Here, the drawings illustrate an example of steps of intaking, compressing, and discharging oil 40 performed in one pump chamber. Regions filled with the oil are indicated with oblique lines.

[0004] A rotary volumetric change pump 20 is provided with an inner rotor 21 and an outer rotor 22 of which the numbers of teeth are different from each other. In the structure, the inner rotor 21 serves as an external gear, the outer rotor 22 serves as an internal gear, and each of the rotors has a tooth form formed based on a trochoid curve. In Fig. 4, the inner rotor 21 has four teeth, and the outer rotor 22 has five teeth. However, this is merely an example, and the numbers of teeth may vary. A circumscribed portion of the outer rotor 22 is accommodated in a round casing (not illustrated). The centers of the inner rotor 21 and the outer rotor 22 do not coincide with each other, thereby being configured to be provided with a certain eccentricity. In such a configuration, when rotation is applied to the inner rotor 21, the outer rotor 22 rotates with a delay in the same direction. Fig. 4 illustrates an example of clockwise rotation as indicated with the arrow.

[0005] When the inner rotor 21 and the outer rotor 22 rotate, gears mesh with each other at a location where the distance between both the gears is short, and a gap is formed at a location where the distance between both the gears is long. When the gap is widened or narrowed due to such movement, the oil 40 is forcibly suctioned into the gap or is discharged from the gap, thereby allowing operation of a pump.

[0006] In Fig. 4, when the inner rotor 21 and the outer rotor 22 rotate clockwise, the oil 40 starts to be taken into a pump chamber through an intake side 31 as illustrated in Fig. 4(a), and when the inner rotor 21 and the outer rotor 22 further rotate, more oil 40 is taken in as illustrated

in Fig. 4(b).

[0007] Next, in Fig. 4(c), the oil 40 is in the maximum intake state, and therefrom a compressing step illustrated in Fig. 4(d) and thereafter is started. Lastly, as illustrated in Fig. 4(e), the oil 40 is discharged from the pump chamber through a discharge side 33 and is pressure-fed toward a cooling subject device 17.

[0008] The rotary volumetric change pump 20 is driven when a brushless DC motor or the like causes the inner rotor 21 to rotate. The operation of the motor is configured to be controlled by an electric oil pump controller in response to a command from a host controller (for example, refer to Patent Literature 1).

[0009] When the rotary volumetric change pump 20 is used, the oil 40 is taken into the pump chamber through the intake side 31 and negative pressure is generated inside the pump chamber. Particularly, when the oil temperature is low, the viscosity of the oil 40 increases and the oil 40 is unlikely to be taken in. Consequently, higher negative pressure is generated.

[0010] When being in circumstances in which the negative pressure inside the pump chamber is high as described above, if the rotary volumetric change pump 20 is shut down, there are cases where air enters the pump chamber due to the influence of the negative pressure. Empirically, it has been ascertained that when the kinematic viscosity coefficient of oil is equal to or higher than approximately 1,000 mm²/s, the negative pressure inside the pump chamber reaches a state of having dropped 30 kPa from atmospheric pressure, and air enters the pump chamber through a seal portion. When the pump is restarted in a state in which air has entered the pump chamber, it is difficult for the oil 40 to be supplied or to circulate smoothly until the oil temperature of the oil 40 sufficiently rises and the kinematic viscosity coefficient of the oil is lowered.

[0011] Actual examples, in which such circumstances are likely to be caused, include a case where after a parked vehicle is exposed to a low temperature for many hours, an engine is started, and the engine is instantly shut down. Specifically, the examples include circumstances where after a vehicle is exposed to outside air overnight in a cold region or the like, an engine is started in the early morning, and the engine is shut down before the engine is sufficiently warmed up. It is generally considered that an electric oil pump is started and shut down in response to a start and a shutdown of an engine.

[0012] In such circumstances, above all, since the vehicle has been exposed to outside air overnight, oil is in a state in which the viscosity coefficient is high compared to when being at an ordinary temperature. Accordingly, since the oil is unlikely to be taken in smoothly when the engine is started, significant negative pressure is generated on the intake side of the pump chamber compared to when being at an ordinary temperature. If the engine is shut down in a state in which such negative pressure is applied, excessively low pressure is applied to the intake side of the pump chamber compared to atmospheric

pressure. Consequently, in some cases, air enters the pump chamber through the intake side.

