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- **Kawaguchi, Masahiro**
Kariya-shi, Aichi-ken (JP)
- **Uchiyama, Osamu**
Kariya-shi, Aichi-ken (JP)

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(71) Applicant: **Kabushiki Kaisha Toyota Jidoshokki**
Kariya-shi, Aichi-ken (JP)

(72) Inventors:
• **Yamamoto, Shinya**
Kariya-shi, Aichi-ken (JP)

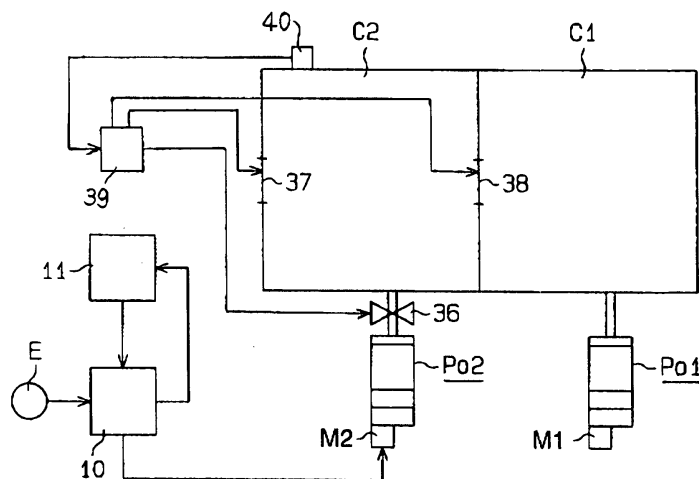
(74) Representative:
Leson, Thomas Johannes Alois, Dipl.-Ing.
Tiedtke-Bühling-Kinne & Partner GbR,
TBK-Patent,
Bavariaring 4
80336 München (DE)

(54) **Control system for vacuum pump**

(57) A vacuum pump has an alternating current motor, a rotary shaft and a gas transferring body. The alternating current motor runs at a certain speed based on frequency of alternating current and is sufficiently supplied with the alternating current. Gas is transferred from a certain space by the gas transferring body driven by the alternating current motor through the rotary shaft. A method for controlling a vacuum pump includes keeping a rotational speed of the alternating current motor at

a second predetermined rotational speed, detecting a value of the alternating current to the alternating current motor, keeping the rotational speed at a first predetermined rotational speed that is higher than the second predetermined rotational speed when the detected alternating current value exceeds a first predetermined value, and keeping the rotational speed at the second predetermined rotational speed when the detected alternating current value becomes equal to a second predetermined value.

FIG. 1



Description

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to an operation method of controlling a vacuum pump and a control system for controlling the vacuum pump whose rotary shaft is driven by an alternating current motor and whose gas transferring body is driven by the rotating movement of the rotary shaft to cause vacuum action in a vacuum area.

[0002] As disclosed in Japanese Unexamined Patent Publication No. H5-231381, in a vacuum pump, an actual intake pressure at an inlet is detected and is compared with a predetermined intake pressure. The rotational speed of an electric motor is controlled based on the difference in the above pressure comparison. When the actual intake pressure is larger than the predetermined intake pressure, the rotational speed of the vacuum pump is increased. In contrast, when the actual intake pressure is lower than the predetermined intake pressure, the rotational speed of the vacuum pump is decreased. As a result, power loss is relatively reduced due to the above operation control.

[0003] Although a pressure detector is needed for detecting the actual intake pressure at the inlet of the vacuum pump, however, the pressure detector increases cost of the vacuum pump.

[0004] The present invention addresses the above mentioned problem associated with the cost while the power loss is controlled in the vacuum pump.

SUMMARY OF THE INVENTION

[0005] In accordance with the present invention, a vacuum pump has an alternating current motor, a rotary shaft and a gas transferring body. The alternating current motor runs at a certain speed based on frequency of alternating current. The motor is sufficiently supplied with the current. Gas is transferred from a certain space by the gas transferring body that is driven by the motor through the rotary shaft. A method for controlling the vacuum pump includes keeping a rotational speed of the motor at a first predetermined rotational speed, detecting a value of the current to the motor, keeping the rotational speed at a second predetermined rotational speed that is higher than the first predetermined rotational speed when the value of the current exceeds a first predetermined value, and keeping the rotational speed at the first predetermined rotational speed when the value of the current becomes lower than a second predetermined value.

[0006] The present invention also provides a method for controlling a vacuum pump. The vacuum pump has an alternating current motor, a rotary shaft and a gas transferring body. The alternating current motor runs at a certain speed based on frequency of alternating current. The motor is sufficiently supplied with the current.

Gas is transferred from a certain space by the gas transferring body that is driven by the motor through the rotary shaft. The method includes detecting a value of the current to the motor, and changing the rotational speed of the motor to cancel the variation of the current such that the detected value of the current becomes a predetermined value.

[0007] The present invention also provides a control system for controlling pump torque on a vacuum pump. The vacuum pump has an alternating current motor, a rotary shaft and a gas transferring body. The motor is actuated by an external power source. The motor runs at a certain speed based on frequency of alternating current. The motor is sufficiently supplied with the current. Gas is transferred from a certain space by the gas transferring body that is driven by the motor through the rotary shaft, the control system including a rotational speed adjuster and a controller. The rotational speed adjuster is electrically connected to the motor and the external power source. The rotational speed adjuster changes the value of the current supplied to the motor in response to the pump torque in order to keep the rotational speed of the motor at a predetermined rotational speed. The controller is electrically connected to the rotational speed adjuster. The controller detects a value of the current to the motor from the rotational speed adjuster compares the detected value of the current with a predetermined value. The controller changes the rotational speed of the motor in such a manner that the detected value approaches the predetermined value when the detected value is different from the predetermined value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a schematic view of a first preferred embodiment according to the present invention;

FIG. 2 is a longitudinal cross-sectional view of the vacuum pump in the first preferred embodiment according to the present invention;

FIG. 3A is a cross-sectional view of the vacuum pump taken along the line I - I in FIG. 2;

FIG. 3B is a cross-sectional view of the vacuum pump taken along the line II - II in FIG. 2;

FIG. 3C is a cross-sectional view of the vacuum pump taken along the line III-III in FIG. 2;

FIG. 4 shows four timing graphs describing a rotational speed control in relation to pressure and alternating current in the first preferred embodiment according to the present invention;

FIG. 5 is a schematic view of a second preferred embodiment according to the present invention; and

FIG. 6 shows four timing graphs depicting a rotational speed control in relation to pressure and alternating current in the second preferred embodiment according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] A first preferred embodiment according to the present invention will now be described by referring to FIGs. 1 through 4. As shown in FIG. 1, a semi-conductor is produced in a vacuum chamber C1 of a first predetermined embodiment of the present invention. Work piece (not shown) stands by at a load lock chamber C2 and is subsequently supplied to the vacuum chamber C1. Completed work piece stands by at the load lock chamber C2 before it is taken out. The pressure in the vacuum chamber C1 is reduced to a desired low pressure level by a first vacuum pump Po1. A second vacuum pump Po2 is connected to the load lock chamber C2 via an electromagnetic valve 36 that is normally closed. Similarly, the pressure in the load lock chamber C2 is reduced to a desired low pressure by the second vacuum pump Po2. Namely, the second vacuum pump Po2 vacuums the load lock chamber C2 or a vacuumed area.

