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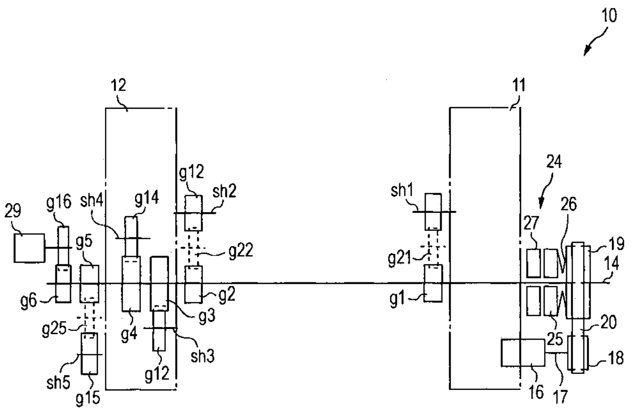
## (54) Driving apparatus for loom

(57) A driving apparatus (30, 50) for a loom (10) includes a main shaft (14) that transmits a rotational force to devices included in the loom (10), an alternating-current motor (16), a speed-reducing mechanism for transmitting rotation of the motor (16) to the main shaft (14) while reducing a rotational speed of the motor (16) at a predetermined ratio, an electromagnetic brake (24) that applies a braking torque to the main shaft (14) when an excitation current is supplied thereto, a drive circuit (34) that supplies alternating-current power to the motor (16), and a brake circuit (36) that supplies the excitation current to the electromagnetic brake (24). When the loom (10) stops, the drive circuit (34) outputs an alternating-current voltage at a frequency corresponding to a synchronous speed lower than the actual rotational speed of the motor (16), so that the motor (16) generates a braking torque in a direction opposite to the rotating direction. In addition, the brake circuit (36) outputs the excitation current to stop the main shaft (14).

FIG. 1



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## Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

**[0001]** The present invention relates to a driving apparatus' which is included in a loom capable of readily varying a drive rotational speed thereof and which can maintain good braking performance of a loom main shaft even when a heavy load is applied to the loom or when the loom is driven at a high speed.

2. Description of the Related Art

**[0002]** In general, a main-shaft driving system for a loom includes, for example, a motor, a loom main shaft that functions as drive sources for devices included in the loom, and a speed-reducing mechanism that includes a plurality of pulleys and a transmission belt and transmits rotation of the motor to the loom main shaft. An electromagnetic brake connected to the loom main shaft for stopping the loom main shaft. When the loom is in operation, the electromagnetic brake is inactivated and an alternating-current (AC) power supply is connected to the motor to drive the loom. If a cause of stoppage, such as a yarn breakage, occurs, a loom stop signal is output so that the electromagnetic brake is activated to stop the loom. An example of such a main-shaft driving apparatus is disclosed in, for example, Japanese Unexamined Patent Application Publication No. 6-158478, which is hereinafter referred to as Patent Document 1 (see paragraphs [0014] to [0026] and Fig. 1).

**[0003]** On the other hand, in weaving mills, looms capable of readily changing rotational speeds thereof without replacing a pulley with another pulley having a different radius are demanded. A known technique that can provide such a loom is described in Japanese Unexamined Utility Model Registration Application Publication No. 61-90877, which is hereinafter referred to as Patent Document 2 (see the entire specification of pages 1 to 8 and Fig. 1). Patent Document 2 describes a main-shaft driving system including a polyphase induction motor and a variable-frequency inverter for supplying AC power to the motor. When the loom is in continuous operation, the inverter outputs AC power at a frequency corresponding to a preset desired rotational speed of the loom, so that the loom can be driven at the desired rotational speed. The structure for setting the rotational speed of the loom using the variable-frequency inverter is also commonly used in looms in which the main shaft is driven by the speed-reducing mechanism as described in Patent Document 1.

**[0004]** Recently, high-speed looms and looms including so-called cam shedding devices, dobby devices, jacquard devices, etc., as shedding devices for weaving high-value-added cloth have been demanded. In such a loom, a stop point (main-shaft angle at which the loom is stopped) tends to delay. In particular, if the main shaft rotates by two turns or more during coasting of the loom after the occurrence of a cause of stoppage and then stops, beating-up motion is performed twice or more during the coasting period. Accordingly, a weaving bar is generated or a missing pile defect occurs when the loom is a pile loom. This leads to a reduction in the quality of woven cloth. This problem may be solved by increasing the braking torque of the electromagnetic brake. However, in such a case, the electromagnetic brake is quickly worn due to the increase in the load applied thereto, and the above-described problem regarding the quality of woven cloth periodically occurs.

**[0005]** The electromagnetic brake includes, for example, an armature attached to a rotating body, such as a pulley, provided on a rotating shaft with a leaf spring or the like provided between the armature and the rotating body, and a stator composed of a laminate of friction material layers. The electromagnetic brake generates a frictional torque by electromagnetically attracting the armature to a surface of the stator. Therefore, the stop point is delayed as the friction material is worn, and eventually, mechanical maintenance tasks, such as an adjustment of an air gap between the armature and the stator, are required. Such a task is complex and requires a long adjustment time. Then, when the friction material is further worn, it becomes necessary to replace the electromagnetic brake. Thus, management problems, such as a reduction in the productivity of woven cloth, an increase in the maintenance cost of the loom, etc., occur.

SUMMARY OF THE INVENTION

**[0006]** In light of the above, it is an object of the present invention to prevent the problems regarding the quality of woven cloth and other problems by maintaining good braking performance of a loom main shaft without increasing the load applied to an electromagnetic brake in a loom capable of weaving high-value added cloth, a high-speed loom, etc., in which a stop point (main-shaft angle at which the loom is stopped) tends to delay.

**[0007]** According to an aspect of the present invention, a driving apparatus for a loom includes a main shaft that transmits a rotational force to devices included in the loom; an alternating-current motor; a speed-reducing mechanism for transmitting rotation of the motor to the main shaft while reducing a rotational speed of the motor at a predetermined ratio; an electromagnetic brake provided on the main shaft, the electromagnetic brake applying a braking torque to the main shaft when an excitation current is supplied to the electromagnetic brake; a drive circuit that supplies alternating-current power to the motor; and a brake circuit that supplies the excitation current to the electromagnetic brake. When the loom stops, the drive circuit stops supplying the alternating-current power and the brake circuit outputs the excitation current to stop the main shaft. In addition, as a characteristic feature of the present invention, the drive circuit rotates the main shaft by supplying the alternating-current power with an output frequency that corresponds to a set rotational speed of the loom while the loom is in operation. When the loom stops, during at least a part of a period from when the supply of the alternating-current power is stopped to when the rotation of the main shaft stops, the drive circuit outputs an alternating-current voltage with a frequency lower than the output frequency for when the loom is in operation, thereby causing the motor to apply a braking torque to the main shaft.