[Citation List]

[Patent Literature]

[0013]

[Patent Literature 1]

Japanese Unexamined Patent Application Publication No. 2014-131453

[Patent Literature 2]

Japanese Unexamined Patent Application Publication No. 2002-339874

[Summary of Invention]

[Technical Problem]

[0014] In consideration of the foregoing circumstances, an object of the present invention is to provide an oil supply device in which negative pressure inside a pump chamber is reduced or eliminated when an electric oil pump is shut down, thereby preventing air from entering the pump chamber and allowing oil to be supplied or to circulate smoothly, and a method of controlling an electric oil pump.

[Solution to Problem]

[0015] In order to achieve the object, according to the present invention, there is provided an oil supply device including an electric oil pump in which a rotary volumetric change pump provided with an inner rotor and an outer rotor is operated by a motor, and an electric oil pump controller which controls the motor such that when the electric oil pump is to be shut down, the rotary volumetric change pump is caused to temporarily stop and to rotate by a predetermined angle in a direction opposite to a rotation direction during oil supply, and the electric oil pump is then shut down.

[0016] In addition, according to the present invention, there is provided a method of controlling an electric oil pump including controlling a motor such that when the electric oil pump, in which a rotary volumetric change pump provided with an inner rotor and an outer rotor is operated by the motor, is to be shut down, the rotary volumetric change pump is caused to temporarily stop and to rotate by a predetermined angle in a direction opposite to a rotation direction during oil supply, and the electric oil pump is then shut down.

[0017] Here, in the oil supply device and the method of controlling an electric oil pump, the predetermined angle, by which the rotary volumetric change pump is caused to rotate in the direction opposite to the rotation direction during oil supply, may be 360 degrees with respect to the inner rotor. In addition, the kinematic viscosity

coefficient of oil to be supplied using the rotary volumetric change pump may be equal to or higher than 1,000 mm²/s.

5 [Advantageous Effects of Invention]

[0018] When the oil supply device and the method of controlling an electric oil pump according to the present invention are employed, it is possible to avoid a state in which negative pressure is high inside a pump chamber of the rotary volumetric change pump when the electric oil pump is shut down, and it is possible to prevent air from entering the pump chamber through an intake side. Therefore, when being actuated afterward, the electric oil pump has an effect that a sufficient amount of oil can be smoothly applied immediately after the electric oil pump is actuated.

[Brief Description of Drawings]

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[0019]

Fig. 1 is a block diagram of an oil supply device of the present invention.

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Fig. 2 illustrates a simplified diagram of an electric oil pump showing the internal structure.

Fig. 3 is a flow chart of control over a motor conducted by the electric oil pump controller.

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Fig. 4 is an operation diagram for describing an operation of a rotary volumetric change pump in which a rotor rotates, in the order of Figs. (a), (b), (c), (d), and (e).

[Description of Embodiments]

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[0020] Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings.

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[0021] Fig. 1 is a block diagram of an oil supply device 10 of the present invention. In addition, Fig. 2 illustrates a simplified diagram of an electric oil pump showing the internal structure. The oil supply device 10 of the present invention causes cooling oil 40 to circulate, thereby cooling a cooling subject device 17 such as an electric motor and a generator. The oil supply device 10 includes a rotary volumetric change pump 20 and an electric oil pump 11 provided with a motor 12 which operates the rotary volumetric change pump 20.

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[0022] Similar to rotary volumetric change pumps in the related art, the rotary volumetric change pump 20 has a structure in which an inner rotor 21 serves as an external gear, an outer rotor 22 serves as an internal gear, and each of the rotors has a tooth form formed based on a trochoid curve. A circumscribed portion of the outer rotor 22 is accommodated in a round casing. The centers of the inner rotor 21 and the outer rotor 22 do not coincide with each other, thereby being provided with a certain eccentricity. A gap between the inner rotor

21 and the outer rotor 22 becomes the inside of a pump chamber. When each of the rotors rotates, the gap which is the inside of the pump chamber is widened or narrowed, thereby allowing operation of a pump. A place, at which the gap is widened when the inner rotor 21 and the outer rotor 22 rotate, becomes an intake side 31 of the pump chamber, and a place at which the gap is narrowed becomes a discharge side 33 of the pump chamber. The intake side 31 of the pump chamber and the discharge side 33 of the pump chamber are the places which are each surrounded by the bold line in Fig. 2.

[0023] The cooling oil 40 accumulated in an oil sump of an oil pan 15 is suctioned up through an intake port 30 by the rotary volumetric change pump 20, and the cooling oil 40 is pressure-fed to the cooling subject device 17, such as the electric motor and the generator, through a discharge port 32 via an oil cooler 16. The oil cooler 16 radiates heat of the oil 40 passing through. Then, the oil 40 which has cooled the cooling subject device 17 is configured to return to the oil pan 15.