[0010] In the first preferred embodiment, the first and second vacuum pumps Po1 and Po2 are called roots pump, and FIGs. 2 through 3C illustrate the internal structures of the first and second vacuum pumps Po1 and Po2. As shown in FIG. 2, a front housing 13 and a rear housing 14 are fixedly connected to a rotor housing 12. A pair of rotary shafts 15 and 16 is rotatably supported by the front housing 13 and the rear housing 14. Rotors 17 through 21 are integrally formed with the rotary shaft 15 while rotors 22 through 26 are integrally formed with the rotary 16. The rotors 17 through 21 respectively engage with the rotors 22 through 26 in respective pump chambers 27 through 31 in the rotor housing 12. The rotors 17 through 26 are gas transferring bodies that transfer gas from the vacuumed area.

[0011] A gear housing 32 is fixedly connected to the rear housing 14. The rotary shafts 15 and 16 protrude through the rear housing 14 into the gear housing 32. Gears 33 and 34 are respectively secured at the rear ends of the rotary shafts 15 and 16. The gear 33 engages with the gear 34. An alternating current (AC) motor M1 or M2 is placed adjacent to the gear housing 32. The motor M1 or M2 is actuated by an alternating current power source E as a power source. The rotational speed

of the motor M1 or M2 is determined by frequency of alternating current. Namely, the motor M1 or M2 runs at a certain speed in response to a certain frequency of the alternating current. The rotational power of the motor M1 or M2 is transmitted to the rotary shaft 15, and the rotary shaft 15 is rotated in the direction of arrows R1 as shown in FIGs. 3A through 3C. The rotation of the rotary shaft 15 is transmitted to the rotary shaft 16 via the gears 33 and 34. The rotary shaft 16 is rotated in the direction opposite to the rotary shaft 15 as indicated by arrows R2 in FIGs. 3A through 3C.

[0012] As shown in FIG. 3A, an inlet 121 is formed in the rotor housing 12. The gas is introduced from the inlet 121 into the first pump chamber 27. The gas in the first pump chamber 27 is compressed by the rotation of the rotors 17 and 22, and is transferred to the second pump chamber 28 via a passage 351 in a partition wall 35 as shown in FIGs. 2 and 3B. Similarly, as the gas is sequentially transferred to the pump chambers 28, 29, 30 and 31, the volume of the gas is gradually reduced. The gas in the pump chamber 31 is discharged from an outlet 122, which is formed in the rotor housing 12 as shown in FIG. 3C, due to the rotations of the rotors 21 and 26.

[0013] Referring back to FIG. 1, an inverter 10 as a rotational speed adjuster is electrically connected to the second motor M2 and an alternating-power source E. A controller 11 is electrically connected to the inverter 10. The inverter 10 controls the rotational speed of the second motor M2 according to the control command from the controller 11. The inverter 10 changes the value of the alternating current in order to keep the rotational speed of the second motor M2 in response to pump torque from the second motor M2. When the pump torque increases, the second motor M2 needs relatively large value of the alternating current to keep its rotational speed so that the inverter 10 increases the value of the alternating current supplied to the second motor M2. On the other hand, when the pump torque decreases, the second motor M2 needs relatively small value of the alternating current to keep its rotational speed so that the inverter 10 decreases the value of the alternating current supplied to the second motor M2. The controller 11 changes the rotational speed of the second motor M2 by causing the inverter 10 to change frequency of the alternating current to the second motor M2. The controller 11 detects a value of the alternating current from the inverter 10 to the second motor M2. The alternating current value from the inverter 10 to the second motor M2 reflects pump torque that is essentially the load applied to the second motor M2. Namely, the controller 11 detects the value of the alternating current to indirectly detect the pump torque or the load applied to the second motor M2.

[0014] FIG. 4 shows relationships among the rotational speed of the second motor M2, the pressure in the load lock chamber C2, the pressure in a passage between an electromagnetic valve 36 and the second vacuum pump Po2, and the value of the alternating current

with respect to time. A graph H shows the change in the rotational speed of the second motor M2 as a function of time. A graph J shows the pressure change in the passage between an electromagnetic valve 36 and the second vacuum pump Po2 as a function of time. The pressure in the passage varies based on the rotational speed control by the controller 11. A graph F shows the pressure change in the load lock chamber C2 as a function of time. The pressure in the load lock chamber C2 varies based on the opening and closing position of a first electric gate 37 and the rotational speed control by the controller 11. A graph G shows the change in the alternating current value to the second motor M2 of the second vacuum pump Po2 as a function of time.

[0015] A first predetermined pressure P1 as shown in FIG. 4 is a desired pressure level in the load lock chamber C2, and a second predetermined pressure P2 is a transient target pressure in the passage between the electromagnetic valve 36 and the second vacuum pump Po2. The second predetermined pressure P2 is lower than the first predetermined pressure P1. A first predetermined alternating current value W1 as shown in FIG. 4 is an expected alternating current value supplied from the inverter 10 to the second motor M2 when the pressure in the load lock chamber C2 is at the first predetermined pressure P1 and the electromagnetic valve 36 is open. A second predetermined alternating current value W2 is an expected alternating current value supplied from the inverter 10 to the second motor M2 when the pressure in the above passage is at the transient target pressure P2, the electromagnetic valve 36 is closed and the rotational speed of the second motor M2 is at a first predetermined rotational speed N1 that is a maximum speed of the second motor M2. The second predetermined alternating current value W2 is lower than the first predetermined alternating current value W1.

[0016] Referring back to FIG. 1, in order to move the work piece from the vacuum chamber C1 into the load lock chamber C2 and to remove the completed work piece from the load lock chamber C2, the load lock chamber C2 is opened to the atmosphere by opening the first electric gate 37. When a second electric gate 38 is opened, the work piece in the load lock chamber C2 is moved to the vacuum chamber C1. A switch control device 39, which is different from the controller 11, controls the opening and closing of the electromagnetic valve 36 and the first and second electric gates 37 and 38. The electromagnetic valve 36, and the first and second electric gates 37 and 38 function as an electric opening and closing means. The pressure in the load lock chamber C2 is detected by a pressure detector 40. The opening and closing of the electromagnetic valve 36 is controlled based on the detected pressure by the pressure detector 40.

