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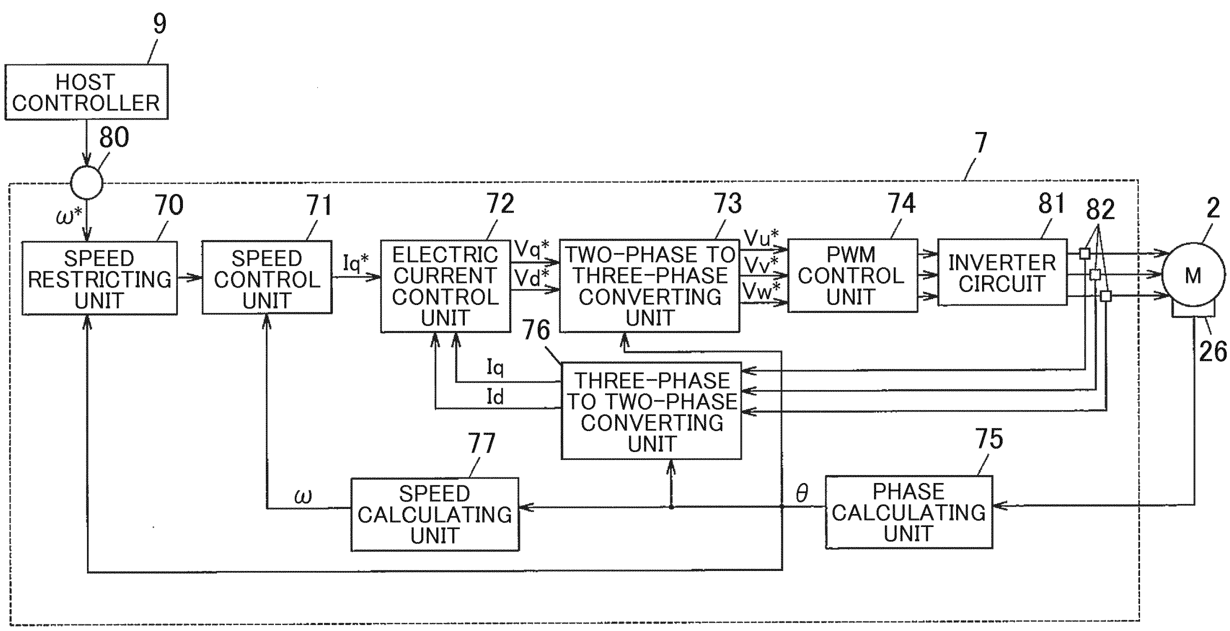
(54) ELECTRIC GEAR PUMP

(57) An electric gear pump includes: an electric motor 2 in which a supply of motor current rotates a motor shaft 21; a driving gear 3 that is coupled to the motor shaft 21 to be rotated; a driven gear 4 that is rotated by meshing between outer teeth 31 of the driving gear 3 and outer teeth 41 of the driven gear 4; and a control unit 7 that outputs motor current to control the electric motor 2. When the electric motor 2 that stopped is started and when the rotation of the electric motor 2 is reversed, the control unit 7 executes rotational speed restricting control that suppresses the motor current to restrict the rotational speed of the electric motor 2 at least during an idling period, the idling period being a period until the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other in a rotational direction of the electric motor 2. Selected drawing:

FIG. 5



EP 3 521 623 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an electric gear pump including an electric motor as a driving source.

2. Description of the Related Art

[0002] Conventionally, an electric gear pump including a driving gear that is driven by an electric motor and a driven gear that is rotated by rotation of the driving gear is used for various purposes. If this kind of gear pump is installed in a vehicle for example, noise may be generated by gear teeth colliding with each other when the gear pump is starting to move or when a rotating direction of the gear pump is reversed.

[0003] In a gear pump according to Japanese Patent Application Publication No. 2001-289180 (JP 2001-289180 A), among a pair of gears, both or one of the gears are provided with fairly thick abraded layers on engaging tooth surfaces. A part of the abraded layer is abraded at the beginning of usage so that almost no backlash occurs between the pair of gears, and thus the noise is reduced. The abraded layer is a relatively soft solid lubricant made of molybdenum disulfide or tetrafluoroethylene, for example.

[0004] In the gear pump according to JP 2001-289180 A, the noise is expected to be reduced by controlling backlash to generally zero. However, since the abraded layer needs to be formed of a soft solid lubricant, abrasion may progress even after the abraded layer is abraded at the beginning of usage, depending on a discharge pressure etc. In this case, the backlash increases and noise may be generated due to tooth contact when the gear pump is starting to move or when a rotating direction of the gear pump is reversed.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide an electric gear pump that includes an electric motor, a driving gear that is driven by the electric motor, and a driven gear that is rotated by rotation of the driving gear and that is able to suppress noise even when there is a backlash between the driving gear and the driven gear.

[0006] An electric gear pump according to an aspect of the present invention includes:

an electric motor in which a supply of motor current rotates a motor shaft;
a driving gear that is coupled to the motor shaft to be rotated;
a driven gear that is rotated by meshing between gear teeth of the driving gear and gear teeth of the driven gear;
a pump housing that houses the driving gear and the driven gear; and
a control unit that outputs the motor current to control the electric motor.

When the electric motor that stopped is started and when the rotation of the electric motor is reversed, the control unit executes rotational speed restricting control that suppresses the motor current to restrict a rotational speed of the electric motor at least during an idling period, the idling period being a period until a gear tooth of the driving gear and a gear tooth of the driven gear abut against each other in a rotational direction of the electric motor.

[0007] According to the above aspect, in an electric gear pump that includes an electric motor, a driving gear that is driven by the electric motor, and a driven gear that is rotated by rotation of the driving gear, it is possible to suppress noise even when there is a backlash between the driving gear and the driven gear.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing and further features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a sectional view of an external gear pump according to an embodiment of the present invention;
FIG. 2 is an exploded perspective view of a pump portion of the external gear pump;
FIG. 3 is an explanatory view illustrating an operation state of an electric motor during positive rotation;
FIG. 4 is an explanatory view illustrating an operation state of the electric motor during reverse rotation;
FIG. 5 is a schematic block diagram of a configuration example of a control unit; and
FIG. 6 is a schematic block diagram of a configuration example of the control unit according to a modification.

DETAILED DESCRIPTION OF EMBODIMENTS

[0009] An embodiment of the present invention will be described with reference to FIGS. 1 to 5.

[0010] FIG. 1 is a sectional view of an external gear pump according to an embodiment of the present invention. FIG. 2 is an exploded perspective view of a pump portion of the external gear pump. FIG. 3 is an explanatory view of an operation state of the external gear pump during positive rotation of an electric motor. FIG. 4 is an explanatory view of an operation state of the external gear pump during positive rotation of the electric motor.