[0024] The rotary volumetric change pump 20 is operated when a movement of the motor 12 is transmitted to the inner rotor 21, and the operation of the motor 12 is controlled by an electric oil pump controller 13. A host controller 14 sends a control signal to this electric oil pump controller 13.

[0025] When the electric oil pump 11 is shut down, negative pressure is generated on the intake side 31 of the pump chamber in the rotary volumetric change pump 20. As described above, when the negative pressure increases, there is a possibility that air will enter the pump chamber. Particularly, it is known that when the viscosity coefficient of oil is high (for example, when the kinematic viscosity coefficient of oil is equal to or higher than approximately 1,000 mm²/s), since the oil is unlikely to be taken in, the negative pressure is likely to increase, thereby easily resulting in such a phenomenon.

[0026] Therefore, in the present invention, before the electric oil pump 11 is shut down, the rotary volumetric change pump 20 is caused to rotate reversely by a predetermined angle so that the negative pressure is reduced or eliminated, thereby preventing air from entering the pump chamber. The motor 12 is controlled by the electric oil pump controller 13. A step of controlling the motor 12 carried out by the electric oil pump controller 13 will be described below using the drawings. Fig. 3 is a flow chart of control over the motor 12 conducted by the electric oil pump controller 13.

[0027] First, in Step S10 at the start, work is performed to turn on power, for example, an engine of a vehicle is started.

[0028] Next, in Step S11, the electric oil pump controller 13 receives a motor control signal. Then, in Step S12, it is determined whether or not the received control signal has changed.

[0029] In Step S12, when the control signal has not changed, the state is retained as it is, and the electric oil pump controller 13 waits for reception of a control signal

again. When the control signal has changed in Step S12, the process proceeds to Step S13, and it is determined whether or not the control signal is for operation or not.

[0030] In Step S13, when it is determined that the control signal is for operation, the process proceeds to Step S14, and the motor 12 is caused to rotate normally. In Step S13, when it is determined that the control signal is not for operation, that is, in a case of a control signal for shutdown, the process proceeds to Step S15, and the motor 12 is caused to temporarily stop. Furthermore, the process proceeds to Step S16, and the motor 12 is caused to rotate reversely by a certain amount of rotation, thereby eliminating the negative pressure inside the pump chamber. Lastly, the process proceeds to Step S17, and the motor 12 is completely shut down. Naturally, the angle of the reverse rotation required to eliminate the negative pressure is determined depending on various factors such as the viscosity coefficient of oil and the shapes of rotors. Therefore, the angle varies case by case. However, in order to suppress generation of excessive negative pressure, it is considered that a sufficient effect can be obtained when the inner rotor 21 is caused to rotate reversely by 360 degrees.

[0031] In devices in the related art, when a control signal for a shutdown is received, it is usual that a motor is instantly shut down. However, as described above, the present invention is characterized in that after it is determined that a control signal is not for operation any longer, a step is performed at all times, in which the motor is caused to temporarily stop, the motor is caused to rotate reversely, and the motor is then completely shut down. If it is intended to determine whether or not the motor is to be caused to rotate reversely in accordance with the magnitude of negative pressure inside the pump chamber, the oil pressure has to be measured, so that there is a need to separately provide a device therefor. However, in the present invention, the motor is caused to rotate reversely at all times, and the angle of the reverse rotation is set in advance within a range in which a sufficient effect can be obtained and the circulation of oil is not affected. Accordingly, even though no extra device is provided, it is possible to achieve a sufficient effect.

[0032] In this manner, if air can be prevented from entering the pump chamber by reducing or eliminating the negative pressure, when the pump is restarted, the pump chamber is in a state of being filled with oil. Therefore, even before the oil temperature sufficiently rises and the kinematic viscosity coefficient of the oil is lowered, it is possible to achieve an effect that the oil sufficiently circulates and the oil can be smoothly discharged.

[0033] The configuration of the present invention is not limited to only oil pumps used for cooling a device and can also be widely utilized in devices in which fluid having a high viscosity coefficient is supplied and circulates.

[Reference Signs List]

[0034]

10 Oil supply device
 11 Electric oil pump
 12 Motor
 13 Electric oil pump controller
 14 Host controller
 20 Rotary volumetric change pump
 21 Inner rotor
 22 Outer rotor
 30 Intake port
 31 Intake side of pump chamber
 32 Discharge port
 33 Discharge side of pump chamber
 40 Oil

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tary volumetric change pump is caused to rotate in the direction opposite to the rotation direction during oil supply, is 360 degrees with respect to the inner rotor.