[0017] Before the first electric gate 37 is opened or before time t1 in FIG. 4, the rotational speed of the second motor M2 is kept at a second predetermined rotational speed N2, and the pressure in the load lock cham-

ber C2 is at the first predetermined pressure P1. When the first electric gate 37 is opened at the time t1 as shown in FIG. 4, the electromagnetic valve 36 is closed and the load lock chamber C2 and the second vacuum pump Po2 are not connected. In a state when the load lock chamber C2 is open to the atmosphere, the second vacuum pump Po2 is driven at the second predetermined rotational speed N2. The second predetermined rotational speed N2 is an expected rotational speed that causes the pressure in the load lock chamber C2 to be kept at the first predetermined pressure P1 when the electromagnetic valve 36 is open. Namely, the second predetermined rotational speed N2 is set in such a manner that the pressure in the load lock chamber C2 is at the first predetermined pressure P1 when the value of the alternating current is at the second predetermined alternating current value W2. After the work piece is supplied to the load lock chamber C2, the switch control device 39 commands that the first electric gate 37 should be closed and the electromagnetic valve 36 should be open when time is at t2 in FIG. 4. Thereby, the first electric gate 37 is closed, and the load lock chamber C2 is closed from the atmosphere. Also, the second vacuum pump Po2 communicates with the load lock chamber C2, which becomes under the atmospheric pressure.

[0018] When the electromagnetic valve 36 is open, the pressure in the passage between the electromagnetic valve 36 and the second vacuum pump Po2 increases and the pump torque from the second vacuum pump Po2 also increases. The inverter 10 increases the value of the alternating current to the second motor M2 of the second vacuum pump Po2 in response to the pump torque of the second vacuum pump Po2 in order to keep the rotational speed of the second motor M2 at the second predetermined rotational speed N2. The controller 11, which detects the value of the alternating current from the inverter 10 to the second motor M2, compares the detected value of the alternating current with the first predetermined alternating current value W1. When the detected alternating current value exceeds the first alternating current value W1, the controller 11 changes the rotational speed of the second motor M2 from the second predetermined rotational speed N2 to the first predetermined rotational speed N1. Therefore, the pressure in the load lock chamber C2 and the passage between the electromagnetic valve 36 and the second vacuum pump Po2 decreases.

[0019] After the rotational speed of the second motor M2 is changed from the second predetermined rotational speed N2 to the first predetermined rotational speed N1, the controller 11, which detects the value of the alternating current from the inverter 10 to the second motor M2, compares the detected alternating current value with the second predetermined alternating current value W2. The inverter 10 keeps the rotational speed at the first predetermined rotational speed N1. If the pressure in the load lock chamber C2 is relatively high or if the amount of exhaust gas that is transferred by the second

vacuum pump Po2 is relatively large, the pump torque or the load applied to the second motor M2 becomes relatively large, and the alternating current value to the second motor M2 also becomes relatively large. As the pressure in the load lock chamber C2 is decreased, the alternating current value decreases.

[0020] When the pressure detector 40 detects a pressure value at the first predetermined pressure P1 at t3 in FIG. 4, the switch control device 39 causes the electromagnetic valve 36 to close. Therefore, the communication between the load lock chamber C2 and the second vacuum pump Po2 is also closed. At this time, the pressure in the load lock chamber C2 and in the passage between the electromagnetic valve 36 and the second vacuum pump Po2 is at the first predetermined pressure P1, and the detected alternating current value is at the first predetermined alternating current value W1.

[0021] After the electromagnetic valve 36 becomes closed, the pressure in the passage between the electromagnetic valve 36 and the second vacuum pump Po2 is further decreased by the suction of the second vacuum pump Po2 whose second motor M2 runs at the first predetermined rotational speed N1. Namely, the alternating current to the second vacuum pump Po2 is reduced. When the detected alternating current value becomes lower than the second predetermined alternating current value W2 at t4 in FIG. 4, the controller 11 changes the rotational speed of the second motor M2 from the first predetermined rotational speed N1 to the second predetermined rotational speed N2. At the time, the passage pressure between the electromagnetic valve 36 and the second vacuum pump Po2 is at a second predetermined pressure P2 that is lower than the first predetermined pressure P1. When the rotational speed of the second motor M2 is changed from the first predetermined rotational speed N1 to the second predetermined rotational speed N2, it is expected that the passage pressure between the electromagnetic valve 36 and the second vacuum pump Po2 changes from the transient target pressure P2 to the first predetermined pressure P1.

[0022] The controller 11 compares the detected alternating current value corresponding to the detected pump torque with a predetermined alternating current value corresponding to a predetermined pump torque value. The inverter 10 and the controller 11 constitute a rotation control means that controls the rotational speed of the second motor M2 in such a manner that the detected alternating current value approaches the predetermined pump torque value.

[0023] In the first preferred embodiment, following advantageous effects are obtained.

(1-1) The controller 11 controls the rotational speed of the second motor M2 in such a manner that the detected alternating current value approaches the predetermined value by controlling the detected

pump torque to approach the predetermined pump torque that reflects the desired pressure. In the first preferred embodiment, the second motor M2 is driven at the first predetermined rotational speed N1, and the pressure is controlled to be the transient target pressure P2. Then, when the detected pump torque reaches pump torque that corresponds to the transient target pressure P2, the rotational speed of the second motor M2 is changed to the second predetermined rotational speed N2, which is lower than the first predetermined rotational speed N1. Namely, the controller 11 controls the rotational speed of the second motor M2 based on the detected alternating current value. The above operation control of the second vacuum pump Po2 reduces its power loss.

(1-2) A pressure detector is relatively expensive. Furthermore, a structure for setting the pressure detector is necessary so that the pressure detector detects the pressure in a predetermined space in which the exhaust gas exists.

The predetermined space includes an exhaust gas route from the inlet 121 to the load lock chamber C2. Introducing the above structure also increases the cost. It is also possible that the flow rate of the exhaust gas is detected instead of the pressure of the exhaust gas and that the rotational speed of the second rotor M2 is controlled based on the detected flow rate of the exhaust gas. However, detecting the flow rate of the exhaust gas is equally disadvantageous to the cost as detecting the pressure of the exhaust gas.

The pump torque, which reflects the pressure and the flow rate of the exhaust gas, is determined by detecting the alternating current value from the inverter 10 to the second motor M2. Detecting the pump torque is more advantageous to cost than detecting directly the pressure of the exhaust gas or the flow rate of the exhaust gas.

(1-3) The rotational speed of the second motor M2 is set at either of only two speeds, the first and second predetermined rotational speed N1 and N2. Therefore, the operation control of the second vacuum pump Po2 becomes a simple control that switches either of the first and second predetermined rotational speed N1 and N2.

(1-4) The value of the alternating current from the inverter 10 to the second motor M2 substantially reflects the pump torque, which is the load applied to the second motor M2. The alternating current detecting means is an appropriate means for improving the accuracy to detect the pump torque. Furthermore, the alternating current detecting means is simple to implement detecting the pump torque.

(1-5) As the first predetermined rotational speed N1 becomes large, it is quicker for the pressure in the load lock chamber C2 to reach the first predetermined pressure P1. However, since the second vacuum pump Po2 cannot be operated over its maximum operational capacity, the second vacuum pump Po2 is operated at its maximum operational capacity at the first predetermined rotational speed N1. Thereby, it is the quickest for the pressure in the load lock chamber C2 to reach the first predetermined pressure P1. The above reduction in time also shortens the semi-conductor manufacturing process.