**[0008]** According to the above-described aspect of the present invention, when the loom is in operation, the drive circuit rotates the main shaft by supplying the alternating-current power with the output frequency that corresponds to the set rotational speed of the loom. Therefore, unlike the known structure, the rotational speed of the loom can be readily set to a desired value without replacing the pulley. In addition, when the loom stops, during at least the part of the period from when the supply of the alternating-current power is stopped to when the rotation of the loom main shaft stops, the drive circuit outputs the alternating-current voltage with the frequency lower than the output frequency for when the loom is in operation. Therefore, the motor can generate a braking torque in a direction opposite to the rotating direction thereof. In other words, in addition to the braking torque of the electromagnetic brake, the braking torque generated by the motor is also applied to the driving system of the main shaft. Therefore, compared to the known apparatus in which the main shaft is stopped using only the braking torque of the electromagnetic brake, the delay in the stop point of the loom can be reduced without increasing the braking torque of the electromagnetic brake. Accordingly, problems of weaving bars and missing pile defects, which occur due to the delay in the stop point in the known apparatus, can be prevented. In addition, since the braking torque generated by the motor is additionally applied, braking workload placed on the electromagnetic brake is reduced. Therefore, the rate at which the electromagnetic brake is worn is reduced. As a result, the frequency of occurrence of defects in the woven cloth due to wearing of the electromagnetic brake can be reduced and the life of the electromagnetic brake can be increased. In addition, an impact applied to the speed-reducing mechanism when the loom is stopped can be reduced, so that the life of the speed-reducing mechanism can also be increased.

**[0009]** In the above-described driving apparatus for the loom, the output shaft of the motor and the main shaft are arranged on the frames of the loom such that the rotational axes thereof are separated from each other. The speed-reducing mechanism includes, for example, first and second pulleys that are attached coaxially with the output shaft of the motor and the main shaft, respectively, and an endless belt stretched between the first and second pulleys. However, the speed-reducing mechanism is not limited to this, and other known speed-reducing mechanisms, such as a mechanism including gears with different numbers of teeth that are attached coaxially with the output shaft of the motor and the main shaft to reduce the rotational speed, may also be used.

**[0010]** Preferably, the brake circuit is capable of selectively applying one of a holding voltage and an overexcitation voltage that is higher than the holding voltage to the electromagnetic brake, and the brake circuit starts supplying the overexcitation voltage at a predetermined brake start time and supplies the holding voltage after the rotation of the main shaft stops. In such a case, during a period in which a braking torque for stopping the loom is required, a braking torque larger than that applied after the rotation of the main shaft stops is generated. Therefore, the rotation of the loom main shaft can be stopped more quickly. Then, after the rotation of the main shaft stops, the voltage is switched to the holding voltage so that a braking torque enough to simply maintain the stopped state is generated. Accordingly, power consumed by the electromagnetic brake in the process of stopping the loom can be reduced and an energy saving effect can be obtained.

**[0011]** More preferably, the frequency of the alternating-current voltage output by the drive circuit during the part of the period from when the supply of the alternating-current power is stopped to when the rotation of the loom main shaft stops corresponds to a synchronous speed lower than the actual rotational speed of the motor at the time when the alternating-current voltage is output. In such a case, the motor can reliably and continuously generate the braking torque in the direction opposite to the rotating direction thereof during the part of the above-described period. The part of the above-described period may be, for example, 1) a period starting at a time later than the time at which the supply of the alternating-current power to the motor is stopped; 2) a period ending at a time earlier than the time at which the rotation of the loom main shaft stops; and 3) the entire period from when the supply of the alternating-current power to the motor is stopped to when the rotation of the loom main shaft stops. The start time and the end time of the part of the above-described period are determined by the loom manufacturer.

**[0012]** Preferably, the start time of the part of the above-described period is earlier than the brake start time of the electromagnetic brake. In such a case, unlike the known structure, by the time the electromagnetic brake is activated, the rotational speed is already reduced by the amount corresponding to the braking torque generated by the motor. Therefore, the loom main shaft can be more quickly stopped and the amount of rotation of the main shaft during the period in which the braking torque is applied by the electromagnetic brake (that is, braking workload) can be reduced. As a result, the life of the electromagnetic brake can be increased. In addition, an impact applied to the speed-reducing mechanism when the electromagnetic brake is activated is reduced because the rotational speed is already somewhat reduced by the time the electromagnetic brake is activated.

Therefore, the lives of the gears, the endless belt, etc., included in the speed-reducing mechanism can also be increased.

**[0013]** The above-described alternating-current motor is not particularly limited as long as the motor can be driven by a power source that outputs a voltage whose sign is switched between positive and negative with time, and may either be a polyphase or single-phase motor. For example, an induction motor or a synchronous motor that can be driven by a commercial power source, a brushless direct-current motor, a reluctance motor including a rotor free from permanent magnets or electromagnets, etc., may be used.

**[0014]** In the case in which the above-mentioned synchronous motor or the reluctance motor is used, the drive circuit outputs an alternating-current voltage with a command frequency that is gradually reduced so that loss of synchronism does not occur (so that the braking torque can be generated by the rotating motor) in the part of the above-described period. Accordingly, the motor effectively generates the braking torque for reducing the rotational speed thereof. In addition, when the induction motor is used, a variable-voltage, variable-frequency inverter may be used as the drive circuit. In such a case, similar to the above-described drive circuit, the inverter may generate an alternating-current voltage with a command frequency that is gradually reduced in the part of the above-described period. Alternatively, the inverter may switch the output voltage to an alternating-current voltage with a frequency lower than the rated operating frequency of the motor (for example, one-third or less of the rated operating frequency of the motor). The braking torque can be generated by the rotating induction motor by applying the alternating-current in either of the above-described manners.

**[0015]** In the case in which the induction motor is used and the output voltage is switched to an alternating-current voltage with a low frequency, if the speed is reduced to below the synchronous speed corresponding to the frequency of the output alternating-current voltage due to the operation of the motor and the electromagnetic brake, the motor starts to generate an accelerating torque instead of the braking torque. To prevent this, preferably, the end time of the part of the above-described period is set to be earlier than the time at which the actual rotational speed of the motor that is reduced due to the operation of the motor and the electromagnetic brake reaches the synchronous speed corresponding to the frequency of the output voltage. Alternatively, when the actual rotational speed reaches the synchronous speed corresponding to the frequency of the output voltage, the output voltage may be switched again to an alternating-current voltage with a frequency corresponding to a synchronous speed that is lower than the actual rotational speed at that time.

**[0016]** The load applied to the loom main shaft largely varies in accordance with the preset rotational speed of the loom, settings regarding warp-yarn shedding motion (the shedding pattern, the shed size, etc.) set in the shedding device, etc., and accordingly the stop point of the loom also largely varies. Therefore, the time at which the braking torque is generated by the motor and the brake start time of the electromagnetic brake may be adequately set when an adjustment operation is performed before the continuous operation. Accordingly, a structure capable of setting at least one of the time at which the braking torque is generated by the motor and the brake start time of the electromagnetic brake is provided. However, the stop point of the loom often changes from the initially set point due to the change in the rotational speed of the loom or the like. Therefore, preferably, a structure capable of correcting the above-mentioned times on the basis of deviation of a stop point of the loom from a target stop point is provided so that the corrected times can be used the next time the loom is stopped. More specifically, the driving apparatus may further include a correction circuit that outputs a correction signal based on deviation of a stop point at which the rotation of the main shaft is stopped from a target stop point. The next time the loom stops, the driving apparatus corrects at least one of the time at which the output of the alternating-current voltage with the low frequency from the drive circuit is started and the brake start time at which the brake circuit starts supplying the overexcitation voltage using the correction signal. Accordingly, the times at which the braking torques are generated by the motor and the electromagnetic brake are automatically corrected such that the deviation of the actual stop point from the target stop point can be canceled. Therefore, accidents and quality problems due to the delay of the stop point can be prevented.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0017]**

Fig. 1 is a plan view illustrating a main-shaft driving system of a loom;

Fig. 2 is a block diagram illustrating the inner structure of a driving apparatus for a loom according to an embodiment of the present invention;

Fig. 3 is a timing chart illustrating outputs from an inverter and a brake circuit and a rotational speed of a loom main shaft in a process of stopping the loom performed by the driving apparatus according to the embodiment of the present invention; and

Fig. 4 is a block diagram illustrating the inner structure of a driving apparatus according to another embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0018]** Embodiments for carrying out the present invention will be described below with reference to the drawings. Fig. 1 is a schematic plan view of a driving system for a loom main shaft. Referring to Fig. 1, a loom 10 includes right and left frames 11 and 12 and a main shaft 14 for transmitting a rotational force from the right frame 11 on which a motor 16 is provided to the left frame 12. The main shaft 14 is disposed so as to extend through the frames 11 and 12 and is rotatably supported by the frames 11 and 12 at both ends thereof.