[0011] An external gear pump 1 includes: an electric motor 2 in which a supply of motor current rotates a motor shaft; a driving gear 3 that is coupled to the motor shaft

21 to be rotated; a driven gear 4 that is rotated by rotation of the driving gear 3; first and second side plates 51, 52 made from resin; sliding bearings 53 to 56 held by the first and second side plates 51, 52; a pump housing 6 that houses the driving gear 3 and the driven gear 4 with the first and second side plates 51, 52 and the sliding bearings 53 to 56; and a control unit 7 that outputs motor current to control the electric motor 2.

[0012] The external gear pump 1 is installed in a vehicle and sucks hydraulic oil for operation of on-vehicle devices from a suction side and discharges the hydraulic oil to a discharge side with the rotation of the driving gear 3 and the driven gear 4. Examples of the on-vehicle devices include a transmission and a power steering device. In FIG. 3, rotation directions of the driving gear 3 and the driven gear 4 when the electric motor 2 is positively rotated are indicated by arrows A_1, A_2, and a suction direction and a discharge direction of the hydraulic oil are indicated by white block arrows. In FIG. 4, rotation directions of the driving gear 3 and the driven gear 4 when the electric motor 2 is rotated in reverse are indicated by arrows B_1, B_2, and a suction direction and a discharge direction of the hydraulic oil are indicated by white block arrows.

[0013] The electric motor 2 includes: a motor housing 20; a motor shaft 21; an annular stator 22 held by the motor housing 20; a rotor 23 disposed inside the stator 22; rolling bearings 24, 25 that hold the motor shaft 21; and a rotation angle sensor 26 that detects a rotation angle of the motor shaft 21 with respect to the stator 22.

[0014] The stator 22 includes: an iron core 221; an insulator 222 attached to the iron core 221; and a winding 223 that is wound around the insulator 222. Motor current is supplied to the winding 223 from the control unit 7. The rotor 23 has a core 231 fixed to the motor shaft 21 and a plurality of permanent magnets 232 attached to an outer peripheral surface of the core 231. The rotation angle sensor 26 has a permanent magnet 261 that is fixed to a flange 211 provided on one end portion of the motor shaft 21 and that has a plurality of magnetic poles, and a magnetic sensor 262 that is fixed to the motor housing 20 and that detects a magnetic field of each magnetic pole of the permanent magnet 261. Detection signals of the magnetic sensor 262 are transmitted to the control unit 7.

[0015] The driving gear 3 integrally includes: a gear portion 32 provided with a plurality of outer teeth 31; a first shaft portion 33 that protrudes from a center portion of the gear portion 32 to one side in an axial direction; and a second shaft portion 34 that protrudes from the center portion of the gear portion 32 to the other side in the axial direction. An end portion 331 of the first shaft portion 33 is coupled to the motor shaft 21 of the electric motor 2 via a coupling (shaft coupling) 27. The electric motor 2 is supplied with motor current from the control unit 7 and generates torque that rotationally drives the driving gear 3.

[0016] Similar to the driving gear 3, the driven gear 4 integrally includes: a gear portion 42 provided with a plurality of outer teeth 41; a first shaft portion 43 that protrudes from a center portion of the gear portion 42 to one side in an axial direction; and a second shaft portion 44 that protrudes from the center portion of the gear portion 42 to the other side in the axial direction. The outer teeth 31 of the driving gear 3 and the outer teeth 41 of the driven gear 4 function as gear teeth of the present invention and are meshed with each other in a pump chamber 600 of the pump housing 6. The driven gear 4 is rotated by meshing with the driving gear 3, in which the outer teeth 31, 41 of the driving gear 3 and the driven gear 4 mesh with each other.

[0017] The pump housing 6 includes a tubular portion 60 having an inner surface 60a that faces top lands 31a, 41a (see FIG. 3) of the outer teeth 31, 41 of the driving gear 3 and the driven gear 4, and first and second side plate portions 61, 62 that have a flat plate shape and that are arranged so as to hold the tubular portion 60 therebetween in an axial direction. The tubular portion 60, the first and second side plate portions 61, 62, and the motor housing 20 are fastened by a plurality of bolts 63.

[0018] First and second flow holes 601, 602 in which hydraulic oil flows through are formed in the tubular portion 60. When the electric motor 2 is positively rotated, hydraulic oil that is sucked into the pump chamber 600 through the first flow hole 601 is discharged through the second flow hole 602. When the electric motor 2 is reversely rotated, hydraulic oil that is sucked into the pump chamber 600 through the second flow hole 602 is discharged through the first flow hole 601.

[0019] An insertion hole 611 for inserting the first shaft portion 33 of the driving gear 3 is formed in the first side plate portion 61. A sealing member 64 is disposed between an inner peripheral surface of the insertion hole 611 and an outer peripheral surface of the first shaft portion 33. The first side plate 51 is disposed between the gear portions 32, 42 of the driving gear 3 and the driven gear 4 and the first side plate portion 61. The second side plate 52 is disposed between the gear portions 32, 42 of the driving gear 3 and the driven gear 4 and the second side plate portion 62.

[0020] An insertion hole 511 for inserting the first shaft portion 33 of the driving gear 3 and an insertion hole 512 for inserting the first shaft portion 43 of the driven gear 4 are formed in the first side plate 51. The sliding bearing 53 that supports the first shaft portion 33 of the driving gear 3 is fitted into the insertion hole 511. The sliding bearing 54 that supports the first shaft portion 43 of the driven gear 4 is fitted into the insertion hole 512. A groove 513 is formed on a surface of the first side plate 51 that faces the first side plate portion 61. A side seal 65 that is made of an elastic body such as rubber is housed in the groove 513.

[0021] An insertion hole 521 for inserting the second shaft portion 34 of the driving gear 3 and an insertion hole 522 for inserting the second shaft portion 44 of the driven gear 4 are formed in the second side plate 52. The sliding bearing 55 that supports the second shaft portion 34 of the driving gear 3 is fitted into the insertion hole 521. The sliding bearing 56 that supports the second shaft portion 44 of the driven gear 4 is fitted into the insertion hole 522. A groove 523 is formed on a surface of the second side plate 52 that faces the second side plate portion 62. A side seal 66 that is made of an elastic body such as rubber is housed in the groove 523.