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6. The method of controlling an electric oil pump according to claim 4 or 5, wherein a kinematic viscosity coefficient of oil to be supplied using the rotary volumetric change pump is equal to or higher than 1,000 mm²/s.

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Claims

1. An oil supply device comprising:

an electric oil pump in which a rotary volumetric change pump provided with an inner rotor and an outer rotor is operated by a motor; and an electric oil pump controller which controls the motor such that when the electric oil pump is to be shut down, the rotary volumetric change pump is caused to temporarily stop and to rotate by a predetermined angle in a direction opposite to a rotation direction during oil supply, and the electric oil pump is then shut down.

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2. The oil supply device according to claim 1, wherein the predetermined angle, by which the rotary volumetric change pump is caused to rotate in the direction opposite to the rotation direction during oil supply, is 360 degrees with respect to the inner rotor.

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3. The oil supply device according to claim 1 or 2, wherein a kinematic viscosity coefficient of oil to be supplied using the rotary volumetric change pump is equal to or higher than 1,000 mm²/s.

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4. A method of controlling an electric oil pump comprising:

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controlling a motor such that when the electric oil pump, in which a rotary volumetric change pump provided with an inner rotor and an outer rotor is operated by the motor, is to be shut down, the rotary volumetric change pump is caused to temporarily stop and is caused to rotate by a predetermined angle in a direction opposite to a rotation direction during oil supply, and the electric oil pump is then stopped.

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5. The method of controlling an electric oil pump according to claim 3, wherein the predetermined angle, by which the ro-