**[0019]** A driving unit for the main shaft 14 basically includes the motor 16, a motor pulley 18, a loom pulley 19, an endless belt 20, and an electromagnetic brake 24, which are disposed around the right frame 11, as shown at the right in Fig. 1. The motor pulley 18 is coaxially and integrally attached to an output shaft of the motor 16, and the loom pulley 19, which has a larger diameter than that of the motor pulley 18, is coaxially and integrally attached to the main shaft 14 at the right end thereof. Each of the motor pulley 18 and the loom pulley 19 has a plurality of V-shaped grooves arranged in an axial direction in an outer periphery thereof. The endless belt 20 includes a plurality of V-belts and is stretched between the motor pulley 18 and the loom pulley 19 with a predetermined tension applied thereto. The motor pulley 18, the loom pulley 19, and the endless belt 20 form a speed-reducing mechanism for transmitting the rotation of the output shaft of the motor 16 to the main shaft 14 at a reduced speed.

**[0020]** A disc-shaped armature 25 is provided adjacent to a surface of the loom pulley 19 that faces the right frame 11. The armature 25 is coaxially attached to the loom pulley 19 with a leaf spring 26 provided therebetween. In addition, a disc-shaped stator 27 is attached to the right frame 11 so as to face the armature 25. The armature 25 is made of magnetic material, such as steel. The stator 27 is formed in a disc shape by providing a so-called brake shoe, which is obtained by laminating friction material layers, on a surface of an annular electromagnetic coil. The stator 27 is attached such that the brake shoe faces the armature 25. The positions at which the armature 25 and the stator 27 are attached to the right frame 11 are adjusted such that an air gap of several millimeters is provided between the armature 25 and the stator 27. When the electromagnetic coil receives electricity from a brake circuit 36, which will be described below, the armature 25 is electromagnetically attracted to the stator 27 against the force applied by the leaf spring 26. When the electricity supplied to the electromagnetic coil is cut off, the armature 25 is released from the stator 27 due to the force applied by the leaf spring 26. Thus, the armature 25, the leaf spring 26, and the stator 27 form the electromagnetic brake 24.

**[0021]** The main shaft 14 is used as a drive shaft for transmitting the rotational force to devices that are mechanically driven in synchronization with the rotation of the main shaft 14 in the loom, and thereby functions as a crankshaft of the loom. More specifically, the loom 10 further includes drive shafts sh1 and sh2 for respectively driving right and left selvage devices, a drive shaft sh3 for driving a beating device, a drive shaft sh4 for driving a warp-yarn shedding device, and a drive shaft sh5 for driving a take-up device for taking up woven cloth. In Fig. 1, gears g1 to g5 are rotated integrally with the main shaft 14, and gears g11 to g15 are rotated integrally with the drive shafts sh1 to sh5, respectively. Gears g21, g22, and g25 are idling gears that mesh with both the corresponding gears on the main shaft and the corresponding gears integrated with the drive shafts of the devices so as to transmit the rotational force of the main shaft to the drive shafts.

**[0022]** An encoder 29 that functions as an angle detector is attached to the main shaft 14. A gear g16 is integrally attached to an input shaft of the encoder 29, and a gear g6 having the same number of teeth as that of the gear g16 is attached to the main shaft 14 at an end thereof. The encoder 29 is attached to the left frame 12 such that the gear g16 on the input shaft of the encoder 29 meshes with the gear g6. Accordingly, as the main shaft 14 rotates, the encoder 29 outputs an angle signal S0 that corresponds to a rotational angle θ of the main shaft 14.

First Embodiment

**[0023]** Fig. 2 illustrates the inner structure of a driving apparatus 30 for the loom 10 according to a first embodiment of the present invention. The driving apparatus 30 basically includes a main controller 32 for controlling the overall operation of the loom 10, a drive circuit 34 for generating electric power to be supplied to the motor 16, and the brake circuit 36 for supplying a braking current to the electromagnetic brake 24. The main controller 32 receives the main-shaft angle signal S0 from the encoder 29. In addition, the main controller 32 is connected to loom operation buttons including a drive button 37 and a stop button 38 from which a drive operation signal S1 and a stop operation signal S2, respectively, are input to the main controller 32. A cause-of-stoppage signal S3 is also input to the main controller 32 from a feeler that detects a weft insertion error, a warp breakage sensor, etc. The main controller 32 executes a control program installed in advance by the loom manufacturer and controls the overall operation of the loom by outputting corresponding control signals. More specifically, the main controller 32 outputs a drive signal S5 when the drive operation signal S1 is input thereto. When the stop operation signal S2 or the cause-of-stoppage signal S3 is input, the main controller 32 turns off the drive signal S5 and outputs a stop signal S8 at a predetermined set angle ST1 and then outputs a brake signal S9 at a predetermined set angle ST2.

**[0024]** According to the present embodiment, a three-phase induction motor, which is an alternating-current (AC) motor, is used as the motor 16, and a variable-voltage, variable-frequency (VVVF) inverter is used as the drive circuit 34. However, other single-phase or polyphase induction motors may also be used as the motor 16. Alternatively, a polyphase synchronous motor or a pulse motor may also be used as the motor 16 while a circuit corresponding to the motor is used as the drive circuit 34.

**[0025]** The inverter 34 is connected to a commercial power source 46 that supplies three-phase AC power, and is also connected to a primary winding (not shown) of the motor 16 at an output terminal thereof. In addition, the inverter 34 is connected to the main controller 32 such that the drive signal S5, a low-speed forward rotation signal S6, a low-speed reverse rotation signal S7, and the stop signal S8 can be respectively input to four input terminals A to D that function as control-signal input terminals of the inverter 34. In addition, the inverter 34 is also connected to a setter 39 such that information can be electrically communicated therebetween, whereby the inverter 34 can receive a set-value signal S4 representing the information regarding a set rotational speed of the loom and the like.

**[0026]** With regard to the input terminals of the inverter 34, the terminals A, B, and C are input terminals for receiving the drive signal, the low-speed forward rotation signal, and the low-speed reverse rotation signal, respectively. In addition, the terminal D is an input terminal for receiving the stop signal. When this signal is input, the inverter 34 carries out a regenerative braking operation, which will be described below. A drive rotational speed of the loom (rotational speed of the loom main shaft) is input to the setter 39 in advance by an operator. The setter 39 determines an output command frequency to be output from the inverter 34 on the basis of information regarding the outer diameters of the motor pulley 18 and the loom pulley 19, the number of poles and the rated operating frequency of the motor 16, etc., which are input thereto in advance. The information of the thus determined output command frequency is transmitted to the inverter 34 as the set-value signal S4.