[0022] In the external gear pump 1 configured as described above, the driving gear 3 is driven to be rotated by the electric motor 2. The outer teeth 41 of the driven gear 4 are meshed with the outer teeth 31 of the driving gear 3, whereby the driven gear 4 rotates in the direction reverse to the rotating direction of the driving gear 3. An oil chamber C is formed between two outer teeth 31 of the driving gear 3 which are circumferentially adjacent to each other, and between two outer teeth 41 of the driven gear 4 which are circumferentially adjacent to each other. Hydraulic oil sucked through the first flow hole 601 or the second flow hole 602 is moved from a low pressure chamber side to a high pressure chamber side of the pump chamber 600 through the oil chambers C, with the rotation of the driving gear 3 and the driven gear 4. On the high pressure chamber side, pressure of hydraulic oil is increased by a change in volume resulting from the outer teeth 31 of the driving gear 3 meshing with the outer teeth 41 of the driven gear 4.

[0023] When the electric motor 2 positively rotates, a tooth surface 31b on a front side of the outer teeth 31 of the driving gear 3 in the rotating direction (direction of arrow A_1) is in contact with a tooth surface 41b on a rear side of the outer teeth 41 of the driven gear 4 in the rotating direction (direction of arrow A_2), as shown in FIG. 3. A contact portion of the tooth surface 31b and the tooth surface 41b is a seal portion S that defines the low pressure chamber side and the high pressure chamber side. When the electric motor 2 positively rotates, the first flow hole 601 side of the seal portion S is the low pressure chamber side and the second flow hole 602 side of the seal portion S is the high pressure chamber side. A gap G is formed between the outer tooth 41 of the driven gear 4 that forms the seal portion S and the outer tooth 31 of the driving gear 3 on a front side of that outer tooth 41 in the rotational direction.

[0024] In contrast, when the electric motor 2 reversely rotates, a tooth surface 31c on a front side of the outer teeth 31 of the driving gear 3 in the rotating direction (direction of arrow B_1) is in contact with a tooth surface 41c on a rear side of the outer teeth 41 of the driven gear 4 in the rotating direction (direction of arrow B_2), as shown in FIG. 4. A contact portion of the tooth surface 31c and the tooth surface 41c is the seal portion S that defines the low pressure chamber side and the high pressure chamber side. The second flow hole 602 side of the seal portion S is the low pressure chamber side and the first flow hole 601 side of the seal portion S is the high pressure chamber side. The gap G is formed between the outer tooth 41 of the driven gear 4 that forms the seal portion S and the outer tooth 31 of the driving gear 3 on a front side of that outer tooth 41 in the rotational direction.

[0025] When the rotational direction of the electric motor 2 is reversed, that is, when the rotational direction switches from the positive rotation to the reverse rotation and when the rotational direction switches from the reverse rotation to the positive rotation, a noise may be generated depending on a rotational speed of the driving gear 3. The noise is a collision noise that is generated when the gap G is shortened due to the rotation of the driving gear 3 so that the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other. If the external gear pump 1 is installed in a vehicle for example, the noise may cause a driver or passenger to feel uncomfortable. The noise may also be generated at the time of starting the electric motor 2 that stopped with the rotation of the motor shaft 21 being stopped.

[0026] In the present embodiment, when the electric motor 2 that stopped is started and when the rotation of the electric motor 2 is reversed, the control unit 7 executes rotational speed restricting control that suppresses the motor current to restrict the rotational speed of the electric motor 2 at least during an idling period, and thus the generation of the noise is suppressed. The idling period is a period until the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other in the rotational direction of the electric motor 2 (rotational direction of the driving gear 3). The idling period is a period from the time when the electric motor 2 is started or when the rotational direction is reversed to the time when the gap G is shortened and the outer tooth 31 of the driving gear 3 abuts against the outer tooth 41 of the driven gear 4. Hereinafter, a configuration and a control method of the control unit 7 will be described.

[0027] FIG. 5 is a schematic block diagram of a configuration example of the control unit 7. The control unit 7 functions as a speed restricting unit 70, a speed control unit 71, an electric current control unit 72, a two-phase to three-phase converting unit 73, a PWM control unit 74, a phase calculating unit 75, a three-phase to two-phase converting unit 76, and a speed calculating unit 77, by causing a CPU to execute previously stored programs. The CPU of the control unit 7 executes each process described below for every predetermined operation period. The operation period is 5 ms, for example.

[0028] The control unit 7 includes a receiving circuit 80 that receives a rotational speed command value ω^* from a host controller 9, an inverter circuit 81 that has a plurality of switching elements, and three electric current sensors 82 that individually detect a corresponding one of phase currents of a U phase, a V phase, and a W phase that are output from the inverter circuit 81.

[0029] The receiving circuit 80, the speed restricting unit 70, the speed control unit 71, and the electric current control unit 72 function as a receiver, a speed restrictor, a speed controller, and an electric current restrictor, respectively, of the present invention. The speed control unit 71 and the electric current control unit 72 function as to a feedback controller of the present invention.

[0030] The control unit 7 receives the rotational speed command value ω* of the electric motor 2 from the host controller 9 through communication in the receiving circuit 80. The speed restricting unit 70 is able to restrict the rotational speed command value ω* received in the receiving circuit 80 to be equal to or less than a prescribed value. Specifically, when the electric motor 2 that stopped is started and when the rotation of the electric motor is reversed, the speed restricting unit 70 restricts the rotational speed command value ω* to be equal to or less than the prescribed value, at least until the idling period passes and the driving gear 3 begins to rotate as the driving gear 3 rotates. The speed restricting unit 70 then releases the restriction. That is, the speed restricting unit 70 executes the rotational speed restricting control by restricting the received rotational speed command value ω* to be equal to or less than the prescribed value during the idling period.

[0031] The prescribed value is a value set so that rotational energy of the driving gear 3 when the gap G becomes zero and the idling period ends (when the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other) is smaller than rotational energy with which collision noise at a volume level that can be heard by the driver of the vehicle etc. is generated. When E represents rotational energy of the driving gear 3, m represents mass of the driving gear 3, and v represents rotational speed of the driving gear 3, the rotational energy of the driving gear 3 can be obtained by the following formula (1).

$$E = 1/2 \times m \times v^2 \quad ...(1)$$

[0032] In other words, an upper limit value of v is set as the prescribed value described above such that E < Emin is satisfied, provided that a lower limit value of the rotational energy of the driving gear 3 that generates collision noise at a volume level that can be heard by the driver of the vehicle etc. is Emin. The prescribed value is stored in a nonvolatile memory of the control unit 7 as a constant in the program.

[0033] The speed control unit 71 and the electric current control unit 72 perform feedback control of the motor current so that the electric motor 2 rotates at a rotational speed based on the rotational speed command value ω* received from the receiving circuit 80 or the rotational speed command value ω* restricted to be equal to or less than the prescribed value by the speed restricting unit 70.