(1-6) In the first preferred embodiment, the maximum capacity of the second vacuum pump Po2 reduces the pressure in the load lock chamber C2 to the transient target pressure P2. When a comparative vacuum pump reduces the pressure in the load lock chamber C2 to the first predetermined pressure P1, the vacuum pump has a lower maximum capacity than that of the second vacuum pump Po2, and the maximum rotational speed of the vacuum pump is lower than that of the second vacuum pump Po2. The above vacuum pump is capable of reducing the pressure in the load lock chamber C2 to the first predetermined pressure P1. However, to reduce the pressure in the load lock chamber C2 to the transient target pressure P2, which is lower than the first predetermined pressure P1, the second vacuum pump Po2 needs to be used. Therefore, the time is relatively short for the pressure in the load lock chamber C2 to reach the first predetermined pressure P1 by using the pump Po2. Furthermore, since the rotational speed of the second motor M2 is switched from the first predetermined rotational speed N1 to the second predetermined rotational speed N2 after the pump torque of the second vacuum pump Po2 reaches the pump torque that corresponds to the transient target pressure P2, power loss is reduced.

(1-7) If the electromagnetic valve 36 belongs to the load lock chamber C2, the controller 11 controls devices belonging to the second vacuum pump Po2, and the switch control device 39 controls devices belonging to the load lock chamber C2. Namely, since the controller 11 and the switch control valve 39 independently work, the controller 11 cannot utilize information from the pressure detector 40. The controller 11 utilizes information on the pressure that is estimated based on the detected alternating current value. Thereby, the cost is reduced for operating the second vacuum pump Po2.

[0024] When the electromagnetic valve 36 is open and the gas flows in the passage between the load lock chamber C2 and the second vacuum pump Po2, the ac-

curacy of the pressure estimated by detecting the alternating current value falls slightly compared to the situation where the gas does not flow in the passage between the load lock chamber C2 and the second vacuum pump Po2. Therefore, if a switch from the opening of the electromagnetic valve 36 to the closing of it is decided by detecting the first predetermined pressure P1 that is estimated based on the alternating current, the switch may lead an erroneous detection.

[0025] If the transient target pressure P2 is appropriately set, the transient target pressure P2 is estimated by detecting the alternating current value when the gas does not flow in the passage between the load lock chamber C2 and the second vacuum pump Po2. Therefore, when the electromagnetic valve 36 is closed upon detecting the second predetermined pressure P2 that is estimated based on the detected alternating current value, the above error is avoided. Namely, when the electromagnetic valve 36 is closed, it is confirmed by detecting the transient target pressure P2, which is lower than the first predetermined pressure P1. The above control is effective for accurately operating the control of the devices belonging to the second vacuum pump Po2 after the electromagnetic valve 36 becomes closed.

[0026] A second preferred embodiment of the present invention will be described by referring to FIGs. 5 and 6. Now referring to FIG.5, reference numerals denote the substantially identical components in the first preferred embodiment. The first vacuum pump Po1 vacuums the vacuum chamber C1 or the vacuumed area, and it is controlled by rotational control means that is constituted of an inverter 10A as a speed rotational adjuster and a controller 11 A. A desired pressure in the vacuum chamber C1 is set at a third predetermined pressure P3 that is lower than the first predetermined pressure P1 in the load lock chamber C2. The first predetermined rotational speed N1 of the first motor M1 is fast enough to cause the pressure in the vacuum chamber C1 to be the third predetermined pressure P3. A graph H1 as shown in FIG. 6 shows the change in the rotational speed of the first motor M1 as a function of time, and a graph G1 shows the change in the alternating current value to the first motor M1 as a function of time. A graph F1 shows the change in the pressure in the vacuum chamber C1 as a function of time, and a graph J1 shows the change in the pressure at an inlet of the first vacuum pump Po1 as a function of time. A third predetermined value W3 of the alternating current is a predetermined alternating current value that is expected to be supplied to the first vacuum pump Po1 when the pressure in the vacuum chamber C1 is at the third predetermined pressure P3.

[0027] Before the second electric gate 38 is opened or before the time t5 in FIG. 6, the rotational speed of the first motor M1 is kept at a third predetermined rotational speed N3, and it is expected that the pressure in the vacuum chamber C1 is at the third predetermined pressure P3. When the second electric gate 38 is open,

the pressure in the vacuum chamber C1 is increased and the pump torque of the first vacuum pump Po1 increases. The inverter 10A increases the value of the alternating current to the first motor M1 of the first vacuum pump Po1 in response to the pump torque of the first vacuum pump Po1. The controller 11A detects an increase in the alternating current of the first motor M1. The controller 11A controls the rotational speed of the first motor M1 to the first predetermined rotational speed N1 by a feedback control based on the detected alternating current value. Namely, the controller 11A continuously increases the rotational speed of the first motor M1, when the value of the alternating current is larger than the third predetermined alternating current value W3. The segment H11 in the graph H1 in FIG. 6 indicates the change of the rotational speed of the first motor M1 by the feedback control after the second electric gate 38 has been opened. When the second electric gate 38 is opened, the pressure in the vacuum chamber C1 is increased from the third predetermined pressure P3 since the pressure in the load lock chamber C2 is higher than that in the vacuum chamber C1. Then the value of the alternating current to the first motor M1 is increased in accordance with the increase of the pressure in the vacuum chamber C1. As the value of the alternating current to the first motor M1 increases, the rotational speed of the first motor M1 is increased from the third predetermined rotational speed N3. When the time is at t6 in FIG. 6, the second electric gate 38 is closed.

[0028] When the rotational speed of the first motor M1 reaches the first predetermined rotational speed N1 at the time t7 in FIG. 6, the controller 11A stops the feedback control and controls the rotational speed of the first motor M1 at the first predetermined rotational speed N1 during the period that corresponds to the segment H12 in the graph H1 in FIG. 6. The pressure in the vacuum chamber C1 is decreased in accordance with the increasing rotational speed of the first motor M1. As the pressure in the vacuum chamber C1 is decreased, the alternating current value to the first motor M1 decreases.

[0029] When the detected alternating current value becomes the third predetermined value W3 at the time t8 in FIG. 6, the controller 11A starts the feedback control based on the detected alternating current value in such a manner that the detected alternating current value approaches the third predetermined alternating current value W3 again. The feedback control is operated during the time that corresponds to the segment H13 in the graph H1 in FIG. 6. When the rotational speed of the first motor M1 reaches the third predetermined rotational speed N3 at the time t9 in FIG. 6, the controller 11A stops the feedback control. The controller 11A controls the rotational speed of the first motor M1 at the first predetermined rotational speed N1 during the period that corresponds to the segment H14 in the graph H1 in FIG. 6.

[0030] In the second preferred embodiment, substan-

tially the same advantageous effects are obtained as mentioned in the preceding paragraphs (1-1), (1-2) and (1-4) according to the first preferred embodiment. Although it is described with respect to FIG. 6 that the rotational speed of the first motor M1 reaches the first predetermined rotational speed N1, the rotational speed of the first motor M1 may not reach the first predetermined rotational speed N1 since the change of the pressure affects the increasing rotational speed of the first motor M1.