**[0027]** When the drive signal S5 is input, the inverter 34 outputs an AC voltage corresponding to the above-described command frequency in accordance with a so-called V/f pattern that shows a ratio of the output voltage to the output frequency and that is programmed in advance. Accordingly, the motor 16 is rotated at a speed corresponding to the command frequency. In addition, when the low-speed forward rotation signal S6 or the low-speed reverse rotation signal S7 is input from the main controller 32, the inverter 34 outputs an AC voltage at a low frequency (5 Hz to 10 Hz) that corresponds to a fraction of the rated operating frequency of the motor 16. Accordingly, the motor 16 can be rotated in the forward or reverse direction at a low speed. When the stop signal S8 is input, the inverter 34 outputs an AC voltage at a low frequency compared to the synchronous speed corresponding to the current rotational speed, so that an electric braking torque is generated by the motor 16 during coasting thereof. Details of this operation will be described below.

**[0028]** The brake circuit 36 is connected to an overexcitation power source 47 that outputs a direct-current (DC) overexcitation voltage V11 and a holding power source 48 that outputs a holding voltage V12. In addition, an output terminal of the brake circuit 36 is connected to the electromagnetic coil (not shown) included in the stator 27. The brake circuit 36 is also connected to the main controller 32 such that the brake signal S9 can be input to the brake circuit 36. When the brake signal S9 is turned on, the brake circuit 36 outputs the DC voltage supplied from the overexcitation power source 47 to the electromagnetic brake 24, and then waits for a predetermined time P2 to elapse. Then, the brake circuit 36 outputs the DC voltage supplied from the holding power source 48 to the electromagnetic brake 24. When the brake signal S9 is turned off, the brake circuit 36 stops supplying the DC voltage to the electromagnetic brake 24.

**[0029]** The operation of the driving apparatus 30 performed when the loom stops will be described below with reference to Fig. 3. Fig. 3 is an operation timing chart in which the vertical axis represents the signal levels of control signals output from the main controller 32 and the rotational speed of the loom main shaft. In addition, the horizontal axis represents time. The timing chart also shows the operational state of the inverter that functions as the drive circuit 34, the output frequency and voltage thereof, and the level of voltage output from the brake circuit 36. Variation in the rotational speed of the loom main shaft according to the present invention is shown by the solid line. In comparison, as an example of the known apparatus, variation in the rotational speed of the loom main shaft obtained when only the electromagnetic brake is activated using a power source with the same voltage V11 as that of the overexcitation power source 47 is shown by the dashed line.

**[0030]** At time t0, the drive signal S5 is turned on and the brake signal S9 is turned off by the main controller 32. Accordingly, the loom 10 is in a continuous operation in which weft insertion is performed. More specifically, because the drive signal S5 is turned on, the inverter 34 continuously outputs AC power with the output voltage V1 and the output frequency f1 corresponding to the set rotational speed, so that the main shaft is continuously driven at a rotational speed r0.

**[0031]** Then, when a warp breakage occurs during the continuous operation and a yarn breakage signal is input as the cause-of-stoppage signal S3, the main controller 32 immediately starts a sequence for stopping the loom. More specifically, first, the main controller 32 turns off the drive signal S5 and turns on the stop signal S8 at a predetermined angular time ST1. Accordingly, the inverter 34 changes the output frequency from the frequency f1 for driving to a frequency f2 corresponding to the frequency less than a fraction of the output frequency f1 and changes the output voltage to a voltage V2 corresponding to the frequency f2 in accordance with the V/f pattern. The AC power with the output voltage V2 and the output frequency f2 is output to the motor 16 for a period P1 (period between time t1 and time t3). Thus, the operation of the motor 16 is changed from driving to regenerative braking, that is, to dynamic braking in which the AC power with the frequency f2 is returned to the inverter 34. Accordingly, the output shaft of the motor 16 that has been rotating at the rotational speed r0 receives a braking torque Q1 in a direction opposite to the rotating direction. Therefore, the rotational speed of the motor 16 is gradually reduced toward a rotational speed r3, which is a synchronous rotational speed corresponding to the output frequency f2. The output frequencies f1 and f2 and the output voltages V1 and V2 satisfy $f1 \geq 3 \cdot f2$ and $V1 > V2$. With regard to numerical ranges, f1 and V1 are in the ranges of 30 Hz to 60 Hz and 100 V to 200 V, respectively, and f2 and V2 are in the ranges of 1 Hz to 10 Hz and 60 V to 80 V, respectively. For example, f1 and V1 are set to 60 Hz and 200 V, respectively, and f2 and V2 are set to 15 Hz and 80 V, respectively. The regenerative AC power obtained by the inverter 34 is stored in the inverter 34 or consumed by being dissipated as thermal energy.

**[0032]** The main controller 32 turns on the brake signal S9 at time t2 which corresponds to a brake start time input through the setter 39 in advance. Accordingly, the brake circuit 36 supplies the overexcitation DC voltage V11 supplied from the overexcitation power source 47 to the electromagnetic brake 24 for a period P2. Therefore, the electromagnetic brake 24 applies a braking torque Q2 higher than that in a normal holding state to the main shaft 14, so that the rotational speed of the main shaft 14 is rapidly reduced from a rotational speed r1 due to the braking torque Q1 of the motor 16 generated after time t1 and the braking torque Q2 generated by the electromagnetic brake.

**[0033]** At time t3, which is the end time of the period P1 of regenerative braking, the rotational speed of the main shaft 14 is reduced to a rotational speed r2 that is slightly higher than the rotational speed r3. At this time, the main controller 32 turns off the stop signal S8 and accordingly the inverter 34 stops outputting the AC power with the output voltage V2 and the output frequency f2, which has been output for regenerative braking. Then, the output is electrically open-circuited so as to allow free running of the motor 16. Therefore, no braking torque is generated by the motor 16. However, the brake circuit 36 continuously supplies the DC overexcitation voltage V11 to generate the high braking torque Q2, so that the main shaft 14 continues to decelerate until the rotation thereof completely stops at time t4. Then, at time t5, which is the end time of the period P2 that starts at time t2, the brake circuit 36 switches the voltage output to the electromagnetic brake 24 to the DC holding voltage-V12. Accordingly, the electromagnetic brake 24 continuously applies a braking torque Q3 to the main shaft 14 so that the main shaft 14 can be held at the stop position. When the continuous rated voltage of the electromagnetic brake 24 is V13, the relationship $V11 > V13 \geq V12$ is satisfied. For example, when V13 is 24 V, V11 is set to 60 V and V12 is set in the range of 9 V to 24 V.