[0034] The speed control unit 71 calculates an electric current command value that is a target value of the motor current, based on the rotational speed command value ω* received from the receiving circuit 80 or the rotational speed command value ω* restricted to be equal to or less than the prescribed value by the speed restricting unit 70. More specifically, the speed control unit 71 calculates a q-axis electric current command value Iq* that is a target value of a torque component of the motor current that is supplied to the electric motor 2. This is performed by proportionally integrating a difference (ω* - ω) between the rotational speed command value ω* and an actual rotational speed ω that indicates the actual rotational speed of the electric motor 2 calculated by the speed calculating unit 77 described below.

[0035] The electric current control unit 72 calculates a voltage command value that is a target value of a voltage that should be applied to the electric motor 2, based on the q-axis electric current command value Iq* calculated by the speed control unit 71. More specifically, proportional integral calculation is performed, based on the q-axis electric current command value Iq* and a q-axis electric current detection value Iq and a d-axis electric current detection value Id calculated by the three-phase to two-phase converting unit 76 described below. Thus, a q-axis voltage command value Vq* and a d-axis voltage command value Vd* are calculated.

[0036] The two-phase to three-phase converting unit 73 converts the q-axis voltage command value Vq* and the d-axis voltage command value Vd* to voltage command values Vu*, Vv*, and Vw* of the U phase, the V phase, and the W phase, using a rotation angle θ that is calculated by the phase calculating unit 75 described below. The PWM control unit 74 generates a U-phase PWM control signal, a V-phase PWM control signal, and a W-phase PWM control signal with duty cycles corresponding to the three voltage command values Vu*, Vv*, and Vw*, and supplies the signals to the inverter circuit 81. The inverter circuit 81 turns on or turns off the switching elements based on the PWM control signal of each phase and supplies three-phase alternating currents to the electric motor 2 as the motor current.

[0037] The phase calculating unit 75 calculates the rotation angle θ of the motor shaft 21 of the electric motor 2, based on the detection signal of the rotation angle sensor 36 of the electric motor 2. The three-phase to two-phase converting unit 76 uses the rotation angle θ calculated by the phase calculating unit 75 to convert the phase currents of the phases obtained by the three electric current sensors 82 to the q-axis electric current detection value Iq and the d-axis electric current detection value Id. It is possible to omit one sensor of the three electric current sensors 82, based on a relationship in which the sum of the phase currents of the U phase, the V phase, and the W phase is zero. The speed calculating unit 77 calculates the actual rotational speed ω of the electric motor 2 for every prescribed operation period, based on a difference between the rotation angle θ of the previous operation period and the rotational speed θ of the present operation period.

[0038] Suppose the rotational speed command value ω* received from the receiving circuit 80 changes from a positive value (ω*> 0) to a negative value (ω*< 0), or the rotational speed command value ω* changes from zero to a value other than zero. In such a case, the speed restricting unit 70 starts a process of restricting the rotational speed command value ω* to be equal to or less than the prescribed value (rotational speed restricting control), and when the speed restricting unit 70 determines that the idling period ends, the process is terminated.

[0039] The end of the idling period is determined when a rotational amount of the electric motor 2 from the time when the process of restricting the rotational speed command value ω* to be equal to or less than the prescribed value is started, becomes equal to or more than a threshold. The threshold is set based on a maximum value of the gap G, for example. The way of determining the end of the idling period is not limited to the way described above. The end of the idling period may be determined based on an elapsed time from the time the process has started. The end of the idling period may be determined when there is an increase in the motor current resulting from an increase of a load, due to the driven gear 4 starting to rotate as the driving gear 3 rotates. That is, since only the driving gear 3 rotates with the rotation of the motor shaft 21 of the electric motor 2 during the idling period, a load of the electric motor 2 is small and the driving gear 3 is more easily accelerated even with a small motor current. However, since the load of the electric motor 2 is increased when the idling period ends, the motor current is increased due to feedback control. Thus, with the increase of the motor current, it is possible to determine that the idling period has ended.

[0040] When the idling period ends, a speed difference between the rotational speed command value ω* from the host controller 9 and the actual rotational speed ω is large. Thus, when the process of restricting the rotational speed command value ω* by the speed restricting unit 70 is released, the motor current may be increased rapidly. However, since the driven gear 4 has started to rotate with the driving gear 3 at that point in time, a large collision noise is not generated due to the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abutting against each other, even if the motor current is increased rapidly.

[0041] According to the embodiment of the present invention described above, it is possible to suppress noise of the external gear pump 1 even when there is a backlash between the driving gear 3 and the driven gear 4. Since the noise during the reversal of rotation or start of the electric motor 2 is suppressed with the control of the control unit 7, it is possible to have a noise reduction effect without increasing costs.

[0042] Next, a modification of the embodiment of the present invention will be described with reference to FIG. 6. FIG. 6 is a schematic block diagram of a configuration example of the control unit 7 according to the modification.

[0043] In the embodiment described above, the case in which the rotational speed restricting control is performed by the speed restricting unit 70 was described. In the modification below, the case in which the rotational speed restricting control is performed by restricting the electric current command value or the voltage command value calculated by the speed control unit 71 (speed controller) or the electric current control unit 72 (electric current controller) during the idling period will be described. In FIG. 6, components with the same functions as the components described with reference to FIG. 5 are denoted with the same symbols as in FIG. 5, and descriptions of the same content will be omitted.

[0044] In the modification, the speed control unit 71 obtains the rotational speed command value ω* received by the receiving circuit 80 and calculates the q-axis electric current command value Iq*. Suppose the rotational speed restricting control is performed by restricting the electric current command value calculated by the speed control unit 71. In such as case, the q-axis electric current command value Iq* calculated by the speed control unit 71 during the idling period is restricted by an electric current restricting unit 710 to be equal to or less than a prescribed value, and is transmitted to the electric current control unit 72. A function of the electric current restricting unit 710 is realized by the CPU executing a program for example, as the electric current controller of the control unit 7. The prescribed value used when the electric current restricting unit 710 restricts the q-axis electric current command value Iq* is a value that is set so that the collision noise that is generated when the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other is not heard by the driver etc., for example.

[0045] Suppose the rotational speed restricting control is performed by restricting the voltage command value calculated by the electric current control unit 72. In such a case, the q-axis voltage command value Vq* and the d-axis voltage command value Vd* calculated by the electric current control unit 72 during the idling period is restricted by a voltage restricting unit 720 to be equal to or less than a prescribed value, and is transmitted to the two-phase to three-phase converting unit 73. A function of the voltage restricting unit 720 is realized by the CPU executing a program for example, as a voltage restrictor of the control unit 7. The prescribed value used when the voltage restricting unit 720 restricts the q-axis voltage command value Vq* and the d-axis voltage command value Vd* is a value that is set so that the collision noise that is generated when the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other is not heard by the driver etc., for example.