[0031] According to the present invention, following alternative embodiments can be possible. Strain of the rotary shaft 15 or 16, which reflects the pump torque, may be detected by a strain gauge. The detected strain is compared with a predetermined strain, and the rotational speed of the motor M1 or M2 is controlled in such a manner that the detected strain converges into the predetermined strain. In this case, a strain detecting element of the strain gauge is attached on the circumferential surface of the rotary shaft 15 or 16, and the strain of the circumferential surface of the rotary shaft 15 or 16 is detected.

[0032] In the first preferred embodiment, the rotational speed of the first motor M1 is controlled in such a manner that the pressure in the load lock chamber C2 becomes the first predetermined pressure P1 from the beginning. Namely, the second predetermined alternating current value W2 is equal to the first predetermined alternating current value W1. The rotational speed of the second motor M2 is changed from the first predetermined rotational speed N1 to the second predetermined rotational speed N2 when the detected alternating current value becomes lower than the first predetermined alternating current value W1.

[0033] In the first preferred embodiment, the electromagnetic valve 36 is removed. When the detected alternating current value exceeds the first predetermined alternating current value W1, the feedback control is performed to cause the detected alternating current value to converge into the second predetermined alternating current value W2. When the detected alternating current value becomes the second predetermined alternating current value W2, the feedback control is performed to cause the detected alternating current value to converge into the first predetermined alternating current value W1.

[0034] In the second preferred embodiment, the third predetermined rotational speed N3 does not need to be set. In this case, in order to keep the pressure in the vacuum chamber C1 at the third predetermined pressure P3, the feedback control is performed all throughout the operation based on the detected alternating current value in such a manner that the detected alternating current value approaches the third predetermined alternating current value W3. Namely, when the detected alternating current value is larger than the third predetermined alternating current value W3, the rotational speed of the first motor M1 is continuously increased until the

detected alternating current value becomes equal to the third predetermined alternating current value W3. When the detected alternating current value is smaller than the third predetermined alternating current value W3, the rotational speed of the first motor M1 is continuously decreased until the detected alternating current value becomes equal to the third predetermined alternating current value W3.

[0035] Any combination of the above described preferred embodiments and or the above described alternative embodiments is practiced according to the current invention. The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

A vacuum pump has an alternating current motor, a rotary shaft and a gas transferring body. The alternating current motor runs at a certain speed based on frequency of alternating current and is sufficiently supplied with the alternating current. Gas is transferred from a certain space by the gas transferring body driven by the alternating current motor through the rotary shaft. A method for controlling a vacuum pump includes keeping a rotational speed of the alternating current motor at a second predetermined rotational speed, detecting a value of the alternating current to the alternating current motor, keeping the rotational speed at a first predetermined rotational speed that is higher than the second predetermined rotational speed when the detected alternating current value exceeds a first predetermined value, and keeping the rotational speed at the second predetermined rotational speed when the detected alternating current value becomes equal to a second predetermined value.

Claims

1. A method for controlling a vacuum pump that has an alternating current motor, a rotary shaft and a gas transferring body, the alternating current motor running at a certain speed based on frequency of alternating current, the alternating current motor being sufficiently supplied with the alternating current, gas being transferred from a certain space by the gas transferring body that is driven by the alternating current motor through the rotary shaft, the method comprising the steps of:

keeping a rotational speed of the alternating current motor at a second predetermined rotational speed;
detecting a value of the alternating current to the alternating current motor;
keeping the rotational speed at a first predetermined rotational speed that is higher than the second predetermined rotational speed when

the detected value of the alternating current exceeds a first predetermined value; and
keeping the rotational speed at the second predetermined rotational speed when the detected value of the alternating current becomes equal to a second predetermined value.

2. The method according to claim 1, wherein the second predetermined value is lower than the first predetermined value.
3. The method according to claim 1, wherein the second predetermined value is equal to the first predetermined value.

4. A method for controlling a vacuum pump that has an alternating current motor, a rotary shaft and a gas transferring body, the alternating current motor running at a certain speed based on frequency of alternating current, the alternating current motor being sufficiently supplied with the alternating current, gas being transferred from a certain space by the gas transferring body that is driven by the alternating current motor through the rotary shaft, the method comprising the steps of:

detecting a value of the alternating current to the alternating current motor; and
changing a rotational speed of the alternating current motor to eliminate a variation of the alternating current such that the detected value of the alternating current becomes a predetermined value.

5. The method according to claim 4, wherein the changing step further includes the additional steps of:

continuously increasing the rotational speed of the alternating current motor until the detected value of the alternating current becomes equal to a first predetermined value, when the detected value of the alternating current exceeds a second predetermined value; and
continuously decreasing the rotational speed of the alternating current motor until the detected value of the alternating current becomes equal to the second predetermined value, when the detected value of the alternating current becomes equal to or lower than the first predetermined value.

6. The method according to claim 5, wherein the first predetermined value is lower than the second predetermined value.
7. The method according to claim 5, wherein the first predetermined value is equal to the second predetermined value.

terminated value.

8. The method according to claim 4, further comprising the steps of:

keeping the rotational speed of the alternating current motor at a first predetermined rotational speed when the rotational speed reaches the first predetermined rotational speed; and
keeping the rotational speed of the alternating current motor at a second predetermined rotational speed when the rotational speed reaches the second predetermined rotational speed.

9. The method according to claim 8, wherein the first predetermined rotational speed is higher than the second predetermined rotational speed.

10. The method according to claim 8, wherein the first predetermined rotational speed is equal to the second predetermined rotational speed.

11. A control system for controlling pump torque on a vacuum pump having an alternating current motor, a rotary shaft and a gas transferring body, the alternating current motor being actuated by an external power source, the alternating current motor running at a certain speed based on frequency of alternating current, the alternating current motor being sufficiently supplied with the alternating current, gas being transferred from a certain space by the gas transferring body that is driven by the alternating current motor through the rotary shaft, the control system comprising:

a rotational speed adjuster electrically connected to the alternating current motor, the rotational speed adjuster changing the value of the alternating current supplied to the alternating current motor in response to the pump torque in order to keep the rotational speed of the alternating current motor at a predetermined rotational speed; and
a controller electrically connected to the rotational speed adjuster, the controller detecting a value of the alternating current to the alternating current motor from the rotational speed adjuster, the controller comparing the detected value of the alternating current with a predetermined value, the controller changing the rotational speed of the alternating current motor in such a manner that the detected value approaches the predetermined value when the detected value is different from the predetermined value.

12. The control system according to claim 11, wherein the controller changes the rotational speed of the

alternating current motor by changing frequency of alternating current supplied to the alternating current motor.

13. The control system according to claim 11, wherein the predetermined value includes a first predetermined value and a second predetermined value, the rotational speed adjuster keeping the rotational speed of the alternating current motor at a first predetermined rotational speed when the detected value of the alternating current exceeds the first predetermined value, the rotational speed adjuster keeping the rotational speed of the alternating current motor at a second predetermined rotational speed that is smaller than the first predetermined rotational speed when the detected value of the alternating current becomes equal to the second predetermined value.