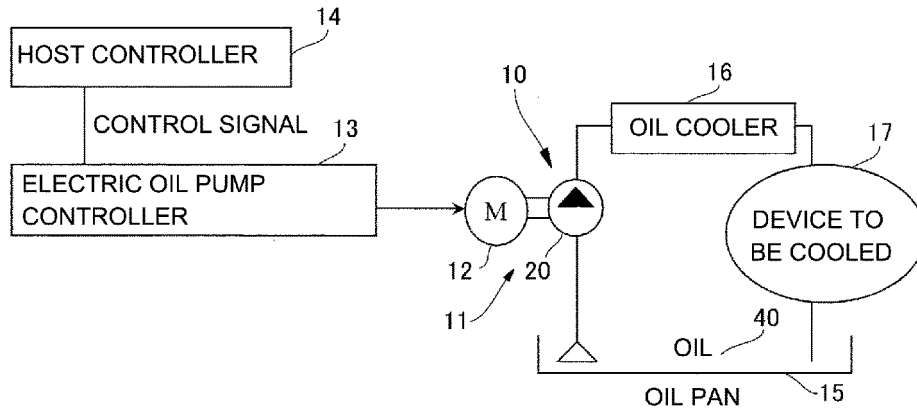


FIG. 1

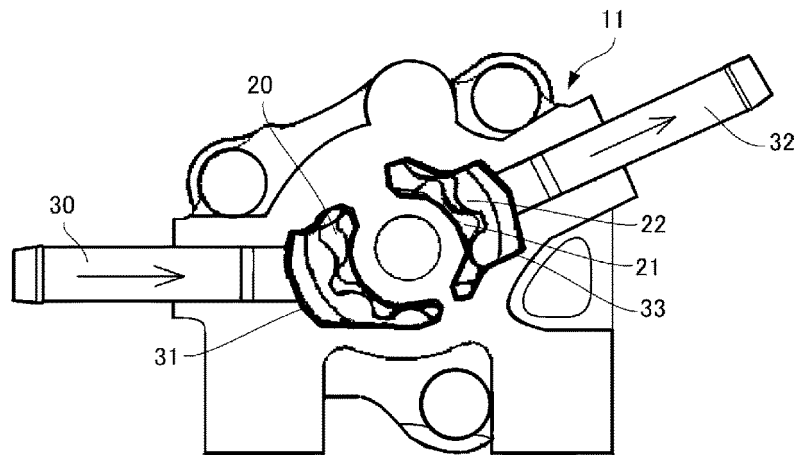


FIG. 2

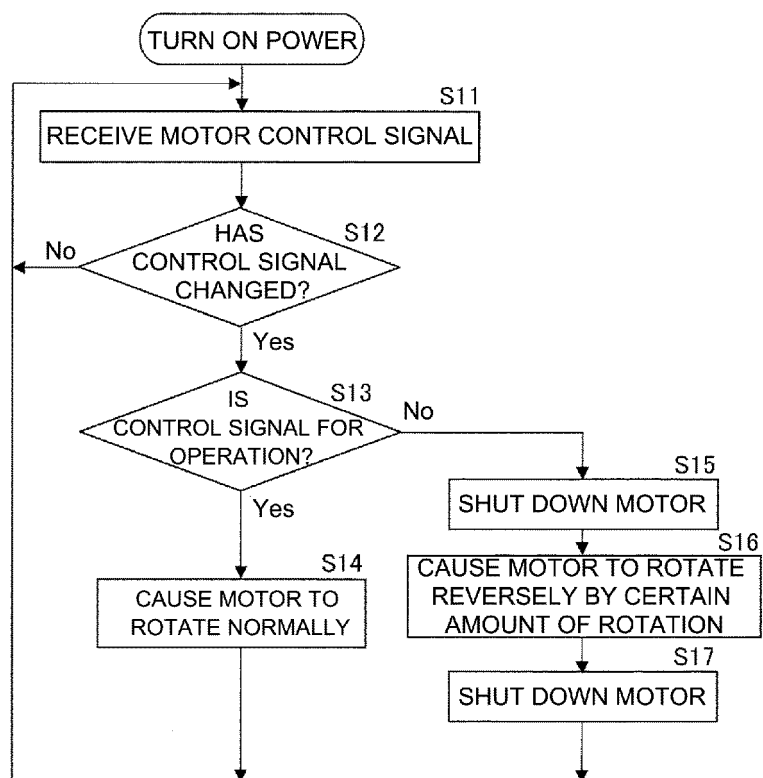


FIG. 3

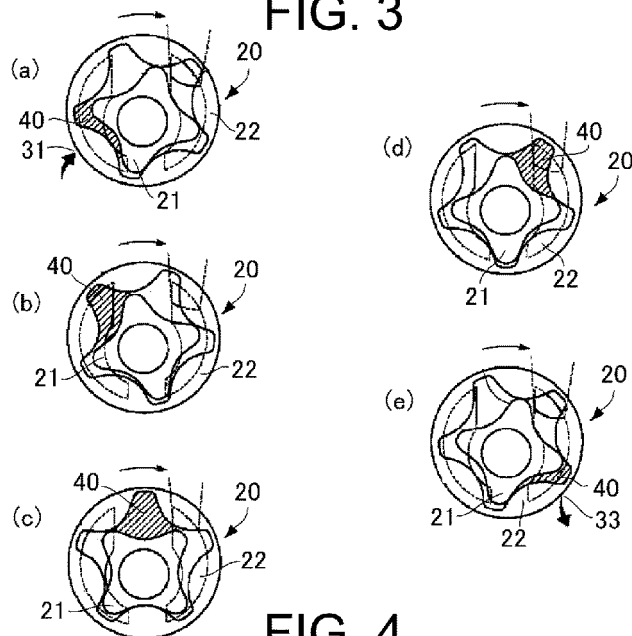


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/064163

A. CLASSIFICATION OF SUBJECT MATTER

F04C14/06(2006.01)*i*, *F04B49/02*(2006.01)*i*, *F04C2/10*(2006.01)*i*, *F04C15/00*(2006.01)*i*, *F04C15/06*(2006.01)*i*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04C14/06, *F04B49/02*, *F04C2/10*, *F04C15/00*, *F04C15/06*

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016
Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 4-29774 A (Takahiro HOSHINO), 31 January 1992 (31.01.1992), page 2, upper right column, line 7 to page 4, lower left column, line 12; fig. 1 to 5 (Family: none)	1-6
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 65620/1992 (Laid-open No. 30482/1994) (Kabushiki Kaisha Taisei Tekkosho), 22 April 1994 (22.04.1994), paragraphs [0009] to [0016]; fig. 1 to 2 (Family: none)	1-6

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

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/064163

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-291962 A (Komatsu Ltd.), 08 November 2007 (08.11.2007), paragraphs [0001] to [0007]; fig. 8 to 9 (Family: none)	1-6
Y	JP 9-60594 A (Daido Machinery Corp.), 04 March 1997 (04.03.1997), paragraphs [0001] to [0002] (Family: none)	1-6
A	JP 11-164584 A (Toshiba Corp.), 18 June 1999 (18.06.1999), paragraphs [0020] to [0045]; fig. 1 to 7 (Family: none)	1-6

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2014131453 A [0013]
- JP 2002339874 A [0013]