**[0034]** As shown in Fig. 3, in the driving apparatus according to the present invention, during the coasting period in the process of stopping the loom, the drive circuit outputs an AC voltage at a frequency corresponding to a synchronous speed lower than the actual rotational speed of the motor. Accordingly, the motor generates a braking torque in a direction opposite to the rotating direction. As a result, the rotation of the main shaft of the loom can be stopped at time t4, which is earlier than a stop time t6 at which the main shaft can be stopped by the known apparatus. In addition, as is clear from Fig. 3, according to the apparatus of the present invention, braking workload (amount of rotation during braking) of the electromagnetic brake 24 is reduced compared to that in the known apparatus. As a result, the rate at which the electromagnetic brake 24 is worn can be reduced and the life of the electromagnetic brake 24 can be increased accordingly. In addition, an impact applied to the endless belt included in the speed-reducing mechanism when the electromagnetic brake 24 is activated is reduced compared to that in the case in which the loom is stopped using only the braking torque applied by the electromagnetic brake as in the know structure. Therefore, the lives of the endless belt and the pulleys included in the speed-reducing mechanism are increased.

**[0035]** In the above-described embodiment, regenerating braking of the motor 16 is started at time t1, which is earlier than time t2, which is a brake start time of the electromagnetic brake 24. Accordingly, unlike the known structure, by the time t2 at which the electromagnetic brake 24 is activated, the rotational speed is already reduced to r1 due to the braking torque applied by the motor 16 since time t1. Therefore, the main shaft 14 can be quickly stopped at time t4, and accordingly the stop point (angle) of the main shaft 14 can be shifted frontward. However, the present invention is not limited to this, and regenerative braking of the motor 16 may also be started at a time after time t2.

**[0036]** The period P1 during which regenerative braking is performed and the period P2 during which the overexcitation voltage is output are determined by the loom manufacturer in accordance with the expected load and the set rotational speed of the loom, and are programmed in the main controller 32 and the brake circuit 36 in advance. The start time of the period P1 is preferably set to an activation start time of the electromagnetic brake 24 or a time earlier than the activation start time. However, the start time of the period P1 is not particularly limited as long as it is set to a time earlier than the time at which the rotational speed of the motor 16 is reduced to about two-third of the rotational speed r0 due to the operation of the electromagnetic brake 24. In addition, the end time of the period P1 is preferably set to a time between the time at which the rotational speed is reduced to about a half of the rotational speed r0 due to the braking torques of the motor 16 and the electromagnetic brake 24 and the time immediately before the main shaft 14 stops. In such a case, the braking torque of the motor 16 can be effectively exploited. The end point of the period P2 is not particularly limited as long as the end point is set to a time after the rotation of the main shaft 14 is completely stopped. Preferably, the end point of the period P2 is set to a time immediately after the main shaft 14 is stopped.

**[0037]** With regard to the voltage output mode applied when the inverter 34 causes the motor 16 to generate the braking torque, the output frequency is directly switched to the frequency f2 in a single step in the above-described embodiment. The frequency f2 may be set to about one-third of the rated operating frequency of the motor 16 (50 Hz to 60 Hz) or less, and is preferably set in the range of 5 Hz to 10 Hz. Instead of switching the output frequency in a single step as described above, the output frequency may also be changed stepwise to a plurality of intermediate frequencies in a plurality of regenerative braking steps until the output frequency is finally set to the frequency f2.

**[0038]** Alternatively, a pattern for reducing the output frequency with time may be set in the inverter 34 in advance. In such a case, when the drive signal S5 is turned off, regenerative braking may be performed by reducing the output frequency in accordance with the preset pattern for reducing the output frequency. Alternatively, the inverter 34 may successively calculate the rotational speed of the motor 16 by performing vector operation or the like based on the relationship between the current output to the motor 16 and the flux linkage and reduce the output frequency so as to set the braking torque at a maximum on the basis of the determined rotational speed. Alternatively, the drive circuit may successively reduce the output frequency on the basis of a rotational speed that is actually measured by a rotational speed sensor attached to the output shaft, so that the motor 16 generates the braking torque.

**[0039]** After the regenerating braking operation is performed at the frequency f2, the output frequency may be further reduced to continue the regenerative braking operation. In addition, a braking operation for generating another braking torque may also be performed. For example, so-called DC injection braking may be performed in which a direct current is applied to any of the wirings included in the polyphase motor to generate a braking torque.

**[0040]** Although an induction motor is used in the above-described embodiment, the present invention is not limited to this, and other kinds of AC motors that are driven by receiving an AC voltage supplied from the drive circuit and having a pole inverted at a frequency corresponding to the set rotational speed of the loom while the loom is in operation may also be used. For example, a synchronous motor, a brushless DC motor, a reluctance motor that includes a rotor free from permanent magnets or electromagnets and rotates the rotor by generating magnetic poles on the rotor with a magnetic flux from the stator, etc., may be used. In the process of stopping the loom, the drive circuit outputs an AC voltage with a frequency that is gradually reduced from the frequency set in the driving operation, so that the braking torque is generated.

**[0041]** In the electromagnetic brake 24, the friction material is worn with age, and therefore the air gap between the armature 25 and the stator 27 is gradually increased. Accordingly, the loom stop point is gradually delayed. In order to prevent this, the overexcitation power source 47 for supplying the overexcitation voltage in the process of stopping the loom may be structured such that the output voltage thereof can be changed. When the stop point starts to delay, the overexcitation voltage is increased (in other words, the braking torque is increased) to reduce the delay.

**[0042]** Another method for reducing the delay of the stop point of the loom is to reset the brake start time input through the setter to a time earlier than the currently set time (angle), so that the brake signal S9 is output earlier. In addition, to reduce power consumption, the brake start time of the loom may be automatically corrected on the basis of information regarding the delay of stop point. In a second embodiment which will be described below, a driving apparatus 50 is structured such that when the stop signal S8 is generated, a stop point of the loom is measured and deviation of the stop point from a target stop point is calculated. Then, the next time the process of stopping the loom is performed, the driving apparatus 50 corrects the brake start time on the basis of the determined deviation from the target stop point.

Second Embodiment

**[0043]** A drive apparatus according to the second embodiment of the present invention is illustrated in Fig. 4. The structure of the driving apparatus according to the second embodiment is similar to that shown in Fig. 2 except a correction circuit 40 is additionally provided. The correction circuit 40 corrects both the time at which the output of the AC voltage with the frequency corresponding to a low synchronous speed to the motor is started and the brake start time of the electromagnetic brake 24. Fig. 4 shows in detail the structure around the correction circuit 40. In Fig. 4, the motor 16 and the electromagnetic brake 24 positioned downstream of the drive circuit 34 and the brake circuit 36, respectively, and operation buttons positioned upstream of the main controller 32 are omitted. In addition, components having the same functions as those of the components shown in Fig. 2 are denoted by the same reference numerals, and detailed explanations thereof are thus omitted.

**[0044]** In the driving apparatus 50 shown in Fig. 4, the correction circuit 40 is additionally connected to the main controller 32. The correction circuit 40 outputs correction signals to the main controller 32 in order to correct both the time at which the output of the AC voltage with the frequency corresponding to a low synchronous speed to the motor is started and the brake start time of the electromagnetic brake 24. The correction circuit 40 basically includes a setter 42 and a correction-signal generator 44.