[0046] In FIG. 6, both the electric current restricting unit 710 and the voltage restricting unit 720 are illustrated for convenience. However, when the electric current restricting unit 710 is provided, the voltage restricting unit 720 is unnecessary and when the voltage restricting unit 720 is provided, the electric current restricting unit 710 is unnecessary. That is, either the electric current restricting unit 710 or the voltage restricting unit 720 should be provided in the control unit 7.

[0047] Similar to the embodiment described above, it is also possible to suppress the noise of the external gear pump 1 without increasing costs with the modification described above.

[0048] The present invention may be implemented in various modified embodiments without departing from the spirit and scope of the present invention. For example, in the embodiment and the modification described above, the cases where the functions of the units are realized by the CPU of the control unit 7 executing the programs are described. However, some functions or all functions of the units may be realized by hardware such as an application specific integrated circuit (ASIC). Mechanical configurations of the external gear pump 1 illustrated in FIGS. 1 to 4 are merely exemplary. As long as an electric gear pump is configured so that a driving gear is driven by an electric motor and a driven gear is rotated by meshing with the driving gear, in which the gear teeth mesh with each other, the present invention may be applied to electric gear pumps with various mechanical configurations.

[0049] An electric gear pump includes: an electric motor 2 in which a supply of motor current rotates a motor shaft 21; a driving gear 3 that is coupled to the motor shaft 21 to be rotated; a driven gear 4 that is rotated by meshing between outer teeth 31 of the driving gear 3 and outer teeth 41 of the driven gear 4; and a control unit 7 that outputs motor current to control the electric motor 2. When the electric motor 2 that stopped is started and when the rotation of the electric motor 2 is reversed, the control unit 7 executes rotational speed restricting control that suppresses the motor current to restrict the rotational speed of the electric motor 2 at least during an idling period, the idling period being a period until the outer tooth 31 of the driving gear 3 and the outer tooth 41 of the driven gear 4 abut against each other in a rotational direction of the electric motor 2.

Claims

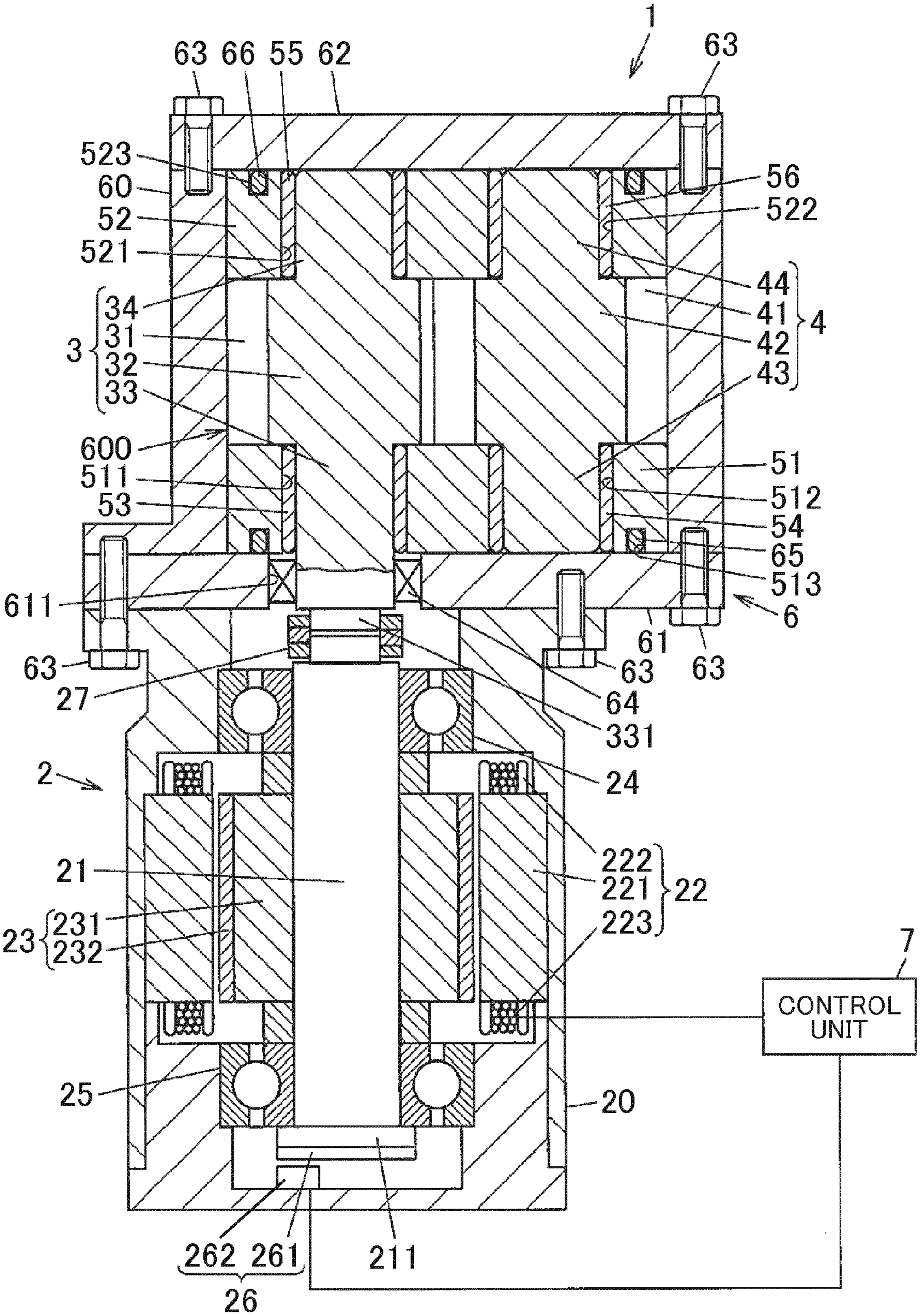
1. An electric gear pump comprising:

    an electric motor in which a supply of motor current rotates a motor shaft;
    a driving gear that is coupled to the motor shaft to be rotated;
    a driven gear that is rotated by meshing between gear teeth of the driving gear and gear teeth of the driven gear;
    a pump housing that houses the driving gear and the driven gear; and
    a control unit that outputs the motor current to control the electric motor; wherein
    when the electric motor that stopped is started and when the rotation of the electric motor is reversed, the control unit executes rotational speed restricting control that suppresses the motor current to restrict a rotational speed of the electric motor at least during an idling period, the idling period being a period until a gear tooth of the driving gear and a gear tooth of the driven gear abut against each other in a rotational direction of the electric motor.

2. The electric gear pump according to claim 1, wherein the control unit includes: a receiver that receives a rotational speed command value of the electric motor; a speed restrictor that is able to restrict the received rotational speed command value to be equal to or less than a prescribed value; and a feedback controller that performs feedback control of the motor current so that the electric motor rotates at a rotational speed according to the received rotational speed command value or the rotational speed command value restricted by the speed restrictor, and
the speed restrictor executes the rotational speed restricting control by restricting the received rotational speed command value to be equal to or less than the prescribed value during the idling period.