14. The control system according to claim 13, wherein the second predetermined value is lower than the first predetermined value.

15. The control system according to claim 13, wherein the second predetermined value is equal to the first predetermined value.

16. The control system according to claim 11, wherein the predetermined value includes a first predetermined value and a second predetermined value, the controller adjusting the rotational speed of the alternating current motor to a first predetermined rotational speed when the detected value of the alternating current exceeds the first predetermined value, the controller adjusting the rotational speed of the alternating current motor to a second predetermined rotational speed that is slower than the first predetermined rotational speed when the detected value of the alternating current becomes equal to or lower than the second predetermined value.

17. The control system according to claim 16, wherein the second predetermined value is lower than the first predetermined value.

18. The control system according to claim 16, wherein the second predetermined value is equal to the first predetermined value.

19. The control system according to claim 11, wherein the certain space is a load lock chamber, the control system further comprising a valve through which the vacuum pump communicates with the load lock chamber, the rotational speed of the alternating current motor being kept at the first predetermined rotational speed in a state that the electric control valve is open while the pressure in the load lock chamber is reduced to a predetermined pressure

value, the electric control valve being closed at the time when the value of the alternating current reaches a value that corresponds to the predetermined pressure value.

20. A method of controlling pressure in a chamber using a vacuum pump having a motor, the vacuum pump being connected to the chamber via an adjustable valve, comprising the steps of:

running the motor at a predetermined slow rotational speed and a predetermined low current level with the adjustable valve in an open state to maintain a chamber pressure at a first predetermined pressure;
closing the adjustable valve for a first time to modify the chamber pressure to a second predetermined pressure above the first predetermined pressure;
opening the adjustable valve to modify the chamber pressure towards the first predetermined pressure;
continuously monitoring electric current to the motor to compare the electric current to a first predetermined electric current value;
changing the slow rotational speed to a predetermined fast rotational speed if the electric current exceeds the first predetermined electric current value;
continuously monitoring the chamber pressure;
closing the adjustable valve for a second time when the chamber pressure reaches the first predetermined pressure; and
changing the predetermined fast rotational speed to the predetermined slow rotational speed when the electric current reaches the predetermined low current level.

21. The method of controlling pressure according to claim 20, wherein the first predetermined pressure is under the atmospheric pressure.
22. The method of controlling pressure according to claim 20, wherein the second predetermined pressure is near the atmospheric pressure.
23. The method of controlling pressure according to claim 20, wherein a first predetermined task is performed when the chamber pressure is at the first predetermined pressure.
24. The method of controlling pressure according to claim 20, wherein a second predetermined task is performed when the chamber pressure is at the second predetermined pressure.
25. The method of controlling pressure according to claim 20, further comprising an additional step of

opening the adjustable valve to run the monitor at the predetermined slow rotational speed and the predetermined low current so that the chamber pressure is maintained at the first predetermined pressure.

26. The method of controlling pressure according to claim 20, wherein pressure near the adjustable valve is below the first predetermined pressure and at a third predetermined pressure when the electric current reaches the predetermined low current level after closing the adjustable valve for the second time.

27. A system for controlling pressure in a chamber, comprising:

a vacuum pump having a motor connected to the chamber, the motor initially running at a predetermined slow rotational speed and a predetermined low current level to maintain a chamber pressure at a first predetermined pressure;
an adjustable valve connected to and placed between the chamber and the vacuum pump for opening and closing a passage between the chamber and the vacuum pump;
a switching control device connected to the adjustable valve, the switching control device closing the adjustable valve for a first time to modify the chamber pressure to a second predetermined pressure above the first predetermined pressure, the switching control device opening the adjustable valve to modify the chamber pressure towards the first predetermined pressure;
a controller operationally connected to the vacuum pump for continuously monitoring electric current to the motor to compare the electric current to a first predetermined electric current value, the controller changing the slow rotational speed to a predetermined fast rotational speed if the electric current exceeds the first predetermined electric current value; and
a pressure detector connected to the switching control device and the chamber for continuously monitoring the chamber pressure, the switching control device closing the adjustable valve for a second time when the chamber pressure reaches the first predetermined pressure, wherein the controller changing the predetermined fast rotational speed to the predetermined slow rotational speed when the electric current reaches the predetermined low current level.

28. The system for controlling pressure according to claim 27, wherein the first predetermined pressure is under the atmospheric pressure.

29. The system for controlling pressure according to claim 27, wherein the second predetermined pressure is near the atmospheric pressure.
30. The system for controlling pressure according to claim 27, wherein a first predetermined task is performed when the chamber pressure is at the first predetermined pressure. 5
31. The system for controlling pressure according to claim 27, wherein a second predetermined task is performed when the chamber pressure is at the second predetermined pressure. 10
32. The system for controlling pressure according to claim 27, wherein the motor runs at the predetermined slow speed and the predetermined low current so that the chamber pressure is maintained at the first predetermined pressure when the adjustable valve is open. 15 20
33. The system for controlling pressure according to claim 27, wherein pressure near the adjustable valve is below the first predetermined pressure and at a third predetermined pressure when the electric current reaches the predetermined low current level after the adjustable valve is closed for the second time. 25