**[0045]** The correction-signal generator 44 receives the stop signal S8 from the main controller 32 and also receives a main-shaft-angle signal S0 from the encoder 29. In addition, correction-signal generator 44 is connected to the main controller 32 such that output signals S11 and S12 can be supplied to the main controller 32. In addition, the correction-signal generator 44 is connected to the setter 42 for setting a target stop angle. The correction-signal generator 44 measures the time elapsed since the stop signal S8 is turned on. Then, when the elapsed time reaches a predetermined time tx at which the loom main shaft is expected to be completely stopped, the correction-signal generator 44 compares the main shaft angle θ with the target stop angle θS set by the setter 42 and outputs delay angle signals S11 and S12 that correspond to the deviation from the target stop angle to the main controller 32 as correction signals. The main controller 32 reads the signal values of the input delay angle signals S11 and S12, that is, angles Δθ1 and Δθ2 corresponding to the amounts of correction. The main controller 32 is programmed in advance such that the main controller 32 outputs the stop signal S8 and the brake signal S9 when the angle reaches the set angles ST1 and ST2, respectively, which are used as references. The main controller 32 corrects the set angles ST1 and ST2 by adding the correction angles Δθ1 and Δθ2, respectively, so as to cancel the deviation from the target stop point, and thereby determines the corrected angles ST1' and ST2' to be used the next time the process of stopping the loom is performed. The set angle ST2 can be arbitrarily changed by an operator through an input screen on the setter 39 (not shown in Fig. 4), and the set angle ST1 is determined by the loom manufacturer and is stored in a memory (not shown) in advance.

**[0046]** Then, if the loom is reactivated and the yarn breakage signal S3 is input again while the loom is in continuous operation, the main controller 32 turns off the drive signal S5 and turns on the stop signal S8 when the angle reaches the corrected set angle ST1'. Then, the main controller 32 turns on the brake signal S9 when the angle reaches the corrected set angle ST2'. Accordingly, both the time at which the inverter 34 starts outputting the AC voltage with the frequency corresponding to a low synchronous speed and the brake start time of the electromagnetic brake 24 can be corrected by adding the correction angles Δθ1 and Δθ2, respectively, so as to cancel the deviation from the target stop angle θS. Therefore, the stop point of the loom becomes closer to the target stop angle θS.

**[0047]** Although the time at which the output of the AC voltage with the frequency corresponding to a low synchronous speed to the motor is started and the brake start time of the electromagnetic brake are both corrected in the above-described second embodiment, the apparatus may also be structured such that only one of them is corrected. In addition, the times at which the signals S8 and S9 are output are set in terms of the angle in the above-described second embodiment. However, the present invention may also be applied to an apparatus that sets the times at which the signals S8 and S9 are output in terms of times elapsed since the angle reaches predetermined angles.

**[0048]** The present invention may be applied not only to looms, such as fluid jet looms, that are driven at a high speed but also to looms including devices to which heavy load is applied, for example, to looms including dobby devices, jacquard devices, etc., as warp-yarn shedding devices.

## Claims

1. A driving apparatus (30, 50) for a loom (10), comprising:

   a main shaft (14) that transmits a rotational force to devices included in the loom (10);
   an alternating-current motor (16);
   speed-reducing means for transmitting rotation of the motor (16) to the main shaft (14) while reducing a rotational speed of the motor (16) at a predetermined ratio;
   an electromagnetic brake (24) provided on the main shaft (14), the electromagnetic brake (24) applying a braking torque to the main shaft (14) when an excitation current is supplied to the electromagnetic brake (24);
   a drive circuit (34) that supplies alternating-current power to the motor (16); and
   a brake circuit (36) that supplies the excitation current to the electromagnetic brake (24),
   wherein, when the loom (10) stops, the drive circuit (34) stops supplying the alternating-current power and the brake circuit (36) outputs the excitation current to stop the main shaft (14),
   wherein the drive circuit (34) rotates the main shaft (14) by supplying the alternating-current power with an output frequency that corresponds to a set rotational speed of the loom (10) while the loom (10) is in operation, and
   wherein, when the loom (10) stops, during at least a part of a period from when the supply of the alternating-current power is stopped to when the rotation of the main shaft (14) stops, the drive circuit (34) outputs an alternating-current voltage with a frequency lower than the output frequency for when the loom (10) is in operation, thereby causing the motor (16) to apply a braking torque to the main shaft (14).

2. The driving apparatus (30, 50) according to Claim 1, wherein the brake circuit (36) is capable of selectively applying one of a holding voltage and an overexcitation voltage that is higher than the holding voltage to the electromagnetic brake (24), and
   wherein the brake circuit (36) starts supplying the overexcitation voltage at a predetermined brake start time and supplies the holding voltage after the rota-

tion of the main shaft (14) stops.

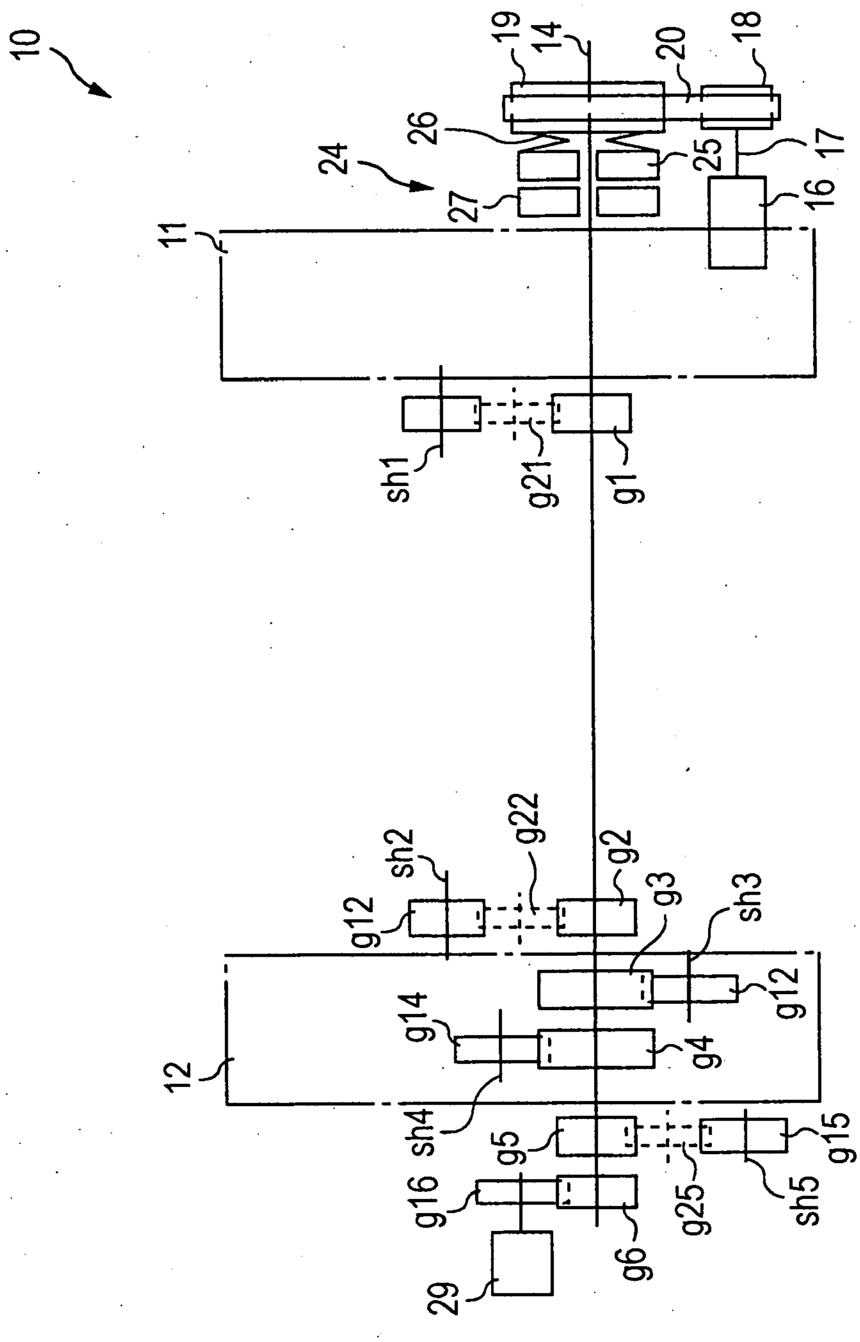
3. The driving apparatus (30, 50) according to one of Claims 1 and 2, wherein the frequency of the alternating-current voltage output by the drive circuit (34) during the part of the period from when the supply of the alternating-current power is stopped to when the rotation of the main shaft (14) stops corresponds to a synchronous speed lower than the actual rotational speed of the motor (16) at the time when the alternating-current voltage is output.