3. The electric gear pump according to claim 1, wherein the control unit has a receiver that receives a rotational speed command value of the electric motor, a speed controller that calculates an electric current command value that is a target value of the motor current based on the rotational speed command value, and
an electric current controller that calculates a voltage command value that is a target value of a voltage to be applied to the electric motor based on the calculated electric current command value, and
the rotational speed restricting control is a control that restricts the electric current command value or the voltage command value calculated by the speed controller or the electric current controller during the idling period.

FIG. 1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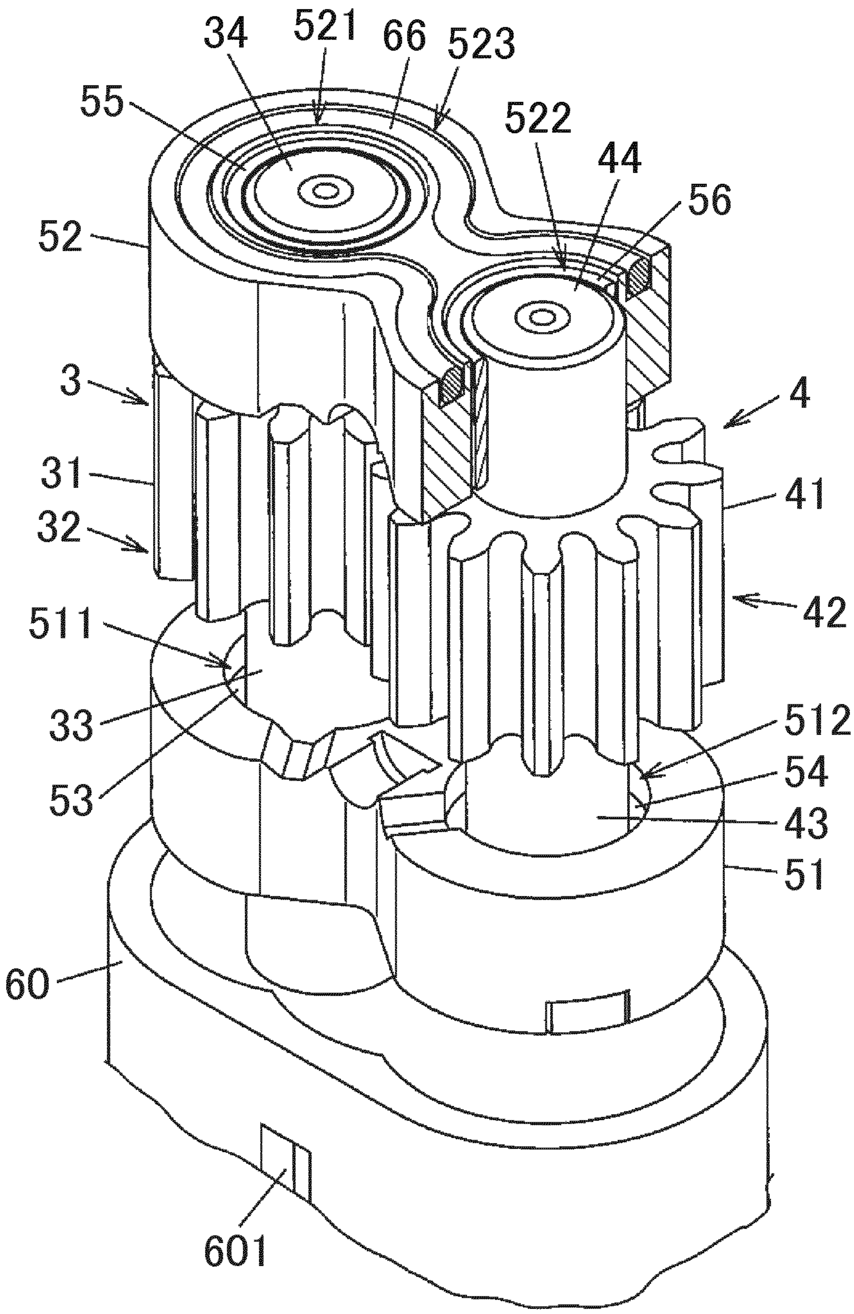
211

F I G . 2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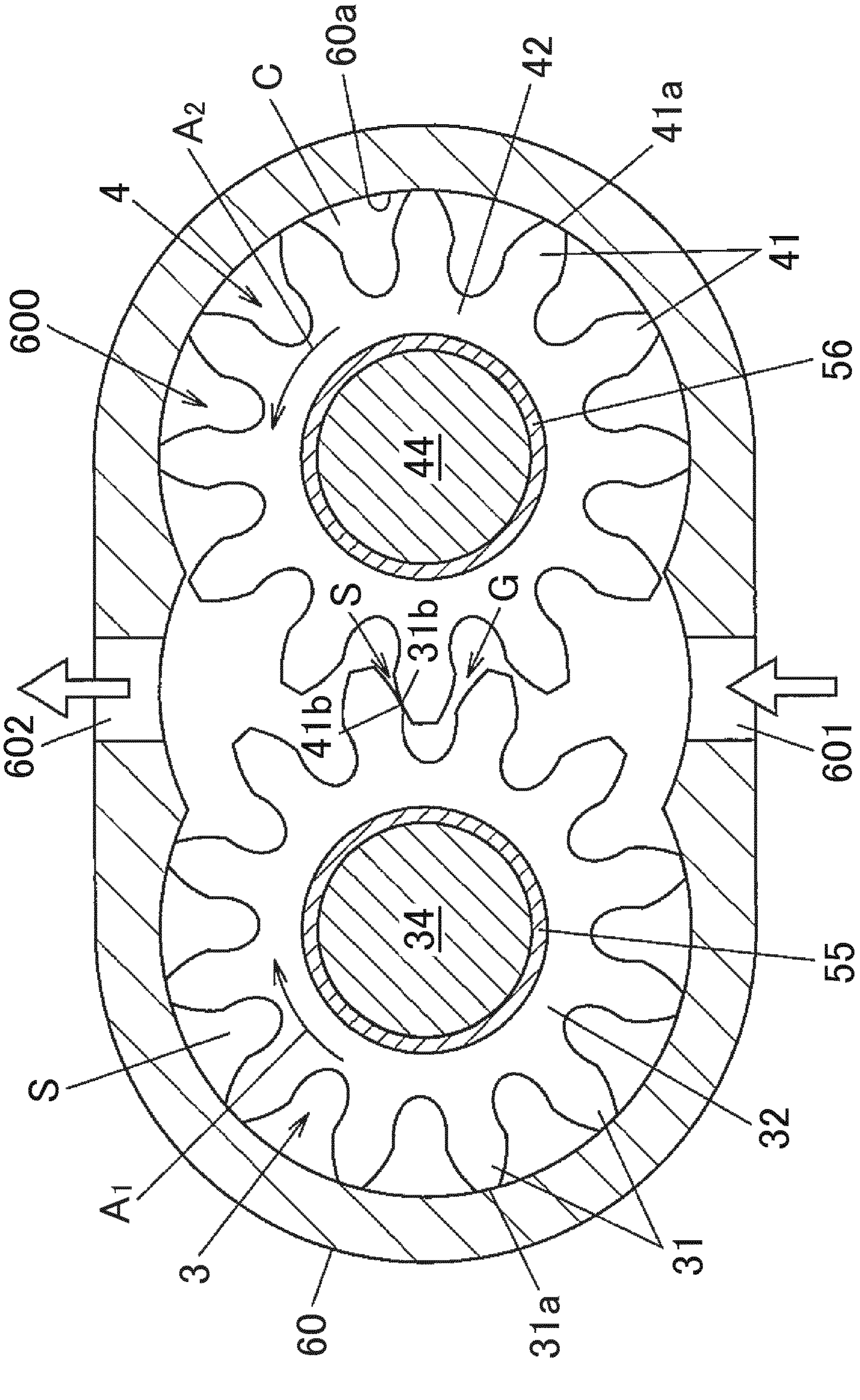
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FIG. 3