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FIG. 1

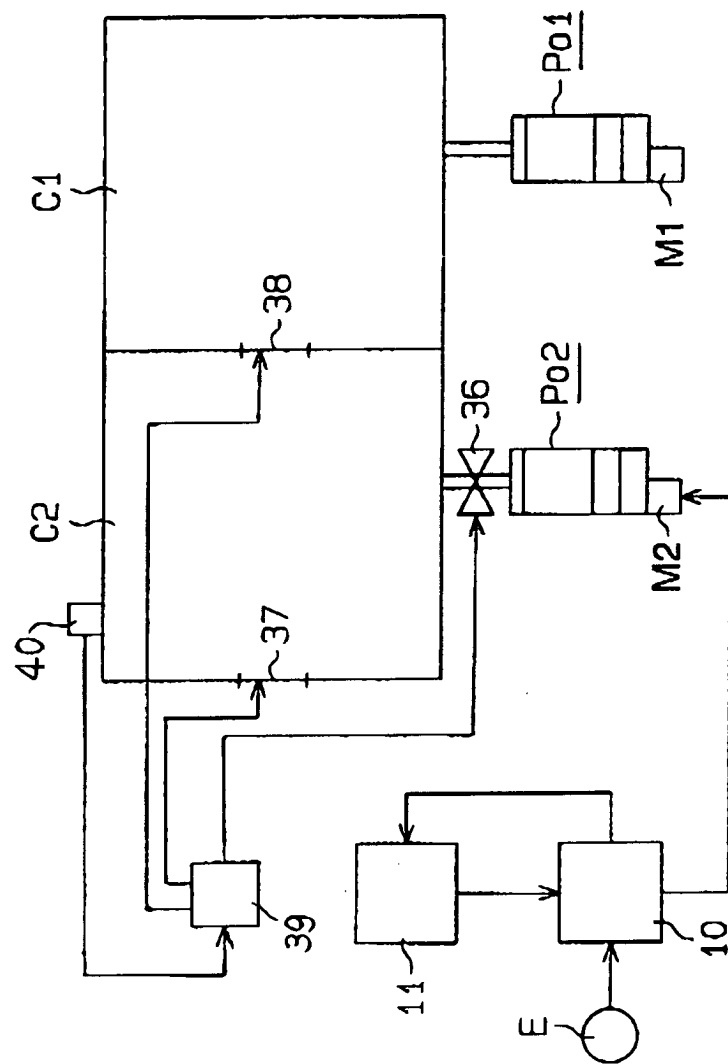


Fig. 2

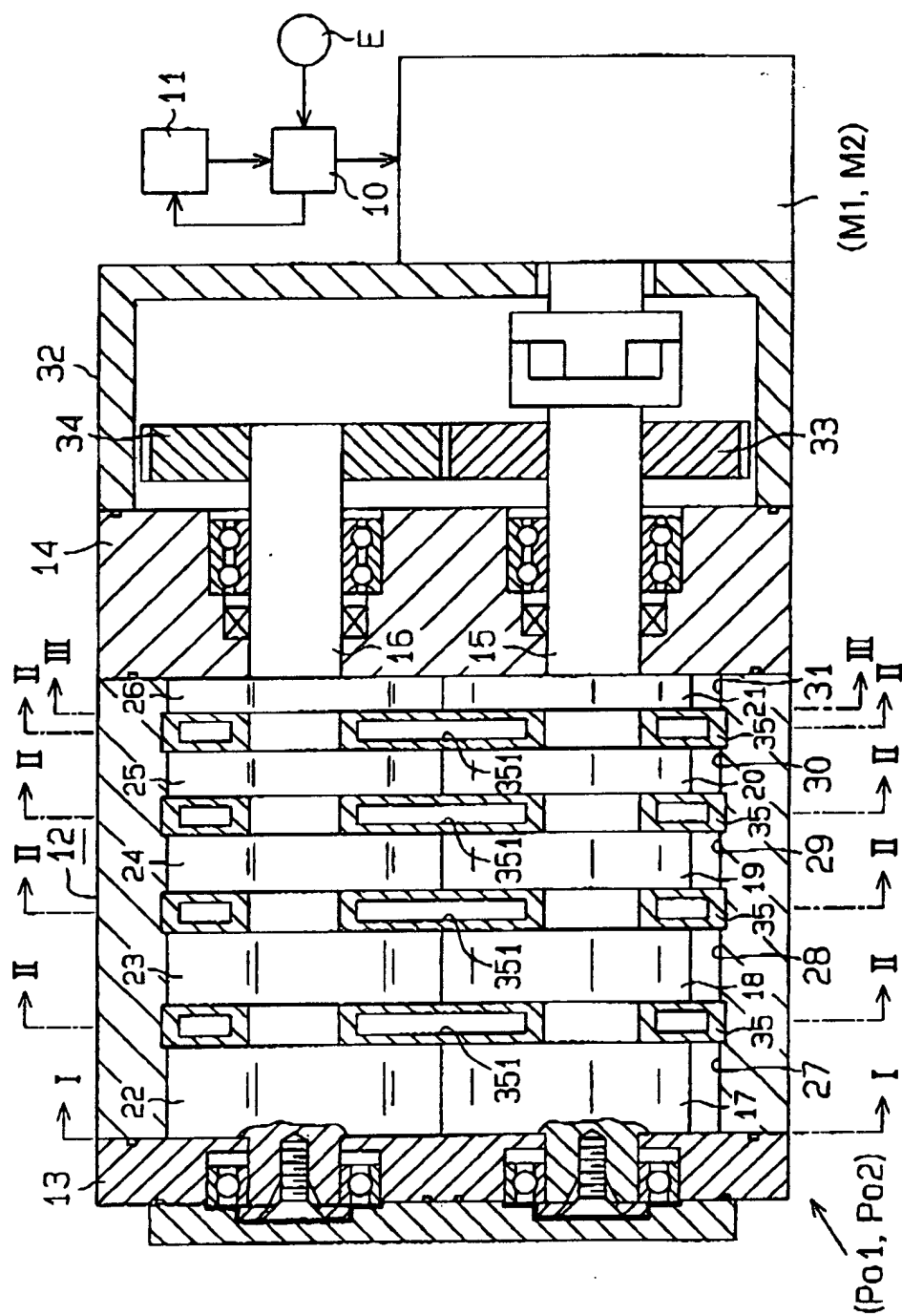


FIG. 3A

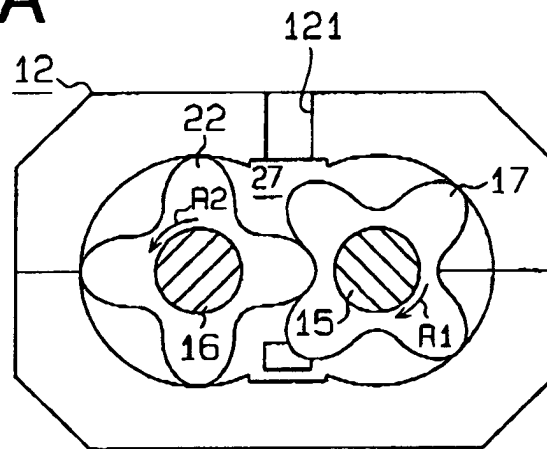