4. The driving apparatus (30, 50) according to one of Claims 1 to 3, wherein the start time of the part of period is earlier than the brake start time of the electromagnetic brake (24).

5. The driving apparatus (30, 50) according to one of Claims 1 to 4, wherein the motor (16) is a polyphase induction motor and the drive circuit (34) is a variable-voltage, variable-frequency inverter, wherein the frequency of the alternating-current voltage output by the drive circuit (34) during the part of the period is one-third or less of the rated operating frequency of the motor (16).

6. The driving apparatus (50) according to one of Claims 1 to 5, further comprising:

a correction circuit (40) that outputs a correction signal based on deviation of a stop point at which the rotation of the main shaft (14) is stopped from a target stop point,
wherein, the next time the loom (10) stops, the driving apparatus (50) corrects at least one of the time at which the output of the alternating-current voltage with the low frequency from the drive circuit (34) is started and the brake start time at which the brake circuit (36) starts supplying the overexcitation voltage using the correction signal.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sh5
g1
g2
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g12
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g14
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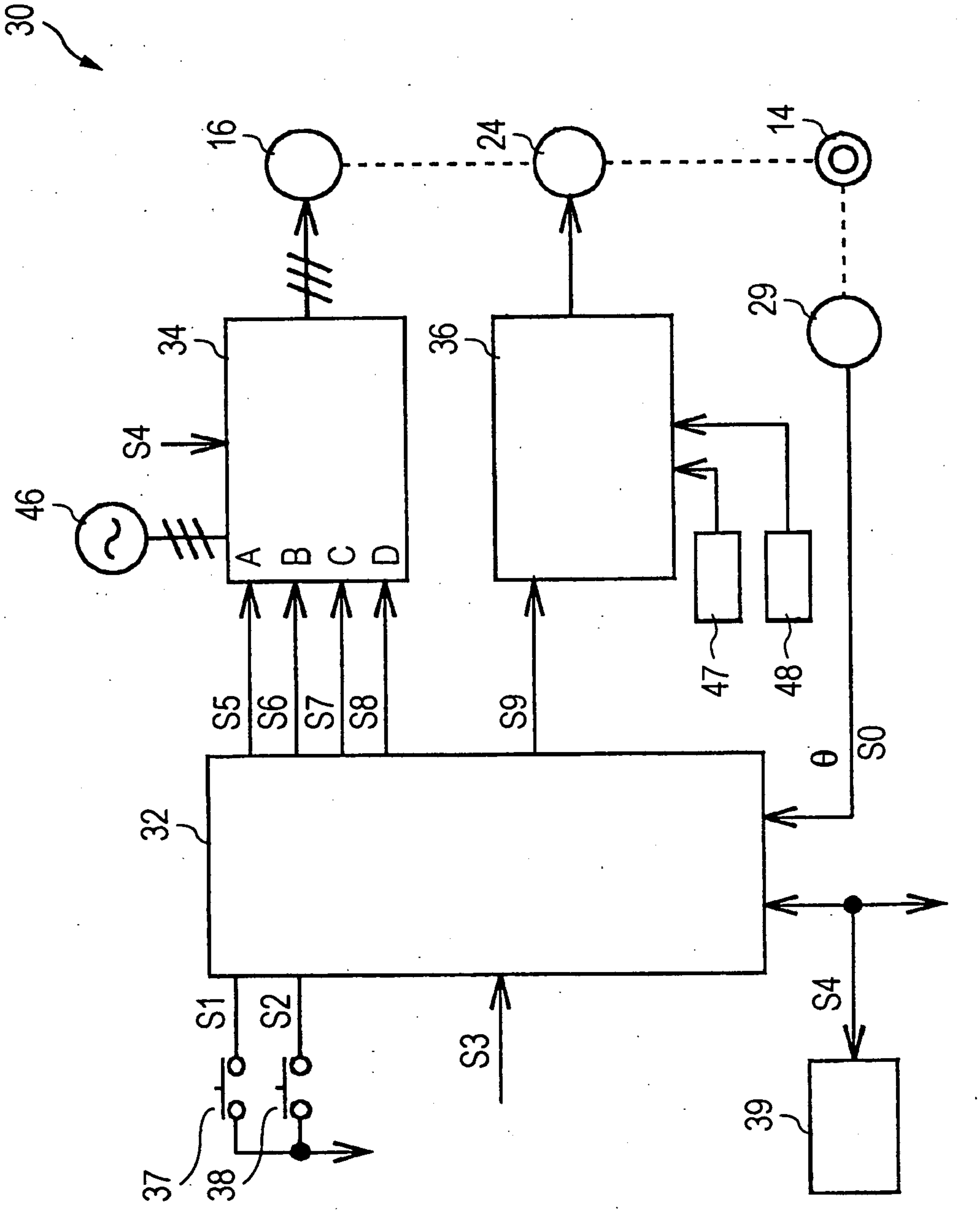
g16
g21
g22
g25