FIG. 4

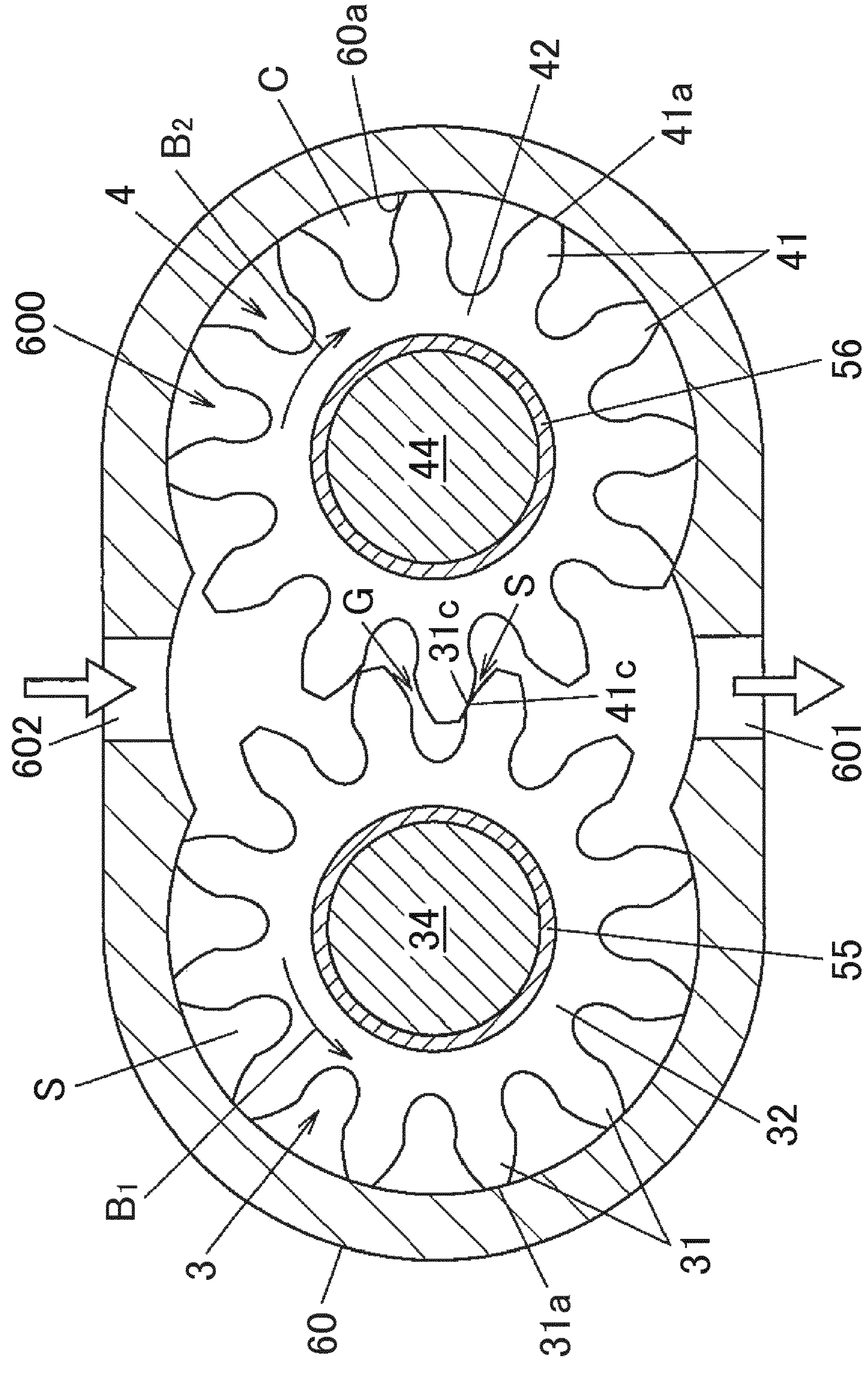
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FIG. 5