FIG. 3B

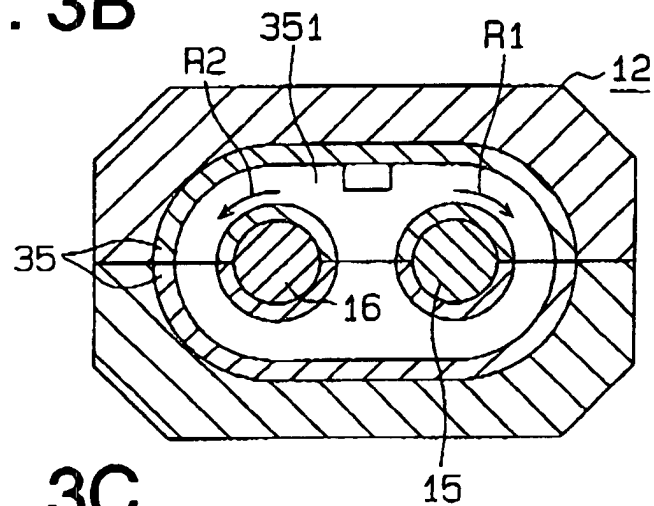


FIG. 3C

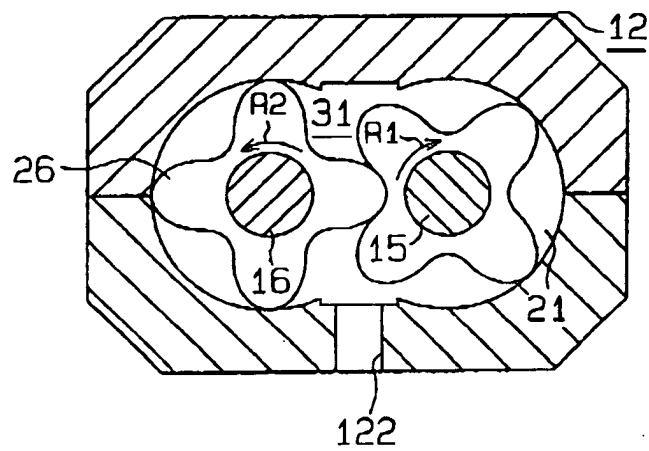


FIG. 4

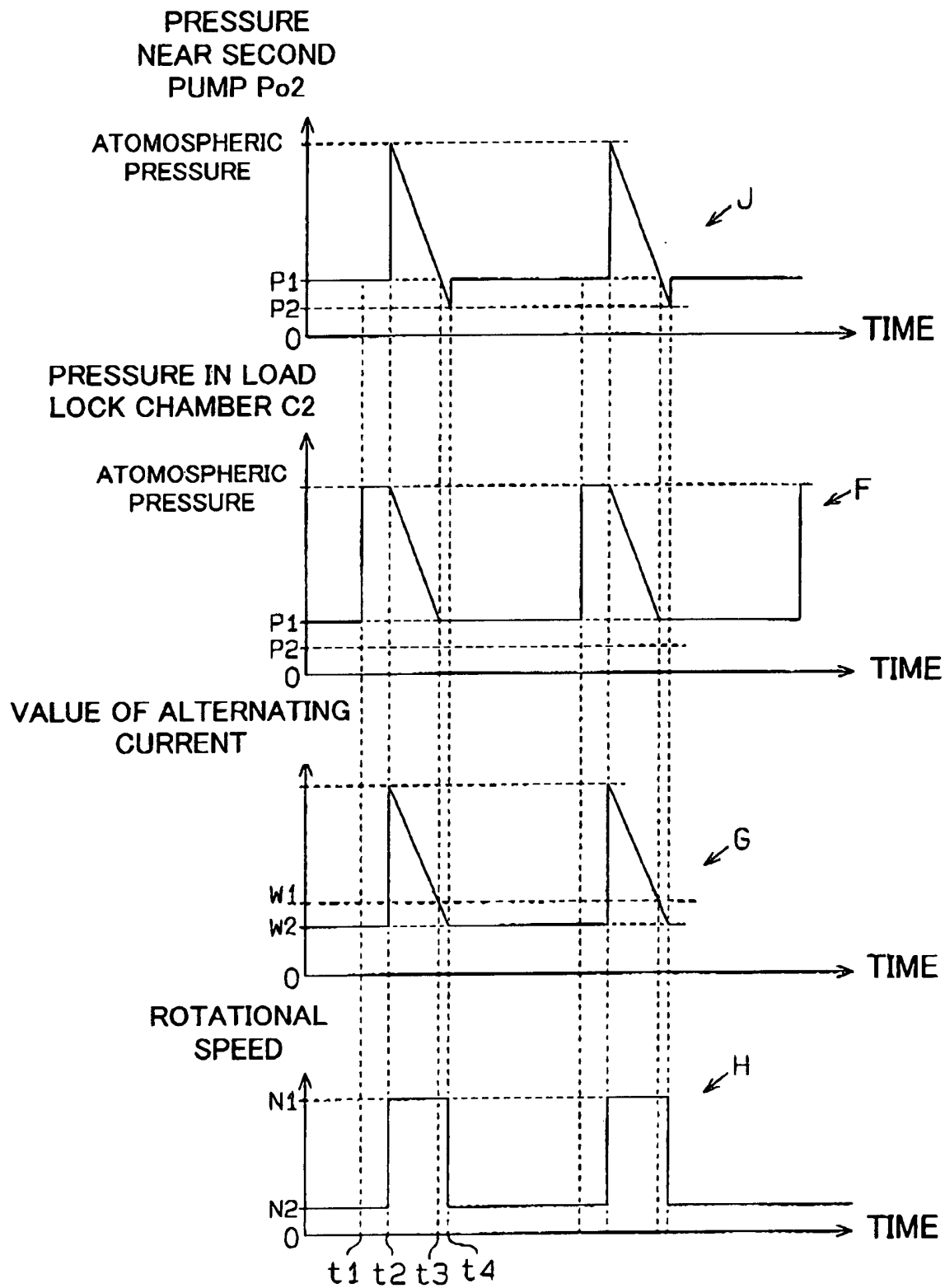


FIG. 5

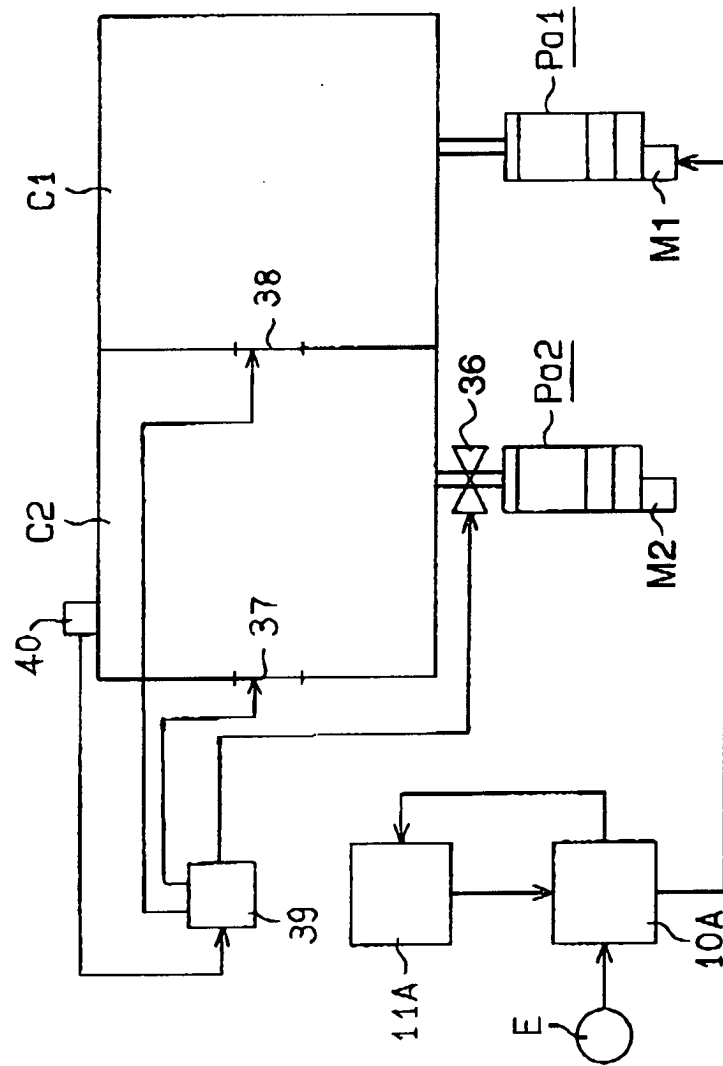


FIG. 6