FIG. 1

FIG. 2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16
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36
29
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S4
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S5
S6
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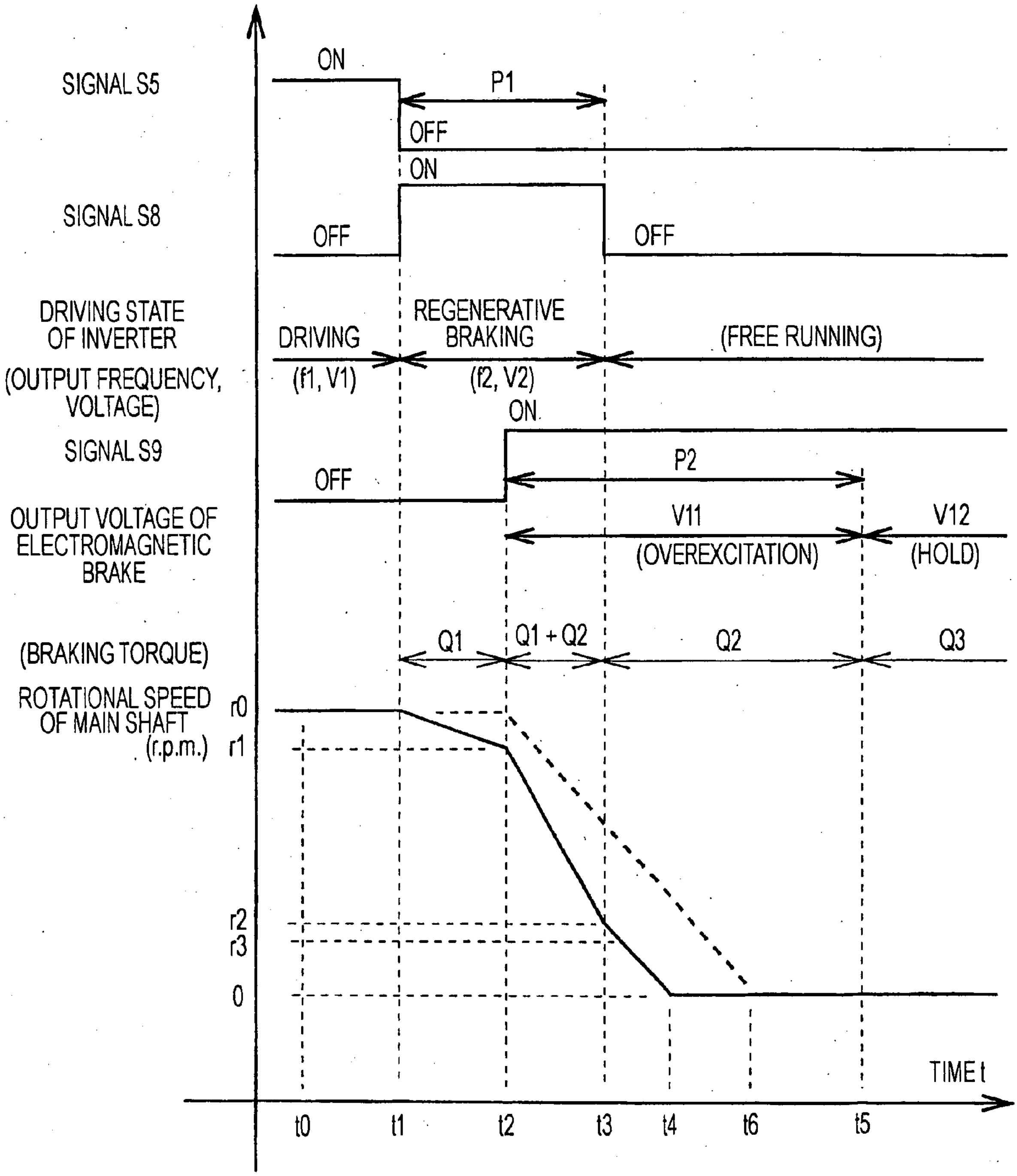
48
32
θ
S0
S1
S2
S3
37
38
S4
39

FIG. 3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ON
P1
OFF
SIGNAL S8
ON
OFF
OFF
DRIVING STATE OF INVERTER
(OUTPUT FREQUENCY, VOLTAGE)
DRIVING
(f1, V1)
REGENERATIVE BRAKING
(f2, V2)
(FREE RUNNING)
SIGNAL S9
ON
OFF
P2
OUTPUT VOLTAGE OF ELECTROMAGNETIC BRAKE
V11
(OVEREXCITATION)
V12
(HOLD)
(BRAKING TORQUE)
Q1
Q1 + Q2
Q2
Q3
ROTATIONAL SPEED OF MAIN SHAFT (r.p.m.)
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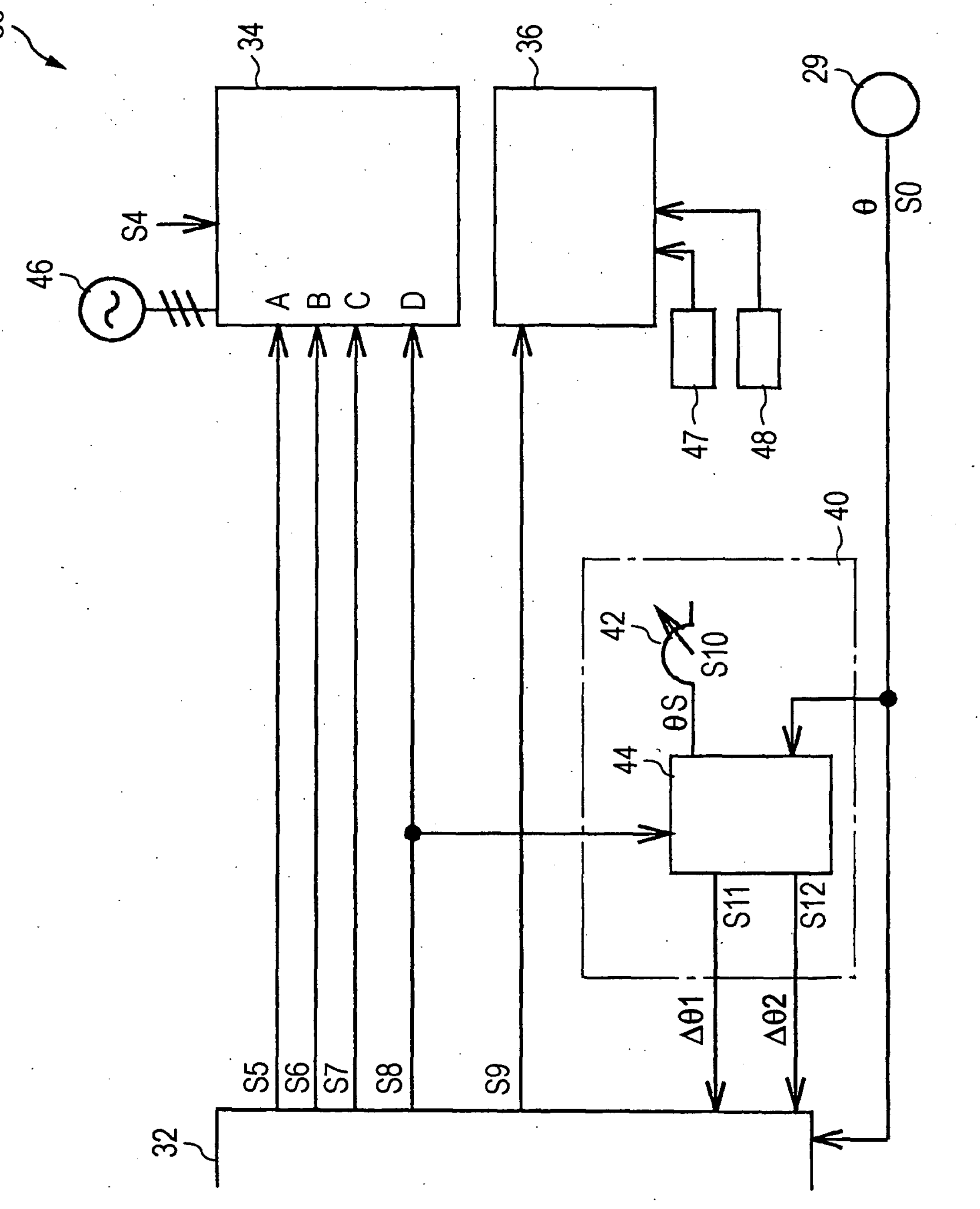
r1
r2
r3
0
TIME t
t0
t1
t2
t3
t4
t6
t5

FIG. 4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S11
S12
Δθ1
Δθ2
S5
S6
S7
S8
S9
32

## REFERENCES CITED IN THE DESCRIPTION

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