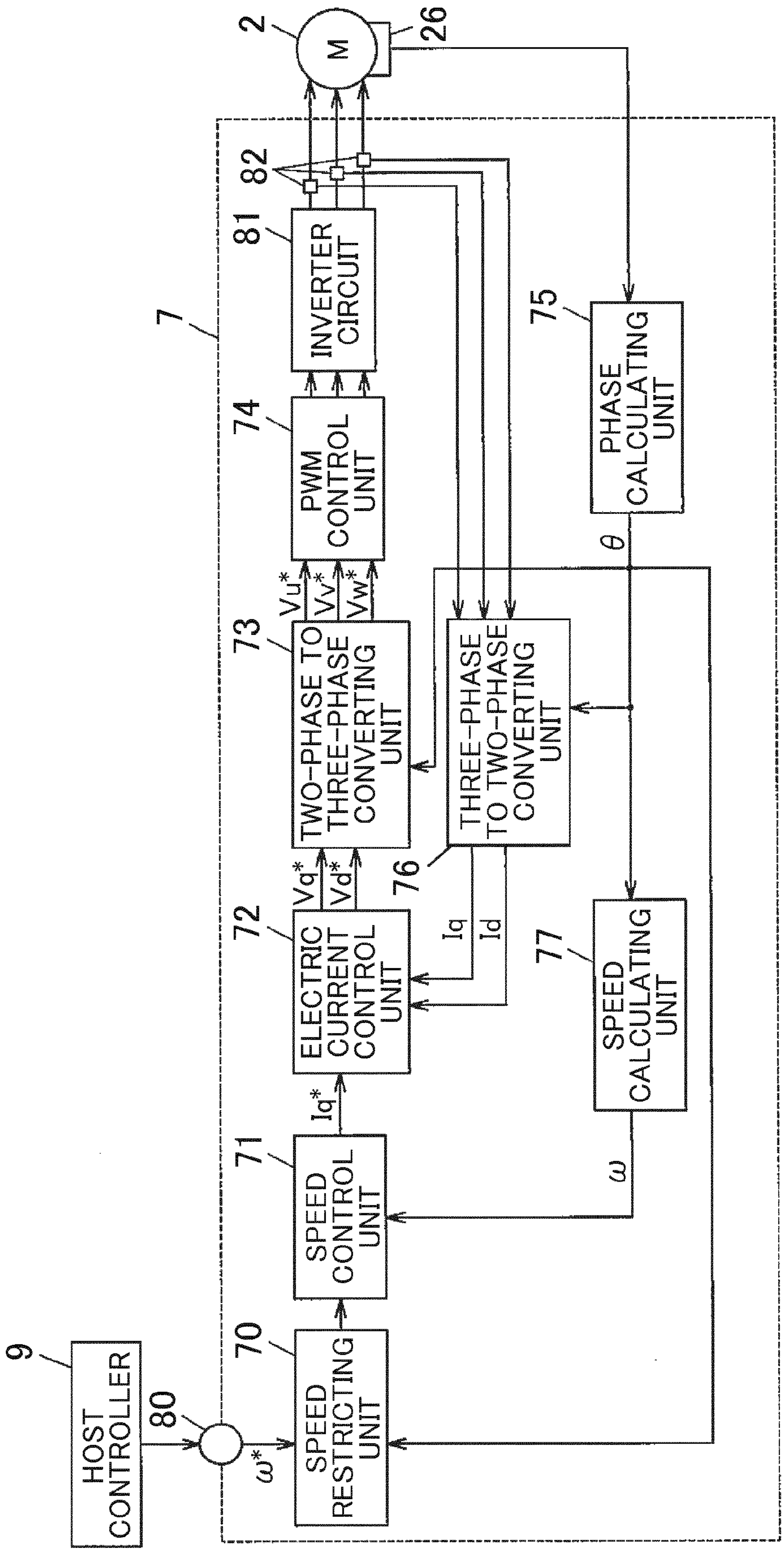
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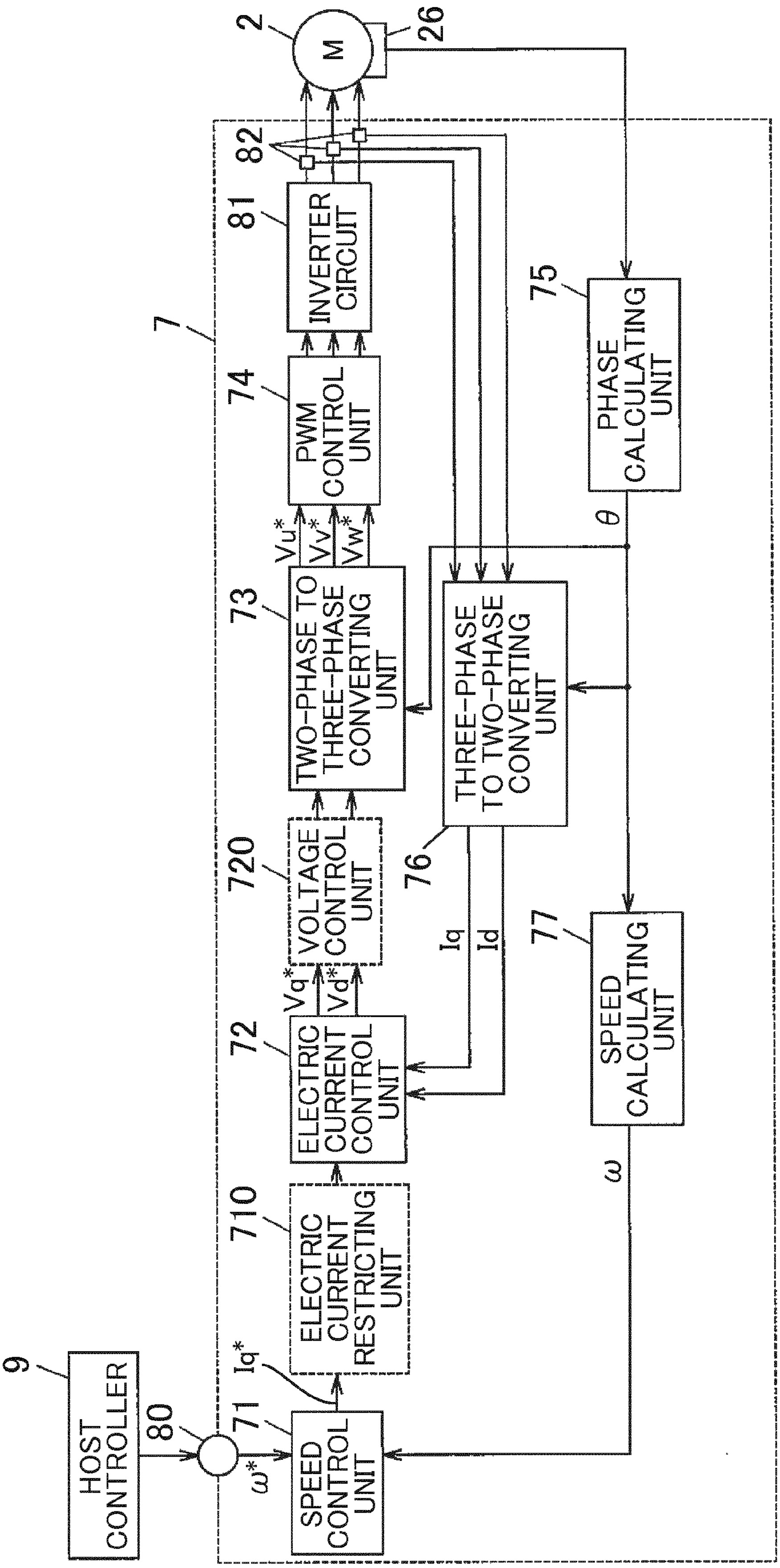
FIG. 6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Iq
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SPEED CALCULATING UNIT
ω

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EUROPEAN SEARCH REPORT

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1

Place of search	Date of completion of the search	Examiner
Munich	5 June 2019	Bocage, Stéphane

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